Millets Traditions, Science and Technology in Nepal

नेपालमा कोदोजन्य बालीहरू: परम्परा, विज्ञान र प्रविधि

Editors

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Food and Agriculture Organization of the United Nations

Kathmandu, Nepal | काठमाडौं, नेपाल
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NAGRC, NARC, (Khumaltar, Lalitpur; https://genebank.narc.gov.np/

The National Agriculture Genetic Resources Center (NAGRC) was established in 2010 under NARC for the conservation and utilization of all agricultural genetic resources (AGRs) that includes six components of agrobiodiversity (crop, forage, livestock, aquatic, insect and microorganism) and four sub components (domesticated, semi domesticated, wild relatives and wild edible). AGRs are managed through four strategies (ex-situ,on-farm, in-situ and breeding) and deploying 101 good practices across the country.

CCDABC, DoA Kathmandu Nepal; http://doanepal.gov.np/ne/

Centre for Crop Development and Agro-biodiversity Conservation (CCDABC) was established in Nepalese calendar year 2075 following the restructuring of Department of Agriculture (DoA) in the fiscal year 2074/75. The centre is a federal focal unit working under DoA and is responsible for the federal affairs including federal policy and regulation related to crop sector and agrobiodiversity conservation. For the past few years, CCDABC has been implementing a countrywide program for the promotion of millets and other indigenous crops by providing conditional grants to Provinces and Local levels.

Food and Agriculture Organization of the United Nations (FAO) https://www.fao.org/countryprofiles/index/en/?iso3=NPL

Food and Agriculture Organization of the United Nations, established in 1945, is a specialized agency of the United Nations that leads international efforts to defeat hunger. FAO aims to achieve food security for all and make sure that people have regular access to enough high-quality food to lead active, healthy lives. Nepal become a member of the FAO in 1951. FAO is the first UN agency operated in Nepal with more than seven decades of continuous cooperation between Nepal and FAO. During these periods, FAO has completed more than 300 projects in crops, horticulture, livestock, fisheries, forest and natural resource management.

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Cover photo: ● Little millet (धानकोदो) ● Finger millet (कोदो) ● Foxtail millet (कागुनो) ● Proso millet (चिनो) ● Pearl millet (घोगे, बाजरो) ● Sorghum (जुनेलो) ● Barnyard Millet (सामा)

Acknowledgements

In Nepal, a remarkable diversity of about 22 millet species exists, serving a multitude of purposes ranging from food, feed, to fodder. These millets comprise both cultivated and wild varieties. This extraordinary array of millet species forms the foundation of the intricate relationship between the people of Nepal and their environment, with each variety playing a unique role in the country's traditions, nutrition, and agriculture. The compilation of "Millets Traditions, Science, and Technology in Nepal" has been a collaborative endeavor that wouldn't have been possible without the invaluable contributions and support from a diverse range of individuals and organizations. We would like to express our heartfelt gratitude to farmers, researchers, extension officials, students, academicians, policy makers business perons, consumers etc.

The custodians of traditional millet knowledge in Nepal, whose expertise in millets' values, production systems, conservation, and storage practices have been the bedrock of this work. They are the true innovators in the millet landscape. The collective efforts of researchers, extension officials, students, academicians, businesspersons, and consumers have significantly enriched our understanding of millets in Nepal. Their commitment and enthusiasm have been instrumental in the compilation of this book.

The fusion of traditional wisdom and contemporary advancements is at the core of this book, and we appreciate the vital role both play in enhancing our knowledge of millets. We extend our deep appreciation to all the authors who have contributed their expertise, insights, and time, ultimately making this publication a success.

The entire journey, from the initial call for papers to the final publishing, involved a multitude of dedicated individuals and organizations. Your involvement has been instrumental in bringing this project to fruition. A special note of thanks to Himani Oli and Surendra Kumar Shrestha who played a pivotal role in maintaining continuous communication among authors and editors, facilitating the exchange of papers, ensuring stylistic consistency, and managing various other aspects of the project. We would like to express our appreciation to Binod Saha, Arjun Thapa, Suman Giri, Balaram Rijal, Mukunda Bhusal, RP Mainali, Pradip Thapa, Mukunda Bhattarai, Ajaya Karkee, Bimal Kumar Baniya, Dilaram Bhandari, Kamal Aryal, Bal Kumar Joshi, Bhakta Bahadur Gurung, Ratna Gurung, and Ganga Shrestha for their support and contributions.

We are grateful for the approval and conducive working environments provided by NARC and DoA of MoALD, and FAO, which were essential for the completion of this book. We extend our sincere thanks to FAO for its financial support, as well as the logistical assistance provided throughout the project. We also appreciate their efforts in organizing the book launching program. A special acknowledgment goes to Dr Ken Shimizu, the FAO Representative to Bhutan and Nepal, for his invaluable support and guidance.

The collective efforts of all these individuals, institutions, and stakeholders have resulted in a comprehensive resource that sheds light on the rich traditions, science, and technology surrounding millets in Nepal. We are profoundly grateful for your contributions and support.

The Editors
7 Nov 2023

Preface

Nepal, a land of rich millet genetic resources and vibrant cultural traditions, has long held an intricate relationship with these humble yet remarkable grains. Millets have been an integral part of our heritage, providing sustenance, celebrating rituals, and embodying the essence of our diverse cultures. But, regrettably, the true potential of millets has often been underutilized, and many of our treasured landraces and traditions have gradually disappeared over time. It was in 1986 that we embarked on a journey to explore the world of millets in Nepal. As we delved into this realm, we discovered that a vast repository of information, both research-based and tradition-based, remained uncharted and poorly documented, primarily due to the lower priority afforded to millets within the broader agricultural landscape.

The realization that our collective knowledge and wisdom surrounding millets needed to be recorded and shared with the world sparked the idea for this book. "Millets Traditions, Science, and Technology in Nepal" was conceived with a vision to capture the essence of millets in our country. With the International Year of Millets in 2023 on the horizon, it was the perfect occasion to undertake this endeavor.

This book represents an earnest effort to provide a comprehensive understanding of millets, their importance, and their multifaceted values. It seeks to advance the science and technology associated with millets, adding value to their cultivation, utilization, production, consumption, and conservation. Our aim is to offer a complete and cohesive picture of millets in Nepal, encompassing a wide spectrum of readers, from researchers and extension officials to policy makers, farmers, entrepreneurs, consumers, students, and academicians. It serves as a valuable resource for all stakeholders with an interest in the world of millets. However, the roles of millets on soil improvement, agro-insects, agro-microbes and birds are lacking in this book.

Our endeavor is to cover a wide array of topics, ranging from the traditions and historical significance of millets to cutting-edge scientific advancements across all millet species, including finger millet, foxtail millet, proso millet, little millet, pearl millet, sorghum, kodo millet, barnyard millet, browntop millet, and their wild relatives. Within the book's seven chapters, you will find a total of 100 articles, complemented by photographs and a glossary of Nepali words with definitions. While a majority of the articles focus on finger millet, we are making diligent efforts to incorporate content on other millet species as well.

The first chapter sets the stage with a vivid portrayal of the history and traditions around millets, delving into their socio-cultural values and ethno-botanical significance. The second chapter, "Science and Technology," unfolds with nine sub-chapters, exploring areas such as botany, biodiversity, and conservation; genetics, breeding, and biotechnology; agronomy and seed science; mechanization, traditional tools, and post-harvest management; soil, manure, and irrigation; crop protection; food, nutrition, and health; environmental and forage values; and the impact of climate changes, abiotic stresses, and gender on millet production.

The third chapter dives into the millet value chain and socioeconomics with three sub-chapters, highlighting product diversification and the use of by-products, along with insights into statistics, economics, and marketing, all supported by case studies. Chapter four provides a comprehensive overview of the policy landscape governing millets in Nepal.

Chapter five explores the status, issues, and challenges confronting millets in Nepal, with particular attention given to provincial variations. Chapter six, "Miscellaneous," adds an intriguing dimension to the book, including poems and celebratory aspects of millets in Nepalese culture. The final chapter is a visual journey through millets, featuring images of different functions, parts, and events associated with millets, along with a pictorial dictionary of the 22 millet species found in Nepal.

We are profoundly thankful to all individuals, institutions, and contributors who have played an integral role in the creation of this book, rich in valuable information. The declaration by the United Nations to celebrate 2023 as the International Year of Millets has been a significant milestone that inspired us to bring this book into the hands of our readers.

We believe that this book will offer substantial value to all its readers and are eagerly awaiting feedback and suggestions for further refinement. Please feel free to reach out to any of the editors or authors for continued communication.

Sincerely
The Editors
7 Nov 2023

Editors’ Note

As we commemorate the International Year of Millets in 2023, we are delighted to present this comprehensive volume, "Millets Traditions, Science, and Technology in Nepal." This book is the result of collaborative efforts among the National Agricultural Genetic Resources Centre (NAGRC), NARC; Centre for Crop Development and Agro-biodiversity Concervation (CCDABC), Department of Agriculture (DoA), and the Food and Agriculture Organization (FAO). Dr. Bal Krishna Joshi and Arun GC first initiated discussion about potential activities during the International Year of Millets at the Himalayan Policy Forum held from May 23 to 25, 2023, in Dhulikhel, Nepal, program organized by the International Centre for Integrated Mountain Development (ICIMOD).

The journey to this book began with the formulation of a tentative list of actions, followed by a visit from the FAO team to the Genebank for the finalization of activities. During this time, we recognized the value and scope of a book dedicated to the rich heritage of millets in Nepal, as well as their contemporary relevance in science and technology (this concept was triggered by the book, Rice Science and Technology in Nepal). Hence, we resolved to compile this insightful work.

Numerous rounds of discussions and planning took place, culminating in the selection of publishers and editors. Arun GC undertook the development of the book's concept and budget, which was subsequently approved by FAO. Dr Bal Krishna Joshi, along with the editorial team, carefully outlined the potential chapters, their titles, and identified suitable authors. These lists were meticulously updated through a collaborative effort using Google Docs.

To ensure the quality and comprehensiveness of the content, Dr. Joshi crafted detailed guidelines for both authors and editors. Two distinct approaches were employed to curate the chapters. Firstly, a call for abstracts was issued, outlining the book's scope and guidelines, and widely shared through email and social media channels.

We received an overwhelming response, with 40 abstracts submitted. Following a rigorous screening process, 12 abstracts were regrettably rejected. Authors whose abstracts were accepted were invited to expand their work into full papers. In tandem, we analyzed the gaps in paper titles and identified over 100 potential topics categorized into seven chapters. Based on their expertise, we approached numerous millet experts at the national level, inviting them to contribute articles to this publication. To facilitate the writing process, we diligently provided all relevant documents and information to the authors. The references in Nepali languages were translated in English and year of publication was substracted by 57.

The editorial process was marked by several rounds of online and in-person meetings, phone calls, and numerous emails to authors. A dedicated editshop was held in Dhulikhel during 5-11 November 2023. Each article was meticulously reviewed by at least two editors and sent back to the respective authors for revision. The final stage involved a comprehensive review and edit during the editshop, where the format and style were meticulously checked and applied by our assistant editor.

After thorough proof reading, we are proud to present the final product. This book not only showcases the diverse traditions surrounding millets in Nepal but also delves into the scientific and technological advancements that are shaping their future. We believe that "Millets Traditions, Science, and Technology in Nepal" will serve as a valuable resource for researchers, policymakers, and anyone interested in the fascinating world of millets.

We extend our gratitude to all the authors, editors, and contributors who have played a pivotal role in bringing this project to fruition. It is our hope that this book will contribute to the global understanding of millets and their significance in Nepal.

नेपाल सरकार

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शुभकामना

संयुक्त राष्ट्रसङ्घको आव्हानमा सन् २०२३ मा विश्वभर मनाइएको अन्तर्राष्ट्रिय कोदो वर्ष (International Year of Millets) को अवसरमा नेपालमा कोदोजन्य बाली : परम्परा, विज्ञान र प्रविधि (Millets:Tradition, Science and Technology) नामक ग्रन्थ प्रकाशन हुन लागेकोमा मलाई खुसी लागेको छ ।

कोदो, कागुनो, चिनो, जुनेलो, बाज्रालगायतका कोदोजन्य बालीहरू विगतमा आम नेपालीको मूख्य खानाको रूपमा रहेकोमा अहिले धान, गहुँजस्ता खाद्यान्नको उपलव्धता र उपभोग बढ्दै जाँदा कोदोजन्य बालीहरूको उत्पादन र उपभोग वर्षेनी घट्दै गइरहेको छ । समाजमा यी बालीहरू र तिनका उत्पादन र उपभोग गर्नेलाई हेयको दृष्टिले हेर्ने गलत मानसिकता र भात खानुलाई वैभवको प्रतिकका रूपमा हेरिने कारणले गर्दा पनि यस्ता बालीहरू ओझेलमा पर्न गएको देखिन्छ । कोदोजन्य बालीहरू अन्य खाद्यान्न बालीहरूको तुलनामा बढी पोषिलो हुनाको साथै खडेरी सहन सक्ने तथा कम मलिलो जमिनमा र सिंचाई नभए पनि खेती गर्न सकिने लगायतका वर्तमानका दुई ठूला समस्या जलवायु परिवर्तन र कुपोषणसँग जुध्न सहयोगी छन् । यिनै तथ्यहरूलाई दृष्टिगत गरी संयुक्त राष्ट्रसङ्घले यस वर्षलाई अन्तर्राष्ट्रिय कोदो वर्ष (International Year of Millets) घोषणा गरेको छ ।

नेपाल विश्वमा धेरै कोदो उत्पादन गर्ने देशहरूमा पर्छ । हामीकहाँ कोदो तथा कोदोजन्य बालीहरुसँग सम्वन्धित विभिन्न जात जाति तथा सम्प्रदायहरूको परम्परा एवं रीतिरिवाज विद्यमान रहेका छन् । यसको प्रवर्द्धनमा सरकारी र गैरसरकारी क्षेत्रहरूबाट पनि विभिन्न प्रयासहरू हुँदै आएका छन् । कोदोजन्य बालीसँग सम्वन्धित यी र यस्तै अनेकौं तथ्यहरू समेटेर नेपालमा पहिलो पटक ग्रन्थको रूपमा प्रकाशित हुनु निकै नै प्रसंशायोग्य कार्य हो भन्ने मलाई लागेको छ ।

नेपाल सरकारको तर्फबाट कोदोजन्य बालीहरूलाई पुनःमूलधारमा फर्काउन विभिन्न पहलहरू भइरहेका छन् । मूलतः तीनै तहका सरकारहरूको सहकार्यमा देशमा 'रैथाने बाली प्रवर्द्धन कार्यक्रम' विगत केहि वर्षदेखि कार्यान्वयनमा रहेको छ । यो र यस्तै अन्य कार्यक्रमहरूबाट सकरात्मक नतिजा पनि प्राप्त भइरहेका छन् । अहिले शहर बजारमा कोदोजन्य रैथाने उत्पादनको धेरै नै माग बढेको छ । यस क्रमलाई अझ विस्तार गर्न हालसम्म हासिल भएका उपलव्धीहरू र कमी कमजोरीको समीक्षा गर्दै हाम्रा नीति तथा कार्यक्रमहरूलाई अझ परिष्कृत गरेर लैजानु पर्ने आवश्यकता छ । यसो गर्न सकियो भने कुपोषण, जलवायु परिवर्तनले पारेको असर, बेरोजगारी तथा खाद्यान्नमा बढ्दो परनिर्भरता कम गरी यसै ग्रन्थमा विभिन्न सन्दर्भमा उल्लेख गरिएजस्तै 'ग्रामिण नेपालको रूपान्तरण' सम्भव हुने देखिन्छ ।

अन्तमा यस ग्रन्थ प्रकाशनमा मुख्य भूमिका खेल्ने मन्त्रालय र अन्तर्गतका कर्मचारीहरू एवं नेपाल कृषि अनुसन्धान परिषद् र संयुक्त राष्ट्रसङ्घ खाद्य तथा कृषि सङ्गठन नेपाललाई विशेष धन्यवाद दिन चाहन्छु । धन्यवाद ।

२०८० मंसिर १८

डा.बेदुराम भुसाल
मन्त्री

Government of Nepal
Ministry of Agriculture and Livestock Development
☎ 4211635, 4211808, 4211932, 4211665, 4211687, 4211915

Ref.:

Singhadurbar, Kathmandu
Nepal

Foreword

Millets are a group of small-seeded grains full of essential nutrients required for a healthy living. Millets also possess a number of climate resilient properties including their capacity to withstand extreme heat and drought. Millets used to be a major source of food security and nutrition for Nepalese people in the hills. Despite the multiple benefits of millets, their production and consumption have been declining over the years due to low returns, extensive labor demand and shift in food habit favoring rice and wheat. However, there has been a renewed interest towards millets due to growing realization of their benefits. The United Nations declaring the year 2023 as the 'International Year of Millets' (IYM) is a testimony of growing global interest in millets. The Government of Nepal (GoN) carried out various activities during the IYM for popularizing millets. The publication of millets compendium-Millets: Traditions, Science and Technology in Nepal- is one of such activities. This publication is the first of its kind being published in Nepal. The compendium covers wide array of topics around millets: history, tradition and culture related to millets; latest production and post-production technologies in millets; government efforts and achievements in promoting millets, and millets value chain development, among others.

Millets have the potential to transform the rural Nepal through improving food security and nutrition; enhancing climate resilience in agriculture; and addressing the issues of poverty and unemployment through the increased production and millets value chain development. The GoN has been involved in promoting millets through providing supports in production, value addition, product diversification, marketing, landrace conservation, and so on areas. It has been implementing a special federal program for the promotion of indigenous crops, which mainly comprise millets, since the fiscal year 2077/78. The program covers the entire value chain of millets and is being implemented in collaboration with provincial and local governments. Federal conditional grant is allocated to provincial and local governments to implement this program. The program has yielded a number of achievements in rejuvenating millets cultivation and consumption. The outcome of special program has led to increased demand for millets and their products in cities and urban centers across the country in recent years. A nationwide wave for popularity of millets has been felt these days. The IYM has given an additional impetus to this end.

Strong support from all stakeholders is warranted to continue the momentum of growth and development in millets. I take this opportunity to thank all the government institutions, non-government agencies, private sectors and others involved in millets promotion. Moreover, I would also like to thank development partners for supporting the GoN in millets promotion endeavors. My special appreciation goes to FAO Nepal for collaborating with and supporting the GoN for observing the IYM, 2023. Finally, I would like to thank the editorial team for their relentless efforts to bring the compendium to this shape.

Sharma

Dr. Govinda Prasad Sharma
Secretary
December, 2023

Government of Nepal
NEPAL AGRICULTURAL RESEARCH COUNCIL
(Established by the Government of Nepal under the Nepal Agricultural Research Council Act, 2048 B.S.)
(.. Division)

Ref. No.:-
Dispatch No.:-

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NEPAL

Foreword

Millets, the ancient grains woven into the historical fabric of Nepal, have long been cultivated and harvested for various purposes. Despite their integral role in the nation's agricultural tapestry, these resilient crops have often lingered in the shadows of neglect within society. The journey of researching and understanding these millets commenced as early as 1971, yet significant contributions remain elusive. Nepal stands as a repository of traditional knowledge concerning millet crops. Often thriving on marginalized lands, millets, cultivated organically with minimal inputs, embody a sustainable and ecologically friendly agricultural approach.

The scarcity of comprehensive information on millets in Nepal is a challenge that this groundbreaking book aims to overcome. A milestone is achieved, covering and compiling details on approximately 22 species of millets found in Nepal. This compendium is not only highly informative but also serves as an invaluable resource for a diverse audience, including farmers, consumers, students, teachers, researchers, extension officers, businesspersons, and policymakers alike. The richness of traditional practices, scientific insights, and technological advancements related to millets are meticulously documented within this compendium. It is a testament to the dedication and hard work of the editors and authors.

This book is more than a collection of facts; it is a great document that has the potential to revolutionize the scope of millet cultivation in the country. By shedding light on the various dimensions of millets—traditions, science, and technology—it serves as a guide to harnessing the full potential of these crops. This book highlights the role of millet production in securing food, nutrition, health, and environmental sustainability, all achieved with minimal input and investments. The Nepal Agricultural Research Council (NARC) takes pride in presenting this book, accomplished through collaboration with the Center of Crop Development and Agrobiodiversity Conservation (CCDABC) and the Food and Agriculture Organization (FAO). The collective efforts of all involved parties underscore the importance and urgency of recognizing millets, especially on global stage, as exemplified by the release of this significant contribution during the International Year of Millets in 2023.

Let us appreciate the dedication and hard work that went into bringing this wealth of knowledge to light. May this book serve as a beacon, guiding us towards a future where millets not only thrive but also contribute significantly to the well-being of our society and the sustainability of our planet.

Dhruba Raj Bhattarai, Ph.D
Executive Director
4 Dec 2023

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Government of Nepal
Ministry of Agriculture and Livestock Development

DEPARTMENT OF AGRICULTURE

Hariharbhawan, Lalitpur

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Foreword

Agriculture is not only important sector for the food security but also equally important for its role in furthering the culture and human civilization. Our culture and traditions are firmly connected with the agriculture and food system. Thus culture, traditions and technology should go together for the betterment of this sector. The Government of Nepal has been engaged in the development of agriculture in the country through formulating plans and policies, enacting legal framework, developing of physical infrastructure, investing on agricultural research, extension services as well as development of human resources.

Millets are small grains but very important crops for human and animal nutrition. These crops have a lot of qualities such as healthy and nutritious food, capable of growing in an adverse weather and soil condition, low nutritional requirement, appropriate for human food and animal feeds and export potentialities. Millets have been grown and consumed in Nepal since long time. These crops are connected with cultural heritage, social values and traditions of Nepalese community. Despite of its importance in Nepal, this crop has got very low attention in research and extension services.

With the celebration of the International Year of Millets in 2023, these crops have started to get attention around the globe. We also celebrated this year with series of events including talks, exhibitions, workshops, food fairs and publications with the coordinated efforts of the governmental, non-governmental organizations, private sector and farming communities. The publication of the "**Millets Traditions, Science, and Technology in Nepal**" is another effort to collect, document and publish the information on millets in Nepal. Attempts are made in this book to incorporate diverse aspects such as religious, cultural, social, economic and technical issues. I hope this publication will be useful for those who seek the knowledge and information on various aspects of millets.

Moreover, this **Millets Traditions, Science, and Technology in Nepal** has recognized the endeavors of our ancestor farmers who had conserved, developed and continuously utilize the traditions and values of these crops. Thanks to the authors and editorial team whose tireless efforts has resulted this compendium. I would like to express my sincere gratitude to The Genebank, NARC; the Centre for Crop Development and Agrobiodiversity Conservation of the Department of Agriculture and the Food and Agriculture Organization (FAO) Nepal for the collaboration effort on publishing this invaluable book in Nepal.

Nov 30, 2023

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Director General

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Foreword

Millets, acknowledged as a dietary staple for centuries and often celebrated as the superfood of the era, have garnered significant attention from scientists and innovators. The United Nations General Assembly at its 75th session in March 2021 declared 2023, the International Year of Millets (IYM 2023). IYM 2023 highlights the value of millets in empowering the small and marginalized farmers, achieving Sustainable Development Goals (SDGs), eliminating hunger, adapting to climate change impacts, preserving agro-biodiversity and strengthening agricultural food systems.

This comprehensive "Millets Compendium" expands the multidimensional narrative of millet grain in Nepal and within the region. The efforts and innovation of researchers, scholars, officials, and experts are substantive and exemplary in bringing together a diverse array of research papers. Apart from the research articles, the inclusion of photo galleries, illustrations and indigenous knowledge enriches this compendium, making it a valuable resource for anyone involved in or interested in the millet value chain.

We believe that the Millet Compendium offers a roadmap for sustainable agriculture, promoting biodiversity, and enhancing nutritional outcomes. It aligns with the global agenda for achieving the SDGs by addressing hunger, promoting responsible consumption, and fostering partnerships for sustainable development.

I would like to express my sincere gratitude to the authors, contributors and editorial team involved in developing this Compendium. Your dedication and expertise have undoubtedly contributed to the advancement of millet-centric agriculture in our regions.

In collaboration with the Government of Nepal, FAO Nepal recognizes and promotes the potential of millets to transform agricultural landscapes, nourish communities, and foster entrepreneurship by establishing millet as a future smart food, contributing to achievements of better production, better nutrition, a better life and a better environment.

I encourage all readers to share the wealth of information presented in these pages and to actively participate in promoting and adopting millets for a healthier, more sustainable future for all. I believe that this compendium will be a foundation for future endeavours and contribute to ongoing discussions and initiatives aimed at unlocking the potential of millets for the benefit of communities and economies, guiding us toward a sustainable and resilient future.

Ken Shimizu

Mr Ken Shimizu
FAO Representative for Bhutan and Nepal

संस्कृत साहित्यमा धान्य बालीको वर्गीकरण

धान्य (धन् = धान्ये = उत्पादन गर्नु, पैदा गर्नु; धन् + यत्) अर्थात् उत्पादन गर्न वा पोषण गर्नमा असल बालीलाई धान्य भनिन्छ। धान्यअन्तर्गत पाँच प्रकारका बाली पर्छन् – "शालिधान्यं व्रीहिधान्यं शूकधान्यं तृतीयकम्। शिम्बीधान्यं क्षुद्रधान्यमित्युक्तं धान्यपञ्चकम्।।"

(१) शालिधान्य (शल् गतौ + इञ्) = नकुटीकनै सेतो चामल दिने, हेमन्तमा पाक्ने, अगहनी, नउसिनेको, कलम वा रोपाइँ गरिने धान। शालिधान मधुर, रुच्य, सुपाच्य, सुकुमार, खेतमा पैदा गरिने (कैदार) हुन्छ। यो धानलाई धान्योत्तम (धानहरूमा उत्तम), नृपप्रिय (राजालाई प्रिय), व्रीहिश्रेष्ठ पनि भनिन्छ। यसको चामल रातो, सेतो, पाण्डु वा बासमती हुन सक्छ।

(२) व्रीहिधान्य (वृंह् + इन्) (जुन वृद्धि प्राप्त गर्छ) = आशुधान्य, बर्खे धान। व्रीहि कुटेपछि मात्र सेतो हुन्छ, चुलोमा पाक्न समय लाग्छ, धान कालो, अण्डाकृति भएको र फूल गुलाफी हुन्छ। शालि र व्रीहिको सतुष (नकुटेको, भुससहित) लाई धान र निस्तुष (कुटेको, भुसरहित) लाई तण्डुल (चामल) भनिन्छ।

(३) शूकधान्य (श्वि + कक्) = शूक वा तिखो झुस वा टुण्डो हुने धान्यलाई शूकधान्य भनिन्छ। जौ (यव = यु मिश्रणे + अच्, पानीमा मिसाएर सातु बनाईने) र गहुँ (गोधूम = गुध् + ऊम; गुध्यते वेष्ट्यते त्वगादिभिः = छाला आदिमा टाँसिने)।

(४) शिम्बीधान्य (शम् + बि ङीष् वा; सम् + बि ङीष् वा) (शम् शाम्यति, सम् समति वा, शिम्बायां = लतायां) = लता वा लहरा जाने, शरीरमा शान्ति गर्ने, कोसा लाग्ने, द्विदलीय बालीलाई शिम्बीधान्य वा सिम्बीधान्य भनिन्छ। सिमीवर्गका धान्य। यसअन्तर्गत मुङ (मुद्ग), मसुर (मसूर), मास (माष), राजमा (राजमाष), अरहर (आढकी), चना (चणक), कलौँ वा मटर (कलाय), खेसरी (त्रिपुट), गहत (कुलत्थी), राजसिमी (राजशिम्बी), भटमास आदि पर्छन् । यसै अन्तर्गत तिल, आलस (अतसी), सर्स्यूँ (सर्षप) पनि राखिएको छ, द्विदलीय हुनाले।

(५) क्षुद्रधान्य (क्षुद् + रक् = क्षुद्र = कमसल; कुधान्य); कुधान्य (कुत्सित धान्य = कुत्स् अवक्षेपणे निन्दायाम् + क्त अर्थात् निन्दित वा तिरष्कृत धान्य); तृणधान्य (तृण वा घाँसका जस्ता पात भएको धान्य)। खानमा खस्रा (रूक्ष) भएकाले र पौष्टिक महत्त्व उजागर नभएकाले क्षुद्र वा कुत्सित धान्य भनिएको हुन सक्छ। कोदो (कोद्रव), कागुनो (कङ्गु), चीनु (चीनक), सामा (श्यामक, शामा) आदि।

(क) कोदो (कोद्रव) – कोद्रव (कु + विच् = कु + ० = पृथ्वी, द्रु गतौ + अच्) (कु + द्रु + अच्) (कौ पृथिव्यां द्रवति इति = पृथ्वीमा वायुले उब्जन्छ अर्थात् स्वतः उम्रिन्छ)। क्रोद्रव = उद्दाल (उत् + दल् दलयति + घञ्, वनकोदो) = मदनाग्रक (मदनं उन्मादकं अग्रं शिरोभागो यस्य, जसको टुप्पा व बाला उन्मादक हुन्छ) = कोरदूष (कोरं संस्त्यानं दूषयतीति = कुललाई दूषित गर्छ)। कोदोले वात बढाउँछ र पित्त र कफ नाश गर्छ। नयाँ कोदो सजिलै पच्दैन। कोदोले घाउ ठीक गर्छ। कोदो हविद्रव्यको रूपमा प्रयुक्त हुँदैन।

(ख) कङ्गु (कं सुखं अङ्गति अङ्गयति वा = सजिलै उब्जाउन र माड्न सकिने, सजिलै पच्ने; क + अङ्ग् + कु) = कागुनो।

(ग) चीनक (चि चयने + नक् = चीन + कन्) (झर्ने भएकाले छानेर परिपक्व बालाको कटाइ गर्नुपर्ने) = काककङ्गु, कागलाई मनपर्ने कङ्गु = चिनु। यो पित्त र कफ नाश गर्ने तथा वायु बढाउने हुन्छ।

(घ) श्यामक (श्याम + कन्) (श्याम वा कालो वर्णको हुनाले) = श्यामाक = सामा = सावाँ = मादरा।

(ङ) इक्षुपत्र (उखुको जस्तो पात भएको) = यवनाल (जौको जस्तो डाँठ भएको) = जुनेलो, देवधान्य।

(च) प्रियङ्गु (प्रियं गच्छतीति, प्रिय + गम् + कु) = बाजरा।

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Abbreviations and Acronyms

AAI	Agriculture Academic Institutions
ADS	Agriculture Development Strategy
AED	Agricultural Engineering Division
AED	Agricultural Engineering Division
AFLP	amplified fragment length polymorphism
AFU	Agriculture and Forestry University
AGG	Australian Grains Genebank
AKC	Agricultural Knowledge Centre
AREE	Agriculture Research, Extension and Education AREE
BC	Benefit Cost
BJ	Bajra
CAGR	compound annual growth rate
CAT	Climate Analog Tool
CDD	Crop Development Directorate
CP	Crude Protein
CPWC	Critical period of weed control
CSB	Community Seed Bank
CTEVT	*Council for Technical Education and Vocational Training*
CV	Coefficient of Variation
CVT	Coordinated Varietal Trial
CVT	coordinated varietal trial
CVT	coordinated varietal trial
DADO	District Agriculture Development Office
DAT	Days After Transplanting
DM	Dry matter
DNA	Deoxyribonucleic acid
FANSEP	Food and Nutrition Security Enhancement Project
FAO	Food and Agriculture Organization of the United Nations
FFT	Farmer's Field Trial
FFT	Farmer's Field Trial
FGD	Focus Group Discussion
FSF	Future Smart Food
FT	foxtail millet
FWU	Far Western University
FYM	Farmyard Manure
GE	Genetic Engineering

GHG	Greenhouse gases
GHI	Global Hunger Index
GI	Glycemic index
GS	Genomic Selection
GWAS	Genome-Wide Association Studies
HCRP	Hill Crops Research Program
HDI	Human Development Index
HKH	Hindu-Kush Himalayan
IAAS	Institute of Agriculture & Animal Sciences
IAEA	International Atomic Energy Agency's
IBBR	Institute of Biosciences and BioResources
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IIN	Instability Index
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
IYOM	International Year of Millets
JIRCAS	Japan International Research Centre for Agricultural Sciences
KII	Key Informant Interview
LCPV	Lake Cluster of Pokhara valley
LR	Likelihood Ratio
LSU	Livestock Unit
MoALD	Ministry of agriculture and livestock development
MSNP	Multi Sector Nutrition Programme
MSNP	Multi-Sector Nutrition Plan
MZ	maize
NAEA	Nepal Agriculture Extension Association
NAERC	Agricultural Engineering Research Centre
NARC	Nepal Agricultural Research Council
NBPGR	National Bureau of Plant Genetic Resources
NGS	next generation sequencing
NIAS	National Institute of Agrobiological Sciences
NPC	National Planning Council
PCR	polymerase chain reaction
PU	Purbanchal University
RAPD	random amplified polymorphic DNA
RCBD	randomized complete block design
RFLP	restriction fragment length polymorphism
RFLP	restriction fragment length polymorphism
RN-E	Regeneration Nursery–Early

SDGs	Sustainable Development Goals
SNP	single nucleotide polymorphism
SNPs	single neucleotide polymorphism
SOD	superoxide dismutase
SOLiD	Sequencing by Oligonucleotide Ligation and Detection
SSR	simple sequence repeats
TDN	total digestible nutrient
TSI	Trade Specialization Index
TU	Tribhuvan University
UNFSS	UN Food System Summit
UUC	underutilized crops
VPKAS	Vivekananda Parbatiya Krishi Ansundhan Shala
VPKAS	Vivekananda Parbatiya Krishi Ansundhan Shala
WCE	Weed Control Efficiency
WHO	World Health Organization

Nepali English Glossary

Term	शब्द	Definition
Baaspaate kodo	बाँसपाते कोदो	Brown top millet
Bata	बाटा	A condenser strategically positioned atop the paini to condense the alcohol vapor
Bharama	भरम्मा	Murcha named by Tamang community
Bhumi jaat	भूमि-जात	Landrace. Genotype not altered by breeders but grown continuously by farmers over years. It may be local or introduced
Bopkha, Khabed	बोप्खा वा खबेढ़	Murcha named by Rai community
Bouza	बौज़ा	Wheat-based Egyptian beer
Braga	ब्रगा	A fermented beverage from millet is a traditional drink from Romania
Busaa	बुसा	Kenyan beer made form maize and finger millet or a blend of finger millet and sorghum
Buth, Thanbum	बुथ वा थान्बुम	Murcha named by the Lepcha community
Sel Roti	सेल रोटी	A circular bread (with large whole in center) in Nepal made of rice flour (sometime of finger millet) cooked in oil or ghee
Chapani	चपनी	A traditional jaad strainer made from bamboo strips
Chhaang	छांग	Chhaang is a sweet-tasting, home-brewed beer by Sherpas communities in Nepal
Chhyan	छ्यान	A millet beer brewed in Sikkim
Chhyang	छ्याङ	Another name of jaad from ragi , rice, or barley, consumed in the sub-Himalayan region and Tibetan settlements
Chino	चिनो	Proso millet
Cho Mana	चो माना	Newari name of mana made from wheat
Daadu	डाडु	A large wooden ladle or spatula used for cooking in traditional Nepali kitchens.
Daalo	डालो	A bamboo basket that is normally used to store dry food, grains, transfer small quantity of goods or even used as decorative item
Dhaan kodo	धान कोदो	Little millet
Dhiki	ढिकी	A wooden platform used for beating grains to remove the husk or for drying grains and vegetables.
Dindo	ढिंडो	Thick porridge, made from finger millet flour in hot water
Dosaa and Idli	डोसा, इडली	Dosa and Idli are South Indian dishes, with dosa being a thin, crispy crepe made from fermented rice and lentil batter, while idli is a soft, steamed rice cake made from the same batter
Duipane	दुई पाने	Alcohol condensed in nani after second water change in the bata during fractional distillation of raski (second water change)
Ekpane	एक पाने	Alcohol condensed in nani after first water change in the bata during fractional distillation of raski
Ghaito or Gaagri	घैंटो, गाग्री	A rounded or cylindrical small earthen pots typically used for storing or serving water, especially in rural areas
Ghonge	घोंगे	Pearl millet
Ghympo	घ्याम्पो	A traditional earthen vessel to ferment jaad

Term	शब्द	Definition
Hyaun Thon	ह्योन थों	Red color jaad especially made by Newar community in
Jaad, Jaandh, Jnar, Jaanr or Jnard	जाड, जाँड, जांर, नार, नार्ड	Jaad is a typical name for traditional, home-brewed beer in Nepalese societies
Jaanto, Jaato or Jaato	जाँतो, जातो	Janto is a type of rotary hand-quern or grinder used in the Himalayan region of Nepal, Sikkim, Darjeeling and Bhutan.
Jaat	जात	Variety. Genotype developed by breeders. It may be under cultivation or in the process of development
Jitiya	जितिया	Jitiya is a festival celebrated in Tarai region during the month of September
Junelo	जुनेलो	Sorghum
Kaaguno	कागुनो	Foxtail millet
Kaalo	कालो	Black
Kaffir	कफ्फिर	African sorghum beer,
Khesung	खेसुंग	Murcha named by Limboo community
Ki Mana	कि माना	Newari name of mana made from rice
Kodi	कोदी	Kodo millet
Kodo	कोदो	Finger millet
Kodo jannya baalee, kode baalee	कोदो जन्य बाली, कोदे बाली	Millet
Kodo ko Khole	कोदोको खोले	Kodo ko Khole is a thin porridge made of millet flour with water or milk
Krishak ko jaat	कृषकको जात	Farmer's variety. Landrace grown by farmers continuously over the year in particular site and maintained by themselves
Krishna Astami	कृष्ण अष्टमी	As per the religious legends of Hindus lord Krishna was born on Krishna Astami which is a date on the 8th day of the lunar calendar around September
Kwati	क्वाँटी	A food cooked with a mixture of different beans which are sprouted
Madhesi	मधेशी	In Nepal southern part is plain and people living from Saptari to Parsa districts are called Madhesi
Mana	माना	A granular, greenish-type fermentation starter prepared from wheat flakes in Nepal
Manapu	मानपु	An ethnic amylolytic starter, similar to murcha, that is prepared from solid-state fermentation using rice flour and millet
Mandro	मान्द्रो	A carpet made from bamboo
Marwa	मरवा	Marwa is the Maithili word equivalent to finger millet (Kodo in Nepali language)
Mungro	मुंग्रो	Mungro is a wooden hammer used in Nepalese communities.
Murcha	मुर्चा	An amylolytic fermentation starter, indigenous to Nepal, is used in the preparation of alcoholic beverages such as jand in Nepal, and also in the Darjeeling hills and Sikkim of India, and Bhutan
Naanglo	नांग्लो	A traditional flat, round, and woven plate or dish made from bamboo strips used to separate dust particles from paddy, rice, dal, beans, and other grains.
Nani	नानी	Small earthen pot to collet condensed alcohol

Term	शब्द	Definition
Nigar	निगार	A clear rice or millet wine that spontaneously accumulates at the top of the fermentation vessel during prolonged fermentation
Nirajala	निर्जला	A fasting that is observed without even drinking water
Okhal, Okhli	ओखल, ओखली	A traditional dehusking or grinding tools
Pa Mana	पा माना	Newari name of mana similar to murcha
Paapad	पापड	A thin, crisp disc-shaped Indian snack typically made from lentil or rice flour and spices, which is deep-fried or roasted.
Paini	पैनी	An earthen pot endowed with perforations at the bottom and tapered top placed above phosi used in the traditional fractional distillation for preparation of raksi
Peepa	पीपा	A bamboo or aluminum tube used to sip tongba extract
Phab	फाब	Murcha named by Bhutia and Tibetan community
Phonsi	फोंसी	A copper still vessel used to place the fermented mash for traditional fractional distillation for preparation of raksi
Phuraula	फुराउला	A food made of bean flour cooked in oil
Raato	रातो	Red
Raithane jaat	रैथाने जात	Native variety, indigenous variety. Genotype or variety in a particular site where, new trait, gene or allele got evolved
Rakshi	रक्सि	A traditional alcoholic beverage in Nepal and other Himalayan regions, typically made from millet or grains and often distilled.
Roti	रोटी	Bread. Roti can be called as bread made of flour mixed with water and cooked in heat
Saamaa	सामा	Barnyard millet
Sake	साके	Japanese rice wine
Seto	सेतो	White
Sthaniya jaat	स्थानीय जात	Local variety. Crop variety grown continuously in particular location for at least over 60 years in same location
Tharu	थारु	Tharu is the ethnic people of the Tarai, living in the southern part of Nepal
Theki	ठेकी	A wooden container or box used for various storage purposes
Thekua	ठेकु	A deep-fried sweet snack or cookie, popular in North India and Nepal, made from wheat flour, sugar, and ghee
Tongba	तोंग्बा	Fermented whole grains of millet consumed by pouring hot water and sipping the extract by a peepa

International Year of Millets 2023 (IYM-2023)

The global food system is confronted with various intricate challenges, such as hunger, malnutrition, a continually expanding global population, limited natural resources, and the impact of a changing climate. A viable solution involves enhancing sustainable crop production, establishing resilient value chains, and ensuring consumer access to affordable and diverse diets. Millets, with their diverse characteristics, can play a pivotal role in this solution by serving as affordable nutrient sources for healthy diets that can be cultivated in challenging climates and arid regions with minimal external inputs.

The International Year of Millets in 2023 provides an opportunity to raise awareness about the numerous benefits of millets, spanning from nutrition and health to environmental sustainability and economic development. This designated year aims to foster science-policy interaction, facilitate partnerships, mobilize stakeholders to actively promote and cultivate millets, and encourage their consumption by the general public. Every individual, ranging from governments and private sector entities to the general public, including chefs, home cooks, and the youth, has a crucial role to play. Collaborative efforts are essential to unlock the potential of millets for the well-being of both humanity and the planet.

In Nepal, many organizations have organized different events and activities on this occasion. Among them, NAGRC, CCDABC and FAO have played crucial role on promoting millets in the country.

NAGRC on the Occasion of International Year of Millets

NAGRC (National (Nepal) Genebank) works for ensuring the availability of genetic diversity of all agricultural genetic resources including millets. Due attention has been given to native and endangered crops and landraces. Millets in Nepal are neglected and underutilized. Natonal Genebank organized a 3rd Minor Cereal Crops Working Group (MCC-WG) Meeting during 21-22 September 2022 in Dolakha. MCC-WG meeting has formed a task force to develop a special program on the occasion of IYM 2023 and to organize different events. The member in MCC task force were

- Dr Bal Krishna Joshi (Coordinator), National Genebank, Khumaltar
- Dr Bandhu Raj Baral, HCRP, Kabre
- Dr Ram Krishna Shrestha, CCDABC, Pulchowk
- Dr Santosh Shrestha, LIBIRD, Kathmandu
- Krishna Hari Ghimire, National Genebank, Khumaltar
- Ramesh Acharya, DoAR, Lumle
- Dr Tek Gotame, NARC, Khumaltar
- Dr Roman Karki (Secretary), NFRC, Khumaltar

Minor cereal crops (MCC) team has worked on short term and long-term R&D strategies and action plans on minor cereals. This committee has submitted recommendations of MCC-WG meeting and action plans to celebrate the IYM. On the occasion of IYM-2023, National Genebank has carried out following activities and actions for conservation and sustainable utilization of millets.

- A program of IYM has been launched in January with showcasing different millets related products, seeds and publications. Key remarks and highlights were presented.
- Different meetings, writeshops and workshops were organized.
- Diversity at species and cultivar levels have been assessed
- Pictorial dictionary of millet species and posters on millets have been published and shared

- Stall of seeds and publications related to millets are established in Nepal Genebank.
- List of publications related to millets is compiled and made available from this link, https://www.researchgate.net/publication/371012844_List_of_publications_related_to_millets_from_Nepal_Genebank_Kathmandu
- All 22 species were explored and collected for conservation, characterization and distribution. These diversities have been conserved in seed bank, agro gene sanctuary, field genebank, community seed bank, community genebank, school field genebank, etc.
- Many different species and landraces of millets are broadcasted in agro gene sanctuary
- Evolutionary population of finger millet and diversity blocks of all species and some unique landraces have been established.
- Breeding work have been focused on developing site specific with polymorphic varieties. Some elite lines have been identified.
- Promotional activities have been regularly carried out through many different approaches and social media. Knowledge products and information about millets have been disseminated through social media (facebook, tiktok, twitter, youtube), TV, Radio, etc.
- Seeds of millets have been distributed to farmers, researchers and students free of cost.
- Millet based food system have been promoted, eg Kaguno khir, Khole, etc

CCDABC on the Occasion of International Year of Millets

A proposal of observing IYM, 2023 in Nepal was developed by Centre for Crop Development and Agro-biodiversity Conservation (CCDABC)/Department of Agriculture (DoA) with the inputs from the national genebank, NARC and other stakeholders and put forwarded to the MoALD through DoA. Activities are being carried out based on the proposal.

IYM 2023 related posters, pamphlet, brochure, sticker, standee, and so on IEC materials were produced and distributed across the country. The IYM, 2023 kick off program was organized at DoA on the first of January 2023 in the presence of relevant stakeholders. Likewise, millets related PSA jingles and other educational contents are being aired from FM radio networks covering the most parts of the country. Millets related food recipes, seeds and plants of millet landraces, various millets food products and drinks, and millets related tradition and culture were showcased in ABD fairs and exhibitions organized in National Agrobiodiversity Day (1st of the month of the Nepalese calendar month Magh which falls on the mid of January) and 'Agrobiodiversity Week' (Magh 1-7).

CCDABC and FAO have collaborated on observing the IYM, 2023 by jointly planning and implementing the various activities eg International millets, millets' food fair, millets' podcast, school millets campaign, twelve-episode radio program, interaction with millets growers of Indrawati, Sindhupalchowk and Barpak, Gorkha on millets tradition and culture, and other various aspects of millets, etc.

FAO

FAO in collaboration with the Government of Nepal launched several initiatives to celebrate the International Year of Millets. Acknowledging the influential power of the consumers to drive millets value chain, series of awareness raising activities were carried out. The value of millets has been displayed in various places using the latest technologies. Likewise, FAO collaborated with the celebrity Chef Shantosh Saha to promote millets consumption and preparation of various millet-based dishes. Further, a slot of Chef Nepal, a reality show, was dedicated for millets-based competition, which was aired via a national television. Additionally, FAO actively participated in various talk programs, workshops and consultations on millets, including a special event organized by the Embassy of India in Nepal. The private sectors also actively participated and collaborated with FAO in promotion of millets, for example the Muktinath Development Bank and Muktinath Krishi Company displayed standees of millets developed by FAO and GoN in their offices throughout the country.

As a part of the awareness-raising campaign a millets video and a millet song has been produced. During the world food forum at FAO Headquarters, Rome, FAO hosted a pavilion to showcase the diversity millets in Nepal and its cultural aspects. Similarly, to bring experts views on millets to the general public, 12 episodes of radio program was aired covering all districts of Nepal. To create awareness among the farming community about various millets varieties, demonstration plots were established in various parts of the country in 60 hectors of land, where farmers grew their own millets varieties and improved millets varieties. FAO is also supporting farmers for processing and value chain development.

As a part knowledge co-creation, FAO hosted a high-level learning sharing visit of government officials and FAO staffs to India, where the delegation visited ICRISAT, IIMR and various farmers and cooperative field and processing facilities. During this visit, the delegation Interacted with high level official and scientists working in the millet value chain development. Likewise, they got exposure to various technological developments in the field of millets value chain development, ranging from seed and variety, tool, equipment, and product diversification to the cutting-edge technologies of precision farming, robotics and AI. Likewise, this millets compendium is also a part of the knowledge co-creation. Similarly, FAO partnered with ICIMOD, Himalayan University Consortium, Government of Nepal, NARC, Agriculture and Forestry University, Reading University, Li-Bird, Alliance Biodiversity and CIAT and GRAPE project, produced a policy brief on millets entitled "Revitalizing millets for rural transformation in Nepal."

To culminate the International Year of Millets 2023, FAO and the GoN are organizing the International Policy Dialogue on Millets, various countries in Asia and Africa are participating and sharing their best practices. Likewise, to provide a platform for farmers and entrepreneurs for showcasing their knowledge, products and technologies, a national millet exhibition is also attached with the international policy dialogue on millets as a side event.

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Nepal in Brief

Geolocation

Nepal, a landlocked country in South Asia, is nestled at the southern foot of the Hindu-Kush Himalaya, with China to the north and India in other directions. Covering an area of 147,181 square kilometers, it ranks as the 93rd largest country in the world by landmass. Positioned between 26° 22' and 30° 27' north latitude and 80° 04' and 88° 12' east longitude, Nepal spans from hot tropical climates in the south to cool arctic conditions in the north, owing to its diverse topography and altitudinal variations from 60 meters to 8,848 meters above sea level. Stretching 885 kilometers from east to west and widening 193 kilometers from north to south, Nepal features three ecological belts that run parallel from east to west with varying elevations. Politically, it's divided into seven provinces with 77 districts (**Figure 1**) and 753 local government bodies according to the present constitution. Renowned as the birthplace of Lord Buddha and home to Mount Everest, the world's highest peak, Nepal holds a unique and prominent place on the global map.

Figure 1. Political map of Nepal

Physiography and Climate

Nepal's physiography is characterized by five distinct regions, each with unique features, bio-cultural settings, agro-ecological conditions, and livelihood patterns, running from south to north (**Figure 2**). These regions are:

- **Tarai Region:** Located in the southern part of Nepal, the Tarai region enjoys a suitable climate for crop cultivation and fruit production. It also benefits from good accessibility to markets, making it a fertile and economically active region.
- **Siwaliks:** The Siwalik region lies north of the Tarai and is characterized by a range of hills. It serves as a transition zone between the Tarai and the middle mountains. The climate here varies but generally offers a warm temperate monsoon climate.
- **Middle Mountain Region:** Situated above the Siwaliks, the middle mountain region continues to experience the influence of the monsoon. The climate in this region shifts from a warm temperate monsoon climate in the lower areas to a cool temperate monsoon climate in the higher parts.

- **High Mountain Region:** This region extends even further north and experiences an alpine climate. It is characterized by cold weather and limited accessibility, which affects crop production.
- **High Himalayas:** At the northernmost part of Nepal, the high Himalayas feature an extreme tundra-type arctic climate, with very cold temperatures and limited agricultural opportunities due to the harsh conditions.

Climatic Variation: Despite its relatively small size, Nepal exhibits remarkable climatic variations, owing to its topography. The country experiences distinct seasons:

Summer: Hot and dry in the lower regions, with the monsoon bringing rainfall.

Winter: Generally dry and cold, occasionally with rain.

Rainfall Patterns: Nepal receives the majority of its annual rainfall during the summer monsoon season, which occurs from June to September. About 75% of the country's precipitation falls during this period. The remaining 20% of precipitation takes place during the winter monsoon. Approximately 5% of the rain comes during pre- or post-monsoon periods.

Regional Variations: Precipitation patterns vary across the country. Eastern and central hilly areas typically receive between 1500 to 2500 mm of rainfall, while western regions receive between 1000 to 1500 mm. Valleys with high mountain ranges to the south have considerably lower precipitation due to the rain shadow effect.

Snowfall: Snowfall is common in high mountain regions, particularly above 4200 meters, contributing to the cold and challenging conditions in these areas.

Temperature: Temperature fluctuates throughout the year, with the highest values during summer (May-July) and the lowest during winter (December-January). Monsoon months (June-September) bring a gradual decline in temperature. In the high mountains and high Himalayas, temperatures remain low year-round, and some areas experience frost and snow, especially on north-facing slopes.

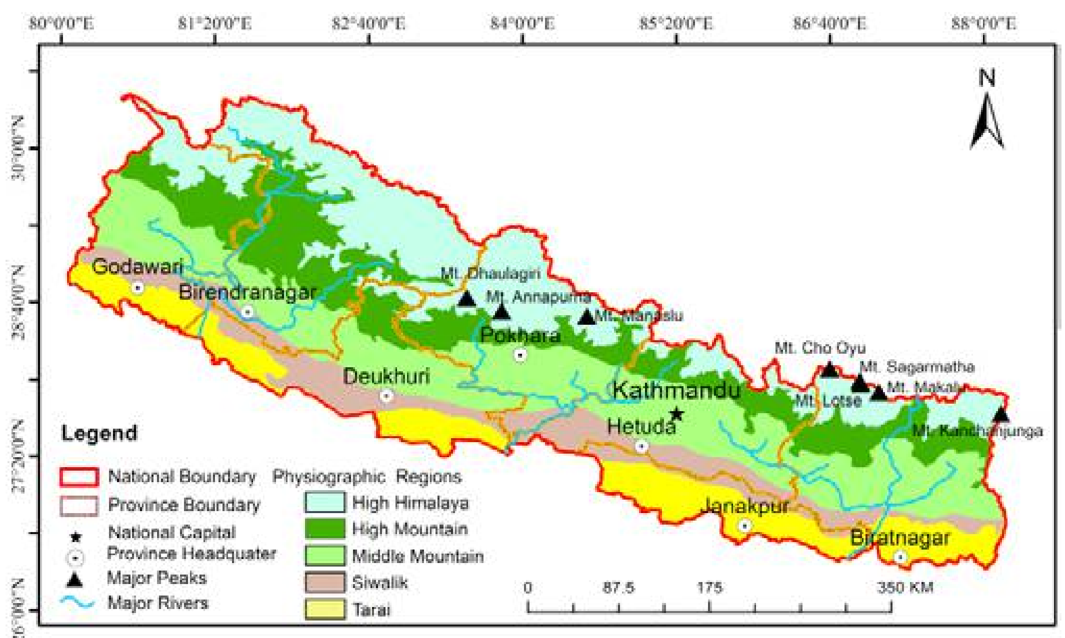

Figure 2. Map showing the physiographic regions of Nepal/ agroecological map
High Himalaya (2,500-8,848 m) High Mountain (2,000-2,500 m Middle Mountain (700-2000 m) Sivalik (300-700 m) Tarai (<300 m).

Demographic and Socioeconomic Setting

Nepal's demography and socioeconomic setting reveal a dynamic and evolving landscape. As of the latest census in November 2021, Nepal's total population stands at 29,164,578, comprising 48.87% males and 51.13% females, resulting in a sex ratio of 95.59 males per 100 females. The annual average population growth rate for 2021 is 0.92%. The country boasts a total of 6,666,937 households, marking a 23% increase since the 2011 census. The average household size is 4.37. Notably, Kathmandu is the district with the highest population, while Manang has the lowest. Population density, or the average number of people per square kilometer, has seen an increase to 198 at the national level, compared to 180 in 2011. Kathmandu district exhibits the highest population density, with 5,169 people per square kilometer, while Manang maintains the lowest, with only 3 people per square kilometer. The overall literacy rate among those aged 5 years and above has risen from 65.9% in 2011 to 76.2% in 2021. Male literacy stands at 83%, while female literacy is at 69.4%. Life expectancy at birth in Nepal is reported at 68.45 years in 2021, with women having a slightly higher life expectancy of about 70.36 years, and men at an average of 66.57 years.

Nepal's major religion is Hinduism, with 81.3% of the population adhering to this faith. Other religious groups include Buddhists (9%), Muslims, predominantly Sunni (4.4%), and Christians (1.4%). Minorities such as Kirats, animists, Bon adherents, Jains, Baha'is, and Sikhs collectively account for less than 5% of the population. The official language of Nepal is Nepali, spoken as a mother tongue by 44.64% of the population. Other significant languages include Maithili (11.67%), Bhojpuri (5.98%), Tamang (5.77%), Tharu (5.11%), Newari (3.2%), Bajjika (2.99%), Magar (2.98%), and various others (17.66%). Nepal is linguistically diverse, with 123 languages spoken as mother tongues.

Nepal is categorized as a developing country with a low-income economy, ranking 143rd out of 189 countries on the Human Development Index (HDI) in 2021. Notably, 15.1% of the population lives below the poverty line, signifying a daily income of less than $1.90 purchasing power parity. Over the past decade, the average size of agricultural land holdings has decreased from 0.68 hectares to 0.55 hectares, highlighting changing land use patterns. Agriculture remains the largest contributing sector to Nepal's economy, contributing approximately one-fourth of the Gross Domestic Product (GDP), with 50.1% of the economically active population engaged in this sector.

Agriculture

Agriculture in Nepal plays a pivotal role in the nation's economic landscape, with a total land area of 2.21 million hectares are cultivated, encompassing 15% of the nation's total land area. Notably, 54% of the cultivated land benefits from irrigation facilities. The agricultural sector serves as the cornerstone of Nepal's economy, contributing a substantial 23.95% to the country's total GDP. It goes beyond economic significance, as agriculture ensures food security, income generation, employment opportunities, and serves as the primary means of livelihood for over 62% households of Nepal's population.

Despite its undeniable importance, agriculture in Nepal faces significant challenges. The sector's growth rate has been modest, standing at 2.30% in an average. A concerning trend of importing agricultural products from neighboring countries, including India and China, has led to a considerable trade deficit. Nepal's historical role as a food grains exporting nation has shifted, making it a net importer. The adoption of advanced agricultural technology remains limited, with a substantial gap between current and potential agricultural productivity across various geographic regions. Farmers predominantly engage in subsistence farming, and the commercialization of the sector is contantly increasing.

Although few districts in Nepal grapple with food insecurity, the Global Hunder Index of Nepal is continuously improving. Several factors contribute to the low growth rate of agricultural development, including insufficient investment in infrastructure and agricultural research, limited adoption of modern technology, complex land ownership structures, fragmented land and less land holdings, insufficient policy and legal framework, insufficicnt irrigation facility, underemployment and disguised employment, inadequate access to improved seeds and fertilizers, lack of basic infrastructure, transportation, warehouses, and guaranteed markets, unutilized barren land, and insufficient market and irrigation assurances. Addressing these challenges is imperative for Nepal to unlock the full potential of its agricultural sector and ensure food security and economic growth.

Farming System

In Nepal, the agricultural landscape is shaped by a diverse climate that enables the cultivation of a wide range of crops across its varied geographical regions. The majority of Nepalese farmers engage in subsistence farming, navigating numerous challenges, both environmental and economic, with a particular focus on the hilly regions where small landholdings are fragmented. The Nepalese farming system intricately intertwines crop production, livestock management, and forestry practices, recognizing their essential interdependence. Traditional methods, such as draft power for land cultivation and the use of farmyard manure to enhance soil fertility, play a pivotal role in Nepalese agriculture. Sustainability in this system is achieved through the recycling of organic materials within the farm and the judicious utilization of forest resources. Cropping patterns vary across agro-ecological zones, with agro-forestry dominating in the north and cereal crops prevailing in the south. Rice holds a prominent position as the primary staple crop, leading in terms of cultivated land, production volume, economic value, contribution to GDP, and its integral role in the Nepali diet, while finger millet ranks as the top millet crop, cultivated across all 77 districts.

Nepal stands as a country abundant in agrobiodiversity, ranking 49th globally in terms of biodiversity richness. Among the country's extensive array of 24,300 species, a notable 28% comprises agricultural genetic resources (AGRs), collectively referred to as agrobiodiversity. This encompassing agrobiodiversity comprises six distinct components, namely crops, forages, livestock, aquatic life, agro-insects, and agro-microorganisms (**Figure 3**). These components further break down into four sub-components, which include domesticated, semi-domesticated, wild relatives, and wild edible varieties. This rich tapestry of agrobiodiversity is manifested across various levels, from agroecosystems, species, and varieties/breeds/biotypes/races/strains to genotypes and alleles, spanning a wide altitude range from 60 to 5,000 meters above sea level.

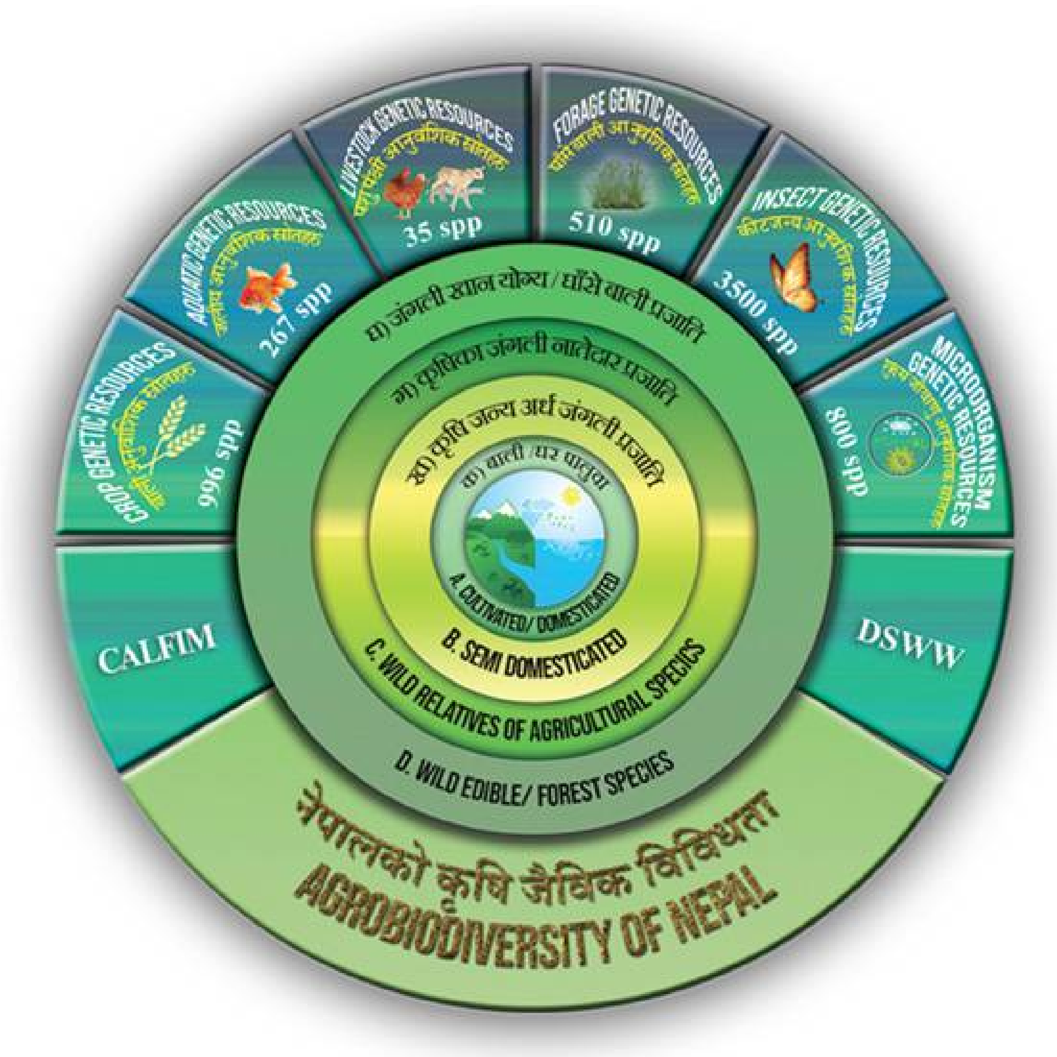

Figure 3. Components of agrobiodiversity

Nepal's agricultural landscape is characterized by three distinct agroecozones, each with its own unique agricultural system and climatic conditions. These agroecozones are mountain agriculture, hill agriculture, and Tarai agriculture.

Mountain Agriculture: The high mountains, often covered in snow, form the mountain agriculture zone, situated at elevations ranging from 2000 to 4500 meters above sea level. Here, the climate is extremely cold, and the primary crops cultivated include barley (both hulled and hull-less), buckwheat, potatoes, finger millet, foxtail millet, amaranths, prosomillet, maize, apples, walnuts, and various herbs. People in these regions raise Chouri cows for milk and keep sheep and Himalayan goat for wool and meat production. Agriculture in the high mountains is characterized by the resilience of mountain communities who adapt to the challenging conditions to grow crops and raise livestock.

Hill Agriculture: The hill region, with elevations ranging from 700 to 2000 meters above sea level, is known for its pleasant subtropical climate in river valleys and temperate conditions in the upper hills. Hill slopes are extensively terraced to maximize agricultural productivity. In the mid-hills, a variety of crops are grown, including maize, millets, wheat, rice, soybeans, and fruits like citrus and walnuts. Livestock such as cows, buffaloes, and goats are also reared. Honey and mushrooms are produced abundantly, and the region supplies off-season produce to the Tarai and valley markets of Nepal. The hill farming system, often based on maize cultivation, is supported by agroforestry, which enhances sustainability by increasing agricultural productivity, reducing soil erosion, and improving soil fertility while providing additional income compared to conventional crop production.

Tarai Agriculture: The Tarai, the southern plain area with a subtropical climate, serves as the granary of Nepal. The inner Tarai and river basins share a similar climate and range from 60 to 700 meters above sea level. The predominant cropping pattern in the Tarai is rice-wheat. In addition to rice and wheat, the Tarai region cultivates sugarcane, maize, jute, potatoes, millets and tropical fruits such as mangoes, bananas, guavas, and litchis. The region is a significant producer of cattle, buffalo, goats, and milk and milk products. Tarai agriculture is vital to Nepal's national agricultural production, supplying essential staples and contributing to the country's food security.

In summary, Nepal's diverse agroecozones represent a rich tapestry of agricultural practices and products, each tailored to the specific climatic conditions and geographical features of their respective regions. These agricultural systems play a crucial role in sustaining the livelihoods of the Nepalese people and ensuring food production for the nation.

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Chapter 1. History, Traditions and Gender

अध्याय १. इतिहास, परम्परा र लैंगिक पक्ष

नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक) । २०८० । राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ ।

तृणधान्य: हिजो र आज

छत्रपति दाहाल

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सारांश

वेदमा समेत कोदोजस्ता तृणधान्यको वर्णन भएकोले यो प्राचीनकालदेखिको अनाज हो । इतिहासको कुनै कालखण्डमा कुअन्न, कुधान्य, क्षुद्रधान्य, पाङदुरे बाली र गरीबको खानेकुराको रूपमा अपमानित भएको यथार्थ रहँदारहँदै पनि पछिल्ला समयमा यो अनाज सम्पन्न र जान्नेबुझ्नेका लागि उत्तम आहारका रूपमा प्रयोग हुन थालेको छ । प्रस्तुत लेख कोदो र कोदोका विभिन्न प्रजातिहरूको प्राचीनदेखि वर्तमानकालसम्मको उपयोगिताबारेमा आधारित रहेर तयार गरिएको छ ।

वृत्तान्त

वेदमा सबभन्दा पहिले यव र धान्यको वर्णन पाइन्छ । त्यसपछि क्रमशः व्रीहि(धान), यव(जौ), माष, तिल, मुद्ग(मूँगी), चणक(चना), कागुनो, अणुधान्य(चिनो), श्यामाक(सामा), नीवार(नावो), गोधूम(गहूँ) र मसूरको बयान वेदमा आएको पाइन्छ ।[१] यसबाट वैदिककालदेखि नै तृणधान्य/क्षुद्रधान्य(Millets)को बारेमा ऋषिमुनिहरूलाई जानकारी भएको बुझ्नसकिन्छ । हवनयोग्य र पूजायोग्य अन्नलाई ऋषिमुनिहरूले हविधान्य भनेका छन् । यिनलाई शास्त्रकारहरूले सातसंख्यामा वर्णन गरेका छन् । यस्ता चोखा अन्नलाई देवकार्य या सर्वकार्यमा प्रयोग गर्नुपर्दछ भन्ने उनीहरूको भनाइ रहेको छ । यी सात संख्याका अन्नहरू सप्तधान्यको रूपमा गणना गरिएका छन् । सप्तधान्यमा कसैले जौ, धान, तिल, कागुनो, मूँगी, चना र सामाको गणना गरेका छन् ।[२] कसैले जौ, गहुँ, धान, तिल, कागुनो, सामा र चनाको नाम उल्लेख गरेका छन् ।[३] कसैले सामा, जौ, गहुँ, मूँगी, माष, चिनो र धानको नाम लिएका छन् ।[४] देश, काल, परिस्थिति र उपलब्धताअनुसार यिनीहरूको व्यावहारिक प्रयोग भइरहेको पाइन्छ । यी गणनामा धान्य र क्षुद्रधान्य दुवै परेका छन् । यस लेखको मूल अभिप्राय तृणधान्य भएकोले यिनका सम्बन्धमा आयुर्वेद लगायत प्राचीन शास्त्रमा भएका कुराहरूलाई उजागर गर्दै नवीन सन्दर्भमा समेत यिनीहरूको उपयोगिताको चर्चा यहाँ प्रस्तुत गरिन्छ ।

तृणधान्यको परिचय

मसिनामसिना दाना हुने अनाज (Small seeded crops)लाई पूर्वीय मनीषीहरूले तृणधान्य भनेका छन् । आयुर्वेदका निघण्टुहरू र विभिन्न पुराणहरूमा पनि तृणधान्य/क्षुद्रधान्यको उल्लेख भएको पाइन्छ ।

कायचिकित्साप्रधान आत्रेय पुनर्वसु, अग्निवेश र चरक ऋषिले संहितावद्ध गरेको चरकसंहितामा कोरदूष, श्यामाक, हस्तिश्यामाक, नीवार, तोयपर्णी, गवेधुक, प्रशातिका, अम्भश्यामाक, लोहिताणु, प्रियङ्गु, मुकुन्द, झिण्टि, गर्मूटी, वरुका, वरका, शिबिर, उत्कट, जूर्ण नामका एकै खालका अनाजविशेषलाई सामाकै गुण भएका भनेर एकै ठाउँमा उल्लेख गरिएको छ ।[५] श्लोकको भाव हेर्दा यसमा कोदो र सामालाई प्रतिनिधि अनाजको रूपमा वर्णन गरिएको बुझ्नसकिन्छ । शल्यचिकित्साप्रधान धन्वन्तरिप्रणीत आचार्य सुश्रुतद्वारा संहितावद्ध सुश्रुतसंहितामा कोरदूषक, श्यामाक, नीवार, शान्तनु, वरक, उद्दालक, प्रियङ्गु, मधूलिका, नन्दीमुखी, कुरुविन्द, गवेधुक, सर, वरुक, तोद(य)पर्णी, मुकुन्दक, वेणुयव प्रभृति कुधान्यविशेषको संग्रह गरिएको छ ।[६]

अष्टाङ्गहृदयकार वृद्धवाग्भटले कङ्गु, कोद्रव, नीवार, श्यामाक आदि तृणधान्य शीतल, हलुका, वातकारक, कफपित्तनाशक र लेखन भएको वर्णन गरेका

१ व्रीहयश्च मे यवांश्च मे माषांश्च मे तिलांश्च मे मुद्गाश्च मे खल्वाश्च मे प्रियङ्गवश्च मेऽणवश्च मे श्यामाकाश्च मे नीवाराश्च मे गोधूमांश्च मे मसूराश्च मे यज्ञेन कल्पन्ताम् । — शुक्लयजुर्वेदीय रुद्राष्टाध्यायी ८।१२ ॥

२ यवधान्यतिलाः कंगु मुद्गचणकश्यामकाः । एतानि सप्तधान्यानि सर्वकार्येषु योजयेत् ॥

३ यवगोधूमधान्यानि तिला कंगुस्तथैव च । श्यामाकाश्चणकाश्चैव सप्तधान्यानि संविदुः ॥

४ श्यामाकयवगोधूममुद्गमाषप्रियङ्गवः । धान्यानि सप्तसंख्याता व्रीहयः सप्त सूरिभिः ॥

५ सकोरदूषः श्यामाकः कषायमधुरो लघुः । वातलः कफपित्तघ्नः शीतः संग्राहि शोषणः ॥
हस्तिश्यामाकनीवारतोयपर्णीगवेधुकाः । प्रशातिकाम्भःश्यामाकलौहित्याणुप्रियङ्गवः ॥
मुकुन्दो झिण्टिगर्मूटी वरुका वरकास्तथा । शिबिरोत्कटजूर्णाह्वाः श्यामाकसदृशाः गुणे ॥ —चरकसंहिता सूत्रस्थानम् २७ अध्यायः श्लोकसंख्या १६,१७, १८ ॥

६ कोरदूषकश्यामाकनीवारशान्तनुवरकोद्दालकप्रियङ्गुमधूलिकानन्दीमुखीकुरुविन्दगवेधुकसरवरुकतोद(य)पर्णीमुकुन्दकवेणुयवप्रभृतयः कुधान्यविशेषाः ॥ —सुश्रुतसंहिता, सूत्रस्थानम्, ४६ अध्यायः, सूत्रसंख्या २१ ॥

छन् ।[७] अष्टाङ्गसंग्रहकार वाग्भटले कङ्गु, कोद्रव, जूर्ण, गर्मूटी, चूर्णपादिका, श्यामाक, तोयश्यामाक, हस्तिश्यामाक, शिम्बिरा, शिम्बिर, दारुनीवार, वरु, कुवर, उत्कट, मधुली, शान्तनु, सण्डी, वेणुपर्णी, प्रशान्तिका, गवेधुक, अण्डलौहित्य, तोदपर्णी, मुकुन्दक लगायतका अनाजहरूलाई तृणधान्य अन्तर्गत गणना गरेका छन् ।[८] वैद्य कैयदेवले तृणधान्यमा सितकंगु, श्यामाक, कोद्रव, उद्दाल, नर्त्तक, गवेधुक, देवधान्य, वरुक, वरिट्टिका, उद्री, नाडी, तोयपर्णी, मुकुन्द, शिम्बिर आदिको नाम लिएका छन् ।[९] विशेष वर्णनमा प्रियङ्गु, चीनाकप्रभृतिहरू(चीनाक, श्यामाक, कोद्रव, नर्त्तक), शरबीज, यावनाल र गवेधुकाको पनि वर्णन गरेका छन् । नरहरि पण्डितले राजनिघण्टुमा श्यामाक, कोद्रव, वरक, कङ्गुणी, नीवार, रागी र कुरी नामका तृणधान्यको वर्णन गरेका छन् ।[१०] १६ औं शताब्दीका भावमिश्रले भावप्रकाशनिघण्टुमा **क्षुद्रधान्यं कुधान्यं च तृणधान्यमिति स्मृतम्** भनेर आयुर्वेदले प्रारम्भदेखि यी तीन नामले चिनिएका कङ्गु, चीनाक, श्यामाक, कोद्रव, वनकोद्रव, चारुक, वंशयव, कुसुम्भबीज, गवेधुका, नीवार, यावनाल यतिको वर्णन गरेका छन् ।[११]

क्षुद्रधान्य, कुधान्य र तृणधान्यको अर्थ

धान्यमा क्षुद्र र कु विशेषण प्रयोग हुनुले यस्ता अनाज नरुचाउनेहरूका लागि बल पुगेको पाइन्छ । तर यथार्थमा यसको अर्थ त्यो होइन । क्षुद्र शब्दका क्रूरता, अधनता र अल्पता तीन अर्थ हुन्छन् । त्यसमध्ये अल्प अर्थमा यहाँ क्षुद्रधान्य शब्दको प्रयोग भएको हो । अर्थात् सानो खालको अनाज । कुत्सित धान्यलाई कुधान्य भनिन्छ । निकृष्ट, प्रतिकृष्ट, अर्वन्, रेफ, याप्य, अवम, अधम, अवद्य, खेट, गर्ह्य र अणक यी अर्थमा कुत्सित शब्द प्रयोग भएको हो ।[१२] धेरै सानो अर्थमा यो कुधान्य शब्दको आचार्यहरूले प्रयोग गरेको हुनुपर्दछ। यी सबैको सन्तुलित अर्थ मसिना दाना भएको बुझ्नुपर्दछ । खेती नलगाइएका, पाखापखेरा र बनजंगलमा धेरैजसो पाइने, घाँस पलाएजस्तै आफैँ पलाएर आउने भएकोले यस्ता अनाजलाई तृणधान्य भनिएको हो ।

वेददेखि वर्तमानसम्म आउँदा क्षुद्रधान्यको उपयोगिता

संहिताकार चरक, सुश्रुत र वाग्भटले क्षुद्रधान्यमा कोदोको वयान पहिले गरेका छन् । यसबाट तृणधान्य/क्षुद्रधान्यमा कोदोको महत्व बुझ्नसकिन्छ । वैदिककालदेखि अहिलेसम्म त्यत्तिकै प्रचलित क्षुद्रधान्यमा निम्नलिखित मुख्य छन्:-

कोरदूष/कोद्रव/कोदरा *Paspalum scrobiculatum* Linn/ Kodo Millet

नेपाली जनजीवनमा प्रचलित कोदो शब्दले यसलाई बुझाउने गरेको पाइन्छ । **कोरदूषस्तु कोद्रवः**, अमरकोशकारको यो भनाइलाई टीकाकार विद्वच्छिरोमणि पं. कुलचन्द्र गौतमले कोदो नै भनेका छन् । नेपाली निघण्टुमा पनि यसलाई कोदो भनिएको छ । संस्कृतज्ञ नेपाली विद्वान् पनि कोद्रव र कोरदूषको नेपाली अर्थ कोदो नै गर्ने गर्दछन् । *P. scrobiculatum* Linn. लाई अंग्रेजीमा Kodo millet भनिएकोले पनि यो शब्द रुढ हुनगयो होला । तर वैज्ञानिक नाम र हिन्दीको कोदरा नेपालमा प्रचलित कोदोभन्दा पृथक् रहेको पाइन्छ। बरु अंग्रेजीमा प्रचलित Finger millet चाहिँ नेपालमा प्रचलित कोदोसित मेल खाने भएकोले यो कुरा यहाँ विचारणीय देखिन्छ ।

केन जलेन वायुना वा द्रवतीति कोद्रवः यस व्युत्पत्तिको आधारमा यो ज्यादै हलुका अनाज हो । हावा र पानीमा बिलाउने खालको हुने भएकोले यसलाई कोद्रव भनिएको हो ।

चरकसंहितामा यसलाई टर्रो–मीठो, हलुका, वातकारक, कफपित्तनाशक, शीतल, ग्राही र शोषण हुन्छ भनिएको छ ।[१३] अष्टाङ्गहृदयमा यो परंग्राही र विषनाशक भनिएको छ ।[१४] प्रमेह(मधुमेह), मेदोरोग(मोटोपन), ऊरुस्तम्भ(तिघ्रा जकडिने रोग), रक्तपित्त(रगतको वमन र रक्तपात हुने रोग) तथा जलोदर(पेटमा पानी भरिने) रोगका लागि यसलाई राम्रो पथ्य मानिएको छ । यसको चूर्णलाई तिलको तेलसित नाडीव्रणमा प्रयोग गरिन्छ। यसको तृणबाट क्षार बनाएर विभिन्न रोगमा प्रक्षालनकर्मका लागि प्रयोग गर्न सकिन्छ । बिच्छीजस्ता विषालु किराको विष झार्न यसको घाँस जलाएर धूपन गर्न सकिन्छ । तृष्णारोगमा यसको पेया बनाएर प्रयोग गर्न सकिन्छ । यो विकासी गुणको भएको हुनाले यसको सेवनपछि नपचिकनै शरीरमा फैलिएर शरीर र सन्धिहरूलाई शिथिल गराइदिन्छ । यसैले यसलाई नयाँ अवस्थामा उपभोग गर्नु वा खानुहुँदैन । आधुनिक खोजहरूले मधुमेह, हाड र मासीको समस्या, मलवद्धता, दम आउने रोग, मृगौला एवं थाइराइड र प्यान्क्रियाज ग्रन्थीका समस्याहरूमा यसको प्रभावकारिता प्रमाणित गरेका छन् । रासायनिक संघटनमा यसमा प्रोटीन, फ्याट, रेशा, कार्बोहाड्रेट, क्याल्सियम, फस्फोरस र लौह रहेको पाइन्छ । कोद्रवको एउटा वन्यप्रजाति पनि छ । यसलाई उद्दालक भनिन्छ । सम्भवतः यो *P. scrobiculatum* var *commersonii* stapf मानिएको छ । उद्दालक कोद्रवभन्दा ज्यादा ग्राही, तीव्र वातकारक र उष्ण हुन्छ ।

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७ कङ्गुकोद्रवनीवारश्यामाकादि हिमं लघु । तृणधान्यं पवनकृल्लेखनं कफपित्तहृत् ॥ —अष्टाङ्गहृदयम्, सूत्रस्थानम्, ६ अध्यायः, श्लोकसंख्या १० ॥

८ कङ्गुकोद्रवजूर्णाह्वगर्मूटीचूर्णपादिकाः । श्यामाकतोयश्यामाकहस्तिश्यामाकशिम्बिरा ॥ शिम्बिरो दारुनीवारवरूकूबरकोत्कटा । मधुली शान्तनुः सण्डिर्वेणुपर्णी प्रशान्तिका ॥ गवेधुकाण्डलौहित्यतोदपर्णीमुकुन्दकाः ॥ —अष्टाङ्गसंग्रहः, सूत्रस्थानम्, ७ अध्यायः, १४–१६ श्लोकाः ॥

९ सितकंगुकश्यामाककोद्रवोद्दालनर्त्तकाः ॥ गवेधुका देवधान्यं वरुकाह्वं वरिट्टिका । उद्री नाडी तोयपर्णी मुकुन्दशिम्बिरादिकम् ॥ तृणधान्यम्.....॥ — कैयदेव निघण्टुः, धान्यवर्गः ९५–९६ ॥

१० राजनिघण्टु, शाल्यादिवर्गः १२६–१३८ सम्म ।

११ भावप्रकाशनिघण्टुः, धान्यवर्गः, ७४–८७ श्लोकाः ।

१२ निकृष्टप्रतिकृष्टार्वरेफयाप्यावमाधमाः । कुपूयकुत्सितावद्यखेटगर्ह्याणकाः समाः । —अमरकोशः, विशेष्यनिघ्नवर्गः ५४ ॥

१३ सकोरदूषः श्यामाकः कषायमधुरो लघुः । वातलः कफपित्तघ्नः शीतः संग्राहीशोषणः ॥ चरकसंहिता सूत्रस्थानम् २०।१६ ॥

१४ कोरदूषः परंग्राही स्पर्शशीतो विषापहः ॥ —अष्टाङ्गहृदयम्, सूत्रस्थानम् ६।१३ ॥

मधूलिका/कोदो, मडुआ, रागी *Eleusine coracana* Gaertn/ Finger Millet

नेपालको समाजले भन्ने गरेको कोदो यही हो। यसका पनि विभिन्न जाति छन्। मधुली, रागिका, रागी र नर्त्तक यसका संस्कृत पर्याय नाम हुन्। राजनिघण्टुमा रागीलाई लाञ्छन, बहुदलकणिश र गुच्छकणिश भनिएको छ। यो तितो, गुलियो, टर्रो, शीतल, रक्तपित्तनाशक र बलकारक छ।[१५] यो पनि कोद्रवजस्तै उपयोगी अनाज हो। यसको अङ्कुरित उत्पादन माल्ट हो। यसलाई मदिरा बनाउन पनि प्रयोग गरिन्छ। यसको रोटी र ढिँडो पोसिलो मानिन्छ। जलोदर रोगमा यसको रोटी उपयोगी मानिएको छ। कतैकतै सुत्केरीलाई पनि यसको रोटी खुवाउने गरेको पाइन्छ। यसमा प्रोटीन, फ्याट, रेशा, कार्बोहाड्रेट, क्याल्सियम, फस्फोरस, आइरन, भिटामिन ए, बी हुनुका साथै आयोडिन तथा गन्धक पनि हुन्छ। अनाजमध्ये आयोडिनको यो राम्रो स्रोत मानिन्छ।

श्यामाक/सामा *Echinochloa frumentacea* Linn/ Barnyard Millet

आचार्य डल्हणले श्यामाकका तीन प्रकार बताएका छन्। श्यामाक, उष्ट्रश्यामाक र हस्तिश्यामाक। श्यामाक भनेको अम्भश्यामाक अर्थात् जलश्यामाक हो। यो जलले पुष्ट हुन्छ। उष्ट्रश्यामाक स्थूलश्यामाक/ स्थलश्यामाक हो। यो ठूलो श्यामाक हो। हस्तिश्यामाकलाई श्यामिका पनि भन्दछन्। यो पनि ठूलो श्यामाक हो।[१६] यसमा प्रोटीन, कार्बोहाइड्रेट, खनिजतत्व, रेशा, आइरन तथा थोरै भिटामिन ए र बी पाइन्छ। श्यामाक टर्रो, गुलियो, हलुका, वातकारक, कफपित्तनाशक, ग्राही, शोषक र शीतल हुन्छ।[१७]

आचार्य चरकले छ महिनासम्म दुधमात्र खाएर तीन महिनासम्म स्नेहलवणरहित पेया खाएपछि सामा वा कोदोको भोजन दिने कुराको उल्लेख गरेका छन्। उनले यसरी सामाको खाना खाएमा जलोदररोग एक वर्षमा निको हुने बताएका छन्।[१८] स्नेहव्यापत् (स्नेह वा चिल्लो पदार्थको अधिकताले हुने समस्या) भएमा त्यसको उपचारका लागि श्यामाकको प्रयोग आचार्य वाग्भटले सुझाएका छन्।[१९] आचार्य सुश्रुतले पनि अतिस्निग्धतामा रुक्षणको लागि यसको प्रयोग गर्नुपर्ने बताएका छन्।[२०] सामान्यतया कोद्रव र श्यामाकका गुणकर्म समान छन्। यो पनि मधुमेह, विबन्ध, यकृतविकार (कलेजोको रोग), वृक्कविकार (मृगौलाको रोग), अर्बुदरोगको अवस्था आदिमा उपयोगी भएको कुरा नवीन खोजहरूले पनि देखाएका छन्।

नीवार/तृणान्न, मुनिधान्य, नावो धान, तिन्नी, देवभात *Hygroryza aristata* Nees/ Wild Rice Asian watergrass

यो तालकिनार र सिमसारक्षेत्रमा पाइने जलीय तृणधान्य हो। हाम्रा ऋषिमुनिहरू जंगलमा यही अनाज खान्थे। यसैले यसलाई मुनिधान्य भनिन्थ्यो। व्रत बस्नेहरूले यसलाई फलाहारको रूपमा प्रयोग गर्ने गरेकाले यो देवभातको नाउँले पनि चिनिन्छ। राजनिघण्टुमा यसलाई अरण्यधान्य, मुनिधान्य, पवित्र, पथ्य, हलुको, मीठो र स्निग्ध भनिएको छ।[२१] सुश्रुतसंहिताको प्रसिद्ध टीका निबन्धसंग्रहमा डल्हणाचार्यले यसलाई दुई किसिमको बताएका छन्। एउटा धानजस्तै बोट हुने धानखेतमा र अर्को ठूलो पात तथा काण्ड हुने सिमसार या जलजक्षेत्रमा पाइन्छ। यसैलाई कसैले प्रशान्तिका भन्ने गरेको पनि उल्लेख गरेका छन्।[२२] भावप्रकाशनिघण्टुमा यसलाइ प्रसाधिका र तृणान्न भनिएको छ। नीवार शीतल, ग्राही, पित्तनाशक र कफवातकारक हुन्छ।[२३] श्यामाकको जस्तै गुणकर्म यसमा पनि पाइन्छ।

कङ्गु/प्रियङ्गु, कागुनो *Setaria italica* Linn, Beauv / Italian Millet/Foxtail Millet

यसलाई निघण्टुकारहरूले कङ्गुणी, कङ्गुनी, चीनक, पीततण्डुल, दुर्जरा, सुकुमार आदि पर्याय नाम दिएका छन्। कालो, रातो, सेतो र पहेंलो गरी यसलाई चार प्रकारको भएको कुरामा पनि निघण्टुकारहरू एकमत रहेका छन्। राजनिघण्टुमा नाना किसिमको बताएको छ र सबभन्दा उत्तम कागुनोमा पहेंलोलाई लिइएको छ।[२४] आचार्य चरकले यसलाई श्यामाकको जस्तै गुण भएको बताएका छन्।[२५] कागुनो विशेषतः भाँचिएको हाडलाई जोड्ने, बलकारक, गह्रुङ्गो, कफनाशक हुन्छ।[२६] खासगरी घोडाहरूका लागि विशेष गुणकारी मानिन्छ।[२७] राजनिघण्टुमा कागुनोलाई गुलियो, रुचिकारक, टर्रो, स्वादिलो, शीतल, वातकारक, पित्तकारक, दाहनाशक, रुखो र भग्नसन्धानकारक भनिएको छ।[२८] कैयदेवनिघण्टुमा कालोभन्दा रातो, रातोभन्दा सेतो र

१५ रागी तु लाञ्छनः स्याद् बहुदलकणिशश्च गुच्छकणिशश्च। तिक्तो मधुरकषायः शीतः पित्तास्रनाशनो बलदः ॥ — राजनिघण्टुः, शाल्यादिवर्गः, १३७॥

१६ श्यामाकस्त्रिविधः श्यामाकः उष्ट्रश्यामाकः हस्तिश्यामाकश्चेति, श्यामाकशब्देन तोयश्यामाक उच्यते, उष्ट्रश्यामाकः स्थूलश्यामाकः, हस्तिश्यामाकः श्यामिकेति लोके ॥ —सुश्रुतसंहिता सूत्रस्थान अध्याय ४६ को २१ सूत्रमा डल्हणको निबन्धसंग्रहव्याख्या ॥

१७ सकोरदूषः श्यामाकः कषायमधुरो लघुः। वातलः कफपित्तघ्नः शीतः संग्राहि शोषणः। —चरकसंहिता सूत्रस्थानम् २७ अध्यायः श्लोकसंख्या १६ ॥

१८ निःस्रुते लंघितः पेयामस्नेहलवणां पिबेत्। अतः परं तु षण्मासान् क्षीरवृत्तिर्भवेन्नरः ॥ त्रीन् मासान् पयसा पेयां पिबेत् त्रींश्चापि भोजयेत्। श्यामाकं कोरदूषं वा पयसालवणं लघु। नरः सम्वत्सरेणैव जयेत् प्राप्तं जलोदरम् ॥ —चरकसंहिता चिकित्सास्थानम्, १४/१९१–९३ ॥

१९ तक्रारिष्टखलोद्दालयवश्यामाककोद्रवम्। पिप्पलीत्रिफलाक्षौद्रपथ्यागोमूत्रगुग्गुलुः ॥.......स्नेहव्यापदि साधनम् ॥ —अष्टाङ्गहृदयम्, सूत्रस्थानम् १४/३३–३४ ॥

२० रुक्षस्य स्नेहनं स्नेहैरतिस्निग्धस्य रुक्षणम्। श्यामाककोरदूषान्नतक्रपिण्याकसक्तुभिः ॥ —सुश्रुतसंहिता, चिकित्सास्थानम्, ३१।५६ ॥

२१ नीवारोऽरण्यधान्यं स्यान्मुनिधान्यं तृणोद्भवम्। नीवारो मधुरः स्निग्धः पवित्रः पथ्यदो लघुः ॥ —राजनिघण्टुः, शाल्यादिवर्गः १३५ ॥

२२ नीवार उलिकाधान्यं तद्द्विविधम्— एकं धान्यसदृशविटपं धान्यक्षेत्रजम्, द्वितीयं महादलकाण्डं तु सलिलजम्, तत्र सलिलजं सलिलवृद्धिमात्रस्तम्बप्रोहं रक्तशूकं च, तदेव प्रशान्तिका इति तन्त्रान्तरेपि पठ्यते ॥ — सुश्रुतसंहिता, सूत्रस्थानम्, ४६।२१ मा डल्हणको टीका ॥

२३ प्रसाधिका तु नीवारस्तृणान्नमिति च स्मृतम्। नीवारः शीतलो ग्राही पित्तघ्नः कफवातकृत् ॥

२४ कङ्गुणी कङ्गुनी प्रोक्ता चीनकः पीततण्डुलः। वातलः सुकुमारश्च स च नानाविधाभिधः ॥ —राजनिघण्टुः, शाल्यादिवर्गः १३२ ॥ पीततण्डुलिका कङ्गुः प्रियङ्गुः दुर्जरा मता........कृष्णा रक्ता च श्वेता च पीताश्चैव प्रियङ्गवः ॥ —कैयदेवनिघण्टुः, धान्यवर्गः ९८–९९ ॥ स्त्रियां कङ्गुप्रियङ्गु द्वे कृष्णा रक्ता सिता तथा। पीता चतुर्विधा कङ्गुस्तासां पीता वरा स्मृता ॥ —भावप्रकाशनिघण्टुः, धान्यवर्गः ७६ ॥

२५ हस्तिश्यामाकनीवारतोयपर्णीगवेधुकाः। प्रशातिकाम्भःश्यामाकलोहित्याणुप्रियङ्गवः ॥ मुकुन्दो झिण्टिर्गर्मूटी वरुका वरकास्तथा शिबिरोत्कटजूर्णाह्वाः श्यामाकसदृशाः गुणैः ॥ —चरकसंहिता, सूत्रस्थानम्, २७। १७–१८ ॥

२६ कङ्गुस्तु भग्नसन्धानवातकृद् बृंहणी गुरुः। रुक्षा श्लेष्महरातीव वाजिनां गुणकृद् भृशम् ॥ —भावप्रकाशनिघण्टुः, धान्यवर्गः ७७ ॥

२७ प्रियङ्गुर्मधुरो रुच्यः कषायः स्वादुशीतलः। वातकृत्पित्तदाहघ्नो रुक्षो भग्नास्थिबन्धकृत् ॥ —राजनिघण्टुः शाल्यादिवर्गः १३३ ॥

२८ प्रियङ्गु भग्नसन्धानवातकृद् बृंहणी गुरुः। कृष्णा रक्ता च श्वेता च पीताश्चैव प्रियङ्गवः ॥ यथोत्तरं प्रधानाः स्युः रुक्षा कफहराः स्मृताः ॥ — कैयदेवनिघण्टुः, धान्यवर्गः ९९–१०० ॥

सेतोभन्दा पहेंलो कागुनो उत्तम मानिएको छ। उत्तम कागुनो भग्नसन्धानकारक, बृंहण, गुरु, रुक्ष र कफनाशक हुन्छ। वैज्ञानिक विश्लेषण अनुसार यसमा प्रोटीन, फ्याट, फाइबर, कार्बोहाइड्रेट, क्याल्सियम, म्याग्नेसियम, फस्फोरस, आइरन आदिका साथै भिटामिन ए र बी पाइन्छ।

चीनाक/चिनो *Panicum milaceum* Linn./ Common Millet

यो काककङ्गु, सुश्लक्ष्ण, श्लक्ष्णक नामले चिनिएको कङ्गुको भेद हो। कागुनोका गुण यसमा पाइन्छन्।[२९] यसमा प्रोटीन, फ्याट, कार्बोहाइड्रेट, फाइबर, क्याल्सियम, फस्फोरस, आइरन तथा भिटामिन ए र बी पाइन्छ।

वरक/वरका/जूर्णा/जुनेलो, ज्वार *Sorghum vulgare* Linn, Pers / Grate Foxtail Millet

यो ठूलो खालको प्रियङ्गु हो। राजनिघण्टुमा यसलाई स्थूलकङ्गु भनिएको पाइन्छ। यसलाई यावनाल, देवधान्य, तुहल, अनिल, वेणुपत्री, प्रशान्तिका आदि नामले चिनिन्छ।[३०] यसमा प्रोटीन, फ्याट, कार्बोहाइड्रेट, क्याल्सियम, फस्फोरस, आइरन तथा भिटामिन ए र बी कम्प्लेक्स पाइन्छन्। राजनिघण्टुले वरक मधुर, रुक्ष, कषाय र वातपित्तकारक भनेको छ।[३१] कैयदेवनिघण्टुमा यावनाल कषाय, मधुर, रुक्ष, रक्तपित्तकफनाशक, अवृष्य, लघु, शीतल, क्लेदनाशक र वातकारक भनिएको छ।[३२] भावप्रकाशनिघण्टुमा यावनाल मधुर, शीतल, कषाय, रक्त एवं कफ तथा पित्तविकारनाशक, अवृष्य(पुरुषत्वशक्ति नबढाउने), टर्रो, क्लेदकारक र लघु बताइएको छ।[३३] गुणमा केही फरक यसको प्रजातिगत भेदका कारणले भएको हुनसक्छ। स्थौल्यरोग(मोटोपन)का लागि यो उपयोगी आहार हो।

वज्रान्न, बाजरो, बाजरा *Pennisetum typhoides* Burm/glaucum/ Pearl Millet

नेपाली निघण्टुमा यसलाई साजक, अग्रधान्य, नालिका, नालिनी, नीलशस्य, नीलकरण, वर्जरिका, वर्जर भनिएको छ।[३४] जैनाचार्य घाँसीलालले स्त्रीलिङ्गमा वर्जरी, वर्जरिका, नाली र पुलिंगमा साजक शब्द बाजराका लागि संग्रह गरेका छन्।[३५] यसमा पनि प्रोटीन, फ्याट, कार्बोहाइड्रेट, फाइबर, क्याल्सियम, फस्फोरस, आइरन तथा भिटामिन ए र बी पाइन्छ। द्रव्यगुणविज्ञानका सुप्रसिद्ध आयुर्वेदज्ञ आचार्य प्रियव्रत शर्माले बाजरालाई मधुर, रुक्ष, उष्ण, बलकारक, जराजन्य अवस्थाका लागि हितकारक, वातपित्तकारक, पुरुषत्वहर र अग्निदीपक बताएका छन्।

पुच्छतृण/सानो कागुनो/ हरियो कागुनो *Panicum ramosa/Urochloa ramosa* / Browntop millet/American millete

यो सानो खालको कागुनो हो। यसमा कागुनोका गुणहरू पाइन्छन्। रेशाको पर्याप्तता यसको खास विशेषता हो। यसैले अर्श र भगन्दर (Piles, Fissure, Fistula)रोगका लागि यसको प्रयोग हितकारक हुन्छ। त्यस्तै गर्भाशय, उदर तथा जोर्नीका समस्या, रक्तचाप, मधुमेह र अर्बुद रोगका लागि राम्रो पथ्यको रूपमा यसको उपयोगिता छ।

अणुधान्य/कुट्की/कुट्टू/*Panicum sumatrense* Roth/ Little millete/ Indian millet

यो चिनो वा बाजरोको सानो किसिम हो। भारतमा व्रतमा यसको निकै प्रयोग हुन्छ। एकादशी, नवरात्री जस्ता पर्वमा कुट्टू बाजरोको पीठोको राम्रै खपत हुन्छ। चिनो र बाजराका सबै विशेषता यसमा पाउन सकिन्छ।

शान्तनु धान

वैदिक वाङ्मयले गंगालाई त्रिधारात्मक मानेको छ। आकाशबाट वर्षाको रूपमा वर्षिने, जमिनमा वहने र जमिनमुनिबाट मूल फुटेर आउने। यसमध्ये आश्विन महिनाको मेघबाट वर्षिने पवित्र जललाई आयुर्वेदका आचार्यहरूले गाङ्गजल भनेका छन्।[३६] यही जलको प्रवाहक्षेत्रमा शान्तनुनामक धान्य उब्जन्थ्यो। महाभारतका राजा शन्तनुको नाम यससित जोडिएको छ। हुनसक्छ यो अनाजको उनी संकलन गराउँथे र आफू पनि प्रयोग गर्दथे। राजा शन्तनुको गङ्गासितको सम्बन्ध कतै यही धान्यविशेषका लागि थियो कि ? यो खोजीको विषय हो। हिजोआज यस धान्यको त्यति चर्चा पाइएको छैन। तर, आयुर्वेदले यस धान्यको गुणकर्म कोद्रव, नीवार र श्यामाकसँग मिल्दोजुल्दो बताएको छ। यी सबै उष्ण हुन्छन्, टर्रा र गुलिया हुन्छन्, कटु विपाक भएका हुन्छन्, कफनाशक हुन्छन्, मूत्रबद्धताकारक हुन्छन् र वातपित्तकारक हुन्छन्। तीमध्ये ज्यादा टर्रा र गुलियाखालका चाहिँ शीतल र पित्तनाशक पनि हुन्छन्।[३७]

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२९ चीनाकः काककङ्गुः स्यात्....।। —कैयदेवनिघण्टुः, धान्यवर्गः १०१ ॥ चीनाकः काककङ्गुश्च सुश्लक्ष्णः श्लक्ष्णकः स्मृतः। चीनाकः कङ्गुभेदोस्ति स ज्ञेयो कङ्गुवद् गुणैः। — भावप्रकाशनिघण्टुः, धान्यवर्गः ७८ ॥

३० वरकः स्थूलकङ्गुश्च रुक्षः स्थूलप्रियङ्गुकः। राजनिघण्टुः, शाल्यादिवर्गः, १३० ॥ यावनालो देवधान्यं जूर्णाह्वस्तुहलोऽनिलः। तानीयको जूर्णविका तिनिका जुन्हुलिस्तथा ॥ वरको वरका जूर्णा वेणुपत्री प्रशातिका ॥ — कैयदेवनिघण्टुः, धान्यवर्गः १०५–०६॥

३१ वरको मधुरो रुक्षः कषायो वातपित्तकृत्। —राजनिघण्टुः, शाल्यादिवर्गः १३१ ॥

३२ कषायाः मधुरा रुक्षा रक्तपित्तकफापहाः। अवृष्याः लघवः शीता क्लेदघ्ना वातकोपनाः ॥ —कैयदेवनिघण्टुः, धान्यवर्गः,१०६–०७ ॥

३३ यावनालो हिमः स्वादुर्लोहितश्लेष्मपित्तजित्। अवृष्यस्तुवरो रुक्षः क्लेदकृत्कथितो लघुः ॥ —भावप्रकाशनिघण्टुः, धान्यवर्गः ८७ ॥

३४ नेपाली निघण्टु, कोषनाथ देवकोटा, क्रमाङ्क ७५३।

३५ स्त्री वर्जरी वर्जरिका नाली स्यात्पुंसि साजकः, शिवकोषः, द्वितीय काण्ड, धान्यादिवर्गः २।

३६ गाङ्गमाश्वयुजे मासि प्रायो वर्षति वारिदः। सर्वथा तज्जलं ज्ञेयम् .....॥ —भावप्रकाशनिघण्टुः, वारिवर्गः ११ ॥

३७ उष्णाः कषायमधुराः रुक्षाः कटुविपाकिनः। श्लेष्मघ्ना बद्धनिस्यन्दा वातपित्तप्रकोपणाः ॥ कषायमधुरस्तेषां शीतः पित्तापहः स्मृतः। कोद्रवश्च सनीवारः श्यामाकश्च सशान्तनुः ॥ — सुश्रुतसंहिता सूत्रस्थानम्, ४६।२२–२३ ॥

निष्कर्ष

प्रस्तुत संख्यामात्र तृणधान्यको संख्या होइन। यहाँ परिचय गराइएकाबाहेक वेणुयव(बाँसको जौ/बिउ), गवेधुक(एक किसिमको बाजरो) लगायत प्रारम्भमा उल्लेख गरिएका अनेकथरिका तृणधान्यहरूको वर्णन आयुर्वेदीय संहिता र निघण्टुहरूमा उल्लेख गरिएका छन्। तीमध्ये कतिपय प्रचलनबाट हटेकाले अपरिचित या खोजी गर्नुपर्ने विषय बनेका छन्। झण्डै पाँचहजार वर्ष अघिदेखि शास्त्रमा उल्लेख भएका र शास्त्र निर्माणभन्दा पहिले श्रुति र परम्पराले जनजीवनमा स्थापित भएका हाम्रा परम्परागत यस्ता अनाजहरूलाई उन्नाइसौं शताब्दीमा भएको पश्चिमी गोलार्धको उन्नयनले तिरोहित बनाइदिएको थियो। पछिल्ला दिनहरूमा वैश्विक सम्पर्क र ज्ञानको आदानप्रदान तीव्र रूपमा अगाडि बढ्यो। मधुमेह, उच्च रक्तचाप, मोटोपन, मुटु र मृगौलाका समस्याहरू, रक्त अल्पता, जोर्नी र वाथरोग, रोग क्षमता शक्तिको ह्रासले गर्दा हुने स्वास्थ्य समस्या, पोषणजन्य विकार आदिले गर्दा पश्चिमी गोलार्धबाट नै तृणधान्य (Small seeded crops/Millets)का वारेमा निकै गहकिला अनुसन्धानहरू भए। भारतका तृणधान्य पुरुष (Millets Man) पद्मश्री डा.खादर वलीले त हाम्रा ऋषिमुनिहरूले उहिल्यै प्रयोग गरेको यो किसिमको अनाज शरीर, इन्द्रिय, मन र आत्मासमेतका लागि हितकारक भएको कुरालाई जोडदार रूपमा प्रस्तुत गरे। उनले कोद्रव, कागुनो, कुट्की, चिनो र सामाजस्ता तृणधान्यलाई श्रीधान्य भनेर व्याख्या गरेका छन्। संसारका विभिन्न भागमा भएका यी र यस्तै कार्यको परिणामस्वरूप विश्व सन् २०२३ लाई विश्व तृणधान्य वर्ष (International Millets Year) को रूपमा मान्न तयार भएको हो।

अहिलेको स्वास्थ्य समस्या भनेको नसर्ने रोगहरूको हो। मधुमेह, उच्च रक्तचाप, मुटुको रोग, मृगौलाका समस्याहरू, श्वासप्रश्वास सम्बन्धी विकार, क्यान्सर, मस्तिष्कघात, मानसिक रोग, नसाका समस्या, जराजन्य रोगहरू, मोटोपन लगायतका जीवनशैली र खानपानजन्य समस्याहरूले आजको मानवजीवन भयावह बनेको छ। रोजगारीको लागि बसाईंसराइ र कामको व्यस्तताले तयारी खानामा भर पर्नुपर्ने अवस्था पनि त्यत्तिकै विकराल भएको छ। यस्तो अवस्थामा स्वास्थ्यको गुणात्मक सुधारका लागि तृणधान्य अर्थात् कोदो र यस्तै अन्य अनाजको निकै महत्व छ। हिजोको हाम्रो ऋषि अनाज कसरी गरीबको/दरिद्रको खाने कुरा भयो ? कसरी कुधान्य र क्षुद्रधान्यको अपव्याख्या हुनगयो ? यसलाई हामीले समीक्षा गर्नुपर्दछ। यस्ता अनाजहरूको उत्पादन र उपयोग बढाएमा मानवस्वास्थ्यमा निकै राम्रो सकारात्मक परिणाम देखापर्ने कुरामा निर्धक्क भन्न सकिने कुरा पछिल्ला अनुसन्धानहरूले छर्लङ्ग तुल्याएका छन्।

सन्दर्भग्रन्थ

१. ऋग्वेदः।
२. शुक्लयजुर्वेदः।
३. अथर्ववेदः।
४. रुद्राष्टाध्यायी।
५. चरकसंहिता भाग १ र २, व्याख्याकार डा. ब्रह्मानन्द त्रिपाठी, चौखम्बा सुरभारती प्रकाशन, वाराणसी।
६. सुश्रुतसंहिता, निबन्धसंग्रहव्याख्यासहिता, चौखम्भा सुरभारती प्रकाशन, वाराणसी।
७. अष्टाङ्गहृदयम्, सर्वाङ्गसुन्दरीव्याख्याविभूषितम्, व्याख्याकारः श्रीलालचन्द्र वैद्य, मोतीलाल बनारसीदास, दिल्ली।
८. अष्टाङ्गसंग्रहः, सर्वाङ्गसुन्दरीव्याख्यासहितः, व्याख्याकार पं.लालचन्द्र शास्त्री वैद्य, वैद्यनाथ आयुर्वेद भवन, प्रा.लि., कलकत्ता।
९. राजनिघण्टुः, पं. नरहरि, व्याख्याकारः डा.इन्द्रदेव त्रिपाठी, चौखम्भा कृष्णदास अकादमी, वाराणसी।
८. कैयदेवनिघण्टुः, व्याख्याकार प्रियव्रत शर्मा, चौखम्भा ओरियन्टालिया, वाराणसी।
९. भावप्रकाशनिघण्टुः, भावमिश्रः, विमर्शकारः कृष्णचन्द्र चुनेकर, सम्पादकः डा.गङ्गासहाय पाण्डेय, चौखम्भा भारती अकादमी, वाराणसी।
१०. नेपालीनिघण्टु, कोषनाथ देवकोटा, नेपाल राजकीय प्रज्ञा प्रतिष्ठान, काठमाण्डू।
११. द्रव्यगुणविज्ञान भाग १, २, ३, ४ र ५, आचार्य प्रियव्रत शर्मा, चौखम्भा भारती अकादमी, वाराणसी।
१२. अमरकोशः, अमरसिंह, टीकाकार कुलचन्द्र शर्मा गौतम, नेपाल राजकीय प्रज्ञा प्रतिष्ठान, काठमाण्डौ।
१३. नेपाली बृहत् शब्दकोश, नेपाल प्रज्ञा प्रतिष्ठान, काठमाण्डौ।
१४. अंग्रेजी नेपाली साझा संक्षिप्त शब्दकोश, नरेन्द्रमणि आचार्य दीक्षित, साझा प्रकाशन, काठमाण्डौ, नेपाल।
१५. नेपाली शब्दसागर, वसन्तकुमार शर्म्मा नेपाल, भाभा पुस्तक भण्डार, काठमाण्डौ।
१६. प्रज्ञा नेपाली अंग्रेजी शब्दकोश, नेपाल प्रज्ञा प्रतिष्ठान, काठमाण्डौ।
१७. व्युत्पत्तिमूलक संस्कृत नेपाली शब्दकोष, प्रा.नीलमणि ढुङ्गाना, साझा प्रकाशन, पुलचोक, ललितपुर, नेपाल।
१८. Medicinal Plants of Nepal, Department of Plant Resources, Kathmandu, Nepal.
१९. सूचना प्रविधिमार्फत प्राप्त सूचना र जानकारीहरू।

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The Historical and Cultural Aspects of Millets

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Summary

This article provides insights into the historical and cultural significance of millet cultivation in various regions of Nepal. In Garhwal, Bhimsen Thapa's Gorkhali Administration encouraged the cultivation of hemp and millet. Hemp was grown for its fibers, while millet served as a vital crop in unirrigated regions. The introduction of taxes on crops like millet in 1861 BS played a role in shaping agricultural practices. The Khamba tribe in Karnali grew millet along with other crops like buckwheat and barley. Similarly, the Khas community, originally from Kashmir, adopted millet cultivation as they moved eastward and contributed to the spread of the Khas Bhasa, now known as the Nepali language. This also highlights historical commodity prices, showcasing the value of millet in various markets. Millet was a staple crop alongside rice, wheat, and other grains from long before. Additionally, the Majhi community in the Koshi River basin depended on millet among other crops, with millet liquor being a part of their festivals. The Mongolian community in the Himalayan region adopted farming, including millet cultivation, as they transitioned from a hunter-gatherer lifestyle. The Thami tribe in Dolakha district grew millet as a key rainfed crop, carefully selecting seeds for planting. Traditional methods of millet processing were described, and millet's nutritional importance was emphasized. Lastly, the text touches on the Jajmani system, where the workers mainly from the scheduled caste individuals received grains, including millet, as payment for various services in agricultural communities. Overall, millets played a significant role in the agricultural and cultural landscapes of Nepal, serving as a crucial crop for livelihood and rituals throughout history.

Keywords: Culture, history, millets, traditions, price

Introduction

Millets, a group of drought-resistant cereal crops, have played a significant role in the agricultural history of Nepal. These resilient crops have been cultivated and consumed by various ethnic communities in the country for centuries, contributing to the diverse and sustainable food culture of Nepal. It has social, cultural, economic and environmental value, rooted in the depth of the community. The indigenous communities of Nepal, such as the Newars, Majhis, Magars and others have a long history of growing millets as a staple crop. Millets are mostly consumed as food and beverage in their traditions. In addition, the Tharu community in the Tarai region has a tradition of cultivating finger millet and preparing traditional alcoholic beverages from it, adding depth to their cultural practices. Likewise, the indigenous Rai and Limbu communities have a rich history of cultivating foxtail millet (kodo) and proso millet (chino) as well as incorporating these grains into their traditional dishes (Riley et al 1991). Millets hold a significant role in the daily lives of the Nepalese people, particularly in the hilly regions from the ancient time. Sharma et al (2009) discuss the substantial social, economic, and cultural significance of millet in the Baglung district. The Magars of Argal, Baglung incorporate millet items both in their rituals and as staple foods, emphasizing the ritual aspects of millet.

Moreover, Regmi (1963) reported that millets were cultivated in upland from the ancient time in Nepal specially in the mid hills and contributed to the food security. During the 1960's people used to exchange millets over cash or with paddy or other commodities or pay tax based on established value for the value. However, the value of millet was lower than the other cereals as it was believed as an inferior food. Regmi (1971) also documented that the Khas people rooted in Kashmir traditionally cultivated millets. Over time, they migrated to Nepal from the western regions, bringing with them their traditional knowledge of millet cultivation and sharing these practices in the areas where they settled.

Millets in Garhwal

According to Regmi (1988) millet was one of the major crops grown in the upland areas of Garhwal region. Bhimsen Thapa extended the territory to Kumau and Garhwal and started the Gorkhali Administration. Cash crops were not extensively cultivated in the Garhwal region. During the period of the Gorkhali administration in Garhwal, the rural people grew wheat and rice to pay the tax and subsided on barley, maize, millet and other coarse grains which supplemented their diet with fruits, and herbs. Meanwhile, millet was exclusively grown in the unirrigated areas in the Garhwal region. In Garhwal, levy (Salami) for land was imposed all over the kingdom in 1804. However, this levy was effectively implemented from crops of the year 1808 at the same time the rate of levy on cropping land called "Tor" was also imposed for crop production. The levy on cropping land (Tor) for growing paddy; kodo, sama, kaguno (millets); barley, wheat, pigeon pea, lentil, horse gram, gram, peas, sesame, mustard, linseed, cotton and sugarcane were 1 anna per rupee of revenue generated from crop produced that is to be paid to the Amil (Revenue collector)

The Semi-Nomadic Khambas and Millets

The Khamba or Khanpa tribe used to live in Karnali, Seti, Rapti Bheri during 1966-1971. They used to change their settlements during summer and winter. The Khamba community is divided into four categories: 1) Dangali Khmabas 2) Dadakhet Khambas 3) Mandara Khambas 4) Dilli-khet Khambas. Dandakhet Khambas reclaimed their lands in the Dandakhet (Karan Dhara Mugu) area in which they paid Serma tax (tax paid on unregistered land). They grew millet, buckwheat (tite-mithe), kaguno and marse (Regmi 1988).

Movement of Khas and Millet

During the Malla dynasty Khas people used to live in Kumau and Garawal regions. The Khas originally came from Kashmir, also the word Khas originated from Kashmir (Gellner 2014). Some of the Khas peaple moved towards the east and reached Nepal while others moved to Iran. The Khasa moved towards the hilly region rather than the Himalayan or Tarai region and reached the valley of the Bheri River. These Khas remained as the farmers who had been cultivating millet (kodo) from ancient times in the hilly region they conquered. They also introduced new crops such as barley, wheat and sesame. Khas moved from west to east and reached Kathmandu. They used to speak the Khas language and they disseminated the Khas Bhasa (now Nepali language). The three Malla states of Kathmandu Valley were mainly inhabited by the newars who cultivated only paddy. They did not face any food shortage so it was not necessary for them to grow dry crops such as maize and millet on unirrigated upland land. These pakho (unirrigated) lands were occupied by Murmis who used to call themselves Tamangs. They grew millet and maize in those pakho lands. In addition, the khas settled in the pakho hills around Kathmandu and grew crops like corn and millet. Meanwhile, King Jaysthiti Malla allowed them to cultivate irrigated land. Gradually Newer communities learn Khas Bhasa from Khas community (Regmi 1988).

Millet Exchange and Price

During the 1908 drought, agricultural commodity prices soared, with 31 seers (1 seer equals 800 grams) of paddy costing a company rupee. However, in 1909, prices dropped, and 56 seers of paddy could be bought with the same amount of money (Regmi 1988). The details of the commodity price that can be bought from a company rupee at Jaleshower market in 1909 is presented here

Table 1. Volume of exchange from a company rupee at Jaleshwor market in 1909 (1966 BS)

SN	Commodity	Volume in seer
1	Bhadaiya, Ansu, gamadi, paddy	56
2	Maize	27
3	Millets	56
4	Coarse rice	14
5	Fine rice	15

Food grains are procured from divisions (dara) other than Humla, Tibrikot, Mugu and Karan in Jumla. A person from the government was deployed to procure grain at an assigned rate.

Table 2. The price of food grain in Jumla in 1779

SN	Crops	Unit	Rate per rupees
1	Rice	Paathi	8
2	Millet (Kodo)	Paathi	12
3	Barley	Paathi	16
4	Blackgram (Mas)	Paathi	8
5	Horse gram, Lentil	Paathi	9
6	Millets (Chino, Kagunu)	Paathi	12
7	Ghee, Oil	Dharni	2
8	Honey, Gur	Dharni	3

In addition, the residents of Panchok, Lamjung; Karabir Thapa was granted an allotment of 21 muris of rice land under jagera tenure for the year 1850 on the payment of Chardam-theki (a kind of tax). He sowed kaguno and kodo (millet) on this land (Regmi 1988).

Table 3. Commutation rate per rupee at various regions of Nepal

Region	Crop	Commutation rate per rupee
Dolakha (East no. 2)	Millet	10 Pathis
	Rice, Wheat	5 Pathis
	Maize	8 Pathis
Sindhupalchowk (East no. 1)	Millet	10 Pathis
	Rice	4 Pathis
	Maize	8 Pathis
	Wheat	6 Pathis
Kabreplanchowk (except seven villages belonging to Bhadgaun)	Millet	7 Pathis
	Rice, Wheat	4 Pathis
	Maize	6 Pathis
Bhadgaun (Seven villages)	Millet	7 Pathis
	Rice	3 Pathis
	Maize	5 Pathis
	Wheat	4 Pathis
East number 3	Millet, Maize, Wheat	10 Pathis

Region	Crop	Commutation rate per rupee
West number 1		
Nuwakot	Millet	8 Pathis
	Rice	3 Pathis
	Maize	6 Pathis
	Wheat	5 Pathis
Salyan	Millet	12 Pathis
	Rice	4 Pathis
	Maize	9 Pathis
	Wheat	6 Pathis
Lamidanda (22 Maujas including Pasangkhel)	Millet	7 Pathis
	Rice	6 Pathis
	Maize	3 Pathis
	Wheat	5 Pathis
Jhiltung and 29 other Maujas	Millet	10 Pathis
	Rice	4 Pathis
	Maize	8 Pathis
	Wheat	6 Pathis
West no. 2	Maize, Wheat, Millets	10 Pathis
	Rice	6 Pathis
West 4 and 5	Maize, Millets	1 Muri
	Wheat	12 Pathis
	Rice	8 Pathis
Pyuthan	Maize, Millets	15 Pathis
	Wheat, Rice	8 Pathis
Gulmi	Maize, Millets	16 Pathis
	Wheat	12 Pathis
	Rice	8 Pathis
Palpa		
Madi and 51 other Maujas	Maize, Millets	7 Pathis
	Wheat, Rice	4 Pathis
Malang, Rakuwa and 45 other Maujas	Maize, Millets	14 Pathis
	Wheat	6 Pathis
	Rice	8 Pathis
Dansinghdanda and 51 other Maujas	Maize, Millets	10 Pathis
	Wheat	5 Pathis
	Rice	6 Pathis
Kathmandu and Kritipur (Inside the Valley)	Millet (Milled)	5 Pathis 1 Mana
	Maize	3 Pathis 2 Mana
	Wheat	3 Pathis 7 Mana
	Rice (Milled)	3 Pathis 1 Mana

Unit conversion (approx.): 1 pathi = 8 mana = 4 kg, Source: Regmi 1988

The Majhi Community and Millets (During the 1903's)

Majhi communities were settled across the Sunkoshi and Tamakoshi riverbanks. They row boats in the river to cross the cattle, goods and the people. They fish and lay baits in the Koshi River regularly. The Majhis of the Koshi River basin grew maize, millet, paddy, lentil, cotton, etc. as their major crops. They were hauling grain by the Okhli. They didn't have the Dhiki in their house as they believed having the Dhikis in the house was the presence of evil spirits. Kipat system of land tenure existed at that period and Majhis were obliged to acquire land under Kipat. Kipat is the system of acquiring rent-free land under the royal order issued by the King (Regmi 1966). On their behalf, they have to provide ferry service to the government officials, arms, documents goods and ammunition, even in the rain. They used to drink millet liquor during their festivals and rituals. The Aitabare festival takes place on Sunday during the months of Jestha or Ashad. During this event, a special altar is constructed at a sacred location for the Aitabare deity, who is seen as a guardian of cattle. A male shaman (jhankri) receives a rooster, while a female shaman (jhankrini) receives a fowl as an offering. They present *baabar bread* made from millet flour cooked in oil or ghee as part of the rituals. The purpose of the festival is to pray for the safety of cattle from wild animals and treacherous hills. As part of the celebration, chicken, baabar bread, and millet liquor were consumed as a blessed meal (Regmi 1988).

Mangols and Millets

During the pre-historic period (1000 BC), Mongolians were the residents of the Himalayan region of Nepal. They were dependent on the wild plants and hunting animals for food. Gradually they adopted farming crops in the hills. Mongolian groups living in the forest areas of Tirhut had adopted a sedentary life and started agriculture, animal husbandry and weaving of cloth. Magar community also learnt those skills from them and started living a sedentary life. They had less chance of growing paddy in the hilly region so they started to cultivate maize, millet, mustard and other crops in their hillside lands.

Agriculture in Kathmandu Valley

Prime Minister Chandra Shumshere, commanded by General Tej Shumshere issued the following order to the Pahad Bandobast Adda in 1925: Agricultural officer was deployed to inspect the crop condition and production status in different areas (Regmi 1966). He was also an authorized person to suggest alternative crops in rainy areas and infested areas. Paddy was grown in high lands of Kathmandu valley where irrigation facilities were not available. This was done for some profit and was obliged to pay the rents in the form of paddy, though the land was not suitable for paddy. This led to bear loss both to the tenant and the landlord, so an order was issued to the Hohinaike Bandobast Adda in 1922 to cultivate maize, millet, ghaiya (upland rice) or other suitable crops on such lands. It was also prescribed that the jagirdars (owners) shall accept the rents in the form of half of the crop that was raised over there (Regmi 1988).

Thami and Millet

Magar and Pyakurel (2018) reported that Thami tribe are the residents of eastern Nepal and mostly live in the Dolakha district. Many Thami farmers primarily cultivate maize and harvest it once a year, followed by millet, rice, and wheat. In the Suspa region, most Thami farmers grow millet on rainfed lands. When selecting millet seeds, they carefully observe the plants, preferably larger plants with straight-standing grains (known as "Kodo ko bala") and healthy, sizeable panicles of millet are used for seed. Sometimes, they harvest millet plants for seeds separately before harvesting the entire millet crop.

Local millet varieties grown by Thami farmers include "Dallo Mudke Kodo" (resembling curled fingers), "Chyalthye Kodo" (long Finger millet), "Juwain Kodo" or "Seto Kodo," and "Sunkoshi Kodo." After harvesting, millet plants are sun-dried, threshed, and de-husked using a traditional tool called "Gyalbi" or "Gyabri." According to Thami farmers, millet seed grains are less susceptible to insect pests compared to other grains. Finger millet was an essential crop for them, especially when they have insufficient rice production. They consider food items like "Dhedo" and "Roti" made from millet to be highly nutritious and energizing.

Millets and Other Traditions

In the Manjushree Parajika it was written that during the Shraddha (after death ceremony) rice-balls were offered to ancestor in their remembrance must be made of good quality grains, such as rice, beaten rice, rice powder, barley powder, etc rather than the material that was prohibited by the people (such as maize powder, millet powder etc), and they must be mixed with ghee, honey, milk, and curd (Regmi 1988).

During the 1970s-80s, the customary arrangement where specialist-artisan served the needs of agricultural communities and goods given on their behalf was called the Jajmani system. Usually, the so-called low caste people used to do works such as cloth weaving, house building, making bamboo baskets, rice-stalk mats and metal works. On the cost of their work, they used to collect grains and offered meals and drinks during festivals. During the period of Jajmani system, the annual payment for the leather workers was eight pouns (250 gram) of either millet or maize (Regmi 1988).

In 1884, individuals engaged in the cultivation of diverse crops within valleys like Dang and Deukhuri. Murroowa was a small millet-like grain which was grown largely on the hills and plains in the valley. It was sown in May or June and was harvested in October. This particular crop didn't need irrigation, and minimal attention was given to it. The typical yield for this crop was approximately 15 bushels per acre (Regmi 1988).

Conclusion

The historical accounts and cultural practices regarding millets in various regions of Nepal reveal their significant role in the livelihood of the local communities. Millets, such as finger millet and foxtail millet, and maize, were staple crops for many, especially in the hilly and unirrigated areas of Garhwal, Dolakha, and Kathmandu Valley from ancient time. These hardy crops provided sustenance to the rural population supplemented their diets with essential nutrients and served as a vital source of food security during adverse climatic conditions. Millets also played a crucial role in trade and exchange, with specific regions specializing in their cultivation. The Khambas, Majhis, Magars, and Thami tribes cultivated millets as a primary crop, showcasing the diversity of millet farming practices across Nepal.

Furthermore, millets were deeply intertwined with cultural traditions, as seen in rituals, festivals, and offerings. The nutritional value of millets made them an integral part of the diet, and their hardiness in challenging terrains made them a reliable source of sustenance. In conclusion, millets in Nepal were not marginal crops; they were an essential part of the socioeconomics, sustaining communities, contributing to trade, and preserving cultural heritage. Their adaptability to local conditions, resistance to pests, and nutritional benefits made millets a resilient and cherished crop in Nepal's agricultural landscape.

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Finger Millet: A Holistic Exploration of its Cultural, Historical, Religious, Indigenous Knowledge, and Culinary Significance

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Summary

The findings of this study reveal the enduring significance of finger millet (*Eleusine coracana*) in the cultural, agricultural, and spiritual tapestry of Nepal. Indigenous knowledge and technology associated with finger millet cultivation demonstrate its deep-rooted connection to traditional farming practices and highlight the challenges and opportunities for integrating modern science with indigenous wisdom. The historical origins of finger millet in Nepal illustrate its early cultivation dating back to the Bronze Age and its adaptive capacity across diverse agro-ecological zones. The religious significance of finger millet is showcased through its role in offerings, rituals, and its mention in ancient texts, emphasizing its transcendent nature beyond just being a source of food. The review uncovers the diverse culinary applications of finger millet in Nepalese cuisine, from the preparation of traditional dishes such as Kodo ko Khole and Thekua to the formulation of alcoholic beverages like Rakshi. This review underscores the multifaceted importance of finger millet as a crop that nourishes both the body and the spirit of the Nepalese people. Due to its strong ties to culture, religion, and food, finger millet remains essential in Nepal's farming and cooking, helping to maintain traditions and strengthen resilience.

Keywords: Culinary applications, finger millet, future smart food, Indigenous knowledge, religious significance, underutilized crop

Introduction

The common name finger millet refers to the "finger-like" branching of the panicle, while the generic name *Eleusine* is derived from the Greek name for cereals, "*Eleusine* (Gupta et al 2017). According to Liu et al (2014), it originated from a wild species called *E. coracana ssp. Africana*, which is a natural hybrid of the wild species *E. indica* (L.) Gaertn. and an extinct unidentified species. As a C4 crop, millets including finger millet are highly efficient at photosynthesizing. Even though they are minor crops that are underutilized in the country, they have the potential to improve the nutrition and health of the expanding urban and global population in the context of changing climatic conditions and other natural environments (Ghimire et al 2020, Gauchan et al 2020). The millets of Nepal contain globally significant unique gene pools of nutrition as well as cold, drought, and pest tolerance (Bhatta et al 2017). These gene pools are crucial for the food and nutrition security of smallholder farmers and marginalized mountain communities in the face of climate change (Gairhe et al 2021). In areas, where maize, rice, wheat, and other cereals are difficult to grow, finger millet can be grown because it is a subtropical and tropical grain that can withstand drought and high temperatures (Rathore et al 2019).

It provides smallholder mountain farmers with multiple sources of food, fodder, nutrition, livelihood, and ecological security. Finger millet is gluten-free; rich in dietary fibre, rare amino acids, and vitamins; and accounts for higher protein, calcium, and iron compared to major staples such as rice, maize and wheat (Gauchan 2019). It is also referred to as "Future Smart Food" due to its excellent nutritional value, capacity for local adaptation to climate change, resilience to risk, and risk diversification (Li and Siddique 2018; Joshi et al 2019). Due to its long-lasting strength and ability to be stored safely for many years without experiencing insect or pest infestation, finger millet is often referred to as the poor man's crop (Rathore et al 2019). Finger millet is now moving from being a neglected and underutilized crop to an emerging high-potential crop for functional and high-value foods (Kandel et al 2020).

Finger millet's kernel is primarily made up of the endosperm, embryo, and seed coat (testa). It has a five-layer seed coat that is rich in dietary fiber and antioxidants. According to Saleh et al (2013), finger millet has the same amount of carbohydrates (81.5%), dietary fiber (18% to 20%), starch (65–75%), protein (9.8%), fat (1.7%–1.7%), minerals (2.7%), and crude fiber (4.3%). It contains more minerals and crude fiber than other millets, specifically more than rice (minerals 0.6%, fiber 0.2%) and wheat (minerals 1.5%, fiber 1.2%); its protein content is also more evenly balanced than other millets (Rathore et al 2019: Katel et al 2023). By maintaining a healthy blood glucose level, regular consumption of finger millet as a staple food and whole meal-based products will aid in treating unusual bodily disorders (House 1995). Tryptophan, which is present in it and controls our appetite, helps us maintain a healthy weight (Harris and Burns 1978).

Moreover, reducing anti-nutritional elements is crucial to improving the shelf life of processed foods and finger millet flour. Additionally, finger millet contains saponins, which have hemolytic activity (0.36%). Both the digestive system and the central nervous system are impacted. Also, it contributes to CVD. Protein digestion and absorption are both decreased by saponin. In addition to lowering cholesterol and post-meal blood glucose responses, saponins may help prevent the development of cancer (Kumar et al 2016). Oxalate, an antinutritional factor, is present in finger millet at 0.27%. It interferes with the metabolism of calcium and magnesium (Oke 1969) and binds to proteins to inhibit peptic digestion preventing their absorption into the human body (Rathore et al 2019).

More than 25 countries in Asia and Africa grow finger millet. The African nation of Ethiopia is the origin of finger millet. The top four producers of finger millet worldwide are China, India, Nepal, and Uganda (Dhanushkodi et al 2023). In terms of area and production, finger millet, proso millet, and foxtail millet are the most significant crops in Nepal (Ghimire et al 2017). Due to its adaptability and suitability for low, marginal lands as well as for harsh weather conditions, there is potential for increasing the areas where finger millet is grown under the scenario of climate change (Kandel et al 2019). Khotang, Sindhupalchok, Baglung, Syangja, Kaski, Gorkha, and Sindhuli are the main production areas for this crop in Nepal. It is regarded as a crucial crop for food and nutrition security in both mid-hill and mountain regions. Regarding area and production, finger millet is the most important crop in the districts of Humla and Mugu, but it is the second most significant crop in Jumla, Khotang, and Sindhupalchok. The largest area and production of finger millet are found in Nepal's Baglung district of Gandaki Province (Gairhe et al 2021, Mathanghi and Sudha 2012, Shashi et al 2007, Thapliyal and Singh 2015).

Indigenous Knowledge and Technology

Finger millet is a cereal crop deeply intertwined with the cultural fabric of many indigenous communities across Africa and Asia (Mirza and Marla 2019). Throughout history, indigenous knowledge and traditional agricultural practices have played a pivotal role in the cultivation, processing, and utilization of finger millet (Luitel et al 2020, Luitel et al 2017). Indigenous knowledge refers to the accumulated wisdom and practices of local communities that have evolved over centuries in response to their specific ecological and cultural contexts (Joshi et al 2019). In the case of finger millet, indigenous knowledge encompasses a wide array of practices, from seed selection to cultivation techniques and post-harvest processing. These practices have been passed down through oral traditions, making them a vital part of the cultural heritage of many societies (Bajracharya et al 2006, Upreti and Upreti 2002). In this paper, we explore the rich tapestry of indigenous knowledge and technology, sustainable farming practices, preservation methods, and tools developed by indigenous communities.

Indigenous cultivation techniques

The cultivation of finger millet in Nepal has a deep foundation in traditional knowledge that has been handed down through generations. Traditional practices such as crop rotation, intercropping with legumes such as lentil, and mixed cropping with other cereals have been employed to enhance soil fertility and minimize pest issues (Baniya et al 2004, Pallante et al 2016). The persistence of these time-tested farming methods, guided by the traditional farming calendar, which emphasizes mixed cropping, intercropping, and rotation, serves to optimize the utilization of the limited arable lands available (Qing-Xiong et al 2018). Finger millet is grown across a wide range of altitudes in Nepal, spanning from the Tarai (eg, Kachorwa, Bara, at 85 meters above sea level) to the high mountains (eg, Burounse, Humla, at 3130 meters above sea level).

Records indicate that finger millet cultivation is observed in all 77 districts of Nepal. The majority of finger millet production, accounting for 77% of the total, comes from hill districts, with mountain districts contributing 20%. However, the productivity of finger millet has remained nearly constant, ranging from 1.17 to 1.19 tons per hectare over the past three decades (Ghimire et al 2020). Millet is a relatively minor crop, cultivated on 0.26 million hectares, primarily in the hills and mountains of Nepal (Krupnik et al 2021). In the Tarai region, it is usually grown as a sole crop, followed by paddy, wheat, or oilseed cultivation. Conversely, in hilly regions, it is commonly grown as a mixed crop or intercrop. In many parts of the hilly regions, it is cultivated as a relay crop following maize, and it is followed by wheat, oilseed, or fallow crops. In mountainous areas, millet is typically grown as a sole crop, followed by barley, wheat, potato, or buckwheat (Gyawali 2021 Halbrendt et al 2014). In the Tarai, finger millet is primarily cultivated in sandy soil where water retention for paddy cultivation is challenging. Therefore, finger millet has become a crop of choice for marginal lands and is commonly grown with minimal external inputs (Luitel et al 2017). Adhikari et al (2021) and Tiwari et al (2004) reported that the common cropping pattern in unirrigated land (bari) involves maize as the primary crop, with finger millet either intercropped or grown as a sole crop. In contrast, in irrigated land (khet), rice-based farming dominates.

Additionally, finger millet is relayed with maize in the majority of mid-hill areas, grown as a mono-crop, or integrated into mixed cropping systems with cereals and/or legumes in high hill and some western hill regions of Nepal (Baniya et al 2001, Pandit and Paudel 2013, Karki et al 2020, Parajulee and Panta 2021). Transplanting practices for finger millet differ in various areas. In Kalabang, finger millet is transplanted within the maize field without field cleaning, while in Begnas, it is transplanted after the maize harvest. Major cropping systems found in unirrigated land (bari) include maize-finger millet-mustard/ vegetables/ fallow and maize-finger millet-winter season crops/fallow (Adhikari 2012). Furthermore, in the Ralmare village of Begnas, many farmers practice mixed cropping of finger millet with black gram (Bhandari et al 2010, Joshi et al 2017). Similarly, in rainfed upland (bari), horse gram is intercropped with finger millet, while soybeans are planted on the bund during paddy cultivation in the lowland (khet) (Khatri et al 2021).

Regmi et al (2023) and Gartaula et al (2020) observed that farmers in the Humla region have embraced the practice of broadcasting finger millet seeds, typically in April. These farmers have access to a diverse range of landraces, including Seto Kodo, Kalo Kodo, Khairo Kodo, Riuli Kodo, Kaine Kodo, Damle Kodo, Aangale Kodo, and Samale Kodo. Their study also revealed that farmers intercrop soybean seeds alongside the finger millet crop, which is sown in late May or early June. According to reports by Prasad et al (2010), Paudel (2012), and Ghimire et al (2017), farmers in the region believe that cultivating finger millet as a relay crop under maize-finger millet systems is challenging. However, they find it comparatively easier when grown in sequential cropping after maize harvest. Additionally, they hold the belief that continuous cultivation of cereals or millet without incorporating legumes can lead to a reduction in the population of beneficial soil microorganisms (Rivera-ferre et al 2021). A study conducted by Sharma et al (2023) noted that even in the year 2023, only a few farmers have begun to adopt plastic houses for the production of leafy vegetables during the winter season. Among these farmers, many continue to follow indigenous methods of crop rotation and cropping patterns.

Seed Selection and Preservation

Seed selection plays a pivotal role in indigenous finger millet cultivation. Farmers rely on their accumulated knowledge and experience to carefully choose the most suitable seeds, taking into account traits such as disease resistance and yield potential. They have also developed traditional methods for preserving seeds, which involve storing them in cool and dry environments and using natural materials like ash to protect against pests (Nayaka et al 2021). Based on the information gathered and compiled, farmers traditionally characterize their landraces by assessing various morphological traits, including grain color, ear shape, yield, eating quality, and grain size (Tiwari et al 2001). Furthermore, farmers often seek to improve varieties through participatory methods, promote comprehensive agricultural practices, create market incentives to boost domestic production, and integrate finger millet cultivation into public school programs as policy options to enhance finger millet farming in Nepal (Gairhe et al 2021).

Farmers possess a wealth of knowledge when it comes to selecting seeds for different crop varieties, and they employ various criteria during the harvesting season. They typically remove unwanted plants before harvesting to prevent contamination and to maintain the genetic purity of specific crop varieties. Ear heads are usually handpicked from the fields, and only the best and similar heads are threshed by beating them with a stick to extract the seeds. Occasionally, millet seeds are stored in wooden pots (Adhikari et al 2021). Baniya et al (2005) reported that in Kaski, the majority of farmers (91%) save their seeds for personal use. Some farmers obtain finger millet seeds from their neighbors and relatives, either through purchase, exchange, as gifts, or by collecting them for free. This exchange and sharing of seeds form the basis of seed circulation within the community. Additionally, the practice of saving seeds, which involves preserving and replanting seeds from previous harvests, ensures the continued cultivation of adapted varieties. Farmers often exchange seeds with their neighbors, thus maintaining a reliable supply of high-quality seeds for local varieties in an affordable and timely manner. The role of local traders and government services in seed distribution in the study area was found to be negligible (Adhikari et al 2021).

Furthermore, according to Sharma et al (2023), a significant proportion of farmers, specifically 98% were observed to be employing local seed treatment methods, while 96% were exclusively using high-quality seeds for sowing. Interestingly, only 8% of the respondents acknowledged using drought-tolerant seeds in their fields, even though 75% of individuals in Humla, Nepal, relied on local seeds for sowing. The typical practice for seed selection involves experienced farmers setting aside some ears during the harvest specifically for seed purposes, keeping them separate for each variety. This practice is particularly common for finger millet, as varietal mixtures are prevalent, and only a few ears are required for seed purposes. Farmers either choose the superior ears from their entire field or first identify a better area and select superior ears from that designated area. These selected finger millet seeds are stored in various containers such as small earthen pots (Ghaito, Gagri), wooden vessels (Theki), bamboo containers (Daalo), tin vessels, small plastic bags, and so on (Baniya et al 2005).

Water Management

Millets are a group of hardy and underutilized crops belonging to the grass family. They exhibit resilience and can thrive in adverse conditions, particularly in dry zones and marginal lands where they are primarily rain-fed crops. This characteristic makes millets the preferred choice of cereal crops for areas prone to drought (Sapkota et al 2016, Gauchan et al 2020, Sowmyalatha et al 2022). In Nepal, which boasts a diverse topography, farmers employ various strategies such as constructing terraces and implementing small-scale irrigation systems to ensure a reliable water supply throughout the growing season (Wyss 2016). Additionally, millets are cultivated in regions with poor soil conditions, especially in the hill areas. As a result, farmers typically do not apply manure or fertilizers to these crops (Adhikari et al 2021, Krupnik et al 2021). A study conducted by Sharma et al (2023) revealed that most farmers in Nepal rely on rivers and streams as their primary sources of irrigation, while a smaller number use household wastewater for this purpose.

Harvesting and Processing

Indigenous practices continue to play a significant role in the harvesting and processing of finger millet. One critical aspect is timing the harvest to ensure that the grains reach optimal maturity. After harvesting, farmers employ traditional methods for threshing and winnowing to separate the grains from the chaff (Patel et al 2020). Studies indicate that finger millet is a free-threshing grain, with most grains naturally separating from the chaff after a single round of threshing and winnowing. This is in contrast to cereals like rice and most small millets that require intensive dehusking (Fuller et al 2013). In the case of finger millet, threshing is typically performed after the harvested panicles have been left unventilated for a few days (Regmi et al 2023). Both the harvesting and post-harvest activities related to finger millet, particularly threshing and cleaning, are carried out using traditional methods and tools. At the household level, common tools for threshing and winnowing include sticks, mungro, gyalbi, musli, okhal, jaanto, dhiki, and naanglo. However, it's worth noting that threshing is often a significant challenge in the post-harvest processing of finger millet because it is both labor-intensive and time-consuming. The grinding process is typically conducted using electric huller mills, which have largely replaced the traditional method of grinding with tools like the jaanto (stone grinder). While a dhiki is traditionally used for dehusking rice, women still employ tools like the musli or dhiki for dehusking finger millet at the household level (Pudasaini et al 2016).

Traditional Storage Techniques

Preserving finger millet after harvest is of utmost importance to prevent spoilage and ensure the quality of the grain. Indigenous methods, such as the use of bamboo baskets and clay pots for storage, continue to be widely practiced by Nepalese farmers (Devkota et al 2016). One traditional approach involves storing finger millet grains in bamboo baskets that are lined with neem leaves or leaves from other plants with preservation properties. To further protect the stored grains from external elements, farmers often use dung as a covering. These time-tested storage techniques have proven effective in various indigenous communities and could also be suitable for the Munda tribe and their finger millet storage needs (Downs et al 2022).

Challenges and Adaptations

Despite the effectiveness of indigenous knowledge in finger millet cultivation, modern challenges such as climate change and market demands have prompted some farmers to adapt their practices. These adaptations often involve the integration of modern technologies, including improved seed varieties and mechanized tools, while still maintaining the core principles of indigenous farming practices (Aryal 2022). An example is Budhi Sagar Adhakari from Khanigaum, a mountainous village located at an elevation of 900 meters above sea level in the Nuwakot district of Central Nepal. Adhakari, a traditional finger millet grower, has noticed a decline in the cultivation of finger millet in Khanigaun and neighbouring villages. This decline is attributed to factors such as low yields, high cultivation costs, and a ban on brewing (Ravi 2004). Finger millet is known to be a labor-intensive crop compared to other major cereals, demanding significant labour input, especially during activities like transplanting, weeding, harvesting, threshing, and grinding. This places a substantial workload on farmers, particularly women, throughout the entire cultivation and preparation process of finger millet-based food items (Bista et al 2013, Joshi et al 2019, Devkota et al 2016). Despite being consumed by a majority of households in the mid and high-hill regions, regardless of ethnicity, finger millet is often regarded as a "low-status food" or "food of marginalized communities." However, there is a lack of awareness regarding the nutrient composition and health benefits of finger millet, leading to lower consumption rates, especially among the younger generation (LI-BIRD 2016, Adhikari et al 2017). Furthermore, finger millet has remained neglected by the research and development sectors in Nepal (Krupnik et al 2021, Pant et al 2015), which poses challenges for its continued cultivation and promotion.

History of Finger Millet in Nepal

The history of finger millet cultivation in Nepal serves as a testament to its enduring significance as a staple crop. In this section, we delve into the historical origins of finger millet in Nepal, tracing its evolution and cultural importance across the years (Ghimire et al 2017). It's important to note that obtaining precise data on the area and production of finger millet in many countries has often proven challenging. This is primarily due to the fact that the production statistics of this crop have frequently been combined with those of other millets (Ghimire et al 2020, Tracyline et al 2021), making it difficult to discern the specific contributions of finger millet in various regions.

Origins

Finger millet, believed to have originated in Africa, has a history that stretches back thousands of years and made its way to the Indian subcontinent. Its cultivation is widespread across Sub-Saharan Africa, where it represents an important, often staple, crop for millions of small-scale farmers. It is also cultivated in rural areas of Asia, particularly in countries like India, China, and Nepal (Gari 2001, Gc and Hall 2020, Meena et al 2021, House 1995). In Nepal, the history of finger millet cultivation can be traced back to ancient times, with archaeological evidence suggesting its cultivation in the region dates back to the Bronze Age (Gurung 2019). The evidence of millet cultivation in the Korean Peninsula can also be traced back to around 3,500–2,000 BC. Interestingly, very ancient religious texts like the Yajurveda have mentioned millets, indicating that the production and consumption of this grain have been indigenous practices, especially in the Asian region, dating as far back as around 4,500 BC (Koirala 2020). In Nepal, finger millet is grown in all 77 districts and is considered the fourth staple food crop, afer rice, wheat, and maize, in terms of cultivation area (271,183 hectares), production (304,105 tons per year), yield (1121 kg/ha), and various uses (Luitel et al 2017). The cultivated finger millet is believed to have originated from the selection and domestication of a large-grained mutant of the wild *E. coracana* subsp. Africana. Evidence for the ancestry of cultivated millet has been supported by cytological, morphological, and molecular data (Dida and Devos 2006). It's worth noting that in older archaeological studies, there have been misattributions of other small millets to "finger millet" due to confusion between the husk of Setaria/ Brachiaria and the grain surface of *Eleusine*. This, along with an anachronistic assumption that finger millet is the most widespread small-grained millet, has led to some confusion (Fuller et al 2013).

Historical Significance

Finger millet has played a significant and enduring role in Nepalese agriculture and culture throughout history. It served not only as a dietary staple but also as a crucial means of addressing food security challenges during periods of crop failures (Tamang et al 2010). Its resilience in the face of adverse growing conditions contributed to its continued cultivation. Historical and archaeological studies also suggest that early civilizations in Eastern Africa heavily relied on sorghum and millets for sustenance (Mburu et al 1989).

Role in Ancient Civilizations

Finger millet has deep historical roots in the diets of various ancient civilizations in Nepal. It served as a staple food for the Kiratis, one of the earliest recorded ethnic groups in the region. The presence of finger millet in the diets of these early communities underscores its historical significance (Tamang et al 2022, Blench 2016). It is not just a crop; it carries with it a historical legacy that has been passed down through generations. It can be seen as a gift from our ancestors, something we are entrusted with preserving and passing on to future generations (Dangol et al 2021).

Adaptive Cultivation

One remarkable aspect of finger millet's history in Nepal is its adaptability to diverse agro-ecological zones. Over the centuries, Nepalese farmers have developed specific varieties of finger millet suited to different altitudes and climates, allowing for its widespread cultivation (Luitel et al 2017). It occupies nearly 9% of the total cultivated area in the country, with approximately 75% of millet cultivation taking place in the mid-hills. As a result, it holds the position of being the third most important crop for the hilly regions. A survey conducted in 1991 revealed that 90% of households in the mid-hills of Nepal relied on finger millet (Bhandari et al 2010, Gurung et al 2023). Finger millet demonstrates remarkable diversity in its adaptability. Some varieties are resistant to pests and drought, while others thrive at different growth stages. They can be found growing on steep slopes, in plains, from foothills to high hills. Some are well-suited for mixed cropping, while others are cultivated as single crops. These diverse landraces are a natural gift, having evolved over centuries through farmer intervention. They cannot be owned by any individual and are considered the common heritage of humanity (Joshi and Joshi 2002).

While finger millet is primarily associated with upland regions in Asia, particularly the Himalayas from India to Nepal and southern China, it can also be grown in lowland areas. The upland races, which are widespread in the Himalayas, appear to be a secondary adaptation (Fuller et al 2013). Predictions of potential habitat suitability indicate that the most suitable areas for finger millet in Nepal include the Siwalik, mid-hill, and the lower part of the mountain regions. The central and eastern parts of the country are more suitable for its cultivation compared to the western regions (Luitel et al 2020). The history of finger millet cultivation in Nepal also includes periods of decline, often linked to changing dietary preferences and the introduction of other cereal crops. However, in recent years, there has been a renewed interest in finger millet due to its recognized nutritional value and resilience to climate challenges (Koirala 2020).

Religious Significance of Finger Millet in Nepal

Finger millet holds a profound religious significance in Nepalese culture and spirituality. This section delves into the role of finger millet in religious practices, rituals, and symbolism, highlighting its transcendence beyond being a mere staple food.

Offerings and Rituals Significance

Finger millet holds a special place in Nepalese culture and religious practices. It is frequently used as an offering in various religious rituals and ceremonies. Considered sacred, finger millet is presented to deities and ancestral spirits during festivals, weddings, and other significant occasions. This act of offering finger millet is believed to bring blessings and prosperity to the community. In addition to its role in religious offerings, finger millet is a key ingredient in the production of alcoholic beverages in Nepal. Traditional beverages like Jandh, Tumba, Chhaang, and Rakshi are often made from finger millet. These alcoholic beverages hold cultural and religious significance in various ethnic communities (Bhandari et al 2010). For example, in Gurung culture, millet played a crucial role in making jand (a local fermented beverage) and alcohol (raksi), and these alcoholic beverages were integral to festivals, ceremonies, and worship within the Gurung community (Adhikari et al 2021). Finger millet also plays a prominent role in the culture of the Limbu and Rai communities, as well as among other ethnic groups. The tradition of offering jand to guests is a unique way of expressing hospitality, and finger millet is used in various festive occasions, ritual rites, dispute settlements, and appeasing deities (Gurung 2019). Furthermore, finger millet carries deep symbolic meaning in Nepalese religious traditions. Its ability to thrive in adverse growing conditions symbolizes strength and endurance. The unique growth pattern of its grains, bending down in a humble gesture, is often associated with qualities like humility and gratitude (Adhikari et al 2021).

Religious Texts and Stories

In Hinduism, which is the predominant religion in Nepal, finger millet holds a special place and is mentioned in ancient religious texts. It is believed to have been one of the grains created by Lord Shiva, and its consumption is considered highly auspicious. Finger millet is deeply rooted in Hindu religious traditions, and some folktales and stories revolve around it, further reinforcing its cultural and religious significance (Kumar 2023, Adhikari et al 2021). For instance, in the Treta Yuga, Lord Rama returned to Ayodhya after fourteen years of exile, and the people celebrated his homecoming by lighting earthen lamps and preparing finger millet sweets as a sign of welcome. Similarly, the festival of colours (made of flower petals), known as Holi, has its roots in the celebration of Lord Krishna during the Dwapar Yuga. Lord Krishna, along with the Gopikas, celebrated by sharing finger millet milk sweets, and today, Holi is celebrated internationally. The significance of finger millet is also noted in ancient texts like the Abhijnana Sakuntalam of Kalidas Mahakavi (4-5th AD), where sage Kanva pours millet while bidding farewell to Sakuntala in Dushyanta's court, indicating the auspicious nature of millet. Furthermore, international sources, such as ICRISET, mention that some of the oldest Yajurveda texts mention foxtail millet (Priyangava), barnyard millet (Aanaya), and black finger millet (Shyaamaka), indicating the consumption pattern of millets dating back to the Bhartiya Bronze Age around 4500 BC (Kumar 2023).

Sacred Foods and Fasting

In certain religious fasts and observances, finger millet-based foods, like millet porridge (Kodo ko Jhol), are consumed because they are considered pure and sattvic. This practice reflects the deep connection between dietary choices and spirituality. One such traditional preparation is Satu, made from millet and barley flour, which is considered a sacred food. It is often offered to deities such as Lord Vishnu (during

Sakranti) and Lord Shiva (on the day of Akcchyayatritiya) along with juices (Koirala 2020, Upreti 2005). Finger millet is also used in various culinary preparations, including Venn Pongal, Sakkarai Pongal, Kozhi Pongal, and Sanyasi Pongal, where it is cooked in boiling milk. These dishes are part of festive cuisines and are associated with the worship of Mother Nature during a four-day celebration in the Pongal month of Magha (January). The celebration spans four days, each dedicated to a different deity, including Lord Indra (Rain God) and Lord Bhaskar (Sun God). On the final day of the celebration, people share millet meals as part of their festive traditions (Kumar 2023, Pant and Ramisch 2009).

Culinary Applications

Papad

The procedure for producing papad using finger millet flour is a systematic one. First, high-quality finger millet flour is chosen. It is then mixed with precise amounts of salt, spices, and other ingredients. Careful attention is paid to maintaining controlled conditions, including temperature and humidity, to ensure a consistent outcome. This method ensures that each papad is crafted with precision and care, resulting in a delightful culinary experience (Verma and Patel 2013).

Kodo ko Khole

The finger millet flour and water are combined using a ratio of one-part finger millet flour to 2.5 parts water. This uniform approach ensures a consistently satisfying result every time we prepare this nutritious soup (Verma and Patel 2013).

Finger millet liquors

Since ancient times, various indigenous groups in Nepal have produced Rakshi, also known as finger millet whiskey. Jand, Toongba, Nigar, and Rakshi are the main alcoholic fermented liquors traditionally consumed in various parts of Nepal (Kharel et al 2009).

Jaad

The most popular fermented alcoholic beverage made from dry grains of finger millet is called Kodo ko Jand (Thapa and Tamang 2004). When referring to sweet-sour cereal beer made from grains like finger millet, rice (*Oryza sativa*), wheat (*Triticum spp.),* and maize (*Zea mays*). Jaad is also spelled Jand, Jandh, Jnar, Jaanr, and Jnard. It is common practice among the Limbu and Rai ethnic groups to extend hospitality to visitors. When making jand, the readily extractable components are removed from the fermented mash using water, typically lukewarm water. The liquor is typically strained using a perforated aluminum strainer or a strainer made of thin bamboo strips. The beverage appears cloudy and has a very brief shelf life of only a few hours (Gurung 2019). The preparation steps are 1. Dry seeds of finger millet, 2. Cleaned and washed, 3. Cooked (excessed water drained off), 4. Cooked seeds are spread on babmo mat for cooling (20-25^{o}C), 5. Packed in heaps and saccharified for 2-4 days and transferred in closed earthern pot, 6. Fermentation (25-30^{0}C), 7. Kodo ko jaand.

Nigar

During the extended anaerobic fermentation of jand, a crystal-clear liquid known as Nigar spontaneously emerges. Nigar is, therefore, a specific type of cereal wine, crafted through this consistent and intriguing process. It showcases the remarkable transformation that can occur in the realm of fermentation, where cereal grains are magically turned into this distinctive and clear libation.

Toongba

Approximately 500 grams of fermented millet are moved into a cylindrical bamboo or wooden barrel, which holds around one-fourth of hot water. The liquid is naturally and gradually released, and after approximately 15 minutes, it is drawn in through a pipe made of bamboo or metal, known as a "Peepa." The mixture can be steeped repeatedly, and the liquid can be drawn in multiple times to extract all of it. It is often noted that a high-quality Toongba has a mild bitterness and imparts a peppery sensation (Gurung 2019).

Rakshi

Rakshi is an indigenous alcoholic beverage known for its distinctive scent, produced through the distillation of the traditional fermented cereal drink called "Jand." Rakshi, which can also be spelled as Raksi or Rukshi, is a clear, unaged distilled spirit derived from the fermented mixture of jand, achieved through pot distillation (Rai 2006). Rakshi goes by various names in different ethnic communities, such as Asarak (Tibetans, Bhutia, Drukpa, Sherpa), Aarok (Lepcha), Aaerak (Tamang), Aayala (Newar), Sijongwaaaara (Limbu), Aarakha/Hemma (Rai), Paa (Gurung), Rindho (Sunwar), Dhise (Magar) etc.

Thekua

Thekua was made by combining finger millet flour with white wheat flour after the grain had been germinated (Dangal et al 2021). It can be produced as a functional food, improving people's nutritional status and increasing the utilization of underutilized crops such as finger millet (Ragi) (Dangal et al 2021).

Noodles

Noodles are pasta items, often referred to as convenience foods, that are created using a cold extrusion process and become firm and fragile once they have been dried. The desire for millet-based noodles, especially those crafted from finger millet, is on the rise as people become more conscious of its nutritional benefits (Verma and Patel 2013).

Bakery Products

Bakery products like biscuits, nakhatai, muffins and bread are made from the finger millet as a value-added product. Similarly, in India, Dosa and Idli are made that are high in protein, calcium, and fibre (Verma and Patel 2013).

Conclusion

Finger millet is a versatile and nutritionally rich crop that has been deeply integrated into the fabric of various societies, particularly in Nepal. From its origins as a resilient and climate-resilient C4 crop to its role as a source of nutrition, livelihood, and ecological security for smallholder farmers, finger millet has demonstrated its unique potential in addressing the challenges of a changing climate and environmental conditions. Its gluten-free, nutrient-dense nature, along with its exceptional adaptability, has earned it the title of "Current and Future Smart Food." Indigenous knowledge and technology have played a pivotal role in the cultivation, preservation, and utilization of finger millet. Sustainable farming practices, seed selection, water management, and traditional storage techniques have been passed down through generations, contributing to the crop's continued success in diverse agroecological zones. The history of finger millet in Nepal is a testament to its enduring significance as a staple crop. Its deep roots in ancient civilizations, its role in addressing food security challenges, and its adaptability to diverse altitudes and climates underscore its historical importance. Furthermore, finger millet holds profound religious significance in Nepalese culture, being used in offerings, rituals, and ceremonies. Its mention in ancient religious texts and its association with deities and auspicious occasions highlight its transcendence beyond a mere staple food. Culinary applications of finger millet have also been explored, ranging from traditional preparations like Jand, Toongba, and Rakshi, to contemporary uses in papad, Khole, and bakery products. Its versatility in the culinary world, coupled with its nutritional value, makes it a valuable ingredient in various dishes. Conclusively, finger millet is not just a crop; it is a symbol of resilience, cultural heritage, and nutritional excellence. Its continued cultivation and utilization are essential not only for addressing food security challenges but also for preserving the rich traditions and knowledge associated with this remarkable grain. As we move forward in an ever-changing world, finger millet's role as a "Future Smart Food" remains more relevant than ever, bridging the gap between tradition and innovation for a sustainable and nutritious future.

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Finger Millet Bread is Sacred Food: A Cultural Perspective on the Importance of Millet in Jitiya Festival

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Abstract

Finger millet has significant nutritional value intrinsic to a cultural practice embedded in the Jitiya festival, a celebration of great importance in the Tarai region. A focal point of this celebration is the consumption of millet bread, locally known as Marwa roti (millet bread). Historically the crops are well adapted to the country's diverse landscape. The festival's culmination in the consumption of millet bread reflects an informed choice, considering the health advantages attributed to millet consumption. Fish and millet bread are eaten by women of the Tharu community after listening to the story of King Jitamahan. The consumption of millet bread and fish is believed a tradition established in the ancient time of King Jitamahan who sacrificed himself to save the life of a child. The days-long nirajala fasting is perfectly paired with the consumption of highly nutritious crop millet bread. The advantage encompasses cholesterol reduction, anaemia prevention through iron content, bone and tooth development through calcium, and improved digestion due to its high fiber content. Moreover, millet's unique amino has its holistic importance. Current, concern over rice export restriction, as exemplified by India's recent ban, may impact food security in Nepal. Millet, suited to Nepal's geographic conditions and low water availability, emerges as a sustainable staple food to cope with the overdependency on rice. To acknowledge this cultural symbolism and nutritional benefits of millet consumption, there is a pressing need for systematic intervention to promote millet cultivation and safeguard Nepal's rich heritage. This article explores the intrinsic connection between cultural and nutritional wisdom, emphasizing the imperative of preserving traditional knowledge and promoting sustainable food choices in the face of the changing agricultural landscape. As millet bread remains a sacred emblem of the Jitya festival, it argues to think and act promptly for a balanced and resilient food future for Nepal.

Keywords: Marwa, jitiya, culture, tarai

Context

Nepal is very rich in geographic, cultural, and ethnic diversity. This is a country with 147.18 km^2 of land having a plain region in the southern parts, hills in the middle, and mountains (Himalayas) in the northern side. Nepal has diversity in ethnicity, culture, and food practices. Nepali people celebrate different festivals throughout the year. These festivals bring their ancestral legends. Those festivals are designed to unite family members and celebrate the joys as well as recover the body strength through especial food dedicated at that period. For example, during the Dashain festival, people consume a lot of meat, in Tihar *Cell Roti (*Nepalese traditional bread), in Janaipurnima *Kwati* (a food mix of different cereals together and cooked), in Maghesakranti *Phuraula* (a food made of the floor of black bean), in Jitiya finger millet bread with fish and so on. Finger millet originated in Ethiopia and spread throughout the world which has been to Nepal from India (Koirala and Subedi 2011). Nepal has a suitable environment to grow millet which is being grown all over the country (Luitel et al 2017). This article has been written with primary information collected from key informants of the Siraha and Saptari districts and secondary information from the literature. Jitiya is one of the most widely celebrated festivals in the Tharu community of Tarai which has cultural significance with indigenous food practice. The practice of the ancestral food value of Marwa needs proper understanding in the current context of high nutrition value as well as crop diversification.

Jitya and Cultural Emblem

Jitiya festival is celebrated in Tarai region. This festival falls in the month of Aswin (September). The main motto to celebrate the festival is to pray for the long life of the son (We all Nepali 2023). The legend of the festival is linked with King Jimutvahan who gave up his kingdom to his brother and was staying in the forest serving his father. During that time, he saw an old mother mourning as she has to give her only son to Garuda. Seeing her pain, he promises to save her son and offers himself to Garuda. However, understanding this situation Garuda did not eat him. In memory of this good deed of King Jimutvahan, Jitya festival was started to celebrate in every Krishnapakchya of Aswin (Dark lunar calendar that falls around September) (Wikipedia 2023). The ancestral practice in this festival, after having hard two days of fasting, women go to water sources like ponds and streams and take a bath and worship with some chanting that recalls the good deed of king Jimutvahan. As part of the festival celebration, finger millet bread and fish are the symbols of the completion of great faith towards the longevity and personality of their lineage (Chaudahry 2023).

Figure 1. Jitiya festival and culture Tharu community
Source google.

A Balance of Nutrition through Millet Bread

The festival Jitiya which is also called Nirajal Barata festival (fasting without even drinking water) is ended having highly nutritious finger millet bread. During this festival, women having husbands called Sadhva women eat fish and millet bread, while widows eat rice, cucumber, and finger millet bread. According to 76-year-old female of Kshireshwarnath Municipality-5 Mahendranagar, mention that it is customary to eat millet bread, salty greens, and fish after worship on the first day of the fast. The millet is called Maruwa in the local language (New Spotlight Online Media 2022). Millet is rich in nutrition, has a great role in staple food as well as hold a cultural value and is fourth most important crop in Nepal (Ghimire et al 2020).

The ending of the festival with millet bread might have been initiated with a good understanding of the benefits of consuming the millet. Among the several benefits of the consumption of millet are:

Figure 2. Harvesting Millet
Source: Google 2023

- Decrease the cholesterol in the blood
- Rich in iron and save from anaemia
- Rich in calcium and support to make the bone and tooth of the child grow better
- Millet consists of methionine and Sulphur amino acid balance amino acid
- Millet has lots of fibre which supports to have a better digestive system.
- Common cold patients will have a better recovery after having the soup of the millet.

Social Cohesion and Food Exchange between Ecological Zone

Nepal is a country with a diverse ecology with different biodiversity, culture as well and coherence. People's food consumption patterns among the different ethnic are diverse. Land and soil type throughout the ecological zone and irrigation provision has no similar situation. Now Nepal has unpredictable climate events that make uncertainty of staple food production that depends on water. Finger millet is adaptive and can be grown with less water and in all type of soil. Production of finger millet support an important role in situ bio-crop diversity (Tiwari et al 2004). Southern plain region comparatively grows lots of rice and the hill and mountains are suitable for millet (Tiwari et al 2004). Nepalese main staple food rice has been mostly grown and transported to hill and mountains through the Tarai. This cultural emblem of the Tharu community to consume finger millet bread may contribute to the interchange of the crops among different ecologies.

Concern about Food Security while Overdependence in Rice

Nepal having a geographical area of mountain and hill do not have good irrigation to grow the paddy. However, millet which does not need much water could be a good source of staple food production. Recently India has banned to export the rice which may affect more than 140 countries (The Economic Times, 2023) including Nepal. It may cause an imbalance in the food security of Nepal. The systematic intervention and production of millet are required from both perspectives of protecting our cultural aspects as well as rich nutritious food. The cultural practice of having millet bread is also a symbol of rich knowledge of the benefits of millet. This also balances the exchange of food between hill and Tarai where paddy and millet growth are interchangeable. However, this good practice of having millet bread after fasting is decreasing due to the unavailability of millet in Tarai as mentioned by a local resident of Saptari (Chaudhary 2023).

Conclusion

Nepal's rich tapestry of geography, culture, and tradition is interwoven with the significance of millet. The Jitiya festival, celebrated with fasting and the consumption of millet bread, symbolizes the deep cultural connection to this nutritious grain. Beyond its cultural importance, millet offers a myriad of health benefits, from reducing cholesterol levels to aiding digestion, which underlines its practical value in the Nepali diet. Furthermore, the ecological diversity of Nepal allows for the cultivation of both rice and millet, fostering an exchange of crops between different regions. However, recent concerns over food security, prompted by external factors like the ban on rice exports from India, emphasize the need for a systematic approach to millet production. Preserving this cultural emblem not only safeguards Nepal's rich traditions but also ensures a balanced and sustainable food supply, aligning cultural heritage with contemporary food security needs.

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Gender and Ethnicity in Shaping the Practices of Finger Millet Farming in Lamjung, Nepal

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Abstract

Millet can greatly contribute to food security and livelihood in the rural hill areas of Nepal. However, the crop is underutilized to its potential, and its farming practices through the perspectives of gender and ethnicity is not yet properly documented. The study was conducted in the Dudhpokhari rural municipality of Lamjung dstrict, Nepal during 2023 with the objectives to identify the difference among gender and ethnicity with respect to the conservation strategies and production pattern. Besides, effect of remittance inflow on millet farming, work of farmers group and other government and non-government institutions on the promotion of millet and problems in millet farming are also explored. Using simple random sampling, 100 finger millet farmers were selected for the study. Household survey was carried out with head using semi-structured questionnaire, while Focus Group Discussion (FGD) and Key Informant Interview (KII) was carried with selected informants. Frequency, mean and index value was used to present the major findings of the study. Results revealed that production pattern were different among Janajati and Brahmin ethnic groups. Adoption of conservation strategies was higher in female headed households. Remittance inflow has decreased the farm size due to labor shortage and has no impact on adoption of improved technology. Farmers group and other institutions are minimal to promote the finger millet. Hence, the study suggests that farmers group and other institutions should focus on conservation of finger millet and integrate gender and ethnicity issues to promote sustainable finger millet farming.

Keywords: Gender; ethnicity; millet; conservation strategies

Introduction

Several years have passed since Nepal committed to implementing the Sustainable Development Goals (SDGs), yet the progress in terms of SDG 2, which focuses on food security, is not very promising (WFP 2023). Moreover, there has been a concerning increase in the importation of agricultural products, particularly staples like rice, wheat, potato, and corn (MoFE 2018), leading to a loss of dietary diversity and crop species diversity (Heal et al 2004, Millennium Ecosystem Assessment 2005). This loss of agricultural biodiversity, driven in part by intensified farming, poses significant challenges, including the depletion of valuable resources in marginalized areas managed by smallholder farmers (Cavatassi et al 2011, Di Falco et al 2011, Coromaldi et al 2015). One major driver of this erosion is the replacement of local landraces with modern varieties (Jarvis et al 2011, Tilman et al 2002). This loss of crop diversity threatens food security, incomes, and resilience, especially in the face of climate change (Bellon and van Etten 2013, Vasconcelos et al 2013).

Historically, National Agriculture Policy of Nepal (2004) and Agriculture Development Strategy (ADS) (2015-2035) has heavily focused on large-scale production of commercial crops, leading to the displacement of traditional landraces by hybrid varieties. This has resulted in a significant loss of millet diversity (Joshi 2023), among other underutilized crops. These underutilized crops, though often neglected by researchers and policymakers (Li and Siddique 2019), have the potential to contribute to food security, nutrition, dietary diversity, health, and income generation (Chandra et al 2020, Joshi et al 2020). Farmers tend to favor high-yielding crops that can withstand various stresses and require minimal care (Luitel et al 2017, Goron et al 2015), which may not be suitable for all regions. To address this issue, promoting underutilized crops in less fertile, rain-fed areas with simpler cultivation practices could be a solution, offering nutritional richness, climate resilience, economic viability, and adaptability to local conditions (Gairhe 2021, Padulosi et al 2002).

Finger millet, is a highly adaptable crop in Nepal, well-suited for harsh climates and poor soils (Singh et al 2015). Finger millet ranks as the fourth most significant cereal crop in Nepal, following rice, maize, and wheat, when considering both its cultivation area and production. It typically covers around 7.7% of the total land dedicated to cereal crops, encompassing approximately 265,401 hectares of land. In terms of overall cereal production, finger millet contributes about 2.9%, amounting to 326,443 metric tons, with an average yield of 1.23 metric tons per hectare (MoALD 2022). It boasts nutritional benefits, climate resilience, and adaptability to changing conditions, making it a valuable "Future Smart Food" (FAO 2018, Li and Siddique 2018, Ghimire et al 2018, Joshi et al 2019). However, it has faced challenges due to globalization, changing land use, migration, and a lack of research and policy support leading to a decline in its cultivation over the years (Gauchan 2019). Revitalizing millet could address food and nutritional insecurity in Nepal's high hills and mountains. Recognizing the importance of underutilized crops, the United Nations has declared 2023 as the International Year of Millets (FAO 2023). These crops have the potential to address persistent issues like hunger, malnutrition, and the impacts of climate change. Climate change impacts significantly to food security, with projections indicating a potential 8% mean yield loss of major crops by 2050 in African and South Asian regions (Knox et al 2012). Developing climate-resilient crop varieties and technologies is crucial in this context, especially in countries like Nepal which is heavily reliant on subsistence agriculture (WBG 2021). Cultivating underutilized crops can also enhance genetic biodiversity and improve food security (Chivenge et al 2015).

Since Nepal adopted a federal system of governance, local rural municipalities (local bodies) have the authority to prioritize education and public awareness about locally adapted underutilized crops. Diversifying staple food choices and identifying region-specific traditional crops could stimulate entrepreneurship and investment, ultimately contributing to food and nutrition security and supporting the achievement of SDG 2 (Ghimire 2022). Feminization in agriculture has greatly shaped the gender roles in farming (Spangler & Christie, 2020). Ethnicity plays a role in shaping traditional agricultural knowledge, determining access to resources, influencing gender roles, and affecting consumption patterns (Alonso 2015). Remittance inflow has resulted in cultivation of less intensive crops and decrease in land use for agriculture (KC and Race 2019). Farmers group and other government and nongovernment institution/bodies are promoting the crops but their roles are limited (Niraula et al 2023). This is the observed national scenarios in agriculture sector of the country, mostly in major cereals, vegetables and fruits. Limited research and documentation of the findings on different aspects of millet cultivation and postharvest operation have hampered the efforts to draw the policies and program in the conservation, promotion and market development of millet in Nepal. This study tried to document the findings related to finger millet on the aspects of gender and ethnicity in conservation and promotion strategies, production pattern, profitability, food chain and gender division of labor. Effect of remittance inflow on land use, investment in agriculture and adoption of improved technology was investigated. Similarly, problems faced by finger millet farmers were studied. Hence, this study attempts to bridge the knowledge gap and provide documentation to promote the sustainable development of finger millet.

Methodology

Study area

Lamjung district lies in the mid hills of western Nepal with region mostly experiencing subtropical climate. Government led PMAMP prioritized honey bee, cardamom and vegetables in this district. Besides, farming system is dominated by rice, vegetables and livestock in this district. The district has good infrastructure like rural electrification, irrigation and road necessary for possible expansion of agriculture. *Brahmin*, *Chhetri* and *Janajati* (Gurung mostly) are major ethnical group in this district. The district is divided into 4 municipalities and 4 rural municipalities. Dudhpokhari Rural Municipality is one of the remote areas within the district, consisting of 6 wards. *Janajati* (Gurung mostly) are in majority in this area. Outmigration is common.

Sampling technique and sample size

We employed multistage, purposive and random sampling to select district, rural municipality, ward and farmers. Lamjung district was purposively selected as it is major finger millet producing district and promotion of underutilized crop including finger millet is carried by local bodies, I/NGOs like LI-BIRD, government institution like AKC. Dudhpokhari Rural Municipality was purposively selected as farmers are engaged in large number in the cultivation of finger millet and is directly related to the livelihood of rural communities. Thus, has potential for rapid expansion. Through contact with agriculture section of rural municipality, finger millet farmers were found to be 1400 (Population of the study). We used the formula given by Daniel (1999) to calculate sample size, as;

$$n = N*X / (X + N - 1),$$

Where,

$$X = Z_{\alpha/2}^{2} *p*(1-p) / MOE^{2},$$

and $Z_{\alpha/2}$ is the critical value of the Normal distribution at $\alpha/2$, MOE is the margin of error, p is the sample proportion, and N is the population size.

100 finger millet farmers were randomly selected from the study area. Sample size was further divided into categories of male headed household and female headed household with respect to different ethnical group. We collected primary data from the direct household interviews with household head using pretested semi-structured interview schedule. Interview Similarly**,** 5 Focus Group Discussion (FGD) and 5

Key Informant Interview (KII) was carried out with different progressive farmers, leader farmers, extension workers in order to validate the reliability and authenticity of primary data collected from household survey and possible explanation of findings and situations. We collected secondary data from reports of government bodies and institutions, I/NGOs and others.

Data analysis

We used SPSS to present the descriptive statistics (Mean and SD), frequency, B:C ratio and Index value. These were used to interpret the findings of the study.

B:C ratio = Total benefit/Incurred cost

Index value: $I_{imp} = \Sigma(S_i f_i)/N$, where

I_{imp} = Index of importance

S_i = Scale value

F_i = Frequency of importance given by the respondents

N = Total number of respondents

Results and Discussion

Descriptive statistics

Descriptive statistics of the variables used in the study are presented in **Table 1**. On average, respondents were of 59.34 years and 58% of the household head were male. Respondents on average have same farming experience in terms of general agriculture practices and farming which was 47.98 years. Average family size was of 5.62 members and only 2.46 were involved in millet farming. Farm size was recorded to be 6.1 *hal*, only 1.895 *hal* was used for millet farming while 1.71 *hal* was left uncultivated. Annual income of the household was NPR 218860 in which NPR 81900 was contribution from agricultural activities. On average, 28% of the respondents participate in off-farm work, 16% of the respondents have access to credit, none of them have access to extension services, 37% of the respondents participate in farmers group and 68% of respondents participate in agricultural cooperatives. Similarly, none of the respondents have training on millet farming, 20% of the respondents have access to labor, 42% of the respondents perceive millet farming as laborious operation, 74% of the respondents was satisfied with millet farming and 92% of the respondents perceive millet subsector as profitable. On average, 98% of the respondents have access to input and output market.

Table 1. Descriptive statistics of the variables used in the study

Variables	Description	Mean	SD
Age	Age of the respondent (years)	59.34	12.464
Gender	Gender of the respondent (1-male, 0-female)	0.58	0.49
Experience (ag)	Respondents farming experience (years)	47.98	12.892
Experience (millet)	Respondents farming experience in millet (years)	47.98	12.892
Family size	Number of members in household	5.62	3.196
Member involvement	Household members involvement in millet farming	2.46	1.410
Farm size (ag)	Area for agriculture operation (*hal*)	6.1	3.099
Farm size (millet)	Area for millet farming (*hal*)	1.895	1.283
Farm size (bajo)	Area left uncultivated (*hal*)	1.71	1.771

Variables	Description	Mean	SD
Income	Annual income of household (NPR)	218860	238643.9
Income (ag)	Annual income from agricultural activities (NPR)	81900	44185.67
Off farm work	=1 if respondent participate in off-farm work, 0 otherwise	0.28	0.451
Credit	=1 if respondent have access to credit, 0 otherwise	0.16	0.368
Ext services	=1 if respondent have access to extension services, 0 otherwise	0	0
Contact extension	Number of contacts between respondent and extension worker	0	0
Member group	=1 if household member participates in farmers group, 0 otherwise	0.37	0.485
Member cooperatives	=1 if household member participates in ag cooperatives, 0 otherwise	0.68	0.468
Training	=1 if respondent have training on millet farming, 0 otherwise	0	0
Labor	=1 if respondent have access to labor, 0 otherwise	0.2	0.402
Laborious	=1 if respondent perceive millet farming as laborious, 0 otherwise	0.42	1.164
Satisfaction	=1 if respondent is satisfied with millet farming, 0 otherwise	0.74	0.440
Profit	=1 if respondent perceive millet farming as profitable subsector, 0 otherwise	0.92	0.272
Input	=1 if respondent have access to input market and prices, 0 otherwise	0.98	0.140
Output	=1 if respondent have access to output market and price, 0 otherwise	0.98	0.140

Note: 1 *hal* = 1.5 *ropani*; 1 USD = 132.95 NPR. Source: Field survey 2023

Table 2. Descriptive statistics with respect to ethnic groups used in the study

Variables	*Janajati (n=67)*		*Chhetri (n=3)*		*Dalit (n=2)*		*Brahmin (n=28)*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	59.164	11.631	56.333	28.023	57	21.213	60.413	12.520
Gender	0.611	0.490	0.333	0.577	0.50	0.707	0.551	0.506
Experience (ag)	48.283	13.166	47	15.394	35	21.213	48.379	11.570
Experience (millet)	48.283	13.166	47	15.394	35	21.213	48.379	11.570
Family size	5.955	3.649	7	1.732	5	4.242	4.862	1.787
Member involvement	2.641	1.630	2.666	0.577	3	1.414	1.965	0.565
Farm size (ag)	6.238	3.109	3.666	2.081	8	5.656	5.896	2.956
Farm size (millet)	2.216	1.401	1.166	0.288	1.5	0	1.224	0.662
Farm size (*bajo*)	2.059	1.960	0.333	0.577	0.5	0.707	1.068	1.032
Income	226179.1	262477.9	56666.67	5773.503	105000	77781.75	221103.4	189135.9
Income (ag)	83208.96	50718.63	48333.33	10408.33	85000	49497.47	81379.31	25212.54
Off farm work	0.164	0.373	0	0	0	0	0.586	0.501
Credit	0.223	0.419	0	0	0	0	0.034	0.185
Ext services	0	0	0	0	0	0	0	0

Variables	Janajati (n=67)		Chhetri (n=3)		Dalit (n=2)		Brahmin (n=28)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact extension	0	0	0	0	0	0	0	0
Member group	0.298	0.461	0.666	0.577	0	0	0.551	0.506
Member cooperative	0.641	0.483	1	0	0	0	0.793	0.412
Training	0	0	0	0	0	0	0	0
Labor	0.268	0.446	0	0	0.5	0.707	0.034	0.185
Laborious	0.552	1.384	0	0	0	0	0.172	0.384
Satisfaction	0.671	0.473	1	0	1	0	0.862	0.350
Profit	0.910	0.287	1	0	1	0	0.931	0.257
Input	0.970	0.171	1	0	1	0	1	0
Output	0.970	0.171	1	0	1	0	1	0

Source: Field survey 2023

Table 2 presents the descriptive variables with respect to different ethnic groups. Results revealed that farming experience was similar among *Janajati* and *Brahmin* ethnic groups. Family member involvement in millet farming and farm size under millet was comparatively higher in *Janajati* compared to other ethnic groups.

Table 3. Descriptive statistics with respect to household head in the study area

Variables	MHH (n=58)		FHH (n=42)	
	Mean	SD	Mean	SD
Age	61.120	11.631	56.880	13.279
Experience (ag)	48.137	13.190	47.761	12.625
Experience (millet)	48.137	13.190	47.761	12.625
Family size	5.844	3.138	5.309	3.286
Member involvement	2.5	1.392	2.404	1.449
Farm size (ag)	6.689	3.185	5.285	2.813
Farm size (millet)	2.146	1.538	1.547	0.687
Farm size (*bajo*)	1.931	2.142	1.404	1.013
Income	239844.8	239185	189881	237691.5
Income (ag)	86741.38	45388.21	75214.29	42086.75
Off farm work	0.379	0.489	0.142	0.354
Credit	0.258	0.441	0.023	0.154
Ext services	0	0	0	0
Contact extension	0	0	0	0
Member group	0.517	0.504	0.166	0.377
Member cooperatives	0.672	0.473	0.690	0.467
Training	0	0	0	0
Labor	0.241	0.431	0.142	0.354
Laborious	0.379	0.484	0.476	1.714
Satisfaction	0.741	0.441	0.738	0.445
Profit	0.879	0.328	0.976	0.154
Input	0.982	0.131	0.976	0.154
Output	0.982	0.131	0.976	0.154

Note: MHH-Male Headed Household; FHH-Female Headed Household. Source: Field survey, 2023

Table 3 presents the descriptive statistics of variables used in the study with respect to household head. Farm size under millet was comparatively higher in male headed household compared to female headed household.

Production pattern of millet product

Production pattern of different products from millet in the study area is presented in **Table 4**. *Rakshi* is mostly prepared with 30% share followed by *Dhedo* (20.36%). *Puwa* (3.808%) was least prepared.

Table 4. Production pattern in the study area

Items	Description	Mean	SD
Rakshi	Alcoholic drink	30.95	25.21
Chyang	Alcoholic drink	16.2	14.018
Dhedo	Food	20.36	15.771
Roti	Food	13.18	14.985
Khole	Food	15.14	15.003
Puwa	Food	3.808	6.725

Source: Field survey 2023

Table 5. Production pattern with respect to ethnic groups in the study area

Items	*Janajati (n=67)*		*Chhetri (n=3)*		*Dalit (n=2)*		*Brahmin (n=28)*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Rakshi	46.136	15.561	0	0	25	35.355	0	0
Chyang	23.939	10.433	0	0	10	14.142	0.689	3.713
Dhedo	13.196	13.043	40	10	32.5	24.748	33.793	9.788
Roti	5.121	7.719	30	10	0	0	30.689	11.628
Khole	9.378	8.391	16.666	15.275	32.5	24.748	26.896	18.728
Puwa	2.415	5.138	13.333	5.773	0	0	6.206	8.624

Source: Field survey 2023

Production pattern in the study area with respect to ethnic group is presented in **Table 5**. Result revealed that *Rakshi* was mostly prepared by *Janajati* (46.136%) while *Brahmin* prepared no amount. *Dhedo* and *Roti* was mostly produced by *Brahmin* (33.793% and 30.689% respectively). These figures were much higher than the average amount in the study area. *Rakshi* holds cultural significance and economic benefits, hence *Janajati* were more involved in preparation of Rakshi. Similarly, culture restricts *Brahmin* in the preparation of *Rakshi* and other alcoholic drinks.

Table 6. Production pattern with respect to gender in the study area

Item	MHH (n=58)		FHH (n=42)	
	Mean	SD	Mean	SD
Rakshi	33.793	25.310	27.023	24.842
Chyang	17.758	14.454	14.047	13.262
Dhedo	17.758	14.454	23.952	18.466
Roti	12.758	13.602	13.761	16.865
Khole	13.775	14.675	17.023	15.423
Puwa	3.350	6.561	4.428	6.974

Source: Field survey 2023

Production pattern of millet products is presented in **Table 6**. Results showed that there were no much variations in male and female headed household like in ethnic groups. Alcoholic drink (*Rakshi* and *Chyang*) was produced higher in male headed household (33.793% and 17.758% respectively) compared to female headed household. Since, men consume more alcoholic drinks, they prepare more alcoholic drinks, however female also prepare alcoholic drinks to use in rituals, give to relatives and sell to male in the communities. While production of *Dhedo* was higher in female headed household (23.952%).

Benefit:Cost (B:C) ratio

Table 7 presents the B:C ratio of millet subsector in the study area and with respect to ethnic groups and household heads. Result showed that overall B:C ratio was 1.106. Among the ethnic groups, higher B:C ratio was noticed in *Dalit* (1.910) followed by *Janajati* (1.158), both the ethnic groups experienced higher B:C ratio than overall average value. Similarly, higher B:C ratio (1.174) was noticed in male headed household, which was higher than overall average value. *Dalit*, *Janajati* and male headed household produce more alcoholic drink which contributed in higher benefit. *Rakshi* has high economic return, currently sold at NPR 120 per liter in the study area.

Table 7. B:C ratio with respect to ethnic groups and household head in the study area

Feature	B:C ratio	
	Mean	SD
Overall (n=100)	1.106	0.638
Janajati (n=67)	1.158	0.713
Chhetri (n=3)	0.851	0.229
Dalit (n=2)	1.910	0.719
Brahmin (n=28)	0.962	0.382
MHH (n=58)	1.174	0.693
FHH (n=42)	1.012	0.544

Source: Field survey 2023

Status of production, sale and household consumption

Figures of production, sale and household use is presented in **Table 8**. Result showed that overall average in terms of production was 4.776 *muri*, sale was 0.98 *muri* and household use was 3.801 *muri*. Among the ethnic groups, *Janajati* produced higher produce with 5.658 *muri*, sold the lowest percentage (7.63%) and used highest percentage (92.37%) for household use among ethnic groups. *Brahmin* used the lowest percentage of production share for household use (31.14%). Sale of millet and product is limited within the communities. *Janajati* ethnic groups are major buyer of millet as they prepare alcoholic drinks for cultural events and economic benefits.

Table 8. Production, sale and household use of millet in the study area

	Production		Sale		Use	
	Mean	SD	Mean	SD	Mean	SD
Overall (n=100)	4.776	3.084	0.98	1.675	3.801	3.209
Janajati (n=67)	5.658	3.300	0.432	1.653	5.226	2.942
Chhetri (n=3)	3.333	1.527	2.166	0.288	1.333	1.527
Dalit (n=2)	4.25	1.767	3	1.414	1.25	0.353
Brahmin (n=28)	2.931	1.431	2.017	1.081	0.913	1.118
MHH (n=58)	5.394	3.285	1.215	2.019	4.179	3.275
FHH (n=42)	3.922	2.583	0.654	0.959	3.279	3.078

Note: 1 *muri* = 60 kg. Source: Field survey 2023

Gender involvement in stages of production and postharvest operations

Gender involvement to execute work in different stages of farming and postharvest operations is presented in **Table 9**. Score of 0-100 was distributed among men and women based on their contribution in respective stages. Result showed that nursery bed preparation and land preparation is dominated by men (77.4 and 58.7) while other all operations of transplanting, weeding, urea application, harvesting, threshing and winnowing, storage, alcohol preparation, milling and selling of product is dominated by women. **Table 10** presents the same distribution with respect to ethnic groups. Result is similar to the overall average among ethnic groups also. Nursery preparation and land preparation in dominated by men in all ethnic groups and others operations are dominated by women.

Table 9. Gender involvement to execute work in different stages of farming and postharvest operations in the study area

Work	Men		Women	
	Mean	SD	Mean	SD
Nursery preparation	77.4	6.759	22.6	6.759
Land preparation	58.7	3.379	41.3	3.379
Transplanting	38.7	3.379	61.3	3.379
Weeding	5.8	1.842	94.2	1.842
Urea application	16.8	4.847	83.2	4.847
Harvesting	16.5	4.174	83.5	4.174
Drying	15.7	1.743	84.3	1.743
Threshing and winnowing	15.9	2.289	83.2	4.052
Storage	16.7	2.380	83.3	2.380
Alcohol preparation	28.85	2.114	71.15	2.114
Milling	20	0	80	0
Selling	41.4	5.863	58.6	5.863

Source: Field survey, 2023

Table 10. Gender involvement to execute work in different stages of farming and postharvest operations with respect to ethnic groups in the study area

Variables	*Janajati (n=67)*		*Chhetri (n=3)*		*Dalit (n=2)*		*Brahmin (n=28)*	
	Men	Women	Men	Women	Men	Women	Men	Women
Nursery preparation	77.27	22.73	80	20	80	20	77.24	22.76
Land preparation	58.63	41.37	60	40	60	40	58.62	41.38
Transplanting	38.63	61.37	40	60	40	60	38.62	61.38
Weeding	5.68	94.32	5	95	7.5	92.5	6.03	93.97
Urea application	16.51	83.49	20	80	27.5	72.5	16.37	83.63
Harvesting	15.60	84.40	20	80	15	85	18.27	81.73
Drying	15.75	84.25	15	85	15	85	15.68	84.32
Threshing and winnowing	16.06	83.94	16.67	83.33	15	85	15.51	81.38
Storage	16.66	83.34	18.33	81.67	15	85	16.72	83.28
Alcohol preparation	28.33	71.67	30	70	30	70	29.82	70.18
Milling	20	80	20	80	20	80	20	80
Selling	42.42	57.58	43.33	56.67	40	60	38.96	61.04

Source: Field survey, 2023

Conservation and promotion strategies

Promotion strategies used by millet farmers in the study area is presented in **Table 11**. Overall average and distribution based on ethnic groups and household head is highlighted. Result showed that value addition followed by regular consumption was common promotion strategies among millet farmers. *Janajati* ethnic group contribute significantly in the collection of promising potential landraces from the locality or nearby places and best agronomic practices like weeding compared to other ethnic groups. Similarly, female headed households contributed significantly in the collection of promising potential landraces from the locality or nearby places, selection of farmers based on their interest to do seed multiplication, seed distribution, and farmer-to-farmer seed exchange, adoption of best agronomic practices and use of millet in school lunch compared to male headed households.

Table 11. Conservation and promotion strategies followed by millet farmers in the study area

Strategies	Frequency	Ethnic groups				Household head	
	Overall (n=100)	*Janajati* (n=67)	*Chhetri* (n=3)	*Dalit* (n=2)	*Bramin* (n=28)	MHH (n=58)	FHH (n=42)
Strategies on conservation							
The promising potential landraces are collected from the locality or nearby places	50	40	0	0	10	20	30
The farmers are selected based on their interest to do seed multiplication	20	10	0	0	10	20	30
Seed distribution, farmer-to-farmer seed exchange	40	25	1	2	12	15	35
Strategies on cultivation							
Line Transplanting/Line Sowing rather than broadcasting	5	5	0	0	0	2	3
Other best agronomic practices (spacing, weeding, etc.)	72	67	2	2	1	30	42
Strategies on consumption							
Use of millet in school lunch	35	10	3	2	20	5	30
Regular consumption of millet product	70	66	2	2	0	50	20
Strategies on commercialization							
Value addition	100	67	3	2	28	58	42
Floor pricing	35	2	3	2	28	10	25

Note: Multiple responses of respondent were recorded. Source: Field survey, 2023

Problems in millet farming

Problems faced by millet farmers in the study area are presented in **Table 12**. Result showed that most severe problem among farming communities was unavailability of labor followed by disease and pest incidence. Out migration in the mid hills have reduced the agricultural labor, this is observed throughout the country. Similarly, incidences of grubs, borer, and rodents and associated disease have destroyed the millet in the farmer's field. Unavailability of quality seeds, and timely inputs and animals like boar and monkey are destroying the field. This has reduced the production among farming communities.

Table 12. Problems faced by millet farmers in the study area

Problems	Index value	Rank
Unavailability of labor	1	I
Disease and pests incidence	0.7	II
Unavailability of quality seed	0.55	III
Unavailability of inputs (urea, seed, etc.)	0.25	IV
Animals (Monkey, Boar, etc.)	0	V

Source: Field survey, 2023

Remittance inflow and land use

Utilization of remittance in agriculture and millet farming and change in land use for farming is presented in **Table 13**. Results showed that only 9.076% of remittance amount is used for agriculture while it was even less for millet farming (0.615%). Further result revealed that land under agriculture is decreased by 0.646 hal since remittance inflow. No any improved technology adoption was reported by the respondents, as they were still following the traditional practices. Farming is perceived as laborious, and with remittance inflow they reduced the farm size (KC and Race 2019), as they had other source of income.

Table 13. Utilization of remittance in agriculture and change in land use after remittance inflow in the study area (n=65)

Utilization in agriculture (%)		Utilization in millet (%)		Decrease in land use (*hal*)	
Mean	SD	Mean	SD	Mean	SD
9.076	2.985	0.615	0.946	0.646	0.229

Source: Field survey 2023.

Involvement of local bodies, government institution and I/NGOs in promotion of millet

None of the respondents highlighted participation in any of the programs of the local bodies, government institution and I/NGOs. AKC are promoting the cultivation of *Raithane Bali* (Local crops) which includes millet through formation of farmers groups and standard farm size, Similarly, local bodies are allocating budget in the promotion of *Raithane Bali*. I/NGOs are working on conservation and further promotion of *Raithane Bali*. Areas for market development and value chain development are further explored by these bodies and institutions. However, major focus by these bodies and institutions is still on high yielding varieties of major cereals crops, fruits and vegetables, and livestock. Farmers group and agricultural cooperatives lack initiation to conserve and promote millet in the area. Similarly, majority of the farmers are cropping millet along with maize, this has hampered the expansion of millet as major crop. Rice dominant daily food habit among Nepalese has limited daily consumption of millet. Cultivation of millet for alcoholic drinks (*Rakshi*, *Chyang*, etc.) is common. Access to extension services is limited throughout the country, majority of the farmers are having no regular contact with extension worker (Mishra and Bhatta 2021, Mishra 2021, Dhakal and Mishra, 2022, Mishra et al 2023). This has limited improved practices flow to the farming communities and still farmers are practicing cultivation and postharvest operations through traditional knowledge. Thus, promotion of millet should be initiated in new approach to include the food in daily diet and for this policies and programs should be reshaped to give equal importance to *Raithane Bali* as major cereals crops. Followings are further KII and FGD highlights.

- Generally 6 local variety of finger millet (*kodo*) are grown in this area. *Dalle kodo* (Late maturity variety); *Jhumre kodo* (Break easily while harvesting); *Larfare kodo* (Intercropping with maize during *Jeth* month); *Nangre kodo* (Early maturing variety); *Seto kodo* (Best for flour making; eating); *Kalo kodo* (Best for making alcoholic drinks).
- Nursery bed preparation is done from *Baisakh* to second week of *Jeth* month. Transplanting is done from last week of *Asar* month to second week of *Shrawan* month. Weeding and application of urea is done at last week of *Bhadra* month. Harvesting is done upto first week of *Poush* month.
- Jute bags, pots and cloth bags are used for storage of finger millet seed for planting during next season.
- *Brahmin* and *Chhetri* ethnic groups perform no weeding as they sale most of the production rather than household use, while *Janajati* ethnic group perform weeding 1-2 times as it makes the quality better of various millet products.
- *Janajati* ethnic groups mostly follow maize and millet relay cropping, while sole cropping of millet is seen more in *Brahmin* and *Chhetri* ethnic groups compared to *Janjati*.
- *Pakho bari* which is ideal for finger millet cultivation is less among *Brahmin* compared to *Janajati* ethnic group.

Conclusion

Millet farming can help mitigate the issues of nutritional and food security in the light of climate changes issues. However, rice based daily food habit and major focus on major cereals like rice, wheat and maize from government bodies, institutions and other agencies have limited its potential expansion. The results revealed that conservation strategies like collection of promising potential landraces from the locality or nearby places were significantly contributed by *Janajati* ethnic groups compared to other ethnic groups. Similarly, female headed household contributed significantly in the collection of promising potential landraces from the locality or nearby places, selection of farmers based on their interest to do seed multiplication, seed distribution, and farmer-to-farmer seed exchange. Hence, the extension agencies of government, I/NGOs and other agencies should closely work with *Janajati* ethnic group and female headed farm household as they hold tremendous knowledge on the diversity of finger millet in the study area. Production pattern of millet products was different among ethnic groups, hence the market and value chain development programs should be developed accounting all the groups for sustainable development in the study area. Preparation of alcoholic drinks was significant factor in the higher benefits from millet farming; hence the programs related to branding, market expansion and development of efficient marketing channels should be initiated. Investment of remittance is minimal in agriculture rather it has decreased the farm size due to labor shortage. Hence, policies should be initiated to promote the flow of remittance in agriculture. Women domination in millet farming and postharvest operations is observed in the study area. Hence, the programs and policies should primarily focus on women farmers for the conservation and promotion of finger millet. Outmigration and remittance inflow has reduced labor flow, decreased farm size and has no significant impact on technology adoption and investment in agriculture. Local bodies, government institution, I/NGOs, farmer's organization and other agencies are not benefiting the farming communities in the conservation of finger millet in the study area. Hence, these institutions should reshape their priority areas and initiate more programs in finger millet through group approach. Expansion of extension system is must to reach more farmers. Farmers groups should be further strengthening to promote more participation of farmers in its system and should act as a local carrier of conservation and promotion strategies. Adoption of farm mechanization, measures against pests and access to quality seed should be prioritized in the study area for development of profitable finger millet subsector.

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Policy Attention Awaited: Women's Role in Millets Value Chain

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Summary

Millets are considered as highly nutritious, climate resilient and adaptable to the marginal lands. In Nepal, women are engaged more than their men counterpart in most of the activities from production through processing to food preparation. In the past several decades, millets are seen as inferior crops and not gaining commercial importance and therefore ignored by better off farmers for many years. However, in the recent years millets have been gaining importance because a) increase awareness among consumers about its value for healthy and nutritious diets, b) resilient for climate change impacts, c) potential of product diversification with the use of machines, tools, equipment, d) potential for utilization of women's traditional knowledge and skills that enhance value addition, drudgery reduction and economic gains. It is therefore urgent to prioritize millets and its production system with product diversification for better productivity, nutrition and food security as well as conservation of millets landraces.

Keywords: Climate, food, gender, millets, nutrition, resilience, women

Introduction

Millets are widely grown in Nepal since historic times. In Nepal, 12 millet species (Joshi et al 2023) are found. These 12 types of millets are collectively referred as millets. They are grown in all ecological zones and most often in marginalized areas. Millets are highly nutritious and accessible to poor to ensure food security. Millets in most cases are grown as intercrop with maize for optimal use of land, yield gain, soil stability and food and feed/fodder supplies. Since, millets are grown in remote and marginalized areas, land holders are also mainly of poor, small farmers and women led production systems. Until recent past millets were not purposively grown for commercial purpose, the tasks associated with millets production, harvesting and cooking were almost exclusively managed by women. Therefore, it is basically a women-led agriculture business and enterprise. In the recent years state policies and strategies like Gender Equality and Social Inclusion (GESI) Strategy of Ministry of Agriculture and Livestock Development (MoALD) is also explicitly and or implicitly supporting millets production by women as the strategy aims for GESI inclusive institutions, production supports and investment in value chains and market development.

In a broader perspective, Nepal's Constitution, Multi Sector Nutrition Programme (MSNP) of (GoN, European Union and UNICEF 2021)[1], as well as FAO call on International Year of Millets (FAO 2023)[2] are supportive in promoting role of women in agriculture in general and marginalized crops like millets in particular. Likewise, the UN Women's globally accepted proposal of five ways to build gender equality and sustainability is relevant

1 GoN, European Union and UNICEF, 2021, Multi-Sectoral Nutrition Plan (MSNP)-II, Kathmandu

2 https://www.fao.org/millets-2023/en

in this respect. It covers: a) Empower women smallholders; b) Invest in care; c) Support women's leadership; d) Fund women's organizations; and e) Protect women's health. This helps to understand the dynamic role of women and protection through legal provisions, institutional arrangements and benefit sharing mechanisms. It thus helps to build climate resilient millets value chain that are managed by women and ensure food and nutrition security. Millets thus contribute to realize them.

Women's Role in Millets Value Chain

As indicated in the preceding section, women play an important role in production and management of millets. For the purpose of this paper, women's role in millets value chain is broadly captured under four groups below:

Figure 1. New and renewed labour approvals, MoLESS 2022.

Role of women in genetic resources conservation, research and innovation

As stated above, 12 different millets are grown in almost all districts of Nepal with the coverage of 265,401 ha of land with the average yield of 1.23 MT/ha in fiscal year 2020/21 (MoALD 2022). In the current context of youth-male out migration (**Figure 1**), (Ministry of Labour, Employment and Social Security, 2022), women are managing agricultural jobs including less commercialized crops like millets. Therefore, the landraces and varieties of millets maintained, conserved and promoted so far are primarily by women farmers. Women are providing feedback for varietal selection, food diversification and use of machines in the millets value chain. In this way women are playing significant role in millets promotion and improvement.

Nepal Agricultural Research Council (NARC)'s strategic vision aims for technological development and dissemination that are sensitive and responsive to the conditions of rural farmers, specifically women, whose contribution is often greater than that of men in the millets value chain and diversification of products (NARC 2010). In recent years policy priorities have recognized the role and importance of women even in millets system.

Millets are managed and maintained mostly by women. It is therefore important to recognize the role of local communities in general and women in specific in conserving, protecting, cultivating and utilizing super foods like millets. Their long experience, knowledge, skills and learning about millets-based production system is transferred from generation to generation. Therefore, it is essential to preserve these indigenous knowledges (such as panicle selection for seeds, storage practices, recipes etc.) about millets and their genetic resource pools (Sthapit, updated)[3] for future research and innovation.

As Nepal is being a member of many different international conventions such as Convention of Biological Diversity (CBD) and International Treaty on Plant Genetic Resources (ITPRFA), and so on, important contribution of local communities including of women on maintaining and promoting millets has to be duly recognized. Bringing women within the framework of Prior Informed Consent (PIC) as well as benefit sharing (8j of the CBD) (UN 1990) is essential to fulfil the requirements of the treaties and conventions. Until now, Nepal doesn't have Access to and Benefit Sharing (ABS) law or other national frameworks to implement PIC and BS as per CBD. So, it is urgent to develop in-country legislative framework to ensure effective implementation of CBD.

3 Sthapit B., Himalayan Foods: Healthy and Nutritious crop varieties, Bioversity International, www.bioversityinternational.org

Nepal has 1280 millets accessions in the Gene Bank (Joshi et al 2023), majority of which were originally conserved and preserved by women[4]. Hence, recognizing their roles and ensuring benefit sharing of these genetic diversities are urgent. If women had not preserved these races, it would not be possible for the Genebank to collect and use in future.

Need for women's recognition for 3 Rs (Rights, Resources and Representations) in relation with millets value chain

In this paper 'rights' is meant for ensuring access to justice for women and marginalized groups through gender-equitable laws and equality legislation. Likewise, 'resources', in this context, is ensuring access to and control over resources for women and girls that strengthens their position in millets value chain. Similarly, 'representations' for the purpose of this paper is ensuring full, equal and meaningful participation specially in political and corporate decision-making bodies that provides space for women to influence in ensuring their needs, demands and choices in policies, programmes and allocation of human and financial resources to make millets system more inclusive, resilient and economic..

Women's role in conservation, preservation and promotion of millets has to be recognized by ensuring 'rights', 'resources' and 'representation' (3Rs). To elaborate further, women must be legally recognized as important actors in millets landraces conservation, promotion and protection. There must be legal provisions and institutional mechanisms to ensure women to claim their rights on millets as right holders. Further, it is essential to ensure women's access to land, seeds, technologies, finance, training and information that empowers their negotiation abilities to improve millets value chain. In doing so, women's participation and representation in policy making process, structures and positions under Nepal Agricultural Research System (NARS), universities as well as other knowledge centers should be considered well. Consequently, women will be able to assert their needs, demands and priorities and consequently raise agency-based voices.

Women's engagement in decision making level paves pathway for sustainable millets value chain. For example, farm mechanization, especially in post-production for millets value chain reduces workload and drudgery for women. Once 3Rs are of women and marginalized communities producing millets are ensured, it leads to gender responsive policies, procedures, mechanisms and impact measurements.

Women's role in food and nutrition security

The Global Hunger Index (GHI) of 2020 shows that though Nepal is ranked under moderate condition with 19.5 score, there were distinct variations in the food insecurity conditions across the different geographical locations, age and caste/ethnicities (Welt hunger hilfe and concern worldwide 2020). Among the provinces Karnali Province had highest level of child stunting (54.5) score. Similarly, (mountain ecological reason) Mountains (46.8) score against the national scenario of 35.8. Most regrettably, these are the two high millets potential areas.

Likewise, Madhesh Province had highest percent (12%) of child wasting while the national percent was of 9.7 (welt hunger hilfe and Concern worldwide 2020). As these are potentially high millets growing areas and if the government have given priority in terms of policy, programmes and resource allocation priorities with ensuring 3Rs, there should not be food insecurity in these areas. The mis-match is a real concern.

If we examine the Nepal's food and nutrition security plan, it has adopted five objectives as:

- to increase the country's self-reliance for basic food stuffs;

4 Author's interaction with women from Dolakha, Khotang, Okhaldhunga and Panchthar confirmed that they have been conserving millets varieties because of taste, insect pests and drought resistance, straw preference by livestock, easy to haul and pound and energy from millets recipes (*aadilo*) etc.

- to improve the nutrition situation;
- to enhance standards and safety of food stuffs that are available in markets;
- to enhance capacity for managing food insecurity that arise from emergency conditions; and
- to improve the access to food by groups prone to food and nutritional insecurity.

However, the reality showed that food insecurity was rampant among those groups. The plausible reasons could be lack of their participation, representation and influence while choosing crops production, managing farming system and dealing with food issues. This situation was further aggravated during the Covid-19 period (**Figure 2**), which is evident in the gender differentiated impacts (GoN and WFP 2019).

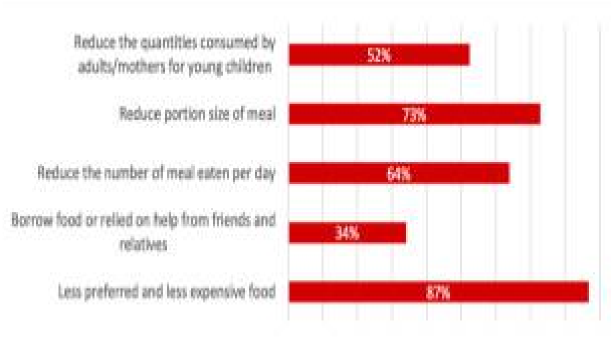

Figure 2A. Strategy of HHs to manage family food security.

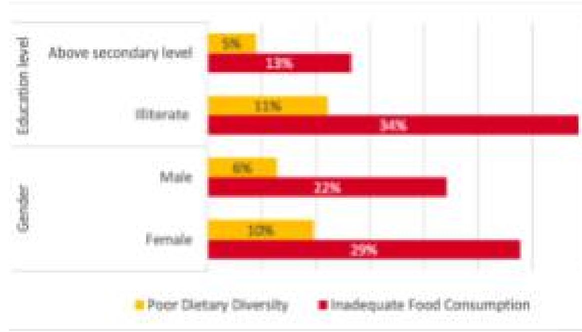

Figure 2B. Gender impacts in HH food security management.

The situation could be different if the local and raithane crops (including millets) were promoted and or given priority. Millets are being rich in nutrients, climate resilient, suitable even in marginal lands and manage by women and therefore could ensure household food security during pandemics (**Figure 3**).

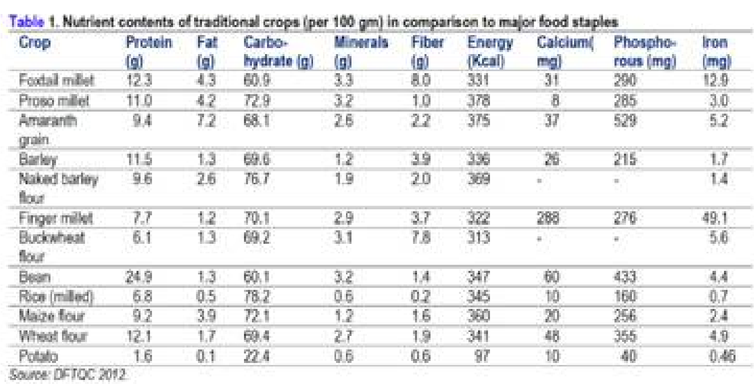

Table 1. Nutrient contents of traditional crops (per 100 gm) in comparison to major food staples

Crop	Protein (g)	Fat (g)	Carbo-hydrate (g)	Minerals (g)	Fiber (g)	Energy (Kcal)	Calcium(mg)	Phospho-rous (mg)	Iron (mg)
Foxtail millet	12.3	4.3	60.9	3.3	8.0	331	31	290	12.9
Proso millet	11.0	4.2	72.9	3.2	1.0	378	8	285	3.0
Amaranth grain	9.4	7.2	68.1	2.6	2.2	375	37	529	5.2
Barley	11.5	1.3	69.6	1.2	3.9	336	26	215	1.7
Naked barley flour	9.6	2.6	76.7	1.9	2.0	369	-	-	1.4
Finger millet	7.7	1.2	70.1	2.9	3.7	322	288	276	49.1
Buckwheat flour	6.1	1.3	69.2	3.1	7.8	313	-	-	5.6
Bean	24.9	1.3	60.1	3.2	1.4	347	60	433	4.4
Rice (milled)	6.8	0.5	78.2	0.6	0.2	345	10	160	0.7
Maize flour	9.2	3.9	72.1	1.2	1.6	360	20	256	2.4
Wheat flour	12.1	1.7	69.4	2.7	1.9	341	48	355	4.9
Potato	1.6	0.1	22.4	0.6	0.6	97	10	40	0.46

Source: DFTQC 2012

Figure 3. Nutrient contents of traditional crops (per 100 grams) in comparison to major staple foods, Gene Bank 2023.

Figure 4. Food pyramid, DFTQC 2017. Source: DFTQC, 2017

The Government and other supporting agencies should be committed in ensuring food production, management, distribution and consumption as shown in the food pyramid (**Figure 4**), and for this they have to give opportunity for women specially from marginalized communities to manage household food system, so they could take care of household level food and nutrition security from their own production, even by using marginal lands they occupy in most of the cases. The government should provide space for women to help in securing genetic diversities, harnessing women's potentials in managing millets and consequently managing food and nutrition security of their family.

FAO study (FAO 2018) shows that current global high level of malnutrition is due to unbalanced diets with insufficient nutrition diversity. Nutrition-sensitive and climate-smart agriculture interventions (like millets value-chain) can contribute in meeting nutritional requirements. Millets are indeed nutritious, climate resilient, economically viable and adaptive to local conditions, and marginal areas (Sthapit, undated). Given the high potential of millets for their climate resilient character, adaptability in marginal areas and nutritional qualities, it is urgent need to promote these crops in Nepal to ensure food availability, affordability and nutrition security (FAO 2018).

Women's role in food diversification, employment and incomes

Recent data of Nepal shows that we have 142 caste and ethnicities (NSO 2023). All castes and ethnicities have their own specific (and unique) cultures and rituals. Each culture and ritual need specific crops and their products. Many of such food item items are prepared from millets. The knowledge and skills of women and cultural values associated with specific millets and millets-based food systems are very much localized, and practiced. Hence, it is an opportunity for women to promote millets for food diversification, generating employment and incomes in specific.

In the changing context of health consciousness and increasing income status of consumers, they are ready to invest in nutrient-dense meals. Further, people coming from rural areas and settling in urban centers and abroad have also shown their emotional connections with millets and local agricultural products. Hence, there is immense potential for food diversification, employment generation and increase incomes which can be led by and for women. The food items from millets have also longer shelve live e.g. nutribar and other diversified products (**Figure 5**), (Ghale 2020). Use of machines, tools and equipment (mechanization) and Information Communication Technologies (ICT) enhance potential to commercialize millet crop production system and food product diversification.

Figure 5. Food recipes made out of millets crops, Ghale 2020.

The recent trend of making bakery items, healthy salads, soups, flex, chips from millets are gaining high popularity. It in turns demands for more production, engagement of women and youth throughout the value chains, use of machines, tools, equipment in millets and millets-based system. For example, the introduction of multi-crop thresher, chino-kutak, graders with different size shelves help women to reduce their workload as well as drudgery (**Figure 6**). However, market-led product diversification is still in rudimentary stage and not getting enough priority in policy and programs.

Figure 6. Millets shelves of different size, Ghale 2023.

Conclusion

While discussing the roles of women in millets value chain system, it is urgent to ensure policy and regulative frameworks as well as operational mechanisms to enhance engagement of women in conserving genetic resources, promote research and innovation, and ensure 3Rs for women. Women's role in ensuring food and nutrition security is proven. Similarly, role of women in genetic resources conservation, research and innovation of millets is pivotal, as well as should receive enough attention at policy level.

Ensuring rights, access to resources and proper representations of women in millets value chain is fundamentally important. Nevertheless, it is quite complicated to align with international commitments, national priorities and local demands until the government has determination to realize it. Since women's role in food and nutrition security at the household is quite critical, their knowledge and skills related to millets and millets-based foods are thus vital to ensure food and nutrition security specially in the adverse conditions. Currently, there is an increasing interest and demand of consumers towards millets-based products. Therefore, strengthening women's engagement in millets value is an emerging arena for food diversification, employment, income generation.

Recommendations

Policy and legislative framework

- Formulate women-responsive in-country policy and legislative framework for the PIC and ABS that ensures implementation of the CBD provisions including millets-based genetic resources;
- Ensure implementation of national policy at the local levels with responsive mechanisms to ensure women get share of benefits for the generational contribution to select, conserve, maintain and promote local millets landraces for now and future;
- Facilitate local governments to understand, locate, prioritize and support millets-based system through localized agricultural practices that provides an opportunity for women to make best use of their indigenous knowledge and skills with certain improvisation and certification as required;
- Introduce millets and its importance in education curriculum and training packages.

Promotional strategy

- Prioritize millets-based farming system to promote women's role in production and management for ensuring nutrition and food security;
- Introduce machines, tools and equipment that helps women to share workload as well as reduce their drudgery in millets-based production, post-production and consumption spheres;
- Invest on consumer awareness and sensitization about nutrient dense and locally produced millets-based diets;
- Promote millets in school meal programmes, events and feasts, menu of hotel and restaurants to create demand, increase production and diversify the products.

Genetic resource conservation and research

- Invest on research and development of millets varieties that are suitable for product diversification, market-led demand, machine friendly and nutrient dense;
- Revive the research system that can capture the experiences and voices of women who helped to retain the diverse varieties so far available for research, gene bank and farmer's field level production;
- Ensure women's meaningful engagement in conserving genetic resources of millets, and most importantly ensure 3Rs for women.

Value addition and product development

- Support youths and women to lead millets-based enterprises for in-country marketing including homestays as well as exports.

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक) । २०८० । राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ ।

बहुगुणकारी अन्न कोदो

डा. बेदुराम भुसाल

माननीय मन्त्री
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कोदो वनस्पति विज्ञानको वर्गिकरण अनुसार पोयसी परिवार अन्तर्गत पर्ने घाँसे अन्न हो । नेपालमा हामीले कोदो भनेपछि ससाना गोलाकार दाना हुने अन्न भन्ने बुझ्दछौँ तर यस अन्नका निम्ति अङ्ग्रेजीमा जुन मिलेट (Millet) भन्ने शब्द प्रयोग गरिन्छ त्यस अनुसार यसका अनेक प्रकार छन् । मुख्य प्रकार हुन् : कोदो, चिनो, कागुनो, बाज्रा, जुनेलो र सामा ।

कोदो वा कोदोजन्य बालीको परम्परा धेरै पुरानो मानिन्छ । यो घाँसे अन्न भएको हुनाले मानव जातिले सुरुमा खेती गरेका अन्नमध्ये एक हुनु पर्दछ भन्ने आम धारणा छ । मानिसले सुरुमा वन्य जन्तुले खाने गरेका दानादार घाँसे बालीहरूको खेती गरेर आफुले उपयोग गर्न थालेको थियो भन्ने निष्कर्ष विभिन्न ऐतिहासिक सन्दर्भहरूबाट निस्किएको मानिन्छ ।

दक्षिण एशियाली क्षेत्रको प्राचिनतम साहित्य मानिने वैदिक सहित्यमा नै धान, मकै, गहुँलगायत कोदोजन्य बालीहरूको पनि उल्लेख भएको पाइन्छ । जस्तो कि यजुर्वेदमा 'प्रियन्गावा', 'अणवा', 'श्यामका' आदि भनेर धान, जौ, गोहुँ, मसुरो मास, तिल, मुग, चनासँगै कोदो वा कोदोजन्य बालीको पनि उल्लेख गरिएको छ । [१] त्यसैगरी वृहदारण्यक उपनिषद्मा धान, जौ, तिल, गहुँ, कागुनो, मास, मसुरो, अणु, खल्व, खलकुल आदि दश प्रकारका ग्राम्य अन्नको चर्चा गरिएको छ[२] भने छान्दोग्य उपनिषद्मा धान, जौ, सर्स्यु, श्यामाका र श्यामकतण्डुल आदि अन्नको उल्लेख छ ।[३] वृहदारण्यक उपनिषद्मा उल्लेख भएको 'अणुप्रियङ्गवो' र छान्दोग्य उपनिषद्मा उल्लेख भएको 'श्यामका' कोदोजन्य बाली हुन् भनिन्छ । यसरी प्रसिद्ध ग्रन्थहरूमा उल्लेख भएबाट आर्यहरूले उत्तर वैदिक कालमा नै धान, गहुँ, जौ र विभिन्न प्रकारका दलहन बालीको साथै कोदो वा कोदोजन्य बालीको पनि खेती गर्ने गर्दथे भन्ने स्पष्ट हुन्छ ।

चीनमा ई.पू.२८०० मा लेखिएको पुस्तक फान शेन चि शु (Fan Shen Chih Shu) मा पनि कोदोको उल्लेख भएको छ । यी सन्दर्भहरूबाट स्पष्ट हुन्छ कि कोदो वा कोदोजन्य बालीको परम्परा धेरै पुरानो समयदेखि चलिआएको छ ।

कोदो एकदमै स्वस्थकर खाद्यान्न मानिन्छ । कोदो र कोदोजन्य बालीहरूमा स्वास्थ्यका लागि लाभदायक धेरै गुणहरू रहेका छन् । त्यसैले यसलाई बहुगुणकारी अन्न पनि भनिन्छ । भारतमा त यसलाई श्रीअन्न समेत भन्ने गरिएको छ । यसमा धेरै पोषक तत्वहरू रहेका छन् । एक अध्ययन अनुसार मुख्य कोदोजन्य बालीहरूको प्रति एकसय ग्राममा निम्नानुसारका तत्वहरू रहेका हुन्छन्[४] ।

पोषक तत्व	कोदो Kodo M.	कोदी Finger M	बाज्रा Pearl M	जुनेलो Sorghum M.	कागुनो Foxtail M	चिनो Proso M	सामा Barnyard M
इनर्जी (क्यालोरी)	३०९	३२८	३६१	३४९	३३१	३४१	३९७
प्रोटीन (ग्राम)	८.३	७.३	११.६	१०.४	१२.३	७.७	६.२
बोसो (ग्राम)	१.४	१.३	५.०	१.९	४.३	४.७	२.२
फाइबर (ग्राम)	९.०	३.६	१२	१.६	८.०	७.६	९.०

१ व्रीहयश्च मे यवाश्च मे माषाश्च मे तिलाश्च मे मुग्दाश्च मे खल्वाश्च मे प्रियङ्गवश्च मेणवश्चमे श्यामकाश्च मे नीवाराश्च मे गोधूमाश्च मे मसूराश्च मे यज्ञेन कल्पन्ताम ॥ -यजु. १८/१२ ।

२ दश ग्राम्याणि धान्यानि भवन्ति व्रीहियवांस्तिलमाषा अणुप्रियङ्गवो गोधुमाश्च, मसुराश्च, खल्वाश्च खलकुलाश्च । - बृ.उ. ६/३/१३ ।

३ व्रीहेर्वा यवाद्वा सर्षपाद्वा, श्यामकाद्वा श्यामकतण्डुलाद्वा । -छा.उ. ३/१४/३ ।

४ Chakraborty M and S Debnath. 2023. Millets: Food of the Future. Agriculture Magazin 2(3): 170-173.

पोषक तत्व	कोदो Kodo M.	कोदी Finger M	बाज्रा Pearl M	जुनेलो Sorghum M.	कागुनो Foxtail M	चिनो Proso M	सामा Barnyard M
क्यल्सियम (मिलिग्राम)	२७.०	३४४	४२.०	२५.०	३१.०	१७.०	२०.०
आइरन (मिलिग्राम)	०.५	३.९	८.०	४.१	२.८	९.३	५.०
जिंक (मिलिग्राम)	०.७.	२३	३.१	१.६	२.४	३.७	३.०
थियामिन (मिलिग्राम)	०.३३	०.४२	०.३३	०.३६	०.५९	०.२१	०.३३
रिबोफ्लेभिन (मिलिग्राम)	०.०९	०.१९	०.२५	०.१३	०.११	०.०१	०.१०
फोलिक एसिड (मिलिग्राम)	२३.१	१८.०	४५.५	२०	१५	९	—

उपर्युक्त तत्वहरू भएको कोदो सहज पाच्य एवम् पोषिलो अन्न हो। यसमा कार्बोहाइड्रेटका अतिरिक्त प्रोटीन, भिटामिन र खनिज पदार्थहरू समेत रहेका छन्। यसमा रहेका पोषक तत्वहरूले शरीरलाई स्वस्थ राख्न मद्दत गर्दछन्। यो रिजिलियन्ट अन्न भएको हुनाले पनि लाभदायक छ। यो ग्लुटेनरहित अन्न पनि हो। त्यसैले भनिन्छ कोदोले हृदय स्वस्थ राख्न मद्दत गर्दछ, चिन्ताग्रस्त मान्छेको मनोदसा सुधार्न मद्दत गर्दछ र मोटो मान्छेको तौल घटाउन पनि मद्दत गर्दछ।

कोदो, कागुनो, चिनो, जुनेलो, बाज्राजस्ता कोदोजन्य बालीहरू नेपालका रैथाने बाली हुन्। यी बालीहरू अन्य खाद्यान्न बालीहरूको तुलनामा बढी पोषिला हुन्छन्। यिनीहरू जलवायु परिवर्तनले गर्दा उत्पन्न समस्या र कुपोषणसँग जुध्न सहयोगी हुन्छन्। विगतमा यी बालीहरू आम नेपालीको मूख्य खाद्यान्नको रूपमा रहेका थिए। कालान्तरमा धान, मकै, गहुँजस्ता खाद्यान्नको उपभोग बढ्दै गएपछि कोदोजन्य बालीहरूको उत्पादन र उपभोग घट्दै गएको देखिन्छ। समाजमा रहेको भात खानुलाई सम्पन्नताको रूपमा हेर्ने तथा कोदोजन्य बालीहरूको उत्पादन र उपभोगलाई हेयको दृष्टिले हेर्ने गलत धारणाको कारणले पनि यस्ता बालीहरू ओझेलमा पर्न गएका हुन्।

कोदोजन्य बालीहरू लगाउन सजिलो छ। किनभने यिनीहरू सुख्खा एवम् खडेरी सहन सक्ने हुन्छन् र यिनीहरूको खेती कम मलिलो जमिनमा र सिँचाइ नभएको जमिनमा पनि गर्न सकिन्छ। पहिले नेपालमा कोदोजन्य बालीको खेती प्रसस्त हुने गर्दथ्यो। विगत दश वर्षको तथ्याङ्क हेर्दा आठ वर्षसम्म लगातार घटेको र पछिल्ला दुई वर्षमा थोरै बढेको देखिन्छ। कृषि गणना २०७८/७९ का अनुसार विगत दश वर्षमा कोदोको खेती गरिएको क्षेत्रफल (हेक्टरमा) निम्नानुसार छ :

आ.व.	२०६९/७०	२०७०/७१	२०७१/७२	२०७२/७३	२०७३/७४	२०७४/७५	२०७५/७६	२०७६/७७	२०७७/७८	२०७८/७९
क्षेत्रफल	२७४३५०	२७११८३	२६८०५०	२६६७९९	२६३५९६	२६३४९७	२६३२६१	२६२५४७	२६५४०१	२६७०७१

अब हामीले कोदोजन्य बालीको गुण र फाइदाको बारेमा जनचेतना अभिवृद्धि गरी यस बालीको विस्तारमा जोड गर्नुपर्ने छ। हाम्रा पहाडका बारीहरूमा कोदोजन्य बाली लगाएर किसानको आम्दानी बढाउने अभियान चलाउनु पर्दछ। स्वस्थ जीवनका निम्ति यसो गर्नु अनिवार्य भइसकेको छ। राष्ट्रिय उत्पादन वृद्धि गर्नका निम्ति पनि यो कार्य गर्नुपर्ने छ। रैथाने बाली संरक्षणको हिसावले समेत यो काम गर्नैपर्ने भएको छ।

कोदोजन्य अन्नबाट खानाका अनेकौँ परिकार बनाउन सकिन्छ। रोटी, खिर, हलुवा, पुवा मात्र होइन उच्च कोटीको नशालु पेय पदार्थ समेत बनाउन सकिन्छ। हाम्रा ग्रामिण भेकमा कोदाको तीनपाने रक्सी परापूर्व कालदेखि नै एकदमै प्रचलित छ। कतिपय जनजातिहरूले त यो रक्सी आफ्ना कुलदेवतालाई चढाउने समेत गर्दछन्। चाडपर्बमा आफन्तजन सँगै बसेर यसको सेवन गरी रमाउने प्रचलन त आम रूपमा नै छ। शहर बजारका ठूलाठूला होटेलहरूमा विदेशबाट आयातित महङ्गा रक्सीहरू प्रयोग गरिन्छ। त्यसो गर्नुभन्दा कोदोको रक्सीलाई ब्राण्डिङ गरेर प्रयोग गर्न सकेमा आर्थिक हिसावले मात्र होइन स्वस्थ्यको हिसावले समेत फाइदाजनक हुनेछ। यसतर्फ पनि ध्यान दिनु जरुरी छ। कोदो फैलाऔँ, समृद्धिकोबाटो पहिलाऔँ।

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Chapter 2. Science and Technology
अध्याय २. विज्ञान र प्रविधि

A. Botany, Biodiversity and Conservation

क. वनस्पति विज्ञान, जैविक विविधता र संरक्षण

Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Status of Millets and Allies Species in Nepal

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Abstract

Millets are herbs or shrubs, small, seeded cereals having capability to adapt in low rainfall regimes, short growing habit, fitted for poor soils and thus resilient in harsh environment. Taxonomically they belong to the *Panicoid* sub family, *Paniceae* tribe except finger millets and teff which are *Eragrostidae* in *Chloridoids* group within the *Poaceae* family. An attempt has been taken to document millets and allies species in Nepal with the help of standard literatures and herbarium studies. Traditionally cultivated allies species are also consider and field data were also analyzed and presented here with. Details are given for domesticated and cultivated species and enumeration for wildly distributed species. Altogether 10 genera and 51 species are documented. This information would be useful for the taxonomists as well as other concerned scientists to develop conservation and utilization of millets in Nepal.

Keywords: Allies species, cereals, documentation, millets, Nepal

Introduction

Millets represent the group of taxa rather than the single taxon, are ancient crops for mankind and are important for the rainfed agriculture. These are originated from Asia and Africa where domesticated by human and spread over other regions of the world. These are small cereal grains belonging to the grass family (*Poaceae*). These species are having characteristics features of resilient in harsh environment. These tend to be small seeded cereals and thus distinct from wheat, barley, oat, rice, maize etc. It represents the diverse group of versatile cereals that have long been a part of many agricultural ecologies in Eurasia and Africa (Fuller 2017). These are commonly adapted to low rainfall regimes, short growing habit and fitted for poor soils too. They serve human being in many ways by providing food as cereals and feed for livestock. They are thus often considering the most reliable cereals and fodders for the many dry and marginal lands. Different kinds of traditional foods and beverages are prepared from these cereals and therefore having potential role for the conservation of indigenous food culture. They have high micronutrient content ie calcium and iron, higher dietary fiber and higher amount of essential amino acids and thus vital role in the food and nutritional security of the poor and marginal ethnic communities.

In spite of those importance, these species are neglected for research and development worldwide and are not getting policy support they need (Mal et al 2010). However, their presence in Nepalese food system had been decreasing due to the other cereal crops like rice, wheat, maize etc. which are getting subsidy directly or indirectly from the government for production. This neglect is resulting further marginalization of the farmers who have been traditionally depending upon these crops for food security and income. But there is increasing demands by the urban residing peoples as favorable food commodities because of their healthy nutrients content and fibers. Thus, apart from the traditional role as staple food for poor and marginalized ethnic communities, they are gaining as new role as crops for healthy food to the high-income urban people.

Methodology

First of all, the desk study and literatures surveyed were done. The collection of primary information and field visits were done in 5 districts namely Baglung, Parbat, Surkhet, Achham and Lalitpur. I have collected the photographs and some herbarium specimens of those plants which couldn't identified in the field. The deposited herbarium specimens were checked in the National Herbarium and Plant Laboratories (KATH), Godawari to identify the collected specimens and photographs. The photographs were taken from the Canon-DSLR Camera and Redmi-9 pro Mobile and later used for the identification. From the field visits and the herbarium study, it cleared about the wild and cultivated species in Nepal. Verma (2019), Doggett (1986), Nagaraja et al (2023) categorized the whole millet species into major millets, minor millets, and pseudo millets but pseudo millets are excluded here. The cultivated and domesticated species are described with distinguishing characters and others wild relatives are enumerated only with scientific names and distributions. The valid names are in bold and italics and the synonyms, if necessary, somewhere are italics only.

Results

Although, taxonomic work was started by Hara et al (1978) but did not treat as millets because it represents the group of taxa. During field visits, literatures survey and herbarium study, altogether 10 genera and 51 species are enumerated (**Table 1**). The taxa which were already in the process of domestication and cultivation mentioned with theirs short notes, distinguishing characters and wild relatives are enumerated alphabetically as follows.

Table 1. List of millets and allies species with their status and distribution in Nepal

SN	Genus	Species	Status	Distribution
1	*Brachiaria* (Trin.) Griseb.	*B. ramosa* (L.) Stapf	Domesticated	
		B. distachya (L.) Stapf	Wild relative	1000-1200 m, CE
		B. kurzii (Hook.f.) A. Camus	Wild relative	150-1000 m, CE
		B. mutica (Forssk.) Stapf	Wild relative	60-200 m, E
		B. reptans (L.) C. A. Gardner & C. E. Hubb.	Wild relative	60-200 m, E
		B. subquadripara (Trin.) Hitche.	Wild relative	200-1400 m, WC
		B. villosa (Lam.) A. Camus	Wild relative	900-2500 m, WCE
2	*Coix* L.	*C. lachryma-jobi* L.	Domesticated	
3	*Dactyloctenium* Willd.	*D. aegypticum* (L.) Willd.	Wild relative	200-1600 m, WCE
4	*Echinochloa* P. Beauv.	*E. crus-galli* subsp. *utilis* (Ohwi & Yabuno) T. Koyama	Domesticated	
		E. colonum subsp. edulis (Honda) Banfi & Galasso	Domesticated	
		E. colona (L.) Link	Wild relative	150-1500 m, WCE
		E. crus-galli (L.) P. Beauv.	Wild relative	500-2400 m, WC
		E. cruspavonis (Kunth) Schult.	Wild relative	60-200 m
		E. picta (J. Koenig) P. W. Michael	Wild relative	60-200 m, WCE
5	*Eleusine* Gaertn.	*E. coracana* (L.) Gaertn.	Cultivated	
		E. *indica* (L.) Gaertn.	Wild relative	600-2600 m, WCE

SN	Genus	Species	Status	Distribution
6	*Panicum* L.	*P. miliaceum* L.	Cultivated	
		P. sumatrense Roth ex Roem. & Schult.	Domesticated	150-1800 m, WCE
		P. antidotale Retz.	Wild relative	150-200 m, W
		P. curviflorum Hornem.	Wild relative	150-800 m, CE
		P. dichotomiflorum Michx.	Wild relative	150-1200 m, WCE
		P. humidorum Buch.-Ham.ex Hook.f.	Wild relative	
		P. humile Nees ex Steud.	Wild relative	150-1300 m, CE
		P. notatum Retz.	Wild relative	150-1800 m, CE
		P. repens L.	Wild relative	150 m, C
7	*Paspalum* L.	*P. scrobiculatum* L.	Domesticated	150-2500 m, WCE
		P. conjugatum P. J. Bergius	Wild relative	150-1000 m, E
		P. dilatatum Poir.	Wild relative	800-1800 m, CE
		P. distichum L.	Wild relative	150-2000 m, WCE
		P. notatum Flugge	Wild relative	1700 m,E
8	*Cenchrus* L.	*C. americanus* (L.) Morrone	Domesticated	
		C. orientale (Rich.) Morrone.	Wild relative	700-2000 m, WC
		C. clandestinum (Hochst. Ex Chiov.) Morrone	Wild relative	1500 m, C
		C. flaccidus (Griseb.) Morrone,	Wild relative	1400-4300 m, WC
		C. hordeoides (Lam.) Morrone	Wild relative	200-350 m, C
		C. pedicellatus (Trin.) Morrone	Wild relative	1050 m, C
		C. purpureus (Schumach.) Morrone	Wild relative	1200-2200 m, C
9	*Setaria* P.Beauv.	*S. italica* (L.) P. Beauv.	Cultivated	
		S. forbesiana (Nees ex Steud.) Hook. f.	Wild relative	1300-2000 m, C
		S. homonyma (Steud.) Chiov.	Wild relative	1000 m, W
		S. intermedia Roth ex Roem. & Schult.	Wild relative	800-1800 m, WCE
		S. palmifolia (J. Koenig) Stapf	Wild relative	200-2800 m, WCE
		S. parviflora (Poir.) M. Kerguelen	Wild relative	150-2500 m, CE
		S. plicata (Lam.) T. Cooke	Wild relative	900-2000 m,CE
		S. pumila (Poir.) Roem. & schult.	Wild relative	150-2100 m,WCE
		S. sphacelata (Schumach.) Stapf & C. E. Hubb. ex-Moss	Wild relative	1700-1800 m, E
		S. verticillata (L.) P. Beauv.	Domesticated	200-900 m, WE
		S. viridis (L.) P.Beauv.	Wild relative	2300-3800 m, WC
10	*Sorghum* (L.) Moench	*S. bicolor* (L.) Moench	Cultivated	
		S. nitidum (Vahl) Pers.	Wild relative	150-200 m, W

1. *Brachiaria* (Trin.) Griseb.

Scientific name: *Brachiaria ramosa* (L.) Stapf
Nepali name: Baanspaate kodo
Common name: Browntop millet
Cultivation status: Domesticated
Distinguishing characters: 30-60 cm tall annual herb, culm tufted, commonly found on grasslands, hill slopes and weedy places. The inflorescences are spreading racemes, leaf blade lanceolate, spikelets in paired, one subsessile and one pedicelled.
Distribution: 100-1800 m in West, Central and Eastern Nepal. Africa, India, Bhutan, Pakistan, China, Thailand, Malaysia, Cambodia, Vietnam.
In Nepal, there are 7 species reported in wild under this genus, except Browntop millet others 6 species ie *B. distachya* (L.) Stapf, *B. kurzii* (Hook.f.) A. Camus, *B. mutica* (Forssk.) Stapf, *B. reptans* (L.) C. A. Gardner & C. E. Hubb., *B. subquadripara* (Trin.) Hitche. and *B. villosa* (Lam.) A. Camus are not at priority for domestication.

2. *Coix* L.

Scientific Name: *Coix lachryma-jobi* L.
Nepali Name: Bhirkaulo
Common Name: Job's tear millet
Cultivation status: Domesticated
Distinguishing characters: upto 3 m tall annual herb commonly found on side of agricultural and marginal lands. The culms are erect, more than 10 noded, branched and robust.
Distribution: 800-2200 m in West, Central and Eastern Nepal. India, Bhutan, Srilanka, China, Myanmar, Thailand, Malaysia, Philippines, Indonesia, New Guinea.

Joshi et al (2023) mentioned *Dactyloctenium aegyptium* (L.) Willd. as wild relative but not domesticated.

3. *Echinochloa* P. Beauv.

Scientific Name: *Echinochloa crus-galli* subsp. *utilis* (Ohwi & Yabuno) T. Koyama
Synonym: *Echinochloa esculenta* (A. Braun) H. Scholz
Nepali Name: Seto saamaa
Common Name: Japanese barnyard millet
Cultivation status: Domesticated
Distinguishing characters: Annual erect herb 1-1.5 m tall. Grains persisting at maturity, spikelets purplish brown when maturity, raceme very dense and closely packed.
Distribution: China South-Central

Scientific Name: *Echinochloa colonum* subsp. edulis (Honda) Banfi & Galasso
Synonym: *Echinochloa frumentacea* Link
Nepali Name: Saamaa
Common Name: Nepalese barnyard millet
Cultivation status: Domesticated
Distinguishing characters: Annual herb, culms erect 1-1.5 m tall, Grains persisting at maturity, spikelets dark greenish when maturity, racemes rather spaced.
Distribution: The native range of this species is cultigen from tropical Africa, widely distributed in India, Central African Repu, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe.

There are 5 species of *Echinochloa* wildly reported from Nepal. Of these, 2 species viz. *E. colona* (L.) Link and *E. crus-galli* (L.) P. Beauv. are reported as wild relatives by Joshi et al (2023). Rest of the two species ie, *E. cruspavonis* (Kunth) Schult., and *E. picta* (J. Koenig) P. W. Michael are not in priority for domestication.

4. *Eleusine* Gaertn.

Scientific Name: *Eleusine coracana* (L.) Gaertn.
Nepali Name: Kodo
Common Name: Finger millet
Cultivation status: Cultivated
Distinguishing characters: Annual or tussocky perennial herb about 50-150 cm tall, racemes stout, incurved and grain globose.
Distribution: Native in Angola, Burkina, Burundi, Cameroon, Central African Repu, Chad, Ethiopia, Nigeria, Rwanda, Socotra, Sudan, Zaire. Cultivated in Nepal from Western to Eastern Nepal upto 2000 m.

Eleusine indica (L.) Gaertn. is reported in Nepal in wild but not yet to be domesticated.

5. *Panicum* L.
Scientific Name: *Panicum miliaceum* L.
Nepali Name: Chino
Common Name: Proso millet
Cultivation status: Cultivated
Distinguishing characters: Annual robust herb 20-150 cm tall, upper floret papillate or smooth, lower glume acuminate to cuspidate, panicles dense and branches drooping.
Distribution: The native range of this species is Indian sub-continent to Myanmar, widely distributed to Bangladesh, East Himalaya, India, Myanmar Maldives, Pakistan, Sri Lanka, West Himalaya.

Scientific Name: *Panicum sumatrense* Roth ex Roem. & Schult.
Nepali Name: Dhaan kodo, Suji kodo
Common Name: Little millet
Cultivation status: Cultivated
Distinguishing characters: Annual erect or decumbent herb 20-60 cm tall, upper floret papillate or smooth, glumes acute to obtuse, panicle branches spreading.
Distribution: 150-1800 m in West, Central and Eastern Nepal. India, Bhutan, Sri Lanka, China Myanmar, Malaysia, Philippines.

Panicum antidotale Retz. is mentioned by Joshi et al (2023) as wild relatives of millet crops. There are others six species of *Panicum* reported in Nepal ie *P. curviflorum* Hornem., *P. dichotomiflorum* Michx., *P. humidorum* Buch.-Ham.ex Hook.f., *P. humile* Nees ex Steud., *P. notatum* Retz. and *P. repens* L. are still waiting for domestication.

6. *Paspalum* L.
Scientific Name: *Paspalum scrobiculatum* L.
Nepali Name: Kodi
Common Name: Kodo millet
Cultivation status: Domesticated
Distinguishing characters: Perennial or annual herb about 30-100 cm tall, culm tufted, erect or decumbent, spikelets, pedicels, nodes, culm apex, leaf blades usually glabrous.
Distribution: 150-2500 m in Western, Central and Eastern Nepal. Pakistan, India, Nepal, Bhutan, China, S. E. Asia, Australia.

There are 4 species of *Paspalum* ie, *P. conjugatum* P. J. Bergius, *P. dilatatum* Poir., *P. distichum* L., and *P. notatum* Flugge reported in Nepal.

7. *Pennisetum* Rich.
Scientific Name: *Cenchrus americanus* (L.) Morrone
Synonym: *Pennisetum glaucum* (L.) R. Br.
Nepali Name: Ghoge
Common Name: Pearl millet
Cultivation status: Domesticated
Distinguishing characters: Annual herb with robust culm up to 3 m tall, inflorescence spike like not winged, upper floret persistent, bristles shorter than spikelet.
Distribution: The native range of this species is Benin to South Tropical Africa namely Angola, Benin, Burkina, Cameroon, Chad, Congo, Gabon, Malawi, Mozambique, Nigeria, Togo, Zambia, Zaire.

Pennisetum orientale Rich. is mentioned by Joshi et al (2023) as wild relatives of millet crops but it is synonymized as *C. orientale* (Rich.) Morrone.

There are six species of *Cenchrus* viz. *C. orientale* (Rich.) Morrone, *C. flaccidus* (Griseb.) Morrone, *C. clandestinum* (Hochst. Ex Chiov.) Morrone, *C. hordeoides* (Lam.) Morrone, *C. pedicellatus* (Trin.) Morrone, *C. purpureus* (Schumach.) Morrone wildly reported in Nepal.

8. *Setaria* P. Beauv.
Scientific Name: *Setaria italica* (L.) P. Beauv.
Nepali Name: Kaaguno
Common Name: Foxtail millet
Cultivation status: Cultivated
Distinguishing characters: Annual herb, culm robust erect up to 150 cm, panicle densely spike like congested branchlets, each branchlet from the main axis with several mature spikelets, upper floret falling free from the glumes.
Distribution: This species is a cultigen and is found in North-Central and South-Eastern China.

There are eleven species of *Setaria* viz. *S. forbesiana* (Nees ex Steud.) Hook. f., *S. homonyma* (Steud.) *Chiov., S. intermedia* Roth ex Roem. & Schult.*, S. palmifolia* (J. Koenig) Stapf*, S. parviflora* (Poir.) M. Kerguelen*, S. plicata* (Lam.) T. Cooke, *S. pumila* (Poir.) Roem. & Schult., *S. sphacelata* (Schumach.) Stapf & C. E. Hubb. ex-Moss, *S. verticillata* (L.) P. Beauv., *S. viridis* (L.) P. Beauv. *reported in Nepal.*

9. *Sorghum* (L.) Moench
Scientific Name: *Sorghum bicolor* (L.) Moench
Nepali Name: Junelo
Common Name: Sorghum
Cultivation status: Domesticated
Distinguishing characters: Annual robust herb 3-5 m tall, nodes of culm glabrous or shortly pubescent, panicle branches subdivided, plants without rhizomes, racemes tough at maturity.
Distribution: The native range of this species is Africa, Indian sub-continent, widely distributed in Angola, Benin, Botswana, Burkina, Burundi, Cameroon, Cape Provinces, Cape Verde, Central African Repu, Chad, Congo, East Himalaya, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, India, Ivory Coast, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Tanzania, Uganda, West Himalaya, Zambia, Zaire, Zimbabwe.

There is one species of *Sorghum* viz. *S. nitidum* (Vahl) Pers. reported from Nepal.

Conclusion

Altogether 10 genera (*Brachiaria, Coix, Dactyloctenium, Digitaria, Echinochloa, Eleusine, Panicum, Paspalum, Pennisetum* and *Sorghum*) and 51 species are documented from this study. This study mainly based on the secondary literatures and herbarium specimens, although few districts were surveyed for the primary source of information. As millets are the most neglected crops by the government and policy they need, in spite of the essential crops for the better health and forage supplement. Identification and documentation of the wild ancestors of crops is essential for understanding their evolutionary history, including during and after domestication changes (Hammer 1984, Vaughan et al 2007). Because of their complete scientific neglect, the potential of these crops for food and agriculture is not adequately exploited for improvement. So, detail field survey, collections and maintenance of all millet and wild relatives is recommended for the concerned government organizations. Fonio millets (*Digitaria exilis, D. iburua*) are used as the important indigenous cereal crops that greatly contribute to household food security in semi-arid and sub-humid drought-prone areas of West-Africa. So, eleven species of *Digitaria* are considered here for the wild relatives of the fonio millets.

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Millet Genetic Resources and Diversity in Nepal

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Summary

Nepal boasts a rich repository of millet genetic resources and diversity, marked by a high degree of variation within the millet species. However, despite this wealth of diversity, there has been a historical underutilization of these resources in research, education, and extension activities. Formal research efforts in millet, particularly finger millet, only commenced in 1986. Within Nepal, there are a total of 22 millet species, with 12 currently under cultivation. Among these, 10 species are primarily cultivated for grain production, while the remaining 10 wild and 2 cultivated species serve as valuable resources for livestock. The country holds an impressive collection of 1100 millet accessions, each possessing unique characteristics. In addition, there are eight varieties of millets (six of finger millet and one each of foxtail millet, and proso millet) that have been officially recognized in the national list, showcasing the diversity present at various levels, including ecosystems, species, cultivars, genotypes, and alleles. Diversity within and among millet species extends across functional traits, agro-morphological traits, molecular markers, use value, and the nutritional content of food, feed, and nutrients. This wealth of diversity allows millet species to be grouped into different categories based on their distinct features. Furthermore, millet species and landraces in Nepal have demonstrated resilience to various climate conditions and can thrive even in marginalized lands with minimal inputs. This characteristic feature makes them a crucial resource for sustainable agriculture. To fully harness this genetic diversity, it is imperative to focus on developing location-specific millet varieties. By leveraging the varied traits and adaptability of these millets, Nepal can enhance food security, promote climate-smart agriculture, and contribute to sustainable farming practices.

Keywords: Genetic diversity, genetic erosion, genetic resource, grouping millets, landrace, millets

Introduction (Millets and Diversity)

Millets are a diverse group of small-seeded grasses cultivated globally for their grains and straw, serving as both fodder and human food. Remarkably, approximately 90% of the world's millet production is consumed in developing countries, highlighting the crucial role these hardy and nutritious crops play in the food security and livelihoods of populations in these regions. Millet genetic diversity in Nepal is a vital component of the country's agricultural landscape. Nepal's diverse topography, ranging from the Tarai plains to the mountainous regions, offers a wide range of agroecological zones, each with its own set of millet varieties adapted to local conditions. Farmers have cultivated indigenous millet varieties for generations, resulting in a rich reservoir of genetic resources. These local varieties often possess unique traits like disease resistance (Ghimire et al 2022, Gurung et al 2020) and drought tolerance (Ghimire et al 2023), contributing significantly to sustainable agriculture and food security, especially in challenging terrains.

Efforts led by institutions like the Nepal Agricultural Research Council (NARC) focus on the conservation and enhancement of millet genetic diversity. These initiatives involve seed banks, research, and participatory plant breeding programs that engage local communities in selecting and breeding millet varieties tailored to their preferences and climate conditions. Traditional knowledge from indigenous communities also plays a pivotal role in the conservation and sustainable utilization of millet genetic resources. In the face of climate change, maintaining and enhancing millet diversity is critical for the resilience and food security of the country, as certain millet varieties exhibit greater adaptability to shifting weather patterns. Efforts to promote millet consumption and expand market access for millet-based products further encourage farmers to conserve diverse millet varieties, ensuring their continued importance in Nepal's agriculture. Among the different actions on millets (**Table 1**), research in finger millet and sorghum was stated from 1971 (**Table 1**). Lohani (1981) has described about finger millet, sorghum, proso millet, and foxtail millet.

Nepal boasts an impressive diversity of around 22 species of millets, reflecting the country's rich agricultural heritage. Among these, finger millet stands out as the fourth most significant crop in terms of production and cultivated area. Known locally as "Ku-anna" (where "Ku" denotes fermentation or bad), finger millets in Nepal are experiencing a resurgence in popularity and are increasingly referred to as "Su-anna," (where “Su” denotes good) signifying their status as a superfood. These resilient grains are cultivated across a wide altitudinal range, from the low-lying Tarai region to the lofty high hills, spanning all 77 districts of Nepal. Notably, millets are grown organically in Nepal, with minimal to zero pesticide use and limited inputs, making them a sustainable choice for marginalized lands. Their adaptability and hardiness shine through when other crops fail, providing a dependable source of food in times of need and showcasing the invaluable role of millets in Nepal's agricultural landscape.

Millets serve as multifaceted grains, contributing to various aspects of life, including food security, animal feed, nutrition, public health, entrepreneurship, and environmental sustainability (Devi et al l2011, Saleh et al 2013, Shahidi and Chandrasekara 2013). Particularly crucial for impoverished and marginalized populations, millets are a staple food source, playing a pivotal role in mitigating hunger and malnutrition. Their status as one of the world's primary drought-resistant crops, ranking as the sixth most significant cereal crop in global agriculture production, underscores their resilience in challenging growing conditions. However, it is worth noting that millet cultivation demands substantial labor involvement, encompassing tasks such as transplanting, weeding, harvesting, and threshing. This labor-intensive process has given rise to a rich diversity of millet landraces at both species and genetic levels, shaped by centuries of cultivation in diverse locales, reflecting the adaptability and specificity of these grains to local environments.

Table 1. Research and conservation history on millet genetic resources in Nepal

SN	Milestone	Year	Target crop	Remarks
1	Research initiation	1971	Finger millet, Sorghum	In Khumaltar and Banke
2	Introduction	1971	Sorghum	ICRISAT
3	Introduction of germplasm	1971	Finger millet	From India
4	First millet breeding	1971	Finger millet	Shiva Nath Lohani
5	Evaluation of germplasm	1978	Proso millet	In Jumla

SN	Milestone	Year	Target crop	Remarks
6	Variety released	1980	Finger millet	Okhale-1 from Nepal origin and Dalle-1 from India origin
7	Collection and conservation	1984	Finger millet	From western Nepal
8	HCRP establishment	1986	Finger millet	Research program for hill crops
9	Characterization	1986	Finger millet	By HCRP, Kabre, Dolakha
10	Evaluation	1986	Finger millet	By HCRP, Kabre, Dolakha
11	Diversity assessment (agro-morpho based)	1986	Finger millet	By HCRP, Kabre, Dolakha
12	Millet as NUS (neglected and underutilized species)	1991	Finger millet and proso millet	Supported by IPGRI
13	Millet expert	1992	Millet species	Bimal Kumar Baniya
14	In-situ conservation	1997	Finger millet	In Bara, Kaski and Jumla
15	On-farm trial	1997	Finger millet	In Bara, Kaski and Jumla
16	Diversity block	2003	Finger millet	In Kaski, Bara and Jumla
17	Nutrition analysis	2005	Finger millet	Nutrient values explored
18	Product diversification	2005	Cookies	Made from finger millet
19	Safety backup	2012	Finger millet	ICRISAT
20	Use of DNA marker	2013	Finger millet	Diversity assessed and finger print developed along with conservation in DNA bank
21	Conservation Biotechnology	2013	Finger millet	Conserved in DNA bank
22	On-farm conservation	2014	Finger millet, proso millet and foxtail millet	In Jumla, Humla, Lamjung and Dolakha
23	Conservation breeding	2014	Finger millet, proso millet and foxtail millet	In Jumla, Humla, Lamjung and Dolakha
24	Diversity assessment (DNA based)	2020	Finger millet	RAPD and SSR markers
25	Landrace registration	2021	Finger millet, proso millet and foxtail millet	From Jumla, Humla and Lamjung
26	Agro gene sanctuary with millet species	2022	Finger millet, proso millet, foxtail millet, sorghum, wild millet	Khumaltar

Source: Bimal Kumar Baniya 2023, personal communication, Lohani 1981, Upadhyay and Joshi 2003, Joshi et al 2023b, Saud 2009, Tiwari et al 2003, Baniya et al 1992

Millets' Specialties

Millet crops possess several special qualities and attributes, making them a unique and valuable group of grains. Millet has resistance to pests and diseases, short growing season, and high productivity under drought conditions, compared to major cereals (Devi et al 2011). These special qualities make millets a valuable resource for addressing food security and dietary needs in various parts of the world. These specialties are:

1. **Emergency Crops:** Millets can serve as emergency crops due to their ability to grow quickly and tolerate various environmental conditions. In times of food shortages or crises, millets can be relied upon for their fast growth and resilience.

2. **Easy to Grow and Long Storability:** Millets are relatively easy to cultivate, making them accessible to a wide range of farmers. Additionally, they have good storability, allowing them to be stored for extended periods without significant quality loss.
3. **Rooted in Ancient Cultures and Traditions:** Millets have a rich history deeply intertwined with ancient cultures and traditions, especially in regions like Africa and Asia. They have been staple foods for centuries and hold cultural significance in many communities.
4. **Nurture Soils and Ecosystems and Boost Biodiversity:** Millets are known for their positive impact on soil health and ecosystems. They require fewer inputs and can grow in marginal soils, reducing the need for intensive agricultural practices. Their cultivation can also promote biodiversity.
5. **C4 Plants:** Millets are classified as C4 plants, which means they are more efficient at photosynthesis and can thrive in environments with high temperatures and low water availability, making them well-suited for diverse climates.
6. **Climate-Smart Crop:** Millets are considered a climate-smart crop because of their adaptability to a wide range of environmental conditions. They can thrive in both dry and hot climates, which is crucial in the face of climate change.
7. **Hardy Crop with High Buffering Capacity:** Millets are hardy and can withstand various environmental stresses, including drought. They have a high buffering capacity, meaning they can tolerate fluctuations in temperature and precipitation.
8. **Tolerant and Resistant to Stresses:** Millets exhibit resilience to both abiotic (e.g., drought) and biotic (e.g., pests and diseases) stress factors, making them a dependable food source even in challenging conditions.
9. **Nutrition-Dense and Health-Benefited Crops:** Millets are considered "nutri-cereals" because they are rich in essential nutrients. They offer a nutritious and delicious option for a balanced diet and have a high health index. Millets are staple food substitutes for celiac patients as they are gluten-free (Shahidi and Chandrasekara 2013).
10. **Nutritious Feed:** Millets can also be used as nutritious feed for livestock, contributing to animal health and productivity.
11. **Lectin and Gluten-Free:** Millets are naturally free from lectin and gluten, making them suitable for individuals with dietary restrictions or conditions like celiac disease.
12. **Low Glycemic Index:** Millets have a low glycemic index, which means they have a minimal impact on 12. blood sugar levels. This property makes them a favorable choice for individuals with diabetes or those looking to manage their blood sugar.

Grouping Millets

Millet crops are a diverse group of small-seeded, annual cereal grains that have been cultivated for thousands of years across various regions of the world. They are valued for their resilience, nutritional content, and adaptability to different environmental conditions. Millets can be classified based on several criteria, including botanical characteristics, nutritional composition, geographical distribution, and culinary uses.

1. **Botanical Classification:** Millet crops belong to the Poaceae family and are further classified into three tribes:
   - Andropogoneae: Sorghum
   - Paniceae: Proso, foxtail, brown top, pearl, Kodo, little, barnyard
   - Eragrostideae: Finger millet

2. **Geographical Distribution:** Millet crops are grown in various regions of the world, and they are often classified based on their primary cultivation areas:
   - African Millets: This category includes crops like pearl millet and finger millet, which are staple foods in many parts of Africa.
   - Asian Millets: Millets such as foxtail millet, proso millet, and barnyard millet are commonly grown in Asia, particularly in India, China, and Southeast Asia.
   - American Millets: These are lesser-known millets and include species like chilean millet (Stipa neesiana) and goosegrass (*Eleusine indica*), primarily found in the Americas.

3. **Nutritional Composition:** Millets can be classified based on their nutritional profiles, which vary slightly between different types:
   - High-Protein Millets: Some millets, like finger millet, have higher protein content compared to others.
   - Gluten-Free Millets: All millets are naturally gluten-free, making them suitable for those with gluten intolerance or celiac disease.
   - High Fiber Millets: Pearl millet and sorghum are examples of millets with significant dietary fiber content.

4. **Culinary Uses:** Millets have diverse culinary applications, leading to their categorization based on their use:
   - Staple Millets: Pearl millet, finger millet, and sorghum are often staples in various cuisines, used for making flatbreads, porridges, and more.
   - Baking Millets: Foxtail millet and proso millet can be ground into flour and used for making baked goods like bread, muffins, and cookies.
   - Brewing Millets: Certain millets, like pearl millet, are used in traditional beer brewing in some cultures.
   - Animal Feed Millets: Some millet varieties, such as proso millet, are primarily grown as animal feed.

5. **Adaptation to Environmental Conditions:** Millets are classified based on their adaptability to different ecological zones:
   - Drought-Tolerant Millets: Pearl millet and sorghum are renowned for their ability to thrive in arid and semi-arid regions.
   - High-Altitude Millets: Finger millet is well-suited to high-altitude regions and is grown in parts of Africa and Asia with varying altitudes.

In addition to these, millet crops can be classified based on different characteristics as given below.

A. **Based on grain size**
   - Large millets (major): Sorghum, pearl
   - Small (minor) millets: Finger, little, foxtail, proso, barnyard, kodo

B. **Based on husk**
   - Major (naked) millets: Pearl, sorghum, finger
   - Minor (husked) millets: Foxtail, little, kodo, barnyard, browntop, proso

C. **Based on area and production**
   - Major (primary) millets: Finger, sorghum, foxtail, proso
   - Minor (secondary) millets: Little, barnyard, kodo, browntop

D. Based on national list
- Farmer's varieties: Dalle kodo, Kaalo kodo, Seto kodo, Raato kaguno, Raato chino
- Registered native landraces: Rato kodo, Dudhe chino, Bariyo kaaguno
- Released native varieties: Kabre kodo-1, Okhale-1
- Released exotic varieties: Dalle-1, Kabre kodo-2, Sailung kodo-1

E. Based on health benefit
- Neutral millets: Pearl, finger, proso, sorghum
- Positive millets: Foxtail, barnyard, browntop, kodo, little

F. Based on conservation status (population size and distribution, red list)
- Common: Finger, sorghum, proso, foxtail
- Rare, endangered: Little, kodo, pearl, barnyard

G. Based on adaptation
- High hill (mountain) millets: Proso, foxtail, finger, little millet
- Mid Hill (hill) millets: Finger millet, foxtail millet, sorghum
- Tarai (low land) millets: Finger millet, sorghum, kodo, pearl

H. Based on domestication
- Domesticated: Finger, sorghum, proso, foxtail, pearl, little
- Wild: Goose grass, Johnson grass, wild pearl

Cultivated and Wild Millet Species

Cultivated millet species in Nepal are essential components of the country's agricultural landscape. Among the 12 cultivated millet species (**Table 2A**), some, like finger millet, sorghum, foxtail millet, and proso millet, hold significant importance as staple food crops. They are cultivated primarily for their grains, which serve as a vital source of nutrition for Nepalese communities. Additionally, the straw and stalk of these cultivated millets find utility as animal feed, sustaining livestock, and as a source of fuel for cooking and heating. The remarkable diversity of landraces within these crops, such as the approximately 700 landraces of finger millet, reflects the country's rich agricultural heritage and the adaptability of these crops to various ecological niches in Nepal. These cultivated millet species not only contribute to food security but also play a crucial role in supporting rural livelihoods and promoting sustainable farming practices.

In contrast, the wild relatives of millet species in Nepal serve a different ecological and agricultural purpose. Among the 10 wild millet species (**Table 2B**), goose grass (*Eleusine indica*) stands out as a common and widespread forage crop. These wild relatives are typically used for forage, providing essential nutrition to livestock during the summer months. Nepal's diverse geography and climate conditions have given rise to various forms of goose grass, highlighting the adaptability of this wild millet species to different environments. While wild millet species do not directly contribute to human food security, they play a vital role in supporting animal agriculture and maintaining ecological balance, ensuring the availability of forage for livestock across the country. There might be other many millet species in the country and further study is needed to explore the species diversity and their use values.

Table 2. List of millet species in Nepal

A. Cultivated species (either for grain or forage or both purposes)

SN	Common crop	नेपाली नाम	Scientific name	Landraces, n	Origin	Season
1	Bristly foxtail millet	झुसे कागुनो घाँस	*Setaria verticillata* (L.) P.Beauv.	10	Native	Summer
2	Browntop millet, Dixie Signal grass	बाँसपाते कोदो	*Brachiaria ramosa* (L.) Stapf	5	Native	Summer
3	Finger millet, African millet, bird's foot	कोदो	*Eleusine coracana* Gaertn.	700	Native	Summer
4	Foxtail millet, Italian millet	कागुनो, काउनो	*Setaria italica* (L.) Beauv.	150	Native	Summer
5	Japanese barnyard millet, Japanese millet	सेतो सामा	*Echinochloa esculenta* (A.Braun) H.Scholz	10	Native	Summer
6	Job's tear millet, bodhi bead, six millet, pearl rice	भिर्कौलो, जोगी माला	*Coix lachryma-jobi* L.	10	Native	Summer
7	Kodo millet, Ditch millet, water couch, creeping paspalum	कोदी	*Paspalum scrobiculatum* L.	15	Native	Summer
8	Little millet, Blue panic	धानकोदो, सुजीकोदो, कुट्की	*Panicum sumatrense* Roth.	15	Native	Summer
9	Nepalese barnyard millet, Billion dollar grass, Indian barnyard millet	सामा, नेपाली सामा, साँवा	*Echinochloa frumentacea* Link	15	Native	Summer
10	Pearl millet, cattail, candlestick, Bulrush	घोगे, बाज्रा	*Pennisetum glaucum* (L.) R.Br.	25	Native	Summer
11	Proso millet, Common, hog, broomcorn	चिनो	*Panicum miliaceum* L.	75	Native	Summer
12	Sorghum, Great millet, Guinea corn	जुनेलो, ज्वार, जुनेलो मकै	*Sorghum bicolor* (L.) Moench.	70	Native	Summer

B. Wild relatives of millet crops in Nepal

SN	Common crop	नेपाली नाम	Scientific name	Habitat	Season
1	African goose grass	अफ्रिकन कोदे झार	*Eleusine africana* Kenn. O'Byrne	Semi domesticated	Summer
2	Awnless barnyard grass, Jungle rice	बन्सो, सामा घाँस	*Echinochloa colona* (L.) Link	Wild	Summer
3	Barnyard grass	टुँडे सामा, सामा	*Echinochloa crus-galli* (L.) P.Beauv.	Wild	Summer
4	Crowfoot grass	काग खुट्टे झार/ घाँस	*Eleusine aegyptiaca* (L.) Desf.	Wild	Summer
5	Goose grass (wild finger millet)	कोदे झार, दांदे	*Eleusine indica* (L.) Gaertn.	Semi domesticated	Summer
6	Johnson grass	जंगली जुनेलो	*Sorghum miliaceum* (Roxb.) Snowden	Wild	Summer

SN	Common crop	नेपाली नाम	Scientific name	Habitat	Season
7	Wild pearl millet, oriental fountain grass	बन घोगे	*Pennisetum orientale* Rich.	Wild	Summer
8	Wild foxtail millet, Garden bristle-grass	कनिके कागुनो, जंगली कागुनो	*Setaria pallide-fusca* (Schumach.) Stapf & C.E. Hubb.	Wild	Summer
9	Wild proso millet, Blue panic grass	जंगली चिनो	*Panicum antidotale* Retz.	Wild	Summer
10	Wild sorghum, wild red sorghum	जंगली जुनेलो, जंगली रातो जुनेलो	*Sorghum nitidum* (Vahl) Pers	Wild	Summer

Source: Joshi et al 2022, 2023b, 2023c, Upadhyay and Joshi 2003, Saud 2009, Ghimire et al 2017, Lohani 1981, Baniya et al 1992

Millet Biodiversity Measurement

Agrobiodiversity statistics, often referred to as agro-statistics, offer a comprehensive framework for assessing millet biodiversity by employing a variety of indices and measures. These indices operate at multiple scales, ranging from the household and community levels to broader geographic units like municipalities, districts, provinces, and entire countries. They encompass a wide array of dimensions, including diversity measures related to crops, species, and landraces, as well as agro-morphological and nutritional traits and use values. Some key indices used for measuring millet biodiversity include species richness, landrace richness, and varietal richness, each providing insights into the diversity of millet varieties. Additionally, household diversity scores and indices, as well as village/site/district diversity scores and indices, offer a nuanced understanding of millet diversity at various geographic and social levels, contributing to more effective strategies for conservation and sustainable utilization of this invaluable genetic resource.

Millet biodiversity can be effectively assessed through a multidimensional approach, encompassing five distinct levels and five diverse types of measures, as illustrated in **Figure 1**. Among these measures, the most commonly employed include quantifying the number of millet species, landraces, and assessing their agro-morphological and molecular traits. This comprehensive evaluation framework enables a thorough understanding of millet genetic resources and their potential for conservation, breeding, and sustainable utilization, promoting their crucial role in global food security and agricultural resilience.

Data for agrobiodiversity statistics are gathered through various means, including on-station and on-farm experiments, as well as laboratory research and surveys. Within the realm of millet diversity, finger millet emerges as a focal point, displaying notable richness in genetic resources, followed closely by sorghum, foxtail millet, and proso millet. While finger millet and its wild counterparts, like goosegrass, receive considerable attention, certain millets, such as browntop, barnyard, little millet, kodo millet, job's tear, and bristly foxtail millet, remain relatively understudied, highlighting opportunities for further research and conservation efforts to unlock the potential of these less-explored but invaluable genetic resources.

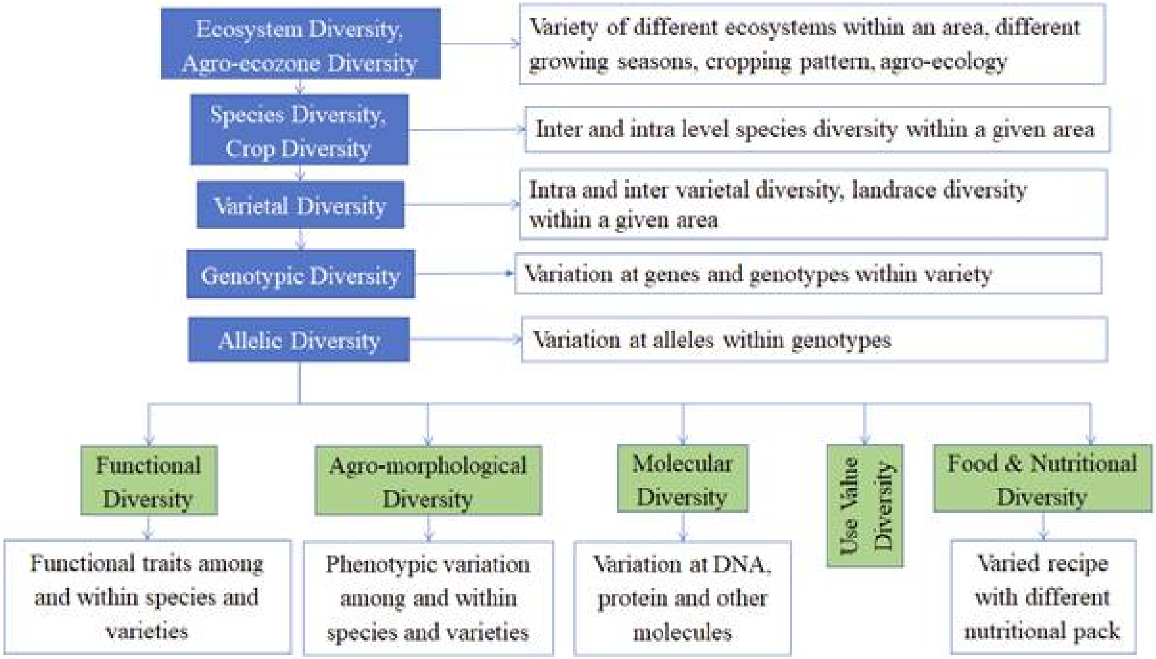

Figure 1. Levels and types of millet biodiversity
Source: Joshi et al 2023a

Millet Crops, Species and Cultivars

Nepal boasts an impressive diversity of millet crops, with a total of 22 different species. Among these, 12 are actively cultivated, demonstrating the significance of millet in the country's agricultural landscape. What's truly remarkable is the vast collection of approximately 1100 landraces belonging to these 12 millet crops (all are annual), signifying the rich genetic heritage and adaptability of these grains (**Table 3**).

Over the years, Nepal has made strides in millet research and development, resulting in the release of six distinct varieties of finger millet (**Table 3**). Among these, one exceptional landrace has earned its place on the national list, highlighting its unique characteristics and importance. The pioneering release of a finger millet variety dates back to 1980, marking a pivotal moment in the promotion of millet cultivation in Nepal. In recent times, Nepal has continued to expand its millet diversity with the registration of two notable landraces, one each of foxtail millet and proso millet. This demonstrates the country's commitment to preserving and promoting its rich millet heritage.

Millet crops find their place across all districts of Nepal, but their prevalence is particularly pronounced in the Karnali Province. This wide distribution underscores their significance in the local diet and agricultural practices. Additionally, millets in Nepal serve a multitude of purposes, each with its own unique set of values, making them an integral part of the country's cultural and culinary heritage. Farmers have maintained very unique landraces (**Table 4**). Very important millets are also called 7-brother millets (foxtail, finger, proso, barnyard, sorghum, pearl, and little), which are smart in terms of nutrition value, environment resilient, hardiness, and food value.

Table 3. List of landraces of different millet species

SN	Common crop	नेपाली नाम	R&R variety (Yr)	Landrace
1	Japanese barnyard millet	सेतो सामा	x	Seto saamaa, Raato saamaa
2	Nepalese barnyard millet	सामा	x	Raato saamaa
3	Bristly foxtail millet	झुसे कागुनो घाँस	x	Jhuse kaaguno ghaans, Kukur banso
4	Browntop millet	बाँसपाते कोदो	X	Baaspaate kodo
5	Finger millet	कोदो	Raato kodo (2021), Kabre kodo-1 (1990), Okhale-1 (1980), Dalle-1 (1980), Kabre kodo-2 (2015), Shailung kodo-1 (2015)	Dalle, Jhapre, Chulthe, Laribari, Paaundure, Thulo, Saano, Lurke, Laarfre, Nangre, Nangkatuwa, Matyangre, Laampaate, Asoje, Kaattike, Mudke, Mangsire, Temase, Chaumaase, Lekaali, Pahenli, Raato, Kaalo, Seto, Dudhe, Jwain, Samdhi, Bhanchuwa, Chyalthe, Jhope, Taauke, Bhotaange, Okhale, Sailunge, Saangle, Barkhe, Kegro, Chhangre, Jhype, Khro, Lamsare, Ustali, Lahare, Ankhule/Aunle, Lapche, Latte, Ryaule, Tyase, Murali
6	Foxtail millet	कागुनो	Bariyo kaaguno (2021)	Kalo kaguno, Seto kaguno, Pahenlo kaguno, Rato kaguno, Maal kaguno, Bariyo, Aulel, Ande kaguno, Tinmase kaguno, Parbeli, Nabo, Lude
7	Job's tear millet	भिर्कौलो	X	Bhirkaaulo
8	Kodo millet	कोदी	X	Kodi
9	Little millet	धानकोदो, सुजीकोदो, कुट्की	X	Dhaan kodo, Suji kodo, Kutki
10	Pearl millet	घोगे, बाज्रा	X	Ghoge, Baajraa
11	Proso millet	चिनो	Dhude chino (2021)	Kaalo chino, Seto chino, Dudhe chino, Raato chino, Haade chino, Kaptede, Katibade, Kolte chino, Batale chino
12	Sorghum	जुनेलो	X	Junelo, Gaazali junelo, Raato junelo, Seto junelo, Laamo junelo

Yr, Year in parenthesis is released or registered year

Source: Joshi and Joshi 2002, Upadhyay and Joshi 2003, Joshi et al 2005a, 2023b, 2022, 2017, 2020b, 2019, Ghimire et al 2017, Gurung et al 2016, 2019, Palikhey et al 2016, Parajuli et al 2016, Pudasaini et al 2016

Table 4. Important and unique landraces of millet species

SN	Crop	Landrace	Important traits	Remarks
1	Finger millet	Muna	Good for low blood pressure, for women after child birth, for animal during diarrhoea	Bara
		Jhalariya	Good for haluwa and bread	Bara
		Muturiya	Small grain and good taste	Bara
		Jhyape	Early maturity, tasty, easy to thresh	Kaski
		Dalle	Tall and compact head, with small grain	Kaski
		Samdhi kodo	White grain, white and tasty flour	Kaski
		Murli kodo	Medicinal value, easy to harvest	Jumla
		Dabli Kodo	Good taste, black seed, black cooked flour	Jumla
		Ryaule kodyaa	Early maturing, tasty, high Yielding	Humla
		Paaundure kodo (Bharse kodo)	Good in back pain, good for spring cultivation, drought tolerant, medicinal value and use during stomach problem due to eating maize as Bhaat	Rarely found in low hills, Lamjung

SN	Crop	Landrace	Important traits	Remarks
2		Pushe kodo	Suitable in cold areas, low land, high fertile areas	Lamjung
		Mangsire kodo	Suitable in dry and upland and marginalized areas	Lamjung
		Raato kodo	Red grains, adapted to high altitudes	Jumla
		Asoje kodo	High yielding and early maturing	Eastern mid hills
		Nangkatuwaa	High yielding, easy harvesting with nails (nangkatuwaa)	Central and western mid hills
		Nagre	Big ear size, easy to harvest	Dolakha
		Ladibadi	Early maturing, easy to harvest, threshing and processing and high production	Dolakha
3	Foxtail millet	Seto kaaguno	Large and attractive panicle, drought tolerant, non-lodging and eld resistant to blast	Lamjung
		Kalo kaaguno	Attractive panicle, medicinal value, dark brown, drought tolerant, resistant to blast	Humla
		Bariyo kaaguno	Less shattering, early maturing, high yielding, pudding very tasty	Lamjung
		Maal kaaguno	Medicinal value, good for lactating animals, effective in mastitis control	Gorkha
		Aulel	Early maturity, typical finger-like branching on the tip of panicle	Jumla
		Pahenlo	Yellow panicle and drought tolerant	Humla
4	Proso millet	Dudhe chino	Long and attractive light brown panicle, white grains, drought tolerant, non-lodging, field resistant to blast	Humla
		Haade chino	Larger panicle and grain size, yellowish orange grains, better for roasting and high yield	Jumla, Humla
		Kaptede chino	Nutritious, early maturing, easy to mill, panicle color white and red, grains are half red and half white	Humla
5	Pearl millet	Ghoge	Bristly heads, used for animal feed and fermentation	Nuwakot
6	Little millet	Dhaankodo	Small oval seeds with shiny brown colours, drought tolerant	Tanahun, Dhading, Chitwan, Gorkha
7	Nepalese barnyard millet	Saamaa	Considered as holy grains, consumed in fasting, difficult for processing	Gorkha
8	Sorghum	Rato junelo	Red color, tasty and high popping	Western Nepal
		Gazali	Large seeded, easy to harvest, tall	Western Nepal

Source: Joshi and Joshi 2002, Upadhyay and Joshi 2003, Joshi et al 2005a, 2023b, 2022, 2017, 2020b, 2019, Ghimire et al 2017, Gurung et al 2016, 2019, Palikhey et al 2016, Parajuli et al 2016, Pudasaini et al 2016

Bristly foxtail millet (*Setaria verticillata*)

Setaria verticillata, commonly referred to as hooked bristlegrass, rough bristle-grass, and bristly foxtail, is a grass species originally native to Europe. However, it has become widely distributed across continents as an introduced species and is frequently considered an invasive weed. This hardy bunchgrass exhibits adaptability, thriving in various urban, cultivated, and disturbed environments. It has gained notoriety as a weed in numerous agricultural crops, including vineyards and fields, with some strains showing resistance to herbicides.

This annual grass presents decumbent or erect stems, reaching lengths of up to one meter. Its leaf blades can extend up to 25 centimeters and envelop the stem with a long sheath. The inflorescence takes the form of a compact panicle, measuring up to 15 centimeters in length, tapering at both ends. Within this structure, numerous small spikelets and bristles are found. Notably, these bristles feature minuscule barbs pointing backward, aiding in their attachment to clothing or animal fur, facilitating their dispersion. The seeds of this grass serve multiple purposes, including their use in beer production and as a famine food ingredient in porridge.

Browntop millet (*Brachiaria ramose*)

Brachiaria ramosa, known as browntop millet, is an annual millet grass belonging to the Poaceae family. It originates from South Asia, where it has a traditional history of cultivation as a cereal crop. This millet, also referred to as dixie signalgrass, has its roots in South East Asia. Browntop millet serves various purposes, including its role as a wildlife attractant for activities like dove fields, erosion control, straw production, and forage production. Given its versatile applications, many agricultural supply stores offer different varieties of browntop millet, occasionally using it for grazing or hay production. Typically, browntop millet attains a height of 2 to 5 feet and yields only 60 to 70% of the dry matter produced by pearl millet (Anuradha et al 2020). It can be sown from mid-April to mid-August in most regions, but later plantings tend to result in reduced yields.

It's worth noting that browntop millet is a crop that accumulates nitrates, which can lead to toxic or even lethal nitrate concentrations, particularly in livestock. Due to this nitrate accumulation and its relatively low yield potential, planting browntop millet is not advisable in anticipation of drought conditions or when drought is forecasted. Additionally, browntop millet is proficient at reseeding itself, with viable seeds persisting in the soil for many years.

Finger millet (*Eleusine coracana*)

Finger millet, scientifically known as *Eleusine coracana*, is a cereal grass highly valued for its grain, which serves as a staple food in numerous African and South Asian nations. This robust and tufted annual grass can reach heights of up to 170 cm, featuring slender, erect stems that root at their lower nodes. The plant's shallow but sturdy fibrous root system makes it resistant to uprooting. The stems and leaves are typically green, with leaves extending up to 75 cm in length and 2 cm in width. The plant's inflorescence takes the form of a panicle bearing 4-19 finger-like spikes, which, when mature, give the plant its distinctive name of finger millet. Each spike can carry up to 70 alternate spikelets, containing 4 to 7 small seeds (Ghimire et al 2017).

Beyond its role as a grain crop, finger millet is cultivated as a valuable fodder grass in various regions, including India, the USA, and Ireland. It is a versatile forage, providing excellent hay and green feed for livestock such as cattle, sheep, and goats. Moreover, the straw obtained after grain harvest is highly valuable and can either be directly grazed by animals or incorporated into cut-and-carry feeding systems. In some parts of Africa, finger millet straw finds use in making strings and thatching materials.

Finger millet's history is rich, believed to have been domesticated during the onset of the Iron Age in Africa. It was later introduced to India around 3000 years ago before spreading to South-East Asia. This adaptable crop can be found in a range of environments, including disturbed areas, roadsides, and riverbanks. It thrives at altitudes between 1000 and 2000 m in Eastern and Southern Africa, reaching as high as 2500-3000 m in the Himalayas. Finger millet prefers average temperatures around 23°C but can withstand both cooler and hotter conditions. Adequate, well-distributed rainfall between 500 to 1000 mm during the growing season is suitable for its growth, making it a resilient crop in various climates. While it can tolerate drier conditions, finger millet is less favored in areas with heavy rains. It is also intolerant of flooding but can withstand some waterlogging. Soil-wise, finger millet is adaptable, though it thrives best in fertile, well-drained sandy to sandy loam soils with a pH range of 5 to 7. This crop, with its strong tillering and root development from lower nodes, contributes to soil erosion control and can be employed in zero-tillage crop/livestock systems for green chop forage, silage, grazing, or as a cover crop.

Foxtail millet (*Setaria italica*)

Foxtail millet, scientifically known as *Setaria italica* (formerly Panicum italicum L.), is an annual grass cultivated for human consumption. Among millet species, it holds the second-largest planting area globally and is the most widely grown millet type in Asia. The earliest traces of foxtail millet cultivation date back to approximately 8,000 years ago, as evidenced along the ancient course of the Yellow River in Cishan, China. This crop also has a longstanding history of cultivation in Nepal. It goes by various names, including dwarf setaria, foxtail bristle-grass, giant setaria, green foxtail, Italian millet, German millet, and Hungarian millet.

Foxtail millet is characterized as an annual grass featuring slender, upright, leafy stems that can attain heights ranging from 120 to 200 cm (3 ft 11 in – 6 ft 7 in). The seedhead forms a dense, hairy panicle measuring 5 to 30 cm (2 in – 1 ft 0 in) in length. The small seeds, approximately 2 millimeters (3⁄32 in) in diameter, are enclosed within a thin, papery hull that can be easily removed during threshing (Ghimire et al 2018b). The seed color can vary significantly among different varieties. Foxtail millet remains a significant crop in arid and semi-arid regions, serving as a staple food source in many areas. It is a warm-season crop typically sown in late spring.

Japanese barnyard millet (*Echinochloa esculenta*)

Echinochloa esculenta, a member of the Poaceae family, is commonly known as Japanese barnyard millet or Japanese millet. This particular species of Echinochloa is cultivated on a limited scale in regions such as India, Japan, China, and Korea. It serves both as a food source and fodder for animals. Japanese barnyard millet finds its niche in areas where the land is unsuitable for paddy rice cultivation, primarily due to climatic conditions being too cool. However, the cultivation of this millet has seen a notable decline with the development of cold-resistant rice varieties, which have become preferred over Japanese barnyard millet. Records of the domesticated form of this millet date back to around 2000 BC during Japan's Jōmon period. Notably, Japanese barnyard millet was domesticated from Echinochloa crus-galli, a common practice in the domestication of grain crops. This domestication process included the enlargement of the grains and spanned approximately one to two thousand years, with its origins in Japan.

Job's tear millet (*Coix lachryma-jobi*)

Job's tears (*Coix lacryma-jobi*), also known as adlay or adlay millet, represents a tall, perennial tropical plant in the Poaceae family (grass family). Indigenous to Southeast Asia, it was introduced to Northern China and India in ancient times and has since been cultivated in gardens as an annual plant. Over time, it has naturalized in the southern United States and various tropical regions across the New World. In its native habitat, it thrives in higher elevation areas where rice and corn face challenges in growth. Job's tears are commonly marketed as Chinese pearl barley. There exist two primary varieties of this plant: one is wild, and the other is cultivated. The wild variant, known as *Coix lacryma-jobi* var. lacryma-jobi, produces hard-shelled pseudocarps—pearly white, exceptionally hard, oval structures frequently used for crafting prayer beads, rosaries, necklaces, and various ornaments. The cultivated variety, Coix lacryma-jobi var. ma-yuen, is grown as a cereal crop, featuring a softer shell, and is employed medicinally in certain regions of Asia. Job's tear is a broad-leaved, monoecious grass characterized by a loose growth pattern, branching, and robust stature, typically reaching heights ranging from 1.20 to 1.80 meters. Like other members of the grass genus, its inflorescences emerge from a leaf sheath at the stem's end, comprising partially hard, spherical or oval, hollow, bead-like structures. Job's tear seeds exhibit varying colors, with the softer-shelled seeds appearing light brown and the hard-shelled variants featuring a dark red pericarp. These grains can be prepared and consumed similarly to rice, whether cooked or even consumed raw, boasting a subtly sweet flavor. Moreover, they can be ground into flour for various culinary applications.

Kodo millet (*Paspalum scrobiculatum*)

Kodo millet, scientifically referred to as *Paspalum scrobiculatum* and commonly known as Kodo millet or Koda millet, is an annual grain crop primarily cultivated in Nepal (distinct from Ragi or Finger millet, *Eleusine coracana*). It is also grown in regions including India, the Philippines, Indonesia, Vietnam, Thailand, and West Africa, where it originally hails from. While it serves as a minor crop in most of these regions, it holds a significant status in the Deccan plateau of India, where it is a major food source.

Kodo millet stands out for its remarkable resilience, demonstrating drought tolerance and the ability to thrive in marginal soils, where other crops struggle. It can yield approximately 450–900 kg of grain per hectare, highlighting its potential to provide nutritious sustenance to subsistence farmers in Africa and beyond. As a monocot and annual grass, Kodo millet typically grows to a height of around four feet. It produces inflorescences with 4-6 racemes measuring 4–9 cm in length. Its slender, light green leaves can reach lengths of 20 to 40 centimeters. The millet's seeds are quite small and ellipsoidal, measuring about 1.5 mm in width and 2 mm in length, varying in color from light brown to dark grey. With its shallow root system, Kodo millet lends itself well to intercropping and has a robust capacity to thrive in challenging soil conditions. Kodo millet is ground into flour and utilized in making pudding. It is a nutritious grain and serves as a viable alternative to rice or wheat, offering valuable dietary benefits.

Little millet (*Panicum sumatrense*)

This cereal species bears a resemblance in growth pattern to proso millet, albeit being smaller in size. It is characterized as an annual herbaceous plant, growing upright or with folded leaves, reaching heights ranging from 30 centimeters (12 inches) to 1 meter (39 inches). P. sumatrense is found in the wild and as a weed in regions including Pakistan, India, Sri Lanka, Nepal, Burma (Myanmar), Thailand, China, the Philippines, and Indonesia. In certain areas like India, Sri Lanka, Pakistan, Nepal, and Burma (Myanmar), it is intentionally cultivated as a cereal crop, with particular significance in the Eastern Ghats of India.

The grains from this plant are prepared and consumed much like rice, and they can also be ground into flour for bread production. Additionally, the entire plant, including the straw, serves as valuable forage. This annual grass can either grow erect or have a decumbent growth habit, reaching heights of up to 2 meters. Decumbent plants establish roots at the lower nodes, while the stem is notably branched, giving rise to as many as 46 erect and branched flowering culms. Erect plants, on the other hand, seldom root from the lower nodes and produce up to 26 flowering culms from the stem. The leaf blade appears linear-lanceolate, with dimensions of up to 56 cm in length and 21 mm in width, varying from hairless to sparsely hairy. The inflorescence takes the form of an open to compact panicle, stretching up to 50 cm in length and featuring 14-52 branches. The spikelet, lanceolate in shape, measures up to 2.5 mm in length and is hairless. The caryopsis, or the grain, exhibits a shiny white to nearly black appearance, with the grain tightly enclosed by the lemma and palea.

Nepalese barnyard millet (*Echinochloa frumentacea*)

Echinochloa frumentacea, known as Indian barnyard millet, sawa millet, or billion-dollar grass, belongs to the Echinochloa genus. Both Echinochloa frumentacea and E. esculenta are commonly referred to as Japanese millet. This millet variety is extensively cultivated as a cereal crop in India, Pakistan, and Nepal. Its wild ancestor is the tropical grass Echinochloa colona, although the precise date and region of domestication remain uncertain. It is typically grown on marginal lands where rice and other crops struggle to thrive. The grains are prepared by boiling in water, similar to rice, or they are boiled with milk and sugar. In some instances, they are fermented to produce beer. Besides being a staple in the diet of certain Indian communities, these seeds are specifically consumed during religious fasting, a practice that involves voluntary abstention from certain types of food or food ingredients. Consequently, these seeds are often referred to as "vrat ke chawal" in Hindi, which translates to "rice for fasting."

Pearl millet (*Pennisetum glaucum*)

Pearl millet, scientifically known as *Pennisetum glaucum*, stands as the most extensively cultivated millet variety, with a rich history of cultivation in Africa and the Indian subcontinent dating back to ancient times. The Sahel zone in West Africa serves as the center of diversity and is the suggested area of domestication for this crop. Recent archaeological and botanical research has provided evidence of domesticated pearl millet in the Sahel zone of northern Mali, dating between 2500 and 2000 BC. Notably, in 2021, the United Nations General Assembly declared 2023 as the International Year of Millets. Pearl millet is distinguished by its ovoid grains, measuring 3–4 millimeters (1⁄8–5⁄32 inch) in length, making them the largest among all millet varieties, excluding sorghum. These grains can exhibit a range of colors, including nearly white, pale yellow, brown, grey, slate blue, or purple. The 1000-seed weight can vary from 2.5 to 14 grams, with an average of 8 grams. The height of the pearl millet plant spans from 0.5 to 4 meters (1 ft 8 in – 13 ft 1 in).

Proso millet (*Panicum miliaceum*)

Proso millet, scientifically known as *Panicum miliaceum* L., belongs to the Poaceae family and is a tetraploid species (2n=4x=36). It is a warm-season crop, commonly referred to as broomcorn millet, hog millet, white millet, yellow millet, or common millet. This crop holds the distinction of being one of the earliest domesticated crops, with a history of cultivation in Northern China dating back at least 10,000 years. Proso millet finds cultivation in the Himalayan region encompassing Afghanistan, Bhutan, China, India, Nepal, and Pakistan, primarily for human consumption. In contrast, in Europe and America, it is predominantly grown for avian consumption.

Proso millet is characterized by its remarkably short growing cycle, typically spanning 60-90 days (Ghimire et al 2018a). It thrives with minimal water and nutrient requirements, making it suitable for cultivation across a wide range of altitudes, including marginal lands where other cereal crops struggle to thrive. Notably, proso millet is regarded as a health food due to its unique nutritional attributes, including a relatively high protein content, particularly alkaline proteins, surpassing those found in crops such as wheat, rice, and oats. It also boasts an abundance of easily absorbed amino acids, as well as a well-balanced assortment of trace elements and vitamin precursors.

In the context of Nepal, proso millet, locally known as "Chino," holds significance as the second most important food security crop among millets. Its versatile utility extends to making various dishes such as boiled rice (bhat), pudding (kheer), and liquor (raksi) from the grains, while the flour is employed in preparing porridge (dhindo) and flatbreads (roti). Given the changing climate scenario, proso millet is viewed as a promising crop with the potential to address food insecurity in remote regions of the country.

Currently, it is primarily cultivated in the Karnali zone, with an average productivity of approximately 800 kg/ha. Key proso millet-producing districts include Mugu, Dolpa, Humla, Jumla, Kalikot, Bajura, and Jajarkot.

Sorghum (*Sorghum bicolor*)

Sorghum, scientifically known as *Sorghum bicolor* and commonly referred to as great millet, Indian millet, milo, is a cereal grain plant belonging to the Poaceae family, known for its starchy, edible seeds. This versatile plant is believed to have its origins in Africa, where it holds a significant role as a staple food crop. Sorghum exhibits a wide array of varieties, including grain sorghums, which are cultivated for food consumption; grass sorghums, primarily grown for hay and fodder; and broomcorn, utilized in the production of brooms and brushes. In India, it goes by the names jowar, cholam, or jonna, while West Africa refers to it as Guinea corn, and in China, it is known as kaoliang. Sorghum's exceptional resistance to drought and high temperatures makes it particularly valuable in hot and arid regions. It is a robust grass that typically reaches heights ranging from 0.6 to 2.4 meters (2 to 8 feet), occasionally reaching as high as 4.6 meters (15 feet). The stalks and leaves are coated with a white wax, and certain varieties have a juicy and sweet pith at the center of their stalks. Its leaves are approximately 5 cm (2 inches) wide and 76 cm (2.5 feet) long. The plant produces tiny flowers in panicles that vary from loose to dense, with each flower cluster containing 800 to 3,000 kernels. While the seeds exhibit diversity in color, shape, and size among different types, they are generally smaller than those of wheat.

African goose grass (*Eleusine africana*)

Eleusine africana Kenn.-O'Byrne, commonly referred to as African goose grass, is a robust, tetraploid annual grass species with a chromosome count of 2n = 36. Notably, it stands as the immediate progenitor of *Eleusine coracana*, sharing the same chromosome number and exhibiting genetic compatibility. Typically found growing along roadsides and in fields, this hardy plant boasts a digitate inflorescence characterized by upright spikes numbering 2-3. Thriving in warm conditions, *Eleusine* africana follows an annual life cycle, flowering during the warm months and drying up before the onset of winter. Referred to as summer season African wild finger millet, it serves various purposes, including use as livestock fodder and its ability to bind soil effectively, making it a valuable component in ecological systems.

Awnless barnyard grass (*Echinochloa colona*)

Echinochloa colona, also known as jungle rice or awnless barnyard grass, is a tufted annual grass that can reach heights of up to 60 cm. Its stems are either reddish-purple or green, ascending to erect, and lack hairs. The leaves are linear, typically measuring 10 to 15 cm in length, with the basal portion often displaying a reddish tinge, and they do not possess ligules. The inflorescence is simple, featuring ascending racemes ranging from green to purple, approximately 5 to 15 cm in length, and bearing subsessile spikelets measuring 1 to 3 mm long.

This grass species flowers throughout the year and primarily reproduces through seeds, which have a short dormancy period. Echinochloa colona tends to thrive in moist but unflooded conditions and is particularly problematic in upland and rainfed lowland rice fields rather than flooded ones. In terms of agricultural significance, Echinochloa colona closely resembles rice during its vegetative growth stage and poses a significant competitive threat to rice crops. Additionally, it serves as a host for diseases like tungro and rice yellow dwarf. On the positive side, it can be utilized as palatable fodder for milking animals and water buffalo, providing some agricultural value.

Barnyard grass (*Echinochloa crus-galli*)

Echinochloa crus-galli, commonly known as Common barnyardgrass, is an annual grass species found in various regions. In Asia, it is native to China, Japan, and Korea, while in South and Southeast Asia, it can be located in countries such as India, Indonesia, Cambodia, Lao PDR, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam. This grass typically grows as an erect, tufted plant, reaching heights of up to 200 cm. Its stems, or culms, root at the lower nodes and are cylindrical, lacking hairs while containing white spongy pith. The leaves are linear with a broad round base and a narrow top, with blades extending 10 to 40 cm in length, and they lack a ligule. The inflorescence is loose and can vary in color from green to purplish, measuring 10 to 25 cm in length, consisting of compound racemes with spikelets that are generally elliptical and pointed, often slightly hairy. If present, awns are green to purplish and typically measure 2 to 5 mm in length.

From a biological and ecological perspective, Common barnyardgrass reproduces via seeds and is known to flower throughout the year, capable of producing seeds within as little as 60 days. It thrives in moist to wet land conditions and can easily establish itself in direct-seeded rice fields, wastelands, swamps, and aquatic environments. In terms of agricultural importance, it poses a significant challenge as a weed in lowland rice fields due to its rapid growth, competitive nature, and capacity for rapid multiplication. However, in some regions, the young shoots of this grass are consumed, such as in Java, and it is utilized for land reclamation in saline areas of Egypt. Additionally, it serves as a valuable source of feed for animals in grasslands and wastelands.

Crowfoot grass (*Eleusine* *aegyptiaca*)

Crowfoot Grass, a slender to moderately robust annual herb, boasts wiry stems that spread and bend at their lower nodes, with tips that can reach heights of approximately 2 feet. It is a prevalent weed commonly found in open areas and wastelands. Its grass-like leaves typically measure 2-30 cm in length and 2-9 mm in width, featuring blades and sheaths devoid of any hair. Notably, the leaf margins are adorned with long, stiff hairs. The flowers emerge in 1-7 spikes, each spanning 1-6.2 cm in length and 3-7 mm in width, situated at the stem's tip. The seed head bears a resemblance to a crow's foot, hence the plant's common name. While native to Africa, Crowfoot Grass has naturalized across the globe. The juice extracted from fresh Crowfoot Grass plants is traditionally recommended for treating fevers.

Goose grass (wild finger millet) (*Eleusine indica*)

Eleusine indica, commonly known as Indian goosegrass, yard-grass, goosegrass, wiregrass, or crowfootgrass, belongs to the Poaceae family and is a petite annual grass found in regions with warmer climates, extending up to approximately 50 degrees latitude around the world. This species is regarded as invasive in some areas. It shares a close genetic relationship with *Eleusine coracana*, commonly known as finger millet or African finger millet, with the diploid E. indica likely serving as an ancestor to the allotetraploid E. coracana.

While the seeds of E. indica are edible and occasionally used as famine food, their yields are limited. This grass holds significance as a weed in cultivated fields, lawns, and golf courses, thriving in disturbed areas with compacted soils and full sun exposure. Control methods involve both tillage and herbicides, and notably, it can produce seeds even when closely mowed. Some populations have developed resistance to specific herbicides, including glyphosate. *Eleusine indica* employs C4 photosynthesis, enabling it to thrive in hot climates and during the warmer months in temperate zones. Although typically classified as an annual, it may persist for more than a year in frost-free climates.

Johnson grass (*Sorghum miliaceum*)

Sorghum miliaceum is an annual grass with plant heights typically averaging around 100 cm. The stems are sturdy, often exceeding 1 meter in height, and they exhibit a smooth texture or slight hairiness, particularly for several centimeters below each node. This is especially noticeable in areas not covered by the leaf sheath.

Wild pearl millet (*Pennisetum orientale*)

Pennisetum orientale, commonly referred to as the oriental fountain grass, is a flowering plant belonging to the Poaceae grass family. It is indigenous to North West Asia and North Africa. This ornamental perennial grass, reaching a height and width of 60 cm (24 inches), clusters together, producing several tufted panicles that can grow up to 14 cm (5.5 inches) in length. These panicles start off as pale pink and transition to a brown hue as they mature.

Wild foxtail millet (*Setaria pallide-fusca*)

Panicum pallide-fuscum, which can be annuals or biennials, lacks rhizomes and features branched culms that are geniculate at their lower nodes, occasionally ascending, and typically stand at heights of 20-50 cm. Its blades, measuring about 10-20 cm in length and 4-8 mm in width, exhibit a slight infolding. The ligule takes the form of a ring of hairs, and the sheath is mildly compressed. The inflorescence presents as a compact cylindrical panicle, spanning 4-15 cm in length. Spikelets are 2-3 mm long and accompanied by brownish or purplish-brown bristles, which are 2-3 times longer than the spikelet itself. The lower glume is roughly one-third the length of the spikelet, with three veins, while the upper glume is approximately half the length of the spikelet, featuring five veins. Both the lower lemma and upper glume are nearly equal in size, possessing five veins and enclosing a narrow lower palea. The upper lemma is coriaceous, ovate-elliptic, and rugose. Panicum pallide-fuscum serves as famine food, with its seeds being consumed as a source of sustenance.

Wild proso millet *(Panicum antidotale*)

Panicum antidotale, commonly known as Blue panic or blue panic grass, is a robust perennial grass with tufted growth, capable of reaching heights between 1.5 to 3 meters. It boasts deep roots and emerges from short, thick, somewhat bulbous rhizomes. The stems are upright, sturdy, and bear a resemblance to sugarcane due to their swollen base. Its smooth bluish leaves measure 15-30 cm in length and 4-12 mm in width, while the sheaths are 4-8 cm long and devoid of hair. The plant's inflorescence takes the form of a 13-30 cm long panicle, featuring 3 mm long spikelets supported by 2.5 mm long woody stalks. Panicum antidotale finds primary use in fodder and grain production and is available in various commercial cultivars.

Originating from the Indian subcontinent, the Arabian peninsula, and Western Asia, *Panicum antidotale* has since naturalized in numerous tropical and subtropical regions. Some countries cultivate it, leveraging its ecological advantage of salt tolerance.

Genetic Diversity

The genetic diversity of millet species in Nepal is exceptionally rich, extending well beyond the species level to encompass a diverse array of traits both within and among the 12 millet species, including 1,108 cultivars, comprising 8 varieties and 1,100 landraces. This diversity spans genes, alleles, functional traits, agromorphological traits, molecular markers, use values, and food, feed, and nutrition diversity (Joshi et al 2020a, Ghimire et al 2017). Within these millet crops, significant variations are observed in functional traits, agromorphological characteristics, and even seed morphology, although the small size of the seeds can pose identification challenges (Amgain et al 2005, Tiwari et al 2003, 2005, Joshi et al 2016, 2005b, Gurung et al 2020, Ghimire et al 2020, 2018a, Bhattarai et al 2014). Millets serve a multitude of purposes in Nepal, from the production of different types of food products, including grains and flours, to feeds, and some are utilized exclusively as forage crops. Additionally, nutrient content varies among the cultivars, with certain varieties being rich in essential nutrients like iron, calcium, and zinc.

The hierarchy of millet diversity is established with finger millet leading the list, followed by sorghum, foxtail millet, proso millet, pearl millet, barnyard millet, little millet, kodo millet, and browntop millet. Among these, finger millet and wild finger millet have a widespread presence across the country. However, the distribution of millet diversity is not uniform across Nepal. It is notably higher in the high hill areas, particularly in the Karnali province. Karnali emerges as the province with the most abundant diversity, followed by Gandaki, while the Madesh Province exhibits the least diversity. Several districts in Nepal (millet crops diversity districts), such as Arghakhanchi, Baglung, Dhading, Dolakha, Gorkha, Humla, Ilam, Jumla, Kaski, Kavreplanchok, Lamjung, Palpa, Parbat, Ramechhap, Sindhupalchok and Tanahu are recognized for their significant contributions to the preservation and utilization of millet genetic diversity, underscoring the necessity for conservation efforts to safeguard these invaluable crops. Remarkably, despite the wealth of diversity, approximately 50% of millet diversity has been lost over time, emphasizing the urgency of conservation and promotion initiatives to protect these essential crops. Based on the literature and Genebank experiments, agromophological values of millet species are given in **Table 5**.

Table 5. Minimum and maximum values of agro morphological traits of millet crops

a. Finger millet and wild relatives

Crop	Plant height (cm)		Culm branching		Ear exertion (cm)		Culm thickness (mm)		Productive tiller		Flag leaf length		Flag leaf width		Peduncle length	
	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min
Crowfoot grass	60	45.5	5	2	16.6	2.2										
Gosse Grass	62.7	52	2	1	17	9.8	1.42	1.72			22.00	16.6	0.7	0.6	12.3	16.2
Finger millet (NGRC07952)	126.5	105			20	15.5	9.05	6.42	6	2	49.3	35.8	1.4	1.2	35.5	27.3

Finger millet and wild relatives

Crop	Leaf blade length		Leaf blade width		Finger length		Finger Width		Leaf sheath length		Leaf sheath width		Leaf number per plant		Finger number per ear	
	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min
Crowfoot grass					8.1	6.6	0.9	0.6								
Gosse Grass	26.2	20.5	0.7	0.6	9.1	7.6	0.7	0.6	8.3	5.6	6.84	2.80	8	7	5	2
Finger millet (NGRC07952)	53	32.4	1.6	1.3	5.5	4.5	1.5	1	16	12	5.18	4.23	15	10	18	8

b. Foxtail millet

Crop	Plant height (cm)		Productive Tiller		Leaf blade length		Leaf blade width		Peduncle Length	
	max	min	max	min	max	min	max	min	max	min
Bariyo kaguno	106.5	90.5	4	1	35.2	22.4	3.4	2.8	32.5	29.5
NGRC 07952	100	82.5	2	5	24.7	20.8	2.7	2.2	29.5	28
Bristly foxtail millet	211	148.5	7	21	21.3	13.8	0.8	0.5	69.2	45.9

c. Pearl millet

Crop	Plant height (cm)		Number of leaves per plant		Number of nodal per tiller		Number of leaves per plant		Number of tiller		Leaf length		Leaf width		Stem diameter (mm)	
	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min
Co15531	198	137	11	8	7	6	11	8	5	4	46.4	30.6	3.6	2.3	11..25	8.24

Pearl millet

Crop	Sheath length (cm)		Peduncle length		Spike length (cm)		Spike thickness (diameter) (mm)		Stem internode length (cm)	
	max	min	max	min	max	min	max	min	max	min
Co15531	26	23	5	4	30.3	20.5	23.89	22.13	24.1	18

d. Barnyard millet

Crop	Plant height (cm)		Leaf length		Leaf width		Length of inflorescence (cm)	
	max	min	max	min	max	min	max	min
Barnyard millet	138	122..4	29	22.3	2.8	2.3	30.2	25

Agro-morphological Characters of Millet Species

The list of descriptors for characterization and evaluation of different millet species are given in **Table 6**. Morphological and agronomical traits are listed in **Table 7** and 8. These traits were measured in Genebank, Khumaltar and some traits were from published papers and database. Seed characters are given in **Table 7** and **Figure 2** describe their images.

Table 6. Descriptors for characterization and evaluation of different millet crops

SN	Character	Finger	Foxtail	Pearl	Little	Barnyard	Browntop	Sorghum
1	Juice flavor							✓
2	100-seed weight							✓
3	1000 grain weight	✓	✓					
4	Anther color			✓				
5	Apex shape			✓				
6	Awns							✓
7	Basal tillers number					✓		
8	Blade length of flag leaf		✓					
9	Blade pigmentation			✓				
10	Blade width of flag leaf							
11	Blister color			✓				
12	Branching from lower raceme					✓		
13	Bristle length			✓				
14	Bristle ornamentation			✓				
15	Color of Inflorescence					✓		
16	Culm branching		✓			✓		
17	Culm Thickness		✓					
18	Days to 50% flowering	✓					✓	
19	Days to flowering	✓			✓			✓
20	Days to flowering-rainy					✓		
21	Days to maturity		✓				✓	
22	Degree of lodging					✓		
23	Discontinuity of spikelet		✓					
24	Ear exertion		✓					
25	Ear exertion distance			✓				
26	Ear exertion type			✓				

SN	Character	Finger	Foxtail	Pearl	Little	Barnyard	Browntop	Sorghum
27	Ear shape		✓			✓		
28	Ear size		✓					
29	Earhead length	✓						
30	Early vigor			✓				
31	Endosperm color							✓
32	Endosperm texture			✓				✓
33	Endosperm type							✓
34	Finger branching		✓					
35	Finger Length, cm		✓					
36	Finger number		✓					
37	Finger width, cm		✓					
38	Flag leaf length						✓	
39	Flag leaf width						✓	
40	Flag leaf: Blade length	✓			✓			
41	Flag leaf: Blade width	✓			✓			
42	Flage leaf sheath length				✓			
43	Flage leaf sheath width				✓			
44	Florets per spikelet			✓				
45	Flowering range			✓				
46	Fodder yield						✓	
47	Glume color							✓
48	Glume length, cm		✓					
49	Grain color		✓			✓		✓
50	Grain color							
51	Grain covering		✓					✓
52	Grain form							✓
53	Grain hardness							
54	Grain luster							✓
55	Grain number per panicle							✓
56	Grain plumpness							✓
57	Grain shape		✓			✓		
58	Grain sub-coat							✓
59	Grain surface		✓					
60	Grain uniformity		✓					
61	Grain weathering susceptibility							
62	Grain yield						✓	
63	Grain yield per plant		✓		✓			
64	Grain yield potential		✓					
65	Green fodder yield		✓					
66	Green fodder yield potential			✓				
67	Growth habit	✓	✓			✓		
68	Inflorescence Apical sterility	✓						
69	Inflorescence Bristles	✓						
70	Inflorescence compactness	✓				✓		✓
71	Inflorescence exertion							✓
72	Inflorescence length					✓		
73	Inflorescence length							✓
74	Inflorescence lobes	✓						
75	Inflorescence shape	✓				✓		✓
76	Inflorescence width (head)							✓
77	Internode pigmentation			✓				
78	Internode pubescence			✓				

SN	Character	Finger	Foxtail	Pearl	Little	Barnyard	Browntop	Sorghum
79	Involucre stalk length			✓				
80	Juice quality			✓				
81	Leaf attitude	✓		✓				
82	Leaf blade length		✓					
83	leaf Blade pubescence	✓						
84	Leaf blade width		✓					
85	Leaf color	✓		✓				
86	Leaf length			✓				
87	Leaf midrib color							✓
88	Leaf number		✓					
89	Leaf sheath intensity of pubescence	✓						
90	Leaf sheath length		✓					
91	Leaf sheath pubescence							
92	Leaf sheath width		✓					
93	Leaf width			✓				
94	Length of primary rachis						✓	
95	Lodging susceptibility		✓	✓				
96	Lodging susceptibility							✓
97	Lower raceme shape					✓		
98	Lowest raceme length (mm)					✓		
99	Male sterile cytoplasm system							✓
100	Malting quality		✓					
101	Mono-aristation length			✓				
102	No. of primary rachis in a panicle						✓	
103	No. of productive tillers						✓	
104	Node pigmentation			✓				
105	Node pubescence			✓				
106	Number of fertile spikelet per involucre			✓				
107	Number of flowering stems per plant							✓
108	number of grains per spikelet		✓					
109	Number of leaf			✓				
110	Number of nodal tillers			✓				
111	Number of productive tiller	✓		✓	✓			
112	Overall plant aspect							✓
113	Panicle exertion (mm)					✓		
114	Panicle length				✓		✓	
115	peduncle length (cm)	✓	✓			✓	✓	
116	pericarp persistence after threshing		✓					
117	Photosensitivity							✓
118	Plant aspect			✓		✓		
119	plant color							✓
120	Plant height		✓	✓	✓	✓	✓	✓
121	Plant height at maturity	✓						
122	Plant pigmentation		✓			✓		
123	Plant pigmentation auricle	✓						
124	Poly-aristation density			✓				
125	Productive tillers		✓					
126	Raceme number					✓		

SN	Character	Finger	Foxtail	Pearl	Little	Barnyard	Browntop	Sorghum
127	Rachis diameter			✓				
128	Rachis pubescence			✓				
129	Rachis tip			✓				
130	Restoration response			✓				
131	Restoration response (Milo source)							✓
132	Seed color	✓		✓				
133	Seed color	✓						
134	Seed covering			✓				
135	Seed shape	✓		✓				
136	Seed Shape	✓						
137	Seed volume			✓				
138	Seed weight			✓				
139	Seed weight per spike			✓				
140	Seedling vigor							✓
141	Senescence			✓				
142	Senescence							✓
143	Sensitivity of photoperiod			✓				
144	Separation			✓				
145	Shape of lower raceme					✓		
146	Shattering							✓
147	Sheath length							
148	Sheath pigmentation			✓				
149	Sheath pubescence			✓				
150	Spike density			✓				
151	Spike length			✓				
152	Spike shape			✓				
153	Spike thickness			✓				
154	Spikelet density		✓					
155	Spikelet shattering /threshing		✓	✓				
156	Spikelet glume color			✓				
157	Spikelet shattering							
158	Stalk juiciness			✓				
159	Stalk juiciness							✓
160	Stem diameter			✓				
161	Stem internode length			✓				
162	Stigma pigmentation			✓				
163	Stomatal frequency		✓					
164	Surface			✓				
165	Synchrony of ear maturity		✓	✓				
166	Synchrony of flowering							✓
167	Threshabilitv							
168	Tillering attitude			✓				
169	Total number of tillers			✓	✓			
170	Waxy bloom							✓
171	Yellow endosperm			✓				
172	Yield potential			✓				

Source: Anuradha et al 2020, Bioversity International et al 2010, Elangovan et al 2023, IBPGR and ICRISAT 1993a, 1993b, IBPGRI 1983, 1985, ICRISAT 2023, IIMR nd, Kuraloviya et al 2019, Natesan et al 2020, Nilavarasi et al 2020, Nirmalakumari et al 2010, Nirubana et al 2019, Sheahan 2014

Table 7. Seed characters of millet crops

Millet	Grain color	Grain shape	Grain covering	Surface	Seed lusture	1000 seed wt (g)	Grain length (mm)	Grain width (mm)
Finger	Light brown	Round	Enclosed	Wrinkled		3.1		
Foxtail	Brown	Oval				1.99		
Proso	Brown white					6.81	3.65	2.3
Pearl	Grey	Hexagonal	Intermediate	Wrinkled	Non-mucronate	9.85	3.79	2.5
Little	Brown	oval				1.5		
Browntop	Grey	conceolate				4.06	2.51	1.83
Kodo	Dark brown					5.85	2.59	2.37
Japanese Barnyard	White grey	oval				2.96		
Sorghum	5		7-grain fully covered		+ Lusturous	14.04	3.84	3.29
Bristly foxtail millet	Brown	oval				0.76		
Nepalese barnyard	brown	oval				3.31	2.27	1.75
Job's tear						201.42	9.14	7.68
Awnless barnyard	brown	oval						
Crowfoot grass	Light brown	round				0.31		
Goose grass	purple					0.97		
Wild Foxtail	Light green	oval				1.7		
African goose	Brown	round				1.96		

Figure 2. Seeds of different millet species

Genetic Erosion and Drivers of Millet Biodiversity

Nepal has witnessed a concerning phenomenon of genetic erosion in its millet diversity, with reports indicating that over 50% of native landraces have been lost. The lands where millets thrived in the past now lay barren, reflecting the stark transformation of agricultural landscapes. Numerous farmers across different regions have lamented the complete loss of millet genetic resources, signifying the magnitude of this issue (**Table 8**). The most endangered millet crops are little millet, barnyard millet, sorghum, kodo millet. This genetic erosion not only threatens the traditional agricultural heritage of Nepal but also jeopardizes the resilience of its farming communities in the face of changing environmental conditions, emphasizing the urgent need for conservation efforts and revitalization of millet cultivation.

The preservation and dynamics of millet biodiversity are influenced by a spectrum of drivers (**Figure 3**), which can be broadly categorized into three groups: major, medium, and minor drivers. Among the major drivers, the advancement in science and technology, changing economic and socio-political conditions, and shifts in land and water use practices play pivotal roles in shaping the trajectory of millet biodiversity. Notably, millets' resilience to climate changes serves as a significant mitigating factor, with climate change having a relatively low impact on the loss of millet genetic diversity. As these diverse drivers interact and evolve, understanding their interplay becomes crucial for developing strategies that sustain and enhance the genetic resources of millets, securing their critical role in global agriculture and food security.

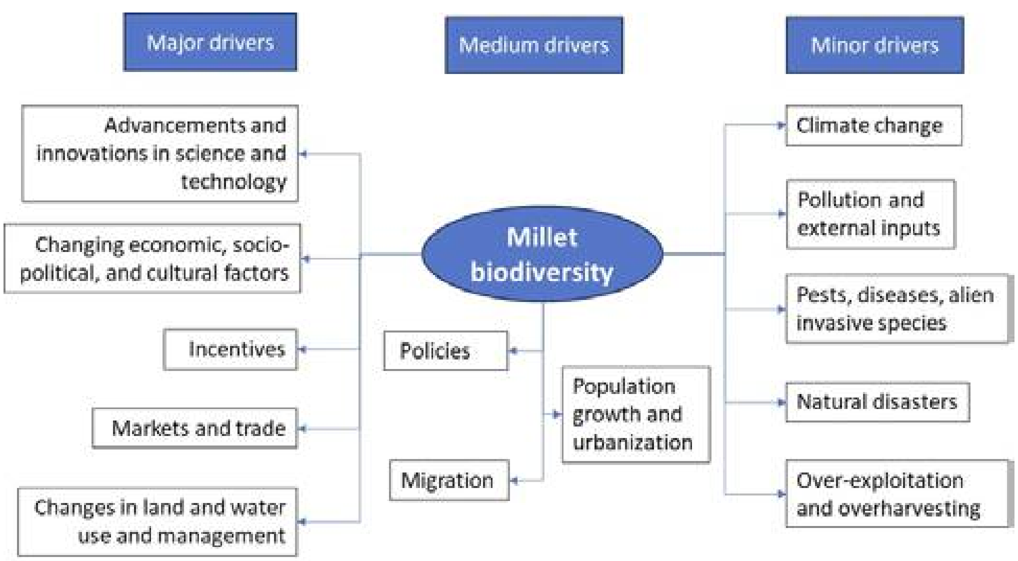

Figure 3. Broad categories of drivers on changing the millet biodiversity

Table 8. Lost landraces of millet crops

SN	Crop	Lost landraces
1	Finger millet	Achaure kodo, Andhikhole kodo, Asoje kodo, Augaure, Bablale kodo, Bachuwa, Bahrakote, Baidi khole, Banse kodo, Bhachuw kodo, Bharuke kodo,Chamre kodo, Chanure, Charsa kodo, Chaumase kodo, Chaure, Chharuwa kodo, Chhyangre kodo, Chiwal, Chyalthe kodo, Dhabali kodo, Dhawali, Dudhe kodo, Ekle kodo, Furke, Hiude maruwa, Jhalli kodo, Jhamke kodo, Jhupe kodo, Kalo bhuni, Kalo dalle kodo, Kalo mudule kodo, Kaatike, Kaule, Kirante kodo, Kukurkane, Kuwakote, Kyalda, Laibare kodo, Laphre, Latte kodo, Lekali chaure, Lopre kodo, Lurke, Maduwa, Mangire bhachuwa, Mangsire kodo, Maruwa, Matyangre kodo, Mudke, Nagare kodo, Nakahuwa kodo, Nancha kodo, Nangkatuwa kodo, Nangre, Pahenle kodo, Pangdure kodo, Phalse kodo, Pokali kodo, Pumdeli kodo, Pushe, Rato daude kodo, Rato mangsire kodo, Riuli kodo, Samdhi kodo, Sathiya, Seto dalle kodo, Seto dudhe, Seto Jhape kodo, Tauke kodo, Thangre kodo, Thulo Mudke kodo, Tinmase kodo, Urchho

SN	Crop	Lost landraces
2	Foxtail millet	Rato kaguno, Tomran, Dane Karnu, Kakamu, Seto kaguno, Rato kaguno, Tinmase, Parbeli, Lude, Aulel, Pahenlo
3	Proso millet	Dudhe cheenu, Jhumauro cheena, Kalo cheenu, Rato cheenu, Haade chino
4	Sorghum	Rato junelo, Seto junelo, Lamo junelo, Gazali junelo

Source: Joshi and Joshi 2002, Upadhyay and Joshi 2003, Joshi et al 2005a, 2023b, 2022, 2017, 2020b, 2019, Ghimire et al 2017, Gurung et al 2016, 2019, Palikhey et al 2016, Parajuli et al 2016, Pudasaini et al 2016

Conclusion

Nepal boasts a wealth of millet diversity, with numerous species and localized genetic variations spread across the country. However, a significant proportion of these millet varieties finds themselves endangered, emphasizing the need for concerted conservation efforts. The assurance of a reliable market for millets and their derived products has become increasingly important, stimulating the development of site-specific and polymorphic millet varieties tailored to local needs. This trend extends to the creation of use-specific varieties, catering to traditional staples like roti, raksi, dindo, and tongbaa. The mainstreaming of evolutionary plant breeding and cultivar mixtures, combined with product diversification and the promotion of traditional recipes, contributes to revitalizing millet agriculture. Moreover, legalizing millet-based beverages such as raksi, tongbaa, and chyaang further bolsters the economic prospects of millet farming. The holistic approach extends to the development of comprehensive ecological agriculture practices, while the conservation of millet diversity remains a cornerstone, achieved through seed banks, agro gene sanctuaries, diversity blocks, and evolutionary populations, ensuring the preservation of this invaluable genetic resource.

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Conservation, Storage and Utilization of Millet Genetic Resources

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Summary

The conservation and storage of millet seeds are of paramount importance, given the endangered status of millet genetic diversity resulting from long-standing neglect. Key conservation strategies encompass on-farm, in-situ, ex-situ, and conservation breeding methods, with seed banks emerging as the primary means of millet preservation. These seed banks are classified into three categories: on-farm, ex-situ, and in-situ. Priority areas for conservation should be identified through the red zone and red listing approach. Conservation efforts for millets have been in progress since 1961, with a diverse range of 36 conservation methods available for adoption. Currently, Nepal carefully preserves a total of 1,056 accessions representing seven millet species in long-term and medium-term storage conditions at the National Agriculture Genetic Resources Center (Genebank), Khumaltar facility. Impressively, collection efforts have extended to a remarkable 70 districts across Nepal, encompassing a wide altitude range from 64 to 3,677 meters. Furthermore, foreign gene banks in countries such as India, Japan, Italy, the USA, and Australia collectively house 1,657 accessions of various millet species collected from different parts of Nepal. However, utilization of millet genetic resources remains considerably underexplored, underscoring the need for a robust research, education, and extension system to promote and ensure the continued vitality of millet genetic diversity.

Keywords: Conservation breeding, conservation strategy, ex-situ, in-situ, on-farm, seed bank

Introduction

The conservation of millet genetic resources in Nepal presents a critical yet often overlooked facet of agricultural and environmental preservation. Millets, a group of highly resilient cereal crops, offer a multitude of benefits for human consumption, livestock feed, and environmental sustainability. However, their significance has often been marginalized, reflecting their lower social status within the Nepalese diet. Millets are classified as underutilized crops, receiving limited attention and minimal investment in research and development. Consequently, both farmers and consumers have shown a preference for other staple grains, further diminishing the cultivation and consumption of millets. This neglect has direct consequences, with many unique millet landraces now endangered, and some have tragically gone extinct (Ghimire et al 2017, Joshi and Joshi 2002, Palikhey et al 2016, Joshi et al 2005).

Despite these challenges, there have been noteworthy efforts to conserve millet genetic diversity dating back to a very early period. Various organizations, operating at both national and international levels, have been involved in collecting millet genetic resources from diverse regions of Nepal (https://www.genesys-pgr.org/, Joshi et al 2023b). Understanding the characteristics of millet species is fundamental to their conservation efforts. All millet species in Nepal are annual crops with C4 photosynthesis, predominantly self-pollinated (except pearl millet), and cultivated during the summer season. Recognizing the intrinsic value of these resilient grains, ongoing efforts strive to bolster their conservation and ensure their continued contribution to agriculture, nutrition, and environmental sustainability in Nepal.

The characteristics and behavior of millet seeds play a crucial role in their conservation and storage. Millet seeds are classified as orthodox, meaning they have the ability to withstand desiccation and can be stored for extended periods under the right conditions without losing viability. These seeds can be grouped into various categories (**Table 1**), such as landrace seeds, high-yielding variety seeds, and hybrid seeds. Despite the differences in their genetic makeup and performance, millet seeds share common characteristics as monocotyledon seeds, with a single embryonic leaf in the seed.

It's noteworthy that in Nepal, currently there are no hybrid or genetically modified millet varieties. This underscores the importance of preserving and conserving traditional landraces and high-yielding varieties of millet, as they represent the primary genetic resources for millet production in the region. The orthodox nature of millet seeds allows for their long-term storage, ensuring a stable supply of viable seeds for future planting and research, contributing to the sustainability of millet cultivation in Nepal (Ghimire et al 2017, Saud 2009).

Table 1. Types of millet seeds and their features

SN	Type (seed or variety)	Feature	Synonym
Based on breeding perspective			
1	Indigenous seed	Landrace of a particular site where, this was originated	Native seed
2	Local variety	Landrace does not introduce from other areas, if introduced, localized after growing several generations	Heirloom
3	Landrace	Genotype not altered by formal breeders but grown continuously by farmers over years	Traditional, farmer's variety
4	High yielding variety	Developed by selecting & following principles of genetics	Improved, modern variety
5	Hybrid seed	Produced by crossing two different parents	F1 seed
6	Genetically modified seed	Seeds of genotype having distantly related genes	GMO seed
Based on conservation perspective			
1	Orthodox seed	Successfully dried to moisture contents <12% without injury and are able to tolerate freezing	-
2	Recalcitrant seed	Do not tolerate drying moisture contents below 12% without injury and are unable to tolerate freezing	-
Based on botanical perspective			
1	Monocot seed	A single (mono) embryonic leaf or cotyledon	-
2	Dicot seed	Two embryonic leaves or cotyledons	-

Red Zone and Red List of Millet Genetic Resources

The concepts of "red zone" and "red listing" are vital tools in the conservation of millet crops, particularly in identifying and prioritizing the preservation of diverse landraces. A "red zone" designates regions where local millet landraces face a heightened risk of extinction or loss due to various factors such as natural disasters, shifts in land use, population migration, commercialization of agriculture, and changing cultural preferences (**Figure 1**). These zones are critical focal points for conservation efforts as they pinpoint areas where the genetic diversity of millet landraces is most vulnerable.

On the other hand, "red listing" categorizes millet landraces based on specific criteria, including their geographical distribution, the number of farmers cultivating them (**Figure 2**), and the presence of unique traits (**Figure 3**). This classification system helps prioritize the conservation of landraces by highlighting those that are rare, culturally significant, or agriculturally valuable. By systematically assessing and categorizing millet landraces, conservationists can allocate resources effectively, ensuring the protection and continued availability of these diverse genetic resources, which are essential for food security and agricultural sustainability.

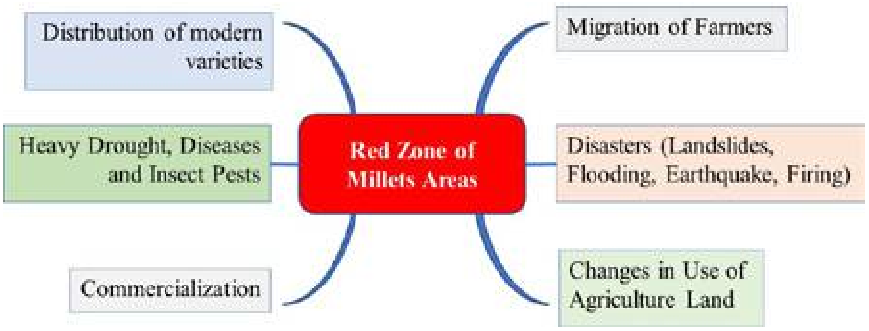

Figure 1. Factors that convert millet growing areas to red zone
Source: Joshi and Gauchan 2017

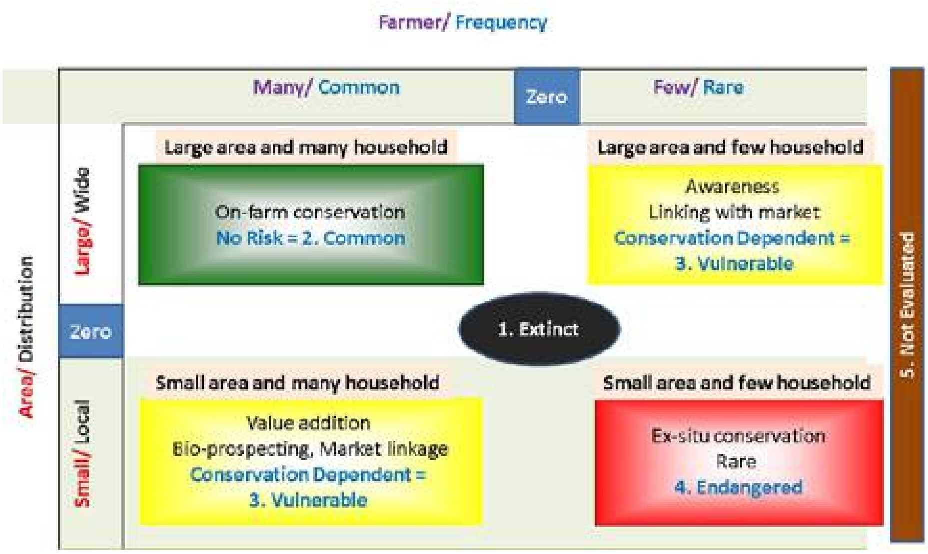

Figure 2. Five cell analysis (landrace distribution analysis) based on areas and number of growers to identify the red list of millet landraces.
Source: Joshi and Gauchan 2017

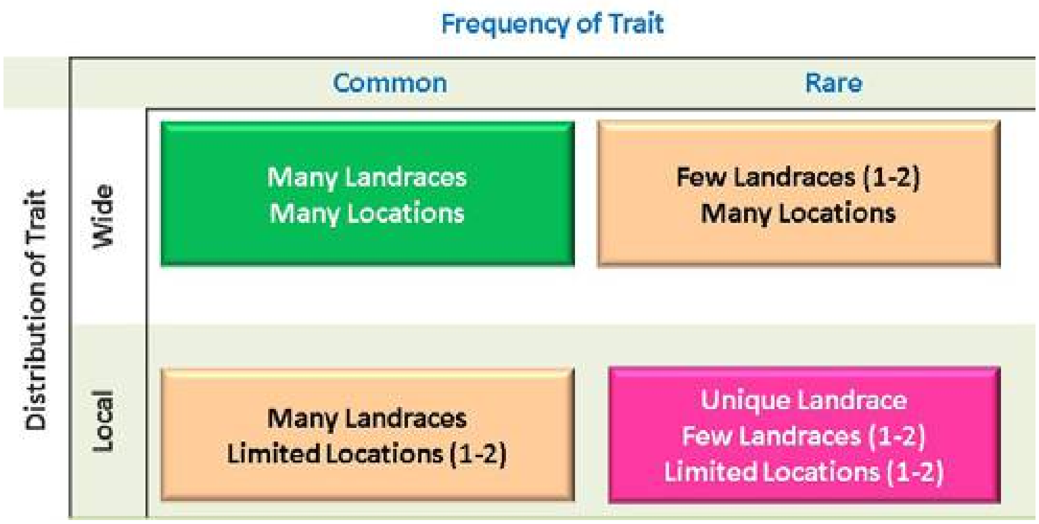

Figure 3. Trait distribution analysis to identify unique and endangered landraces of millet crops
Source: Joshi and Gauchan 2017

Conservation and Storage

Conservation in the context of millet species in Nepal involves the long-term preservation of their genetic diversity, ensuring that these valuable genetic resources remain viable and available for use over an extended period, typically beyond a few seasons. Modern conservation science has introduced various mechanisms and methods to achieve this goal. These methods aim to protect millet germplasm from genetic erosion and loss, which can occur due to factors such as environmental changes, disease, or shifts in agricultural practices.

Storage, on the other hand, typically refers to the short-term preservation of planting materials, typically for one to two seasons under normal conditions. This practice is commonly employed by farmers in Nepal to safeguard their planting materials until the next planting season. It's a practical and immediate solution for maintaining access to seeds and planting materials while awaiting the next crop cycle.

In Nepal, both conservation and storage strategies are employed for millet species. For ensuring the genetic diversity in future, common techniques include the continuous cultivation of diverse millet varieties to ensure their survival and genetic stability. Additionally, millet germplasm is utilized in breeding programs to develop improved varieties with desirable traits. Another approach is the practice of making millet competitive through landrace enhancement, which involves the selection and propagation of locally adapted landraces to maintain their unique genetic characteristics.

Furthermore, Nepal has established various conservation banks, such as seed banks to store millet genetic resources under controlled conditions. Seed banks are vital repositories that extend the longevity of millet germplasm by preserving it at low temperatures and controlled humidity levels. These institutions play a crucial role in safeguarding millet diversity and ensuring its availability for future agricultural development and research. Overall, the coexistence of both conservation and storage strategies in Nepal reflects a comprehensive approach to protecting millet genetic diversity and promoting its sustainable use in agriculture.

Conservation history

The conservation history of millet crops in Nepal reflects the nation's commitment to preserving its valuable genetic resources. It can be divided into several key phases:

1. ***Early Collection and Medium-Term Storage (1984 - 2010)**:* The conservation efforts for millet crops in Nepal began in 1984 under the purview of the Agriculture Botany Division of the National Agriculture Research Council (NARC). During this period, millet collections were initiated, and these genetic resources were conserved in medium-term storage facilities. This marked the early stages of systematic conservation to safeguard the genetic diversity of millet species.
2. ***Establishment of National Genebank (2010)**:* A significant milestone in millet crop conservation occurred in 2010 with the establishment of the National Genebank in Nepal. This state-of-the-art facility provided a dedicated space for the systematic and comprehensive preservation of millet species. It enabled the collection, storage, and maintenance of millet accessions in both Long-term and Medium-term storage conditions, ensuring their long-term viability and accessibility for research and breeding programs.
3. ***International Collaboration (1960s - 1980s)**:* In addition to Nepal's efforts, global partners also contributed to millet conservation. The National Bureau of Plant Genetic Resources (NBPGR) in India initiated collections as early as 1961. Similarly, the USDA-ARS Germplasm Resources Information Network began collecting millet accessions, some of which date back to 1966. These international efforts emphasized the importance of preserving millet genetic diversity not only at the national level but also on a global scale.

Conservation Strategy

Conservation strategies for millet biodiversity encompass various components and approaches aimed at ensuring the long-term preservation of these valuable genetic resources. These strategies are critical for maintaining genetic diversity and safeguarding millet crops against potential threats and challenges. Here's an overview of the key components (**Figure 4**) and strategies involved in millet biodiversity conservation:

1. ***Sensitization**:* Sensitization is a crucial component of millet biodiversity conservation. It involves raising awareness among stakeholders, including farmers, researchers, policymakers, and the general public, about the importance of preserving millet genetic resources. Effective communication and education campaigns can help garner support and engagement in conservation efforts.
2. ***Strategies and Methods***: Developing comprehensive conservation strategies and methods is essential. This includes the identification of priority areas for millet cultivation and the red zoning of millet-growing regions. Landraces of millet crops are also red-listed to highlight their significance in genetic diversity conservation. These strategies guide the targeted collection, preservation, and management of millet germplasm.
3. ***Accelerators***: Accelerators refer to the tools, technologies, and resources that expedite the conservation process. One such tool is the Climate Analog Tool (CAT), which plays a multifaceted role. CAT assists in identifying potential sites for millet genetic resources, aiding in exploration and collection efforts. It can also be instrumental in repatriating germplasm to suitable locations in response to changing climate conditions.
4. ***Enabling Environment**:* Creating an enabling environment involves establishing policies, regulations, and institutional frameworks that support millet biodiversity conservation. This includes the establishment of genebanks, research collaborations, and partnerships at national and international levels. Adequate funding and resources are essential to sustain conservation efforts over the long term.

5. **Values**: Recognizing and valuing the significance of millet genetic resources is a fundamental aspect of conservation. This component emphasizes the cultural, nutritional, and economic importance of millet crops in various societies. It encourages the integration of millet conservation into broader agricultural and food security agendas.

These components work together to ensure the long-term viability and availability of millet crops in the face of environmental and agricultural challenges.

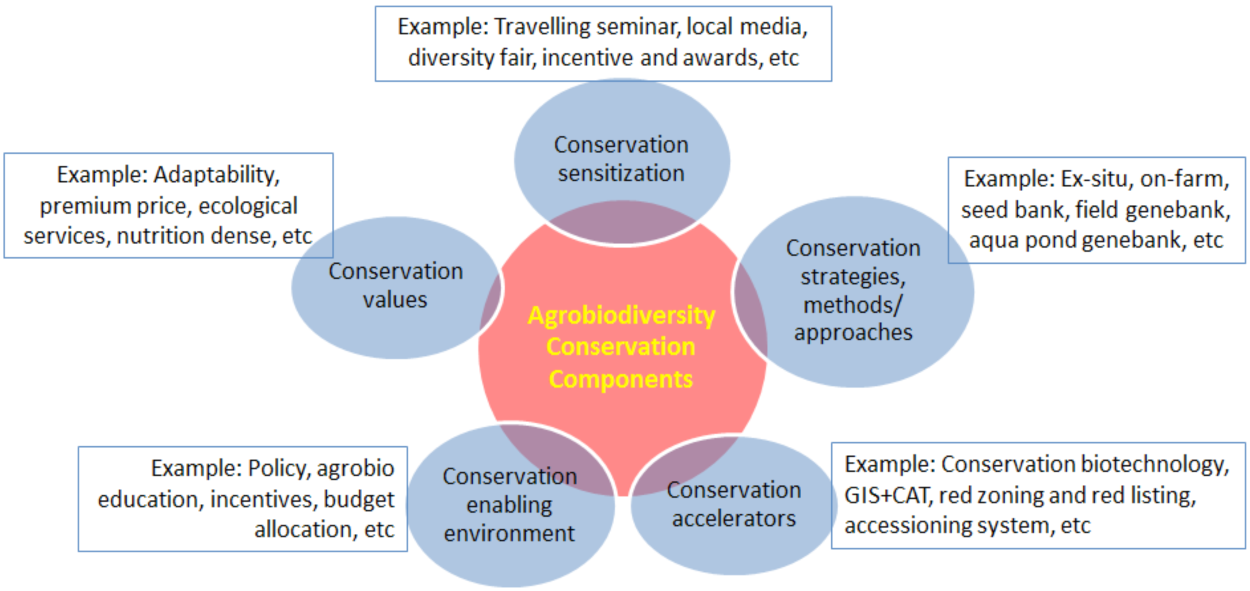

Figure 4. Conservation components of millet biodiversity
Source: Joshi et al 2020b

Indeed, conservation strategies for millet biodiversity can be designed and implemented based on various factors and considerations (**Figure 5**, **6** and **9**). Four common strategies are ex-situ, on-farm, in-situ and conservation breeding.

1. Based on Evolution in Target Populations (Static or Dynamic):

- Static Conservation: Some conservation strategies may focus on maintaining the genetic diversity of millet populations in a stable or static manner. This approach aims to preserve the existing genetic characteristics of millet varieties and landraces without significant change.
- Dynamic Conservation: Dynamic conservation strategies, on the other hand, may involve the deliberate introduction of new genetic material or traits to enhance the adaptive capacity of millet populations. This approach allows for the evolution and adaptation of millet crops to changing environmental conditions and emerging challenges.

2. Based on Governance (Local, Provincial, National, and International):

- Local Conservation: Local communities and farming groups may implement conservation methods tailored to their specific needs and priorities. This can involve on-farm conservation practices and the preservation of locally adapted landraces.
- Provincial and National Conservation: Regional or national governments often play a significant role in millet conservation efforts. They may establish policies, regulations, and genebanks to safeguard millet genetic diversity at a broader scale.

- International Conservation: Millet biodiversity is a global concern, and international organizations, such as the Food and Agriculture Organization (FAO) and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), promote cooperation and coordination among countries to conserve millet genetic resources. This can involve sharing germplasm, research, and conservation best practices.

3. Based on Origin and Conservation Sites (Ex-situ, On-farm, In-situ, and Conservation Breeding):

- Ex-situ Conservation: This approach involves the collection and storage of millet germplasm outside its natural habitat. This is typically done in genebanks under controlled conditions, such as in the National Genebank you mentioned earlier. It ensures the long-term availability of millet genetic resources.
- On-farm Conservation: Farmers play a critical role in on-farm conservation by cultivating and maintaining diverse millet varieties on their farms. This method is valuable for preserving locally adapted landraces and traditional farming practices.
- In-situ Conservation: In-situ conservation efforts focus on the preservation of millet genetic diversity within its natural habitat. This can involve protecting millet populations in their native agro-ecosystems or through community-based conservation initiatives.
- Conservation Breeding: Conservation breeding programs aim to develop improved millet varieties with desirable traits with broad genetic bases, often using genetic material from genebanks. These programs contribute to both conservation and crop improvement goals.

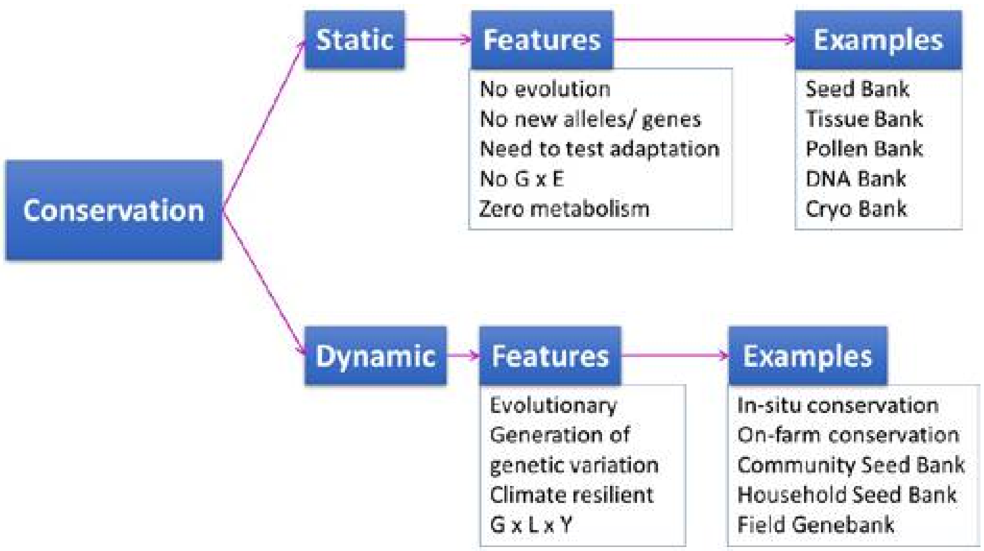

Figure 5. Conservation strategy based on evolution with examples.

Figure 6. Conservation strategy based on governance with good practices and actions
Source: Joshi et al 2017a

Conservation and Storage Approaches

Numerous conservation and storage approaches have been employed to protect millet biodiversity, with seed banks emerging as a common and highly successful method (Bramel et al 2022, Joshi 2017, Joshi 2021). Seed banks can be categorized into three main types: on-farm seed banks, ex-situ seed banks, and in-situ seed banks (**Figure 7**). Within each category, a diverse array of specialized banks and facilities exists, each tailored to specific conservation needs and objectives. These seed banks serve as invaluable repositories for millet genetic resources, ensuring their long-term viability, availability for research and breeding, and resilience in the face of environmental challenges. The extensive diversity in seed bank types and approaches reflects the comprehensive commitment to safeguarding millet biodiversity and promoting its sustainable use in agriculture and food security.

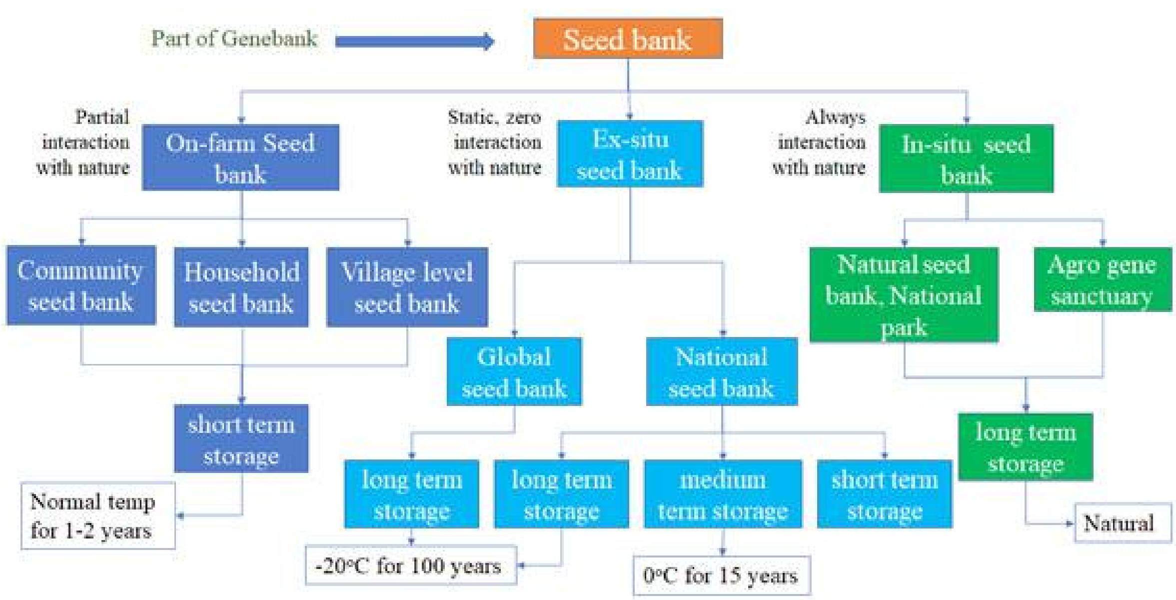

Figure 7. Types of seed bank for management of millet biodiversity
Source: Joshi 2021

Community seed banks typically store seeds at room temperature, ensuring accessibility and ease of management for local communities (**Figure 8**). Modern seed banks, in contrast, employ low-temperature storage, often below freezing, in air-sealed containers to maximize seed longevity. Natural seed banks rely on seeds' innate ability to persist in their native environments, subject to natural conditions. Each approach balances trade-offs between accessibility, long-term viability, and environmental resilience to preserve millet genetic diversity effectively.

Figure 8. Storage conditions of 3 broad types of storage

Traditional storage system

Farmers have developed a variety of innovative millet storage methods over the years, demonstrating their deep knowledge and resourcefulness in preserving these valuable grains (Mobolade et al 2019, Ragupathy et al 2016)). Some of these traditional storage techniques include Bhakari (a type of traditional granary), wooden boxes, underground pits, soil pots, and bamboo-made storage items. These methods often take advantage of natural materials and local craftsmanship to create storage solutions suitable for their millet crops (Wyss et al 2016).

One remarkable aspect of these traditional storage systems is their ability to maintain millet grains' quality and longevity (Mutegi et al 2001). In some cases, finger millet grains can be stored for over 40 years within the farmer's system of storage. This remarkable durability is due, in part, to the protective husk surrounding the grains. When the husk is not removed, it acts as a natural barrier, shielding the grains from environmental factors and pests. This preservation technique highlights the wisdom and practical knowledge of farmers in safeguarding their millet harvests for extended periods, ensuring a stable food supply and seed sources for future planting. Millet grains can be stored for many years if husk was not removed.

On-farm Conservation and Community Seed Banks

On-farm conservation are grassroots approaches that empower local communities to play a central role in preserving millet genetic diversity. Community genebanks including community seed banks are community-managed facilities were farmers store and exchange traditional crop varieties, including millet. These initiatives promote product diversification by maintaining diverse landraces, fostering conservation through utilization. Farmers continue to grow these landraces continuously, contributing to their ongoing adaptation and evolution within local farming systems. This approach often involves the registration of landraces, allowing for their legal recognition and protection. Additionally, repatriation efforts may return locally adapted millet varieties to their regions of origin, further enriching genetic diversity. The assurance of a market for these traditional varieties incentivizes their cultivation. Initiatives like school field genebanks, diversity fairs, food fairs and traditional seed storage systems also play vital roles in preserving millet genetic resources within local communities. By blending traditional wisdom with modern practices, on-farm conservation contributes significantly to the sustainable management and continuity of millet crop diversity (Pallante et al 2016).

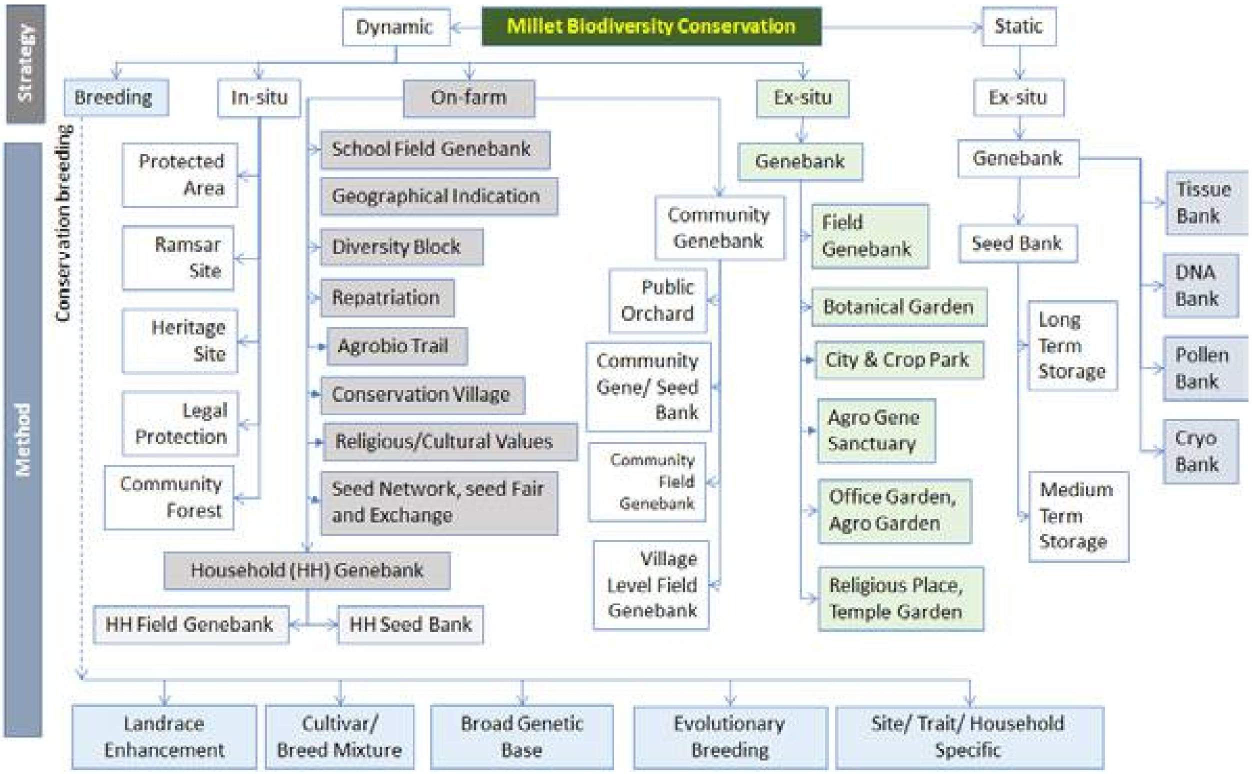

Figure 9. Conservation strategies (4) based on the origin and conservation sites along with good practices and actions
Source: Joshi et al 2017a

In-situ conservation

In-situ conservation represents a unique and natural approach to preserving the genetic diversity of millet crops. It involves the conservation of these valuable resources within their native habitats, where they grow continuously, complete their life cycles, and reproduce in the same sites. In-situ conservation takes advantage of the natural processes of selection and adaptation that occur in these environments. Millet crops interact with the surrounding natural factors, such as soil conditions, climate, and local ecosystems, which collectively contribute to their genetic resilience and evolution. Unlike ex-situ methods, in-situ conservation relies on the innate mechanisms of nature to manage and safeguard the genetic diversity of millet varieties. This approach not only maintains the integrity of these crops within their ecological niches but also ensures their sustained interaction with the environment, promoting their long-term adaptability and survival.

Ex-situ conservation

Ex-situ conservation is a vital component of efforts to preserve the genetic diversity of crops like millet. It involves the maintenance and storage of plant genetic resources outside their natural habitats, thereby safeguarding them from potential threats and ensuring their availability for future generations. Ex-situ conservation is facilitated through various means, including genebanks, which come in diverse forms. These genebanks encompass seed banks, DNA banks, cryo banks, field genebanks, temple gardens, gardens, and parks. Seed banks store viable seeds under controlled conditions, while DNA banks preserve genetic information for research and future regeneration. Cryo banks utilize ultra-low temperatures to store plant materials in a frozen state, ensuring long-term viability. Field genebanks cultivate and maintain diverse crop varieties in living collections, while temple gardens, gardens, and parks offer culturally significant spaces for conserving traditional landraces and heirloom varieties. These ex-situ conservation methods collectively play a crucial role in safeguarding millet genetic resources, supporting research, and maintaining agricultural diversity for the benefit of current and future generations.

Conservation breeding

Conservation breeding encompasses various innovative methods and strategies aimed at preserving and enhancing the genetic diversity of crops while simultaneously meeting the needs of farmers and promoting sustainable agriculture. Here are some key methods and approaches within conservation breeding:

- **Cultivar Mixture**: Cultivar mixtures involve planting multiple crop varieties or landraces together in the same field. This method encourages diversity within a single planting, reducing the risk of crop failure due to pests, diseases, or environmental stresses (Joshi et al 2020a, 2016). It enhances overall resilience and stability in agricultural systems.
- **Evolutionary Plant Breeding:** Evolutionary plant breeding focuses on creating populations of crops that adapt and evolve over time. By allowing plants to naturally crossbreed and select for desirable traits, this method promotes genetic diversity and the development of locally adapted varieties.
- **Participatory Plant Breeding**: Participatory plant breeding engages farmers and local communities in the breeding process. Farmers actively participate in selecting and developing crop varieties that meet their specific needs and environmental conditions. This approach ensures that breeding efforts are context-appropriate and community-driven.
- **Landrace Enhancement**: Landrace enhancement involves improving and maintaining traditional landraces—local crop varieties with unique traits and adaptability. Through selective breeding, landraces can be enhanced to address modern challenges while preserving their traditional value.
- **Participatory Varietal Selection**: This method engages farmers in selecting the most suitable crop varieties for their specific farming systems and preferences. Farmers' feedback and preferences are integrated into the breeding process, leading to the development of locally preferred varieties.
- **Broad Genetic Base**: Maintaining a broad genetic base in breeding programs involves incorporating diverse genetic resources, including landraces and wild relatives. This approach helps counter genetic erosion and enhances adaptability to changing conditions.
- **Site-Specific Variety Development**: Site-specific variety development tailors crop varieties to the unique environmental conditions and farming practices of specific regions. This ensures that varieties are well-suited to local ecosystems and farming systems.
- **Agro Gene Sanctuary**: Agro gene sanctuaries protect and conserve traditional landraces and heirloom varieties within their native agro-ecosystems. These sanctuaries play a crucial role in preserving genetic diversity and cultural heritage.

Conservation breeding methods are integral to maintaining crop diversity, addressing emerging challenges, and promoting sustainable agriculture while involving farmers and communities in the process. These approaches collectively contribute to the resilience and adaptability of crop varieties in a changing world.

Advanced conservation approaches

Advanced conservation approaches for preserving millet genetic resources encompass a diverse range of techniques and facilities. These approaches go beyond traditional seed banking and offer innovative solutions for safeguarding genetic diversity. Here are explanations of some advanced conservation approaches:

1. **Seed Bank**: Seed banks are essential repositories for conserving millet genetic diversity. They store seeds of various millet landraces and varieties under controlled conditions, ensuring their long-term viability. These seeds can be used for research, breeding, and crop improvement.
2. **DNA Bank**: DNA banks focus on preserving genetic information in the form of DNA samples. They store genetic material extracted from millet crops, allowing for molecular studies, genetic analysis, and potential future regeneration of plants from stored DNA.
3. **Tissue Bank**: Tissue banks store plant tissues, such as shoot tips, embryos, or meristems, in a cryopreserved state. This method offers an alternative to seed banking and is particularly useful for conserving recalcitrant or difficult-to-store species.
4. **Cryo Bank**: Cryo banks use ultra-low temperatures to preserve plant materials, including seeds, tissues, or embryos, in a frozen state. Cryopreservation ensures long-term survival and regeneration potential, especially for species sensitive to desiccation.
5. **Evolutionary Population**: This approach involves the establishment and maintenance of populations of millet varieties that allow for ongoing evolution and adaptation to changing environmental conditions. It supports the development of resilient and locally adapted millet populations.
6. **Agro Gene Sanctuary**: Agro gene sanctuaries are designated areas where traditional landraces and heirloom millet varieties are conserved in their natural agro-ecosystems. These sanctuaries protect the genetic diversity of millet crops within their native environments.

Each of these advanced conservation approaches serves a specific purpose and offers unique advantages in preserving millet genetic resources. By employing a combination of these techniques, conservationists can ensure the resilience and availability of millet varieties for future generations, even in the face of changing environmental conditions and emerging challenges.

Conservation Status

Following the establishment of a National Genebank in Nepal in 2010, the country has made significant strides in the conservation of millet genetic resources. Currently, a total of 1,056 accessions representing seven millet species are carefully preserved in Long-term and Medium-term storage conditions at the Khumaltar facility (**Table 2**). Notably, among these accessions, there is one particularly wild finger millet accession, highlighting the importance of preserving wild genetic diversity for future breeding and research purposes. The comprehensive collection efforts extended to a remarkable 70 districts across Nepal, reflecting a wide-reaching and inclusive approach to millet genetic resource conservation. The geographic distribution of these collected accessions is illustrated in the collection map (**Figure 10**), providing valuable insights into the regional diversity of millet genetic resources in Nepal. Among the districts, Baglung emerges as a significant contributor to the genebank, with the highest number of collections (77), followed closely by Dolakha (74). Furthermore, it's noteworthy that collections of finger millet, one of the most important millet species, constitute a significant portion of the conserved genetic resources (989 accessions), underlining the emphasis on its preservation and potential for future agricultural and research applications. Accessions which were collected from the highest and the lowest altitude, longitude and latitude are given in (**Table 3**).

Table 2. Number of accessions of millet crops collected from different districts and conserved in Nepal Genebank, Kathmandu

SN	District	Barnyard	Finger	Foxtail	Little	Porso	Sorghum	Wild Finger	Total
1	Achham		3						3
2	Arghakhanchi		15						15
3	Baglung		77						77
4	Baitadi		16						16
5	Baitadi		3						3
6	Bajhang		19	1		1			21
7	Bajura		6	1			1		8
8	Bara		3						3
9	Bardiya							1	1
10	Bhojpur		10						10
11	Chitawan		2						2
12	Dadeldhura		12	1					13
13	Dailekh		18						18
14	Dang						1		1
15	Darchula		18						18
16	Dhading		28						28
17	Dhankuta		14						14
18	Dolakha		74						74
19	Dolakha		2						2
20	Dolpa		2						2
21	Doti		22						22
22	Gorkha	1	23						24
23	Gorkha		5						5
24	Gulmi		5						5
25	Humla		10	15		1			26
26	Ilam		24						24
27	Jajarkot		14	1					15
28	Jhapa		2						2
29	Jumla		25	10		6			41
30	Jumla		1						1
31	Kailali		7	1					8
32	Kalikot		3						3
33	Kanchanpur		2						2
34	Kapilvastu		2						2
35	Kaski		33						33
36	Kavreplanchok		24	1					25
37	Khotang		12						12
38	Lalitpur		7						7
39	Lamjung		27	11		3			41
40	Makawanpur		7						7
41	Mugu		14			1			15

SN	District	Barnyard	Finger	Foxtail	Little	Porso	Sorghum	Wild Finger	Total
42	Mustang		7						7
43	Myagdi		20						20
44	Nawalpur		4						4
45	Nuwakot		18						18
46	Okhaldhunga		20		1				21
47	Paachthar		3						3
48	Palpa		30						30
49	Panchthar		3						3
50	Parbat		46						46
51	Pyuthan		5						5
52	Ramechhap		38	2		1	1		42
53	Rasuwa		26						26
54	Rautahat	2							2
55	Rolpa		1						1
56	Rukum		14						14
57	Sallyan		7						7
58	Sankhuwasabha		7						7
59	Sindhuli		13	1			1		15
60	Sindhupalchok		39						39
61	Siraha		1						1
62	Solukhumbu		15						15
63	Sunsari		4						4
64	Sunsari		1						1
65	Surkhet		5						5
66	Syangja		22						22
67	Tanahu		35						35
68	Taplejung		5						5
69	Terhathum		3						3
70	Udayapur		6						6
	Total	3	989	45	1	13	4	1	1056

Source: Joshi et al 2023a, 2023b

Table 3. Accessions collected from the highest and the lowest altitude, longitude and latitude

Accession	Crop	District	Site	Longitude, E	Latitude, N	Altitude, m
Altitude, m						
NGRC08311	Barnyard Millet	Rautahat	Jayanagar	26.91793	85.31055	64
NGRC03520	Finger millet	Darchula	Bamkha	29.90000	80.92000	3677
Longitude, E						
NGRC08868	Finger millet	Kanchanpur	Belauri	28.68551	80.35117	
NGRC01407	Finger millet	Ilam	Shirpugaun	26.88986	88.11964	
Latitude, N						
NGRC09977	Finger millet	Udayapur	Triyuga	26.42345	86.73983	628
NGRC03593	Finger millet	Humla		30.05900	82.07930	

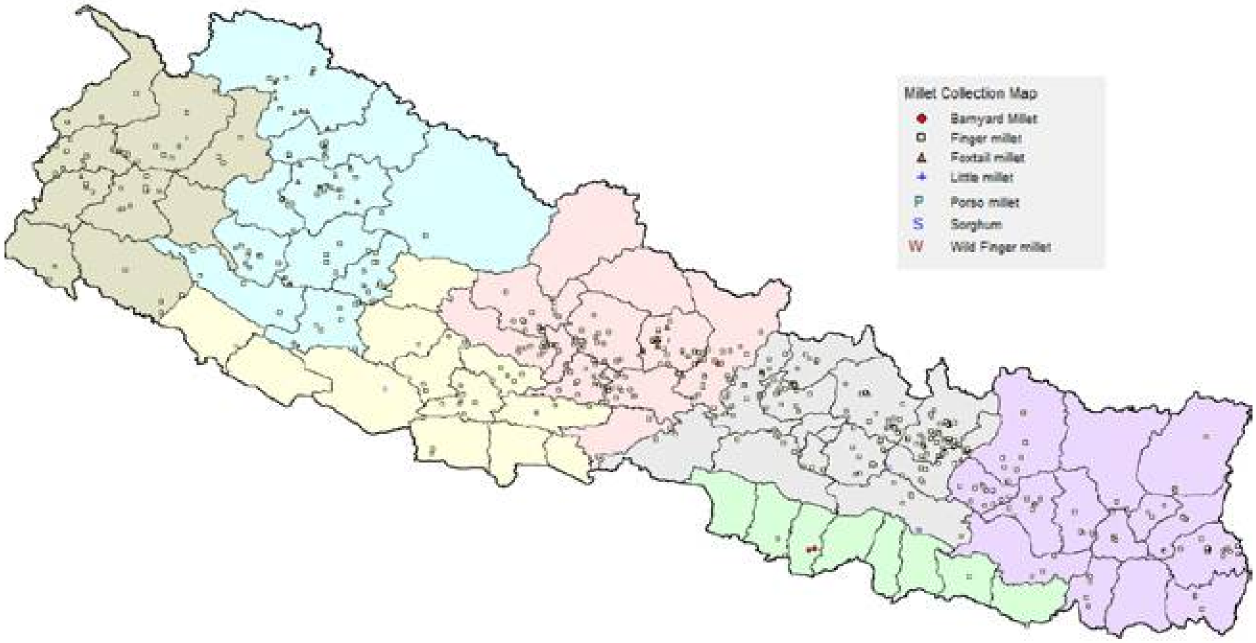

Figure 10. Collection map of millet accessions conserved in Nepal genebank

Before the establishment of a National Genebank in Nepal, the Agriculture Botany Division of the National Agriculture Research Council (NARC) had undertaken the collection and conservation of a total of 975 accessions of five different millet crops (**Table 4**). These valuable genetic resources were stored in Medium Term Storage facilities located in Khumaltar. The collection efforts spanned across a wide geographical range, with accessions gathered from a total of 63 districts in Nepal. This collection initiative commenced in 1984, signifying a substantial and long-standing commitment to preserving the genetic diversity of millet crops in the country. Notably, among the districts, Kanchanpur and Bajura emerged as the primary sources of these collections, highlighting their significance in contributing to the genetic diversity of millet crops in Nepal's agricultural landscape.

Table 4. Collection number of millet crops before 2010 in Agriculture Botany Division, NARC

SN	District	Barnyard millet	Finger millet	Foxtail millet	Proso millet	Sorghum	Total
1	Achham		10				10
2	Arghakhanchi		13				13
3	Baglung		20			4	24
4	Baitadi		10	1			11
5	Bajhang		9	8	1	2	20
6	Bajura		30	2	1	2	35
7	Banke		2				2
8	Bara		1				1
9	Bhojpur		11			1	12
10	Dandeldhura		11	6			17
11	Dang		1				1
12	Darchula		7	2			9
13	Dhading		18	2	2		22
14	Dhankuta		5				5
15	Dhanusha		9				9
16	Dolkha		28				28

SN	District	Barnyard millet	Finger millet	Foxtail millet	Proso millet	Sorghum	Total
17	Dolpa		10		3		13
18	Doti		23	1		1	25
19	Gorkha		24				24
20	Gulmi		24				24
21	Humla		24	3	3	1	31
22	Ilam		22				22
23	Jajarkot		6				6
24	Jhapa		6			2	8
25	Jumla		24	4	4		32
26	Kabhre		4				4
27	Kalikot		3	2	1	1	7
28	Kanchanpur		1				1
29	Kaski		110			1	111
30	Khotang		10	1			11
31	Lamjung		29	4		1	34
32	Mahottary		4				4
33	Manang			1			1
34	Morang		2			1	3
35	Mugu		13	2	2		17
36	Mustang		7				7
37	Myagdi		27			5	32
38	Okhaldhunga		17		1		18
39	Palpa		2				2
40	Panchthar		8				8
41	Parbat		6				6
42	Parsa		1				1
43	Ramechhap		29				29
44	Rasuwa		17				17
45	Rautahat		2			1	3
46	Rolpa		6				6
47	Rukum		12			1	13
48	Rupandehi		1				1
49	Sallyan		16			1	17
50	Sankhuwasabha		5				5
51	Saptari		2			1	3
52	Sarlahi		1				1
53	Sindhuli		2				2
54	Sindhupalchok		12				12
55	Siraha		2			1	3
56	Solukhumbu		21				21
57	Sunsari		1				1
58	Syangja		34				34
59	Tanahun		22				22
60	Taplejung		11				11
61	Terhathum		14				14
62	Udaypur		1				1
63	Unknown	1	76	2	2	7	88
	Total	1	879	41	20	34	975

Source: Gupta et al 2000 (updated)

The Nepal Genebank, dedicated to the conservation and preservation of millet genetic resources, conducts a wide array of essential activities. These encompass exploration and collection efforts to acquire diverse millet germplasm from various regions. Upon collection, the bank undertakes rigorous processes such as registration, seed testing, and processing to ensure the genetic integrity and viability of stored materials. Conservation measures are applied through long-term storage, and periodic regeneration and multiplication are carried out to maintain the vitality of millet accessions. Viability monitoring, characterization, and evaluation activities help in assessing the health and traits of stored genetic resources. Moreover, genotyping, screening, and pre-breeding activities contribute to genetic improvement and adaptability. The bank also facilitates the distribution and exchange of materials to support research and breeding programs while efficiently managing extensive databases to organize and document its invaluable collection.

Nepalese Millets Around the World

Nepal's rich millet diversity is well-preserved in foreign genebanks, with a total of 1,657 accessions of various millet species (**Table 5**) collected from different parts of Nepal (**Figure 11**). The Genesys Plant Genetic Resources (PGR) data portal serves as a valuable resource for accessing detailed information about these genetic resources. 550 accessions of them, shown in Genesys are carefully curated in the national genebank, contributing to the conservation of indigenous millet varieties. International institutions such as the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) play a pivotal role in this endeavor, holding 1,042 accessions of finger millet, 21 accessions of foxtail millet, 8 accessions of sorghum, and 6 accessions of proso millet. The USDA National Plant Germplasm System, located in Gerdia, USA, and the Institute of Biosciences and BioResources (IBBR) in Italy are also vital contributors, conserving 13 accessions of sorghum and finger millet and 12 accessions of proso millet, respectively. Additionally, the Australian Grains Genebank (AGG) houses 5 accessions of sorghum, while Japan's National Institute of Agrobiological Sciences (NIAS) maintains 459 accessions of various millet species, further enriching the global millet diversity pool. The presence of 20 accessions of four millet species in the USDA-ARS Germplasm Resources Information Network, some dating back to 1966, underscores the long-term commitment to genetic resource conservation. Lastly, the National Bureau of Plant Genetic Resources (NBPGR) in India plays a crucial role, preserving 304 accessions of millet species, with some collected as early as 1961. Notably, 1,077 accessions of Nepalese millet species are safeguarded under the multi-lateral system of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), deposited by ICRISAT. These foreign genebanks collectively form a global network dedicated to conserving the genetic diversity of Nepalese millet species, supporting ongoing research and enabling future advancements in millet agriculture and food security.

Table 5. Nepalese millet accessions conserved in foreign genebanks

Institute and Country	Finger millet	Foxtail millet (Italian millet)	Proso millet (common millet)	Sorghum	Total
NBPGR (National Bureau of Plant Genetic Resources), India		1		6	7
NIAS (National Institute of Agrobiological Sciences), Japan	295	113	46	5	459
GRIN (USDA-ARS Germplasm Resources Information Network), USA	4	3	4	9	20
ICRISAT (International Crop Research Institute for the Semi-Arid Tropics), India	1042	21	6	8	1077
PGRCU (Plant Genetic Resources Conservation Unit), University of Georgia, USDA-ARS, USA	4			9	13
IBBR (Institute of Biosciences and BioResources), Italy			12		12
AGG (Australian Grains Genebank), Australia				5	5

Source: https://www.gene.affrc.go.jp/databases_en.php, https://www.ars-grin.gov/collections, https://www.genesys-pgr.org/a/overview/v2jL86kPY6M, http://genebank.nbpgr.ernet.in/SeedBank/CountryCropGrWise.aspx?cnt=NEPAL

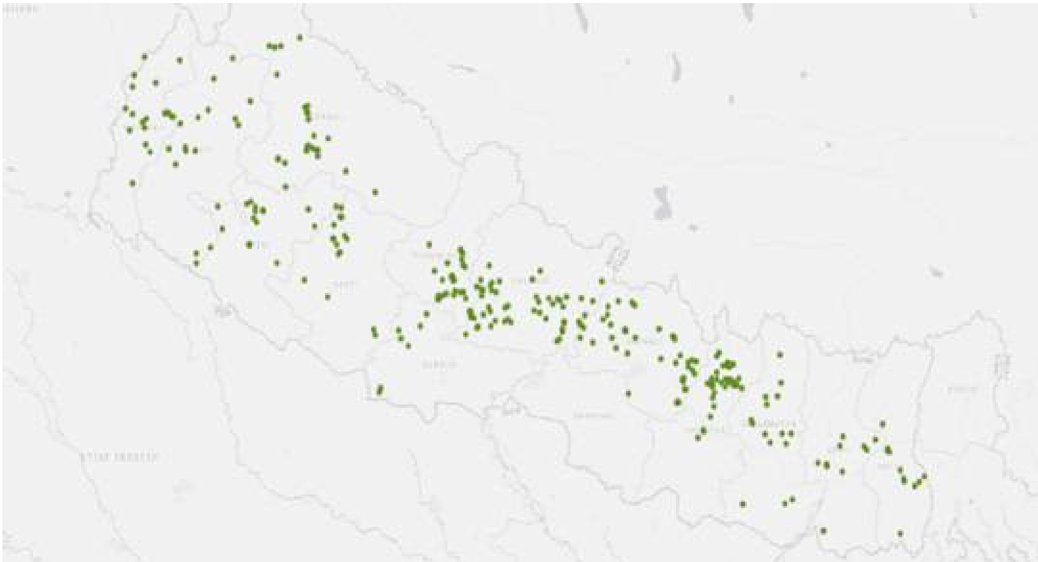

Figure 11. Collection sites of 624 millets accessions (finger millet, foxtail millet, proso millet and sorghum) available through Genesys

Utilization

Millet species, mainly finger millet, proso millet, foxtail millet, and sorghum, play a significant role in Nepal's agricultural landscape. Finger millet has been most commonly utilized and rest are not (Joshi et al 2023b). Many accessions of finger, proso, foxtail and sorghum have been characterized and evaluated in Nepal. This research helps identify traits such as yield potential, disease resistance, and adaptability to local conditions. In Nepal, several varieties of millets have been developed and released for cultivation. Specifically, six varieties of finger millet and one variety each of foxtail millet and proso millet have been released and registered (**Table 6**). These varieties are likely selected for their suitability to different agro-climatic zones and production systems in Nepal. Millets are not only grown for grain production but also for forage. They can serve as valuable fodder for livestock, particularly in areas with limited grazing resources.

Millets are integrated very poorly into the education system in Nepal. MSc theses (by RB Khadka and S Acharya) as well as PhD theses (by KH Ghimire) on finger millet are few examples. These research efforts contribute to a better understanding of millet cultivation, genetics, and agronomy. Although there is limited utilization in the context of health and nutrition, millets have the potential to play a crucial role in improving the nutritional and health status of the population. Millets are highly nutritious, gluten-free grains rich in minerals, dietary fiber, and essential nutrients. Promoting millet consumption can have a positive impact on addressing malnutrition and dietary diversification. There are no specific studies on the ecological services and environmental benefits of millet cultivation. However, millets are known for their adaptability to diverse agro-ecological conditions, and their cultivation can have potential benefits for soil health and conservation. There is room for further exploration of millets' potential in promoting health and nutrition, as well as assessing their ecological services and environmental impact. These areas may offer opportunities for future research and development efforts in Nepal.

Table 6. Released and registered (R&R) varieties of millet crops in Nepal

SN	Common crop	नेपाली नाम	R&R variety
1	Barnyard millet, Japanese millet	सामा	X
2	Bristly foxtail millet	झुसे कागुनो घाँस	X
3	Browntop millet	बाँसपाते कोदो	X
4	Finger millet	कोदो	Raato kodo, Kaabre kodo-1, Okhale-1, Dalle-1, Kaabre kodo-2, Sailung kodo-1
5	Foxtail millet	कागुनो	Bariyo kaaguno
6	Job's tear millet	भिर्कौलो, जोगी माला	X
7	Kodo millet	कोदी	X
8	Little millet	धानकोदो, सुजीकोदो, कुट्की	X
9	Pearl millet	घोगे, बाज्रा	X
10	Proso millet	चिनो	Dhude chino
11	Sorghum	जुनेलो	X

Source: Joshi et al 2017b

Strategy and Action Plan

The conservation and utilization of millet genetic resources, coupled with traditional knowledge, require a comprehensive strategy and action plan to ensure the resilience and sustainability of these vital crops. Here's an overview of key strategies and action plans:

- **Multiple Conservation Strategies:** Implement a range of conservation approaches, including in-situ, ex-situ, and on-farm conservation, to preserve millet genetic diversity.
- **Site-Specific Varieties and Landraces:** Promote the development and cultivation of site-specific millet varieties and traditional landraces adapted to local agro-ecosystems, ensuring resilience and productivity.
- **Multistakeholder Engagement:** Involve various stakeholders, including farmers, researchers, policymakers, and civil society, in conservation efforts to facilitate knowledge exchange, collaboration, and collective action.
- **Investment:** Allocate resources and funding for millet conservation programs, research, infrastructure development, and capacity-building initiatives.
- **Education and Awareness:** Educate communities, farmers, and consumers about the nutritional, health, and environmental benefits of millets. Raise awareness about the cultural and economic significance of millet crops.
- **Research and Extension:** Conduct research on millet genetics, breeding, and agronomy to develop improved varieties and sustainable farming practices. Extend research findings to farmers through extension services.
- **Value Chain Enhancement:** Strengthen millet value chains by promoting processing, marketing, and product diversification. Encourage businesses to invest in millet-based products, creating market opportunities.
- **Conservation of Traditional Knowledge:** Document and preserve traditional knowledge related to millet cultivation, processing, and utilization. Incorporate indigenous practices into modern conservation and farming methods.
- **Food, Nutrition, Health, Business, and Environmental Security:** Emphasize the multifaceted value of millets in addressing food and nutrition security, improving health outcomes, supporting local businesses, and enhancing environmental sustainability.

- **Policy Support:** Advocate for policies that recognize the importance of millet crops in food security and sustainable agriculture. Encourage government support for millet research, conservation, and market access.

By implementing these strategies and action plans, stakeholders should work together to ensure the conservation, utilization, and promotion of millet genetic resources, contributing to the well-being of communities, the environment, and the resilience of agriculture in the face of global challenges.

Conclusion

The conservation of millet genetic resources in Nepal has a rich history dating back to a very early period. Collections have been made from all major districts, and these valuable genetic resources are now conserved in numerous seed banks, both at the national and foreign levels. Multiple strategies have been employed, along with various actions, although the focus has been primarily on a few millet species. To enhance millet genetic diversity conservation, it is imperative to expand efforts to cover all millet species and adopt a dynamic mode of conservation through utilization. Collaboration with multiple partners across the country is essential to ensure the success of these initiatives. Additionally, considering the growing importance of millets in nutrition and food security, the establishment of a national millets research program or center can further drive research, development, and promotion of millets as a vital component of sustainable agriculture and food systems in Nepal.

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On-Farm Experiment to Assess the Suitability of Millet Types and Landraces

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Abstract

In Nepal's Himalayan regions, millets hold significance as resilient cereal crops, valued for their nutrition and adaptability to challenging climates and contributing to food and nutrition security. However, their cultivation and consumption have declined due to shifting food preferences, market constraints, climate change, pests, and diseases. The on-farm experiment was conducted in Bajura to address these challenges, allowing farmers to directly experience the benefits of millet cultivation and select landraces based on desired parameters. The on-farm experiment featured five millet types ie finger millet, sorghum, foxtail millet, barnyard millet, and porso-millet and 14 landraces collected from the local farmers, diversity fairs, seed exchange, and the National Agriculture Genetic Resource Centre (Gene Bank). Agro-morphological parameters such as plant height, days to flowering, seed yield, disease, plant resistance to disease, and pests were monitored by farmers, revealing significant diversity among millet landraces and millet types. Proso-millet emerged as a standout performer, displaying a shorter day to maturity, moderate disease resistance, and a high yield of 1.7 tons per hectare. Finger millet, while yielding up to 0.9 tons per hectare, exhibited disease susceptibility. Sorghum's *Jera Sthaniya* demonstrates high disease resistance with a 0% incidence of blast disease, making it a promising choice for disease-prone regions. Foxtail millet exhibited moderate disease resistance, yielding 0.8 tons per hectare. Notably, local millet landraces consistently outperformed imported landraces in disease resistance and yield, underscoring the value of preserving indigenous genetic resources. Collaborative efforts between farmers and researchers provide immediate benefits and support the long-term conservation and improvement of millet crops.

Keywords: Agricultural resilience, agro-morphological parameters, food security, landraces, millets, on farm experiment.

Introduction

Millets are a group of small-seeded cereal crops renowned for their remarkable adaptability to various challenging agro-ecological environments (Fuller 2014). In the Himalayan regions of Nepal, millets have served as cornerstones of sustenance and culture for generations (Kumar et al 2018). These hardy cereal crops are renowned for their remarkable adaptability to various challenging agro-ecological environments, including the demanding climatic conditions of Nepal's high mountains (Sukumaran Sreekala et al 2023).

There are 12 cultivated millet species, nine wild relative species, and 1,100 millet landraces in Nepal. Finger millet is the most important crop in area and production, followed by proso millet and foxtail millet. Sorghum, barnyard millet, pearl millet, little millet, and kodo millet are also grown in some parts of the country (Ghimire et al 2017, NARC 2023). Millet's historical significance is deeply rooted in their role as not just sources of nutrition but as symbols of resilience against the backdrop of challenging terrain and unpredictable weather patterns. Millets, serving as staple food sources, have played a pivotal role in bolstering food security, and sustaining the livelihoods of local communities in these regions (FAO 2023).

However, the traditional cultivation and consumption of millets have experienced a gradual decline, influenced by a constellation of factors (Kumar et al 2018). Rapid changes in dietary preferences driven by urbanization, limited availability of diverse millet varieties, and the pervasive influence of mainstream crops have shifted the landscape of agricultural practices (de Bruin et al 2021). Modern market constraints and the allure of alternative food sources have further marginalized millets, diminishing their once-central status (Hawkes et al 2017). The CBS annual household survey data presents a significant shift in consumer preferences between 2015/16 and 2016/17, with a marked decrease in urban millet consumption and a slight dip in rural areas. This shift is notable as only 3.5 percent of households nationwide now opt for millet as a dietary choice. Similarly, Thapa et al (2019) studied dietary patterns from 1993 to 2011 in Nepal unveiled a gradual transformation in consumer choices. Nepalese consumers moved from low-cost, calorie-rich foods to more expensive, calorie-dense alternatives. This shift in dietary preferences was facilitated by factors such as rising income levels, evolving lifestyles, and other contributing elements. Over the past 32 years (1990/91 to 2021/22), Nepal's millet cultivation area has remained relatively stable despite a decrease in the percentage of agricultural households. While total millet production has shown an upward trend, it falls short of making Nepal self-sufficient in cereal production (MoAD 2015, MoALD 2023). The country's heavy reliance on millet imports is evident, substantially increasing from Rs 722 million in 2021/22 to Rs 732 million in 2022/23 (TAE 2023).

Millet faces several constraints and challenges in Nepal's food system. Policy constraints hinder the effective implementation of well-intentioned millet promotion policies due to inadequate coordination (Gyawali 2021), limited resources, political instability (Joshi and Joshi 2021), and a lack of evidence-based research (Khadka et al 2014). Market challenges include poor access, lack of standards, certifications, branding, and market information. From a consumer perspective, millet is often perceived as a crop for the marginalized, with low social status compared to rice and wheat (de Bruin et al 2021). Technological constraints involve labour-intensive processes, a need for improved seed varieties, and inadequate equipment (Gyawali 2021, Shrestha et al 2020). Behavioural issues include negative perceptions of millet and a lack of awareness of its nutritional benefits. Disappearing culinary traditions compound the problem, as more convenient options replace millet due to urbanization and globalization.

Bajura is one of the remote areas of Nepal that lies in 77th position in terms of the Human Development Index (HDI) with the lowest value (0.364) (Human Development Report 2015). About 71% of Bajura's households live below the poverty line (Human Development Report 2020). The Agricultural Knowledge Centre (AKC) in Bajura has reported a production of 5,250 metric tonnes from 50,250 hectares of land in the fiscal year 2021/2022. This trend has been declining due to the lack of facilities such as market access, road transportation, agri-input facilities, and storage facilities. Due to all these factors and the low production potential of indigenous crops, the farmers are shifting cultivation to paddy and wheat crops using improved and hybrid varieties. According to a news report by The Rising Nepal (2021), millet production in the Bajura district is only 15% compared to native crops such as paddy and wheat. In the past, farmers used to grow mainly landrace such as proso millet (*Kathine Chino, Mal Chino, Aulo Chino,* *Dudhe Chino, Lekali Chino*), foxtail millet (*Rato Kaguno, Seto Kaguno, Bariyo Kaguno*), barnyard millet, sorghum (*Hunalo, Junalo*), finger millet (*Kano Kodo, Kalo Kodo, Goro Koda, Laafre Kodo, Dalle kodo*), buckwheat (*Tite Phapar, Mithe Faapar, Bhadule Fapar*), barley (*Thanga jau, Jhuse jau, Lekali Jau*), local landrace of rice (*Jumli Marsi, Satuke, Thapa Chino, Kalo Dhan*) and wheat (*Mule Gahu, Jhuse Gahu, Rato Bhabri, Seto Bhabri, Ramale, Geru Gahu).* However, most landraces are in the extinction phase or have disappeared completely.

Compounding these issues is the shadow cast by climate change, which has introduced a layer of uncertainty and instability to agricultural systems. The emergence of new pests and diseases, often facilitated by changing climatic conditions, has added to the challenges farmers face (FAO 2023). In the face of these multifaceted challenges, there is a pressing need for innovative approaches that revive millet cultivation and enhance its resilience in an increasingly unpredictable environment.

In the Bajura district of Nepal, an on-farm experiment is being conducted to find the suitable millet type and landrace at Bajura district. Moreover, it shows the diversity of millet types and landrace among farmers. It aimed to create a platform for farmers to directly experience the benefits of millet cultivation and collaboratively select specific landraces based on desired parameters. This experiment bridges traditional wisdom and modern agricultural science, creating a dynamic platform to test the boundaries of millet cultivation under real-world conditions. The experiment features a curated selection of five millet types-finger millet, sorghum, foxtail millet, and proso millet—alongside 15 distinct landraces, providing an experimental arena for exploring the possibilities of millet cultivation.

The core philosophy of the on-farm experiment centres on experiential learning and active collaboration with the primary stewards of these lands—the farmers themselves. By blending local wisdom and external expertise, the on-farm experiment harnesses the power of traditional knowledge while infusing it with scientific rigour. This synergy creates an environment where farmers can directly witness the benefits of diverse millet landrace, helping them make informed decisions about which landrace best suits their specific needs and the demands of their local ecosystems.

Methodologies

The study was conducted in the Swamikartik Khapar rural municipality, Ward 5, Jera of Bajura district, Nepal. The study site has a long history of growing millet such as finger millet, foxtail millet, proso millet, sorghum, and barnyard millet for consumption. This area's climate and soil conditions are ideal for growing millet, and the farmers have a wealth of knowledge about traditional millet cultivation practices. The region was selected for this study because of its high millet diversity and the farmers' willingness to participate in research.

This study employed an on-farm experiment approach to assess the performance of various millet types (finger millet, foxtail millet, proso millet, sorghum, and barnyard millet) and highlight the rich diversity within the millet group. The on-farm experiment consisted of five millet species and 14 different landraces (**Table 1**), procured from various sources, including local seeds collected from the farmers, seeds collected through diversity fairs and seed exchange programmes, and the National Agriculture Genetic Resource Centre (Gene Bank). Farmers' preferences for specific agro-morphological parameters were considered during the selection process. Each millet landrace was cultivated in plots measuring 2 meters by 3 meters. The experiment was carried out using the Randomized Completely Block Design (RCBD), which is well-suited for our homogeneous field conditions. Each treatment was replicated three times to ensure robust results. All landrace crops and genotypes received the same level of inputs and irrigation to ensure a fair comparison. The plot preparation and plantation were done on June 10, 2023, and the harvesting was done on different dates based on the crops and their landrace. Irrigation and weeding were done twice at 30 DAS and 45 DAS.

The study meticulously recorded data on agro-morphological parameters such as plant height, days to flowering, seed yield, disease incidence, and insect infestation. The disease incidence and insect infestations were recorded based on the farmer's visual observation and the frequency of infection and infestation on plots. This method involves counting the number of plants in a population affected by the disease and dividing that number by the total number of plants in the population. The result is expressed as a percentage. Importantly, this data collection process was carried out in close collaboration with farmers, who actively participated in all experiment stages, from planting to data collection and subsequent analysis.

Using Python, a one-way analysis of variance (ANOVA) was conducted to assess the significance of variations among different millet landraces. Descriptive statistics were employed to comprehensively summarise its agro-morphological parameters for a deeper understanding of the dataset. Moreover, to look at the significance of variances among millet on key parameters (Days to maturity and yield), we aggregated the data by taking the mean of parameters for each landrace to ensure that all groups have the same number of data points before running ANOVA. The ANOVA test was performed at a significance level of 0.05.

Table 1. Millet and landrace selected for the study and their source.

Millet Crops	Landrace	Seed source
Proso Millet	Maal Chino	Swamikartik Khapar RM -5, Jera, Bajura
	Dudhe Chino	Swamikartik Khapar RM -5, Jera, Bajura
	NGRCO 7350	National Agriculture Genetic Resource Center- Genebank
	NGRCO 7345	National Agriculture Genetic Resource Center- Genebank
	NGRCO 7348	National Agriculture Genetic Resource Center- Genebank
Finger Millet	Kaalo Kodo	Budhinanda Municipality -10, Dimmarpani, Bajura
	Dalle Kodo	Budhinanda Municipality -10, Dimmarpani, Bajura
	Laafre Kodo	Budhinanda Municipality -10, Dimmarpani, Bajura
Sorghum	Jeraa Sthaniya	Swamikartik Khapar RM -5, Jera, Bajura
Fox tail millet	Rato kaaguno	Swamikartik Khapar RM -5, Jera, Bajura
	Seto Kaaguno	Himali RM -6, Dhim, Bajura
	Jukot Sthaniya	Swamikartik Khapar RM -3, Jukot, Bajura
Barnyard millet	Jukot Sthaniya Jhumuro	Swamikartik Khapar RM-3, Jukot, Bajura
	Jeraa Sthaniya Jhumuro	Swamikartik Khapar RM -5, Jera, Bajura

Results

Table 2 presented the results of a study that compared various millet landraces of proso millet, finger millet, sorghum, foxtail millet, and barnyard millet across nine agro-morphological parameters. These characteristics included plant height, the number of tillers, the number of leaves, days to 50% flowering, days to 50% maturity, length of panicle, and yield (in kg/ha). The results were reported regarding F-values and p-values, essential statistical measures in the context of ANOVA tests.

For proso millet, the data showed no significant differences among landraces for plant height, number of tillers, number of leaves, days to 50% flowering, panicle length, yield, blast disease, or spot disease incidence. However, the P-value for days to 50% maturity is relatively low, indicating a significant difference in the time it takes for different landraces of proso millet to mature.

On the other hand, the finger millet landrace exhibited significant variation in several important agro-morphological parameters, including plant height, number of tillers, days to 50% flowering, days to 50% maturity, panicle length, yield, and spot disease incidence. This was evident from the relatively low P-values for all these parameters, with the strongest significance observed for days to 50% maturity.

In the foxtail millet, landrace differed significantly in some agro-morphological parameters but not others. For example, the P-values for plant height, days to 50% flowering, days to 50% maturity, panicle length, and blast disease incidence were relatively high, suggesting that the differences in these parameters among landraces were not statistically significant. However, the P-values for F-value, number of tillers, number of leaves, and yield were relatively low, indicating significant differences among landraces in these parameters.

Similarly, barnyard millet landrace exhibited similar mixed results to proso millet. For some agro-morphological parameters, such as plant height, number of tillers, and panicle length, there were significant differences among landrace, as indicated by the relatively low P-values. However, for other parameters, such as a number of leaves, days to 50% maturity, blast disease incidence, and spot disease incidence, the P-values were higher, suggesting no significant differences among landraces.

In the ANOVA analysis conducted among the millet landraces, focusing on two specific parameters, days to maturity and yield, it was found that significant differences exist among the millet landraces for these characteristics.

Table 2. One-way ANNOVA of different landraces of millet

Millet		Plant Height (cm)	No. of Tillers	No. of Leaves	Days to 50% Flowering	Days to 50% Maturity	Length of Panicle (cm)	Yield (kg/ha)	Blast disease	Spot disease incidence
Proso Millet	F-value	0.02	0.60	0.18	0.80	2.30	31.10	39.70	62.13	83.90
	P-value	0.97	0.50	0.90	0.50	0.12	1.14	4.14	5.03	1.18
Finger Millet	F-value	3.25	7.44	0.30	6.21	70.78	17.10	5.16	19.00	1.57
	P-Value	0.11	0.02	0.78	0.03	6.69	0.00	0.05	0.00	0.28
Sorghum		NA	NA	NA	NA	NA	NA	NA		
Foxtail Millet	F-value	2.04	15.34	78.65	33.71	70.87	2.70	3.23	0.38	0.60
	P-Value	0.21	0.01	4.95	0.00	6.69	0.14	0.11	0.70	0.58
Barnyard Millet	F-value	1.89	1.99	0.40	24.99	30.38	0.20	0.79	0.02	0.46
	P-Value	0.24	0.23	0.56	0.01	0.01	0.67	0.79	0.09	0.53
Millet type	F-value						273.78			10.91
	P-Value						3.61			0.00

Finger millet landraces exhibited more extended maturation periods, ranging from 55 to 79 days to flowering and an additional five days to maturity. Sorghum's Jera Sthaniya took 47 days to flower and 65 days to mature. Proso millet's mal Chino landrace offered a shorter day to maturity, with 31 days to flowering and 40 days to maturity. Foxtail and barnyard landraces fell between these ranges, taking 41 to 65 days to flower and 40 to 56 days to reach maturity.

Disease resistance was another critical consideration in crop cultivation. **Figure 1** illustrates the incidence of two common diseases: blast and spot. *Sorghum's Jera Sthaniya* demonstrated excellent disease resistance with a 0% incidence of blast disease, making it a promising choice for disease-prone regions.

However, it did exhibit a 5% incidence rate of spot disease. In contrast, foxtail millet landraces, including *rato kaaguno, seto kaaguno, and jukot sthaniya,* all had a 10% incidence rate for blast and 5% for spot diseases, indicating moderate disease resistance. Finger millet landraces, such as *kaalo kodo, dalle kodo, and laafre kodo,* presented a higher disease susceptibility. They exhibited a 15% incidence rate for blast disease and a 20% incidence rate for spot disease. The cultivation of these landraces necessitated comprehensive disease management strategies to ensure successful crop yields. Proso millet landraces, including mal chino, dudhe chino, NGRCO 7350, NGRCO 7345, and NGRCO 7348, also exhibited varying degrees of disease susceptibility. They ranged from 5% to 21.6% in blast disease incidence and 7% to 16.6% in spot disease incidence. Both local landraces had less disease incidence than those obtained from gene bank. Barnyard millet landraces, including *jukot sthaniya jhumuro and jera sthaniya jhumuro*, displayed a higher incidence of diseases. They both had a 17% incidence rate for blast disease, with the latter landrace demonstrating a 23% incidence rate for spot disease. These millet landraces necessitated robust disease management practices for successful crop production.

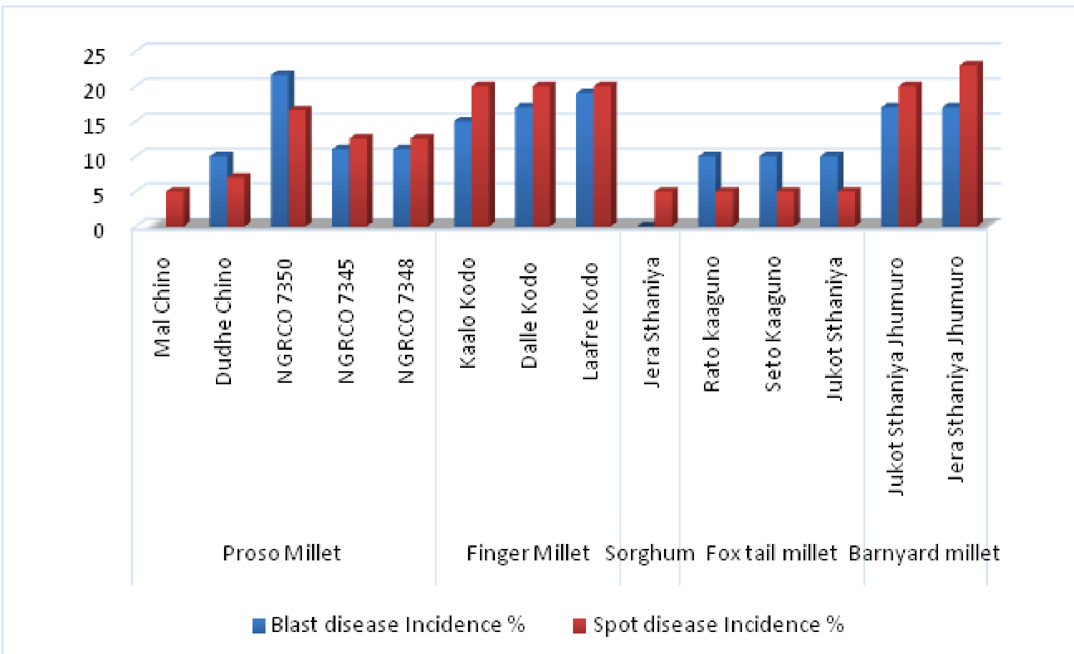

Figure 1. Disease incidence by millet landraces

Finger millet landraces, including kaalo kodo, dalle kodo, and laafre kodo, consistently yielded approximately 0.90 tons per hectare, showcasing their reliability for consistent production. In contrast, proso millet's mal chino landrace had a higher yield, producing 1.70 tons per hectare, making it a robust choice for those seeking higher yields. *Sorghum's jera sthaniya* yielded 0.82 tons per hectare, indicating moderate productivity. Foxtail Millet landraces*, rato kaaguno and seto kaaguno*, yielded 0.70 to 0.80 tons per hectare. Lastly, barnyard millet landraces, *jukot sthaniya jhumuro and jera sthaniya jhumuro,* yielded 0.70 and 0.71 tons per hectare, respectively.

Table 3. Millet mean agro-morphological parameters across various landraces.

S. N	Millet	Landrace	Plant Height	No. of tillers	No. of leaves	Days to 50% flowering	Days to 50% maturity	Yield (Ton/ha)
1	Proso Millet	NGRCO 7350	183.33	7.47	59.13	33.67	43.33	0.80
2		Mal Chino	121.27	12.97	65.70	33.33	45.00	1.70
3		NGRCO 7345	177.13	7.33	56.40	35.33	46.67	0.85
4		Dudhe Chino	194.26	6.84	58.28	36.20	50.00	1.10
5		NGRCO 7348	176.93	6.42	56.20	38.33	52.33	0.88
6	Finger Millet	Kaalo Kodo	72.00	6.67	34.67	55.67	75.00	0.90
7		Dalle Kodo	59.33	3.67	29.67	58.33	79.00	0.87
8		Laafre Kodo	70.00	4.33	31.00	61.33	88.00	0.92
9	Sorghum	Jera Sthaniya	126.00	4.50	30.00	47.00	65.00	0.82
10	Fox tail millet	Rato kaaguno	105.33	3.67	31.33	41.00	65.00	0.70
11		Seto Kaaguno	96.00	12.33	70.00	45.00	57.00	0.80
12		Jukot Sthaniya	108.00	5.33	21.00	49.00	65.67	0.80
13	Barnyard millet	Jukot Sthaniya Jhumuro	96.33	3.33	18.33	47.33	65.33	0.70
14		Jera Sthaniya Jhumuro	82.33	2.67	18.33	49.33	56.00	0.71

Discussion

Days to maturity

Our finding suggested high diversity in terms of the day to maturity of millets. Our finding aligns with a different study conducted in Nepal on different millet, which found that the days maturity of millets can vary from 60 to 150 days (Ghimire et al 2018a, Ghimire et al 2018b, Ghimire et al 2017, Sthapit et al 2003). With the diversity in maturity periods, millet landrace can be grown in various climatic conditions, from the coldest winters to the hottest summers (Patil 2020). For instance, proso millet's *mal chino*, with its relatively shorter days to maturity, could be an excellent choice for regions with shorter growing seasons. Conversely, finger millet's extended maturation period may necessitate meticulous planning to avoid adverse weather conditions. A study by Ceasar et al (2019) found that the maturity period of millets is likely to increase due to rising temperatures. Hence, it will be increasingly important for farmers to choose millet landraces with shorter maturity periods to ensure their crops mature before adverse weather conditions. Millet landraces with varying maturity periods offer flexibility in crop planning, which is crucial for climate resilience. Short-duration millet landraces, such as proso millet, can be cultivated in regions with erratic rainfall, while longer-duration landraces, like finger millet, can withstand extended dry periods (Kumar et al 2013). The staggered maturity periods of millet landraces reduce the risk of total crop failure due to unexpected climate events. For instance, a delayed monsoon may affect one variety but not others, ensuring some level of harvest (Satyavathi et al 2021).

Disease resistance

Most millets showed low to moderate levels of infestation to blast and spot diseases, indicating resistance to these diseases. Various studies reported that millet has specific genes and proteins that help the plant protect itself from the harmful effects of stress (Nagaraja and Das 2016, Shivhare et al 2022). The local landrace exhibits remarkable resistance to both diseases within the millet landrace. Multiple research studies have underscored that local or native crop landraces are often more tolerant to biotic and abiotic stresses than their improved counterparts. It is because local landrace has been selected over generations for their ability to survive in the local environment. They have accumulated genetic mutations that resist pests, diseases, and other environmental stresses (Subbu Thavamurugan et al 2023, Sudisha et al 2012, Tefera et al 2021).

Conversely, the higher incidence rates of blast and spot diseases in some finger millet and barnyard millet landraces emphasize adopting comprehensive, integrated pest management strategies to mitigate disease-related risks (Senthil et al 2018). Consistent with our research, Yoshida et al (2016) also affirmed that blast disease poses the greatest threat to finger millet. It highlights the importance of crop rotation and the meticulous choice of disease-resistant millet landrace as essential measures for minimizing potential yield losses.

Yield considerations

One of the most pivotal aspects of crop selection is yield potential, and (**Table 2**) demonstrates significant yield variations among the diverse millet landraces. Proso millet's *mal chino* landrace is a high-yielding option, boasting an impressive hectare yield of 1.70 tons. Additionally, the finger millet landrace consistently provides a reliable 0.9 ton per hectare yield, reinforcing its reputation as a steady source of millet grain (Upadhyaya et al 2014). These findings underscore the importance of selecting a millet landrace well-suited to specific environmental conditions and yield requirements.

It is worth noting that local millets, especially local proso millet landrace, have demonstrated superior performance, indicating their adaptation to local conditions and climate resilience. This local landrace possesses unique attributes such as local adaptation, climate resilience, genetic diversity, and traditional farming practices, contributing to their consistently high yields (Antony et al 2022, Roe 2010).

However, it is essential to recognize the value of alternative millet landraces as a contingency plan, particularly if local landraces face challenges in the future. A diversified approach to millet cultivation, encompassing both local and alternative landrace, can enhance food security and bolster the resilience of millet-based agriculture (UNEP GEF 2013, Gauchan et al 2019, Gairhe et al 2021).

Farmer's response/perception

The on-farm experiment was established in collaboration with the farmers. The intention of engaging farmers from the land preparation to harvesting the millets was to raise awareness about different millet landraces and their peculiar parameters, such as resistance to disease and pests, days to maturity and productivity. Engaging farmers in the research helped convince them to select the best-performing landraces in their area.

Out of 15 farmers engaged during the on-farm experiment and asked about their opinion on their engagement during the on-farm experiment, more than 90% responded positively, believing that their engagement enhanced their capacity. When asked about the performance and their preference among the cultivated millet types, all of them were fascinated with the performance of sorghum's jera sthaniya, as this landrace showed resistance to blast and spot disease. However, most of the farmers preferred mal chino over other landraces because it had higher production as compared to other landraces.

Picture 1. Farmers measuring plant height of the millet landraces at on-farm experiment at Bajura.
Photo credit: Kailash Bhatta

Picture 2. Tillers of Kalo Kodo. Kalo Kodo are features with compact, round panicles clustered tightly together, like Dalle Kodo except one additional finger at the neck and are adorned with black grains in appearance.
Photo credit: Kailash hatta

Picture 3. Tillers of Laafre Kodo. Laafre kodo possess with long fingers clustered loosely with each other.
Photo credit: Kailash Bhatta

Picture 4. Tillers of Dalle Kodo. Dalle Kodo are showcased with their compact, round panicles tightly clustered together, giving them a small and condensed appearance.
Photo credit: Kailash Bhatta

Conclusion

The findings derived from the on-farm experiment have significant implications for enhancing agricultural resilience. The exceptional performance of proso-millet highlights its potential as a valuable crop for mitigating the impacts of climate change and disease outbreaks. The varying performance of different millet types emphasizes the need for tailored strategies that consider local conditions and preferences. The superior performance of local millet landrace underscores the importance of preserving and effectively utilizing indigenous genetic resources. The on-farm experiment, with the collaborative engagement of farmers and researchers in this process, offers a pathway for immediate benefits and contributes to the long-term conservation and enhancement of millet crops.

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक)। २०८०। राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ।

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सारांश

नेपालमा कोदोजन्य बालीहरूले आर्थिक, सामाजिक, सांस्कृतिक र पर्यावरणीय क्षेत्रमा ठुलो योगदान पुर्याईरहेका छन्। विपन्न वर्गका मानिसहरूको खाद्य सुरक्षा, पोषण, आयआर्जन र जीविकोपार्जनमा यसको विशेष महत्त्व छ। तर आधुनिक कृषिको अनुसरण, उत्पादन तथा प्रशोधनका लागि प्रविधिको अभाव, अनुसन्धान तथा प्रवर्द्धनात्मक कार्यक्रमको कमी, खाद्य संस्कृतिमा आएको परिवर्तन, बसाई सराई र चेतनाको अभावमा कोदोजन्य बालीहरूका स्थानीय जातहरू क्रमशः लोप भईरहेका छन्। विगत केही दशक देखि भने विभिन्न संघसंस्थाहरूको सहजिकरणमा स्थापना भएका सामुदायिक बीउ बैंकहरूले कोदोजन्य बालीहरूको संरक्षण तथा प्रवर्द्धनमा उल्लेखनीय भूमिका निभाईरहेका छन्। हालसालै अद्यावधि गरिएको जानकारी अनुसार सामुदायिक बीउ बैंक संघ नेपालमा आवद्ध सात वटै प्रदेशमा रहेका २३ वटा सामुदायिक बीउ बैंकहरू मध्ये १७ वटा सामुदायिक बीउ बैंकहरूले केही नाम दोहोरिएका जातहरू सहित कोदो, कागुनो, चिनो, जुनेलो र बाजराका ११३ वटा जातहरू सरंक्षण गरेको पाईयो। यी सबै जातहरूको आ-आफ्नै विशेषता र महत्त्व छ। ती जातहरूको संरक्षणको अवस्था हेर्दा धैरै घरधुरीले २३ वटा जातहरू ठुलो क्षेत्रफलमा लगाएका छन्, १२ वटा जातहरू धैरै घरधुरीले सानो क्षेत्रफलमा र बाँकी ७८ वटा जातहरू थोरै घरधुरीले सानो क्षेत्रफलमा मात्र लगाएको पाईयो। सामुदायिक बीउ बैंकहरूले यी जातहरू संरक्षण नगरेका भए थोरै घरधुरीले सानो क्षेत्रफलमा मात्र लगाएका सम्भवत: कतिपय जातहरू लोप भईसकेका हुने थिए। संरक्षणको अलावा सामुदायिक बीउ बैंकहरूले ती स्थानीय जातहरूको नियमित बीउ तथा खाद्यान्न उत्पादन, वितरण, बजारीकरण लगायतका प्रवर्द्धनात्मक कार्यहरू पनि गरिरहेका छन्। सामुदायिक बीउ बैंकहरूले संरक्षण गरेका कोदोजन्य बालीहरूको विस्तृत अध्ययन गर्न भने बाँकी नै छ।

मुख्य शब्दावलीहरू : कोदोजन्य बाली, सामुदायिक बीउ बैंक, संरक्षण, स्थानीय जात

पृष्ठभूमि

नेपालको तराई देखि बेंसी, खोंच, टार, मध्य पहाड र उच्च पहाडी भेगसम्म कोदोजन्य बालीहरूको खेती गरिन्छ। कोदोजन्य बाली अन्तर्गत कोदो, चिनो, कागुनो, जुनेलो, बाजरा लगायतका बाली पर्दछन्। तर कोदो बाहेकका बालीहरूको खेती सिमित स्थानमा मात्र हुने गरेको छ। नेपालमा मूलतः कोदोको प्रशस्त जातीय विविधता पाईन्छ। ग्रामीण क्षेत्रका मानिसहरूको खाद्य सुरक्षा, पोषण र आयआर्जनमा कोदोजन्य बालीको विशेष महत्त्व छ। तर ग्रामीण भेगमा कोदोको पिठोबाट तयार गरिने ढिँडो, रोटी, खोले आदि खाने चलन क्रमशः कम हुँदै गएको छ। यसो हुनुमा यो तयार गर्न झञ्झटिलो हुनु, खान कम स्वादिलो हुनु, हेर्दा त्यति आकर्षक नहुनु, खाद्य परिकारमा विविधकरण नहुनु र यसमा पाईने पोषक तत्वबारे चेतना नहुनु हो। कोदोबाट बनेका परिकारको उपभोग सामाजिक मुल्यमान्यता र प्रतिष्ठासँग पनि जोडिएको हुन्छ। अर्थात् यसलाई विपन्न वर्गका मानिसहरूले खाने अन्नको रुपमा लिईन्छ। तर नेपालको पूर्वी पहाडी भेगका गाउँ तथा बजार क्षेत्रमा कोदोबाट तयार गरिने जाँड, तोङ्बा र रक्सीको ठुलो परिमाणमा वर्षभरी नै कारोवार हुने गरेको छ। धैरै मानिसहरूका लागि यो आयआर्जनको राम्रो स्रोत पनि हो। कतिपय आदिवासी तथा जनजातीहरूले मनाउने विशेष चाडपर्वमा कोदोबाट बनेको जाँड वा रक्सी वा दुवै चिज देउतालाई चढाउने गरिन्छ र पुजाकार्य समाप्त भएपछि त्यसलाई प्रसादको रुपमा उपस्थित मानिसहरूले बाँडीचुँडी ग्रहण गर्ने चलन छ। आदिवासी तथा जनजाती महिलाहरू माईत वा मावल वा अन्य आफन्तकोमा चाडपर्व वा अन्य समयमा भेटघाट गर्न जाँदा कोदोको रक्सी कोसेली लिएर जाने चलन अझ पनि छँदैछ। संखुवासभा जिल्लाको खाँदबारी र तुम्लिङटारमा कोदोबाट बन्ने विशेष पेय पदार्थ 'सरुवा' उपभोक्तामाझ निकै लोकप्रिय छ।

कोदोजन्य बाली उत्पादन गर्दा कुनैपनि किसिमको रासायनिक मल वा विषादीको प्रयोग गर्नु पर्दैन र गरिंदैन पनि । यो बाली सिंचाईको सुविधा नभएको रुखोपाखो जमिनमा खेती गरिन्छ भने धान वा अन्य बाली जस्तो आकाशबाट पर्ने पानीको मात्रा कम वा बढी भएर त्यति फरक पर्दैन । हिउँद महिनामा कोदोको नल (नरुवा) भरपर्दो पशुआहाराको रुपमा प्रयोग गरिन्छ । यसरी हेर्दा सानो दाना फल्ने कोदोको नेपाली समाजमा ठुलो महत्त्व छ भन्ने कुरा स्पष्ट छ। तर कोदो बाली उत्पादन तथा प्रशोधन विधि निकै झञ्झटिलो हुने, उत्पादन कम हुने तर धेरै श्रम गर्नु पर्ने र विशेषतः महिलाहरूले नै कोदोसँग सम्बन्धीत अधिकांश काम गर्नुपर्ने भएकाले यो बाली क्रमशः घट्दो क्रममा छ । त्यसो त युवाहरू कृषि प्रति आकर्षित नहुनु, बैदेशिक रोजगारी र बसाई सराईको व्यापकताले ग्रामीण भेगमा आवश्यक श्रमिक उपलब्ध नहुनु, भौतिक पूर्वाधारको विकास भएपछि बजारमा चामलको सहज आपूर्ती हुनु, कोदोजन्य बाली उत्पादन तथा प्रशोधनका लागि प्रविधि नहुनु र भएका प्रविधिहरूमा पनि कृषकहरूको पहुँच नहुनु कोदोजन्य बालीहरूको उत्पादन तथा प्रवर्द्धनमा देखिएका चुनौतीहरू हुन् । यसको असर कोदोजन्यबाली खेती गर्ने कृषकको संख्या, क्षेत्रफल र जातीय विविधता घट्दो क्रममा रहेको छ ।

नेपालमा कोदोजन्य बालीहरूको प्रवर्द्धनमा देखिएका चुनौतीहरूको सामना गर्न केही सकारात्मक कामहरू पनि भएका छन् । त्यस मध्ये जैविक विविधता, अनुसन्धान तथा विकासका लागि स्थानीय पहल (ली-बर्ड) ले महिलाहरूको कार्यबोझ घटाउनका लागि करिब एक दशक पहिला देखि नै विभिन्न संघसंस्थाहरूसँग सहकार्य गरी कोदो चुट्ने मेशिनको परीक्षण, प्रचारप्रसार र वितरण गर्दै आएको छ । कृषक समुदाय, नेपाल कृषि अनुसन्धान परिषद् र वायोभर्सिटी ईन्टरनेसनलसँग भएको सहकार्यमा चिनो, कागुनो र कोदो बालीका स्थानीय जातहरूमा गरिएको अनुसन्धान र परीक्षणबाट हुम्लाको दुधे चिनो, लमजुङको बरियो कागुनो र जुम्लाको रातो कोदो राष्ट्रिय बीउ बिजन समितिमा दर्ता भएका छन् । कास्की जिल्लामा त्यहाँको लोपोन्मुख सेतो कागुनोको खेती विस्तार, मुल्य अभिवृद्धि र बजारीकरण भएको छ । त्यसैगरी सन् २००३ देखि हालसम्म ली-बर्डले विभिन्न संघसस्थाहरूसँग सहकार्य गरी नेपालको सात वटै प्रदेशमा स्थापना गरिएका २३ वटा सामुदायिक बीउ बैंकहरूले कोदोजन्य बालीका स्थानीय जातहरूको संरक्षण र प्रचारप्रसारमा महत्त्वपूर्ण भूमिका निभाईरहेका छन्। यस कार्यपत्रमा विशेषतः यिनै सामुदायिक बीउ बैंकहरूले कोदोजन्य बालीका स्थानीय जातहरूको संरक्षण तथा प्रवर्द्धनमा पुर्याएको भूमिकाबारे चर्चा गरिएको छ ।

सामुदायिक बीउ बैंकहरूले संरक्षण गरेका कोदोजन्य बालीका स्थानीय जातहरू र तिनको अवस्था

सामुदायिक बीउ बैंकको मुख्य काम स्थानीय बालीहरूको विविधता संरक्षण गर्नु, कृषकहरूमा यसको महत्त्वबारे चेतना जगाउनु, कृषकहरूको माग अनुसार स्थानीय तथा उन्नत जातको बीउ उत्पादन तथा सहज रुपमा विक्रीवितरण गर्नु र स्थानीय जातमा आधारित खाद्य परिकार उत्पादन गरी बजारीकरण गर्नु हो । नेपालमा यो उद्देश्य लिएर धेरै सामुदायिक बीउ बैंकहरू स्थापना भएका छन् र ती मध्ये २३ वटा सामुदायिक बीउ बैंकहरू सामुदायिक बीउ बैंक संघ नेपालमा आबद्ध भएका छन् । सामुदायिक बीउ बैंक संघमा आवद्ध सामुदायिक बीउ बैंकहरूले ७५ बाली प्रजातीका १,४०० भन्दा बढी स्थानीय जातहहरू संरक्षण गरेका छन् । सामुदायिक बीउ बैंक संघमा उपलब्ध तथ्याङक अनुसार २३ वटा सामुदायिक बीउ बैंक मध्ये १७ वटा सामुदायिक बीउ बैंकहहरूले चार प्रजातीका कोदोजन्य बालीहरूका ११३ जात संरक्षण गरेको पाईयो । यसमा कतिपय जातहरू दोहोरिएका पनि छन् (अनुसूची १) । तर यी सबै ११३ जातको संरक्षणको अवस्था एकैनासको छैन । यी मध्ये २० प्रतिशत (२३) जातहरू धेरै कृषकहरूले ठुलो क्षेत्रफलमा लगाएका छन्, ११ प्रतिशत (१२) जातहरू धेरै कृषहरूले लगाएको भएतापनि सानो क्षेत्रफलमा लगाएका छन् र बाँकी ६९ प्रतिशत (७८) जातहरू थोरै घरधुरीले सानो क्षेक्रफलमा मात्र लगाएका छन् (**तालिका १**) । यसबाट के स्पष्ट हुन्छ भने धेरै कृषकहरूले ठुलो क्षेत्रफलमा लगाएका २० प्रतिशत जात र धेरै कृषकहरूले सानो क्षेत्रफलमा लगाएका ११ प्रतिशत जातहरू संरक्षणको हिसाबले तत्कालका लागि चिन्ता गर्नु नपर्ने भएतापनि बाँकी ६९ प्रतिशत जातहरू लोपहुने अवस्थामा रहेको देखिन्छ । सम्भवत सामुदायिक बीउ बैंकहरूले यी जातहरू संरक्षण नगरेका भए ती स्थानबाट कतिपय जातहरू लोप भईसकेको हुने थिए । यसमा अझ मनन् गर्नुपर्ने कुरा के छ भने यहाँ प्रस्तुत गरिएको जानकारी तथा तथ्याङक केही गाउँको अवस्था हो । नेपालमा यस्ता गाउँ हजारौं छन् र ती गाउँहरूमा निश्चय पनि कोदोजन्य बालीका सयौं स्थानीय जातहरू थिए होलान्, ती मध्ये कतिपय अझ पनि खेती भईरहेका होलान् र कतिपय भने लोप भईसके पनि होलान् ।

तालिका १. सामुदायिक बीउ बैंकहरूले संरक्षण गरेका कोदोजन्य बालीका स्थानीय जाातहरूको चारवर्ग विष्लेषण

धेरै घरधुरीले ठुलो क्षेत्रफलमा लगाउने जातहरू	धेरै घरधुरीले सानो क्षेत्रफलमा लगाउने जातहरू
कोदो: डल्ले१, लट्टे१, पहेंलो डल्ले५, च्याल्थे५, लरिबरी५, डल्ले६, मुड्के६, रातो७, डल्ले७, केस्रे७, मंसिरे८, डल्ले८, ठुलो मुड्के१०, लाफ्रे१०, असोजे१०, कार्तिके१०, नङग्रे११, च्याङग्रे११, झ्यापे१३, डल्ले१३, रातो१५, रातो१६, स्थानीय१७ । कुल जम्मा: २३ (२०%)	कोदो: चोगिले१, चमारे८, सेतो झ्यापे८, सेतो८, कालो १६(५) कागुनो: पहेँलो१५, औलेल१५, रातो १५, कालो१६, पहेँले१६ (५) चिनो: हाडे१५, दुधे१६ (२)। कुल जम्मा: १२ (११%)

थोरै घरधुरीले ठुलो क्षेत्रफलमा लगाउने जातहरू कुल जम्मा : ० (०%)	थोरै घरधुरीले सानो क्षेत्रफलमा लगाउने जातहरू कोदो : डाँडा गाउँले१, पाँउदुरे१, मुड्के२, पाँउदुरे२, मंसिरे२, औंला छापे३, मुठिया३, मुना४, झालरी४, नङग्रे५, भोटाङगे५, मुड्के५, लाम्रे५, मंसिरे५, लट्टे५, लुर्के६, कैलो६, झ्यापे६, सेतो६, किर्ने६, छाप्रे६, नङ्ग्रे६, खमलि६, झाप्रे६, मंसिरे६, सम्धी६, पाथ्रोगे६, सेतो डल्ले६, सेतो७, नङग्रे७, झुम्के७, ठुलो डल्ले७, ज्वाँई७, बन्से७, ओख्ले७, झ्यापे७, च्याल्थे७, पाउँदुरे८, कार्तिके८, मुड्के९, सेतो९, पाङदुरे१०, सेतो दुधे१०, तनहुँ१०, सानो मुड्के१०, चम्रे१०, गोर्खाली१०, डल्लो११, पाउँदुरे११, सेतो११, कालो घुँडे१२, सेतो१२, झ्यापे१२, सठिया१३, सम्धी१३, कालो१४, सेतो१४, कालो१५, प्याँचे१६, कालो१७, मुड्के१७ (६१) कागुनो : कागुनो ७, कागुनो १०, बरियो कागुनो ११, कागुनो १२, सेतो १५, रातो १६, कागुनो १७ (७) चिनो : धान कोदो ८, चिनो ११, दुधे१५, रातो १६ (४) जुनेलो : सेतो ६, रातो ६, जुनेलो १०, जुनेलो १०, जुनेलो १२ (५) बाजरा : बाजरा ६(१)। कुल जम्मा : ७८ (६९%)

नोट : यो तालिकामा प्रस्तुत गरिएको विवरण टेलिफोन सम्वादका माध्यमबाट सन् २०२३ को अगस्ट महिनामा संकलन गरिएको हो । जातको पछि राखिएको अंकले अनुसूची १ मा तोकिए अनुसारको सामुदायिक बीउ बैंक क्रमसंख्या जनाउँदछ । एउटै नाम भएका जाात एक भन्दा बढी सामुदायिक बीउ बैंकमा भएकाले केही नाम दोहोरिएका छन् ।

बीउ उत्पादन, वितरण तथा बजारीकरण

सामुदायिक बीउ बैंक पद्धति स्थानीय जातहरूको यथास्थानीय संरक्षण अवधारणामा आधारित छ । अतः सबै सामुदायिक बीउ बैंकहरूले संरक्षण गरेका कोदोजन्य बाली लगायत सबै बालीहरू प्रत्येक वर्ष निश्चित कृषकलाई जिम्मा दिएर वा बीउ उत्पादनका माध्यमबाट वा विविधता प्रदर्शनी स्थल स्थापना गरेर बीउलाई वातावरण अनुकुल वृद्धिविकास हुने क्रमलाई निरन्तरता दिईरहेको छ । विशेषतः धेरै थरिका कोदोका जातहरू संरक्षण गरेका सामुदायिक बीउ बैंकहरू जस्तै पिङडाँडा सामुदायिक बीउ बैंक, जुँगु सामुदायिक बीउ बैंक र पुर्कोट सामुदायिक बीउ बैंकहरूले प्रत्येक वर्ष विविधता प्रदर्शनी स्थल स्थापना गर्दछन् भने अन्य सामुदायिक बीउ बैंकहरूले कृषकहरूलाई बीउ उत्पादनका लागि दिएर र उत्पादित बीउ सामुदायिक बीउ बैंकले खरिद गरेर संरक्षण गरिरहेका छन् । बजारीकरणको सन्दर्भमा घनपोखरा सामुदायिक बीउ बैंकले बरियो कागुनोको बीउ उत्पादन तथा बजारीकरण गरिरहेको छ भने पुर्कोट सामुदायिक बीउ बैंकले पनि कृषकहरूले उत्पादन गरेको कोदोको बीउ खरिद गरेर विक्री गर्ने कार्य गर्दै आएको छ । सामुदायिक बीउ बैंकहरूले वार्षिक रुपमा उत्पादन गर्ने बीउको परिमाण र बीउ लैजाने कृषकको संख्या अनुसूची २ मा प्रस्तुत गरिएको छ ।

जातीय सुधार तथा पञ्जिकरण

ली-बर्ड, नेपाल कृषि अनुसन्धान परिषद् र वायोभर्सिटी ईन्टरनेशनलको अगुवाई तथा सामुदायिक बीउ बैंकको सहभागितामा सञ्चालन गरिएको अनुसन्धानमूलक परियोजनाबाट कोदोजन्य बालीका तीन वटा स्थानीय जातहरू राष्ट्रिय बीउ विजन समितिमा पञ्जिकरण भएका छन् । केही वर्षको अनुसन्धान र जातीय छनोट विधि अपनाएर हुम्लाको छिप्रा सामुदायिक बीउ बैंकको सहभागितामा त्यहाँको दुधे चिनो, जुम्लाको हाँकु सामुदायिक बीउ बैंकको सहभागितामा त्यहाँको रातो कोदो र लमजुङको घनपोखरा सामुदायिक बीउ बैंकको सहभागितामा त्यहाँको बरियो कागुनो पञ्जिकरण गरिएको हो । परियोजना सञ्चालनपुर्व दुधे चिनो र रातो कोदोको खेती प्रशस्त हुने गरेको भए तापनि बरियो कागुनो भने लोप हुने अवस्थामा पुगेको थियो । तर पञ्जिकरण पश्चात् बरियो कागुनोको खेती पुनः विस्तार हुन थालेको छ । यी जातहरूको पञ्जिकरण वि.सं. २०७७ मा भएको हो । पञ्जिकरण भएका जातहरूको स्रोत बीउ तथा कृषकका लागि आवश्यक बीउ उत्पादन तथा विक्रीवितरण गर्ने कार्य सम्बन्धीत सामुदायिक बीउ बैंकहरूले नै गर्दै आएका छन् ।

तालिका २. पञ्जिकरण भएका कोदोजन्य बालीका स्थानीय जातहरूको संक्षिप्त जानकारी

क्र.सं.	संलग्न सामुदायिक बीउ बैंक	बाली	जात	जातीय विशेषता
१.	छिप्रा सामुदायिक बीउ बैंक, खार्पुनाथ गाउँपालिका ४, छिप्रा, हुम्ला	चिनो	दुधे चिनो	दाना सेतो हुन्छ, छिटो पाक्छ, यसबाट भात, खीर र रोटी जस्ता परिकार बनाएर खाईन्छ, बढी फल्ने, सुख्खा तथा रोगकीरा सहने क्षमता छ, पराल अग्लो र पशुहरूले मन पराउने हुन्छ ।
२.	हाँकु सामुदायिक बीउ बैंक, तातोपानी गाउँपालिका ४, ऐनी, जुम्ला	कोदो	रातो कोदो	बोटको उचाइ करिब ११५ से.मी. हुन्छ, डाँठ हल्का पहेँलो मिश्रित सेतो, चौडा र गाँठा भएको हुन्छ, प्रत्येक बालामा नौ वटासम्म औंलाहरू हुन्छन् र दाना गाढा रातो हुन्छ ।
३.	घनपोखरा सामुदायिक बीउ बैंक, मस्र्याङ्दी गाउँपालिका २, रोप्लेफाँट, लमजुङ	कागुनो	बरियो कागुनो	छिटो पाक्छ, डाँठ हरियो रंगको, मसिनो, कडा, जर्रो खालको हुन्छ, पात खस्रो, हरियो रंगको, लाम्चो आकारको तलतिर भुकेको हुन्छ, दाना सानो, गोलो र सेतो रंगको हुन्छ । यसको खीर निकै स्वादिलो हुन्छ ।

Source: www.himalayancrops.org

क्याटलग प्रकाशन

कोदोजन्य बाली मात्र नभएर सम्पूर्ण स्थानीय जातहरूका विषयमा खेती गरिरहेका कृषकहरूसँग प्रशस्त परम्परागत ज्ञान र जानकारी हुन्छ। समयमा नै त्यस्ता जातहरू सम्बन्धी परम्परागत ज्ञान तथा जानकारी अभिलेखिकरण गर्न सकिएको खण्डमा भविष्यमा थप अध्ययन अनुसन्धानका लागि सहज हुन सक्दछ। यिनै कुरालाई मध्यनजर गरी ली-बर्डले साझेदार संघ संस्थासँगको समन्वयमा कृषक सममुदायलाई स्थानीय जातहरूको जातीय सूची पुस्तक अर्थात् क्याटलग प्रकाशन गर्न टेवा पुर्याईरहेको छ। यो कार्य कास्की, लमजुङ, दोलखा, जुम्ला, हुम्ला जिल्लाका सामुदायिक बीउ बैंकहरूले संरक्षण गरेका स्थानीय जातहरूमा केही वर्ष पहिला नै सम्पन्न गरिसकिएको छ। त्यसैगरी अन्तराष्ट्रिय कोदो वर्षको अवसरमा ली-बर्डको सहजिकरणमा सिन्धुपाल्चोक जिल्लाको पिङडाँडा सामुदायिक बीउ बैंकले सुनकोशी गाउँपालिकामा खेती भईरहेका १५ वटा स्थानीय जातका कोदोको सूचि पुस्तिका तयार गरेको छ। सूचि पुस्तिकामा राखिएका जानकारी तथा सुचनाहरू पिङडाँडा सामुदायिक बीउ बैंकले स्थापना गरेको कोदो बालीको विविधता प्रदर्शनी स्थलबाट, खेती गरिरहेका कृषकहरूको अनुभव संकलन गरेर र कृषक समूहमा छलफल गरेर तयार गरिएको हो। सूचि पुस्तिकामा कोदोको जात, पाईने स्थान, उत्पादकत्व, बोटको उचाई, बालाको लम्बाई, बालामा केस्राको संख्या, बाली पाक्ने अवधी, हुलिया, विशेष गुणहरू, प्रयोग र हालको अवस्था जस्ता जानकारी समावेश गरिएको छ। सूचि पुस्तिकामा चार वर्ग विश्लेषण गरी प्रशस्त खेती गरिने र जोखिममा रहेका जातहरूको वर्गीकरण पनि गरिएको छ। साथै सूची पुस्तिकामा राखिएका सबै जातहरू पिङडाँडा सामुदायिक बीउ बैंक मार्फत् संरक्षण गरिएको छ।

विद्यालयको दिवा खाजामा कोदोका परिकार

नेपाल सरकारले सामुदायिक विद्यालयहरूमा दिवा खाजाको व्यवस्थाका लागि रकम विनियोजन गरिरहेको छ। यो रकमबाट विद्यार्थीहरूलाई विभिन्न प्रकारका खाजा खुवाउने गरिन्छ। केही स्थानीय तहहरूमा विद्यार्थीहरूलाई दिईने दिवा खाजामा रैथाने बालीका परिकारहरू समावेश गर्ने गरेको पाईन्छ। यसै क्रममा जैविक विविधता अनुसन्धान तथा विकासका लागि स्थानीय पहल (ली-बर्ड) को पर्यावरणीय कृषि प्रवर्द्धन कार्यक्रम मार्फत् सिन्धुपाल्चोक जिल्लाको पिङडाडा सामुदायिक बीउ बैंकको सहजिकरणमा सुनकोशी गाउँपालिकाको पाँच वटा विद्यालयहरूमा कागुनोको खिर खुवाउने व्यवस्था मिलाईएको थियो। यो कार्य कास्की जिल्लाको अन्नपूर्ण सामुदायिक बीउ बैंकको सहकार्यमा पनि त्यहाँको एक विद्यालयमा गरिएको थियो। त्यसपछि सुनकोशी गाउँपालिका वडा नं ६ को एक सामुदायिक विद्यालयले हप्ताको एक दिन कागुनोको खिर खुवाउने कार्य शुरु गरेको छ। त्यसै गरी कास्की जिल्लाको अन्नपूर्ण गाउँपालिका वडा नं २, नागडाँडामा सञ्चालित अधिकारी बेकरीसँगको सहकार्यमा ३३ प्रतिशत कोदोको पिठो मिश्रण गरी पाउरोटी बनाउने कार्य थालनी गरियो। यसरी उत्पादन गरिएको पाउरोटी शुरुवातमा दुईवटा विद्यालयका विद्यार्थीहरूलाई र त्यहाँका शिक्षकहरूलाई उपलब्ध गराईयो। यस मध्ये अन्नपूर्ण गाउँपालिका वडा नं ३ मा अवस्थित ५०० विद्यार्थी अध्ययन गर्ने बाल मन्दिर माध्यमिक विद्यालयका विद्यार्थीहरूले यो पाउरोटी अत्यन्तै मन पराएपछि उक्त विद्यालयका शिक्षकहरूले हप्ताको एक दिन कोदोको मिश्रणबाट तयार गरिएको पाउरोटी विद्यार्थीहरूलाई दिवा खाजाको रुपमा उपलब्ध गराउन व्यवस्थापन समितिको बैठकमा निर्णय गराउने प्रतिवद्धता गरेका छन्। यसरी विभिन्न विद्यालयहरूले दिवा खाजामा कोदोजन्य बालीबाट तयार गरिने परिकार नियमितरुपमा समावेश गरेमा बालबालीकाको पोषणको अवस्थामा सुधार त हुन्छ नै साथसाथै कोदोजन्य बालीका स्थानीय जातहरूको संरक्षणमा पनि योगदान पुग्ने अपेक्षा गर्न सकिन्छ।

कोदोबालीका स्थानीय जातहरू संरक्षणमा देखिएका समस्या तथा चुनौती

कृषि जैविक विविधता संरक्षणमा संलग्न सामुदायिक बीउ बैंकहरूको आ-आफ्नै समस्या र चुनौतीहरू छन्। कोदोजन्य बालीहरूका स्थानीय जातहरू संरक्षणमा पनि सामुदायिक बीउ बैंकहरूले विभिन्न कठिनाई भोग्दै आईरहेका छन्। कोदो खेती विशेषतः मध्यपहाडी क्षेत्रमा बढी हुन्छ। तर बसाई सराई तथा रोजगारीका लागि विदेश जाने परम्पराले खेतबारी बाँसो रहने क्रम बढ्दो छ। यसले कोदोजन्य बाली संरक्षणमा पनि चुनौती बढेको छ। कोदो खेती अलि झञ्जटिलो हुने, खर्च बढी लाग्ने तर उत्पादन कम हुने भएकाले कृषकहरू अन्य बाली तर्फ बढी आकर्षित छन्। कतिपय स्थानमा बीउ उत्पादन प्लट र विविधता प्रदर्शनी स्थल बाँदरले नोक्सान पुर्याउने गरेको छ भने विविधता प्रदर्शनी स्थल स्थापना गर्न जग्गा भाडा महँगो हुने भएकाले संरक्षण कार्य खर्चिलो बन्दै गईरहेको छ।

कृतज्ञता

यो कार्यपत्र तयारीका लागि कतिपय जानकारी पहिला नै उपलब्ध थिए भने केही जानकारी टेलिफोन सम्वादका माध्यमबाट संकलन गरिएको हो। अतः आवश्यक जानकारी तथा डाटा उपलब्ध गराउने सामुदायिक बीउ बैंकका कर्मचारी तथा सदस्यहरूप्रति हामी आभारी छौं। कोदोजन्य बाली लगायत थुप्रै बालीहरूका स्थानीय जातहरू संरक्षण कार्यमा संलग्न सम्पूर्ण सामुदायिक बीउ बैंकहरूलाई बिशेष धन्यवाद दिन चाहान्छौ।

अनुसूची १. सामुदायिक बीउ बैंकहरूले संरक्षण गरेका कोदो बालीका स्थानीय जाातहरू

क्र. सं.	सामुदायिक बीउ बैंक	ठेगाना	संरक्षण गरेका कोदो बालीका रैथाने जातहरू						जम्मा जात र बाली संख्या
			कोदो	कागुनो	चिनो	जुनेलो	बाजरा	धान कोदो	
१.	तामाफोक सामुदायिक बीउ बैंक	धर्मदेवी नगरपालिका २, तामाफोक, संखुवासभा	डल्ले, चोगिले, डाँडा गाउँले, लट्टे, पाँउदुरे (५)			जुनेलो (१)			६ (२)*
२	शिवगञ्ज सामुदायिक बीउ बैंक	शिवसताक्षी नगरपालिका ७, चन्द्रडाँगी, झापा	मुड्के, पाँउदुरे, मंसिरे (३)						३ (१)
३	चारपाते सामुदायिक बीउ बैंक	ग्रामथान गाउँपालिका १, मोरङ	औंला छापे, मुठिया (२)						२ (१)
४	कचोर्वा सामुदायिक बीउ बैंक	सिम्रौनगढ नगरपालिका ८, कचोर्वा, बारा	मुना, झालरी (२)						२ (१)
५	जुँगु सामुदायिक बीउ बैंक	गौरीशंकर गाउँपालिका १, जुँगु, दोलखा	पहेंलो डल्ले, च्याल्थे, नङग्रे, लरिबरी, भोटाङगे, मुड्के, लाथ्रे, मंसिरे, लट्टे (९)						९ (१)
६	पिङडाँडा सामुदायिक बीउ बैंक	सुनकोशी गाउँपालिका २, ठोकर्पा, सिन्धुपाल्चोक	डल्ले, मुड्के, लुर्के, कैलो, झ्यापे, सेतो, किर्ने, छाप्रे, नङ्ग्रे, खमलि, झाप्रे, मंसिरे, सम्धी, पाश्नोगे, सेतो डल्ले (१५)			सेतो, रातो (२)	बाजरा (१)		१८ (३)
७	दलचोकी सामुदायिक बीउ बैंक	कोन्जोस्योम गाउँपालिका ३, दलचोकी, ललितपुर	रातो, सेतो, डल्ले, नङग्रे, झुम्के, ठुलो डल्ले, ज्वाँई, केस्रे, बन्से, ओख्ले, झ्यापे, च्याल्थे, (१२)	कागुनो (१)					१३ (२)
८	जोगिमारा सामुदायिक बीउ बैंक	बेनिघाट रोराङ गाउँपालिका ९, मझिमटार, धादिङ	पाउँदुरे, कार्तिके, चमारे, मंसिरे, डल्ले, सेतो झ्याँपे, सेतो (७)					धान कोदो (१)	८ (२)
९	अग्यौली सामुदायिक बीउ बैंक	कावासोति नगरपालिका १४, नवलपरासी	मुड्के, सेतो (२)						२ (१)
१०	पुर्कोट सामुदायिक बीउ बैंक	भानु नगरपालिका ७, पुर्कोट तनहुँ	पाङदुरे, ठुलो मुड्के, सेतो दुधे, तनहुँ, लाफ्रे, सानो मुड्के, असोजे, कार्तिके, चम्रे, गोर्खाली (१०)	कागुनो (१)		जुनेलो (१)			१२ (३)
११	घनपोखरा सामुदायिक बीउ बैंक	मस्याङ्दी गाउँपालिका २, रोप्लेफाँट, लमजुङ	डल्लो, नङग्रे, च्याङग्रे, पाउँदुरे, सेतो (५)	बरियो कागुनो (१)	चिनो (१)	जुनेलो (१)			८ (४)
१२	अन्नपुर्ण सामुदायिक बीउ बैंक	अन्नपूर्ण गाउँपालिका ३, मराम्चे, कास्की	कालो घुँडे, सेतो, भmयापे (३)	कागुनो (१)		जुनेलो (१)			५ (३)
१३	आर्बा सामुदायिक बीउ बैंक	पोखरा महानगरपालिका १३, आर्बा, कास्की	सठिया, झ्यापे, डल्ले, सम्धी (४)						४ (१)
१४	सुनौलो सामुदायिक बीउ बैंक	घोराही उपमहानगरपालिका २, रामपुर, दाङ	कालो, सेतो (२)						२ (१)
१५	हाँकु सामुदायिक बीउ बैंक	तातोपानी गाउँपालिका ४, ऐरेनी, जुम्ला	रातो, कालो (२)	सेतो, पहेँलो, औलेल, रातो (३)	हाडे, दुधे (२)				७ (३)
१६	छिप्रा सामूदायिक बीउ बैंक	खार्पुनाथ गाउँपालिका ४, छिप्रा, हुम्ला	रातो, कालो, प्याँचे (३)	कालो, पहेँले, रातो (३)	दुधे, रातो				
१७	घण्टेश्वर सामुदायिक बीउ बैंक	जोरायल गाउँपालिका १, गैरा, डोटी	स्थानीय, कालो, मुड्के (३)	स्थानीय कागुनो (१)					४ (२)
			८९	११	६	६	१	१	११३ (६)

*कोष्टक बाहिरको जात र भित्रको बालीको संख्या

अनुसूची २. सामुदायिक बीउ बैंकहरूबाट हुने बीउ उत्पादन तथा वितरणबारे जानकारी

क्र. सं.	सामुदायिक बीउ बैंक	ठेगाना	कोदोजन्य बालीअनुसार वार्षिक बीउ उत्पादन र वितरण (के.जी.)						जम्मा
			कोदो	कागुनो	चिनो	जुनेलो	बाजरा	धानकोदो	
१.	तामाफोक सामुदायिक बीउ बैंक*	धर्मदेवी नगरपालिका २, तामाफोक, संखुवासभा	–	–	–	–	–		–
२	शिवगञ्ज सामुदायिक बीउ बैंक	शिवसताक्षी नगरपालिका ७, चन्द्रडाँगी, झापा	३ (५)	–	–	–	–	–	३ (५)
३	चारपाते सामुदायिक बीउ बैंक	ग्रामथान गाउँपालिका १, मोरङ	२ (०)	–	–	–	–	–	२ (०)
४	कचोर्वा सामुदायिक बीउ बैंक	सिम्रौनगढ नगरपालिका ८, कचोर्वा, बारा	२ (२)	–	–	–	–	–	२ (२)
५	जुँगु सामुदायिक बीउ बैंक	गौरीशंकर गाउँपालिक १, जुँगु, दोलखा	१५० (२००)	–	–	–	–	–	१५० (२००)
६	पिङडाँडा सामुदायिक बीउ बैंक	सुनकोशी गाउँपालिका २, ठोकर्पा, सिन्धुपाल्चोक	१५ (२६)	२ (३)	१ (०)	१ (२५)	१ (२)	–	२० (५६)
७	दलचोकी सामुदायिक बीउ बैंक	कोन्जोस्योम गाउँपालिका ३, दलचोकी, ललितपुर	१३ (०)	–	–	–	–	–	१३ (०)
८	जोगिमारा सामुदायिक बीउ बैंक	बेनिघाट रोराङ गाउँपालिका ९, मझिमटार, धादिङ	६ (२०)	–	–	–	–	१ (०)	६ (२१)
९	अग्यौली सामुदायिक बीउ बैंक	कावासोति नगरपालिका १४, नवलपरासी	१ (०)	–	–	–	–	–	१ (०)
१०	पुर्कोट सामुदायिक बीउ बैंक	भानु नगरपालिका ७ ,पुर्कोट तनहुँ	४०० (८०)	७ (४)	–	८ (१०)	–	–	४१५ (९४)
११	घनपोखरा सामुदायिक बीउ बैंक	मस्र्याङ्दी गाउँपालिका २, रोप्लेफाँट, लमजुङ	५० (४०)	२०० (५३)	१ (०)	२ (१५)	–	–	२५३ (१०८)
१२	अन्नपुर्ण सामुदायिक बीउ बैंक	अन्नपूर्ण गाउँपालिका ३, मराम्चे, कास्की	८ (०)	५ (५)	–	१ (६)	–	–	१४ (११)
१३	आर्बा सामुदायिक बीउ बैंक	पोखरा महानगरपालिका १३, आर्बा, कास्की	४ (०)	–	–	–	–	–	४ (०)
१४	सुनौलो सामुदायिक बीउ बैंक	घोराही उपमहानगरपालिका २, रामपुर, दाङ	५ (२)	–	–	–	–	–	५ (२)
१५	हाँकु सामुदायिक बीउ बैंक	तातोपानी गाउँपालिका ४, ऐरेनी, जुम्ला	३०० (१८)	१० (१०)	१२ (१३)	–	–	–	३२२ (४१)
१६	छिप्रा सामूदायिक बीउ बैंक	खार्पुनाथ गाउँपालिका ४, छिप्रा, हुम्ला	४० (२०	१५ (१५)	६० (४०)	–	–	–	११५ (७५)
१७	घण्टेश्वर सामुदायिक बीउ बैंक	जोरायल गाउँपालिका १, गैरा, डोटी	१६ (५)	१ (८)	–	–	–	–	१७ (१३)
जम्मा			१०१५ (४१८)	२४० (९८)	७४ (५३)	१२ (५६)	१ (२)	१ (0)	१३४३(६२७)

*दोस्रो चरणमा सम्पर्क हुन नसकेको। कोष्ठक भित्रको तथ्याङकले वि.सं. २०८० मा बीउ लाने कृषकको संख्या जनाउँछ। बीउ उत्पादन परिमाण वि.सं. २०७९ को हो।

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B. Genetics, Breeding and Biotechnology

ख. आनुवंशिक, प्रजनन् र जैविक-प्रविधि

Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Status, Research Achievements and Prospects of Millets in Nepal

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Summary

Minor cereal crops particularly millets such as finger millet, proso millet and foxtail millet play important role in food security of hill and maintain region of Nepal. The productivity of these crops is very low due to lack of high yielding, abiotic and biotic stress tolerant varieties as well as poor practice of improved production technologies. Farmers from mid and high hills have been cultivating these crops in small areas from ancient time. The Hill Crops Research Program (HCRP) has mandate to collect and characterize native and exotic germplasm, conduct on-station and on-farm experiments and recommend for release of varieties as well as develop crop production technologies. In varietal research, efforts are focused on improving local landraces through selection and genetic modification for specific traits while preserving genetic diversity, so that specific cultivars can be developed for different agroecological environments. In addition to HCRP Kabre, it has been conducting collaborative multilocation testing on different agroecological environments: Pakhribas, Lumle, Jumla, Salyan, Dailekh, Surkhet, Doti, and so on. Collaborative research at various research stations, commodity programs and DoARs generate technologies that are appropriate for a specific environment. So far, HCRP has recommended five varieties of finger millet (Okhle-1, Dalle-1, Kabre Kodo-1, Kabre Kodo-2 and Shailung Kodo-1). Similarly, one landrace each of finger millet (Rato Kodo), foxtail millet (Bariyo Kaguno) and proso millet (Dudhe Chino) were registered. Many promising and pipeline varieties are identified through long research efforts. Not only varieties, but crop management technologies are also developed. These varieties and technologies need to be disseminated to the larger farming communities for food and nutrition security of the country.

Keywords: Finger millet, food security, hill crops, minor cereal crops, technologies, varieties

Introduction

In Nepal, diversified crop species are grown depending upon the agroecological environment. Minor cereal crops particularly finger millet, foxtail millet and proso millet are predominantly grown under marginal upland condition of mid and high hills of Nepal (MoALD 2020) where food and nutritional security is a major challenge. These crops thrive well under moisture stress condition and can be grown under marginal, poor soil. Due to enrich in nutrients, many health benefits and climate resilience, these crops are often considered as future smart food crops. Thus, to increase production and productivity of these crops, technologies need to develop which give high yield, better adoption to the biotic and abiotic stress and diversified cropping systems. Developing drought tolerant cultivars appears to be the most promising approach to tackle the water shortage (Dhami et al 2019). Millet cultivars have high yield potential under favorable conditions and are also drought resistant which commences the most promising and deliverable technology for increasing productivity in drought prone areas. These crops provide more balanced diets, diversified income to farmers as well as related sectors of the society, better maintenance of agroecosystems and greater use of marginal lands along with preservation of cultural identity. With a wide gap in variety release and unavailability of new high yielding varieties, farmers are facing different problems in production of the minor crops. Farmers from mid hills and high hills have been cultivating these crops in small areas from ancient time. Only five varieties of finger millet are released whereas one variety each of finger millet, foxtail millet and proso millet are registered so far. These are not sufficient for all agroecological zones and for long time. To improve food insufficiency and malnutrition condition prevailed in the remote hilly areas of the country, production, productivity and consumption of these crops needs to be enhanced. Thus, to increase production and productivity of minor cereal crops, high yielding as well as abiotic and biotic stress tolerant varieties need to be developed.

Finger millet

Trend of Area, Production and Productivity

The area and production trends from 2010 to till 2021 showed a constant trend. However, there has been exponential growth in yield while area and production remaining constant (**Figure 1**).

Figure 1. Area, production and yield trends of finger millet during 2010 to 2021 (MoALD 2022)

In 2021, the area of cultivation of finger millet in Nepal was 265,401 hectares, with a production of 326,443 metric tons and the yield of 1.23 ton per hectare (MoALD 2022). Agro-ecologically most of the finger millet growing area lies under mid hill which accounts 77% of the total area of finger millet followed by mountain 20%) and very limited area in terai which covered only 3% (**Figure 2**). Among the seven provinces, Gandaki province has 33.17 percent of Nepal's total finger millet coverage, followed by Koshi Province (26.68%), Bagmati province (22.61%), Karnali province (7.14%), Sudurpaschim province (5.92%), Lumbini province (3.85%) and Madhesh province (0.62%). Similar trend was seen in production part also where Gandaki province produces 33.07%, followed by Koshi Province (29.66%), Bagmati province (21.71%), Karnali province (6.36%), Sudurpaschim province (5.02%), Lumbini province (3.67%) and Madhesh province (0.51%) respectively (**Figure 3**) (MoALD 2022).

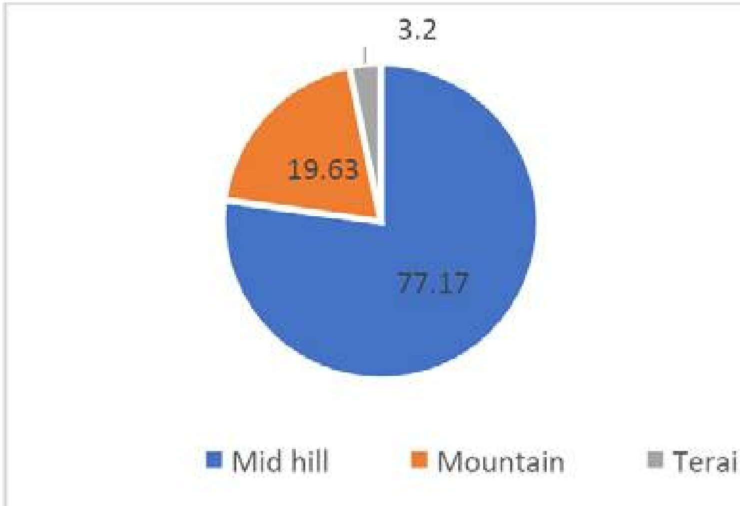

Figure 2. Agro-ecological zone wise Area of finger millet during 2021 (MoALD 2022)

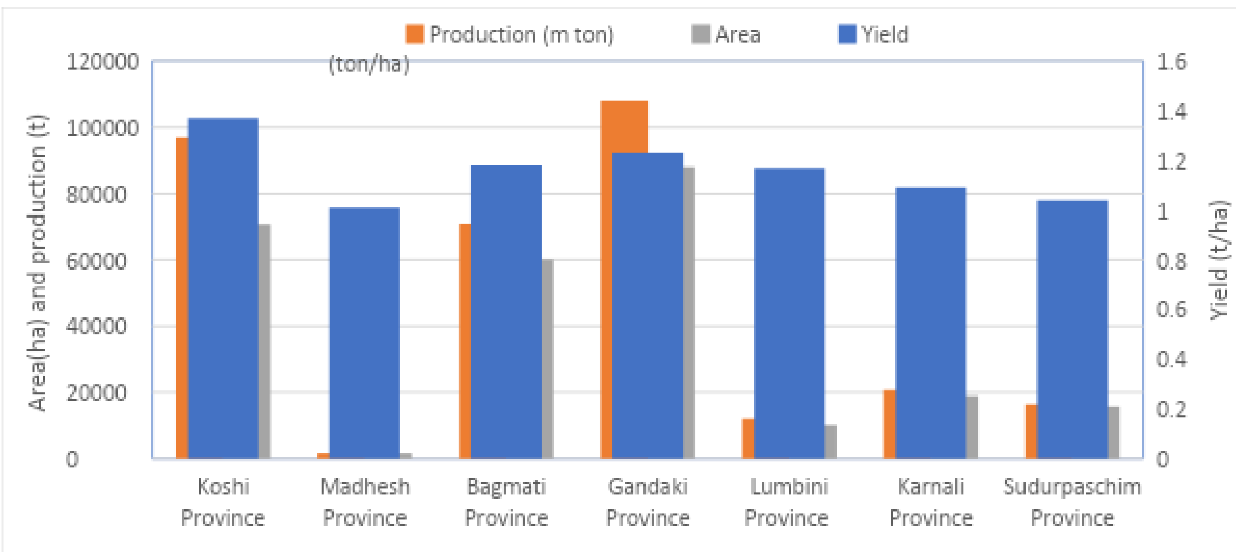

Figure 3. Area, production and yield trends of finger millet province wise during 2021 (MoALD 2022)

Export/Import trends

The trend of export showed that very low amount and value of millet was exported from Nepal as compared to import quantity and value. (**Figure 4** and **Figure 5**). The export quantity was increased during 2014 to 2016 and thereafter decreasing trend. There is sharp increasing trend of millet import quantity and value from 2018 onward.

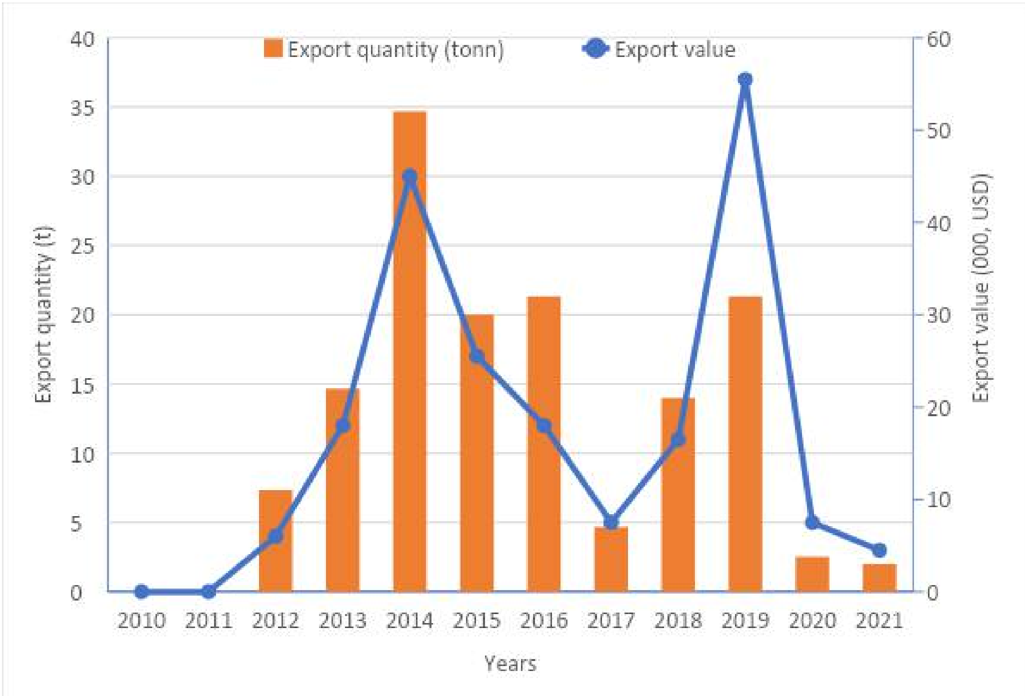

Figure 4. Trend of Export quantity and value of millet during 2010- 2021 (FAOSTAT 2023)

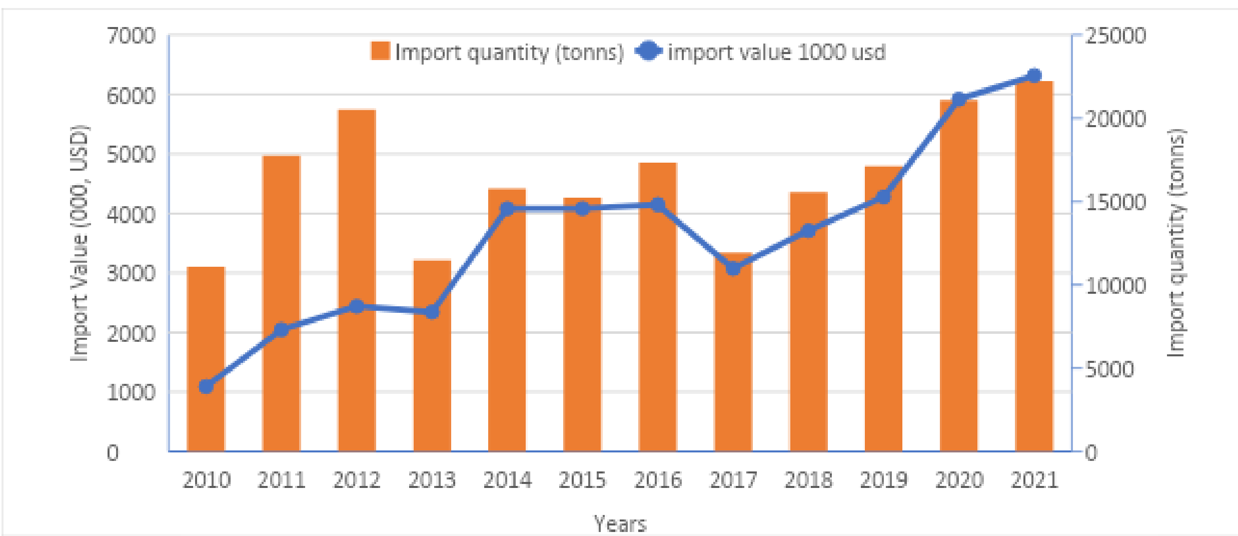

Figure 5. Trend of Import quantity and value of millet during 2010- 2021 (FAOSTAT 2023)

Yield gap

There is a wide yield gap in finger millet. The experimental yield is 3.5 t/ha while the on-farm yield is 2.9 t/ha. The national average yield of finger millet is 1.2 t/ha in Nepal. So, the gap between experimental yield and national yield is about 2.3 t/ha (**Figure 6**). The major factor for the wide yield gap is due to lack of adoption improved varieties, abiotic and biotic stress, poor adoption of improved production technologies and growing on marginal land.

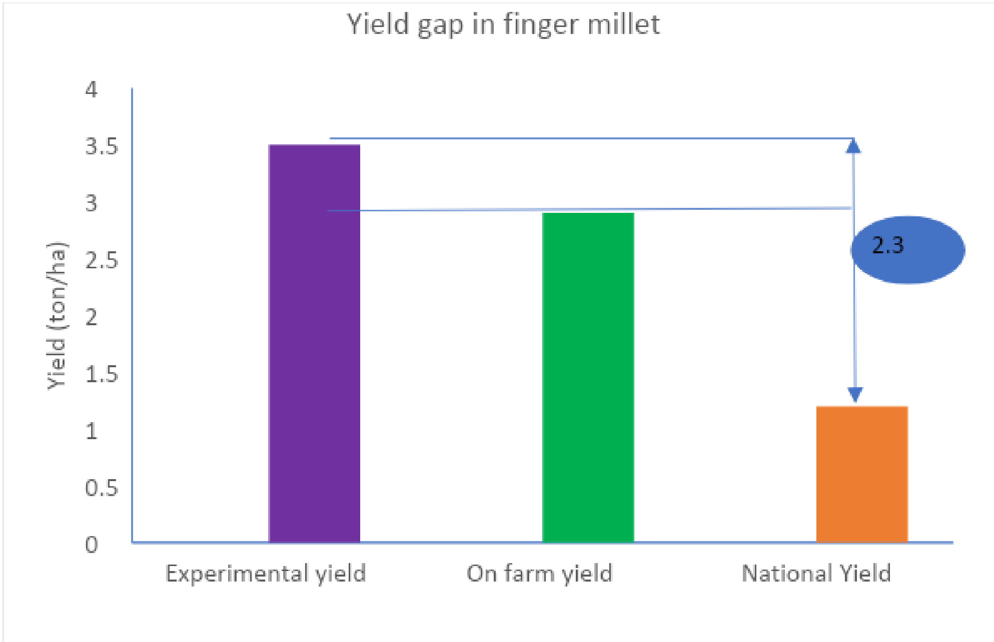

Figure 6. Yield gap of finger miller in Nepal

Proso millet

There is lack of national data about coverage area, production and yield of proso millet in Nepal. It is mainly grown in high hill district of Karnali province and Sudurpashim province (Bajhang, Bajura). Besides this also grown in Dhading, Okhaldhunga. It is one of the main crops of high hill district of Karnali province. This crop grown up to 3500 m in elevation and has one of the lowest water requirements of any cereal, makes it an incredibly resilient crop. It is completely gluten-free and packed with a variety of essential minerals, potassium in particular, contributes to nervous system health.

Foxtail millet

There is lack of national data about coverage area, production and yield of Foxtail millet in Nepal. It is mainly grown in high hill district of Sudurpashim province (Bajura, Bajhang) and Karnali province (Jumla, Humla, Mugu, Kalikot, Dolpa, Jajarkot), Gandaki province (Kaski, Gorkha, Lamjung), Bagmati province (Ramechhap, Kavre). Among the millets it ranges third after finger millet and proso millet among millets production in Nepal. Foxtail millet features a variety of uses, from being cooked and eaten like rice, ground into a hearty porridge or used to brew alcoholic beverages. It is a traditional staple food in drier parts of the high mountain landscape and has been used as an offering to local deities. This crop leads to a significant fall in blood glucose, making it a useful food to help manage and prevent diabetes.

Research Status Highlights

Varietal development work

Variety improvement work is a continuous process. Among millets crops till date, six varieties of finger millet, one variety of proso millet and one variety of foxtail millet have been released and registered so far (**Table 1**). Many promising and pipeline varieties of minor cereal crops are identified. The released and registered varieties with their recommendation domain and agronomic traits are presented in the table below.

Table 1. List of released and registered varieties of summer minor cereals crops in Nepal

Crop	Name of Varieties	Origin	Released Year (AD)	Maturity Days	Recommended Domains	Grain Yield (t/ha)
Finger millet	Dalle-1	India	1980	125-151	Inner Tarai to Mid-hills	3.3
	Okhle-1	Nepal	1980	154-194	Mid-High-hills	3.3
	Kabre Kodo-1	Nepal	1989	167	Mid-hills	2.3
	Kabre Kodo-2	India	2015	152	Mid-hills	2.5
	Sailung Kodo-1	India	2015	155	High-hills	2.4
	Rato kodo	Nepal	2021	150	High hill	2.5
Proso millet	Dudhe Chino	Nepal	2021	79	High hill	2.4
Foxtail millet	Bariyo Kagunu	Nepal	2021	100	Mid hill	2.0-2.5

Germplasms maintenance and evaluation of finger millet at HCRP, Dolakha

Germplasms collection, introduction, evaluation and maintenance are major varietal development activities. A total of one hundred forty-eight genotypes including Kabre Kodo-2 as a check were maintained and evaluated at HCRP, Kabre, Dolakha during summer season of 2021 to 2022. The design of the experiment was rod row. The check was repeated after each 10 test entries. The unit plot size was two rows of one-meter-long with 25 cm row to row spacing and continues plant to plant spacing was maintained and net harvested plot was 0.5 square meters. The crop was planted at first week of June every year. The fertilizer was applied 50:30:20 N: P_2O_5:K_2O kg/ha. Other agronomic practices were followed as recommended.

The recorded data (**Table 2**) showed that days to heading ranged from (70-100 days), days to maturity (122-152 days), grain yield (0.78-6.78) t/ha, leaf blast (1.50-3.5), neck blast (2-3.3.2), finger blast (2-4). The high yielding finger millet genotypes were ACC# 499 (5.43 t/ha), ACC#504 (4.66 t/ha), ACC#2316 (6.78 t/ha), ACC# 2413 (5.31 t/ha) ACC#6563 (5.46 t/ha), ACC#108 (6.07 t/ha). Some of the early maturity germplasms were ACC# 0680 (123 days), ACC#108 (121 days), ACC#6582 (121 days) and COLL#DT3 (122 days).

Table 2. Maintenance and evaluation of finger millet genotypes at HCRP, Dolakha during 2021 and 2022

SN	Genotypes	DTH			DTM			GY (t/ha)			Disease (1-5)		
		2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	LB	NB	FB
1	ACC# 422	84	96	90	129	149	139	3.455	2.855	3.155	2	3	2
2	ACC# 428	84	96	90	129	148	139	5.515	4.04	4.778	2	2	2
3	ACC# 436	66	84	75	126	128	127	3.41	2.93	3.170	2.5	2.5	2
4	ACC# 463	83	98	91	129	150	140	4.095	2.605	3.350	2	2	2
5	ACC# 464	82	99	91	133	149	141	3.92	2.105	3.013	2	3	2.5
6	ACC# 445	82	96	89	133	152	143	4.59	3.02	3.805	2.5	2.5	2.5
7	ACC# 466	83	97	90	133	153	143	2.675	2.625	2.650	2	2	2
8	ACC# 489	84	102	93	131	157	144	0.995	1.64	1.318	2	2.5	3
9	ACC# 499	84	104	94	134	157	146	5.305	2.945	4.125	2	3	3
10	ACC# 504	86	100	93	135	154	145	4.66	3.505	4.083	2	3	2
11	ACC# 505	96	100	98	141	154	148	5.18	3.23	4.205	2.5	2	3
12	ACC# 509	96	102	99	143	157	150	2.805	2.24	2.523	3	3	3
13	ACC# 510	96	101	99	144	155	150	3.54	2.12	2.830	2.5	3.5	2.5
14	ACC# 518	88	87	88	137	157	147	4.925	2.695	3.810	2	2	2
15	ACC# 520	82	104	93	133	158	146	4.035	2.06	3.048	2	2.5	2.5

SN	Genotypes	DTH			DTM			GY (t/ha)			Disease (1-5)		
		2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	LB	NB	FB
16	ACC# 535	96	77	87	125	126	126	3.40	1.17	2.285	2.5	3	3
17	ACC#2286	93	104	99	131	157	144	3.83	2.135	2.983	3	2	2
18	ACC#2287	84	101	93	129	155	142	4.43	2.305	3.368	2.5	2.5	2
19	ACC#2289	84	104	94	131	158	145	5.065	3.045	4.055	2	2	2
20	ACC#2298	84	103	94	135	157	146	2.90	1.46	2.180	2	2	2
21	ACC#2299	83	106	95	127	156	142	4.67	3.635	4.153	2	3.5	4
22	ACC#2301	68	101	85	126	154	140	2.70	2.045	2.373	2	3	3
23	ACC#2302	83	98	91	126	152	139	3.795	2.575	3.185	2.5	3.5	3
24	ACC#2304	82	93	88	127	149	138	3.365	1.65	2.508	2	3	3
25	ACC#2309	87	94	91	136	149	143	4.03	3.14	3.585	2.5	3.5	3.5
26	ACC#2316	84	96	90	131	148	140	6.78	3.76	5.270	2	3	3
27	ACC#2227	75	97	86	124	148	136	3.95	2.445	3.198	2	2.5	2.5
28	ACC#2329	84	100	92	134	154	144	4.505	2.415	3.460	2.5	2	2
29	ACC#2343	68	83	76	127	127	127	3.07	1.825	2.448	3	3.5	3.5
30	ACC#2361	68	75	72	131	120	126	2.16	1.025	1.593	2	3	3
31	ACC#2370	93	100	97	135	122	129	3.375	3.21	3.293	2	2	2
32	ACC#2373	84	102	93	133	126	130	3.415	3.465	3.440	2	2.5	2.5
33	ACC#2374	87	104	96	135	125	130	3.975	2.825	3.400	2	2	2
34	ACC#2381	93	86	90	135	127	131	3.04	3.285	3.163	2.5	2.5	2.5
35	ACC#2385	74	82	78	125	125	125	2.51	2.315	2.413	2.5	3	3
36	ACC#2389	87	104	96	136	122	129	4.085	3.445	3.765	2.5	3	3
37	ACC#2392	93	103	98	134	124	129	3.32	4.45	3.885	3	2	2
38	ACC#2399	85	102	94	134	125	130	3.09	4.54	3.815	2	2.5	2.5
39	ACC#2405	83	106	95	134	126	130	4.45	4.63	4.540	2	2	2
40	ACC#2408	82	104	93	133	157	145	4.825	2.935	3.880	2	2.5	2
41	ACC#2413	82	102	92	134	157	146	5.315	4.765	5.040	2	3.5	3
42	ACC#2424	84	100	92	135	154	145	3.64	3.475	3.558	2	3	3
43	ACC#2428	83	98	91	135	149	142	4.58	3.645	4.113	2.5	3	3
44	ACC#2432	86	97	92	134	149	142	3.48	2.36	2.920	2.5	3	3
45	ACC#2447	83	83	83	133	126	130	2.19	2.2	2.195	2.5	2	2.5
46	ACC#2496	87	100	94	131	155	143	3.545	1.74	2.643	2	2.5	2
47	ACC#2605	84	101	93	131	156	144	4.645	2.595	3.620	2	2	2
48	ACC#2608	82	98	90	125	152	139	3.475	2.3	2.888	2.5	2.5	2
49	ACC#2620	83	97	90	133	151	142	5.02	3.13	4.075	2	2	2
50	ACC#2621	63	77	70	125	124	125	4.15	2.915	3.533	2.5	2	2
51	ACC#2655	74	101	88	127	153	140	4.65	3.06	3.855	2	2.5	2.5
52	ACC# 267	81	102	92	126	154	140	3.1	2.625	2.863	2	2	2
53	ACC#2727	74	101	88	126	154	140	4.555	2.85	3.703	2	2.5	2
54	ACC#2734	68	83	76	127	126	127	4.57	2.94	3.755	2	3	3
55	ACC#2743	66	78	72	125	126	126	3.735	3.77	3.753	2	3	3
56	ACC#2753	65	80	73	125	128	127	2.765	2.275	2.520	3	2.5	2
57	ACC#2754	64	75	70	125	125	125	2.765	2.025	2.395	2	2.5	2

SN	Genotypes	DTH			DTM			GY (t/ha)			Disease (1-5)		
		2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	LB	NB	FB
58	ACC#2764	64	76	70	125	126	126	2.085	1.065	1.575	2	2	2
59	ACC#2768	83	100	92	135	154	145	4.115	3.49	3.803	2	2.5	2
60	ACC#2777	84	101	93	134	156	145	5.58	4.50	5.040	2	2	2
61	ACC#2789	84	104	94	133	157	145	1.98	3.09	2.535	2.5	3	3
62	ACC#2799	85	106	96	136	159	148	3.385	2.94	3.163	2	3.5	2
63	ACC#2820	87	107	97	136	157	147	4.41	3.25	3.830	2	2	2
64	ACC#2838	87	106	97	135	157	146	4.215	2.81	3.513	2.5	2.5	2.5
65	ACC#2851	87	104	96	136	155	146	3.93	2.66	3.295	2	3	3
66	ACC#2860	87	102	95	135	156	146	4.405	3.395	3.900	2	2	2
67	ACC#2899	76	100	88	125	154	140	3.57	3.41	3.490	2.5	2.5	2
68	ACC#2917	96	96	96	141	150	146	4.605	3.125	3.865	2.5	3	3
69	ACC#2930	66	79	73	125	126	126	3.325	1.915	2.620	3	3	3
70	ACC#2948	96	88	92	140	145	143	3.34	2.82	3.080	3	3	3
71	ACC#2954	84	93	89	134	149	142	3.13	2.30	2.715	2.5	2	2
72	ACC#2955	86	94	90	136	150	143	3.72	2.025	2.873	2.5	2.5	2
73	ACC#2960	88	95	92	134	150	142	3.395	1.525	2.460	3	2.5	2
74	ACC#2964	84	96	90	135	150	143	2.61	1.855	2.233	3.5	2	2
75	ACC#2965	74	86	80	124	124	124	2.4	2.215	2.308	3.5	2.5	2
76	ACC#3779	75	86	81	124	124	124	3.175	2.68	2.928	3	3	3
77	ACC#6353	75	85	80	126	124	125	2.485	4.49	3.488	3	3.5	3
78	ACC#6371	83	100	92	125	153	139	1.71	2.33	2.020	3.5	3	3
79	ACC#6375	84	98	91	124	151	138	3.235	1.915	2.575	3	2	2
80	ACC#6377	75	85	80	123	124	124	3.3	2.395	2.848	2.5	3	3
81	ACC#6379	75	86	81	124	125	125	2.63	2.405	2.518	3	2	2
82	ACC#6384	76	103	90	123	157	140	4.27	2.67	3.470	2	2	2
83	ACC#6386	81	102	92	123	153	138	4.495	2.58	3.538	2.5	2.5	2
84	ACC#6398	76	86	81	123	124	124	4.75	2.82	3.785	2	3	3
85	ACC#6401	88	88	88	134	145	140	3.04	1.505	2.273	3	3	2
86	ACC#6409	83	99	91	133	152	143	3.055	2.215	2.635	2	3.5	2
87	ACC#6412	96	90	93	144	148	146	2.56	1.83	2.195	2.5	2	2
88	ACC#6416	96	104	100	145	155	150	2.425	2.38	2.403	2	2.5	2
89	ACC#6418	96	90	93	147	148	148	1.84	2.735	2.288	2	3	3
90	ACC#6426	85	88	87	139	148	144	3.82	4.40	4.110	2.5	2	2
91	ACC#6434	96	90	93	146	148	147	1.55	1.75	1.650	3	2.5	2
92	ACC#6436	96	91	94	148	149	149	6.29	2.46	4.375	3	3	3
93	ACC#6438	96	93	95	135	149	142	3.21	2.145	2.678	2.5	3	3
94	ACC#6440	84	94	89	135	148	142	3.74	3.34	3.540	2.5	3	3
95	ACC#6445	84	95	90	133	149	141	2.8	2.005	2.403	2.5	3.5	3
96	ACC#6453	87	96	92	134	150	142	2.095	2.515	2.305	2.5	3	3
97	ACC#6451	88	97	93	137	151	144	1.625	2.735	2.180	2	2.5	2
98	ACC#6495	84	96	90	133	151	142	4.235	1.575	2.905	2	2.5	2
99	ACC#6517	87	90	89	135	148	142	3.755	1.785	2.770	2	3	3

SN	Genotypes	DTH			DTM			GY (t/ha)			Disease (1-5)		
		2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	LB	NB	FB
100	ACC#6520	84	91	88	134	148	141	3.3	1.545	2.423	2.5	3	3
101	ACC#6522	75	86	81	123	125	124	3.59	2.62	3.105	2.5	2.5	2
102	ACC#6525	85	93	89	133	149	141	4.13	2.415	3.273	2	2	2
103	ACC#6527	64	81	73	122	122	122	3.91	2.615	3.263	2.5	2	2
104	ACC#6529	63	77	70	122	126	124	3.305	1.125	2.215	2.5	3	3
105	ACC#6532	64	77	71	122	126	124	3.49	2.12	2.805	2	3.5	3
106	ACC#6532	85	94	90	133	149	141	3.88	2.765	3.323	2	3	3.5
107	ACC#6533	85	88	87	132	141	137	3.005	2.835	2.920	3	32	2
108	ACC#6542	84	88	86	131	148	140	3.65	2.305	2.978	2.5	2.5	3
109	ACC#6552	96	100	98	138	155	147	3.41	2.32	2.865	2	3	3
110	ACC#6554	85	99	92	133	154	144	2.925	1.935	2.430	2	3.5	2
111	ACC#6558	85	97	91	133	154	144	3.89	2.00	2.945	3	2.5	3
112	ACC#6542	65	80	73	122	127	125	2.83	1.64	2.235	2.5	3	3
113	ACC#6562	83	101	92	131	155	143	3.87	2.44	3.155	2	3	3
114	ACC#6563	82	100	91	131	156	144	5.465	3.955	4.710	2	2	2
115	ACC#6566	83	98	91	134	152	143	3.56	5.035	4.298	2	3	3
116	ACC#2964	86	97	92	135	152	144	3.92	2.11	3.015	2.5	2	2
117	ACC#6573	66	81	74	129	126	128	3.63	2.87	3.250	2	3	3
118	ACC#6575	72	86	79	122	126	124	4.245	2.80	3.523	2.5	3	3
119	ACC#6582	66	79	73	121	126	124	3.895	3.095	3.495	2	3.5	2
120	ACC#6588	74	79	77	131	122	127	5.025	2.035	3.530	2.5	2.5	2
121	ACC#6602	85	100	93	131	151	141	4.81	4.70	4.755	2.5	2.5	3
122	COLL#ARU10	96	98	97	145	151	148	3.095	3.02	3.058	2	3	3
123	COLL#R-R-6	63	79	71	122	127	125	3.395	3.75	3.573	2	3	3
124	COLL# C46055	96	94	95	147	149	148	2.75	3.035	2.893	2	2.5	2
125	COLL#D.T.3	64	79	72	122	126	124	3.71	3.87	3.790	2	3	3.5
126	COLL#D14	87	98	93	125	150	138	2.065	0.97	1.518	2	3	3
127	COLL# DJ7	85	88	87	125	145	135	3.875	3.525	3.700	2	3.5	3
128	COLL# DH-2	96	89	93	148	145	147	2.67	3.27	2.970	2	3	3
129	COLL# DH-3	86	86	86	135	126	131	2.91	3.49	3.200	2	2.5	2
130	ACC#GE322	85	92	89	131	118	125	2.94	4.69	3.815	2	2	2
131	GPU-48	73	92	83	135	149	142	2.425	1.855	2.140	2	2.5	2
132	ACC# 108	64	93	79	121	128	125	3.42	3.115	3.268	1.5	3	3
133	VL-49	84	110	97	133	157	145	2.86	2.83	2.845	1.5	3	3
134	PR-203	86	108	97	135	156	146	5.66	3.94	4.800	2	2	2
135	ACC# 152	85	102	94	135	155	145	6.075	4.77	5.423	3	2	2
136	GPU-28	98	100	99	147	156	152	5.88	3.615	4.748	2	3	3
137	HR-911	83	88	86	125	136	131	3.03	1.93	2.480	2	2	2
138	ACC#0682	83	90	87	126	148	137	2.705	2.54	2.623	2.5	2.5	2.5
139	ACC#6683	83	93	88	126	149	138	2.90	2.705	2.803	2	3	3
140	ACC#0685	73	80	77	124	128	126	3.305	3.655	3.480	2	3	3
141	ACC#0680	66	79	73	123	126	125	3.395	3.19	3.293	2	2	2

SN	Genotypes	DTH			DTM			GY (t/ha)			Disease (1-5)		
		2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	LB	NB	FB
142	ACC#06811	96	92	94	149	148	149	2.045	2.645	2.345	2.5	2	2
143	ACC# 06816	96	89	93	147	148	148	1.73	2.32	2.025	2.5	2.5	3
144	ACC# 06818	96	91	94	148	148	148	1.31	2.005	1.658	2.5	3	3
145	Local Check	85	85	85	124	123	124	1.515	2.505	2.010	2.5	3	3
146	ACC# 6841	87	92	90	135	149	142	2.06	2.095	2.078	2	2.5	2.5
147	ACC# 06842	96	96	96	148	151	150	0.78	2.01	1.395	2.5	3	3
148	ACC# 06843	87	86	87	135	122	129	1.565	2.46	2.013	2	2	2
	Mean	82	94	88	132	144	138	3.541	2.731	3.136	2	3	3
	Maximum	98	110	100	149	159	152	6.78	5.035	5.422	3.5	3	4
	Minimum	63	75	70	121	118	122	0.78	0.97	1.317	1.5	2	2

DTH-days to heading, DTM-days to maturity, GY-grain yield, LB-leaf blast, NB-neck blast, FB-finger blast, t/ha-ton/hectare.

Regeneration Nursery-Early (RN-E)-HCRP, Dolakha

A total of one hundred and seven genotypes along with standard (std.) check Kabre Kodo-2 and Local Check were evaluated in Regeneration Nursery–Early (RN-E) set at HCRP, Kabre, Dolakha during summer season of 2021 and 2022. The design of the experiment was rod row. The unit plot size was two rows of two-meter-long with 25 cm row to row spacing and continuous plant to plant spacing was maintained and net harvested plot was 2 square meters. The experiment was planted in the first week of June of each year. The fertilizer 50:30:20 kg/ha N:P_2O_5:K_2O was applied. Other agronomic practices were followed as recommended.

The data recorded (**Table 3**) showed that the days to heading ranged from (79-116 days), days to maturity (125-152 days), grain yield (0.315-4.425) ton/ha, leaf blast (1.50-4.0), neck blast (1.5-4), finger blast (2-3.5). The high yielding finger millet genotypes were NGRCO-1527 (4.425 t/ha), NGRCO-1401 (3.14 t/ha), NGRCO-1512 (3.578 t/ha), NGRCO-1517 (3.785 t/ha), NGRCO-1546 (3.343 t/ha), NGRCO-1559 (3.583 t/ha), NGRCO-1586 (3.353 t/ha), NGRCO-1592 (3.368 t/ha), NGRCO-3459 (3.568 t/ha), NGRCO-3460 (3.183 t/ha), NGRCO-4816(3.05 t/ha), NGRCO-4817(3.09 t/ha), NGRCO-4880(3.325 t/ha), NGRCO-3589 (3.563 t/ha), NGRCO-6483 (3.488 t/ha).

Table 3. Performance of finger millet genotypes under Regeneration Nursery-Early (RN-E) set at HCRP, Dolakha during 2021 and 2022 (Mean)

SN	Genotypes	DTH			DTM			GY (t/ha)			Disease score (0-5)		
		2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	LB	NB	FB
1	NGRCO-1401	95	87	91	127	145	136	1.205	5.075	3.140	3	2	2.5
2	NGRCO-1406	99	91	95	144	148	146	0.955	2.885	1.920	3.5	2	2
3	NGRCO-1420	96	93	95	145	147	146	1.17	1.195	1.183	3.5	2	3
4	NGRCO-1423	86	80	83	126	144	135	1.085	1.574	1.330	3	2	2
5	NGRCO-1428	95	78	87	126	143	135	1.105	0.885	0.995	4	2.5	3
6	NGRCO-1429	93	95	94	134	152	143	1.605	1.69	1.648	3	2	2.5
7	NGRCO-1431	92	94	93	133	151	142	2.15	2.615	2.383	3.5	3	3
8	NGRCO-1435	94	95	95	135	151	143	3.355	2.26	2.808	3	2	2
9	NGRCO-1441	95	93	94	133	152	143	2.865	1.975	2.420	3	3	3
10	NGRCO-1449	110	100	105	145	158	152	1.745	0.835	1.290	2.5	2	2

SN	Genotypes	DTH			DTM			GY (t/ha)			Disease score (0-5)		
		2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	LB	NB	FB
11	Kabre Kodo-2	93	99	96	133	152	143	3.79	4.925	4.358	2	2	3
12	Local Check	90	97	94	143	152	148	2.53	4.14	3.335	3	2	2
13	NGRCO-1455	99	95	97	141	152	147	3.05	2.875	2.963	3.5	1.5	2.5
14	NGRCO-1459	93	91	92	127	151	139	1.56	1.54	1.550	3.5	2	2
15	NGRCO-1483	105	82	94	124	133	129	2.245	3.11	2.678	3	2	2.5
16	NGRCO-1485	98	93	96	134	152	143	2.1	1.73	1.915	3.5	2	2
17	NGRCO-1492	97	95	96	135	151	143	1.86	1.92	1.890	3.5	2	2.5
18	NGRCO-1494	96	90	93	128	121	125	2.015	2.465	2.240	3	3	3.5
19	NGRCO-1498	76	85	81	125	133	129	2.94	1.435	2.188	3.5	3	3
20	NGRCO-1512	108	91	100	127	148	138	4.56	2.595	3.578	2.5	2	2
21	NGRCO-1517	75	85	80	124	132	128	3.1	4.47	3.785	3	2	2.5
22	NGRCO-1521	75	84	80	124	133	129	2.73	1.02	1.875	3	2	2
23	Kabre Kodo-2	96	94	95	134	151	143	4.545	3.36	3.953	2.5	2.5	3.5
24	Local Check	95	95	95	133	151	142	4.62	2.055	3.338	2.5	2.5	3.5
25	NGRCO-1524	77	87	82	124	148	136	3.64	3.375	3.508	3	2.5	2
26	NGRCO-1527	74	83	79	124	134	129	3.72	5.13	4.425	3	2	2
27	NGRCO-1546	95	89	92	127	131	129	3.005	3.680	3.343	2.5	2.5	2.5
28	NGRCO-1559	95	89	92	134	146	140	3.63	3.535	3.583	2.5	3	3
29	NGRCO-1563	108	124	116	141	159	150	2.71	2.94	2.825	3	2	2.5
30	NGRCO-1578	96	131	114	127	145	136	3.1	2.115	2.608	3	2	2.5
31	NGRCO-1586	98	91	95	135	147	141	4.12	2.585	3.353	3.5	2	2
32	NGRCO-1592	87	93	90	127	148	138	3.84	2.895	3.368	3	2.5	3.5
33	NGRCO-1610	87	89	88	124	131	128	1.665	2.21	1.938	3	2.5	3.5
34	NGRCO-1645	95	92	94	126	147	137	1.91	2.03	1.970	3.5	2.5	3
35	Kabre Kodo-2	96	91	94	140	121	131	4.005	3.655	3.830	2.5	2	2
36	Local Check	96	92	94	139	148	144	2.945	2.07	2.508	2.5	2.5	3
37	NGRCO-1652	77	82	80	124	129	127	2.18	1.195	1.688	3	2	3.5
38	NGRCO-3441	94	93	94	124	148	136	3.64	2.195	2.918	3	2	2
39	NGRCO-3442	95	91	93	125	148	137	3.85	2.525	3.188	3.5	2	2
40	NGRCO-3459	97	92	95	136	148	142	4.07	3.065	3.568	2.5	2	3.5
41	NGRCO-3460	98	93	96	136	148	142	2.49	3.875	3.183	3	2.5	3.5
42	NGRCO-3466	88	87	88	126	129	128	2.225	3.355	2.790	3.5	2	3.5
43	NGRCO-3467	88	87	88	125	130	128	1.455	2.07	1.763	4	2	2.5
44	NGRCO-3486	95	82	89	125	130	128	0.44	2.99	1.715	4	2	2
45	NGRCO-3491	97	89	93	143	131	137	0.575	3.095	1.835	4	2	3
46	NGRCO-3498	97	86	92	139	131	135	0.035	3.13	1.583	4	3	3
47	Kabre Kodo-2	96	86	91	140	129	135	0.57	5.715	3.143	4	4	3
48	Local Check	99	84	92	132	129	131	0.085	3.035	1.560	4	3	3
49	NGRCO-3500	100	76	88	136	129	133	0.09	1.035	0.563	4	3	3
50	NGRCO-3501	99	91	95	136	148	142	0.125	2.285	1.205	4	4	3
51	NGRCO-3505	96	89	93	134	130	132	0.48	3.535	2.008	4	3	3
52	NGRCO-3513	100	93	97	132	121	127	0.46	2.80	1.630	4	3	3

SN	Genotypes	DTH			DTM			GY (t/ha)			Disease score (0-5)		
		2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	LB	NB	FB
53	NGRCO-3528	97	89	93	137	129	133	0.435	2.365	1.400	4	2.5	2
54	NGRCO-3544	99	93	96	137	151	144	0.335	2.63	1.483	4	2.5	2.5
55	NGRCO-3559	90	91	91	124	151	138	0.155	1.79	0.973	4	2.5	2
56	NGRCO-3577	95	85	90	124	129	127	0.195	3.92	2.058	4	3	3
57	NGRCO-3579	88	82	85	125	127	126	0.465	2.385	1.425	4	2.5	2
58	NGRCO-3580	97	86	92	126	130	128	0.635	3.305	1.970	4	2	3
59	Kabre Kodo-2	99	95	97	137	148	143	2.925	5.13	4.028	2	2.5	3.5
60	Local Check	99	90	95	137	147	142	1.605	3.765	2.685	3	2	2
61	NGRCO-3586	76	83	80	125	129	127	1.64	3.065	2.353	3.5	2	3.5
62	NGRCO-3612	98	91	95	135	148	142	1.87	2.37	2.120	3.5	2	3.5
63	NGRCO-3615	97	91	94	127	148	138	1.43	1.93	1.680	3.5	2.5	2
64	NGRCO-3624	88	98	93	126	152	139	1.64	0.845	1.243	3.5	2	2
65	NGRCO-3627	98	97	98	126	152	139	0.235	0.40	0.318	3.5	2.5	2.5
66	NGRCO-3629	98	98	98	134	152	143	0.305	0.725	0.515	4	2	2
67	NGRCO-3631	88	95	92	123	151	137	0.265	0.945	0.605	4	3	2
68	NGRCO-3632	91	91	91	123	131	127	0.36	0.845	0.603	4	2	3
69	NGRCO-3644	90	97	94	125	152	139	0.395	2.45	1.423	4	2.5	2
70	NGRCO-3656	92	97	95	127	152	140	0.1	1.365	0.733	4	2	2
71	Kabre Kodo-2	92	98	95	127	152	140	0.17	1.81	0.990	4	3	2.5
72	Local Check	91	91	91	127	148	138	0.21	1.44	0.825	4	2	2
73	NGRCO-3668	91	95	93	127	151	139	0.165	0.465	0.315	4	3.5	3
74	NGRCO-3677	88	93	91	124	151	138	0.415	0.87	0.643	4	2	2.5
75	NGRCO-3678	88	93	91	124	151	138	0.4	1.445	0.923	4	2	2
76	NGRCO-3680	89	91	90	124	151	138	1.00	2.538	1.769	3.5	3	2.5
77	NGRCO-3683	99	91	95	134	152	143	1.7	1.89	1.795	3	2	3
78	NGRCO-3694	99	95	97	125	152	139	2.28	2.54	2.410	2.5	2.5	3.5
79	NGRCO-4727	97	93	95	128	145	137	2.735	2.76	2.748	2.5	3	3
80	NGRCO-4729	98	88	93	126	132	129	1.28	2.715	1.998	3	2.5	2
81	NGRCO-4732	96	87	92	126	131	129	1.43	2.585	2.008	3.5	2	2.5
82	NGRCO-4737	96	88	92	126	131	129	1.285	1.53	1.408	3.5	2	2
83	Kabre Kodo-2	98	91	95	128	144	136	1.6	3.45	2.525	3	2	3
84	Local Check	98	94	96	141	144	143	0.83	3.715	2.273	4	2.5	3.5
85	NGRCO-4738	98	89	94	126	133	130	0.425	2.795	1.610	4	2.5	3
86	NGRCO-4746	98	96	97	135	144	140	1.435	3.145	2.290	3.5	2	3.5
87	NGRCO-4779	98	98	98	133	145	139	1.68	2.205	1.943	3	3	3
88	NGRCO-4781	96	91	94	127	134	131	1.975	2.56	2.268	3	3	3
89	NGRCO-4786	96	93	95	128	135	132	3.1	2.725	2.913	2	2	3.5
90	NGRCO-4789	96	93	95	133	146	140	3.385	2.835	3.110	2	2	3
91	NGRCO-4790	99	93	96	128	146	137	0.705	2.055	1.380	3.5	2.5	3
92	NGRCO-4794	98	96	97	126	127	127	1.595	1.965	1.780	2.5	3	2.5
93	NGRCO-4820	94	85	90	126	132	129	1.235	1.465	1.350	2.5	3	3
94	NGRCO-4807	87	89	88	126	131	129	2.07	0.58	1.325	3	2	2.5

SN	Genotypes	DTH			DTM			GY (t/ha)			Disease score (0-5)		
		2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	LB	NB	FB
95	Kabre Kodo-2	98	96	97	135	145	140	3.98	3.89	3.935	2	2	3
96	Local Check	98	95	97	136	146	141	2.26	1.22	1.740	3	2	2.5
97	NGRCO-4812	94	91	93	126	132	129	2.665	1.55	2.108	2.5	3	3
98	NGRCO-4816	96	91	94	133	131	132	2.86	3.24	3.050	2	3	2
99	NGRCO-4817	88	91	90	133	133	133	3.25	2.93	3.090	2.5	2.5	2
100	NGRCO-4818	91	95	93	127	145	136	2.77	1.79	2.280	2.5	3	3
101	NGRCO-4837	87	96	92	126	145	136	3.12	1.82	2.470	2.5	2	2.5
102	NGRCO-4821	96	98	97	125	148	137	2.87	1.96	2.415	2	3.5	2
103	NGRCO-4824	85	89	87	125	133	129	1.775	1.115	1.445	2.5	2.5	2
104	NGRCO-4830	92	89	91	126	131	129	2.01	1.16	1.585	2.5	2	2
105	NGRCO-4832	96	88	92	126	132	129	0.6	1.24	0.920	3	3.5	3
106	NGRCO-4836	96	86	91	126	132	129	0.96	1.72	1.340	3	3	2.5
107	Kabre Kodo-2	99	93	96	141	135	138	1.325	4.65	2.988	3.5	2	3
108	Local Check	99	92	96	125	133	129	1.29	2.29	1.790	3.5	2.5	3.5
109	NGRCO-4847	99	96	98	135	145	140	0.895	1.51	1.203	3.5	3	3
110	NGRCO-4848	98	89	94	127	129	128	2.115	3.00	2.558	3	3	3
111	NGRCO-4850	98	89	94	133	128	131	1.85	3.475	2.663	2.5	2	2.5
112	NGRCO-4880	109	88	99	134	129	132	2.485	4.165	3.325	3	3	3.5
113	NGRCO-5109	108	95	102	134	146	140	1.265	1.14	1.203	2	2	3
114	NGRCO-5125	108	95	102	143	146	145	2.24	3.91	3.075	3	2.5	3.5
115	NGRCO-5126	109	94	102	143	145	144	1.805	2.815	2.310	2.5	2	2
116	NGRCO-6481	95	82	89	126	129	128	1.99	2.52	2.255	2	2	2.5
117	NGRCO-3566	96	82	89	126	129	128	1.45	1.39	1.420	2	2	2
118	NGRCO-3589	99	92	96	146	144	145	2.28	4.845	3.563	1.5	2	3
119	Kabre Kodo-2	99	93	96	146	145	146	2.71	1.025	1.868	2.5	2	2.5
120	Local Check	105	91	98	147	143	145	2.015	2.665	2.340	2	2	2
121	NGRCO-6483	105	92	99	135	143	139	2.475	4.50	3.488	2.5	2.5	3
122	NGRCO-6487	97	89	93	135	131	133	2.18	3.135	2.658	2.5	2.5	3.5
123	NGRCO-6494	87	81	84	126	129	128	1.705	3.235	2.470	3	3	2.5
124	NGRCO-6498	87	84	86	127	129	128	2.095	3.29	2.693	2.5	3	3
125	NGRCO-6499	87	85	86	127	127	127	2.08	3.41	2.745	2.5	2.5	3
126	Kabre Kodo-2	97	91	94	138	144	141	2.68	3.29	2.985	2	2	2.5
127	Local Check	99	93	96	147	144	146	1.325	3.705	2.515	1.5	2	2
	Mean	95	91	93	131	141	136	1.869	2.525	2.197	3	2	3
	Maximum	110	131	116	147	159	152	4.62	5.715	4.425	4	4	3.5
	Minimum	74	76	79	123	121	125	0.035	0.400	0.315	1.5	1.5	2

Note: DTH-days to heading, DTM-days to maturity, GY-grain yield, LB-leaf blast, NB-neck blast, FB-finger blast

Coordinated Varietal Trial (CVT) of finger millet - mountain set at HCRP, Dolakha

A total of sixteen Finger millet genotypes including Shailung Kodo-1 as a standard check and local genotype as a Local Check were evaluated in coordinated varietal trial (CVT)-Mono- mountain set at HCRP, Kabre, Dolakha during summer season of 2020 to 2022. The design of the experiment was Randomized Complete Block having two replications. The unit plot size was 3m x 2m with 10 cm row to row spacing and continues plant to plant spacing was maintained and net harvested plot was 6 m^2. The seed was shown in the first week of June of each year and 35 to 45 days old seedlings were transplanted in the main experimental field. The fertilizer was applied @ 50:30:20 N: P_2O_5:K_2O kg/ha. Other agronomic practices were followed as recommended.

The analysis of variance showed that there were significant differences among the tested genotypes for days to heading, days to maturity, bearing head/m^2, finger number per head, grain yield, straw yield, neck blast and finger blast (**Table 4**). The days to heading ranged from (94-108 days), days to maturity (145-156 days), bearing head (82-140), finger number (6-8), plant height (87.5-111.7 cm), grain yield (2.67-4.557 t/ha), straw yield (8.59-12.993 t/ha), thousand grain weight (2.7-3.7 g), leaf blast (1.75-2.75), neck blast (2-3), finger blast (2.25-3.25).Finger millet genotypes KLE-216 (4.257 t/ha), ACC#2705 (4.198 t/ha), ACC#2311 (4.196 t/ha) were the high yielding genotypes (**Table 4**).

Table 4. Evaluation of finger millet genotypes in CVT - mountain set at HCRP, Dolakha during 2020 to 2022

Genotypes	DTH	DTM	BH/m^2	FN/ head	PH (cm)	GY (t/ha)	SY (t/ha)	TGW (g)	LB (1-5)	NB (1-5)	FB (1-5)
KLE-178	94	145	140	6	87.5	3.979	11.914	3.0	2.00	2.00	2.25
ACC#2843	105	158	84	7	111.8	4.042	12.665	3.0	2.00	2.00	2.50
ACC#2334-1	99	154	99	8	106.6	3.803	9.942	3.1	2.75	3.00	3.00
ACC#2311	99	153	98	8	98.7	4.196	10.118	2.8	2.00	2.50	2.75
ACC#6022	100	153	99	7	107.3	4.054	10.561	2.8	2.25	2.50	3.00
NE-1734	102	154	93	7	107.6	3.456	9.413	2.7	2.25	3.00	3.25
NE-94	97	151	91	8	106.1	3.649	10.312	3.5	2.25	3.00	3.00
ACC#2705	99	155	105	7	102.6	4.198	12.039	3.6	2.25	2.00	3.00
GE-0150	100	153	100	8	103.1	4.038	9.674	2.8	2.25	3.00	3.50
KLE-236	98	152	91	7	103.9	2.677	9.31	3.7	2.25	2.00	2.75
ACC#2954	103	156	93	7	105.3	2.814	8.722	3.2	2.00	2.00	3.00
KLE-5220	97	149	113	6	93.9	3.934	9.421	3.7	2.00	3.00	3.00
KLE-216	104	156	82	7	105.4	4.257	10.837	3.4	2.25	2.50	3.25
ACC#2827-1	102	152	98	8	100.5	3.843	8.597	3.0	2.25	2.50	2.75
Shailung Kodo-1	103	156	86	8	108.4	4.557	12.993	3.5	2.00	2.00	3.00
Local Check	108	156	90	8	104.9	4.179	11.734	3.2	1.75	3.00	3.00
P-value	<.001	<.001	0.008	<.001	<.001	<.001	<.001	0.56	0.71	0.005	0.03
LSD (0.05)	5.45	5.65	41.7	1.32	16.8	1.47	3.92			0.67	0.54
CV (%)	2.7	1.6	21.8	8.1	7.1	17.6	16.5	27.3	16.80	12.6	8.7

DTH-Days to heading, DTM-Days to maturity, BH-Bearing head, FN-Finger number, PH-Plant height GY-Grain yield, TGW-Thousand grain weight, SY-Straw yield, LB-leaf blast, NB-neck blast, FB-finger blast.

Farmer's Field Trial (FFT) of Finger millet Under Mono Cropping Condition-Mountain Set at HCRP, Dolakha

In Farmer's Field Trial (FFT), a total of seven cultivars including Shailung Kodo-1 as a standard check and local genotype as a Local Check were evaluated at HCRP, Kabre, Dolakha during summer season of 2020 to 2022. The unit plot size was 3m x 2m with 10 cm row to row spacing and continues plant to plant spacing was maintained and net harvested plot was 6 square meters. The seed sowing was done on first week of June in each year and 35 to 40 days old seedlings were transplanted in the main field. The fertilizer was applied @50:30:20 N: P2O5:K2O kg/ha. Other agronomic practices were followed as recommended.

Data revealed that the days to heading ranged from (98-106 days), days to maturity (144-149 days), bearing head (102-125), finger number (6-7), plant height (98-114 cm), grain yield (3.36-4.03 t/ha), straw yield (9.08-11.93 t/ha), leaf blast (2-2.5), neck blast (2-3), finger blast (2.5-3). Finger millet genotypes ACC#433-1 (4.03 t/ha), KLE-158 (4.00 t/ha) were the high yielding genotypes.

Table 5. Performance of Finger millet genotypes evaluated in FFT under Mono cropping condition -mountain set at HCRP, Dolakha during 2021 to 2022 (mean)

SN	Genotypes	DTH	DTM	BH/m²	FN/ Head	PH (cm)	GY (t/ha)	SY (t/ha)	DISEASE (1-5)		
									LB	NB	FB
1	GE-382	98	144	112	7	114.0	3.940	11.930	2	2	3
2	NE-559	102	147	109	6	104.2	3.716	10.420	2	2	2.5
3	KLE-158	99	144	125	6	99.2	4.007	9.410	2.5	3	3
4	ACC#433-1	99	146	123	7	98.0	4.037	9.370	2	3	3
5	KLE-159	100	146	113	7	105.1	3.362	9.080	2	3	3
6	NE-1703-34	100	147	121	6	102.7	3.969	9.500	2.5	3	3
7	SAILUNG KODO-1	106	149	102	6	99.8	3.509	10.720	2	2	3
	P value	<.001	<.001	0.34	<.001	0.81	0.4	0.51			
	LSD	1.39	0.92		0.31						
	CV (%)	1.06	0.26	12.04	2.02	15.49	13.28	20.56			

DTH- Days to heading, DTM-Days to maturity, BH-Bearing head, FN-Finger number, PH-Plant height, GY- Grain yield, SY-Straw yield, LB-leaf blast, NB-neck blast, FB-finger blast

Coordinated Varietal Trial (CVT) on Finger millet Under Mono Cropping Condition -Hill Set at HCRP

A total of sixteen Finger millet genotypes including Kabre Kodo-2 as a standard check and local genotype as a Local Check were evaluated in coordinated varietal trial (CVT)-Mono- Hill set at HCRP, Kabre, Dolakha during summer season of 2020 to 2022. The design of the experiment was Randomized Complete Block having two replications. The unit plot size was 3m x 2 m with 10 cm row to row spacing and continues plant to plant spacing was maintained and net harvested plot was 6 square meters. The seed sowing was done on in the first week of June each year and 35 to 40 days old seedlings were transplanted in the main field. The fertilizer was applied @ 50:30:20 N: P_2O_5:K_2O kg/ha. Other agronomic practices were followed as recommended.

The analysis of variance showed that there were significant differences among the tested genotypes for days to heading, days to maturity, plant height and stover yield (**Table 6**). The days to heading ranged from (95-110 days), days to maturity (153-163 days), bearing head (90-120), finger number (6-7), plant height (81.4-117.4 cm), grain yield (2.62-3.98 t/ha), thousand grain weight (2.8-3.8 g), straw yield (6.41-13.42 t/ha), leaf blast (2-3), neck blast (2-2.5), finger blast (2-3). Finger millet genotypes Kabre Kodo-2 (3.98 t/ha), ACC#2860 (3.73 t/ha), ACC#2400 (3.72 t/ha), ACC#150 (3.60 t/ha), DR-2 (3.60 t/ha), were the high yielding (**Table 6**).

Table 6. Evaluation of finger millet genotypes in CVT under mono cropping condition - Hill set at HCRP, Dolakha during 2020 to 2022 (Mean)

Genotypes	DTH	DTM	BH/m²	FN/ head	PH (cm)	GY (t/ha)	SY (t/ha)	TGW (g)	LB (1-5)	NB (1-5)	FB (1-5)
ACC#2844	109	161	93	6	116.9	3.456	13.429	3.3	2.3	2.0	2.5
ACC#2303	105	154	92	7	97.8	3.321	9.118	3.5	2.3	2.3	2.5
ACC#2408	103	153	94	7	98.1	2.774	7.679	3.8	2.5	2.3	3.3
ACC#2275	107	156	98	7	117.4	2.835	7.299	3.4	3.0	2.0	3.0
ACC#2400	106	153	95	6	98.3	3.722	8.262	2.9	2.3	2.5	3.0
ACC#2860	106	158	90	7	101.1	3.739	9.094	3.5	2.0	2.0	2.8
ACC#150	95	163	120	6	89.2	3.609	9.776	2.8	2.0	2.0	2.8
BN-3	106	159	96	7	111.0	3.155	10.031	3.3	2.3	2.0	2.5
DR-2	109	158	95	6	100.0	3.606	8.5	3.2	2.5	2.3	2.8
ACC#3454	110	159	92	6	106.8	3.216	9.507	3.4	2.3	2.0	2.5
ACC#6369	110	161	104	7	81.4	2.624	6.41	3.3	2.8	2.3	3.0
NE-94	104	153	94	6	96.1	3.391	8.5	2.8	2.3	2.3	2.8

Genotypes	DTH	DTM	BH/m²	FN/ head	PH (cm)	GY (t/ha)	SY (t/ha)	TGW (g)	LB (1-5)	NB (1-5)	FB (1-5)
ACC#5434	103	158	103	6	95.7	3.434	7.319	3.2	2.5	2.0	2.5
GE-507	108	161	96	7	98.3	3.383	7.864	3.4	2.5	2.0	2.0
Kabre Kodo-2	102	158	119	6	91.7	3.982	8.187	3.5	2.0	2.5	2.5
Local Check	107	153	97	6	95.3	2.886	6.879	3.3	2.8	2.3	3.0
P-value	<.001	<.001	0.48	0.5	0.001	0.29	0.001	0.58	0.46	0.83	0.59
LSD (0.05)	5.30	1.86			28.02		6.71				
CV (%)	2.1	0.40	22.8	13.2	12.9	25.7	26.4	20.2	16.8	15.3	17.0

DTH- Days to heading, DTM-Days to maturity, BH-Bearing head, FN-Finger number, PH-Plant height, GY- Grain yield, TGW-Thousand grain weight, SY-Straw yield, LB-leaf blast, NB-neck blast, FB-finger blast.

Farmer's Field Trial on Finger millet Under Mono Cropping Condition – Hill Set at HCRP, Dolakha

In Farmer's Field Trial (FFT), a total of seven cultivars including Kabre Kodo-2 as a standard check were evaluated at HCRP, Kabre, Dolakha during summer season of 2021 and 2022. The unit plot size was 3m x 2m with 10 cm row to row spacing and continues plant to plant spacing was maintained and net harvested plot was 6 m^2. The seed sowing was done on first week of June of each year and 35 to 40 days old seedlings were transplanted on the main field. The fertilizer was applied @ 50:30:20 kg/ha N: P2O5:K2O. Other agronomic practices were followed as recommended.

Data revealed that the days to heading ranged from 98-102 days, days to maturity 145-150 days, bearing head 97-128, finger number (5-6), plant height 82-92 cm, grain yield 3.62-5.10 t/ha, straw yield 9.25-14.03 t/ha, leaf blast (2.-2.5), neck blast (2-3). Finger millet genotypes Kabre Kodo-2 (5.106 t/ha), KLE-1 (4.973 t/ha), KLE-192 (4.643 t/ha), KLE-158 (4.681 t/ha) were the high yielding (**Table 7**).

Table 7. Performance of Finger millet genotypes evaluated in FFT under mono cropping condition-Hill set at HCRP, Dolakha during 2021 and 2022 (Mean)

SN	Genotypes	DTH	DTM	BH/m²	FN/head	PH (cm)	GY (t/ha)	SY (t/ha)	Disease (1-9)	
									LB	NB
1	KLE-1	100	149	111	6	82.9	4.973	12.19	2	2
2	KLE-192	101	150	125	6	85.5	4.643	10.69	2.5	3
3	KLE-158	99	148	125	6	85.3	4.681	9.58	2.5	3
4	KLE-236	100	148	111	6	84.5	4.157	9.69	2	2
5	KLE-298	98	145	128	6	90.5	3.627	11.67	2.5	3
6	GE-507	102	148	122	5	89.9	3.872	11.68	2.5	3
7	Kabre Kodo-2	101	150	107	5	91.8	5.106	14.03	2	3
8	Local Check	101	150	97	6	91.9	4.136	9.25	2.5	2

DTH-Days to heading, DTM-Days to maturity, BH-Bearing head, FN-Finger number, PH-Plant height, GY-Grain yield, TGW-Thousand grain weight, SY-Straw yield, LB-leaf blast, NB-neck blast, FB-finger blast

Coordinated Varietal Trial (CVT) on Proso millet at HCRP, Dolakha

A total of fourteen proso millet genotypes including farmer's cultivar as a Local Check were evaluated in coordinated varietal trial (CVT) at HCRP, Kabre, Dolakha during summer season of 2020 to 2022. The design of the experiment was Randomized Complete Block having two replications. The unit plot size was 2m x 2 m with 25 cm row to row spacing and continuous plant to plant spacing was maintained and net harvested plot was 4 m^2. The experiment was planted in the second week of May. The fertilizer was applied @ 50:30:20 kg/ha N: P2O5: K2O and FYM 8 t/ha. Other agronomic practices were followed as recommended.

The analysis of variance revealed significant differences among the tested proso millet genotypes for days to heading, days to maturity, plant height, leaf length, leaf width, No. of nodes/tiller, panicle length, thousand grains weight, grain yield per spike, grain yield, leaf blast and bacterial stripe (**Table 8**). The days to heading ranged from (53-59 days), days to maturity (91-95 days), plant height (106-121) cm, leaf length (31.1-38.8) cm, leaf width (2.1-2.5) cm, node per tiller (6.2-7.5), panicle length (31-34.6) cm, thousand grain weight (5.6-7.4) g, grain yield per spike (3.8-5.7) g, grain yield (1.44-2.09) t/ha blast (3.5-5.1) and bacterial stripe (2.9-4.3). The high yielding proso millet genotypes were Co 4654 (2.09 t/ha), Co-4651(2.03 t/ha), Co 4645 (1.89 t/ha), Humla-383 (1.88 t/ha) were the high yielding (**Table 8**).

Table 8. Evaluation of proso millet genotypes in Coordinated Varietal Trial (CVT) at HCRP, Dolakha during 2020 to 2022 (Mean)

Genotypes	DTH	DTM	PH (cm)	LL (cm)	LW (cm)	Node/ tiller	PL (cm)	TGW (g)	GY/ spike (g)	GY (t/ ha)	Blast (1-9)	Bacterial stripe (1-9)
Co 4651	56	93	114.0	33.6	2.5	6.7	32.0	6.3	4.83	2.037	3.5	2.9
Co 4645	55	92	110.9	34.0	2.3	6.4	31.0	6.7	4.45	1.897	3.7	3.6
Co 4654	54	92	119.6	38.1	2.1	6.3	31.6	7.4	5.3	2.097	4.4	3.9
Co 4656	59	94	107.1	35.8	2.3	7.1	33.0	6.3	4.58	1.535	5.1	4.3
Co 3149	55	92	109.6	32.5	2.4	6.2	31.2	6.9	5.5	1.489	4.6	4.3
Humla-237	53	91	121.1	35.8	2.5	6.3	32.2	6.8	3.97	1.633	4.8	4.3
Humla-239	54	93	115.8	33.2	2.2	6.2	31.1	6.8	3.84	1.845	4.4	3.2
Humla-312	58	95	111.8	35.2	2.3	6.4	33.4	6.7	4.5	1.597	4.8	3.9
Humla-383	56	95	115.9	33.3	2.2	6.2	32.3	6.3	5.13	1.883	5.1	3.6
Humla-488	55	93	116.4	34.0	2.3	6.0	33.0	6.1	5.67	1.841	4.5	3.9
Humla-530	54	92	112.7	33.1	2.2	6.4	33.0	7.4	4.13	1.662	4.4	3.6
Humla-653	57	93	114.3	33.2	2.5	7.5	31.9	6.6	5.75	1.652	4.2	3.2
Humla-725	54	93	115.7	31.1	2.1	6.3	31.3	5.6	4.48	1.815	4.8	3.6
Farmers Local	57	94	106.0	35.3	2.4	6.5	34.6	6.5	5.68	1.445	4.9	4.3
P-value	0.01	<0.01	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.05	<0.01	0.01
LSD (0.05)	2.28	2.44	14.09	3.51	0.30	1.25	2.43	1.20	2.16	0.75	1.08	0.73
CV (%)	2.1	1.3	5.0	4.8	6.8	7.5	3.8	9.1	22.6	20.3	11.5	15.6

DTH-days to heading, DTM-days to maturity, PH-plant height, LL-leaf length, LW-leaf width, PL-panicle length, TGW-thousand grain weight, GY-grain yield.

Coordinated Varietal Trial (CVT) on Foxtail millet at HCRP, Dolakha

A total of fourteen foxtail-millet genotypes including local cultivar as Local Check were evaluated in coordinated varietal trial (CVT) at HCRP, Kabre, Dolakha during summer season of 2020 to 2022. The design of the experiment was Randomized Complete Block having two replications. The unit plot size was 2m x 2m with 25 cm row to row spacing and continues plant to plant spacing was maintained and net harvested plot was 4 m^2. The experiment was planted in second week of May in each year. The fertilizer was applied @ 50:30:20 N: P_2O_5:K_2O kg/ha. Other agronomic practices were followed as recommended.

The analysis of variance revealed significant differences among the tested foxtail-millet genotypes for days to heading, days to maturity, plant height, node per tiller, panicle length, grain yield, grain yield per spike, blast, smut and bacterial leaf and sheath blight disease (**Table 9**). The days to heading ranged from (58-85 days), days to maturity (99-128 days), plant height (129.6-160.3) cm, node per tiller (5-10), panicle length (16.0-22.7) cm, grain yield per spike (2.6-8.2) g, grain yield (0.616-1.679) t/ha, leaf blast (4.2-6.3), smut (2.2-4.7) and banded leaf and sheath blight (3.0-4.3). The high yielding foxtail-millet genotypes were Co-3474 (1.679 t/ha), Co-1896 (1.612 t/ha), Humla-163 (1.35 t/ha), Humla-252 (1.41 t/ha) (**Table 9**).

Table 9. Evaluation of foxtail millet genotypes in Coordinated Varietal Trial (CVT) at HCRP, Dolakha during 2020 to 2022 (Mean)

Genotypes	DTH	DTM	PH (cm)	Node/ tiller	PL (cm)	Grain wt/ spike (g)	GY (t/ha)	TWG (g)	Blast (1-9)	Smut (1-9)	BLSB (1-5)
Co-1896	85	116	143.1	10	16.3	6.2	1.612	3.9	4.5	2.7	4.3
Co-3474	91	128	152.2	8	16.2	5.7	1.679	3.6	4.6	2.2	3.0
Co-3475	71	108	153.3	8	15.7	4.4	0.976	3.8	5.4	4.0	3.2
Humla-163	66	109	139.2	8	19.8	5.2	1.357	3.9	4.2	4.0	3.2
Humla-213	78	116	160	10	17.6	8.2	1.199	2.8	5.9	2.9	3.5
Humla-252	63	109	136.2	7	21.0	4.8	1.413	4.0	5.5	3.8	3.5
Humla-379	84	112	146.3	9	16.2	5.7	0.985	3.8	5.5	4.1	4.3
Humla-468	82	116	148.6	9	18.1	5.7	0.87	3.5	6.1	3.5	3.8
Humla-522	58	99	129.6	5	18.0	3.6	0.775	4.0	4.6	4.1	3.4
Humla-523	82	116	145.2	9	17.8	5.9	0.935	3.8	5.8	3.4	3.8
Humla-524	80	117	142.5	8	17.2	5.1	0.755	3.5	5.2	3.0	3.2
Humla-606	61	107	132.9	6	22.7	3.7	1.02	3.5	6.3	2.7	4.0
Humla-631	72	107	148.7	7	16.0	2.6	0.616	4.0	5.9	4.7	3.8
Local Check	73	123	160.3	9	16.0	6.5	1.38	3.5	4.9	3.8	3.2
P-value	<.001	<.001	0.002	<.001	<.001	<0.01	<0.01	0.41	<.001	<0.01	0.04
LSD (0.05)	3.25	3.95	25.2	1.9	3.67	1.98	0.599		1.35	1.2	1.38
CV(%)	2.2	1.8	8.7	11.7	10.6	18.7	27.3	20.7	9.2	17.4	18.6

DTH-days to heading, DTM-days to maturity, PH-plant height, PL-panicle length, TGW-thousand grain weight, GY-grain yield, BLSB-banded leaf and sheath blight.

Agronomical Traits of HCRP Released and Pipeline Finger Millet Varieties

Dalle Kodo-1

Head: Tip curved, Semi Compact, 5-6 fingers/head
Maturity: Synchronized, 125-151 days
Plant Height: 110 cm
Nodal pigmentation: Green
Productivity: 3300 kg/ha
Not suitable to rainy area

Okhle Kodo-1

Head: Incurved, semi erect and 6-7 fingers/head
Maturity: Synchronized, 154 days.
Plant Height: 80 cm
Productivity: 3300 kg/ha
Stress Reaction: Drought and disease tolerant

Kabre Kodo-1

Head: Open, Upright, 6-8 fingers/head
Maturity: Synchronized, 151-162 days
Plant height: 100-114 cm
Productivity: 1830-4830 Kg/ha
Stress Reaction: Field resistant to blast, Cercospora leaf spot disease and water logging

Kabre Kodo-2


Head: Compact, Closed, 6 fingers/head
Maturity: Synchronized ,153 days
Plant Height: 91 cm
Productivity: 2530 kg/ha
Stress reaction: Drought tolerant, non-lodging, unsuitable in rainy area

Shailung Kodo-1


Head: Compact, Closed and 7 fingers/head
Maturity: Synchronized maturity,155 Days
Plant Height: 100 cm
Productivity: 2490 kg/ha
Purple color in leaves, peduncle and young fingers

Pipeline Genotypes of Finger Millets

KLE 158

Yield: 2.5 ton/ha
Maturity: 150-160 days
Recommended area: Mid and high hill
Disease reaction: Blast and Cercosphora leaf spot resistant

KLE-236

Yield: 2.5-3.0 ton/ha
Maturity: 150-155 days
Recommended area: Mid and high hill (600-3500m)
Disease reaction: Blast and Cercosphora leaf spot moderately resistant

Seed Cycle Chain

Hill Crops Research Program has been producing source seed of mandate crops as well as location demand based other cereals. HCRP is producing breeder and foundation seed of finger millet, buckwheat, barley, rice, maize, wheat, soybean, lentil. The quantity of seed produced of different varieties of finger millet during 2020/21 to 2021/22 is given in table below.

Table 10. Source seed production of different crops at HCRP, Kabre station during 2020/21 and 2021/22

Crop	Variety	Breeder seed (kg)		Foundation seed (kg)	
		2020/21	2021/22	2020/21	2021/22
Finger millet	Kabre Kodo-1	51	30	655	812
	Kabre Kodo-2	29	30	560	1102
	Dalle Kodo-1	66	25	847	594
	Okhle Kodo-1	25.5	30	327	349
	Shailung Kodo-1	21	30	295.5	791
	Total	192.5	145	2694.5	3648

Problems and Issues of Millets Production

- Unavailability of suitable varieties for varied agro-ecological domains and technologies for millets
- Disease and pest, Finger millet- Blast (leaves, neck, finger), Cercospora leaf spot, sheath blight, seedling blight, wilt, borer, grubs, grasshopper, Proso millet/ Foxtail millet - Blast, sheath blight, smut, downey mildew, borer, bugs, termite
- Undulated and sloppy land difficult to cultivate and mechanize farming.
- Low priority or neglected research and development of millets
- Scarcity of labour and quality agricultural inputs (seed, fertilizer)
- Lack of awareness on the nutrient composition and value on human health (low rate of crop consumption especially among the younger generation)
- Reduced diversity in farming system by introduction of higher value commodities – mono cropping -leading to ecosystem unsustainability and cultural disintegrate
- Inadequate policy support for variety development, cultivation, value addition and promotion
- Limited scientific manpower, shortage of disciplinary scientist and researcher

Way Forward

- Research and development institutions of future smart crops at local, regional and central level.
- Make strong commodity research program from research and development perspective.
- Deputation of crop specific multi-disciplinary scientists and technicians in each mandated crop.
- Establishment of conservation facilities at commodity program, regional stations.
- Enhanced laboratory facilities (molecular level).
- Research incentives (awards).
- Technology transfer (mass media).
- National and international collaboration (Exchange of germplasms and capacity building

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Characterization and Evaluation of Millets Genetic Resources

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Summary

Millets play significant role in food and nutrition security of developing countries like Nepal. In Nepal, largely cultivated millets are finger millet, proso millet, foxtail millet and sorghum. Plant breeding research on these crops is in infant stage except in finger millet. Finger millet is the fourth important crop of the country in terms of area and production and widely grown in all 77 districts of the country with large landrace diversity. Characterization and evaluation of native landraces or pre-breeding is the prerequisite activity of varietal improvement research. Pre-breeding research in millets is mainly concentrated on finger millet with very little work on foxtail millet and proso millet. Two native landraces of finger millet (Okhle-1 and Kabre Kodo-1) have released whereas one landrace each of finger millet (Rato Kodo), foxtail millet (Bariyo Kaguno) and proso millet (Dudhe Chino) have been registered after selection in Nepal. Hill Crops Research Program (HCRP) and National Agriculture Genetic Resources Center (NAGRC) are institutionally involved in characterization and evaluation of native landraces as well as exotic genetic resources of millets. This chapter highlights the findings of pre-breeding researches done on different millet species in the country which would be useful to concerned breeders to prioritize the millet improvement work in Nepal.

Keywords: Characterization and evaluation, finger millet, foxtail millet, native landraces, pre-breeding, proso millet

Introduction

Millets are the small seeded cereals of grass family with significant role in food and nutrition security of many developing countries. Disaggregated data on global area and production of different millet species is not available (Upadhyaya et al 2010). Globally, sorghum (*Sorghum bicolor* L. Moench.) is the leading millet in terms of area and production followed by pearl millet (*Pennisetum glaucum* L. R.Br.), foxtail millet (*Setaria italica* L. Beauv.) and finger millet (*Eleusine coracana* L. Gaertn.) whereas finger millet is the leading millet followed by proso millet (*Panicum miliaceum* L.), foxtail millet and sorghum in Nepal (Ghimire et al 2017). Barnyarn millet (*Echinochloa frumentaceae* L.), little millet (*Panicum sumatrense* L.), pearl millet, browntop millet (*Brachiaria ramosa* L. Stapf) and kodo millet (*Paspalum scrobitulatum* L.) are the other cultivated species of millets grown in Nepal (Joshi et al 2023).

Nutritional importance of millets is well recognized due to their high dietary fiber, high minerals, vitamins and phenolic compounds, and low glycemic index. Millets are also valued for their health benefits like anti-diabetic, anti-tumorigenic, antioxidant and antimicrobial properties (Devi et al 2011). Besides food and nutrition, they are an integral component of agrotourism in Nepal due to their traditional recipes such as *Chino ra Kaguno ko khir* (pudding), *kodoko dhindo* (thick porridge), *roti* (pancake) and high quality *raksi* (home-made wine). Having C4 photosynthetic pathway (Hittalmani et al 2017), millets are hardy crops grown in marginal land and stress environments with minimum input (Goron et al 2015). According to the FAO-WIEWS/Genesys database (www.croptrust.org), there are more than 479795 accessions of millets conserved in global gene banks among them 259595 of sorghum, 73578 of pearl millet, 46368 of foxtail millet, 43862 of finger millet, 29865 of proso millet, 8920 of barnyard millet, 8305 of teff, 4398 of kodo millet, 3734 of little millet, and 1170 of fonio. Only about 10% of these resources have been utilized in breeding programs, which mainly due to a lack of information about the desirable accessions resulting from the poor characterization and evaluation data (Hodgkin et al 2003, Nguyen and Norton 2020).

History of Millets Germplasm Characterization in Nepal

In Nepal, collection of millets germplasm was started from 1950 but the characterization was started from 1972 with the characterization of 38 finger millet landraces at Khumaltar (Baniya et al 2001). Several lines were selected, purified and evaluated at Khumal, Kakani and Kabre. Local landraces namely NE-1304-43 from Okhaldhunga and NE-6401-26 from Surkhet were released in 1980 as Okhle-1 and Kabre Kodo-1. Later in 1986, Hill Crops Research Program (HCRP) was established at Khumaltar when 360 finger millet landraces were characterized. HCRP was moved to Kabre, Dolakha in 1989 when a total of 629 finger millet landraces were characterized. Besides characterization, various evaluation trials namely Observation Nursery, Initial Evaluation Trial (IET) and Advance Varietal Trial (AVT) were conducted. Evaluation of germplasm at different locations like Kabre, Kakani, Khumaltar, Lumle, Pakhribas, Surkhet, Dailekh, Jumla, Rampur, Khairenitar, etc was continued after the establishment of HCRP. Similarly, 70 finger millet landraces were characterized and evaluated at multiple locations during 1994. Unfortunately, a total of 1081 accessions of millets including 790 finger millet, 160 proso millet and 106 proso millet accessions were irreversibly lost during insurgency period (HCRP 2002). Some collection, characterization and evaluation works were continued at HCRP Kabre after receiving the conserved accessions from Agriculture Botany Division, Khumaltar. After the establishment of National Genebank at Khumaltar in 2010, germplasm collection, characterization and evaluation works are restarted on different millet species as routine pre-breeding activity. Besides this, various experiments on characterization and evaluation of millets genetic resources are being conducted continuously by the scientists from HCRP as well as the periodic researches are being done by the students from different agricultural universities to accomplish their academic requirements. Characterization at molecular level has recently been started on finger millet (Joshi et al 2020) while phenotypic characterization is the main practice in Nepal. However, these efforts are mainly concentrated on finger millet only in the past with very little research on foxtail millet and proso millet.

Characterization and Evaluation of Millets

Characterization of collected landraces is the most important avenue to open the door for their utilization. However, less utilization of local genetic resources for crop improvement programs is evident in Nepal due to lack of information about the desirable accessions in the genebank resulting from the poor characterization and evaluation data. Five out of eight millet varieties notified in the country were improved from native landraces, which includes Okhle-1, Kabre kodo-1 and Rato kodo of finger millet, Bariyo Kakugo of foxtail millet and Dudhe Chino of proso millet.

Finger millet

Baniya et al (2001) reported wide range of variation among 629 finger millet landraces characterized at Kabre, Dolakha during 1988-1989. Maximum grain yield was observed up to 7080 kg/ha and earliest maturity was 92 days. Among the characterized landraces, 10 accessions were selected for breeding parents, 1228 single plants were selected from medium to late maturing landraces, 486 single plants were selected from early maturing landraces. Selected plants were grown in individual lines, from which, 85 lines from medium late and 23 lines from early set were promoted. The descriptive statistics of 629 landraces for agronomical traits has been presented in **Table 1**.

Table 1. Range, mean and standard deviation for the traits in 629 finger millet landraces at Kabre, 1988-1989

Traits	Minimum	Maximum	Mean	Standard error of mean
Days to flowering	64	125	90	0.51
Days to maturity	92	187	145	0.61
Grain filling period (days)	27	79	54	0.03
Plant height (cm)	38	163	98	0.69
Finger length of main ear (cm)	2.6	11	5.1	0.06
Number of fingers on main ear	2.9	12.5	7.7	0.06
Grain yield (kg/ha)	100	7080	3040	49.0
Grain yield per plant (g)	0.35	29.78	10.98	0.19
Fodder yield (t/ha)	1.0	38.0	13.81	0.26
Fodder yield per plant (g)	3.82	211.1	49.67	0.94
Bearing tillers per plant	1.16	13.0	3.75	0.08
1000-grain weight	0.83	3.97	2.46	0.02

Source: Baniya et al (2001)

A total of 537 finger millet landraces were characterized during 2010-2012 at NAGRC Khumaltar and observed wide phenotypic variation (Bhattarai et al 2014). Highest degree of diversity was observed for number of leaves, leaf sheath length, ear exertion, blade length of flag leaf, leaf blade width, heading days, plant height, leaf blade length, number of productive tillers, finger length and ear size (**Table 2**).

Table 2. Diversity in 537 finger millet landraces of Nepal on different quantitative and qualitative traits at Khumaltar during 2010-2012

Traits	Maximum	Minimum	Mean	Standard Deviation	Shannon-Weaver Diversity Index (H')
Days to heading	99	52	79.5	10.12	0.885
Days to maturity	161	89	128.9	23.23	0.689
Leaf sheath length (cm)	13.3	1.8	9.60	1.11	0.902
Number of productive tillers	5	1	2.9	0.65	0.860
Ear exertion (cm)	20.8	5.8	12.3	2.40	0.901
Leaf blade length (cm)	47.8	23.4	33.2	4.58	0.872
Leaf blade width (cm)	1.5	0.7	1.07	0.11	0.886
Blade length of flag leaf (cm)	33.9	14.9	23.4	3.16	0.893
Blade width of flag leaf (cm)	2.64	0.48	0.88	0.15	0.818
Plant height (cm)	154.6	23.4	92.3	17.37	0.879
Finger length (cm)	13.2	3.7	7.0	1.88	0.841
Number of leaves	18.8	8	14.0	1.97	0.906

Source: Bhattarai et al (2014)

Bastola et al (2015) evaluated 50 finger millet landraces received from NAGRC at Rampur, Chitwan during 2011 to determine phenotypic variability among Nepalese finger millet landraces which showed significant variation for all 17 traits studied (**Table 3**). Most of variation was contributed from phenological characters, plant height, grain yield per ear, finger length, finger width, finger number per ear and productive tillers number.

Table 3. Statistical parameters for quantitative characteristics of fifty accessions at Rampur, Chitwan (2011)

Traits	Maximum	Minimum	Mean ± SE	F-Value
Days to heading	94	46	82.2 ± 1.29	81.73**
Days to flowering	104	52	88.99 ± 1.27	75.04**
Flag Leaf sheath length (cm)	12.9	8.7	10.53 ± 0.13	3.388**
Flag Leaf sheath width (cm)	1.08	0.58	0.95 ± 0.01	4.767**
Flag leaf blade length (cm)	37.4	22.3	27.65 ± 0.4	5.82**
Flag leaf blade width (cm)	0.95	0.73	0.85 ± 0.007	6.158**
Peduncle length (cm)	24.2	18.1	20.86 ± 0.2	3.242*
Plant height (cm)	119	47	96.34 ± 1.82	10.50**
Productive tillers number per plant	3.5	1.9	2.54 ± 0.05	2.572**
Finger length (cm)	12.9	4.6	6.66 ± 0.32	15.05**
Finger width (cm)	1.17	0.87	1.02 ± 0.01	1.772*
Number of fingers per ear	9.2	4.3	7.35 ± 0.15	5.46**
Days to maturity	128	74	117.36 ± 1.44	14.73**
Thousand kernel weight (g)	3.04	1.33	2.29 ± 0.05	2.468**
Straw yield per plant (g)	88.6	30.1	63.34 ± 1.75	2.644**
Grain yield per ear (g)	5.3	0.96	3.98 ± 0.12	5.615**
Grain yield per plant (g)	16.2	2.4	10.03 ± 0.36	3.497**

Source: Bastola et al (2015)

Similarly, 127 finger millet genotypes including Kabre Kodo-1 as a standard check were evaluated under National Observation Nursery at HCRP, Dolakha during two consecutive years of 2014 and 2015 (Adhikari et al 2017). Combined result showed the top highest yielding genotypes were KLE-278 (3725 kg/ha), ACC#2817(2850 kg/ha), ACC#2373 (2822 kg/ha), ACC#6416 (2815 kg/ha) and COLL#2424 (2720 kg/ha) where as standard check variety produced only 1907 kg/ha. Among high yielding genotypes, ACC#2373 was observed early in maturity (144 days) which was 12 days earlier than Kabre Kodo-1. KLE 278 was found with the bold seeds having 1000-grain weight of 3.45 g. Descriptive statistics from the experiment has been presented in **Table 4**.

Table 4. Diversity in 127 finger millet genotypes for different quantitative traits at HCRP Dolakha, 2014-2015

Traits	Mean	Minimum	Maximum	Standard Deviation
Daya to flowering	100	90	123	4.96
Days to maturity	156	144	162	3.10
Plant height (cm)	89	48	258	18.30
Grain yield (kg/ha)	1690	225	3725	542.2
Straw yield t/ha	3.61	0.85	6.05	1.02
1000 grain weight	2.74	1.94	3.45	0.28

Source: Adhikari et al (2017)

A total of 46 finger millet landraces (received from NAGRC and local collection) were characterized on-farm establishing diversity blocks at Ghanpokhara, Lamjung during 2015 (Yadav et al 2018b). Landraces were divided in five clusters with wide phenotypic variation (**Table 5**).

Table 5. Agro-morphological variation among 46 finger millet landraces (5 clusters) tested at Lamjung, 2015

Cluster	Member	Days to heading	Days to maturity	Plant height (cm)	Ear exertion (cm)	Flag leaf length (cm)	Finger width (mm)	Grain yield (t/ ha)
I	9	108±6.21 (98-117)	157±7.05 (150-166)	114±17.65 (102-125)	15.7±1.58 (12-17)	29±2.50 (25-32)	8.44±0.53 (8-9)	0.74±0.37 (0.37-1.56)
II	30	126±6.29 (114-136)	174±9.53 (152-194)	123±13.29 (94-143)	15.7±2.77 (11-23)	31±3.74 (23-39)	9.13±1.07 (7-12)	1.90±0.70 (0.71-3.17)

Cluster	Member	Days to heading	Days to maturity	Plant height (cm)	Ear exertion (cm)	Flag leaf length (cm)	Finger width (mm)	Grain yield (t/ ha)
III	3	135±2.31 (132-136)	180±13.45 (165-191)	103±6.08 (99-110)	16±1.00 (15-17)	33±3.51 (29-36)	7.67±0.57 (7-8)	1.17±0.36 (0.82-1.55)
IV	3	138±8.02 (130-146)	194±12.70 (179-201)	112±9.29 (102-120)	10.7±3.79 (8-15)	31±3.05 (28-34)	9±0.00	1.83±0.89 (0.80-2.35)
V	1	130	184	121	14	37	12	3.81

Source: Yadav et al (2018b)

Ghimire et al (2020) reported medium to high level of diversity among the 300 finger millet accessions for the qualitative traits. Thirty-nine percent of finger millet accessions were having open ears followed by 37% semi-compact heads. Sixty-five percent of accessions had intermediate size of ears followed by 30% large ears. Eighty percent of the accessions had pigmented plants while 51% accessions had light-brown seed color followed by 42% had purple-brown colored seeds (**Table 6**).

Table 6. Shannon-Weaver diversity indices, descriptor states and frequency of qualitative traits observed in 300 finger millet accessions at Khumaltar, 2017

Qualitative trait	S-W diversity index (H')	Descriptor states	Frequency (n)	Proportion (%)
		Droopy	67	23.1
Ear shape	0.799	Open	112	38.6
		Semi compact	109	37.4
		Compact	2	0.7
		Small	15	5.0
Ear size	0.725	Intermediate	188	64.7
		Large	88	30.2
		Exposed	36	12.6
Grain covering by glumes	0.691	Intermediate	207	73.7
		Enclosed	38	13.5
		Low	215	73.4
Lodging score	0.569	Intermediate	76	25.8
		High	3	0.9
Plant pigmentation	0.722	Not pigmented	236	80.1
		Pigmented	59	19.9
		White	9	3.0
Seed color	0.678	Light-brown	147	50.9
		Copper-brown	11	3.6
		Purple-brown	123	42.5
		Sparse	87	30.0
Spikelet density	0.716	Intermediate	189	65.2
		Dense	14	4.7

Source: Ghimire et al (2020)

A total of 300 finger millet genotypes (295 landraces from 54 districts and five released varieties) were evaluated for leaf, finger, and neck blast resistance under natural epiphytotic conditions across three hill locations in Dolakha, Jumla and Lalitpur during 2017 and 2018 (Ghimire et al 2022). The highest incidence of leaf, neck, and finger blast was observed at Lalitpur, followed by Dolakha and Jumla, whereas the overall disease incidence was higher in 2018 compared to 2017. Combined analysis over environments revealed non-significant differences among accessions for leaf blast, but the difference was highly significant for neck and finger blast. Among 300 accessions, 95 had lower scores for finger blast, 30 for neck blast, and 74 for leaf blast than the score of Kabre Kodo-2, the latest released variety in Nepal. Genotypes namely NGRC04798, NGRC03478, NGRC05765, NGRC03539, NGRC06484, NGRC01458, NGRC01495 and

NGRC01597 were found as the resistant genotypes for finger blast (2.1-2.3) and neck blast (1.5-2.3) based on pooled mean scores. Scores of different blast diseases among best and worst genotypes have been presented in **Figure 1**.

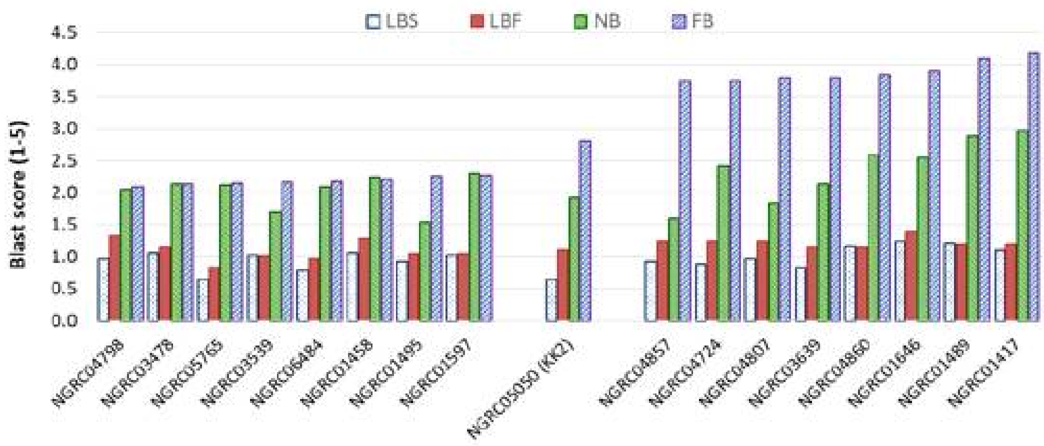

Figure 1. Resistant and susceptible finger millet landraces with the latest released variety Kabre Kodo-2. Data are mean of 12 observations: 2 replications × 3 locations × 2 years
Source: Ghimire et al 2022

The same set of 300 landraces were evaluated during 2017-2018 at NAGRC Khumaltar under plastic tunnel to identify drought tolerant landraces. The result revealed that Five landraces namely NGRC4849, NGRC6487, NGRC04852, NGRC03491 and NGRC6490 with average grain yield of 4670, 3624, 3426, 3191 and 3132 kg/ha, respectively (Ghimire et al 2023b), were identified as stable drought tolerant landraces compared to the released varieties (**Figure 2**).

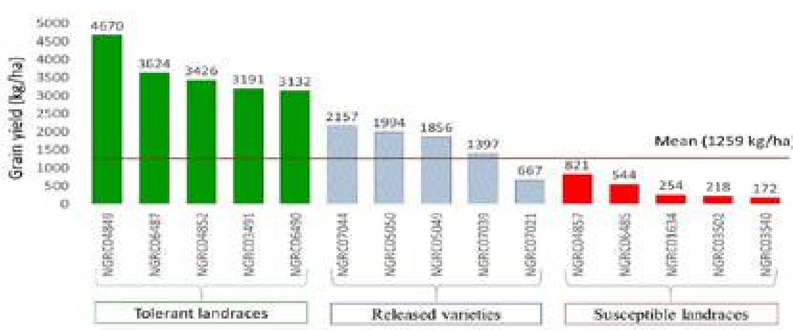

Figure 2. Mean grain yield of tolerant and susceptible landraces with released varieties of finger millet, 2017-2018
Source: Ghimire et al 2023b

Agro-morphological diversity accessed by evaluating 300 finger millet genotypes in two replications at three locations in 2017 and 2018. Wide range of variation was observed among the landraces as presented in **Table 7**. Variation in grain color and ear heads has been presented in **Figure 3**.

Table 7. Variability statistics and Shannon-Weaver diversity indices of 17 quantitative traits based on mean data

Trait	Minimum	Maximum	Mean	Standard error of mean	Shannon-Weaver Diversity (H')
Days to 50% flowering (n)	75	140	112.2	0.70	0.870
Days to 80% maturity (n)	122	174	154.4	0.59	0.871
Plant height (cm)	61	119	95.4	0.44	0.864
Tillers per hill (n)	2.5	5.9	4.4	0.03	0.898
Flag leaf length (cm)	22	32	27.2	0.10	0.880
Flag leaf width (cm)	0.5	1.2	0.91	0.01	0.906
Flag leaf sheath length (cm)	11	22	15.1	0.08	0.872
Ear exsertion (cm)	7.2	14	10.8	0.07	0.899
Ear head length (cm)	4.5	8.8	6.2	0.04	0.880
Ear head width (cm)	3.0	6.5	4.2	0.03	0.867
Fingers per head (n)	4.1	8.9	7.0	0.04	0.878
Length of the longest finger (cm)	4.0	9.8	5.9	0.06	0.875
Width of the longest finger (cm)	0.48	0.93	0.68	0.005	0.902
Weight per head (g)	3.1	10	5.9	0.06	0.897
Weight of 1,000 grains (g)	1.8	3.2	2.3	0.01	0.882
Grain yield (kg/ha)	230	3494	1577	30.3	0.884
Straw yield (t/ha)	2.0	20.2	9.3	0.17	0.907

Source: Ghimire et al (2023a)

Figure 3. Variation in grain color (left) and heads (right) of finger millet landraces
Source: Ghimire et al 2023a

Promising trait-specific donors were identified from the evaluation of 300 finger millet landraces at three locations (**Table 8**). Some landraces were good for multiple traits and some others for particular traits. For instance, NGRC06490 was high yielding with higher number of tillers; NGRC04849 was high yielding with higher 1,000-grain weight; NGRC04871 was high yielding with taller plant, longer ears and higher 1,000-grains weight; Kabre kodo-2 was high yielding with higher 1,000-grain weight and higher number of tillers; and NGRC04818 was high yielding with taller plant, higher 1,000-grain weight and higher weight per head.

Table 8. Promising finger millet trait donors selected based on combined analysis, 2017-2018.

Trait	Promising accessions
Days to flowering (< 90 d)	NGRC03581, NGRC03540, NGRC03502, NGRC01516, NGRC01489, NGRC03635, NGRC03636, NGRC03539, NGRC06503, NGRC06485, NGRC03650
Days to maturity (> 130 d)	NGRC03502, NGRC03540, NGRC01489, NGRC03581, NGRC03636, NGRC03539, NGRC06503
Plant height (< 70cm)	NGRC06503, NGRC03502, NGRC03639, NGRC04814
Plant height (> 110cm)	Dalle-1, **NGRC04871**, NGRC03511, **NGRC04818**, NGRC05764
Number of tillers/plant (> 5.4)	**NGRC06490**, **Kabre kodo-2**, NGRC04852, NGRC01609, NGRC03579, NGRC05739
Flag leaf length (> 30cm)	NGRC05109, NGRC01490, NGRC03605, NGRC04852, NGRC06493, Kabre kodo-1, NGRC03678, NGRC03690, NGRC04746, NGRC01401
Flag leaf sheath length (> 17.5cm)	NGRC01655, **NGRC04871**, NGRC04724, NGRC06498, **NGRC04818**, NGRC03528, NGRC06504, NGRC04863
Ear exsertion (> 14cm)	NGRC06493, NGRC01527, NGRC01610, NGRC03693
Ear length (> 7.5cm)	**NGRC04871**, NGRC01406, NGRC04821, NGRC01447, NGRC04817, NGRC01458, NGRC01609, NGRC01451
Weight per head (> 8g)	**NGRC04818**, Dalle-1, NGRC04804, NGRC01446, NGRC04806, NGRC01401, NGRC01639, NGRC01487
1000-grain weight (> 2.8g)	**Kabre kodo-2**, NGRC04816, **NGRC04849**, NGRC01418, NGRC04873, NGRC04850, NGRC04824, **NGRC04871**, **NGRC04818**
Grain yield (> 2,769kg/ha)	**NGRC04849**, **NGRC06490**, **NGRC04871**, **Kabre kodo-2**, NGRC06487, NGRC04727, NGRC04836, NGRC04806, **NGRC04818**
Straw yield (> 13t/ha)	Kabre kodo-1, NGRC01456, NGRC01452, Okhle-1, NGRC01455, NGRC01539, NGRC05758

Source: Ghimire et al (2023a)

A total of 72 finger millet landraces were characterized and evaluated at NAGRC Khumaltar during 2020, resulted high phenotypic variation among the landraces (**Table 9**). Landraces CO11707, CO12803, CO12570 and CO11696 performed better in direct seeded condition whereas CO13408 and CO10848 observed superior in transplanted condition. Most stable genotypes were CO12435, CO13252 and CO12937 in both the conditions.

Table 9. Agronomical traits diversity among 72 finger millet accessions at Khumaltar, 2020

Trait	Mean	Standard error of mean	Coefficient of variation (%)	Shannon-Weaver Diversity (H')
Days to heading	96	0.74	6	0.71
Plant height (cm)	103	1.1	9	0.8
Ear head length (cm)	7.6	0.2	27	0.74
Ear weight (gm)	9.8	0.25	22	0.72
Number of fingers per ear	7.0	0.1	16	0.71
Number of leaves per plant	12.4	0.2	16	0.71
Area of flag leaf	35.2	0.8	18	0.65
1000-grain weight (g)	2.84	0.04	13	0.76
Grain yield (kg/ha)	4.38	0.13	26	0.7

Foxtail millet

While evaluating 560 global foxtail millet genotypes including 37 landraces from Nepal, high genetic diversity was reported among Nepalese landraces for *pro-2* loci concluding China including Nepal as one of the centers of diversity for foxtail millet (Nakayama et al 1999). Five landraces from Dolpa, Mugu, Bajura, Bajhang and Lamjung districts were evaluated at Khumaltar, Lalitpur during 2010 and reported higher level of variability in many traits (Amgai et al 2011). Days to heading and days to maturity varied from 33-56 and 59 to 87 days, respectively. Similarly, flag leaf length/breadth ratio, flag leaf sheath length, ligule length, peduncle length, panicle exertion and plant height ranged from 3.8-10.9, 5.5-9.8 cm, 0.1-0.2 cm, 10-22.6 cm, 2.7-13.6 cm and 41.7-120 cm, respectively. Fruit and apiculus color varied from straw to black. Similarly, the 1000-grain weight ranged from 1.06-2.17 g. The authors suggested to select landraces producing lower number of tillers with synchronized maturity between primary and secondary tillers for yield improvement. Ten foxtail millet accessions were evaluated for assessing the diversity in different characters at Rampur, Chitwan with the maximum diversity in traits of lobe compactness followed by panicle lodging, inflorescence compactness and length of bristles. Least diversity was observed in trait of growth habit followed by panicle anthocyanin coloration and lobes in panicles (Sapkota et al 2016).

On-farm characterization and diversity assessment of 27 Nepalese foxtail millet landraces (**Table 10**) at Humla, Jumla, Lamjung districts during 2015 identified four locally adaptable landraces namely Kalo Kaguno, Seto Kaguno, Aule Kaguno, and CO1896 (Yadav et al 2018a).

Table 10. Descriptive statistics and Shannon-Weaver index of quantitative traits of foxtail millet accessions, 2015

Quantitative traits	Shannon-Weaver Diversity (H’)	Mean ± SE	Minimum	Maximum
Plant height (cm)	0.74	133.7 ± 3.00	94	162
Panicle exertion (cm)	0.76	16.2 ± 0.60	10	22
Panicle length (cm)	0.80	14 ± 0.50	11	21
Flag leaf length (cm)	0.80	21.4 ± 0.77	16.1	32.1

Source: Yadav et al (2018a)

Similarly, a total of 41 foxtail millet landraces collected from six districts were characterized using morphological markers at NAGRC, Khumaltar, Lalitpur during 2015 to enhance the utilization of foxtail millet landraces (Ghimire et al 2018b). Among them, high level diversity was observed for growth habit, phenology, plant stature, length and width of inflorescence, flag leaf angle, leaf and sheath pubescence, leaf blast and stem borer susceptibility, and grain color. Six elite landraces namely C5644, H252, C5647, C5808, C5643, and C4581, produced average grain yield (3136 kg/ha) with earlier maturity (89 days), taller plant height (172 cm) and thicker panicle width (27 mm). **Table 11** showed the agro-morphological variation among the tested landraces.

Table 11. Descriptive statistics and Shannon-Weaver diversity index (H’) for quantitative traits of 41 foxtail millet landraces at Khumaltar, 2015

Trait	Minimum	Maximum	Mean ± SE	Shannon-Weaver Diversity Index (H’)
Days to heading	45	71	60 ±1.1	0.835
Days to maturity	81	113	98 ±1.8	0.806
Plant height (cm)	108	232	159 ±4.2	0.852
Panicle length (cm)	13	30	21.7 ±0.6	0.843
Panicle width (mm)	10	33	18.2 ±0.8	0.820
Panicle exertion (cm)	7	30	15.9 ±0.8	0.899
Grain yield (kg/ha)	89	3483	1247 ±161	0.689

Source: Ghimire et al (2018b)

A total of 50 foxtail millet landraces from 10 districts were characterized in two replications at NAGRC, Khumaltar during 2023. Among them, a substantial level of diversity was evident for inflorescence traits, earliness, plant height, and yield potential (**Table 12**). Landraces namely NGRC07947, NGRC05089, NGRC05087, NGRC07953, NGRC7945, NGRC07419, NGRC7944, NGRC05088, NGRC06109, NGRC08640, NGRC08643, NGRC06659, and NGRC07949 were found superior than the others. However, NGRC05087 was the highest yielding with largest panicles, NGRC05091 was the earliest in maturity, and NGRC07949 was observed as leaf blight resistant landrace. **Figure 4** showed the grain color variation in foxtail millet landraces used in the study.

Table 12. Descriptive statistics and Shannon-Weaver diversity indices for different quantitative traits of 50 foxtail millet landraces at Khumaltar, 2023.

Traits	Minimum	Maximum	Mean	Standard error of mean	Shannon-Weaver Diversity (H')
Days to Heading	88	132	110	1.39	0.863
Days to flowering	92	136	112	1.54	0.819
Days to maturity	138	170	149	1.51	0.665
Number of basal tillers	1	3	1.29	0.06	0.703
Blade length of flag leaf (cm)	29	44	36.51	0.58	0.882
Blade width of flag leaf (cm)	2	4	2.94	0.04	0.856
Sheath length of flag leaf (cm)	15	27	19.48	0.42	0.876
Number of leaves per plant	9	26	13.70	0.51	0.811
Length of peduncle (cm)	23	45	34.32	0.71	0.874
Peduncle exsertion (cm)	7	23	14.99	0.55	0.864
Sheath diameter of stem (mm)	4	7	5.58	0.12	0.901
Plant height (cm)	119	214	163.43	3.81	0.867
Length of inflorescence (cm)	16	26	22.88	0.31	0.834
Bristle length (cm)	0	1	0.28	0.02	0.801
Panicle width (cm)	1	4	2.04	0.07	0.821
Weight of inflorescence (g)	2	22	10.85	0.70	0.861
Weight of grain per panicle (g)	1	18	8.53	0.60	0.908
Number of grains per panicle	674	11670	4757	410.8	0.712
Seed diameter (mm)	0.59	1.38	1.04	0.02	0.844
1000-grain weight (g)	0.15	2.70	1.79	0.07	0.842
Grain yield (kg/ha)	217	4965	2073	177.1	0.813

Figure 4. Diversity of seed color (left) and panicles (right) in foxtail millet landraces at Khumaltar, 2023

Proso millet

Ghimire et al (2018a) characterized 42 proso millet landraces at NAGRC Khumaltar in 2015 and reported medium to wide variation in qualitative and quantitative traits (**Table 13**). Landraces H237, H176, H311, H489, H490, H643 and H653, all from the Humla district, performed better in terms of yield and earliness.

Table 13. Descriptive statistics and Shannon-Weaver diversity index (H') for quantitative traits of 42 proso millet landraces at Khumaltar, 2015

Trait	Minimum	Maximum	Mean	Standard error of mean	Shannon-Weaver Diversity (H')
Days to flowering	28	57	41.8	1.21	0.768
Days to maturity	72	96	80.5	1.03	0.728
Plant height (cm)	80	155	128	2.18	0.796
Panicle length (cm)	27	43	34.0	0.53	0.880
Panicle exertion (cm)	3	13	7.5	0.37	0.889
Flag leaf length (cm)	21	42	30.7	0.78	0.840
Grain yield (kg/ha)	100	3867	1784	130	0.831

Source: Ghimire et al (2018a)

During 2023, a total of 37 proso millet landraces collected from Humla, Jumla and Mugu were evaluated in two replications at NAGRC Khumaltar showed significant variations among germplasm in both qualitative and quantitative traits (**Table 14**). Overall, NGRC07364, NGRC07338, NGRC07339, NGRC07346, NGRC10228 from Humla, and NGRC09157 from Mugu exhibited earlier maturity and higher grain yield. NGRC10228 is the highest yielding landrace, NGRC09157 is the earliest in maturity and NGRC07339 is observed as leaf blast resistant.

Table 14. Descriptive statistics parameter and Shannon-Weaver diversity indices for different quantitative traits of 37 Nepalese proso millet germplasm

Trait	Minimum	Maximum	Mean	Standard error of mean	Shannon-Weaver Diversity (H')
Days to heading	86	99	91	0.44	0.822
Days to flowering	90	103	96	0.44	0.846
Days to maturity	127	134	130	0.28	0.836
Number of basal tillers	4	14	7	0.26	0.730
Blade length of flag leaf (mm)	305.4	414.8	359.6	4.37	0.901
Blade width of flag leaf (mm)	21.6	28.2	25.5	0.25	0.863
Sheath length of flag leaf (mm)	106.5	125.6	115.6	0.84	0.865
Length of peduncle (mm)	139.6	303.8	194.9	4.56	0.802
Peduncle exertion (mm)	30.3	184.6	79.3	4.26	0.799
Plant height (cm)	84.4	139.1	111.5	1.94	0.872
Number of culm branches	1	4	2	0.11	0.817
Length of inflorescence (mm)	289.5	373.3	329.6	3.66	0.856
Number of primary inflorescence branches	6	14	10	0.29	0.869
Number of nodes per primary axis of inflorescence	4	7	5	0.13	0.859
Number of secondary inflorescence branches	38	88	59	1.97	0.885
Weight of panicle (g)	1.58	7.29	3.50	0.23	0.784
Number of grains per panicle	156	928	409	30.86	0.780
Weight of grains per panicle (g)	0.95	5.95	2.61	0.20	0.791
Length of seed (mm)	2.90	3.21	3.03	0.01	0.826
Width of seed (mm)	2.18	2.36	2.24	0.01	0.773
1000-grain weight (g)	5.70	7.25	6.51	0.06	0.895
Grain yield (kg/ha)	261	2187	1131	79.17	0.855

Conclusion

Characterization and evaluation of native landraces of millets was started from 1972 in Khumaltar. Several attempts were made to characterize and evaluate thousands of landraces mainly of finger millet then by foxtail millet and proso millets. This characterization was mainly used morphological descriptors. Recent works on finger millet, foxtail millet and proso millet exploited high level of phenotypic diversity among Nepalese millets landraces and identified some promising trait-specific landraces. These landraces could be included in national coordinated varietal trials and released or registered for the farming communities. Plant breeders should utilize these findings to select the suitable landraces to include in millet improvement programs and improve the productivity of millets in Nepal.

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Biotechnology in Millet Crops

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Summary

Biotechnological tools play a pivotal role in millet research, with a focus on tissue culture, molecular marker technology, and genetic engineering. Among millet species, especially sorghum, finger millet, pearl millet, and foxtail millet, biotechnological methods have been extensively employed. Successful tissue culture techniques have been developed for various millet species using diverse explants. Both isozymes and DNA markers have been instrumental in screening millet genotypes. Genome sequences are available for several millet species, including sorghum, foxtail millet, pearl millet, finger millet, proso millet, and barnyard millet. Notably, genetically modified sorghum varieties have been created. Major focusses on using biotechnology are enhancing genetic variation and developing millet varieties resistant to both biotic and abiotic stresses. However, the application of biotechnological tools in Nepal, where 21 millet species are reported, remains very limited. Only genetic diversity in finger millet had been assessed using RAPD and SSR markers. Advances made around the world in millet biotechnology could be very useful and applicable to millets improvement in Nepal which can help to accelerate the development of high yielding and environment resilient varieties suitable to a particular area.

Keywords: Biofortification, DNA sequence, genomics, molecular marker, tissue culture

Introduction

Biotechnology, which harnesses cellular and biomolecular processes to develop innovative products, methods, and organisms, has found a compelling application in the realm of millet species. Millets, renowned for their hardiness and resilience to various environmental conditions, offer a fertile ground for biotechnological advancements. The major areas of biotechnology focus for millet crops include tissue culture, molecular markers technology, and genetic engineering (Kothari et al 2005). These approaches have expanded the scope of millet cultivation and hold immense promise for both farmers and consumers. Classical breeding methods, coupled with modern marker-assisted selection, genetic manipulation, and in vitro culture techniques, have contributed significantly to the improvement of various millet species. These techniques have enabled the transfer of genes governing specific traits between species, broadening the gene pool available for crop enhancement.

Sorghum, finger millet, pearl millet, foxtail millet, and proso millet have been extensively studied using biotechnological tools. Several markers being employed to screen for disease-resistance in pearl millet (Mahatma et al 2011, Verma et al 2021), sorghum (Upadhyaya et al 2013), finger millet (Babu et al 2014) and foxtail millet (Li et al 2021). O'Kennedy et al (2006) discussed the state of transformation technology for sorghum and millets, while Lata (2015) conducted extensive genome-wide investigations in foxtail millet. Saleem et al (2021) reviewed the molecular-level adaptation strategies of millets. The molecular basis of waxy starch has been identified in foxtail millet, proso millet, and barnyard millet, which has implications for their use in infant foods (Vinoth and Ravindhran 2017). Biotechnological advancements, particularly the Biolistic-mediated gene delivery method, have been employed for millet transformation, although Agrobacterium-mediated transformation lags (Ceasar and Ignacimuthu 2009). Additionally, advanced approaches such as Genomic Selection (GS), Genome-Wide Association Studies (GWAS), functional genomics, gene validation, and Genetic Engineering (GE) have been explored for millet improvement, as documented by Ajeesh Krishna et al (2022).

While global research and development efforts have given priority to millets due to their environmental resilience and nutritional value, the application of biotechnological advancements in millet improvement in Nepal remains limited, though there are more than 15 biotechnology labs in Nepal. Genetic diversity studies, particularly using DNA markers, have been scarce, with the focus primarily on finger millet among the 21 millet species in Nepal (Joshi et al 2023). The neglect and undervaluation of other millet species underscore the untapped potential of biotechnology in improving millet crops, both locally and globally. From tissue culture to DNA sequencing, biotechnology continues to unlock new horizons for millets, offering solutions to the challenges of modern agriculture and nutrition.

History of Millets Biotechnology

In the realm of biotechnology, the history of advancements in millets, including sorghum, pearl millet, and finger millet, is marked by a series of notable achievements (**Figure 1**). Tissue culture techniques, first explored in the 1970s, paved the way for successful callus formation and plant regeneration in these millet species (Rangan 1974, 1976). Various millet species, including finger millet, Nepalese barnyard millet, awnless barnyard grass, Kodo millet, foxtail millet, pearl millet, and wild relatives of millet crops, were cultured in vitro using different growth regulators for callus induction and plant regeneration (Kothari et al 2005).

From 1991, transgenic plant development took center stage, as researchers harnessed microprojectile bombardment to introduce specific genes into sorghum and pearl millet (Taylor and Vasil 1991, Casas et al 1993, Girgi et al 2002), with the creation of transgenic pearl millet varieties by Girgi et al (2002) using *bar* and *gus* genes. Transformation of finger millet and barnyard grass was studied by Gupta et al (2001).

Mutation breeding, initiated in 1982 in pearl millet and sorghum continued to induce genetic mutations using various agents eg gamma rays, ethyl methane sulfonate, and diethyl sulfate (Hanna 1982). In 1995, the implementation of a gel electrophoresis system was initiated to identify pearl millet hybrids and their respective lines, as documented by Kumar et al (1995).

Molecular markers played a pivotal role, with the tagging of the head smut resistance gene in sorghum (Oh et al 1994) and the use of ISSR markers in pearl millet (Yadav et al 2007). Marker-Assisted Breeding (MAB) led to the development of a new pearl millet variety, HHB 67, in 2006, known for its resistance to downy mildew disease (Hash et al 2006), which was the first product of MAB available to Indian farmers. Finally, genome sequencing, with the smallest genome belonging to foxtail millet (510 Mb) and the largest to pearl millet (~ 1.79 Gb), has opened doors for comprehensive functional genomics studies, particularly in foxtail millet, the first millet to have its entire genome sequenced in 2012. In millets, genome sequences are available for foxtail millet, pearl millet, finger millet, proso millet, and barnyard millet (Ajeesh Krishna et al 2022).

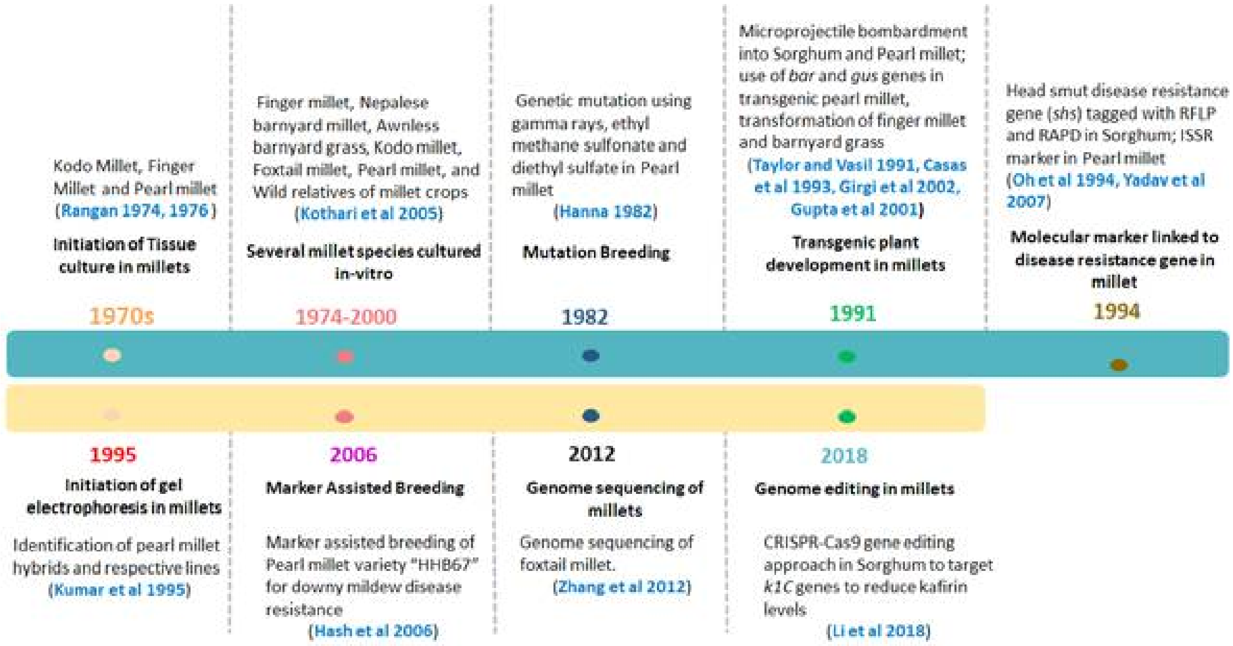

Figure 1. Major milestones on biotechnological progress on millet genetic resources

Isozymes markers

Phenotypic marker-based crop improvement programs typically move more slowly than intended because genotypic performance is not always accurately represented by phenotypic assessment. Furthermore, the environment has an impact on phenotypic markers, which may only tangentially correlate with the desired feature or traits. In comparison to phenotypic markers, molecular markers exhibit coinheritance with the target trait(s), are simple to screen, and are not affected by the environment (Chhabra et al 2001). Among molecular markers, isozyme markers are the most ancient (Manivannan et al 2013).

Markert and Moller (1959) first used the term "isozymes" to refer to the many molecular forms of proteins that share the same enzymatic specificity (Shannon 1968). A class of enzymes known as isoenzymes, or isozymes, catalyze the same reaction but differ in their forms and catalytic efficiencies. The most common way to identify isozymes is via their electrophoretic mobilities (Eun 1996). Isozymes' consistent expression across environmental conditions has made them trustworthy genetic markers in plant species breeding and genetic research (Heinz 1987). According to William and Mujeeb (1992) isozymes offer helpful evidence when examining how cultivars differ in terms of the strength of common bands and the existence or absence of other bands. Moreover, analyzing the isozyme pattern is thought to be a crucial tool for determining the genetic link between individuals as well as for identifying hybrids (Manivannan et al 2013).

Isozymes are a product of gene expression that can be used as a fundamental analytical tool to evaluate molecular characterization (Manivannan et al 2013). These techniques have been used to characterize specific plant genotypes, cultivars, inbred lines, screen variability in plant populations, and map chromosomes (Moore and Collins 1983). It is frequently utilized at the molecular level as a key genetic marker to detect inheritance and variance among various species or cultivars within the species

(Manivannan et al 2013). Isozymes are also used both directly and indirectly in host-pathogen interactions (Mahatma et al 2011). Enzyme diversity in pearl millet has primarily been investigated in relation to disease resistance/susceptibility, as genetic markers for linkage map construction, to evaluate taxonomic/ phylogenetic affinities within the species, and to understand genetic variability in relation to geographic distribution and evolution.

In a study, Mahatma et al (2011) used isozyme, protein, randomly amplified polymorphic DNA, and inter-simple sequence repeat markers to identify downy mildew resistant and susceptible pearl millet genotypes. In resistant genotypes, two distinct proteins measuring ~97 and ~100 kDa were found to be present, according to total seed protein profiling. Six markers were identified by inter-simple sequence repeat (ISSR) analysis in resistant genotypes: UBC-825 (900 bp), UBC-827 (900 bp), UBC-857 (1000 bp, 700 bp, 375 bp and 200 bp). A single distinct band, UBC-857 (400 bp), was also only found in susceptible genotypes. A combined examination of isozyme, protein profiling, RAPD, and ISSR data revealed two separate groups of genotypes that were resistant and susceptible. These findings suggested that ISSR markers and seed protein profiling might be utilized to extensively screen germplasm for disease reaction characteristic.

A study of Anatala et al (2015) aimed to understand the drought tolerant mechanism of pearl millet through a consolidated study on changes in physiological, biochemical and protein profile. The biochemical study showed increased content of proline and glycine betaine in water stress treatment. Different levels of bands were detected in all three different isoenzymes. All bands showed monomorphic banding pattern. However, the exact mechanism of drought tolerance remained to be investigated.

Manivannan et al (2013) used peroxidase isozyme to define 21 genotypes (7 hybrids, 6 female parents, 5 male parents, and 3 open pollinated varieties) of pearl millet. The Rm/Rf value ranges of 0.5 to 0.64 were observed in five bands that were discovered. A band with Rm value of 0.55, which was present in all genotypes, was the only band that was discovered to be polymorphic in nature. Out of all 21 genotypes, only three (H 77/29-2, HMS 7A and HHB 94) could be distinguished from one another. Based on POX banding patterns, similarity indices showed that hybrid HHB 50, HHB 60, HHB 67 and HHB 146 and their female parents MS 81A, MS 843A and ICMA 95222A were nearly identical (SI 1.000). This demonstrated the female parent's maximum contribution to the hybrid's development as compared to the male parent.

Peroxidase enzyme was studied by Shivakumar et al (2003) as a potential biochemical measure of downy mildew disease resistance. The outcomes demonstrated that although very susceptible seedlings only displayed 12 isozymes, highly resistant and induced-resistant seedlings recorded 22 isozymes with pI ranging from 3.6 to 9.8. Cultivar-specific studies revealed distinct differences in peroxidase activity across highly resistant, resistant, susceptible, and highly susceptible seedlings at the constitutive level: 55.2 and 54.9, 40.9 and 44.8, 40.8 and 41.9, and 33.6 and 32.9 units, respectively. Moreover, highly resistant, resistant, and induced-resistant seedlings showed an increase in enzyme activity following inoculation, while susceptible and extremely susceptible seedlings showed a drop.

The role of superoxide dismutase (SOD) in pearl millet against downy mildew disease stress was examined. The findings demonstrated that when the pathogen *S. graminicola* was injected into a resistant genotype, SOD activity increased. In contrast, in the susceptible genotypes, a modest rise in enzyme activity happens too late (Babitha et al 2002). These results suggest that SOD contributes to pearl millet's ability to fend off downy mildew disease. Likewise, Babitha et al (2004) reported that resistant pearl millet seedlings showed a 2.4-fold increase in LOX activity following inoculation with the downy mildew pathogen, mostly attributed to the creation of a novel LOX isozyme known as LOX-6.

A study of Kumar et al (2007) employed seed esterases to assess the uniqueness of 45 genotypes of pearl millet, including 14 hybrids and their parental lines. Of the 45 genotypes examined, 36 could be distinguished from one another, and 11 fell into four groups with a 2.29×10^{-3} likelihood of having an identical match by chance. Additionally, they discovered that the seed esterase marker is not linked to any physical characteristics, is highly polymorphic among pearl millet cultivars, stable over generations, and unaffected by the environment.

Omics science of millets/millet genomics

In recent decades, biofortified millet cultivars have been successfully developed by conventional breeding procedures. But these methods by themselves won't be enough to meet the growing population's future dietary and nutritional needs (Kudapa et al 2023). Recent advancements in omics methods have the potential to greatly speed the development of biofortified millet and sorghum cultivars for future climates (Varshney et al 2021). In order to create biofortified crops for the future, it is imperative that many omics methodologies be integrated, including transcriptomics, proteomics, metabolomics, and ionomics.

Genomics

Novel advancements in the field of genomics have resulted in the creation of many marker systems, such as mapping microsatellite or simple sequence repeat (SSR) markers, SNPs markers, insertion-deletion (InDel) markers, and, more recently, haplotype-based SNP markers (Kudapa et al 2023).

Because polyphenols and tannins are complex compounds, one of the main issues with sorghum is the poor bioavailability of micronutrients in the grain. Using a hybrid 296B × PVK 801 with parents that differed in grain Fe and Zn content, Phuke et al (2017) created a RIL population to identify QTLs for these two nutrients. The RIL population's grain Zn (10.2–58.7 mg kg^{-1}) and Fe (10.8–76.4 mg kg^{-1}) contents varied widely. It was discovered that there was a selection pressure for bolder seeds in biofortification programs because the grain Fe and Zn content was favorably connected with 100-seed weight and negatively correlated with yield. For both micronutrients, there was a strong G×E interaction, with Fe being more impacted by the environment than Zn (Phuke et al 2017). In order to decipher the genetic factors influencing the natural variation seen in the concentration of seed elements, Shakoor et al (2016) carried out a GWA mapping of alleles controlling 20 traits that affect the sorghum seed ionome, or the mineral, nutrient, and trace element composition that represents the inorganic part of cellular and organismal systems (Salt et al 2008). Putative genes controlling the accumulation of zinc, magnesium, nickel, calcium, and cadmium in sorghum seeds were also discovered in this investigation.

The discovered genetic heterogeneity in adapted pearl millet hybrids and inbreds raises the prospect of selective breeding leading to higher grain micronutrient concentrations. Using an association mapping panel of 130 different lines of pearl millet, which displays a wide range in grain micronutrient content, Anuradha et al (2017) performed GWAS. A total of 16 genomic areas were found to have high Fe and Zn concentration in this investigation. Additionally, a GWAS that used three million SNPs that were produced using GBS identified several hundred important MTAs for the Fe and Zn content of grain. Six potential genes related to Fe/Zn uptake were also identified by this investigation. The YUCCA-11 gene emerged as the most noteworthy contender, as it is recognized to propel Zn efficiency through auxin biosynthesis (Manwaring 2018).

Puranik et al (2020) used mixed model and general linear model techniques to identify 418 frequent MTAs for finger millet that were linked to varying mineral contents. Eighteen of these 34 MTAs showed similarity with putative binding, remobilization, or metal ion transport genes (Puranik et al 2020). Following functional confirmation of these MTAs, these markers can be used in genomic breeding techniques to breed finger millet for high-grain nutritional quality.

Transcriptomics

Transcriptome sequencing has been completely transformed by recent developments in next-generation sequencing technologies. Transcriptomics has been used in several crop species to find candidate genes linked to nutrient production and accumulation since it is a high-coverage, cost-effective method (Mishra et al 2019). Moreover, high-throughput molecular marker development is made possible by RNA-sequencing (RNA-seq), which also offers information regarding the relative abundance of transcripts (at a particular stage or condition).

Zhou et al (2020) reported that RNA-seq analysis of grains from three different sorghum cultivars with varying grain colors revealed over 3,000 genes that were differentially expressed. These genes were primarily enriched in the metabolism of carbohydrates, amino acids, and flavonoids, which may have an impact on the nutritional content of the grain. Additionally, a potential alpha-amylase 3 gene was identified as a strong candidate linked to the variation in protein and fat content in sorghum grains by comparing the expression patterns of the genes (from an RNA-seq dataset) underlying a GWAS QTL (Rhodes et al 2017).

A recent study found that candidate genes expressed in developing spikes and those linked to the variation in Fe and Zn levels were found by performing transcriptome profiling of stage-specific spikes of pearl millet genotypes contrasting for grain Fe and Zn content (Satyavathi et al 2022). In the genotypes exhibiting high Fe and Zn content, 155 and 251 transcripts were discovered to be up-regulated, respectively, whereas 349 and 378 transcripts were found to be differentially expressed throughout the flowering and milking stages of development. Since the calcium content of finger millet grains is higher than that of other millet genotypes (GP45, high calcium content; GP-1, low calcium content), an RNA-seq analysis of the spike tissues of the two genotypes was conducted (Singh et al 2014). 24 calcium sensor genes (such as CaM, CaMLs, CBLs, CIPKs, and CRKs) were shown to be highly expressed in individuals with high calcium genotypes based on a comparison of the relative abundance of transcripts. All together, these findings show how transcriptomics may be applied and promote the use of RNA-seq in millets to fully identify and functionally characterize the role of genes controlling nutritional content in these crops.

Proteomics and metabolomics

Among the omics techniques, proteomics and metabolomics are prominent players because they are essential for identifying the biomolecules and trace components with significant nutritional significance. By providing important insights into the biological processes, these methods have the ability to improve the production of vital metabolic chemicals in millets and discover the role of the protein. For instance, a recent study (Ramalingam et al 2021) distinguished between temperate and tropical sorghums based on the accumulation of phenolic acids, phytosterols, flavonoids, carotenoids, amino acids, sugars, and fatty acids through the use of non-targeted metabolomics analysis on a set of 61 distinct sorghum accessions. This work provided fresh possibilities for producing sorghum varieties that have been biofortified with improved medicinal and nutraceutical properties. Although millets are the main source of nutrition for people in impoverished nations, it is still important to identify potential genes and their roles in nutrient production and accumulation by analyzing the proteome and metabolome at different stages of seed growth.

Ionomics

As genotyping and sequencing platforms continue to advance technologically, high-throughput phenotyping becomes increasingly important for improving grain micronutrient content in various crops. As a result, ionomics has become a high-throughput method for "elemental profiling" that may be used to precisely determine the mineral nutritional content of a living thing (Huang and Salt 2016). Ionomics, from the perspective of nutrition, will be a useful method to determine the processes of mineral transport in millets by identifying the genes encoding the transporters and describing their molecular activities (Kumar et al 2014a). While ionomic research in crops is still in its early phases, ionome's function can be extended to determine grain crop nutrient levels.

Molecular markers in millets

A specific DNA sequence can be found in unknown gene pool using molecular markers. Since they may be found in all tissues and are stable, molecular markers have many advantages over traditional, phenotype-based alternatives. This is truly independent of the cell's state of development, growth, differentiation, or defense. They are also not affected by pleiotropic, epistatic, or environmental impacts (Mondini et al 2009). Genomic variability at DNA level can be present in many forms including single nucleotide polymorphisms, variable number of tandem repeats (e.g., mini- and microsatellites), transposable elements (e.g., Alu repeats), structural alterations, and copy number variations (Teama 2018). According to Yang et al (2015), DNA markers can be divided into two groups: (1) DNA hybridization-based methods, such as restriction fragment length polymorphism (RFLP) and DNA chips, and (2) polymerase chain reaction methods, such as simple sequence repeats (SSR), random amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP) and single nucleotide polymorphism (SNP). Molecular approaches have been employed to understand genetic diversity in major and various small millet species (Salimath et al 1995, Chowdari et al 1998, Parani et al 2001, Gupta et al 2010, Panwar et al 2010a) (**Table 1**).

Table 1. Genetic Diversity of millet species

SN	Crop	Markers	Accession	Allele per locus	PIC	Diversity Index	References
1	Finger millet	RAPD SSR	40	6.3 7.8	0.31 0.37		Joshi et al (2020)
2	Finger millet	SSR	959		0.53	0.58	Bharathi (2011)
3	Finger millet	SSR	128	2.1	0.44	0.14	Ramakrishnan et al (2016)
4	Finger millet	SSR	138	11.1	0.61		Lule et al (2018)
5	Finger millet	SSR	90	2.43	0.66	0.18	Pandian et al (2018)
6	Foxtail millet		125	1.8		0.18	Kumari et al (2011)
7	Foxtail millet	SSR	26	10.6	0.62	0.65	Kim et al (2012)
8	Foxtail millet	SSR	250	20.9	0.84	0.86	Wang et al (2012)
9	Foxtail millet	SSR	128		0.72	0.75	Liu et al (2011)
10	Pearl millet	SSR	214		0.77	0.82	Bashir et al (2015)
11	Pearl millet	SSR	404	8.4		0.48	Diack et al (2017)
12	Pearl millet	SSR	86	3.7	0.68	0.61	Bougma et al (2021)
13	Proso millet	SSR	90	2.4			Rajput et al (2016)
14	Proso millet	SSR	88	2.7	0.38	0.44	Liu et al (2016)
15	Proso millet	SSR	98	4.9	0.36	0.39	Hunt et al (2011)
16	Sorghum	SSR	24	1.5	0.24	0.29	Enyew et al (2022)
17	Sorghum	SSR	100	7.2	0.25	0.80	Mamo et al (2023)
18	Sorghum	SSR	3367	19.1		0.67	Billot et al (2013)

Molecular Markers in Genetic Diversity Study

Finger millet (*Eleusine coracana* Gaertn)

Finger millet grain contains 12.3 % protein, 4.7 % fat, 60.6 % carbohydrates, and 3.2 % ash (Jayawardana et al 2019). Genome of finger millet is 1.5 Gb (Vetriventhan et al 2020). The evaluation of genetic diversity among numerous species, including finger millet, has been accomplished with the help of SSR markers. Reports on the analysis of genetic diversity of millet using SSR markers with a significant level of polymorphism; 10 genomic SSR markers were used to detect 70.19% polymorphism in 83 genotypes (Panwar et al 2010); 24 genomic SSR markers were used to detect 66.6% polymorphism in 52 genotypes (Kumar et al 2012); and 30 genic SSR markers were used to detect 68.23% polymorphism in 103 genotypes (Nirgude et al 2014). Ramakrishnan et al (2016) reported that SSR markers showed 73.80 % polymorphism using 87 genomic SSR markers in 128 genotypes. However, out of 87 markers, only 72 markers (82.75 %) were discovered to be polymorphic. The cross-genome transferability of 101 finger millet and 26 foxtail millet using SSR markers ranged from 47.52 % to 61.38 % and from 30.76 % to 69.23 % respectively (Krishna et al 2018). Genetic diversity was assessed in 40 landraces collected from Kaski and Dhading district using 9 RAPD and 5 SSR markers which have exhibited intermediate diversity. The result showed 6.33 and 7.8 per RAPD and SSR primers respectively, whereas Mean Polymorphism Information Content was 0.314 for RAPD and 0.37 for SSR (Joshi et al 2020). Using eight probe-three enzyme RFLP, 18 RAPD primers, and six ISSR primers, respectively, to study 22 accessions from five species of *Eleusine*, three DNA marker approaches showed 14, 10, and 26% polymorphism in 17 accessions of *E. coracana* from Africa and Asia.

Utilizing the full potential of the crop mainly depends on an in-depth exploration of the vast diversity in its germplasm. The worldwide finger millet germplasm diversity panel of 314 accessions from ICRISAT was genotyped to analyze genetic diversity and population structure using the DArTseq technique. After filtering, 33,884 high-quality single nucleotide polymorphism (SNP) markers from 306 accessions. The genetic diversity of finger millet germplasm was high, with mean polymorphic information content, gene diversity, and Shannon Index values of 0.110, 0.114, and 0.194, respectively. The overall average genetic distance was 0.301 (range 0.040 - 0.450). The race *elongata* accessions had the highest (0.326) average genetic distance, while the race *elongata* and *vulgaris* had larger (0.320) genetic divergence (Backiyalakshmi et al 2021)

Pearl millet (*Pennisetum glaucum* (L.) R. Br.)

A study on a collection of 214 pearl millet accessions from different geographical regions of Sudan, and 11 accessions using 30 SSR markers revealed PIC= 0.77, GD= 0.82, Ho= 0.72. Analysis of molecular variance revealed that the variation of pearl millet accessions within the regions was much higher than among the regions (Bashir et al 2015). These findings show that the pearl millet accessions examined possess a high level of genetic diversity and are suitable for improving pearl millet breeding in Sudan.

Foxtail millet (*Setaria italica* (L.) Beauv.)

According to Vetriventhan et al (2020), the genome of foxtail millet is the smallest (423-510 Mb). A study by Kumari et al (2011) using RAPD and ISSR markers on 125 accessions of foxtail millet from India, the southern region, comprising of Andhra Pradesh, Karnataka, and Tamil Nadu, had the most alleles per locus (1.78), followed by the northern hill region, comprising of Uttarakhand, Jammu, and Kashmir (1.61) while the central-western region comprising Maharashtra, MP and Rajasthan showed the lowest number of alleles per locus (1.5). Evaluating accessions from Korea, China, and Pakistan, respectively, the average gene diversity values were 0.652, 0.692, and 0.491, while the PIC values were 0.621, 0.653, and 0.438. Evaluation of the genetic diversity revealed that the accessions from China showed higher SSR diversity than those of Korea and Pakistan (Kim et al 2012)

Proso millet (*Panicum miliaceum* (L.)

Studies on the molecular diversity of proso millet collections are limited and seldom used next generation sequencing (NGS) technologies: genetic diversity studies in proso millet mostly relied on RAPD, AFLP and SSR markers (Boukail et al 2021). A set of 90 proso millet genotypes (landraces and cultivars) and 100 SSR markers were used, 1287 alleles with size range from 40 to 1500 bp were amplified (Rajput et al 2016).

Marker Linked Traits

In order to enhance the breeding of superior crops, useful alleles from a variety of agro-ecological zones throughout the world should be collected from large plant genetic resources. Crop landraces and wild relatives still contain a reservoir of untapped useful alleles that might be responsibly harnessed to create superior cultivars that can resist environmental changes (Mbinda and Masaki 2000). The use of molecular markers developed will speed up germplasm characterization and verification process and enhance the process of superior variety development. Multiparent populations will also need to be developed to ensure future genomic selection and characterization of major traits of interest (Dida et al 2021). RFLP was used to create the first genetic map of sorghum, which was then followed by maps of finger, foxtail, and pearl millet (Kiranmayee et al 2020).

The major limiting factor for production and productivity of finger millet crop is blast disease caused by *Magnaporthe grisea*. Since, the genome sequence information available in finger millet crop is scarce, comparative genomics plays a very important role in identification of genes/QTLs linked to the blast resistance genes using SSR marker (**Table 2**). The distribution of resistant allele (710 bp) of FMBLEST32 SSR marker among the finger millet genotypes showed that the resistant allele was present mostly in exotic genotypes. However, among the Indian genotypes, the resistant allele was present in few genotypes, which were from southern and northern part of India (Babu et al 2014).

Table 2. Details of marker linked to agromorphological traits of different millet accessions

SN	Traits	Name of marker	Type of Marker	Crop	Resistant Variety	References
1	Finger blast	FMBLEST32	SSR	Finger millet	VHC3997 VHC3996 VHC3930 IE6082 (Nepal)	Babu et al (2014)
2	Pyricularia leaf spot	OP-D11700	RAPD	Pearl millet	THAK0285 THAK0201	Verma et al (2021)
3	Neck Blast	FMBLEST35 and FMBLEST36	SSR	Finger millet		Babu et al (2018)
4	Basal tiller number	RM5963	SSR	Finger millet		Babu et al (2018)
5	Flag Leaf Width	FMBLEST2	SSR	Finger Millet		Babu et al (2018)
6	Ear Length	TP351642	SNP	Finger Millet		Sharma et al (2018)
7	Days to 50%flowering	TP1071491	SNP	Finger Millet		Sharma et al (2018)
8	Days to Maturity	TP1600637	SNP	Finger Millet		Sharma et al (2018)

Genome Sequencing of Millet Crops

Globally approximately, 164447 accessions of millets are being conserved at different organizations and institutions where higher collection are of finger millet, foxtail millet and proso millet and low representation of small millets (Muthamilarasan and Prasad 2021). Genome sequencing is extensively used to identify genetic variability among the accessions and to track key genes responsible for the expression of agronomical and nutritional important traits (Kumar et al 2014b). Sequencing allows to develop varieties with different useful traits such as stress tolerance, high nitrogen use efficiency and other traits in cost-effective ways (Nirgude et al 2014, Saha 2016). It is helpful in accessing the coding and non-coding regions of the genome and provide information on genome that regulates plant growth, development and response to the environment (Vetriventhan et al 2020). However, millets have gained very little attention in genomic studies in comparison with those of the staple crops ie rice, maize and Wheat (Ceasar and Maharajan 2022). Genome sequencing have been done in different millets namely foxtail millet, pearl millet, finger millet, proso millet and barnyard millet (Ajeesh Krishna et al 2022) (**Table 3**).

Finger Millet (*Eleusine coracana* Gaertn.) is the first polyploid genome sequenced among the millets. Hittalmani et al (2017) and Hatakeyama et al (2018) published whole genome sequencing in ML-365 and PR-202 accessions of finger millet respectively. The sequencing of ML-365 was done using Illumina (Illumina HiSeq4000 and NextSeq500) and Sequencing by Oligonucleotide Ligation and Detection (SOLiD) sequencing (SOLiD 5500) platforms while the draft genome of the cultivar PR 202 was sequenced later using Illumina NextSeq 500, Illumina Miseq, and PacBio RSII sequencing platforms. The whole genome sequencing of ML-365 yielded 1.19 GB assembly size (82.31% of estimated 1.45 GB size) with estimated 85,243 genes and PR-202 produced 1.19 GB assembly size (78.20% of estimated 1.5 GB size) with 62,348 estimated genes. ML-365 contained 2866 drought responsive genes were distributed across protein domain (Pfam). The protein kinases, protein tyrosine kinases, BTB/POZ, NAD dependent epimerase/dehydratase family, U-box, universal stress protein family and DCPS genes associated with drought tolerance were found in the accession (Hittalmani et al 2017). The homology-based analysis indicated 330 Calcium transport and accumulation genes. Among them six genes were associated with calcium transport and accumulation confirmed from previously identified genes (Mirza et al 2014).

Foxtail millet (*Setaria italica* (L.) Beauv.) is an important C4 crops and has been considered as model grass for genetic and genomic studies due its easy cultivation and short life cycle (Ceasar 2019). Zhang et al (2012) produced draft genome of 423 MB size anchored into 9 chromosomes and annotated 38,801 genes. The researchers used genome shotgun combined with next generation sequencing using Illumina second-generation sequencers. Recently, Pan-genome of *Setaria* was established by assembling 110 representative genomes of 35 wild, 40 landraces and 35 modern varieties cultivated *Setaria* accessions. The researcher performed large scale genetic studies for 68 traits across 13 different environments to construct the first graph-based genome sequence of *Setaria*. One of the findings of the study is that the gene SiGW3 regulates grain yield of foxtail millet (He et al 2023).

Whole genome sequencing of Pearl millet was carried out using Illumina short read which revealed ~1.79 GB genome size of a reference genotype Tift 23 D_2B_1-P1-P5 that contained an estimated 38,579 genes (Varshney et al 2017). The research work also annotated 27,893 (72.3%) gene functions. The researchers predicted 170 possible hybrid combination that made the work important for pearl millet improvement in coming days. Further, research on Pearl millet was carried out with improved quality with long read sequence that added around 200 MB of chromosome (Salson et al 223).

Proso millet or broom corn millet (*Panicum miliaceum* (L.)) is shorter duration C4 crop grown in marginal land. Genome sequencing and assembling was done for Chinese accession (ACC#00000390) obtained from National Crop Germplasm Resource Reservation Center of China. The sequencing was done using Illumina short read that resulted ~923 MB genome size. The researcher annotated 55,930 protein coding genes, 55,527 protein coding genes in 18 pseudochromosomes (Zou et al 2019). Khound et al (2022) reported identification of single neucleotide polymorphism (SNPs) by low pass (1x) genome sequence of 85 diverse proso millet accessions from 23 different countries and obtained 972863 bi-allelic SNPs. This information was used to identify population and phylogenetic relationship among the accessions.

The reference genome for sorghum is the inbred “BTx623”, a short and early maturing genotype (Smith and Frederiksen 2000). Genome assembly of ~730 megabase was prepared for *S. bicolor* (Paterson et al 2009). Later on, sorghum reference genome was refined to 732.2 Mb covering ~91.5% (McCormick et al 2018). Cooper et al (2019) generated 729.4 Mb genome from “Rio” line that was 99.6% of the reference genome “BTx623. A pan genome analysis in Sorghum was performed with 354 genetically diverse accessions belonging to different races. The researchers identified different genes associated with important agronomic traits (Ruperao et al 2021).

Barnyard millet is commonly called for the weeds belonging to the family *Echinochloa* species. Out of 35 *Echinochloa* species, *E. frumentacea* Link and *E. Utilis* Ohwi and Yabuno are cultivated species. *E. colona* (L.) Link is a wild species commonly called as “Jungle grass” (Gomashe 2017). Whole genome sequencing of *E. crus-galli* was done using Illumina HiSeq 2000 system from STB08 genomic DNA libraries that estimated ~1.27 GB sized genome. The researcher also predicted 108,771 protein coding genes while 785 microRNAs and other non-coding RNAs were also identified in E. crus-galli (Guo et al 2017). Chloroplast genome sequencing was done in *E. frumentacea* by Perumal et al (2016) revealed 139,593 genome size with 112 genes of which 77 were protein coding genes.

There is lack of molecular map of kodo millet (*Paspalum scrobiculatum* L.) genome (Vetriventhan et al 2020). However, few works have been initiated for the crop at molecular level. Molecular marker-based analysis for characterization and phylogeny has been done. It has been found that the crop exhibits genotype cluster by African and Indian origin (M’Ribu and Hilu 1996). The crop has three different races: *regularis*, *irregularis* and *variabilis* classified based on their panicle morphology (de Wet et al 1983, Prasada et al 1993). First genome-wide population structure analysis of 165 kodo millet accessions of core collection from ICRISAT genebank was carried out by Johnson et al (2019). Existing core collection were designated with the races of the species. This work revealed that genetic groupings had very low correlation with designation based on race. The researchers concluded that core collection of kodo millet can be improved using genomic data rather than race designation. De novo assembly and transcriptome analysis of kodo millet variety “CO3” was carried out to study the dehydration stress in kodo millet. The study identified factors associated with the drought response of kodo millet (Suresh et al 2022).

Little millet (*Panicum sumatrense* Roth ex Roem. & Schult.) is one of the economically important species within the genus, cultivated widely as a cereal across India, Nepal, and western Myanmar (Baltensperger 1996). The crop is one of the least studies among the small millets. Parani et al (2001) identified seven species of little millet among 119 accessions from chloroplast DNA. The researchers amplified trnS-*psbC* regions from total genomic DNA by polymerase chain reaction (PCR) and digested with eight individual and combinations of restriction enzymes to generate restriction fragment length polymorphism (RFLP). The study found that the species identification can be done with combination of two enzymes, especially *Hae*III and *Msp*I. The phylogenetic relationship of little millet was studied by complete chloroplast genome sequencing by MiSeq instrument. The result revealed that cp genome of *P. sumatrense* was 139,384 bp in length and contained 125 known genes including 91 protein coding genes, 30 tRNA and 4rRNA genes. The study showed that little millet (*P. sumatrense*) was closely related with common millet (*P. miliaceum*) and witchgrass (*P. capillare*) (Sebastin et al 2018). Das et al (2020) performed *de novo* transcriptome analysis to identify genes involved in drought and salinity tolerance.

Table 3. Whole genome sequencing of millets

SN	Common crop	Ploidy level	Genotype	Plantform used	Findings	Reference
1	Finger millet	Tetraploid (2n=4x=36)	PR 202	Illumina HiSeq4000 and NextSeq500	1.19 GB assembly size (82.31% of estimated 1.45 GB size) with estimated 85,243 genes	Hittalmani et al (2017)
			ML-365	Illumina NextSeq 500, Illumina Miseq, and PacBio RSII	1.19 GB assembly size (78.20% of estimated 1.5 GB size) with 62,348 estimated genes.	Hatakeyama et al (2018)
2	Foxtail millet	Diploid (2n=2x=18)	Zhang gu and A2	Illumina Genome Analyzer II and HiSeq 2000	423 MB size anchored into 9 chromosomes and annotated 38,801 genes	Zhang et al (2012)
3	Pearl millet	Diploid (2n=2x=14)	Tift 23 D2B1-P1-P5	Illumina HiSeq 2000	~1.79 GB genome size (90% of estimated size) with an estimated 38,579 genes	Varshney et al (2017)
4	Proso millet	Tetraploid (2n=4x=36)	Landrace (ACC#00000390)	Illumina short read and PacBio RS II	~923 MB genome size and annotated 55,930 protein coding genes	Zou et al (2019)
5	Sorghum	Diploid (2n=2x=20)	BTx623	Sanger sequencing method	~730 megabase size genome	Paterson et al (2009)
6	Barn Yard grass	Hexaploid (2n=6x=54)	STB08	Illumina HiSeq 2000	~1.27 GB sized genome	Guo et al (2017)

Genetic Engineering and Gene Editing in Millets

Genetic engineering, or recombinant DNA technology, is a set of methods used to manipulate DNA from different sources, combining and modifying it to create new genetic material. This engineered DNA is then introduced into an organism, allowing for the development of new, heritable genetic traits or the production of specific proteins for various purposes. Genetic engineering in millets, such as sorghum and pearl millet, has opened new possibilities for enhancing these important cereal crops. Researchers have utilized a variety of techniques to introduce foreign genetic material into millet plants, leading to the development of transgenic varieties with improved traits. Casas et al (1993) made a significant breakthrough by reporting the successful production of transgenic sorghum plants using particle bombardment. This method involved the use of small particles coated with DNA to deliver genetic material into sorghum cells. This innovative technique marked a significant step forward in millet genetic engineering.

Subsequently, Zhao et al (2000) demonstrated the transformation of sorghum using Agrobacterium-mediated techniques. Agrobacterium, a bacterium known for its ability to transfer genetic material into plant cells, provided an alternative approach for introducing new genes into sorghum. This breakthrough expanded the toolbox for millet genetic engineering, making it possible to target specific traits and functions in these crops. One of the most promising outcomes of genetic engineering in millets is the development of biofortified sorghum varieties. Zhao et al (2019) succeeded in creating a biofortified sorghum with enhanced and stabilized pro-vitamin A content. This biofortified sorghum variety now provides a substantial portion of the estimated average requirement for pro-vitamin A, particularly crucial for young children. These developments in genetic engineering hold the potential to combat nutritional deficiencies in regions where sorghum is a dietary staple.

Another area of genetic improvement in millets has been the enhancement of essential amino acids. Zhao et al (2003) improved the lysine content in sorghum by introducing a genetically engineered high lysine protein into sorghum cells. This approach has significant implications for improving the nutritional quality of sorghum-based foods, which are important staples in many parts of the world. Furthermore, in the case of pearl millet, herbicide resistance has been achieved through genetic engineering. A transformation protocol was established using the herbicide resistance selectable marker gene, bar, and the particle inflow gun (PIG) (Girgi et al 2002). This advancement simplifies weed control in pearl millet cultivation, offering a practical solution for farmers and potentially increasing crop yields. These remarkable achievements in millet genetic engineering have been thoroughly reviewed by scientists in the field. Comprehensive reviews by Ceasar and Ignacimuthu (2009) and O'Kennedy et al (2006) have summarized the transformation methods and genes of interest in sorghum, pearl millet, finger millet, foxtail millet and barnyard millet. Among the two methods of transformation, Biolistics and Agrobacterium, Biolistics have been used commonly to develop variety (**Table 4**).

Genome editing, also referred to as gene editing, represents a groundbreaking set of technologies that grant scientists the ability to precisely alter an organism's DNA. These cutting-edge techniques empower researchers to add, remove, or modify genetic material at specific locations within the genome. In the context of gene editing in millets, it's crucial to note that for successful genome editing, a comprehensive understanding of the target species' genetic makeup is required. However, as of now, annotated genome sequences are available for only a few millet varieties, with foxtail millet being among them and therefore, gene editing has been carried out in this species (Ceaser 2022). This limitation presents challenges in assessing off-target effects of genome-edited millets in other species. Therefore, the future application of genome editing systems in millets will depend significantly on the availability of complete and annotated genomes (Kudapa et al 2023).

Table 4. Crop Varieties developed using biotech

SN	Crop	Tools used	Explant	Varieties	Gene	Remarks	References
1	Finger millet	Agrobacterium mediated	Shoot apex	GPU 45	Rice chitinase (chi11)	Leaf Blast resistance	Ignacimuthu and Ceasar (2012)
2	Finger millet	Agrobacterium mediated	Embryogenic callus	GPU 28	Bacterial mtlD gene	Multiple stress resistance	Hema et al (2014)
3	Finger millet	Biolistic method	Shoot tip-embryogenic callus	PGEC 2	PcSrp	Salinity tolerance	Mahalakshmi et al (2006)
4	Finger millet	Agrobacterium mediated	Embryogenic callus	Tropikanka and Yaroslav 8	HvTUB1 and TUAm1	Resistance to herbicide	Bayer et al (2014)
5	Foxtail millet	Agrobacterium mediated	callus	cv. Jigu11	SiLEA14	Drought and salinity tolerance	Wang et al (2011)
6	Foxtail millet	Agrobacterium mediated	callus	cv Jigu11	SiARDP	Drought tolerance	Li et al (2014)
7	Foxtail millet	Biolistic	Florets	var. 3661	SiPf40	Functional characterization of SiPf4 gene	Liu et al (2009)
8	Barnyard millet	Biolistic method	Callus	VL 29		Testing the efficiency of various promoters	Gupta et al (2001)
9	Teff	Agrobacterium mediated	Callus	cv. DZ-01-196	PcGA2ox	Inducing semi dwarfsm	Gebre et al (2013)

SiLEA14, Setaria italica late embryogenesis abundant 14; SiARDP Dehydration responsive element binding protein SiPf40; Setaria italica ZIP-like gene; cGA2ox, Phaseolus coccineus gibberellin inactivation gene; PcSrp, Porteresia coarctata serine-rich-protein; HvTUB Hordeum vulgare β1-tubulin; TUAm1, mutant α1-tubulin

The advent of CRISPR/Cas9 technology has ushered in a transformative era in agricultural and plant scientific research. CRISPR/Cas9 is recognized as the most effective gene editing system to date. In the case of foxtail millet, gene editing using CRISPR/Cas9 was initially demonstrated in the disruption of the SiPDS gene through transient protoplast assays, although stable mutants were not obtained at that time (Lin et al 2018). Nevertheless, researchers have continued to explore the potential of CRISPR/Cas9 in millets. For example, Li et al (2018) employed CRISPR/Cas9 technology to target k1C genes in sorghum, aiming to create variants with reduced kafirin levels, improved protein quality, and enhanced digestibility, while also boosting lysine content.

In recent advancements, Liang et al (2022) achieved successful base editing in foxtail millet using two base editors (CBE and ABE) to target the SiALS and SiACC genes. By applying CBE to target the SiALS gene, they managed to generate a homozygous herbicide-tolerant mutant plant. This development demonstrates the evolving sophistication of genome editing in millets. Moreover, Liang et al (2022) introduced a highly efficient genome editing system that allows for single and multiple gene knockouts, as well as single base substitutions, using the CRISPR/Cas9 system, cytosine, and adenine base editing systems in foxtail millet. This comprehensive approach paves the way for the precise modification of millet genomes and the development of customized genetic traits in these important millet crops. As the technology evolves and more genomic data becomes available, gene editing in millets is likely to play a crucial role in advancing their agronomic and nutritional characteristics.

Mutation Breeding

Mutation breeding is a crucial breeding method that harnesses physical radiation or chemical agents to induce spontaneous genetic variations in plants, ultimately leading to the development of new crop varieties. In India, this approach has made significant contributions to millet crop improvement, with approximately 5% of millet varieties having been developed through mutation breeding, as noted by Patel and Vekariya (2023). This technique has been especially effective in enhancing the genetic diversity of millets, resulting in novel traits and improved crop performance.

The choice of mutagens plays a pivotal role in the mutation breeding process. In the case of pearl millet and sorghum, various mutagens have been employed, with ethidium bromide, streptomycin, and mitomycin demonstrating efficacy in inducing cytoplasmic mutations, particularly for the development of cytoplasmic male sterility. On the other hand, thermal neutrons and gamma rays have proven effective in inducing chromosomal breaks, offering potential for creating genetic diversity. Notably, gamma rays, ethyl methane sulfonate, and diethyl sulfate have emerged as highly effective mutagens for generating a wide array of mutations in both pearl millet and sorghum (Hanna 1982).

Research has shown the potential of gamma irradiation in creating novel variations in proso millet and finger millet, as demonstrated by studies conducted by Francis et al (2022) and Msikita (2002). Mutation breeding has led to the development of variants with improved grain yield and related traits in finger millet, as highlighted in the work of Ganapathy et al (2021). Foxtail millet has also been subject to mutation breeding through gamma irradiation, which has resulted in the emergence of variants with diverse traits (Bolbhat and Ishte 2020).

Kodo millet, known for its cleistogamous nature, has been a prime candidate for mutation breeding to induce genetic variations. This approach has been widely followed to create diversity and enhance its agronomic traits, as observed in the study by Nagaraja et al (2023). Similarly, barnyard millet has shown a positive response to mutagenic treatments, including EMS, gamma rays, and combinations of the two

(Ramesh et al 2019). Mutation breeding remains a valuable tool for the development of novel millet varieties, addressing the need for increased crop yield, disease resistance, and adaptation to changing environmental conditions.

Quantitative Trait Loci

Among 888 foxtail millet accessions from different geographic regions in the world, only 14 accessions (1.6%) were highly resistant to leaf blast in a greenhouse test (Li et al 2020). It has also been noted that cultivars from European and Asian nations differ genetically in their resistance to leaf blast (Nakayama et al 2005). A core collection of 155 foxtail millet germplasm accessions from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) gene bank in Patancheru, India, revealed multiple genotypes that are resistant to blast (Sharma et al 2014). In research on foxtail millet carried out in China by Tian et al (2021), three QTL for resistance to leaf blast were identified on chromosomes 1, 2, and 8 of the cultivar Yugu 5. Using 35,065 single nucleotide polymorphism (SNP) markers produced by sequencing the RIL population, an ultra-density genetic linkage map was created. On chromosomes 1, 2, and 8 of Yugu 5, three QTL, QLB-czas1, QLB-czas2, and QLB-cazas8, were identified at the genomic intervals of 276.6 kb, 1.62 Mb, and 1.75 Mb. Common SNPs were found using the bulk segregant analysis (BSA) and RNA sequencing (BSR-Seq) methods to be located in the genomic region of QLB-czas8, adding to the evidence of this QTL's location. In the genomic regions corresponding to QLB-czas2 and QLB-czas8, three and nineteen putative genes, respectively, were identified as being associated to disease resistance. Owing to their distinct locations, these QTL seem to represent novel loci that confer resistance to leaf blast. The identification of this new resistance QTL will help with cultivar improvement and the study of the genetic regulation of blast resistance in foxtail millet (Titan et al 2021).

An association study was carried out on a global collection of 190 finger millet genotypes utilizing the genotypic data of 46 SSR markers and the phenotypic data of 15 agromorphological characters. Association of SSR allelic data with the 15 agro-morphological character data revealed that five markers were linked to four traits at a significant threshold (P) level of ≤ 0.01 and ≤ 0.001. The QTLs for basal tiller number was strongly associated with the loci UGEP81. This locus is located on the 6B chromosome of finger millet at a distance of 2.9 cM from the starting end point. Likewise, Bharathi et al (2011) used genomic SSR markers to conduct an association mapping analysis on the composite collection of finger millet genotypes for agromorphological traits. They also found a QTL for basal tiller number linked by the UGEP8 loci which was located on the 3B chromosome at a P value of 0.003 and explained 4.2 % phenotypic variance. However, the loci linked to the basal tiller number in the study by (Babu et al 2014) explained 10.8 % of phenotypic variance and can be considered as effective QTL for basal tiller number. The markers linked to the QTLs in this study can be further used for cloning of the full-length gene, precise mapping and subsequently applied in marker-assisted breeding schemes to introduce alleles into germplasm that is locally well adapted.

Biofortification

Biofortification, a pivotal method for enhancing the nutritional content of food crops, can be realized through various means, including agronomic practices, conventional breeding, and biotechnology-based approaches such as genetic engineering and genome editing. Millets, as staple crops, have emerged as a promising target for biofortification efforts due to their economic feasibility in combatting micronutrient malnutrition. Recognizing the significance of improving millet nutrition, the HarvestPlus group introduced high-iron pearl millet through conventional breeding in India to address iron deficiency (Vinoth and Ravindhran 2017). Biofortified sorghum with significantly higher iron and zinc had been released in India and Africa. Additionally, researchers have identified the molecular basis of waxy starch in foxtail millet, proso millet, and barnyard millet, which holds potential for enhancing their suitability in infant foods. Furthermore, comparative genomics has aided in uncovering quantitative trait loci and genes associated with protein quality in finger millet. Despite the nutritional richness of various millet varieties, iron biofortification has predominantly centered on pearl millet. Biofortification strategies in millets encompass both increasing nutrient accumulation in milled grains and reducing antinutrients to enhance the bioavailability of essential minerals, thereby advancing the quest for nutritionally enriched millet crops (Vinoth and Ravindhran 2017). However, it's noteworthy that, as of now, biofortified millets developed using biotechnology are not yet available.

DNA Bank, Barcode, Sequence Bank, Bioinformatics

A DNA bank of millets is a vital resource for preserving the genetic diversity of millet species. It involves the extraction and storage of millet DNA at ultra-low temperatures, ensuring long-term viability for future research and breeding programs. In Nepal, the Genebank has taken an important step by establishing a DNA bank specifically for finger millet in 2013. This initiative serves as a valuable repository of genetic material, allowing scientists and breeders to access and study the genetic traits of finger millet, including those related to resilience, nutrition, and disease resistance. Such DNA banks are essential tools for advancing millet research, fostering crop improvement, and contributing to food security in regions where millets are a staple.

DNA barcoding has proven to be a highly effective tool for the rapid identification of plant species based on their DNA sequences. This approach involves the use of multiple DNA regions in a multi-regional approach to accurately identify plants. In the context of millets, DNA barcoding has been employed as a model for conserving genetic diversity and documenting and protecting farmers' rights and traditional knowledge. Researchers, such as Ragupathy et al (2016) have utilized a tiered approach, particularly the ITS2 DNA barcode, to achieve 100% accurate identification of 32 landraces and six species of millets. This technology holds significant potential for applications in the protection of plant varieties and farmers' rights in countries like India and Nepal. Studies, including the work of Newmaster et al (2013), have further emphasized the utility of DNA barcoding for reliable millet identification, demonstrating the effectiveness of genomic regions such as ITS and trnH-psbA in assessing genetic diversity among different millet species and landraces.

Bioinformatics is a fundamental discipline that not only involves the storage of complex biological data but also its in-depth analysis, providing valuable insights into the realm of crop species. Genomic databases play a pivotal role in research, housing extensive repositories of DNA sequences, open reading frames (ORFs), intergenic sequences, and whole genome sequences of important crop species, including various millets. Several dedicated genomic resources are available for specific millet species. For instance, Gramene, millet genome databases, and Phytozome databases serve as comprehensive resources for finger millet and foxtail millet. These repositories offer essential genomic information for researchers, aiding in the exploration of these vital crop species.

Foxtail millet, in particular, benefits from specialized databases. These include transcription factor and microRNA databases, providing valuable insights into regulatory elements within the genome. Additionally, marker databases and transposable elements-based marker databases are valuable resources for marker-related studies, facilitating genetic and breeding research. In a notable bioinformatics study conducted by Han et al (2014), 271 foxtail millet miRNAs from 44 families were identified, unveiling the complex regulatory network governing this millet species. These findings offer a deeper understanding of the genetic mechanisms at play.

Moreover, to enhance accessibility and utility, a user-friendly, web-accessible millets multi-omics database platform known as Milletdb (http://milletdb.novogene.com), developed by Sun et al (2023), offers a comprehensive resource. Milletdb encompasses genomic information for six millet species and their related genomes, graph-based pan-genomics data for pearl millet, and a wealth of stress-related multi-omics data. It stands as the most complete and invaluable database platform for researchers studying millets, facilitating a deeper understanding of these important crops and their responses to environmental stressors. Furthermore, the public domain hosts nuclear genome sequences of various millet species, including foxtail millet, proso millet, kodo millet, finger millet, little millet, Indian and Japanese barnyard millet, making these genomes accessible for researchers to explore and analyze, contributing to advancements in millet research (Thulasinathan et al 2022)

Potential Use of Tissue Culture

Tissue culture is a biotechnological technique that has not been widely used for millet crops in Nepal. Millets are traditionally propagated through seeds, and this has limited the adoption of tissue culture in millet production. However, there are several potential applications of tissue culture in millet species, and research has shown promise in various areas, such as regeneration from different explants, embryo rescue from distant hybridization, cellular hybridization, mutant development, and the regeneration of transgenic organs.

Various explants have been used to initiate cultures in millets (Wakizuka and Yamaguchi 1987, Vasil 1987, Kothari et al 2005, Repellin et al 2001). Immature embryos with scutellum at the milk stage have shown promising results for regenerable cultures. In addition to immature embryos, whole seeds, immature inflorescence, seedling leaf bases, and roots have been used as explants to initiate tissue culture in millets. Some successful examples of tissue culture applications in millets include:

- **Immature Embryo-Derived Regenerative Callus in Finger Millet**: Researchers have achieved success in producing regenerative callus cultures from immature embryos of finger millet.
- Embryogenic Callus Cultures of Kodo Millet: Embryogenic callus cultures have been established in kodo millet, a step towards in vitro propagation and genetic modification.
- **Embryogenic Callus of Pearl Millet:** Researchers have been able to develop embryogenic callus from pearl millet, which is a significant breakthrough for genetic modification and breeding programs.
- **Efficient Protocol for Somatic Embryogenesis and Plant Regeneration in Finger Millet:** An efficient protocol has been established for somatic embryogenesis and plant regeneration in finger millet. This is a crucial step in producing genetically modified millet plants Ngetech et al 2018).
- **Regeneration System Using Mature Seeds as Explants in Finger Millet:** A regeneration system has been developed using mature seeds as explants in finger millet. This method is valuable for mass production of millet plants (Kashyap et al 2018).

It is essential to note that these advancements in tissue culture for millet species offer potential benefits in terms of crop improvement, disease resistance, and genetic diversity. Further research and development in this field can contribute to the sustainable production of millets, especially in Nepal, where millets are important staple crops. Researchers can draw upon existing literature and studies, as well as collaborate with experts in the field to explore the full potential of tissue culture in millet cultivation.

Conclusion

Biotechnology holds great promise for enhancing millet crops due to the unique challenges presented by their tiny flowers. A range of biotechnological tools and methods have been deployed in various millet species, contributing to a deeper understanding of their genetics, the improvement of crop varieties, the creation of genetic variation, and the conservation of genetic diversity. These tools encompass tissue culture, mutagenesis, genetic diversity assessment, marker-assisted selection, DNA barcoding, genomic databases, biofortification, and genetic engineering, each serving a distinct role in advancing millet agriculture. In the context of Nepal, the use of DNA markers for assessing genetic diversity has been a notable contribution, providing essential insights into millet genetics. The availability of freely accessible genetic data can significantly impact the progress of millet science in Nepal, paving the way for crop improvements, disease resistance, and increased yields. With continued research and collaborations, the integration of biotechnology into millet agriculture can prove instrumental in addressing the unique challenges faced by these vital crops, ultimately contributing to food security and sustainability in Nepal where millets are a staple.

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C. Agronomy and Seed Science

ग. बाली विज्ञान र बीउ विज्ञान

Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Improved Millet Production Technologies in Nepal

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Abstract

Millets are a group of highly variable small-seeded grasses, widely grown around the globe as a cereal crop for both food and fodder. Of them finger millet, sorghum, foxtail millet, proso millet, barn yard millet, pearl millet are common millets grown across the world. Each millet is 5 times nutritionally superior to rice and wheat in terms of protein, vitamins and minerals. Despite their superiority over the other cereals, their area and production in Nepal is quite low and one of the reasons might be due to either poor access to or poor adoption of the best crop management practices by the Nepalese farmers. Very limited works in development and promotion of improved crop management technologies for millets have been done in Nepal. Agronomical practices are described for different millet crops.

Keywords: Seed rate, field, spacing, yield, irrigation, nutrient

Introduction

Millets are a group of small-seeded cereals and are grown across the globe for both food and fodder. Finger millet, sorghum, foxtail millet, proso millet, barn yard millet, pearl millet are common millets. Millets are nutritionally superior in terms of protein, vitamins and minerals. They are also considered as climate resilient crop species performing well under rainfed ecologies and marginal soils. Finger millet is the 4th most important crop of Nepal after rice, maize and wheat in terms of area and production and the first among the millets. Proso Millet (Chino) is the 2nd important millet in Nepal followed by foxtail millet (Kaguno), Sorghum (Junelo), Pearl millet (Bajra), Barnyard millet (Sama), and Kodo Millet (Kodi) (https://theannapurnaexpress.com/story/45814/). Despite the significance of millets in Nepal, their area and production among cereals is quite low. There are many reasons for less area and production in Nepal, of them the improved crop management technologies and potential genotypes/varieties are considered to be the key factors to be taken into consideration. Cultivation of millet is declining and the weeding and post-harvest processing is considered tedious. Lack of labor due to outmigration of youth means that more tedious agricultural crops with limited pre-existing markets are being left behind. Also, the young generation do not prefer to eat it (https://himalayancrops.org/).

Attempt has been made to explore the traditional good crop management practices adopted by the farmers and the findings of the research done within and outside the country in this brief review paper. This paper highlights the climatic requirements, existing cropping systems, soil and its preparation, seedbed preparation, time of seeding/planting, seed treatment, planting/transplanting operation, cropping geometries, manuring, irrigation management, harvesting and post-harvest handling and storage.

Climatic Requirements

Finger millet is grown in tropical as well as sub-tropical climate up to an altitude of 3000m asl in Nepal. It is predominantly grown in the hills of Nepal. It can tolerate heat and it can germinate at minimum temperature between 8-10°C. It can grow well within the temperature range of 15-29°C. It is one of the drought tolerant crops and can be grown in areas with 500-900mm annual rainfall. Proso and foxtail millets are grown well under low soil moisture regimes, because they are early in maturity and can avoid droughts (https://www.agrifarming.in/millets-farming-millets-cultivation-practices)

Cropping System

Mostly finger-millet is grown in marginal land where other crops cannot be grown. It is one of the main crops in mid-hills where finger millet is generally grown as a relay crop under maize. Maize/millet is a dominant cropping system in mid-hills of Eastern and Central parts of the country, it grows as mono-crop in Western parts (Prasad 2005). In high hill farmers have been practicing mixed cropping with soybean, potato, horse gram, foxtail millet and proso millet (Upreti 2001). Eighty five percent of finger millet is grown as inter-crop with maize in the hills (Subedi 2002). It is also grown as spring crop in irrigated lower foot-hills and river valleys. It is grown as mono crop in high hills (>1800 masl), Tarai, lower river valley and far western mid-hills and as mixed crop with other millet or niger or legumes in high hills. In Tarai, the finger millet is grown usually in sandy soil where water cannot be impounded for paddy cultivation.

Foxtail millet is grown sole as well as mixed with finger millet, proso millet, beans, amaranths, sorghum, etc (Ghimire et al 2017). Sorghum is grown either sole crop or mixed crop with legumes, finger millet and maize. Other millets are grown either sole or mixed mainly during rainy season across their production ecologies.

Field and Soil

The slope of the site should not exceed 20%. There must be a gentle slope to drain out the excess rainfall in the hills and make a drainage channel in plain areas. It should not be close to the forest to avoid the damage from birds and wild animals (IIMR 2019). Millet can be successfully grown in the soils like alluvial, loamy and sandy soil with good drainage capacity. It cannot be grown in clayey sticky soil with water logging condition. However, it is grown under very poor to very fertile soils and can tolerate a certain degree of alkalinity and salinity. Millets can be cultivated on a variety of soils ranging from rich, medium loam to poor shallow soils and having normal pH level between 7.5-8.0. The best soils are medium textured, red, loamy and shallow soils with good drainage.

Field Preparation

The first ploughing should be done deep with a soil turning plough at the onset of monsoon. Fine tilth is imperative for proper germination and crop establishment. Under relay cropping system with maize, land cannot be made well levelled, therefore small ditches at certain distances must be made to have a proper drainage system. Better to make the terraces having uniform but gentle slope in order to assure the drainage system.

Seedbed Preparation

Finger millet can be grown by direct seeding into the finely prepared soil or transplanted in fine moist soil. For seedlings transplanting, 400-500 grams of seeds having 85% germination capacity is enough for a ropani (500 m^2) of land. The height of the seedbed must be of 20cm and seeds must be sown at a depth of 2-3 cm. Well decomposed farm yard manure @ of 500 kg in a ropani of land should be applied during the soil tillage. There must be a provision of excess water drainage from the seedbed.

Time of Seeding

Seeding time varies with the production ecologies. Seedbed is prepared during Chaitra in the high hills, Chitra to Baisakh in the mid hills and Jestha-Asar in terai. Foxtail millet (Kaguno) used to be grown at lower altitudes between 1000 to 1400 masl. It is generally sown in Falgun ie February/March. (https://himalayancrops.org/). Proso millet is sown in the first fortnight of July with the onset of monsoon rains and as a summer crop it should be sown by the middle of April. In less rainfall areas, Proso millet sowing should be done in start July and in more rainfall areas, sowing should be done in end week of July. Barnyard millet can be sown in the first fortnight of July with the onset of monsoon rains.

Seed Treatment

The fungal diseases (neck blast, finger blast, leaf blast, leaf spot, etc) have been serious problem that may cause severe yield loss in finger millet. Therefore, to prevent from the fungal diseases, the seed should be treated with Thiram @ 2.5g kg^{-1} of seed.

Sowing and transplanting

Seed rate based on sowing method is given in **Table 1**.

Table 1. Millet crops and their corresponding sowing methods and seed rate

Crop	Method of sowing	Seed rate
Sorghum	Line sowing	7 – 8 kg ha^{-1}
Pearl millet	Line sowing	4 – 5 kg ha^{-1}
	Transplanting	2 kg ha^{-1}
Finger millet	Line sowing	5 – 6 kg ha^{-1}
	Transplanting	4 kg ha^{-1}
Barnyard millet	Line sowing	5 – 6 kg ha^{-1}
	Broadcasting	8 – 10 kg ha^{-1}
Foxtail millet	Line sowing	5 – 6 kg ha^{-1}
	Broadcasting	8 – 10 kg ha^{-1}
Proso millet	Line sowing	5 – 6 kg ha^{-1}
	Broadcasting	8 – 10 kg ha^{-1}

Planting Geometry and Planting

Spacing of different millets are given in **Table 2**. Three to four weeks old seedlings should be transplanted with single seedling per hill. However, it is always not possible to have exact cropping geometries under intercropping system. The number of seedlings varies with the crop establishment methods, depending upon the soil's fertility level, type of finger millet variety and planting geometry, growing season and production ecology. Transplanting of seedlings can be done at a depth of 3 to 4 cm into the soil. Do not transplant the seedlings under both the extreme cases of excessive and acute shortage of soil moisture.

Table 2. Millets crops and their cropping geometries

Crop	Spacing
Sorghum	45 × 15 cm
Pearl millet	40 × 15 cm
Finger millet	22.5 × 10 cm
Barnyard, Foxtail and Proso millet	20.0 x 10.0 cm

Nutrient Management

Well decomposed Farm Yard Manure (FYM) @ of 10 tons ha^{-1} should be applied at the time of land preparation. Depending upon the soil fertility level, 60kg N ha^{-1}, 30kg P_2O_5 ha^{-1}, 30kg K_2O ha^{-1} is suggested to apply for all millets except sorghum being a tall, robust and high nutrient responsive crop, adopt a blanket recommendation of 90 N, 45 P_2O_5, 45 K_2O kg ha^{-1} (**Table 3**). Apply N @ 50:25:25 % at 0, 15 and 30 DAS and full dose of P_2O_5 and K_2O as basal dose before sowing (TNAU 2013). No research-based recommendations are there in Nepal for all millets except for finger millet @20:10:10 Kg N P_2O_5 K_2O kg ha^{-1}. Therefore, the recommendations are presented in table 3 as prescribed by IIMR (2019).

Table 3. Millet crops and their season and nutrient requirements

Crop	Season	Dose NPK (kg/ha)
Sorghum	Kharif	80:40:40
	Rabi Rainfed (shallow to medium soil)	40:20:00
	Rabi Rainfed	60:30:00
	Irrigated	80:40:40
Pearl millet	Arid regions	40:20:00
	Semi-arid regions	60:20:00
Finger millet	Irrigated	60:30:30
	Rain fed	40:20:20
Other Small millets	Irrigated	40:20:00
	Rain fed	20:20:00

Source: http://millets.res.in/technologies/Recommended_package_of_practices

FYM should be applied during the land preparation for maize under relay cropping and at least one month prior for sole cropping. Do not apply undecomposed FYM, since it increases pests attack like termites, red ants and white grubs. Full dose of phosphorus and potassium fertilizers need to be applied during land preparation and nitrogenous fertilizer must be splitted twice, first at tillering stage and second at flowering stage. Farmers from mid hills generally practice crop rotation with soybean once in a three to four years so as to improve the soil fertility.

Irrigation Management

Millets require less water compared to maize and wheat. However, moisture stress during tillering and flowering stage can severely affect the grain yield. Based on the availability of water, one life saving irrigation and 3 to 4 irrigations at critical stages needs to be given. Thus, the field should have proper access to irrigation source to provide at least one life saving irrigation during long spell moisture stress condition (IIMR 2019). Water supply should be increased in line with the development of the crop and reach a peak during the change from the vegetative to the reproductive phase. Adequate soil moisture during the peak period has the most positive effect on yields. In cases where water supply is limited, irrigation should focus on avoiding water deficits during flowering to avoid early grain formation. The visible signs for irrigating the crop or the moisture requirement of crop are drooping and withering of leaves during morning period, leaves feel somewhat warm during noon instead of cool, and cracking of the soil surface of the field.

Improved Varieties of Millets

Only improved varieties of three crops, finger millet, foxtail millet and proso millet are available in Nepal (**Table 4**). Many local landraces of sorghum also exist in the country. Farmers used to grow the site-specific non-registered local landraces of other millets and sorghum in Nepal.

Table 4. Released and registered varieties of millets, their crop duration and yield

Crop	Variety	Crop duration	Yield (Mtha^{-1})
Finger millet	Dalle-1	125-151	3.3
	Okhale-1	154-194	3.3
	Kabre kodo-1	167-170	2.3
	Kabre kodo-2	153	2.5
	Sailung kodo-1	155	2.5
Foxtail millet	Bariyo Kaguno	120-125	1.6-1.8
Proso millet	Dudhe Chino	115-130	0.6-0.8
Sorghum	Local landrace	110-120	0.870

Source: IIMR 2018, Ghimire et al 2018, Joshi et al 2017, AICC 2021

Harvesting

Finger millet

Grain maturity starts from the top floret and decent down to the base of panicle. Initially the panicles are green which is the color of husk. All the panicles do not mature uniformly. The main panicle matures first followed by the tiller panicles. Depending upon the stage of maturity of the ear heads, the multiple harvesting must be followed for good quality of grain and longer storage life of the finger millet. Ear heads from the standing crop are harvested and brought to the threshing floor for threshing after 3-4 days of sun-drying. Grain at or below 14% moisture is considered dry. For long-term storage (more than 6 months), grain moisture content should be less than 12%.

Sorghum

Sorghum is harvested at physiological maturity stage and this can be identified when a dark spot (black layer) appears at the basal portion of seed. About 90% of grains in the lower half of the panicle are become hard and developed black layer. Physiological maturity occurs in about 110-115 days from sowing or about 35-40 days after 50% flowering. About 80% grains appear to be turned to pearly white or straw colored. Sorghum crop could be harvested at 20% moisture content, but must be dried to 12-14% moisture content for safe storage. At this stage, the seeds are firm and cannot be compressed or broken between fingers or between the teeth. Ear heads from the standing crop are harvested and brought to the threshing floor for threshing after 3-4 days of sun-drying.

Pearl millet

The best stage to harvest pearl millet is when the plants reach physiological maturity determined by the appearance of black spot in the hilar region of the seed. Physiological maturity occurs in about 75-85 days from sowing or about 22-25 days after 50% stigma emergence. The usual practice of harvesting pearl millet is cutting the ear heads by hand first and collection of stalks (straw) after a week, and the stalks are allowed to dry open and then stacked. Grain at or below 14% moisture is considered dry. For long-term storage (more than 6 months), grain moisture content should be less than 12%.

First harvesting is done when 50% of the panicles in the field have turned brown harvest only the main panicles. All ear heads which have turned brown should be cut. This should be then dried, threshed and cleaned the grains by winnowing. Second harvesting can be at seven days after the first harvest, all the ear heads including the green ones should be cut. You need to cure the grains to obtain maturity by heaping the harvested ear heads in shade for one day without drying, so that the humidity and temperature increase and the grains get cured. The grains can be dried, threshed and cleaned by winnowing.

Foxtail millet

The crop should be harvested when it is ripe. Ripening is observed when the green panicle starts turning brown. Crop is threshed with hand or bullocks or machines. Grain at or below 14% moisture is considered dry. For long-term storage (more than 6 months), grain moisture content should be less than 12%.

Proso millet

This should be harvested the crop when it is about to mature. The seeds in the tip of upper heads ripe and shatter before the lower seeds and later panicles get mature. Therefore, the crop should be harvested when about two thirds of seeds are ripe. Crop is threshed with hand or bullocks or machine threshing. When the panicle browning is more than 80% from the tip. Almost all the panicles mature at the same time. Grain at or below 14% moisture is considered dry. For long-term storage (more than 6 months), grain moisture content should be less than 12%.

Barnyard millet

The panicle turns brown and the grains are hard the crop is ready for harvest. It is cut from the ground level with the help of sickles and stacked in the field for about a week before threshing. Threshing is done by trampling under the feet of bullocks or mechanical thresher. Grain at or below 14% moisture is considered dry. For long-term storage (more than 6 months), grain moisture content should be less than 12%.

Cleaning, Drying and Storage

In order to ensure high grain quality, farmers need to use pure seed, harvest when 80–85% of the grains are straw colored, minimize the time that cut panicles remain lying in the field as field drying causes low grain quality. Threshing should be done as soon as possible after cutting, on a clean surface. Dry the grains as quickly as possible after threshing. If sun drying is used, (a) turn or stir the grains at least once every hour to achieve uniform drying, (b) on hot days cover the grain during mid-day to prevent overheating, and (c) cover the grain immediately if it starts raining. Drying is the best on a mat or plastic sheet until the grain moisture comes to a constant level of 12-14%. Any delay in the drying process, incomplete drying or ineffective drying will reduce the grain quality and result in post-harvest losses. Sun drying on mats and solar drying along with electrical drying can also be done to dry the grains. Clean thoroughly by winnowing manually or mechanically.

Farmers should store the millets in a cool, dry, and clean area, preferably in a sealed container. If a sealed container or airtight plastic bag is used for storage, make sure the sorghum is dried well; otherwise, it might get spoiled due to storage pest. Cool environment is preferred for the storage of millet grains to prevent the growth of pathogens. Ideally, the temperature should be below 21°C to maintain the quality of the millet. Hermetic storage bags/silos can be used to store finger millet and can be stored for more than 20 years.

Conclusion

In order to bridge the huge yield gap of millets, crop management practices play a key role. However, due to constraints of resources, very less research and development works have been done so far in Nepal. Focus must be done in development of improved crop management practices for specific millets.

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Finger Millet Production in Spring Season: Farmers' Innovation and a Novel Practice Adopted in Dhanusha

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Summary

Finger millet is the fourth important staple food of Nepal and a very important summer crop in *Bari*-dominated mid- and high hills. Surprisingly, few pockets of the *Tarai* region, like Mukhiyapatti Musharniya Rural Municipality (RM) of Dhanusha district, have witnessed the cultivation of finger millet during the spring season. Farmers have developed unique cultivation techniques that are not well documented. This uniqueness in planting season/time and cultivation practices were developed by the farmer themselves. A rapid assessment was made to understand the unique production practices and the benefits that farmers are getting from them. Transplanting in March to early April in a puddled field like rice transplanting, irrigation by the flooding method, and very good yields that farmers are getting (2.4 to 3.0 t/ha) in a very short crop period (less than 75 days after transplanting) were the main unique characteristics of finger millet production in the spring season. An observational study of five varieties from the hills was also conducted in the spring of 2023 to assess the suitability of these varieties. None of the introduced varieties performed better in trials. The results of the trial, combined with the experiences of Mukhiyapatti Musharniya RM farmers, are concisely presented in this paper, and it has recommended to expand the area under finger millet in the spring season under a rice-based cropping system. This paper also outlined the areas of intervention required in the spring season production of finger millet, which will be one of the better strategies for food and nutrition security for the targeted population in the country.

Keywords: Cropping system, farmers' innovation, finger millet in spring season, puddling, unique cultivation practices, yield

Introduction

Finger millet is the fourth important staple food of Nepal and a very important crop of *Bari*-dominated mid- and high hills, though it is cultivated from plain area to mountain region, as high as 3500m above sea level (Baniya et al 1992, Ghimire et al 2017), and in general, it is a summer-autumn crop in Nepal. Seeding starts early in mountains (ie in April) and seeding is done later in May in mid-hills and in June in case of low-hills and river basins. However, it was interesting to observe that finger millet was growing well in the spring season in small plots in Mukhiyapatti Musharniya Rural Municipality (RM), Dhanusha district. Farmers have adopted unique cultivation practices, which are not well documented. This unique planting season/time and production practices were developed by farmers themselves. Our attention was grabbed by the spring season finger millet crop when we observed it in the spring 2022. Here, the spring season is meant for the month of March to May, and the finger millet crop, however, is grown until mid- or late June, if seeding is done late. The unique production practices include seeding in March and transplanting in late March to mid-April; transplanting in puddled *Khetland* (like puddling for rice transplanting); and additional 2-4 flooded irrigations during the crop period. The crop is harvested from late May to mid-June, which means it matures in a very short period of time (less than 75 days after transplanting).

Two different activities were conducted to understand the unique finger millet production practice in Dhanusha viz (i) observation of finger millet crop in the field, and informal meeting and interaction with farmers to learn the practice and its' importance, and (ii) conduction of a small varietal trial of finger millet genotypes from the hills to test their suitability in the spring season of terai condition. This paper presents the findings of both types of activities related to finger millet production in the spring season in Mukhiyapatti Musharniya Rural Municipality (RM), Dhanusha.

Methodology

This paper is based on field observations, and informal interaction meetings with farmers, and a varietal trial of finger millet in the spring season. Two different activities were conducted to understand the unique finger millet production practice in Dhanusha: (i) observation of finger millet crops in the field and informal meetings and interactions with farmers to learn about the practice and its' importance; and (ii) the conduction of a small varietal trial of finger millet genotypes from the hills to test their suitability in the spring season of Tarai. Mukhiyapatti Musharniya RM of Dhanusha district is one of the villages with unique cultivation practices for finger millet in Nepal. Hence, this study has followed two separate methodologies to generate and compile the information from the field. These are briefly summarized below:

Engagement and knowledge exchange

Mukhiyapatti Musharniya RM is one of the projects RMs of the Food and Nutrition Security Enhancement Project (FANSEP) and is located in the southern part and on the Indian border of Dhanusha district. In April 2022, the FANSEP team observed a good finger millet crop in Ward No. 5, Bela, and Ward No. 6, Bairiya, within the Mukhiyapatti Musharniya RM. Although only a small number of farmers were involved, the crop exhibited excellent performance. Some farmers were engaged in discussions to acquire knowledge about finger millet production practices during the spring season and the associated benefits. Conversations were also held regarding their interest in evaluating the performance of finger millet varieties from the hill regions in their local spring conditions. These farmers expressed eagerness to test the hill varieties under their own growing conditions. Additionally, in the spring of 2023, further farm visits and interactions with farmers took place. A number of finger millet fields were observed once again in Ward No. 5, Bela, and Ward No. 6, Bairiya, Mukhiyapatti Musharniya RM.

It was interesting to note that farmers in Dhanusha and Mahottari have not grown finger millet in the summer-autumn season (the main or normal season of finger millet cultivation in Nepal). They have grown finger millet in the spring season only; that is, seeding normally in March and harvesting in May-June.

Testing of varieties

Following the visit and farmers interest to test the performance of finger millet varieties from the hills in the spring season under rice - fallow/vegetables/mustard - finger millet cropping system in Tarai. The project team received seeds of four varieties from the National Gene Bank (NARC) and made the necessary arrangements to test these four varieties along with one farmer's variety in Mukhiyapatti Musharniya, Dhanusha. Four varieties from the hills were: Asoje Kodo-NGRCO-1483, Thulo Kodo-NGRCO-4849; Asoje Kodo–NGRCO-1497 and NGRCO-5050-Kavre Kodo-2, and one farmer's existing variety (*Jhalari*) as a check were tested in a randomized complete block design (RCBD) with three replications in Mr Bharosi Yadav's field, Bairiya, Mukhiyapatti Musharniya-6, Dhanusha. The plot size used was 5x2m (10m^2), seeding was done on 28 March 2023 and transplanting in puddled plots was done on 19 April 2023.

Seeding was carried out in well-prepared, dry bed (**Figure 1** and **2**), although it was about two weeks later than the common practice among the farmers (typically, seeding is done from mid-February to mid-March). Transplanting was done in well-puddled plots (**Figure 3**), like rice transplanting. Recommended package of practices such as application of chemical fertilizers at the rate of 50:20:20 kg NPK/ha, transplanting with spacing of 15x10cm in row, and three irrigations during the crop period through flooding system were adopted in the trial crop. Additionally, herbicide called Racer (Pertilachlor 50% EC), a broad spectrum, selective and pre-emergence herbicide was applied on the same day of transplanting. Broadleaf weeds were managed well by Racer and only very few finger millet-like weeds (Kode Jhar – Goose grass) were observed in the plot. Days to maturity and grain yield of whole plot (10m^2) were recorded at the time when farmer's variety attained the maturity.

Figure 1. Seeding on dry bed, 28 March, 2023

Figure 2. Seedlings at 22 days after sowing and at the day of transplanting, 19 April 2023

Figure 3: Transplanting of trial crop, 19 April 2023

Results and Discussion

Finger millet production in spring season in Dhanusha

Growing finger millet in spring season is not a new practice in Dhanusha; it has been a traditional crop. Farmers have mentioned that they used to grown in larger area until a few decades ago. However, the area under finger millet was reduced significantly when the youth labor force was moved away from the villages to engage in other businesses in urban areas or sought employment opportunity abroad. Again, the area under finger millet has increased a little after when all other employment opportunities were hit by Covid-19 pandemic. Slowly, farmers are increasing the area under finger millet in spring season again from the year 2022. However, not all farmers are involved in finger millet production. Those who have (i) access to irrigation, (ii) availability of labor force at home, (iii) reared small ruminants, and (iv) have limited income-generating alternatives are the one engaged in finger millet cultivation in this region. Engagement of male family members in land preparation and transplanting and female members in the harvesting and postharvest operations was reported and observed in this area.

Farmers have noted some distinct benefits of cultivating finger millet in the spring season. Such major benefits are: (i) crop period of finger millet is very short in spring season (less than 75 days after transplanting), (ii) crop growth and performance was very good (**Figure 4**), and productivity is very good (about 2.4 – 3.0 t/ha) - especially for the very short crop duration, this is very high, if compared with national average yield of finger millet - 1.23 t/ha (MoALD 2022), (iii) performance of rice grown after finger millet is better and gives higher yields compared with rice grown after barren field or after Spring (*Chaite)* rice. This could be mainly due to addition of organic matters from finger millet roots and stubbles and loose soil, (iv) price of finger millet is much higher (about NPR 90 per kg) just at harvest than spring rice and can be sold easily, (v) finger millet straw is very good forage/feed for livestock (cattle, buffalo and goat) in the dry period of May-June, including other.

Main purpose of finger millet production varied among farmers. Some farmers reported that this is mainly for sale and household income. Some other farmers reported that this is mainly for household consumption – roti/snacks for family members, feed for milking animals etc. Few other farmers reported that it is partially for sale and partially for household consumption. None of the farmers reported that they make/eat as porridge (*Dhindo*) nor prepare alcoholic beverages in the village.

Finger millet contributes not only for food security but very good for nutrition security as well. Hence, it is worth expanding the area under finger millet in spring season so that nutritious food grains can be produced in a short period of time. It fits well in *Khetland*[1] with rice based cropping system. Normal rice – fallow/winter vegetables/potato or mustard – finger millet and again normal rice is common cropping pattern adopted by the farmers in Mukhiyapatti Musharniya, and same can be followed in many other areas of river basins and low-hills where irrigated *Khetland* is available and irrigation water is not enough for spring rice. Spring season is most-driest period of the year and finger millet cultivation in spring season is not possible without irrigation facility (**Figure 5**). However, water requirement of finger millet is very low as compared to *Chaite*/spring rice, so finger millet can be grown successfully where irrigation water is not sufficient for *Chaite* rice. This is because, about three to four irrigations (at least at transplanting, tillering and flowering time) would be enough for spring crop in *terai-Madhesh*, river basin and low hills.

1 Irrigated low land

Figure 4. Good crop of finger millet at maturity stage, MM-6, Bairiya, Dhanusha, 31 May 2023

Figure 5. Poor crop of Mr. Bindeswor Yadav because of lack of irrigation and poor crop management; fixing shallow tube-well for irrigation on 31 May, MM-5, Bela, Dhanusha

Use of improved seeds; application of recommended dose of fertilizers and manure including two times top-dressing of urea at 20-25 Days After Transplanting (DAT) and at 40-45 DAT; at least three irrigations; and proper weed management are the major interventions required to improve the yield of finger millet, that are possible in rice-based system only, and not possible in rainfed *bariland*[2] condition of mid-hills. Hence, finger millet should not keep orphan, just growing mostly in marginal and sloppy *bariland* with very minimal or no external inputs.

Finger millet varietal trial in spring season

As mentioned in the methodology, the trial crop was transplanted in puddled field on 19 April 2023. Vegetative growth of all four varieties were excellent and better than farmer's variety (upper panel of **Figure 6**), but three of them were unable to reach reproductive phase until the maturity stage of farmer's variety. Asoje Kodo-NGRCO-1483 had attended 40% heading at 68 DAT, where the farmer's variety was already harvested at 62 DAT (lower panel of **Figure 6**). Farmer's variety started heading at 32 DAT and reached maturity stage after 30 days of heading. It was very interesting to note very fast vegetative growth attaining good plant height and reproductive phase (heading) by 32 DAT.

Figure 7. Finger millet varietal trial with Mr. Bharosi Yadav, owner of the trial; farmer's variety in the left side and other varieties in the right, 31 May 2023

Farmer's variety produced the grain yield of 2.93 t/ha (average of three replications) in a crop period of 62 DAT, which is very high if compared with the national average yield (1.23 t/ha). Results of this trial indicated that none of the tested varieties from the hills were suitable for spring season in *Tarai* condition, as they took long growing season and not fit in rice based cropping system. However, only four varieties were tested from the hills and there are many other varieties which may be suitable for spring season conditions in rice-based cropping system. Also, short duration varieties from Karnataka, India which are

2 Unirrigated upland

grown in the spring/summer season may be suitable for the spring season in *terai,* river basin and low hill conditions of Nepal. Variety MR-1 and MR-6 seeded on 18 March have shown very good result (grain yield of >4 t/ha) in Bengaluru, Karnataka (Vishwanath et al 2019). Finger millet is grown almost all year round in Karnataka so possibility of getting suitable varieties for our spring season in *Tarai*, river basin and low hills could be high. Looking into all possibilities, greater attention should be given in research and development of finger millet, which contributes much on food and nutrition security of the country.

Figure 6. Variety Asoje Kodo-NGRCO-1483, that attended just 40% heading at 6 days after the harvest of farmer's variety, 26 June 2023

Recommendations/Suggestions

Field observations, interaction with farmers, and yield data from a varietal trial revealed a very good scope of finger millet production in the spring season in *Tarai*. A grain yield of 2.4 to 3.0 t/ha in a very short crop period (less than 75 DAT) can be considered a miracle crop. Good yields and price of finger millet in Mukhiyapatti Musharniya RM, Dhanusha suggests expanding the finger millet in a larger area of irrigated *Khetland* of low hills (possibly below 800m) and *Tarai* where irrigation and improved production practices can be adopted, and crops can be harvested before normal rice. Hence, finger millet cultivation should not be limited to marginal soils of sloppy *Bariland* under rainfed conditions, where adoption of improved practices is quite limited, but also promoted in irrigated *Khetland* of low hills and river basins (usually below 800m) and *Tarai,* where irrigation and improved production practices can be adopted, and crops can be harvested before transplanting normal rice.

All four varieties of finger millet tested in the spring season performed well until the vegetative phase. They were very late to attain the reproductive phase compared to the farmer's variety (Jhalari) so they were not suitable for rice-based cropping system. However, this is not the conclusion that there are no other varieties suitable for the spring season, as there are a greater number of varieties grown in the hills of Nepal, and finger millets are grown in more than one season in Karnataka, Odisha, Maharastra, and Andra Pradesh of India, where short-duration varieties may be available that may be high-yielding and suitable for the spring season in *Tarai*, river basins, and low hills. Hence, a greater number of possibly suitable genotypes need to be identified and tested in the farmer's field.

Transplanting, weeding, and threshing of finger millet are the most tedious, labor-intensive and/or expensive tasks. Hence, there should be a provision of subsidy for thresher machines appropriate for *Tarai* and for the hills, and proper weed management practices should be promoted. Finger millet is a miracle, climate-resilient and a superfood crop. So, the nutritive value and its health benefits should be communicated and disseminated through various mass media, exhibitions, street dramas, campaigns etc so that consumption of nutritious finger millet food items can be increased. This will certainly contribute to reduce the rice consumption in the longer term.

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Performance of Finger Millet Landraces Under Different Spacings in Spring Season

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Abstract

Finger millet, being enriched in nutritive value, are grown mostly in marginal and fragile regions of Nepal. Besides its huge number of landraces and its nutritious value, it is still being neglected. The present field experiment was conducted in Lamjung, Nepal during spring season of 2023 to evaluate the performance of finger millet landraces under different level of spacing. The experiment was laid in randomized complete block design (RCBD) having ten treatments replicated thrice. The treatment comprised of two factors, viz, finger millet landraces (Saano mudke, Kaartike, Laafe, Tanahunge Local, Thulo mudke and with two spacings (20 cm × 20 cm and 25 cm × 25 cm). The results revealed the substantial response of finger millet landraces to different level of spacings. All landraces showed positive response with the plant height ($p<0.01$), number of fingers per earhead ($p<0.01$), grain yield ($p<0.01$), straw yield ($p<0.01$). The highest grain yield (1.61 t/ha), effective tiller per hill (4.95) and number of fingers per earhead (7.92) was recorded in landrace Kaartike. The effective tiller per plant ($r=0.699^{**}$) and finger number per earhead showed the positive correlation with grain yield. Therefore, transplanting of finger millet landrace Kaartike with spacing of 20 cm × 20 cm in spring season was superior in grain yield. However, other local landraces viz., Thulo Mudke, Saano Mudke, Laafe, Tanahunge local reported the highest straw yield ranges from 42.23-53.35 t/ha can be used as fodder or preparation of hay and silage in the spring season.

Keywords: Finger millet, fodder, landraces, spring season, straw yield

Introduction

Finger millet (*Eleusine coracana* Gaertn) is an important staple food crop in the hills of Nepal. As the crop has good drought recovery and low nutrient demand, it is grown in marginal areas where other major cereals fail to give sustainable yield (Bhagat 2019, Kumar and Kumar 2011). In Nepal, finger millet ranks 4th among cereals with an area of 2,67,071 hectares of land, production of 339462 tons and productivity of 1.27 t/ha after rice, maize and wheat (MoALD 2023). Nepal is considered as secondary center of millet diversity with diverse types of varieties grown from the lowest elevation in Kachorwa village (85 masl), Bara to upper most elevation in Borounse village of Humla (3100 masl) (Ghimire et al 2017, 2020). Gandaki province shares about one third of total area (33%) and production (32%) of finger millet in Nepal (MoALD 2023). The crop is sequenced or relayed under mid hills of eastern, western and central regions. Actually, the crop is inherent hardy and cultivated in marginal, fragile and inaccessible regions where the crops are grown without external inputs (Luitel et al 2017).

Due to the potentiality of millets as climate resilient and nutritious food stuff in marginal lands, millet can play major role in nutritional security (Affholder et al 2013, Mishra 2019). Finger millet grains also have high nutritional content, especially for calcium, iron, and manganese (Gull et al 2015), and have long storability even under normal conditions which made them famine reserves' (Sakamma et al 2018). Delayed transplanting, improper spacing, higher seed rate, low-rate organic matter application are attributed to poor yields of finger millet (Rao et al 2012). Among the different agronomic practices, crop geometry plays a prominent role in achieving higher production by better utilization of moisture, nutrients and maximum solar energy (Uphoff et al 2011). Ideal crop geometry assures healthy and uniform stand in the main field ensuring higher productivity (Kumar et al 2019). Wider spacing was superior to narrow spacing in terms of enhanced grain and straw yield (Korir 2019). It has remarkable influences on the tiller dynamics, grain formation and other yield attributing characters (Pasuquin et al 2008). In the view of above observation, the field experiment was conducted to evaluate the performance of finger millet landraces under different levels of spacing in Lamjung, Nepal.

Materials and Methods

The field experiment was conducted at agronomy farm of Nepali Army Institute of Agriculture Sciences, Lamjung during spring season (March to September) in 2023. The soil of experimental site was sandy loam in texture with slightly acidic reaction, medium organic carbon content, available nitrogen, phosphorus and potassium. The experiment was laid in randomized complete block design (RCBD) having ten treatments replicated thrice. The treatment comprised of two factors, viz., finger landraces (Saano Mudke, Kaartike, Laafe, Tanahunge Local, Thulo Mudke and with different spacings (20 cm × 20 cm and 25 cm × 25 cm). These local landraces were collected from Purkot community seed bank, Tanahun and raised in nursery and the treatment were as follows. T1: Thulo mudke at 25 cm × 25 cm, T2: Tanahunge Local at 25 cm × 25 cm, T3: Kaartike at 25 cm × 25 cm, T4: Laafe at 25 cm × 25 cm, T5: Saano mudke at 25 cm × 25 cm, T6: Thulo Mudke at 20 cm × 20 cm, T7: Tanahunge local at 20 cm × 20 cm, T8: Kaartike at 20 cm × 20 cm, T9: Laafe at 20 cm × 20 cm, T10: Saano Mudke at 20 cm × 20 cm. The raised nursery was prepared with a dimension of 1 m × 1 m and 28 days seedling were transplanted in 2 m × 1 m plot. The FYM was applied at the rate of 10 t/ha to all experimental plot uniformly. The applied recommended dose of nitrogen, phosphorus and potash was 50:20:20 kg NPK/ha. Half doses of nitrogen and full dose of phosphorus were applied at basal application just before transplanting while remaining half dose were applied after 21 days after transplanting. All the growth and yield parameters like plant height, finger length, number of fingers, straw yield and grain yield were collected from randomly sampled plants.

Result and Discussion

Growth parameters

The data presented in **Table 1** indicated that there were the significantly the highest plant height (141 cm) in Tanahunge local, number of effective tillers (4.95) per hill, early days to 50% heading (105 DAS) and early days to maturity (136 DAS) in Kaartike landrace in spring season. Kumar et al (2019) also reported maximum effective tillers per m^2 with transplanting of seedling at 25 cm × 25 cm. There was no any significance difference among different landraces in different level of spacings. The interaction effect between different level of spacings and local landraces were non-significant.

Table 1. Growth parameters of finger millet landraces influenced by different level of spacings in spring season in 2023

Treatment	Plant height	Effective tillers per hill	Days to 50% heading	Days to maturity
Genotypes				
Thulo Mudke	135^{a}	2.1^{b}	158.7^{a}	196.7^{a}
Tanahunge local	141.1^{a}	2.53^{b}	147.3^{b}	183.5^{c}
Kaartike	95.6^{b}	4.95^{a}	105^{d}	136.0^{e}
Laafe	135.5^{a}	2.5^{b}	127.3^{c}	165.0^{d}
Saano Mudke	132.2^{a}	2.76^{b}	156.7^{a}	194.2^{b}
LSD	9.23	0.84	3.3	2.38
SEm ±	3.11	0.28	1.11	0.8
F-value	***	***	***	***
Spacing				
S1=25*25	125.7^{a}	3	139.2^{a}	175.3
S2=20*20	130^{a}	2.9	138.8^{a}	174.8
LSD	2.78	0.53	2.9	1.51
SEm±	1.96	0.18	0.7	0.51
F- value	NS	NS	NS	NS
Interaction effect				
LSD	13.05	1.18	4.67	3.37
Grand mean	127.8	3	139	175.1
CV	3.3%	11.1%	0.8%	0.1%
SEm±	4.39	0.4	1.57	1.13
F-value	NS	NS	NS	NS

Yield parameters

The local landrace Kaartike recorded the significantly highest number of fingers (7.92) followed by Laafe (6.45) and Tanahunge Local (5.43), Saano Mudke (5.2) and Thulo Mudke (5). However, the highest grain yield was recorded in Kaartike (1.61t/ha) followed by Saano Mudke (0.89 t/ha) which was at par with Laafe (0.85 t/ha) and Tanahunge Local (0.82 t/ha). The fresh straw yield was the highest in Thulo Mudke (53.35 t/ha) which was at par with Tanahunge Local (53.32 t/ha), Saano Mudke (47.87 t/ha) and Laafe (42.23 t/ ha). The finger length was the highest significantly in Laafe (8.19 cm) which was at par with Thulo Mudke (7.79 cm). Thousand grain weight was recorded significantly the highest in Thulo Mudke (2.75 g) and Saano Mudke (2.71 g). In contrast, Kumar et al (2019) found that the number of fingers, finger length and test weight were increased significantly by spacing of 25 cm × 25 cm.

The effect of spacing was recorded significantly difference in earhead weight. Earhead weight was the highest in 25 cm × 25 cm followed by 20 cm × 20 cm. However, the number of fingers, finger length, thousand grain weight, straw and grain yield were found non-significant with different level of spacings. The interaction effect due to different level of spacings and landraces was found to be significant (**Table 2**) in earhead weight whereas was non-significant in other yield attributing characters.

Table 2. Yield parameters of finger millet landraces influenced by different level of spacings in spring season in 2023

Treatment	Number of fingers	Finger length, cm	Earhead weight, g	1000 grain weight, g	Straw yield, t/ha	Grain yield, t/ha
Genotypes						
Thulo mudke	5[c]	7.79[a]	9.13[ab]	2.75[a]	53.35[a]	0.61[c]
Tanahunge Local	5.43[c]	7.34[ab]	9.5[a]	2.58[ab]	53.32[a]	0.82[bc]
Kaartike	7.92[a]	6.35[b]	5.95[bc]	2.15[bc]	24.4[b]	1.61[a]
Laafe	6.45[b]	8.19[a]	5.36[c]	1.77[c]	42.23[a]	0.85[bc]
Saano Mudke	5.2[c]	6.87[ab]	7.18[bc]	2.71[a]	47.87[a]	0.89[b]
LSD	0.66	1.27	2.16	0.43	17.33	0.24
Sem ±	0.22	0.43	0.73	0.15	5.83	0.08
F-value	***	*	***	***	***	***
Spacing						
S1=25*25	6	7	6.5[a]	2.4	38.6[a]	0.91[a]
S2=20*20	6	7.6	8[b]	2.4	49.8[b]	1.01[a]
LSD	0.42	0.8	1.37	0.27	10.96	0.15
SeM±	0.14	0.27	0.46	0.09	3.69	0.05
F-value	NS	NS	***	NS	***	NS
Interaction effect						
LSD	0.93	1.79	3.06	0.61	24.51	0.33
Grand mean	6	7.3	7.2	2.4	44.2	0.96
CV	0.31%	2.1%	5.6%	4%	9.7%	12.3%
SEM±	2.3	0.6	1.03	0.21	8.25	0.112
F-value	NS	NS	***	NS	NS	NS

Correlation analysis among different growth and yield attributing parameters

Analysis of variance exhibited significant difference among different landraces for different traits (**Table 3**). The grain yield had positive significant correlation with effective number of tillers and number of fingers whereas it was negative correlation with plant height. The straw yield was found significant positive association with plant height followed by earhead weight and thousand grain weight. The plant height is also found positively correlated with days to maturity. Similar findings were reported by Anitha (2015), and Kalaraju et al (2011).

Table 3. Correlation values

	PH	ET	No. F	EW	TGW	SY	GY
PH	1						
ET	-0.69**	1					
No. F	-0.699**	0.627**	1				
EW	0.450*	-0.079	-0.291	1			
TGW	0.235	-0.089	-0.442*	0.477**	1		
SY	**0.699****	-0.455*	-.536**	**0.493****	**0.458***	1	
GY	**-0.731****	**0.699****	**0.736****	-0.186	-0.146	-0.390*	1

Note: PH= plant height, ET=effective tiller, FL= finger length, No. F= No of finger per earhead, EW= ear head weight, TGW= Thousand grain weight, SY= straw yield, GY= grain yield.
**, Significant at the 0.01 level (2-tailed). *, significant at the 0.05 level (2-tailed).

Conclusion

Among different local landraces found in Lamjung and Tanahun districts, transplanting of finger millet landrace, Kaartike with spacing of 20 cm × 20 cm in spring season was found superior in grain yield with short crop duration of 136 DAS. Other local landraces viz, Thulo Mudke, Saano Mudke, Laafe, Tanahunge Local with the highest straw yield ranges from 42-53 t/ha can be used as fodder or preparation of hay and silage.

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Evaluation of Yield Performance of Finger millet Varieties on Different Planting Methods in Sundarbazar, Lamjung

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Abstract

Finger millet is a crop of many poor and subsistent people in the hills and is the fourth most important staple crop in Nepal. Cultivation in marginal land, use of local landraces due to limited access of improved variety, and transplantation of older seedlings to align with rice schedules has resulted in low yield of finger millet. Field experiment was conducted at farmers' field in Sundarbazar, Lamjung under rainfed condition during July to December 2019 to identify promising finger millet varieties for agro-climatic niche for mid-hills and tars and determine proper planting method for finger-millet. The experiment was laid out in split-plot design with three replications. Five finger-millet varieties (Kabre Kodo-1, Kabre Kodo-2, Dalle-1, Okhale-1 and Pangdure) were used as main-plot factors and three planting methods (Direct sowing (DS) @ 10×10 cm, Conventional Transplanting (CT) @ 10×10 cm with 30 days old seedling and System of Finger millet Intensification (SFI) @ 20×20 cm with 15 days old seedling) were used as sub-plot factors. SFI resulted in higher number of fingers per head, finger length, number of seeds per head, head weight, and straw yield than DS and CT methods. However, CT yielded higher than SFI and DS in other varieties except Kabre Kodo-2. Kabre Kodo-2 recorded highest grain yield in this location. The research suggests that SFI influences some major yield attributes in finger-millet and contribute to better yield attributes with low inputs.

Keywords: Conventional transplanting, direct sowing, improved varieties, seedlings, split-plot design

Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn.) is a minor millet grown in arid and semiarid tropics and subtropics of Asia and Africa (Mirza and Marla 2019). In world, finger millet ranks fourth in importance among millets after sorghum, pearl millet and foxtail millet (Upadhyaya et al 2007). In Nepal, it is the fourth ranked cereal after rice, maize and wheat, cultivated in 2, 67,000 ha of land producing 3, 39,000 tons of grains (MOALD, 2023). The contribution of finger millet to agricultural GDP is 1.19% (MOALD, 2023). The grains of finger millet are used as food and raw materials for distilleries. Finger millet straw is excellent as animal fodder with up to a total of 60% digestible nutrients (Gupta et al 2017). It forms a predominant staple food for people living on marginal lands and with limited economic resources. It is an agronomically sustainable crop that can grow on marginal lands, high altitudes and can easily withstand drought and saline conditions, requires little irrigation and other inputs and yet maintain optimum yields (Kumar et al 2016).

Direct seeding is a planting approach in which seeds are sown directly into the soil, allowing plants to grow and mature without undergoing the stresses of transplanting (Bareja 2021). This method accelerates crop development, and its main economic objectives include reducing labor costs and considering options for crop intensification. However, disadvantages of using the direct-seeded approach include inconsistent crop density, higher weed infestation and difficulties in performing intercultural operations. Similarly, in transplanting method, a seedling of a 30-60 days is transplanted without maintaining proper spacing. Uneven distribution of plants results in competition among finger millet for both moisture and nutrients (Bhatta et al 2017).

System of Crop intensification (SCI) is an agricultural production strategy that seeks to increase and optimize the benefits that can be derived from making better use of available resources: soil, water, seeds, nutrients, solar radiation, and air (Adhikari et al 2018). It emerged as improved agronomic management for transplanted crops after a huge success of System of Rice intensification (SRI) in rice. It has then been adopted successfully in mustard, wheat and many vegetable crops. In the tillering cereals, the principles of SCI advocate the use of younger seedlings to reduce the period of transplanting shock and thus, early establishment of the seedlings. Further, provision of wider spacing and adopting square geometry in tillering crops improves above and below ground growth of the crop and hasten tillering in crops resulting better yield. Moreover, the better root growth is observed to result greater sink capacity of the crops. SRI principles have been creatively adopted to suit the cultivation practices for finger millet, making it possible to produce 3-4 times more crop yield than with farmers' traditional practices, without depending on new varieties (Singh et al 2016).

Finger millet is considered as neglected, lost or orphan crops due to its negligible production and cultivated area (Bastola et al 2015). Its productivity is low because it is cultivated traditionally mostly by broadcasting and by behind the plough to some extent with low inputs under upland situations which results low production (Kumar 2018). Most practiced method in Nepal is broadcasting and random transplanting due to which there is uneven distribution of plants which causes the competition among finger-millet for moisture and nutrient (Bhatta et al 2017).

Planting techniques are an important aspect of agronomic practices for achieving enhanced productivity. Optimal planting methods and choosing improved cultivars are pivotal in maximizing crop yield potential within specific agro-climatic conditions (Tshering et al 2022). Hence, investigating the impact of planting techniques on various finger millet varieties in the mid hill regions of Nepal is of significant importance. The objective of this study is to determine the suitable variety for mid hills and tars as well as best planting method to improve yield attributes of finger millet varieties.

Materials and Methods

Evaluation/trial site

The experiment was conducted in the farmer's field in Sundarbazar, Lamjung under rainfed condition during July to December 2019. The site is located at an elevation of 800m with the latitude of $28^{o}7'$ to $28^{o}10'$ N and longitude of $84^{o}24'$ to $84^{o}28'$ E.

Evaluation methods

The experiment was laid out in split-plot design with three replications. Five finger-millet varieties (Kabre Kodo-1, Kabre Kodo-2, Dalle-1, Okhale-1 and Pangdure) were used as main-plot factors and three planting methods (Direct sowing (DS), Conventional Transplanting (CT) and System of Finger millet Intensification (SFI)) were used as sub-plot factors.

The area of main plot was $18m^2$ and those plots were again divided into 3 sub plot of area $6m^2$ individually. In direct sown crop, the seeds were continuously sown in rows spaced 10 cm and as the seedlings grew

>10 cm, the seedlings were thinned to provide 10 cm space between the plants. The conventional transplanting was done using 30 days old seedlings planted at crop geometry of 10 cm x 10 cm while SCI planting was done using 15 days old seedlings at a crop geometry of 20 cm x 20 cm. The area of nursery was $2m^2$ for single variety. Five nursery plot of $2m^2$ was made for five varieties ie Kabre Kodo-2, Kabre Kodo-1, Pangdure, Dalle-1, Okhale-1. Date of seed sowing in nursery was 11^{th} July, 2019.

Table 1. Different factors used in experiment

SN	Factors
Main plot factors	
1	Kabre Kodo-2
2	Kabre Kodo-1
3	Pangdure
4	Dalle-1
5	Okhale-1
Sub-plot factors	
1	Direct Sowing (DS)
2	System of Finger millet Intensification (SFI)
3	Conventional Transplanting (CT)

Chemical fertilizers, urea (46%), DAP (18%N and 46% P_2O_5) and MOP (60% K_2O) was applied in the field @ 50:30:30 kg NPK/ha. Half dose of nitrogen with full dose of phosphorus and potash was applied as basal dose on main plot during transplanting and remaining half dose of nitrogen was applied as split dose. In a plot of $6m^2$, 24.95 gm of N, 39.13 gm of P and 30 gm of K was applied at basal dose and 12.47 gm of N was applied during each top dressing at 30 days after sowing and 45 days after sowing in each plot. All plots were hand weeded in every 30 days.

Data collection and analysis

Randomly 10 heads of different plants were selected from the net plot area and number of fingers per head, length of finger, number of seeds per head and head weight was noted and average was taken. The plant samples after harvesting were air-dried for a week before being threshed. Threshed grains were then weighed using a digital scale. Grain and straw yields were determined from each net plot and converted to metric tons per hectare (mt/ha). Prior to recording straw yield, bundles of straw from each plot were sun-dried for a week to eliminate excess moisture.

R-studio Version 1.2.1335 computer program was used for running statistical analysis. To test the significance, ANOVA was used for each parameter. The F-test was done at 5% level of significance.

Results and Discussion

Effect of planting methods on number of fingers per head

The planting methods have significant effect on number of fingers per head whereas varieties have non-significant effect. Overall, SFI (6.42) produced the highest average number of fingers per head followed by DS (6.34) and CT (5.78). The results showed that SFI produced highest number of fingers per head in Pangdure (6.86), Dalle-1 (6.66) and Kabre Kodo-2 (6.46). However, highest number of fingers per head was produced in DS in varieties Okhale-1 (6.5) and Kabre Kodo-1 (6.23) (**Figure 1**). The higher number of fingers per head in SFI was due to wider spacing which provided optimum spacing and congenial microclimate to crop for effective utilization of available moisture, nutrient and its early adoption for better partitioning of photosynthates to reproductive parts there by recording better yield attributes (Kumar et al 2019).

Ahiwale et al (2011) reported that the higher yield attributes in transplanting methods is due to improved growth and development parameters.

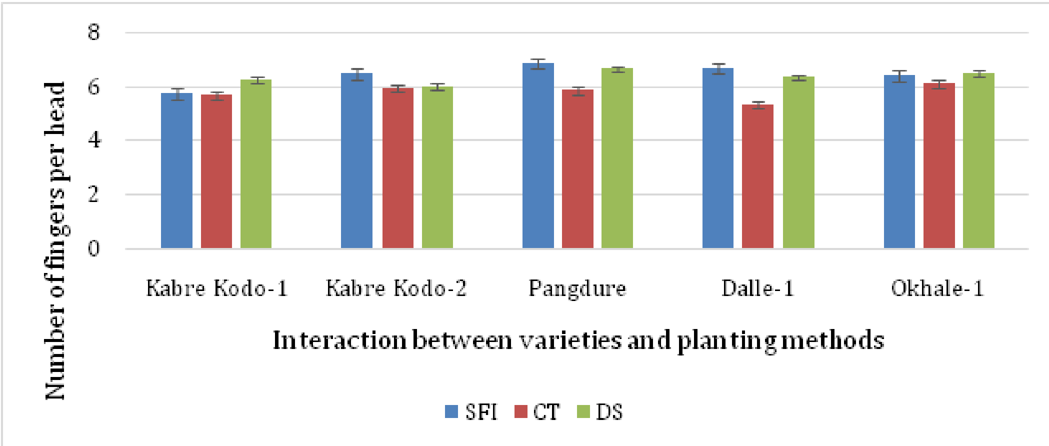

Figure 1. Effects of planting methods on number of fingers per head of finger millet varieties

Effect of planting methods on number of seeds per head

Results have shown significant effect of planting methods on number of seed per head while there was non-significant effect of varieties. Overall, SFI (1942) produced highest average number of seeds per head followed by DS (1690) and CT (1561). SFI produced highest number of seeds per head in all varieties except Dalle-1 (figure 2). In Dalle -1 DS produced highest number of seeds per head (2014) followed by SFI (1995) and CT (1750). The higher number of seed per head is because of wider spacing that means less competition for resources and maximum accumulation of photosynthates (Rajesh 2011).

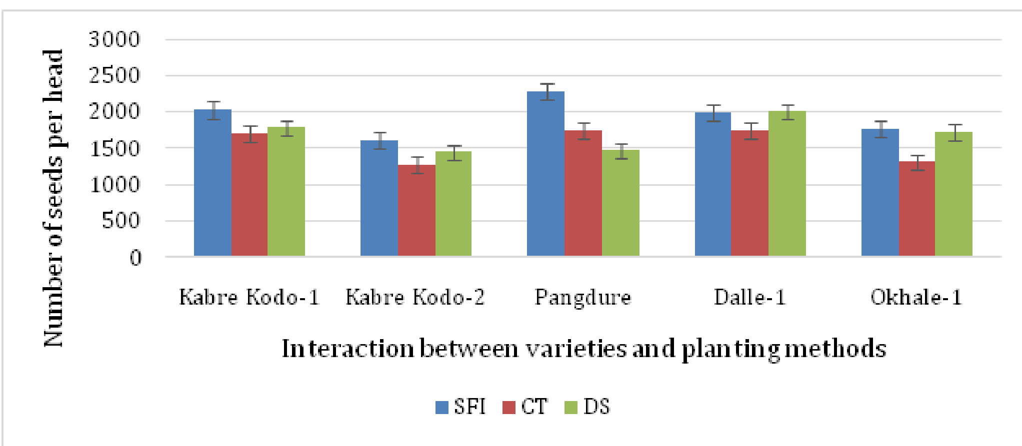

Figure 2. Effect of planting methods on number of seeds per head of finger millet varieties

Effect of planting methods on Head weight

Results have shown significant effect of planting method on head weight while varieties have shown non-significant effect. Overall, among planting methods SFI showed significantly highest head weight (8.05 gm) whereas DS (6.30 gm) and CT (6.16 gm) were statistically at par with each other. Similarly, SFI produced highest head weight in all varieties except Kabre Kodo-1 (**Figure 3**). In Kabre Kodo-1 DS produced highest head weight (7.46 gm). The increase in head weight in SFI was due to increase in growth and development attributes. A similar finding of maximum head weight from transplanting at wider spacing has been reported from Ahiwale et al (2011).

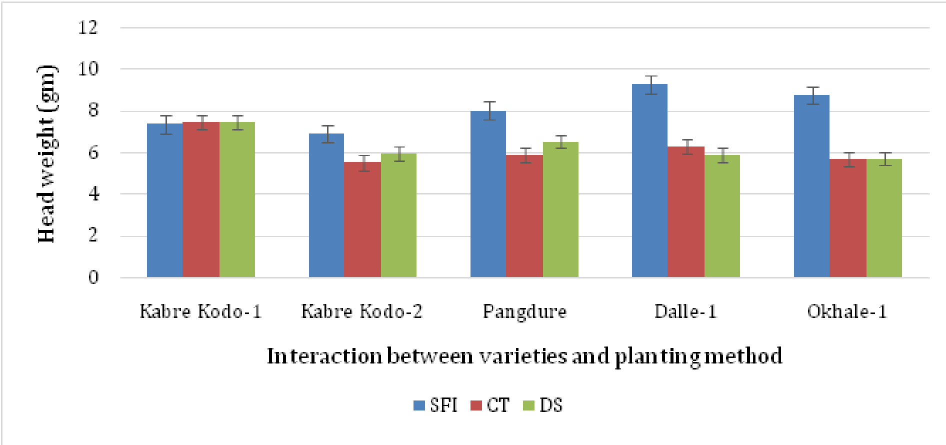

Figure 3. Effect of planting methods on head weight of finger millet varieties

Effect of planting methods on length of finger

Results have shown significant effect of both varieties and planting method on length of finger. Among varieties longest average finger length was found on Kabre Kodo-1 (9.45 cm) followed by Okhale-1 (8.69 cm) which is statistically at par with Dalle-1 (8.16 cm). The shortest was found on Kabre Kodo-2 (5.59 cm). Among planting methods longest finger length was found in SFI in all varieties with average of (8.64 cm) followed by DS (7.25 cm) and CT (6.90 cm) (figure 4). A similar finding of longest finger length in System of crop intensification has been reported from Kumar et al (2019).

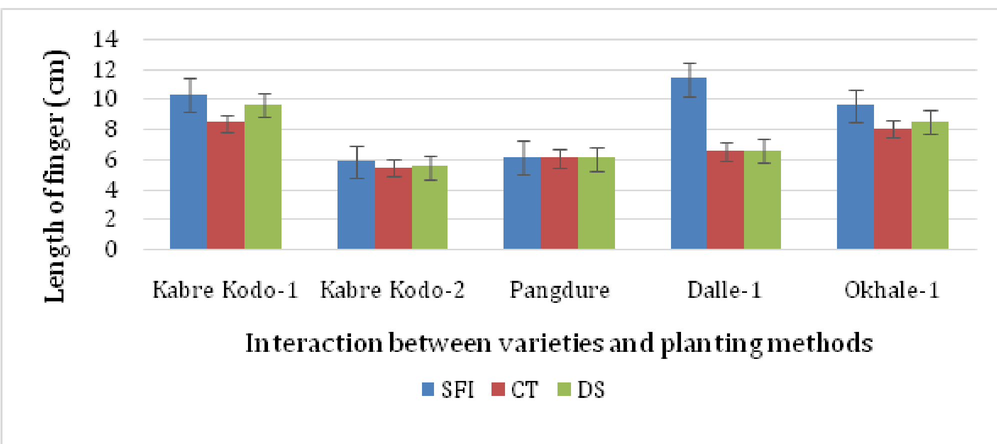

Figure 4. Effects of planting methods on length of finger of finger millet varieties

Effect of planting methods on grain weight

Both varieties and planting methods have shown significant effect on grain weight of finger millet. Highest mean grain yield was obtained from Kabre Kodo-2 (2.73 mt/ha) followed by local (2.54 mt/ha) whereas least was obtained from Dalle-1 (2.13 mt/ha). The maximum yield of Kabre Kodo-2 was due to genetic potential. Overall, highest mean grain yield was obtained from CT with average of 2.73 mt/ha followed by SFI (2.41 mt/ha) and DS (2.14 mt/ha) (**Figure 5**). The more grain yield by CT was due to higher number of effective tillers per square meter ie, it had more plant population and reduced competition with weeds due to closer spacing. The more number of plants have nullified the fact of less yield per plant in conventional transplanting. Manojgwada et al (2021) reported that greater plant population at a closer spacing resulted in a significantly increased grain yield in the closer spacing as compared to the wider spacing. A similar finding of maximum grain yield from transplanting in closer spacing is reported from (Shinggu and Gani 2012). However, this finding is not consistent with the finding of Bhatta et al (2017).

However, in Kabre Kodo-2, significantly highest grain yield was produced by SFI (3.02 mt/ha) followed by CT (2.77 mt/ha) and DS (2.41 mt/ha). Rajesh (2011) also reported highest grain yield under system of finger millet intensification. The higher grain yield for Kabre Kodo-2 in SFI is due to enhanced stature of yield attributes, thus forming larger sink size coupled with efficient translocation of photosynthates to the sink (Kumar et al 2019). The finding is in line with Ahiwale et al (2011) who reported increased growth and development parameters that resulted in improved yield attributes and finally grain yield in recommended transplanting method. Biswas and Das (2023) reported that SFI leads to an expansion of root volume and biomass, which enhances the uptake of nutrients and water, ultimately resulting in increased yields. Furthermore, it extends the crop's time to maturity, promoting substantial vegetative growth and the development of reproductive organs.

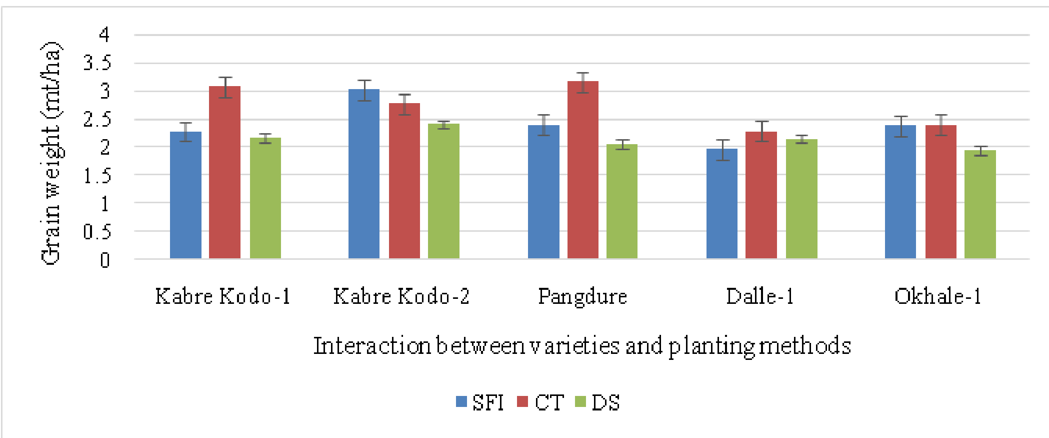

Figure 5. Effect of planting methods on grain weight of finger millet varieties

Effect of planting methods on straw weight

Result has shown significant effect of planting methods on straw yield but varieties have shown non-significant effect. Overall highest straw yield was obtained from SFI (0.97 mt/ha) followed by DS (0.93 mt/ha) and CT (0.8 mt/ha). The higher straw yield in SFI is due to wider spacing and use of younger seedling for better and uniform stand which enhanced higher biomass production in extended vegetative growth period than the late transplanting (Mondol et al 2018). Higher straw yield was obtained from SFI in varieties Okhale-1 (1.11 mt/ha) and Dalle-1 (1.08 mt/ha). However, higher straw yield was obtained from DS in varieties Kabre Kodo-1 (0.96 mt/ha) and Kabre Kodo-2 (1.04 mt/ha) (**Figure 6**). The findings are in line with Rajesh (2011) who reported higher straw yield in finger millets planted closely. Similarly, highest straw yield was obtained from CT in Pangdure variety (0.96 mt/ha).

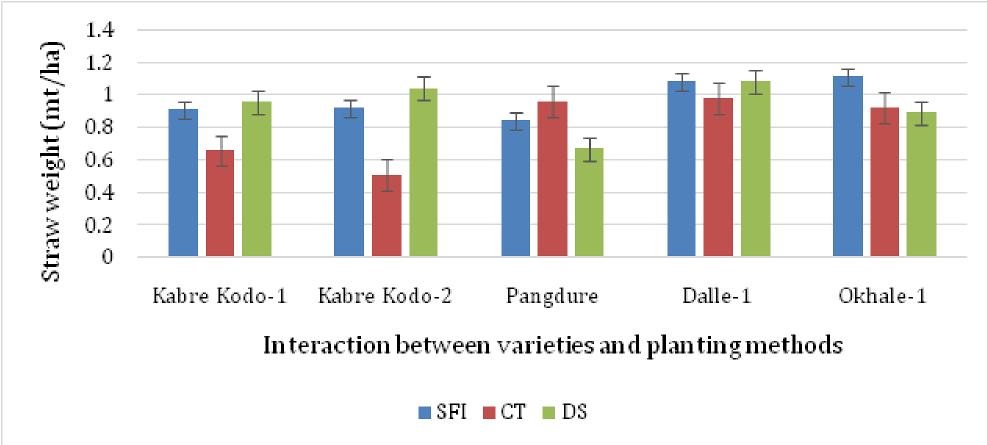

Figure 6. Effect of planting method on straw yield of finger millet varieties

Conclusion

System of finger millet intensification significantly improved number of finger per head, finger length, number of seed per head and head weight. However, conventional transplanting yielded 14.39% to 25.59% higher than system of crop intensification in other varieties except Kabre Kodo-2, the highest yielding variety. In Kabre Kodo-2, system of finger millet intensification proved superior with 8.48% higher yield than conventional transplanting. In the light of the present investigation, it can be concluded that transplanting of Kabre Kodo-2 variety of finger millet is well suited to SFI leading to higher yield in mid hills.

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक)। २०८०। राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ।

कोदोको महत्त्व र खेती प्रविधि

नरबहादुर साउँद

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सारांश

मानिस सुखोन्मुखी छ, तर अभावको समयमा जब उसलाई कोदो, जौ, फापर, मादरा (सामा), लट्टेदाना, कागुनो, चिनु, बेडु, तिमिला, सिस्नु जस्ता हेपिएका तर स्वास्थ्यबर्धक अन्न, फल र साग खुवाएर प्रकृतिले उसलाई दया गरिरहेको हुन्छ। कोदो मध्य पहाडी क्षेत्रको एउटा मुख्य खाद्यान्न हो। कोदो सुक्खा सहने, कम मलिलो माटोमा पनि उब्जनी दिनसक्ने, वर्षा हुने शुष्क क्षेत्रमा, सिञ्चित र असिञ्चित दुवै अवस्थामा उब्जिन सक्ने बर्खे बाली हो। कोदाको दानामा पाइने प्रतिपोषक पदार्थहरूलाई विभिन्न तरिकाले निष्क्रिय पार्न सकिन्छ। कोदो खेती रुखोदेखि ज्यादै मलिलो माटोमा पनि गर्न सकिन्छ। पहाडी भेगमा मकै भाँच्नुअघि घुसुवा बालीका रूपमा कोदोका करिब १ महिना उमेरका बिरुवाहरू मकै बारीभित्र सारिन्छन्। सघनखेती गर्दा एक हेक्टरमा ३७ देखि ७५ क्वि. उब्जनी प्राप्त हुन्छ।

कोदोको महत्त्व

खानलाई छैन मडुवा धुली। यो बूढी भन्छे नाकमा फुली।

कालीकर्णाली र कुमाउँ क्षेत्रमा प्रचलित यस गीतले जनाउँछ कि कोदो विशेषतः गरीब परिवारको खाद्यान्न हो। यसैले यसलाई क्षुद्रधान्य (कमसल धान्य), कुधान्य वा कुअन्न (कुत्सित धान्य वा निन्दित अन्न) भनिएको हुनुपर्छ।

कुन्तीले युद्धपछि कृष्णलाई भनिन् “विपदः सन्तु नः शश्वत्तत्र तत्र जगद्गुरो। भवतो दर्शनं यत्स्यादपुनर्भवदर्शनम्। ” (हे जगद्गुरु कृष्ण, हामीलाई सधैँ जहाँ तहाँ दुःख आइरहून्, जसबाट हजुरको दर्शन भइरहोस् र पुनः भवदुःख भोग्नु नपरोस्)। बालकृष्ण समले पनि भने “दुःखीका घरमा मात्र तेरो बास हुने भए, हे ईश्वर दया राखी मलाई अझ दुःख दे”।

मानिस सुखोन्मुखी छ, तर अभावको समयमा जब उसलाई कोदो, जौ, फापर, मादरा (सामा), लट्टेदाना, कागुनो, चिनु, बेडु, तिमिला, सिस्नु जस्ता हेपिएका तर स्वास्थ्यबर्धक अन्न, फल र साग खुवाएर प्रकृतिले उसलाई दया गरिरहेको हुन्छ।

कोदो अफ्रिका र दक्षिण एसियाको शुष्क क्षेत्रमा हजारौँ वर्ष पहिलेदेखि खेती हुँदै आएको एउटा प्रमुख खाद्यान्न हो । यसलाई मडुवा वा रागी पनि भनिन्छ । यो क्षेत्रफल र उत्पादन दुवै दृष्टिले नेपालको धान, मकै र गहुँपछि चौथो महत्त्वपूर्ण खाद्यान्न बाली हो । कोदोले ओगटेको कुल क्षेत्रफलमध्ये ९६% बढी क्षेत्रफल पहाडी भेगमा रहेकाले यो मुख्य रूपले पहाडी खाद्यान्न हो । नेपालमा खेती गरिने कोदोवर्गका मुख्य बालीहरू कोदो, कागुनो, चिनु र सामा हुन् । यी मध्ये कोदो खेतीले ८५% भन्दा बढी क्षेत्रफल ओगटेको छ ।

उष्ण जलवायु फाप्ने साना बीउ भएका घाँस परिवारका अन्नहरूलाई कोदे बाली वा कोदो वर्ग वा मिलेट भनिन्छ । कोदो, कागुनो, चिनु, कुट्की सामा वा धानकोदो, सामा वा सौँ, सेतो सामा, जाबे वा भिर्कौलो, कोदी, बाजरा अनि कहिलेकाहीँ जुनेलोलाई पनि कोदे बाली अन्तर्गत नै समेटिएको पाइन्छ । यिनको खेती खाद्यान्न वा पशुचाराको लागि गरिन्छ ।

कोदोको दानाको बीजावरण (भुस) मोटो, खस्रो र रेसादार भएकाले यसको उपयोग र उत्पादन कम गरिन्छ, यसलाई गरीबको खाना मानिन्छ, कोदो खेतीमा ध्यान र लगानी कम दिइन्छ र कोदो अन्न र यसबाट बनेका रोटी आदि खाद्य पदार्थ काला र अनाकर्षक भएकाले अज्ञानतावश प्रायः यसको उपेक्षा गरिन्छ । तर पौष्टिकताको दृष्टिकोणले कोदो गहुँसमतुल्य र चामल वा मकैभन्दा बढी पोसिलो छ । कोदोको उत्पादकत्व बढाउन र बजारीकरणका लागि अनुसन्धानमा बढी लगानी र प्रयासको आवश्यकता छ । कोदो प्रायः रासायनिक मल र विषादी बिना उब्जाइने भएकाले यो बढी स्वस्थकर र विषरहित हुन्छ । कोदोको पौष्टिक महत्त्वबारे जनजागरण आवश्यक छ । कोदोका परिकार बनाउने तरिकाबारे पनि जानकारीको अभाव छ ।

समुद्र सतहबाट ३००० मी. सम्मका उच्च पहाडी क्षेत्रमा कोदो खेती धेरै गरिन्छ । कोदो मध्य पहाडी क्षेत्रको एउटा मुख्य खाद्यान्न हो । यसभन्दा माथिका पहाडी क्षेत्रमा फापर, उवा आदिको खेती हुन्छ । कोदो सुक्खा सहने, कम मलिलो माटोमा पनि उब्जनी दिनसक्ने, वर्षा कम हुने शुष्क क्षेत्रमा, सिञ्चित र असिञ्चित दुवै अवस्थामा उब्जिन सक्ने बर्खे बाली हो । सिँचित अवस्थामा एक हेक्टरमा ५० क्वि./हे. भन्दा बढी उब्जनी प्राप्त हुन सक्छ । यस बालीमा रोग र कीराको प्रकोप कम हुने हुनाले यसको बीउलाई चिस्यानबाट बचाउन सकेमा करिब ५ वर्षसम्म पनि भण्डारण गर्न सकिन्छ । कोदोको दानामा कीरा र कुहिने रोग प्रायः नलाग्ने भएकाले अन्य खाद्यान्न नभएको बेला यसले भोकमरीबाट बचाउन सक्छ ।

कोदोको पोषकीय महत्त्व

खेती गर्न सजिलो हुनुका साथै कोदो ज्यादै पौष्टिक खाद्यान्न हो । कोदोको दानामा ७.३% प्रोटीन, १.३% इथर अर्क (फ्याट), २.७% खनिज पदार्थहरू, ३.६% कोरा रेसा, ७२.% कार्बोहाइड्रेट र १३.१% पानी पाइन्छ । कोदोमा पाइने प्रोटीन सजिलै पच्नसक्ने भएकाले कोदो गहुँभन्दा पनि उत्तम मानिन्छ । एक सय ग्राम कोदोमा ३४४ मि.ग्रा. क्याल्सियम, २८३ मि.ग्रा. फस्फरस र ३.९ मि.ग्रा. फलाम पाइन्छ (गोपाल र साथीहरू, १९७१) । कोदो क्याल्सियम, फलाम, म्याँगनीज, रेसा र फस्फरसको धनी स्रोत भएकाले गर्भवती महिलाहरूका लागि कोदो उत्तम भोजन मानिन्छ । यसमा जिङ्क र पोटासियम पनि पाइन्छ । कोदो विशेषतः क्याल्सियमको धनी स्रोतका लागि प्रख्यात छ ।

तालिका १. विभिन्न अन्नमा पाइने पोषक तत्वहरूको तुलना (प्रति १०० ग्राम)

अवयव	खैरो चामल	गहुँ	मकै	कोदो
ऊर्जा (किलो क्यालोरी)	३६२	३४८	३५८	३३६
कार्बोहाईड्रेट (ग्राम)	७६	७१	७३	७२.६
प्रोटीन (ग्राम)	७.९	११.६	९.२	७.७
रेसा (ग्राम)	१.०	२.०	२.८	३.६
चिल्लो पदार्थ (ग्राम)	२.७	२.०	४.६	१.५
क्याल्सियम (मिलिग्राम)	३३	३०	२६	३४४
फलाम (मिलिग्राम)	१.८	३.५	२.७	३.९
नायसिन (मिलिग्राम)	४.३	५.१	३.६	१.१
थायमिन (मिलिग्राम)	०.४१	०.४१	०.३८	०.४२
राइबोफ्लाभिन (मिलिग्राम)	०.०४	०.१	०.२	०.१९

स्रोत: गोपालन र साथीहरू (१९७१)

लट्टेदाना र क्विनोआ अन्नपछि फलामको मात्रा बढी पाइने अन्न कोदो हो । कोदो गर्भवती महिलाहरू र मधुमेहरोगीहरूका लागि पनि फाइदाजनक हुन्छ । मिथायोनीन (गन्धकयुक्त अमिनोअम्ल) अन्य अन्नमा कम मात्रामा पाइन्छ तर कोदोमा यथेष्ट मात्रामा पाइन्छ । फलेको चामल, मकै र सिमलतरुल जस्ता उच्च स्टार्चयुक्त खाद्य पदार्थलाई आडिलो खानाका रूपमा खाने मानिसहरूले मिथायोनीन नामक अमिनो अम्लको कमी सहनु पर्ने भएकाले त्यसको कमी कोदोले घटाउन सक्छ । कोदोको दानामा चिल्लो पदार्थ कम पाइन्छ र यसमा अधिकांश असंतृप्त फ्याटी अम्ल पाइन्छ ।

कोदो+मासको दाल (२:१) भुटेर दूध या पानीमा पकाई लिटो तयार गरिन्छ। अङ्कुरित कोदोबाट निर्मित माल्ट बच्चाहरूलाई खुवाउन सकिन्छ। माल्टको पिठोमा दही, दूध वा तातो पानी मिसाएर खाने गरिन्छ। कोदोको पिठोबाट बनाइएको रोटी पहाडी क्षेत्रमा आडिलो खानाका रूपमा खाने गरिन्छ। यसबाट ढिँडो वा पोरिज पनि तयार गरिन्छ। कोदोको भात र खीर पनि पकाइन्छ। कोदोबाट केक, बिस्कुट, पाउरोटी, चाउचाउ, मालपुवा, ऐँठे/झीर, निम्की, डुनोट, पफ, भुटुरे, पापड, डोसा, इडली, सूप, पकौडा, हलुवा र अन्य मिष्टान्नहरू तयार गरिन्छन्। कोदो र भटमास (९:१), कोदो र गहुँ (३:७) वा अन्य दाल वा अन्नको पिठो मिसाउन सकिन्छ। गहुँ र कोदोको पिठो मिसाई खानामा ग्लुटेनको मात्रा घटाउन सकिन्छ। कोदोबाट जाँड, तुम्बा, रक्सी र बियर पनि तयार गरिन्छ। कोदोबाट निकालिएको इन्जाइमको रस (अर्क) छालाबाट रौं हटाउन प्रयोग गरिन्छ। कोदोको पौष्टिक महत्त्व उच्च भएकोले यसका विभिन्न परिकारहरू होटल तथा रेस्टुराहरूमा प्रचलित भइरहेका छन्। कोदोमा पाइने सबैभन्दा महत्त्वपूर्ण प्रतिपोषक पदार्थ यसको दानाको भुसमा पाइने ट्यानिन (फिनोलयुक्त यौगिक) हो। ट्यानिनले फलाम, प्रोटीन र कार्बोहाइड्रेटको अवशोषण बाधित गर्छ। अप्रसोधित कोदोमा स्यापोनिन (साबुनजस्तो फिंज दिने ग्लुकोसाइड), फाइटेट (फस्फोरसयुक्त यौगिक), स्यानाइड (विष) र अक्जालेट (अक्जालिक अम्लको सल्ट) जस्ता प्रतिपोषक पदार्थहरू पनि पाइन्छन्। फाइटेटले क्याल्सियम, जिङ्क आदि खनिजको अवशोषण बाधित गर्छ। स्यानाइडले धातु (जस्तै: फलाम) युक्त इन्जाइम र प्रोटीनहरूलाई बाँध्छ। अक्जालेटले क्याल्सियम र म्याग्नेसियमको उपयोग र प्रोटीनको पाचनमा बाधा गर्छ। तर यी प्रतिपोषक पदार्थहरूले कोदोको दानालाई विभिन्न रोग र कीराहरूबाट पनि बचाएर राख्छन्।

कोदाको दानामा पाइने उक्त प्रतिपोषक पदार्थहरूलाई विभिन्न तरिकाले निष्क्रिय पार्न सकिन्छ। कोदो प्रायः फलेर भुस हटाएपछि मात्र उपभोग गरिन्छ। कोदो प्रशोधन गर्न ओखलमा कुटेर फल्ने, माल्ट बनाउने (भिजाउने-टुसाउने-सुकाउने-पिस्ने), किण्वन गर्ने (सफा पानीमा रातभर भिजाएको दानालाई बोराले छोपेर २० घन्टासम्म ढड्याउने), भुट्ने (तावामा १०५ डि.से.. तापक्रममा खैरो हुन्जेल चलाउँदै भुट्ने), उमाल्ने (३० मिनटसम्म पानीमा उमालेपछि घाममा सुकाउने), रातभर पानीमा भिजाउने वा अन्य तरिकाले दानाको बोक्रा हटाउने तरिकाहरू अपनाउने गरिन्छ। भिजाएको कोदोलाई घाममा राम्ररी सुकाएपछि पिसेर पिठो बनाई सेलोफेन झोलामा हावाबन्द गरी भण्डारण गर्न सकिन्छ। अङ्कुरित चना र कोदोमा फोलिक अम्लको मात्रा २/३ गुणा बढ्ने पाइएको छ। दाना अङ्कुरण हुँदा फाइटेट आदि प्रतिपोषक पदार्थहरू बिखण्डन हुन्छन्। उमाल्दा वा पकाउँदा पनि प्रतिपोषक पदार्थहरू निष्क्रिय बन्छन्। कोदोको लया (फुल उठ्ने गरी भुटेको) दाना विष्फोट भई फुकेको, नरम, स्वादिलो, बास्नादार र कुरकुरे हुन्छ। दानामा चिस्यानको मात्रा १९% र भुट्दा तापक्रम २४० २४० डि.से. भएमा राम्रो लया (फुल) बन्छ। भिजाएको कोदोलाई २४ घन्टासम्म ढड्याउँदा यसमा रहेका प्रतिपोषक (फाइटेट, ट्यानिन र ट्रिप्सिन अवरोधक) को मात्रा घट्ने, प्रोटीन, खनिज पदार्थ र भिटामिनहरूको मात्रा वृद्धि हुने र स्यानोकोबाल्मिन (भिटामिन बी-१२) को संश्लेषण हुने पाइएको छ। पिस्नु वा पकाउनुभन्दा पहिले कोदोको दानालाई भुटेमा यसको पोषकीय गुणस्तर वृद्धि हुन्छ। कोदोमा रहेका प्रतिपोषक पदार्थहरू हटाउनका लागि किण्वन (ढड्याउने) तरिका बढी उपयुक्त पाइएको छ। कोदोको हरियो नल पशुहरूले रुचाएर खान्छन्। यसको पौष्टिक गुणस्तर पराल वा गहुँको छबालीभन्दा धेरै उच्च हुन्छ। नलमा शुष्क भारका आधारमा ३.८% प्रोटीन र ८.६% खनिज पदार्थहरू पाइन्छन्। यसमा पचनीय प्रोटीन भने नगण्य (०.२%) पाइन्छ। यसको हरियो नल साइलेज बनाउनका लागि उत्तम हुन्छ। यसको साइलेजमा मीठो बास्ना आउँछ र पशुहरूले निकै रुचाएर खान्छन्।

कोदोको औषधीय महत्त्व

कोदोमा रक्तशर्करा घटाउने, कोलेस्टेरोल घटाउने, घाउ निको पार्ने, पेटको अल्सर निको पार्ने आदि गुणहरू पाइएको छ। कोदोमा ग्लुटेन पाइदैन। कोदो खाने व्यक्तिको मोटोपन घट्छ किनकि कोदोमा पाइने जटिल स्टार्च बिस्तारै पच्ने भएकाले र यसमा पाइने रेसाले पेटमा पुगेपछि फुलेर पेट भरिएको अनुभव गराउने हुँदा भोक कम लाग्छ। बालकहरूको हाडहरूको वृद्धि र विकासका लागि र वृद्धहरूको हाडहरू कमजोर र छिद्रमय हुनबाट रोक्न कोदोमा पाइने प्राकृतिक क्याल्सियमले ठूलो मद्दत गर्छ। कोदो खानाले वयस्क व्यक्तिको पनि हाडहरू स्वस्थ रहन्छन् र हाड भाँचिने सम्भावना कम हुन्छ। कोदो खाँदा रगतमा शर्कराको मात्रा धेरै नबढ्ने हुनाले यो मधुमेह रोगीहरूका लागि उपयुक्त अन्न हो। कोदोमा पाइने लेसिथिन नामक फस्फोलिपिड र मिथायोनीन नामक अमिनो अम्लले कलेजोमा विद्यमान कोलेस्टेरोल घटाउन मद्दत गर्छन् र थ्रीयोनाइन नामक अमिनो अम्लले कलेजोमा बोसो जम्मा हुनबाट रोक्छ। यसमा पाइने फलामले रक्ताल्पताबाट बचाउँछ। कोदोले अनिद्रा, चिन्ता र अवसादबाट जोगाई शरीरलाई आरामी राख्न मद्दत गर्छ। यसले कोशिका क्षय हुने रोगहरू लाग्नबाट बच्न र बुढ्यौली रोक्न मद्दत गर्छ। कोदोमा पाइने रेसाले कब्जियत, आन्द्राको क्यान्सर, उच्च रक्तचाप र कोलेस्टेरोल हुनबाट जोगाउँछ। कोदोमा क्याल्सियमको मात्रा बढी पाइने हुनाले मृगौलामा पत्थरीको समस्या हुने व्यक्तिले यसको प्रयोग कम गर्नुपर्छ।

कोदोको झोलमा प्रतिअक्सिकारी गुण पाइन्छ र यसले मुक्त रेडिकलहरूलाई मार्जन गर्ने, विभिन्न रोगाणुको संक्रमणबाट बचाउने, आँखामा मोतिबिन्दु लाग्नबाट बचाउने र प्रोटीन-ग्लाइकेसन (प्रोटीन र रिड्युसिङ शर्करा आपसमा बाँधिने प्रतिक्रिया) रोक्ने कार्य गर्छन्। प्रोटीन-ग्लाईकेसन हुँदा मधुमेही र बृद्धहरूमा मोतिबिन्दु आदि रोग लाग्छन्। कोदोमा पाइने रेसाले र फेनोलिक यौगिकहरूले मुक्त रेडिकलहरूलाई मार्जन गर्छन् र रगतमा शर्करा र कोलेस्टेरोलको मात्रा नियन्त्रण गर्छन्। कोदोको निस्सार (झोल) मा मुक्त रेडिकलहरू मार्जन गर्ने, प्रोटीन-ग्लाईकेसन रोक्ने, मोतिबिन्दु लाग्न नदिने र रोगकारक सूक्ष्मजीवहरूसँग लड्ने क्षमता हुन्छ।

उत्पत्ति र विस्तार

कोदोको उत्पत्ति थलो अफ्रिका (युगाण्डा र इथोपिया आसपासको उच्चभूमि) हो। कोदो पनि एसियाली कपास झैं अफ्रिकामा उत्पत्ति भएर प्राग् ऐतिहासिक कालमा नै भारतीय महाद्वीपमा प्रविष्ट भएको हो। ईस्वीपूर्व २००० वर्ष पहिले कोदो भारतीय उपमहाद्वीपमा भित्रिएको अनुमान छ। कोदोको संस्कृत नाम कोद्रव भएबाट यो भारतीय उपमहाद्वीपको प्राचीन बाली हो भन्ने थाहा हुन्छ। कोद्रव (कु+ विच् = कु = पृथ्वी; द्रु जानु + अच्; कु + द्रु + अच्) = पृथिव्यां द्रवति = पृथ्वीमा वायुले वा स्वतः उम्रिन्छ) लाई उद्दाल (वनकोदो), मदनाग्र (जसको बाला उन्मादक हुन्छ), कोरदूष (कुल वा वंशलाई दूषित गर्ने, कोदो खानेका सन्तान कोदे भनेर) आदि संस्कृत नाम भएबाट कोदो भारतीय उपमहाद्वीपको प्राचीन बाली हो भन्ने प्रमाणित हुन्छ। कोदो हविद्रव्यको रूपमा प्रयोग हुँदैन। आयुर्वेदमा कोदोले वात बढाउँछ तर पित्त र कफ नाश गर्छ, नयाँ कोदो सजिलै पच्दैन भनिएको छ। कोदोको कोराकाना प्रजातीय नाम कोदोको श्रीलङ्काली नाम कुरक्कनबाट लिइएको हो। कोदोको पूर्वज इलुसिन एजिप्सिआका वा इलुसिन इन्डीका (कोदे झार) हुन सक्ने अनुमान गरिएको छ।

संसारमा मिलेट (कोदो वर्गका अन्न) अन्तर्गतको कुल क्षेत्रफल ३.१९ करोड हे. छ र यसबाट २.७७ करोड मे.टन (७.५८ क्वि./हे.) उत्पादन हुन्छ (सन् २०११)। कोदो उत्पादन गर्ने मुख्य देशहरू युगान्डा, भारत, नेपाल र चीन हुन्। अमेरिकातिर कोदो सन् १८७५ तिर मात्र भित्रिएको हो। कृषि तथा पशुपन्छी विकास मन्त्रालय (२०२३) का अनुसार नेपालमा सन् २०२१/२२ मा मिलेट अन्तर्गतको कुल क्षेत्रफल २,६७,०७१ हे. र कुल कोदो उत्पादन ३,३९,४६२ मे.टन (१२.७ क्वि./हे.) छ। नेपालमा मिलेट भन्नाले मुख्यतः कोदो नै जनाउँछ। नेपालमा कोदो अन्तर्गतको क्षेत्रफल पहिलेको तुलनामा घट्दो छ। कोदो उत्पादन गर्ने प्रमुख जिल्लाहरू खोटाङ, बाग्लुङ, कास्की, स्याङ्जा, सिन्धुपाल्चोक, ओखलढुङ्गा, गोर्खा, सिन्धुली, नुवाकोट, धादिङ आदि हुन्। कोदो उत्पादन गण्डकी प्रदेशमा ११०,१५१ मे. टन, कोशी प्रदेशमा ९८,४०० मे. टन, बागमती प्रदेशमा ६७,६२८ मे. टन, कर्णाली प्रदेशमा २४,६७७ मे. टन, सुदूरपश्चिम प्रदेशमा २३,२२६ मे. टन, लुम्बिनी प्रदेशमा १३,७११ मे. टन र मधेस प्रदेशमा १,६६९ मे.टन छ। कोदोको कुल उत्पादनमध्ये उच्च पहाड, मध्य पहाड र तराईमा क्रमशः करिब ७५%, २१% र ४% रहेको छ।

वानस्पतिक विवरण र वर्गीकरण

कोदो घाँस परिवार, इलेउसीन बंश र कोराकाना प्रजातिको एकवर्षीय बिरुवा हो। इलेउसीन वंश अन्तर्गतका ७ वटा प्रजातिहरूमध्ये २ वटा प्रजातिको मात्र खेती गरिन्छ, त्यसमध्ये इलुसिन कोराकाना प्रमुख हो। कोराकानाका चारओटा उपप्रजाति छन्: इलंगाटा, प्लाना, कम्प्याक्टा र भुल्गारिस। अफ्रिकामा खेती गरिने अर्को प्रजाति इलुसिन अफ्रिकाना हो, यसका अफ्रिकाना र स्पोंटानिया गरी दुई उपप्रजाति छन्। अन्य प्रजातिहरू जंगली अवस्थामा वा झारका रूपमा रहेका छन्।

कोदोको बिरुवा ठाडो बढ्ने, गाँजिने, एकयामे र ६०-१२२ से.मी. अग्लो हुन्छ। यसको जरा प्रणाली झाँकरा किसिमको हुन्छ। जरा प्रणाली बलियो भएकाले कोदोको बिरुवालाई हातले तानेर सजिलै उखेल्न सकिदैन। यी जराहरू माटोबाट चिस्यान अवशोषण गर्न ज्यादै सक्षम र कुशल हुन्छन्। यस कारण नै यस बालीले सुख्खा सहन सक्छ। कोदोको बिरुवा ज्यादै गाँजिन्छ। यसको डाँठ चेप्टो हुन्छ, तर आँख्ला/गाँठा भने गोलाकार हुन्छन्। पातहरू लामा र हरिया हुन्छन्। पातको मध्य-नसा स्पष्ट हुन्छ। पर्णफलक (लेमिना) र पर्णच्छद (शीथ) जोडिएको भागमा जिह्विका (लिग्युल) हुन्छ र यसमा मसिना रौंको झल्लर देख्न सकिन्छ। प्रत्येक गाँजको शीर्षस्थ अन्तरआँख्लामा बाला वा पुष्पक्रम (inflorescence) उत्पन्न हुन्छ। बालाको आधारीय बिन्दुबाट २-८ ओटा औंलाजस्ता शाखा बालाहरू उत्पन्न हुन्छन्। यसैले कोदोको बाला एउटा झुत्ताजस्तो देखिन्छ। औंलाजस्तो शाखा बालालाई मञ्जरी (spike) भनिन्छ। औंला (मञ्जरी) को मसिनो प्राक्ष (धुरी) मा दुवैतर्फ बाहिरपट्टि दुई लहर घना अनुमञ्जरी (spikelets) उत्पन्न हुन्छन्। प्रत्येक अनुमञ्जरीमा ४-५ ओटा फूलहरू हुन्छन्। यी फूलहरू नै दानाका रूपमा विकसित हुन्छन्। एउटा मञ्जरी पूरा फुल्नका लागि ६-८ दिन लाग्दछ। सबै औंलामा फूलहरू एकै समयमा फुल्दछन्। बालाको लम्बाइ ३-१३ से.मी. हुन्छ। फूलमा स्वपरागसेचन हुन्छ तर हावाको माध्यमले १% सम्म परपरागसेचन हुन सक्छ। पुष्पन भएको करिब ४० दिनमा बाली काट्न सकिन्छ। कोदोका दाना साना, भुसद्वारा हलुका वा राम्ररी कस्सिएर ढाकिएका र जातअनुसार राता-खैरा वा सेता हुन्छन्। तर कुनै जातका दाना सुन्तले राता, बैजनी वा काला रङका हुन्छन्। दानाहरू फलेर भुस हटाएपछि मात्र खानका लागि प्रयोगमा ल्याइन्छन्। कोदोमा द्विगुणित क्रोमोसोम संख्या ३६ ($4x=2n=36$) हुन्छ। एउटा बालामा करिब २००० दाना लाग्दछन्। १००० दानाको तौल २-३ ग्राम हुन्छ।

नेपालको गाउँघरमा कोदोको बालाको किसिम र दानाको रङ अनुसार कोदोको प्रकार छुट्ट्याइन्छ। कोदोका २५ बढी किसिमहरू कास्की क्षेत्रमा मात्र पाइएका छन्। बालाको प्रकार अनुसार मुख्यतः २ प्रकारका कोदो छन्:

१) नङ्ग्रे कोदो: यस प्रकारको कोदोको बालाका औंलाहरू हत्केला खुला वा अद्र्ध खुला राख्दा झैं फैलिएका हुन्छन्। यसलाई झाम्रे वा झप्रे कोदो पनि भनिन्छ। खुला बाला भएकाले यसमा रोग र कीरा कम लाग्दछन्।

२) डल्ले कोदो: यस प्रकारको कोदोको औंलाहरू मुड्की बाँधे झैं कस्सिएका अर्थात् औंलाहरू भित्रपट्टि घुम्रिएर गोलबन्द भएका हुन्छन्। यस्तो कोदोलाई मुड्के कोदो पनि भनिन्छ। यस प्रकारको बालामा रोग र कीरा लाग्न सक्ने अनुकूल परिस्थिति हुन्छ।

उक्त २ मुख्य किसिमहरू बाहेक बालाको किसिम अलि फरक पनि हुन सक्छ, जस्तैः बालाका औंलाहरू पूरा खुलेर लत्रेका वा औंलाहरू भित्र घुम्रेर राम्ररी नकस्सिएका, अर्ध डल्ले आदि। दानाको रङका आधारमा पनि कोदोको विभेद गरिन्छ। जस्तो कि, सेतो कोदो, कालो कोदो, रातो कोदो। कालो कोदोका दाना गाढा खैरा वा खैरोमा रातो रङ मिसिएका हुन्छन्। सेतो कोदोमा कालो कोदोको अपेक्षा बढी प्रोटीन पाइने, कम खस्रोपन हुने, चाँडै पचाउन सकिने, बढी स्वादिलो वा मीठो हुने, तर ढिला पाक्ने विशेषताहरू हुन्छन्। ढिला पाक्ने र कम उब्जनी दिने भएकाले सेतो कोदोको क्षेत्रफल धेरै कम छ। भारतमा सेतो कोदोका बढी उब्जाशील जातहरू विकास गरिएका छन्।

हावापानी र माटो

कोदो बालीलाई न्यानो जलवायु (११ देखि २७ डि.से.) फाप्दछ। यसको खेती उष्ण र उपोष्ण क्षेत्रहरूमा सफलतापूर्वक गर्न सकिन्छ। न्यानो हावापानी चाहिने भएकाले यो वर्षाकालीन बालीका रूपमा उब्जाइन्छ। यसको खेती तराईदेखि उच्च पहाडी क्षेत्रमा पनि हुन्छ। तर यस बालीलाई मध्य पहाडको जलवायु बढी फाप्दछ। समुद्र सतहदेखि २३०० मी. उचाइका पहाडी क्षेत्रसम्म कोदो खेती गरिन्छ। कोदो सिञ्चित वा असिञ्चित दुवै अवस्थामा उब्जाउन सकिन्छ। यस बालीले सुक्खा सहन सक्ने भएकाले सिँचाइ सुविधा नभएको कम उर्वर जग्गामा कोदो लगाउने गरेको पाइन्छ। सिँचाइको सुविधा भएमा यसको उब्जनीमा निकै वृद्धि हुन्छ। वार्षिक ५०-१०० से.मी. वर्षा हुने क्षेत्रहरू कोदो खेतीका लागि बढी उपयुक्त हुन्छन्। उच्च वर्षा हुने क्षेत्रमा खेतबाट पानी निकास व्यवस्थित गरी कोदोका बेर्ना सारेर रोपण गर्न सकिन्छ। बाली परिपक्व हुने बेला वर्षा कम हुने र सापेक्षिक आर्द्रता न्यून रहने क्षेत्रमा रोगकीरा कम लाग्ने हुँदा उत्पादन बढी हुन्छ। जल निकास कम भएको जग्गामा कोदोका बेर्ना ड्याङमा पनि रोप्न सकिन्छ।

कोदो खेती रुखोदेखि ज्यादै मलिलो माटोमा पनि गर्न सकिन्छ। यसका लागि राम्रो जल निकास भएको दोमट वा चिम्ट्याइलो दोमट माटो सर्वोत्तम हुन्छ। पी.एच. मान ५ देखि ८ भएको माटोमा कोदो खेती गर्न सकिन्छ। पहाडमा ढुङ्गे वा बलौटे र रातो माटोमा पनि कोदो खेती गरिन्छ, तर ढुङ्गे वा पत्थरिलो माटोमा यस बालीले पर्याप्त लाभ दिन सक्तैन। पानी निकास नभएको अर्थात् जलाक्रान्त र चिम्ट्याइलो माटो भएको मटियार भूमि पनि कोदो खेतीका लागि उपयुक्त हुँदैन। यस बालीले अन्य बालीका तुलनामा बढी क्षारीयता सहन सक्छ।

उन्नत जातहरू

कोदोका स्थानीय जातहरू कम उब्जनी दिने, रोगग्राही र एकै समयमा समान रूपले नपाक्ने हुन्छन्। नेपालमा २०२८ सालदेखि कोदो सुधार कार्यक्रम थालिएको हो। बढी उब्जा दिन सक्ने, मल खप्ने र नढल्ने, रोग अवरोधक, विभिन्न समय र क्षेत्रमा लगाउँदा पनि उब्जनीमा स्थिरता भएका, सबै बालाहरू एकै समयमा पाक्ने अर्थात् समकालिक परिपक्वन गुण भएका, चुट्दा दाना सजिलै झर्ने र उच्च पौष्टिक स्तर भएका कोदोका जातहरू परीक्षण र अनुसन्धान गरी उन्नत जातहरू बिकास गर्ने प्रयास देश र विदेशमा जारी छ। नेपालमा हाल पहाडी बाली अनुसन्धान कार्यक्रम अन्तर्गत पहाडी क्षेत्रका मामूली बालीहरू (कोदो, चिनो, कागुनो, जौ, उवा, फापर र लट्टे) सम्बन्धी परीक्षण र अनुसन्धान भइरहेकोले पहाडी क्षेत्रको खाद्य सुरक्षा र यी बालीको पौष्टिक महत्त्वबारे चेतना अभिवृद्धि हुनेछ। स्थानीय जातका कोदोबाट लगभग २२ क्वि./हे. उब्जनी प्राप्त हुन्छ, जबकि छनौट गरिएका उत्कृष्ट स्थानीय लाईनहरू र विदेशहरूबाट प्राप्त उन्नत जातहरूले ३०-३२ क्वि./हे. उत्पादन दिन्छन्। नेपालको विभिन्न क्षेत्रका लागि उन्मोचन तथा पञ्जीकरण गरिएका कोदोका उन्नत जातहरू **तालिका २** मा प्रस्तुत गरिएको छ।

तालिका २. नेपालमा खेतीका लागि सिफारिस भएका कोदो बालीका जातहरू

जात	उत्पत्ति	सिफारिस बर्ष	बोटको उचाई (से.मि.)	पाक्ने अवधि (दिन)	उत्पादन (क्वि./हे.)	बालाको किसिम	सिफारिस क्षेत्र	कैफियत
१. ओख्ले-१	नेपाल	२०३७	८०	१५४-१९४	३३	नंग्रे	मध्य र उच्च पहाड	ओखलढुंगाको स्थानीय जात, मरुवा रोग कम लाग्ने
२. डल्ले-१	भारत	२०३७	११०	१२५-१५१	३३-३५	मुड्के	मध्य पहाड	मरुवा रोग लाग्न सक्ने
३. काब्रे कोदो-१	नेपाल	२०४७	८२	१४७	२३	ठाडा औंले	मध्य र उच्च पहाड (९००-१९०० मि.)	सुर्खेतको स्थानीय जात, मरुवा र पात थोप्ले अवरोधी, सुख्खा सहने, नढल्ने
४. काब्रे कोदो-२	भारत	२०७२	९१	१५३	२५	फिंजारिएको	मध्य पहाड	मरुवा र पात थोप्ले अवरोधी, सुख्खा सहने, नढल्ने

जात	उत्पत्ति	सिफारिस बर्ष	बोटको उचाई (से.मि.)	पाक्ने अवधि (दिन)	उत्पादन (क्वि./हे.)	बालाको किसिम	सिफारिस क्षेत्र	कैफियत
५. शैलुङ कोदो-१	भारत	२०७२	१००	१५५	२५	कस्सिएको मुड्के	उच्च पहाड	मरुवा र पात थोप्ले अवरोधी, नढल्ने
६. रातो कोदो	नेपाल	२०७८	६६-११५	१५०-१६०	२५	भित्र घुम्रेका खंदिला बाला	उच्च पहाड	जुम्लाको स्थानीय जात, मरुवा र पात थोप्ले अवरोधी, सुख्खा र चिसो सहने, नढल्ने

स्रोत: घिमिरे र साथीहरू (२०७५)

बालीचक्र र मिश्रित खेती

कोदो बर्खे बाली हो। कोदोपछि तोरी, आलु, केराउ, गहुँ, मुसुरो, चना, जौ, सस्र्यूं, आलस वा हिउँदे तरकारीहरू लगाउन सकिन्छ। कोदोसँग कोसेबालीहरू (मास, मुङ, मस्याङ, भटमास, रहर, बोडी, गहत) अन्तरबालीका रूपमा वा बालीचक्रमा समावेश गरेमा माटोको उर्वरता कायम रहन्छ र कोदोबालीका लागि मलिलो अवस्था उपलब्ध हुने भएकाले उब्जनी बढ्छ। कोदो चोखो बालीका रूपमा या मिश्रित वा अन्तरबालीका रूपमा खेती गरिन्छ। मिश्रित वा अन्तरबालीका रूपमा कोदोसँग मकै, लट्टे, जुनेलो, कागुनो, झुसेतिल, बर्खे दलहन बालीहरू जस्तै: रहर, बदाम, गहत, भटमास वा बोडी लगाउन सकिन्छ। पहाडी भेगमा मकै भाँच्नुअघि घुसुवा बालीका रूपमा कोदोका करिब १ महिना उमेरका बिरुवाहरू मकै बारीभित्र सारिन्छन्। यस्तै धान रोपाइँ गरेपछि धानको आलीमा कोदोका बिरुवा रोप्ने गरिन्छ। कोदोबालीसँग निम्न मिश्रित वा अन्तरबाली अपनाउँदा अधिकतम उब्जनी प्राप्त हुने पाइएको छ:

क) कोदो+भटमास (१:१ पङ्क्तिमा),
ख) कोदो+भटमास (१०:९० को अनुपातमा बीउ मिश्रण वा प्रत्येक ४ पङ्क्ति कोदोपछि १ पङ्क्ति भटमास रोप्ने),
ग) कोदो+मस्याङ (१०:८० को अनुपातमा बीउ मिश्रण),
घ) कोदो+रहर (२० कि.ग्रा. रहर+६ कि.ग्रा. कोदोको बीउ प्रयोग गरी प्रत्येक २ पङ्क्ति रहरपछि ६ वा ८ पङ्क्ति कोदो रोप्ने)

जमीनको तयारी

कोदो रोप्नका लागि जमीनको तयारी राम्रोसँग गर्नुपर्छ, माटो बुर्बुराउँदो र झारपातरहित तुल्याउनु आवश्यक छ। अघिल्लो बाली काटेपछि कोदोका लागि जमीनको तयारी सुरु गरिहाल्नुपर्छ। पहिलो जोताइ माटो पल्टाउने हलोद्वारा गर्नुपर्छ। गर्मी याममा गहिरो जोताइ गर्दा माटोभित्र रहेका झारका गाँठा, उम्रिरहेका झारहरू, रोगाणुहरू, कीराका विभिन्न अवस्थाहरू सतहमा प्रकट भई घामको प्रभावले वा पानीको कमीले नष्ट हुन्छन्। चैत वा बैशाखमा गहिरो जोतेर खुला छाडेको माटोमा वर्षाको पानी अवशोषित भई माटोभित्र पस्छ र चिस्यान संरक्षण हुन्छ। मनसुन/बर्षा याम सुरु हुनासाथ २-३ पटक स्थानीय हलो वा ह्यारोले जोत्नुपर्छ। जोताइ पश्चात् पाटा लगाएर डल्लाहरू फुटाउने र गह्राहरू समतलीकरण गर्ने कार्य गर्नु जरुरी छ। प्रत्येक जोताइपछि पाटा लगाउँदा माटोमा चिस्यान पनि संरक्षित रहन्छ। जमीनको तयारी गर्ने बेलामा १००-२०० क्वि./हे. का दरले राम्ररी पाकेको गोठे मल वा कम्पोष्ट मल वा ५० क्वि./हे. का दरले गड्यौली कम्पोस्ट प्रयोग गर्नुपर्छ। प्राङ्गारिक मल हाल्नाले माटोको जलधारण क्षमता र खाद्य तत्वहरू धारण एवं आपूर्ति गर्ने क्षमतामा उल्लेखनीय वृद्धि हुन्छ।

बीउ र रोपण

कोदो रोप्ने समय

रोप्ने समयमा माटोमा पर्याप्त चिस्यान उपलब्ध हुनु अति आवश्यक छ। चिस्यानको अभाव भएको माटोमा कोदोको बीउ अङ्कुरण हुन सक्तैनन् वा अङ्कुरण पश्चात् कलिला बिरुवाहरू तुरुन्तै मर्छन्। कोदोका कलिला बिरुवाहरू माटोमा चिस्यानको कमीप्रति धेरै संवेदनशील हुन्छन्। तर एक पटक माटोमा स्थापित भैसकेका बिरुवाहरूले सुक्खा सहन सक्छन्। विलम्ब रोपेमा पनि बालीले ऋतुको अन्त्यतिर वा पुष्पावस्थामा पानीको कमी सहनुपर्ने हुन्छ। यसकारण, खास गरी असिञ्चित क्षेत्रमा, कोदो रोपण समयमै वा सकभर चाँडै गर्नुपर्छ। कोदो रोप्ने कार्य मनसुन सुरु हुनासाथ थाल्नु बेस हुन्छ। विभिन्न क्षेत्रमा कोदो रोप्ने उपयुक्त समय देहाय बमोजिम छ:

क) तराई, भित्री मधेश र बेंसी (११०० मी. सम्म उचाइका क्षेत्र): असार (असारको प्रथम पक्ष बढी उपयुक्त)।
ख) मध्य पहाड (११००-१८०० मी. उचाइ सम्मका क्षेत्र): जेठ दोस्रो पक्ष।
ग) उच्च पहाड (१८०० मी. भन्दा माथिका क्षेत्र): बैशाख -मध्यदेखि जेठ -मध्यसम्म।

रोपुवा कोदोका लागि ब्याड राख्ने उपयुक्त समय बैशाख आधाआधीदेखि असार आधाआधीसम्म हो। तीन देखि चार हप्ता उमेरका बेर्ना, तराई र भित्री मधेशमा सिँचाइ सुविधा र मनसुनको आगमन बमोजिम धेरै विलम्ब भएमा श्रावण-मध्यसम्म सारिसक्नुपर्छ। उच्च पहाडमा कोदो सार्ने कार्य असार पहिलो पक्षभित्रै पूरा गर्नुपर्छ।

बीउ दर, बीउको कठोरीकरण र बीउ उपचार

बीउदर

छरुवा तरिकाले रोपण गर्दा १०-१२ कि.ग्रा., पङ्क्तिमा रोपण गर्दा ८-१० कि.ग्रा. र रोपुवा तरिकामा ब्याड राख्नका लागि ४-५ कि.ग्रा. कोदोको बीउ प्रति हेक्टर का दरले प्रयोग गर्नुपर्छ। ब्याड राख्ने तरिका धानको सुक्खा ब्याड राखेजस्तै हो। कोदोको बीउ सानो भएकाले सुक्खा माटो या बालुवामा मिसाई छर्न वा रोपण गर्न सकिन्छ।

बीउको कठोरीकरण

आकासे पानीको भरमा खेती गरिने माटोमा चिस्यानको कमीले बीउ अङ्कुरण कम हुने भएकाले खेतबारीमा बिरुवाको सङ्ख्या पर्याप्त नहुन सक्छ। फलतः उब्जनी कम प्राप्त हुने पाइएको छ। यस्तो परिस्थितिमा रोप्नुभन्दा पहिले बीउको कठोरीकरण गर्नुपर्छ। यसका लागि बीउलाई ६ घन्टासम्म पानीमा (एक किलोग्राम बीउ एक लिटर पानीका दरले) भिजाउने। त्यसपछि पानी निथार्ने र भिजाएको कपडामा कसेर पोको पारी २ दिनसम्म राख्ने। दुई दिनपछि हेर्दा बीउमा अङ्कुरण सुरु भएको लक्षण देखिनेछ। पोको खोलेर बीउलाई छहारी भएको ठाउँमा कपडामाथि फिँजाएर दुई दिनसम्म सुकाउने। यसरी कठोरीकरण गरिएको बीउ रोप्दा अङ्कुरण राम्रो हुन्छ, बिरुवाको ओज र सुक्खा सहने क्षमता वृद्धि हुन्छ।

ढुसीनाशकद्वारा बीजोपचार

रोप्नुपूर्व कार्बेन्डाजिम वा थाइरम वा भाइटाभ्याक्स २.५ ग्रा. वा थाइरम+कार्बेन्डाजिम (१:१) ३ ग्रा. प्रति कि.ग्रा. बीउका दरले प्रयोग गरी बीउ उपचार गर्नुपर्छ।

सूक्ष्मजैविक मलद्वारा बीजोपचार

कोदोको बीउलाई नाइट्रोजन स्थिरक शाकाणु एजोस्पाइरिलम (*Azospirillum brasiliense*) र फस्फोरसघोलक ढुसी (*Aspergillus awamori*) २५ ग्राम प्रति किलोग्रामका दरले उपचार गरेमा उत्पादन वृद्धि हुन्छ। बीउ उपचार गर्दा पहिले ढुसीनाशकद्वारा र त्यसपछि मात्र सूक्ष्मजैविक मलद्वारा उपचार गर्नुपर्छ। सूक्ष्मजैविक मल बीउको सतहमा राम्ररी टाँसियोस् भनी २५० मि.लि. पानीमा २५ ग्रामका दरले गुड उमालेर घोल तयार गरी ठन्डा भएपछि यसमा सूक्ष्मजीवको धुलो मिसााउनुपर्छ र त्यसपछि घोललाई बीउसँग राम्ररी मिसाउनुपर्छ।

बीजामृतद्वारा बीजोपचार

५ कि.ग्रा. गाईको गोबर ठूलो कपडामा बाँधेर २० ली. पानीमा डुबाएर १२ घन्टासम्म राख्ने। अर्को प्लास्टिक वा माटोको भाँडोमा एक ली. पानीमा ५० ग्राम चुना घोल्ने र रातभर राख्ने। भोलिपल्ट बिहान कपडामा बाँधेको गोबरलाई बेसरी तीनचार पटक पानीमा निचोर्ने। गोबरको गाढा रस तयार हुन्छ। यसमा एक मुठी मलिलो माटो हालेर राम्ररी चलाएर मिसाउने। यसमा ५ ली. गोमूत्र वा मानवमूत्र र चुनपानी मिसाउने। बीजामृत तयार हुन्छ। बीउमाथि बीजामृत छम्केपछि हातले राम्ररी मिसाउने। उपचारित बीउलाई छहारीमुनि सुकाएपछि रोप्न सकिन्छ। बीजामृतमा रहेका लाभदायक सूक्ष्मजीवहरू र पोषक तत्त्वहरूले गर्दा बेर्नाहरूको ओजस वृद्धि हुन्छ। बीजामृतले बीउ र बिरुवाहरूलाई रोगाणु र कीराहरूबाट बचाउँछ।

रोप्ने तरिका

क) सोझै बीउ रोप्ने तरिका

छरुवा विधि: सकभर छरुवा तरिकाले रोपण गर्नुहुँदैन। किनभने छरुवा तरिकाले बीउ रोप्दा खेतमा बीउ एकनासले वितरण हुन सक्दैन र बिरुवाहरू कतै बाक्ला र कतै पातला उम्रन्छन्; बीउ समान गहिराइमा नपर्ने भएकाले बढी गहिराइमा परेका बीउ नउम्रन सक्छन् वा कुहिन सक्छन् र सतहमा परेका बीउ चरादिद्वारा खाइएर वा चिस्यानको कमीले अङ्कुरण नभई नोक्सान हुन्छन्। यसकारण छरुवा तरिकाले रोप्दा बीउ समानरूपले वितरण हुने र बीउ करिब ३ से.मी. गहिराइमा रोपण गर्ने कुरामा ध्यान दिनुपर्छ।

पङ्क्तिमा रोपण: पङ्क्तिमा रोपण गर्दा बीउदर कम लाग्छ, बीउ समान गहिराइमा रोप्न सकिन्छ र गोडमेल गर्न सजिलो हुन्छ। पङ्क्तिदेखि पङ्क्तिको दूरी २०-२५ से.मी. कायम गरी बीउ ३-४ से.मी. गहिराइमा रोप्नुपर्छ। पछि पङ्क्तिमा उम्रेका घना बिरुवाहरू छाँटेर उखेली बोटदेखि बोटको दूरी

८-१० से.मी. कायम गर्नुपर्छ। एक हेक्टर (२० रोपनी वा ३० कठ्ठा) मा ४ देखि ५ लाख बिरुवा कायम हुने गरी रोप्नुपर्छ। पङ्क्तिमा रोप्न सीडड्रिल प्रयोग गर्नु बेस हुन्छ। बीउ उम्रन ५ देखि १० दिन लाग्छ।

ख) कोदोका बेर्ना सार्ने तरिका (रोपाइँ)

माटोमा प्रशस्त चिस्यान उपलब्ध हुने ठाउँमा मात्र कोदोको बेर्ना सारेर रोपण गर्न सकिन्छ। मनसुन ढिला सुरु हुने वा अन्य कारणले कोदो रोप्न ढिला हुने परिस्थितिमा कोदोको रोपुवा खेती गर्नु लाभप्रद पाइएको छ। बेर्ना सारेर रोपेको कोदो बालीबाट सोझै बीउ रोपेको बालीबाट भन्दा बढी उब्जा प्राप्त हुन्छ। रोपुवा कोदोबाली ढल्दैन। रोपुवा कोदोखेतीका लागि ठाउँ अनुसार बैशाखदेखि जेठ-मध्यको अवधिमा ब्याड राख्नुपर्छ। तराई र भित्री मधेशमा ब्याड राख्न ढिला भएमा ब्याड राख्ने कार्य असार-मध्यसम्म पनि गर्न सकिन्छ। तराई, भित्री मधेश र बेँसी टारमा कोदोका बेर्ना २१-२५ दिन उमेरका भएपछि सार्नु उपयुक्त हुन्छ। बढी उमेरका बेर्ना सार्दा उब्जनी ह्रास हुन्छ। लेकाली क्षेत्रमा ४०-५० दिनका र मध्य पहाडी क्षेत्रमा ३०-४० दिन उमेरका बेर्ना सार्न सकिन्छ।

बेर्ना उखेल्नुपूर्व ब्याडमा सिँचाइ दिनुपर्छ र कुटोको सहायताले डाँठ नचुँडिने गरी र जराहरू कम से कम क्षति हुने गरी बेर्ना उखेल्नुपर्छ। राम्ररी खनजोत गरेर तयार गरेको खेत वा बारीको प्रशस्त चिस्यान भएको माटोमा बेर्ना सार्न सकिन्छ। बेर्ना सार्दा पङ्क्तिदेखि पङ्क्ति २० देखि २५ से.मी. र बिरुवादेखि बिरुवाको १० से.मी. दूरी कायम गरी रोप्नुपर्छ। बेर्ना रोप्ने उपयुक्त गहिराइ २-३ से.मी. हो। कुटोले डोब पारेर कोदोको बेर्ना सीधा ठाडो रोपण गरी डोबलाई माटोले पुर्नुपर्छ। यसो गर्दा बेर्ना छिटो सर्दछन्। प्रत्येक डोबमा दुईटा बेर्ना रोप्नु उपयुक्त हुन्छ। बेर्ना रोपाइँ गर्ने (सार्ने) कार्य बर्सात सुरु भएपछि पानी परिरहेको दिनमा गर्नुपर्छ। वर्षाको पानी उपलब्ध नभएको स्थितिमा बेर्ना सारेको तेस्रो दिनमा सिँचाइ दिनु जरुरी छ र सारेका बिरुवाहरू राम्ररी स्थापित नहुन्जेल सम्म आवश्यकता अनुसार नियमित रूपले सिँचाइ दिनु जरुरी छ।

मलखाद

प्राङ्गारिक मलहरू

पहाडी क्षेत्रमा कोदो प्रायः असिञ्चित जग्गामा उब्जाइन्छ। असिञ्चित अवस्थामा माटोमा चिस्यान संरक्षण गर्न प्राङ्गारिक मलहरूले महत्त्वपूर्ण भूमिका खेल्दछन्। प्राङ्गारिक मलका रूपमा राम्ररी कुहेको गोठे मल वा कम्पोस्ट मल वा पिनाहरू वा गँड्यौली कम्पोस्ट प्रयोग गर्न सकिन्छ। प्राङ्गारिक मलहरूले माटोको भौतिक संरचनाका साथै रासायनिक र जैविक गुणहरू पनि सुधार गरी माटोलाई दानेदार बनाउने भएकाले माटोको जलधारण क्षमता वृद्धि हुन्छ, माटोमा वायुको आवागमन राम्रो भई बिरुवाहरूका लागि उपयुक्त सूक्ष्म वातावरण सृजना हुन्छ, पोषक तत्वहरूको उपलब्धता वृद्धि हुन्छ, खाद्यान्नको गुणस्तरमा उल्लेख्य वृद्धि हुन्छ र उब्जनी वृद्धि हुन्छ।

असिञ्चित जमीनमा राम्ररी कुहेको गोबर मल वा कम्पोस्ट मल ५०-१०० क्वि./हे.का दरले कोदो रोप्नुभन्दा करिब एक महिनाअगाडि भूमिको सतहमा एकनासले फिँजाएपछि तुरुन्तै जोतेर माटोमा मिलाउनुपर्छ। उपलब्ध भएमा गँड्यौली कम्पोस्ट र पिनाहरू २०-३० क्वि./हे. का दरले जमीनको तयारी गर्ने बेलामा प्रयोग गर्न सकिन्छ। सकेसम्म बालीका चाहिने पोषक तत्वहरू प्राङ्गारिक मलका रूपमा दिनुपर्छ। रासायनिक मल प्रयोग गर्न चाहेमा पनि प्राङ्गारिक मलहरू अवश्य प्रयोग गर्नुपर्छ। टपड्रेसिङका लागि पनि युरियाको सट्टा गोबरग्यासको लेदोमल, पिना, तरल गोबर मल, कम्पोस्ट चिया, भर्मीवाश आदि प्रयोग गर्न सकिन्छ।

रासायनिक मलहरू

रासायनिक मलहरूले कोदोको उब्जनी बढाउन मद्दत गर्दछन्। रासायनिक मलको मात्रा माटो जाँचका आधारमा दिनु बेस हुन्छ। माटो विश्लेषणको नतीजा उपलब्ध नभएमा, सिञ्चित वा पर्याप्त वर्षा उपलब्ध हुने क्षेत्रमा ५०-६०:३०-४०:२०-३० कि.ग्रा. ना.फ.पो. प्रति हे. का दरले प्रयोग गर्न सकिन्छ। नाइट्रोजनको आधा मात्रा र फस्फोरस एवं पोटासको पूरा मात्रा जमीनको अन्तिम तयारीका समयमा वा रोप्ने समयमा बीउभन्दा ३-४ से.मी. मुनि र पर पर्ने गरी पङ्क्तिमा प्रयोग गर्नुपर्छ। नाइट्रोजनको बाँकी आधा मात्रालाई बराबर २ किस्तामा बाँडेर प्रयोग गर्नुपर्छ। पहिलो किस्ता रोपेको करिब २५-३० दिनमा र दोस्रो किस्ता रोपेको ४०-४५ दिनमा (गाँजिने अवस्था) टपड्रेसिङ गर्नुपर्छ। आकासे पानी अनिश्चित भएको अवस्थामा नाइट्रोजनको आधा मात्रा कोदो रोपेको ३५ दिनमा एकै पटक टपड्रेसिङ गर्न सकिन्छ।

असिञ्चित क्षेत्रमा रासायनिक मलको माथि सिफारिस गरिएको मात्राको केवल आधा मात्रा एकै पटक रोप्ने समयमा वा जमीनको अन्तिम तयारीका समयमा प्रयोग गर्नुपर्छ। असिञ्चित जमीनमा रासायनिक मलहरू माटोमा करिब ८-१० से.मी. गहिराइमा पङ्क्तिमा प्रयोग गर्नुपर्छ। फस्फोरस र पोटासियमयुक्त रासायनिक मललाई १० क्वि. राम्ररी कुहेको गोबर मलमा मिसाएर प्रति हे. का दरले कोदो रोप्नुभन्दा एक महिना पहिले जोतेर माटोमुनि प्रयोग गरेमा मलको उपयोग क्षमता वृद्धि हुन्छ अर्थात् यी खाद्यतत्वहरू बिरुवालाई बढी उपलब्ध हुन्छन्।

सुक्ष्मजैविक मलहरू

एजोटोब्याक्टर वा एजोस्पाइरिलम जीवाणुको कल्चर २-३ कि.ग्रा./हे. का दरले ५० कि.ग्रा. राम्ररी कुहेको गोबर मलमा मिसाएर छरेपछि माटोमा मिलाईदिएमा माटोमा यिनले वायुमण्डलीय नाइट्रोजन स्थिरीकरण गरी उब्जनी वृद्धि गर्दछन्। साथमा फस्फोरस घोलक सूक्ष्मजीवीको कल्चर पनि सोही मात्रामा प्रयोग गरेमा फस्फोरसको उपलब्धता वृद्धि हुन्छ। कोदोबालीसँग फस्फोरस घोलक ढुसी *Aspergillus awamori* र फस्फोरस घोलक जीवाणु *Agrobacterium radiobacter* को साहचर्य ज्यादै प्रभावकारी पाइएको छ।

सिँचाइ

कोदो बर्खे बाली भएकाले यसलाई सामान्यतया सिँचाइको आवश्यकता पर्दैन। तर यदि लामो समयसम्म खडेरी परेमा सिँचाइ दिनु आवश्यक हुन्छ। सिँचाइ पाएको कोदोबालीको उब्जनीमा निकै वृद्धि हुन्छ। किनकि सिञ्चित बालीले पानीका साथै मलखाद पनि बढी प्राप्त गर्छ। सिँचाइका दृष्टिकोणले कोदोबालीका क्रान्तिक अवस्थाहरू हुन्: गाँज निस्कने अवस्था र पुष्पावस्था। क्रान्तिक अवस्थाहरूमा माटोमा चिस्यान पर्याप्त उपलब्ध नभएमा उब्जनी निकै खस्कन्छ। टपड्रेसिङ गर्ने समयमा वर्षा उपलब्ध नभएमा सिँचाइ दिएपछि मात्र टपड्रेसिङ गर्नुपर्छ। माटोमा पर्याप्त चिस्यान उपलब्ध नभएको स्थितिमा कोदो रोपेको एक महिनापछि, गाँज निस्कने बेलामा र फूल फुल्ने अवस्थामा सिँचाइ प्रदान गर्नुपर्छ। सिँचाइ दिनका लागि पङ्क्तिहरूका बीचमा कुलेसोहरू निर्माण गरेमा कुलेसोबाट अत्यधिक पानी निकास गर्न सजिलो हुन्छ। यस बालीले पानी जमेको अवस्था सहन नसक्ने हुनाले वर्षा वा सिँचाइद्वारा खेतमा जम्मा हुन गएको अत्यधिक पानी सजिलै निकास हुने व्यवस्था मिलाउनु धेरै जरुरी छ।

झार नियन्त्रण, विरलीकरण र खाली ठाउँमा पुनर्रोपण

कोदोबालीको प्रारम्भिक अवस्थामा नै झार नियन्त्रण गर्नुपर्छ। बालीको सुरु अवस्थामा झार नियन्त्रण नगरेमा उब्जनी धेरै खस्कन्छ। बाली ठूलो भएपछि झार उखेलेर झारहरूले बालीको प्रारम्भिक अवस्थामा पु¥याएको क्षति परिपूर्ति हुन सक्दैन। झारहरूले बालीसँग ठाउँ, पोषण, पानी र प्रकाशका लागि प्रतिस्पर्धा गर्छन्। अन्य कृषिकर्महरू राम्ररी गरे तापनि झार नियन्त्रण राम्ररी र समयमै नगरेमा सबै लगानी र परिश्रम खेर जान्छ। यस कारण कृषकहरूले झार नियन्त्रणमा विशेष ध्यान दिनुपर्छ। कोदोबालीमा झार नियन्त्रणका दृष्टिकोणले कोदो रोपेपछिको आरम्भिक ६० दिनको अवधि ज्यादै क्रान्तिक (critical) हुन्छ। बर्खे बाली भएकाले कोदोबालीभित्र झारको प्रकोप निकै हुन्छ। उपयुक्त समयमा झार नियन्त्रण नगरिएमा उब्जनी उल्लेख्यरूपले ह्रास हुन्छ। झार नियन्त्रण गर्ने सबभन्दा सरल उपाय गोडमेल हो। कोदोबालीमा २-३ पटक गोडमेल गर्नुपर्छ। पहिलो गोडमेल कोदो रोपेको २५-३० दिनमा र त्यसपछि आवश्यकता अनुसार २०-२५ दिनको समयान्तरालमा एक वा दुई पटक थप गोडमेल गर्नुपर्छ। गोडमेल गर्न कुटो वा हाते हो वा घुर्णिल गोडक (hand hoe, rotary weeder) प्रयोग गर्न सकिन्छ। पङ्क्तिमा रोपेको बाली गोडमेल गर्न सजिलो हुन्छ। हाते हो वा घुर्णिल गोडकले पङ्क्तिमा रोपेको बाली गोडाइ गर्दा काम छिटो र सजिलो हुन्छ। गोडमेल गर्दा पङ्क्तिहरूका बीचमा धुलीआवरण (dust mulch) बन्ने भएकाले चिस्यान संरक्षण पनि हुन्छ। बेर्ना सारेको बालीमा १५-२० दिनका अन्तरालमा गोडमेल गर्नुपर्छ।

खेतबारीमा बिरुवाको संख्या इष्टतम र पर्याप्त भएमा अधिक उब्जनी प्राप्त हुन्छ। यसकारण पङ्क्तिभित्र बाक्ला उम्रेका बिरुवाहरू छाँटेर उखेली बोटहरूबीच उपयुक्त दूरी कायम गर्न विरलीकरण अर्थात् बेढाउने कार्य गर्नु जरुरी छ। साथै खाली ठाउँमा नयाँ बिरुवाहरू सारेर खेतमा बिरुवाको सङ्ख्या पर्याप्त कायम गर्नुपर्छ। विरलीकरण र रिक्त ठाउँ भर्ने ज्यादै महत्त्वपूर्ण कृषि कार्य हो र यसमा हेल्चेक्र्याइँ गर्नुहुँदैन। विरलीकरण र खालि ठाउँमा रोप्ने कार्य रोपेको २० देखि २५ दिनभित्र गर्नुपर्छ। सकभर गोडमेल गरेर नै झारपात नियन्त्रण गर्नुपर्छ किनभने रासायनिक विषादीले माटो र भूमिगत पानी प्रदूषित हुन्छन् र माटोमा रहेको लाभदायक सूक्ष्मजीव पनि मर्छन्। झारनाशक प्रयोग गर्न चाहेमा, चौडा पाते झार नियन्त्रण गर्न २,४-डी सोडियम सल्ट ८०% घुलनशील पाउडरको ०.५ केजी सक्रिय पदार्थ प्रति हे. वा बिस्पाइरिब्याक सोडियम-१० एससी २० ग्रा./हे. का दरले ६००-८०० ली. पानीमा मिसाई रोपेको २०-२५ दिनपछि छर्कन सकिन्छ। अथवा कोदोको बीउ रोपण गरेको तीन दिनभित्र (झार अङ्कुरण हुनुभन्दा पहिले) आइसोप्रोटुरान आधा केजी स.अ. प्रति हे., बेन्सल्फुरोन-मिथाइल-०.६ जी ६० ग्रा./हे.+प्रेटिलाक्लोर-६ जी ६०० ग्रा./हे. छर्कन सकिन्छ।

कोदोका रोगहरू

कोदोबालीमा करिब २० ओटा रोगहरू लाग्दछन्, ती मध्ये मुख्य रोगहरूको पहिचान र रोकथाम गर्ने तरिका निम्नअनुसार छ:

मरुवा रोग (ब्लास्ट)

धानमा मरूवा रोग पैदा गर्ने ढुसी *Magnaporthe (=Pyricularia) grisea* नै कोदोमा पनि लाग्छ। यो रोग उच्च आर्द्रता भएको मौसममा बढी लाग्दछ। रोगाणुहरू प्रायः वायुजन्य हुन्छन्। रोगको प्राथमिक संक्रमण शायद ढुसीका समानान्तर यजमान बिरुवाहरू जस्तै दत्याउरे झार, कागुनु, बाजरा, आदिबाट हुन सक्छ। यो ढुसी बालीअवशेष र रोगी बालाबाट प्राप्त चाउरिएका दानामा पनि बाँच्दछ। नाइट्रोजन बढी दिएमा रोग उग्र हुन्छ, तर सन्तुलित मलखाद दिएमा रोग बढ्न सक्दैन। यस रोगको प्रकोपले ९०% सम्म क्षति हुन सक्छ। मरुवा रोग बालीको कुनै पनि वृद्धि अवस्थामा लाग्न सक्छ। ब्याडमा बेर्नाहरूमा या खेतबारीमा प्रौढ बिरुवाहरूमा पनि रोग लाग्न सक्छ।

आरम्भिक लक्षणहरू पातको सतहमा कतुवा/आँखा आकारका दागहरूका रूपमा देखा पर्छन्। डाँठमा ढुसीको संक्रमण पुगेपछि आँख्ला/गाँठाको दुवैतिर तल र माथि करिब ०.५-१.० से.मी. भाग कालो हुन्छ। सो भाग काटेर हेर्रेमा डाँठको भित्री भाग पनि संक्रमित देखिन्छ। मरुवा रोगको मुख्य लक्षण बिरुवाको शीर्षस्थ आँख्ला र त्यस नजिकको भाग कालो हुनु हो। यो भागका तन्तुहरू रोगको संक्रमणले काला भई कमजोर हुने भएकाले सो भाग भाँचिन्छ र बाला तलतिर झुण्डिन्छ। यस्तै लक्षणहरू बालाको आधारीय भाग र औँलाहरूमा पनि देखिन्छन्। संक्रमित बालामा भुस मात्र बढी देखिन्छ र दानाहरू चाउरिएका वा अविकसित एवं साना हुन्छन् र बाला कालो देखिन्छ।

रोकथाम

- स्वस्थ बीउ मात्र रोप्नुपर्छ। रोगग्रस्त बालीबाट बीउ लिनु हुँदैन। रोप्नुपूर्व कार्बेन्डाजिम वा म्यान्कोजेब २ ग्रा./कि.ग्रा. बीउका दरले प्रयोग गरी बीउ उपचार गर्नुपर्छ।
- बाली घना भएमा रोगका लागि अनुकूल वातावरण बन्ने भएकाले उचित दूरी मिलाएर रोप्नुपर्छ। अत्यधिक मात्रामा नाइट्रोजन प्रयोग गरेमा रोग बढी लाग्छ। दालबालीसँग अन्तरखेती गरेमा कोदोबालीमा रोग कम लाग्छ र स्थिरीकरण भएको नाइट्रोजन उपलब्ध हुन्छ।
- रोग कम लाग्ने जातहरू जस्तै: ओखले-१, काब्रे कोदो-१, काब्रे कोदो-२, शैलुङ कोदो-१, रातो कोदो लगाउनुपर्छ। रोगग्रस्त बाली अवशेष नष्ट गर्नुपर्छ।
- रासायनिक मलको प्रयोग गर्दा रोग उग्र हुने भएकाले रासायनिक मलको सट्टा प्राङ्गारिक मलहरू नै प्रयोग गर्नु बेस हुन्छ। सूक्ष्मजैविक मल प्रयोग गर्दा पनि रोगको संक्रमण कम हुन्छ।
- बीउलाई *Pseudomonas fluorescens* वा *Trichoderma harzianum* को कल्चर १० ग्राम प्रति किलो बीउका दरले प्रयोग गरेमा र खडा बालीमा एक पटक फूल फुल्ने बेला र पुनः दश दिनपछि छर्केमा रोगनियन्त्रण हुन्छ। नीम र लसुनको तेल पानीमा मिसाएर छर्कन सकिन्छ।
- रोगनियन्त्रणका लागि रासायनिक विषादी प्रयोग गर्नु आर्थिक र वातावरणीय दृष्टिले लाभदायक छैन। गर्न चाहेमा ढुसीनाशक ट्राइसाइक्लाजोल (०.०६ प्रतिशत), कार्बेन्डाजिम (०.२ प्रतिशत), म्याङ्कोजेब (०.२ प्रतिशत) गाँज निस्कने र बाला निस्कने बेलामा छर्कन सकिन्छ।

कलिला बिरुवाको हेल्मिन्थोस्पोरियम डढुवा र फेद कुहिने रोग (Seedling blight or leaf blight or leaf spot and Foot rot)

रोगजनक ढुसी *Helminthosporium nodulosum= Drechslera nodulosus* हो। यो ढुसी यसै अपूर्ण (अलैंगिक) अवस्थामा रोगजनक हुन्छ। यो ढुसी तन्तु (hypha) का छेउका कोषहरूबाट अङ्कुरण-नली उत्पन्न गरी अङ्कुरित हुने भएकाले यसलाई *Bipolaris* नामकृत पनि गरिन्छ। यस ढुसीको पूर्ण अवस्था (मैथुनिक संयोगद्वारा बीजाणुहरू पैदा गर्ने अवस्था) *Colchiobolus nodulosus* हो। यस ढुसीले घाँस परिवारका विभिन्न बिरुवाहरू जस्तै कोदो, दत्याउरे झार, कागुनो, सामा, बाजरा, जुनेलो र मकैमा पनि आश्रय लिने भएकाले यिनले पनि रोग उत्तरजीवी राख्न मद्दत गर्न सक्छन्। रोगको प्राथमिक स्रोत रोगग्रस्त बीउ हो र द्वितीयक संक्रमण रोगी भागबाट पैदा हुने कोनिडिया-बीजाणुहरूद्वारा हुन्छ। लगातार वर्षा भएमा रोग बढी लाग्छ। यो रोग बिरुवाको कलिलो वा प्रौढ सबै अवस्थाहरूमा लाग्न सक्छ।

कलिला बिरुवाका नयाँ पातहरूमा साना अण्डाकार र हल्का खैरा रङ्गका दागहरू देखा पर्छन्। बिरुवा बढ्दै जाँदा दागहरू लाम्चा (१०×१-२ मि.मी.) र गाढा खैरा हुन्छन्। यस्ता अनेकौं दागहरू आपसमा मिलेर ठूला धब्बा बन्दछन्। यसरी प्रभावित पातहरू ओइलाउँछन् र कलिला बिरुवाहरू मर्छन्। कहिले काहीँ कलिला बिरुवाको आधारीय भाग (फेद) र जराहरू कुहिन्छन् र अङ्कुरणपछि कलिला बिरुवा मर्ने लक्षण देखा पर्छन्। प्रौढ बिरुवाका पात (पर्णफलक), पर्णच्छद (लीफशीथ) र डाँठमा लाम्चा वा अनियमित आकारका गाढा खैरा रङ्गका दागहरू उत्पन्न हुन्छन्। बालाको गला (बिरुवाको शीर्षस्थ अन्तरआँख्ला) स्पष्टतः खैरो वा गाढा खैरो हुन्छ। यस्तो बालाको गला (बालामुनिको भाग) भाँचिन्छ र बाला तलतिर झुण्डिन्छ। मरुवा रोगमा झैं बाला वा औंलाहरू आंशिकरूपले संक्रमित हुन सक्छन्। कलिला बिरुवाहरू कुहेर मर्ने र रोगग्रस्त बाला फोस्रा रहने भएकाले उब्जनीमा उल्लेख्य ह्रास हुन सक्छ।

रोकथाम

यो बीजजन्य रोग भएकाले क्याप्टान वा थाइरम ४ ग्राम प्रति केजी बीउका दरले मिसाएर बीजोपचार गर्नुपर्छ। (कार्बेन्डाजिमबाहेक)। उपचारित बीउ रोपेमा कलिला बिरुवा मर्ने लक्षण देखिदैनन्। २) खडा बालीमा रोगको रोकथाम कठिन हुन्छ। डाइथेन जेड-७८ (०.२५%) छर्केमा रोगको तीव्रता कम हुन्छ।

मृदुरोमिल ढुसी रोग- सेते रोग (Downy mildew)

रोगजनक ढुसी *Sclerophthora macrospora* हो। बालामा रोगग्रस्त अनुमञ्जरीहरू हरियो पातजस्तो आकृतिमा विकसित हुन्छन् र बालामा पातहरू उत्पन्न भएका देखिन्छन्। रोगी बाला ठाडो रहन्छ र कुच्चोजस्तो देखिन्छ। यसैले यस रोगलाई बाला हरियो हुने रोग पनि भनिन्छ। यो रोग सिञ्चित जग्गामा बढी लाग्छ।

रोकथाम

- स्वच्छ खेती गर्नुपर्छ। झारहरू यथा समयमा नियन्त्रण गरेर खेतबारी सफा राख्नुपर्छ। बिरुवाहरूको संख्या बढी भएमा खेतबारीमा आर्द्रता उच्च रहने भएकाले रोगको उग्रता वृद्धि हुन्छ। रोगग्रस्त बाली अवशेषहरू एकत्र गरी जलाएर वा गाडेर नष्ट गर्नुपर्छ।
- बीउ उपचार गरेमा रोगको आंशिक नियन्त्रण हुन्छ र यसका लागि रिडोमिल ६ ग्राम प्रति केजी बीउ प्रयोग गरिन्छ।
- खडा बालीमा डाइथेन एम-४५ वा रिडोमिल एमजेड (०.२५%) छर्कन सकिन्छ।

सर्कोस्पोरा पात थोप्ले रोग (Cercospora leaf spot)

रोगजनक ढुसी *Cercospora sp.* हो। पातमा आयताकार वा बाटुला वा अनियमित आकारका पृथकपृथक थोप्लाहरू देखा पर्छन्। यो रोग बालीको बेर्ना अवस्थापछि देखा पर्छ। रोकथामका लागि कार्बेन्डाजिम ०.०५% (आधा ग्रा. प्रति ली. पानीमा) रोगको तीव्रताका आधारमा १०-१५ दिनका अन्तरालनमा छर्कनुपर्छ।

ओइलाउने रोग (Wilt or Sclerotial root rot)

रोगजनक ढुसी *Sclerotium rolfsii* हो। यो माटोजन्य रोग हो। रोगी बिरुवाहरू फिक्का पहेंला वा पहेंला देखिन्छन्। डाँठको आधारीय भाग, पर्णच्छद सहित, पानीले भिजेको र नरम हुन्छ, जुन पछि खैरो वा गाढा खैरो हुन्छ। रोग लागेको भाग कालो वा गाढा खैरो भएपछि रोगी बिरुवा चाँडै ओइलाउँछन्। डाँठको आधारीय भाग र गाँठाहरूमा सेतो ढुसीजाल विकसित भएको देख्न सकिन्छ। सेतो ढुसीजालमाथि ढुसीका असंख्य स्क्लेरोशिया कायहरू (साना, सस्र्यूंका दानाजस्ता, सेतादेखि कैला रङ्गका, साह्रा तन्तुपिण्ड) उत्पन्न हुन्छन्।

रोकथाम

रोग लागिसकेपछि यस रोगको खास उपचार छैन। रोप्नुपूर्व जमिनको गहिरो जोताइ गर्ने र बालीचक्रमा गैह्र अन्न बाली समावेश गरेमा रोगको प्रकोप कम हुन्छ। सन्तुलित मलखाद दिएर बिरुवाहरू स्वस्थ र बलिया बनाउनुपर्छ। गोडमेल गर्दा बिरुवाहरूलाई घाउ चोट लगाउनु हुँदैन। जलनिकास सक्रिय राखी माटोमा उचित वातावरण कायम गर्नुपर्छ। *Trichoderma, Bacillus, Aspergillus, Pseudomonas* आदि सूक्ष्मजैविक विषादी माटो, बीउ वा कम्पोस्ट मलमा मिसाएर प्रयोग गरेमा रोगको रोकथाम हुन्छ।

कोदो बालीमा लाग्ने कीराहरू

कोदो बालीमा कीराहरूको प्रकोप कम हुन्छ, तर कीरा लागेमा उब्जनी धेरै ह्रास हुन सक्छ। कोदो बालीमा आक्रमण गर्ने मुख्य कीराहरूको पहिचान र नियन्त्रणका उपाय निम्न अनुसार छन्।

खुम्रे कीरा (White grubs: Phyllophaga rugosa, Anomala sp.)

यिनले कलिला बिरुवाहरूको जरा खान्छन्। जरा क्षति भएका बिरुवाहरू पहेंलिएर सुक्दछन्। यिनले प्रौढ बिरुवाहरूमा पनि क्षति गर्न सक्छन्। माटोमा चिउरी वा नीमको पिना प्रयोग गर्नुपर्छ।

गभारो कीराहरू (Borers)

कोदोबालीमा गुलाबी गभारो *(Sesamia inferens)* र धर्के गभारो *(Chilo partellus)* को प्रकोप हुन सक्छ। लाभ्रेले डाँठलाई छेडेर भित्र पसी गुभो खान्छन्। यसरी बिरुवाको गुभो मरेको अवस्थालाई मृतगुभो (डेड हार्ट) भनिन्छ। बालीको वृद्धि अवस्थामा आक्रमण भएमा बालीको ओज ह्रास हुन्छ र गाँज कम निस्कन्छन्। बालीको पछिल्लो अवस्थामा आक्रमण भएमा सेतो बाला निस्कन्छ र बाला पूर्णतः सुक्दछ।

नियन्त्रण

- कीराको आक्रमण थोरै मात्र बिरुवाहरूमा भए मृत गुभो देखिएका बिरुवाहरू उखेलेर नष्ट गर्ने।
- सर्वाङ्गप्रवाही दानेदार कीटनाशकहरू कार्टाप हाइड्रोक्लोराइड (४ जी) २० कि.ग्रा. प्रति हेक्टरका दरले कोदो रोपेको एक महिनापछि माटोमा प्रयोग गर्न सकिन्छ।
- नल फेदबाट कटाइ गरेमा र बाली कटाइ गरेपछि तुरुन्तै जोताइ गरेमा माटोमुनि बसेका लार्भा र प्युपा नष्ट हुन्छन्।
- बालीचक्रमा कोसेबाली समावेश गरेमा कीराको प्रकोप घट्छ।
- पुतली मार्न रात्रिमा प्रकाशपासो प्रयोग गर्न सकिन्छ।
- अण्डपरजीवी परजीवी ट्राइकोडर्मा चिलोनिस उपयोग गर्न सकिन्छ।

झुसिलकीराहरू (Hairy caterpillars)

कालो झुसिल्कीरा (*Estigmene exigua*) काला एवम् घना झुसयुक्त हुन्छ। यसको वयस्क रात्रिचर पुतली क्रीमी सेतो हुन्छ र यसको टाउको र शरीरमा पहेंला चिह्न हुन्छन्। कालो झुसिल्कीराले कोदोको पात र बालामा आक्रमण गर्दछन्। नङ्ग्रे कोदोमा झुसिल्कीरा कम लाग्छन्। पहेंलो झुसिल्कीराको पनि आक्रमण हुनसक्छ। झुसिल्किरा नियन्त्रण गर्न नीमजन्य विषादी वा नीम र गहुँतको मिश्रण छर्कन सकिन्छ। अथवा स्पिनोसाड ४५ एससी एक मि.ली. प्रति चार ली. वा क्लोरपाइरिफस २० ईसी २ मि.ली. प्रति ली. पानीमा मिसाएर बालीमाथि छर्न सकिन्छ। माटोको गहिरो जोताइ, ८-१० फेरोमोन पासो प्रति हे. प्रयोग, एनपीभी २५० लार्भातुल्य प्रति हे., बीटी जीवाणु एक केजी प्रति हे. छर्कने उपाय गरी झुसिल्कीरा र हेलिकोभर्पा कीरा नियन्त्रण गर्न सकिन्छ।

फौजी कीरा र फेदकटुवा कीराहरू (Army worms and Cut worms)

यिनले बिरुवाको सानो अवस्थादेखि बाली पाकुन्जेलसम्म क्षति गर्छन्। लाभ्रेहरूले साना बिरुवाका फेद काटेर पशुले चरेजस्तो पारिदिन्छन्। लाभ्रे दिउँसो माटो वा झारपातमुनि लुक्छन् र राति क्षति गर्छन्। ठूला बिरुवाका यिनले पात खाएर बिरुवालाई नङ्ग्याइदिन्छन्। झुसिल्किरालाई जस्तै नियन्त्रण गर्न सकिन्छ।

फड्के कीराहरू (Jassids: *Cicadulina bipunctella*)

यस कीराको वयस्क र शिशु दुवै अवस्थाका कीराहरूले पात र डाँठबाट रस चुस्दछन् र कोदोको मोजेइक रोग पनि सार्दछन्। लाही कीरा (*Rhopalosiphum maidis, Schizaphis graminum*) ले पनि कोदोको पात र कोमल भागहरूबाट रस चुस्दछन्। रस चुस्ने कीरा नियन्त्रण गर्न नीमको झोल प्रयोग गर्न सकिन्छ। एक सय लि. अटाउने ड्रममा ५ कि.ग्रा. पिसेर लेदो पारेको नीमका पात वा नीमको पिना, ५ कि.ग्रा. गाईको गोबर र ५ लि. गोमूत्र हालेर राम्ररी मिसाउने। यसमा छाँच र गुड पनि मिसाउन सकिन्छ। यस मिश्रणलाई २४ घन्टासम्म छहारी भएको ठाउँमा राखेर ढड्याउने। यस मिश्रणलाई मलमलको कपडाले छान्ने। प्रतिलीटर पानीमा २० मिलिलिटर छानेको घोल मिसाएर बालीमाथि छर्केमा कीरा नियन्त्रण हुन्छन्। नीमको विषादी तयार गर्दा नीमका पात वा पिनाका साथमा अन्य जडीबुटी जस्तै पपिता, असुरो, धतुरो, ल्यान्टाना, अम्बा, अनार, तितेपाती, बनमारा, सीताफल, आँक, सुर्ती आदिका हरिया पातहरू पिसेर लेदो बनाई त्यसै वा उमालेर रस निकाली मिसाउन सकिन्छ।

कटाइ र चुटाइ

कोदोबाली जात, ठाउँ र रोपेको समयअनुसार रोपेको ६० देखि ८० दिनमा पुष्पित हुन्छ र १२० देखि १८० दिनमा परिपक्व हुन्छ। तराई र भित्री मधेशमा भन्दा उच्च पहाडमा पाक्ने अवधि बढी हुन्छ। उपयुक्त समयमा रोपेको कोदो बाली तराईमा आश्विन दोस्रो पक्षमा र पहाडमा कात्तिक-मध्य देखि मंसिर-मध्यमा परिपक्व हुन्छ। परिपक्व दानाहरू पर्याप्त कडा (२२-२७% चिस्यानयुक्त) हुन्छन् र दानामा भुस गाढा खैरो देखिन्छ। यस अवस्थामा बाली कटाइ गर्नुपर्छ।

पहिले हँसिया वा दराँतीको सहायताले कोदोका बाला कटाइ गरिन्छन् र त्यसपछि नल जमीनको सतह नजिकैबाट कटाइ गरिन्छ। यसप्रकार कोदो बालीको कटाइ २ चरणमा पूरा गरिन्छ। चार देखि छ दिनसम्म बालाहरू थुप्रोमा गुम्स्याएर रोखेमा चुटाइ गर्न एकदम सजिलो हुन्छ। गुम्स्याउने अवधि पूरा भएपछि बालाहरू घाममा सुकाइन्छ। सुकाएका बाला नाङ्गो गोडाले माँडेर वा मुङ्ग्रो या लौरोले चुटेर वा गोरुद्वारा दाँइ गरेर चुटाइ (दाना झार्ने) गरिन्छ। चुटाइपश्चात् बत्ताएर दाना सफा गरिन्छन्। सफा गरेको कोदो अन्न घाममा राम्ररी सुकाएपछि मात्र भण्डारण गर्नुपर्छ। राम्ररी सुकाएको अन्न चिस्यान नपस्ने भण्डारण पात्रमा धेरै वर्षसम्म पनि भण्डारण गर्न सकिन्छ।

माडेर वा दाइँ गरी चुटाइ गर्दा समय र श्रम बढी लाग्छ। हाल कोदो चुट्ने थ्रेशर उपलब्ध छन्। कोदो चुट्ने फल्ने र निफन्ने काम साथै गर्ने थ्रेशर (Finger millet Thresher cum Pearler) पनि उपलब्ध छन्। पेडल चालित थ्रेशर कम पियर्लरले एक घण्टामा ४०–६० किलोग्राम कोदो चुट्न सक्छ। चुटाइयन्त्र सजिलै उपलब्ध हुन सकेमा कोदो खेतीप्रति कृषकको आकर्षण बढ्नेछ।

कोदोका अन्न दाना फलेर भुस हटाएपछि मात्र पिँध्नुपर्छ। दाना भुस (खोस्टा) भित्र आवेष्टित हुन्छ। दानाबाट भुस हटाउन ओखल वा ढिकीमा कुटेर भुस हटाएको (फलेको) कोदो अन्नको पिठोबाट बनाईएको रोटी खस्रो हुँदैन। कोदो धानमिलमा पनि कुट्न सकिन्छ तर दानामा रहेको भ्रूण र अलेउरोन तह क्षति भई भुससँग जान्छ। कोदोदानामा १०% पानी थपेर भिजाएमा दानाको भुस हटाउन सजिलो हुन्छ। पिसेर लेदो बनाउन चाहेमा कोदोलाई २४ घन्टा बढी भिजाइन्छ र सिलौटो वा ग्राइन्डरमा पिस्न सकिन्छ। कोदोलाई अन्य अन्नसँग मिसाएर खाने प्रचलन बढेमा क्याल्सियम र फलामको कमीले गर्भवती महिला, बालकबालीका र वृद्ध मानिसहरूमा देखिने स्वास्थ्य समस्या धेरै कम हुनेछन्, चामल र गहुँमाथिको निर्भरता कम हुनेछ, कोदो उत्पादक कृषकहरूको जीवनस्तर उठ्ने छ र खाद्य सुरक्षामा ठूलो टेवा पुग्ने देखिन्छ।

उब्जनी

उन्नत तरिकाले खेती गरेमा एक हे. बाट २५-४० क्वि. अन्न र ६०-१४० क्वि. नल प्राप्त हुन्छ। कोदोको अन्न दाना र नल (पूरा नसुकेको) को उब्जनी अनुपात १:२.०-२.५ हुन्छ। असिञ्चित क्षेत्रमा १२ देखि २० क्वि. कोदो अन्न प्रतिहेक्टर फल्छ।

कोदोको सघन खेती (System of Finger Millet Intensification)

धानको झैँ कोदोको पनि सघनखेती गरी बढी उत्पादन लिन सकिन्छ। यो तरिका सिञ्चित वा बढी वर्षा हुने क्षेत्रमा बढी सफल पाइएको छ।

नर्सरी तयार गर्ने

एक हेक्टरका लागि १ कि.ग्रा. बीउ राखेर ब्याड तयार गरिन्छ। बीजोपचार गर्नका लागि बीउलाई पानीमा भिजाउने, यसमा २.५ ग्राम प्रतिकिलोग्राम बीउका दरले कार्वेन्डाजिम मिसाउने र २४ घन्टासम्म राखिछोड्ने। एक मी. चौडाइ र आवश्यकताअनुसार लम्बाइ भएका २० देखि ३० से.मी. उठाइएका ब्याड तयार गर्ने। माटो, बालुवा र कम्पोस्ट मल बराबर मात्रामा मिसाएर ब्याड तयार गर्ने। एक हे. का लागि १०० व.मी. ब्याड पर्याप्त हुन्छ। बीउ पंक्तिमा ८ देखि १० से.मी. दूरी कायम गरी करिब १ से.मी. गहिरो रोप्ने। बीउलाई गँड्यौली मल वा गोबरग्यासको लेदोमलको पातलो तहले छोप्ने। उपलब्ध भएमा यसमाथि नियमित रुपले जीवामृत छर्कने। जीवामृत बनाउनका लागि १० ली. पानीमा ५ कि.ग्रा. गाईको गोबर, ५ ली. गोमूत्र, २५० ग्रा. गुड, २५० ग्रा. चनाादि दालको पिठो र एक मुठी ड्याङको वा धमिरे माटो राम्ररी चलाएर मिसाउने। यस मिश्रणलाई ४८ घन्टासम्म छहारीमुनि राखेर किण्वन हुन दिने। जीवामृत तयार भयो। यो तरल मल हो। प्रयोगपूर्व एक ली. जीवामृतमा २० ली. पानी थप्ने र ब्याडमाथि छम्केर वा हजारीको सहायताले प्रयोग गर्ने। एक हे. मा ५०० ली. पानी थपेको घोल चाहिन्छ।

जमिनको तयारी

जमिनको तयारी गर्नका लागि ८ देखि १० दिनको अन्तरालमा २ वा ३ पटक जोताइ गर्ने। उपलब्ध भएमा जोतेपछि माटोमा जीवामृत छर्कने। जोताइपछि पाटा लगाएर समतलीकरण गर्ने। पङ्क्तिदेखि पङ्क्ति र बोटदेखि बोट २५ से.मी. दूरी कायम गर्नुपर्ने भएकाले सोही अनुसार डोरीको सहायताले वा काठको चिह्नकले बिरुवा सानुपर्ने ठाउँमा चिनो लगाउने। कोदो ड्याङमा पनि रोप्न सकिन्छ।

बेर्ना सार्ने

कोदोको सघनखेती गर्दा १५ देखि २० दिन उमेरका बेर्ना पङ्क्तिदेखि पङ्क्ति २५ से.मी. र बोटदेखि बोट पनि २५ से.मी. कायम गरी एक रोपोमा एउटा मात्र बेर्ना रोप्नुपर्छ। बढीमा २५ दिन उमेरका बेर्नाहरू सार्न सकिन्छ। बेर्नाका जराहरू क्षति नहुने गरी माटोसहित उखेलेर माटो र जरा सुक्नुभन्दा पहिल्यै आधा घण्टाभित्र नै सारिसक्नुपर्छ। बेर्ना मथला डोबमा जतनले सानुपर्छ।

गोडमेल र बिरुवा ढलाउने

झारनियन्त्रण गर्न, माटोमा वायुसञ्चार बढाउन र जरा हरूको विकास प्रोत्साहित गर्न ५ देखि ७ पटक गोडमेल गर्नुपर्छ। गोडमेल गर्नका लागि कुटो, हाते हो वा साइकल हो को सहायताले गर्नुपर्छ। पहिलो गोडमेल बेर्ना सारेको १५ दिनमा गर्ने र त्यसपछि हरेक १० देखि १५ दिनको अन्तरालमा गोडाइ गर्ने। प्रत्येक गोडाइपछि माटोमा जीवामृत छर्कने। यस बेला एक लिटर जीवामृतमा १० ली. का दरले पानी मिसाएर छर्कने वा छम्कने। पहिलो गोडमेल रोपेको १५ दिनमा, दोस्रो २५ दिनमा र तेस्रो ४० दिनमा गर्नु उपयुक्त हुन्छ। तेस्रो गोडमेल गरेपछि कोदोका बिरुवाहरूलाई बाँस वा

सोझो लट्ठीको सहायताले हलुका ढलाईदिएमा बिरुवामा गाँज र जराहरू बढी संख्यामा विकास हुन्छन्। सिँचाइ आवश्यकताअनुसार दिनुपर्छ तर पानी जम्न नदिन पानी निकास सक्रिय राख्नुपर्छ।

सघन खेतीमा बिरुवाको जरा प्रणाली धेरै र ३० से.मी. भन्दा बढी गहिराइसम्म वृद्धि हुन्छ, डाँठ मोटो हुन्छ, एउटै बिरुवाबाट ८ देखि १० गाँज निस्कन्छन्। बालामा पनि औँला बढी र ठूला लाग्छन्।

उब्जनी

सघनखेती गर्दा एक हेक्टरमा ३७ देखि ७५ क्वि. उब्जनी प्राप्त हुन्छ।

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक) । २०८० । राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौं ।

दाङ जिल्लामा श्रीअन्न खेती: एक अध्ययन

शान्तराज गौतम

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सारांश

अन्नमा हाल श्रीअन्न/श्रीधान्यका नामले चिनिने कोदो जातिका विभिन्न अन्न पनि पर्दछन् । अन्न भान्साबाट विस्थापित भएको अवस्थामा आरोग्य र पर्यावरणीय सन्तुलनका लागि पनि श्रीअन्नको खेती र उपभोगको आवश्यकता टड्कारो भएको छ । लुम्बिनी प्रदेशमा तल उल्लिंखाति कोदोजन्य बालीको खेतीको राम्रो सम्भावना देखिन्छ । उर्वरा शक्ति कम भएको, पाखो जमीन तथा सिंचाइ सुविधा कम भएको स्थानलाई सदुपयोग गर्न सकिन्छ। रासायनिक मल तथा विषादिको प्रयोग नगर्दा पर्यावरण जोगिनुका साथै श्रीअन्नको सेवनबाट मानवमा आरोग्यता प्राप्त हुने भएकाले बिरामी भएर हुने आर्थिक क्षतिबाट पनि बच्न सकिन्छ ।

पृष्ठभूमि

हाम्रा पूर्वजले प्रयोग गर्ने गरेको अन्नमा हाल श्रीअन्न/श्रीधान्यका नामले चिनिने कोदो जातिका विभिन्न अन्न पनि पर्दछन् । श्रीअन्न (Millets) मा फाइबरको मात्रा ८ देखि १२.५ प्रतिशतसम्म भएको पाइन्छ । यसमा भिन्न/भिन्न खालका पोषण तत्वहरू पाइने भएकाले यसले मानव शरीरलाई आरोग्यता प्रदान गर्दछ । हाल पेट भर्नका लागि र व्यापारका लागि प्रचारमा आएका अन्नले हाम्रा ती पोषणयुक्त अन्न भान्साबाट विस्थापित भएको अवस्थामा आरोग्य र पर्यावरणीय सन्तुलनका लागि पनि श्रीअन्नको खेती र उपभोगको आवश्यकता टड्कारो भएको छ । हामीले बिर्सिसकेका अन्नलाई भोजनको रुपमा हाम्रो भान्सामा पुनः भित्र्याउन र विश्वसमुदायमा चिनाउन, सहजीकरण गर्न तथा प्रत्यक्ष सहभागिता जनाउन संयुक्त राष्ट्रसंघीय खाद्य तथा कृषि सँगठन (FAO) ले खेलेको भूमिका सराहनीय छ । यसबाट जनसमुदायमा आरोग्यता प्राप्तिका साथै पर्यावरण सन्तुलन राख्न पनि सहयोग पुग्ने छ । यसको अनुसन्धानका लागि वानिकी एग्रो एण्ड रिसर्च सेन्टरको उष्ण प्रदेशीय अनुसन्धान केन्द्र लुम्बिनी प्रदेश, दाङ जिल्ला, तुलसीपुर उपमहानगरपालिका वडा नं १७, मजगैंस्थित एकीकृत कृषि प्रणालीको क्षेत्रलाई छनौट गरिएको छ । प्रथम चरणको अनुसन्धानका लागि पाँच किसिमका श्रीअन्नमध्ये चार किसिमका अन्न कोदी (Kodo Millet), कागुनो (Foxtail Millet), धान कोदो (Little Millet) र सामा (Barnyard Millet) को परीक्षण खेती गरिएको छ । यी बालीहरूको पौष्टिक पदार्थको मात्रा तालीका १ मा दिइएको छ ।

तालिका १. श्रीधान्यमा प्राप्त पोषण र फाइबर (डा. खादर बालीबाट प्राप्त सूचनामा आधारित प्रति १०० ग्राममा)

अन्नको नाम	नायसिन (बी ३) मिलिग्राम	रिबोफ्लिबिन (बी २) मिलिग्राम	थायमिन (बी १) मिलिग्राम	क्यारोटीन मिलिग्राम	फलाम मिलिग्राम	क्याल्सियम ग्राम	फस्फोरस ग्राम	प्रोटीन ग्राम	खनिज ग्राम	कर्बोहाइड्रेड ग्राम	रेशा (फाइबर) ग्राम
कोदी	२	०.०९	०.३३	०	२.९	०.०४	०.२४	६.२	२.६	६५.६	९
कागुनो	०.७	०.११	०.५९	३२	६.३	०.०३	०.२९	१२.३	३.३	६०.६	८
सामा	१.५	०.०८	०.३१	०	२.९	०.०२	०.२८	६.२	४.४	६५.५	१०
धान कोदो	१.५	०.०७	०.३	०	२.८	०.०२	०.२८	७.७	१.५	६५.५	९.८
बाँसपाते कोदो	१८.५	०.०२७	३.२	०	०.६५	०.०१	०.४७	११.५	४.२१	६९.३७	१२.५

स्रोतः https://siridhanyamillet.com/wp-content/uploads/2020/09/Sirijeevan-Marg-Biophilians-ProtocolsBook-Sep2020.pdf

उद्देश्य

अन्तर्राष्ट्रिय कोदो वर्ष २०२३बाट प्रभावित भई यसको पोषणयुक्त गुणलाई सदुपयोग गरी पर्यावरणीय सन्तुलन नबिगारीकन आरोग्यता र आर्थिक उपार्जन गर्ने मुख्य उद्देश्य हो, जसलाई निम्न बुँदामा प्रस्तुत गरिएको छ :

१. श्रीअन्नलाई आम जनताको भान्सामा पुर्याउने,
२. श्रीअन्नको सेवनबाट आम जनतालाई स्वस्थ बनाउने,
३. विदेशमा समेत निर्यात गरी आर्थिक उपार्जनमा सहयोग गर्ने,
४. पानीको आवश्यकता कम पर्ने भएकाले सिंचाई सुविधा न्यून भएको तथा आकासे खेतीमा समेत उत्पादन गर्ने,
५. यो घाँसे प्रजातिको बिरुवा भएकाले कम मलिलो अथवा रुखो जमीनलाई पनि सदुपयोग गर्ने,
६. यसको संरक्षण र प्रवर्धन गर्ने,
७. पर्यावरणीय सन्तुलनमा सहयोग पुयाउने ।

सामग्री, विधि र प्राप्ति

प्रायः सबै प्रकारका कोदो बाली घाँसे प्रजातिका भएकाले सजिलै हुर्कन सक्ने र मल, पानी कम चाहिने हुन्छ । त्यसैले समुद्र सतहदेखि ७०० मिटर उचाइमा रहेको लुम्बिनी प्रदेश, दाङ जिल्ला, तुलसीपुर उपमहानगरपालिका, वडा नं १७, मजगैंस्थित एकीकृत कृषि प्रणालीको क्षेत्रमा रहेको भिरालो जमीनमा यसको खेती गरिएको छ । प्राकृतिक खेतीमा बजारबाट ल्याइएका कुनै पनि जैविक उर्वरकसमेत प्रयोग नगरिने भएकाले पहिले ढैंचा लगाएर माटोमा मिलाईएको थियो। त्यसबाहेक अन्य कुनै पनि जैविक तत्वसमेत प्रयोग गरिएको छैन ।

कोदी (Kodo Millet)

कोदी जसमा पोषण प्रति १०० ग्राममा नायसिन २ मिलिग्राम, रिबोफ्लोविन ०.०९ मिलिग्राम, थायमिन ०.३३ मिलिग्राम, फलाम २.९ मिलिग्राम, क्याल्सियम ०.०४ ग्राम, फस्फोरस ०.२४ ग्राम, प्रोटीन ६.२ ग्राम, खनिज २.६ ग्राम, कार्बोहाइड्रेड ६५.६ ग्राम, रेशा (फाइबर) ९ ग्रामपाइनुका साथै एनिमिया लगायतका रक्तविकार सम्बन्धी रोगहरू नियन्त्रण गर्न उपयोगी हुन्छ । रोग प्रतिरोधात्मक क्षमताको बृद्धि हुन्छ ।

कोदीलाई २०७९ चैत्र २१ गते ब्याड राखिएको थियो तर विविध कारणले अलि ढिलो गरी ४८ दिनपछि बिरुवा रोपिएको थियो । संयोगले त्यस दिन जैविक विविधता दिवस परेको थियो । बिरुवालाई २ फिटको बेडको केन्द्रमा बिरुवादेखि बिरुवाको दूरी १ फिटको फरकमा रोपियो । बेडको दुई किनारमध्ये एकातिर नाइट्रोजन फिक्सिङका लागि मुङ र अर्कोतिर बाली विविधीकरणका लागि तिल रोपियो । बिरुवा रोपेपछि २ दिन हल्का सिंचाइ गरियो । त्यसपछि आकासे पानीको भरमा छोडियो । एक बिरुवामा २७ वटा गाँज आएको छ । बिरुवाको उँचाइ ३ फिट र बाला ५ इन्च रहेको छ ।

तस्वीर १. कोदी (क) बेर्ना रोपेको २ महिना पछि (ख) बेर्ना रोपेको ३.५ महिना पछि

तालिका २. कोदीको बेर्ना राखेदेखि फल प्राप्त हुँदासम्मको समग्र विवरण तालिका

बेर्ना राखेको	विरुवा सारेको	बाला देखिएको	बालाको लम्बाई	गाँजको संख्या	उचाई	प्रति बोट अन्न
२०७९/१२/२१	२०८०/०२/०८	२०८०/०५/०२	५ इन्च	२७ वटा	३ फिट	२५ ग्राम

कागुनो (Foxtail Millet)

कागुनोमा पोषण प्रति १०० ग्राममा नायसिन ०.७ मिलिग्राम, रिबोफ्लोविन ०.११ मिलिग्राम, थायमिन ०.५९ मिलिग्राम, क्यारोटीन ३२ मिलिग्रिाम, फलाम ६.३ मिलिग्राम, क्याल्सियम ०.०३ ग्राम, फस्फोरस ०.२९ ग्राम, प्रोटीन १२.३ ग्राम, खनिज ३.३ ग्राम, कार्बोहाइड्रेड ६०.६ ग्राम, रेशा (फाइबर) ८ ग्राम पाइनुका साथै यसले श्वासप्रश्वास र स्नायु प्रणालीमा विशेष फाइदा पुर्याउछ ।

कागुनोको ब्याड २०८० जेठ ९ गते राखियो र ३१ दिनपछि २०८० असार ८ गते बिरुवा रोपियो । यसलाई पनि २ फिटको बेडको केन्द्रमा बिरुवादेखि बिरुवाको दूरी १ फिटको फरकमा रोपियो । दुईवटा बेडको बिचमा १.५ फिटको नाला बनाईएको छ । जसबाट लाईनदेखि लाईनको दूरी ३.५ फिट र बिरुवादेखि बिरुवाको दूरी १ फिट हुनगयो । बिरुवा रोपेपछि २ दिन हल्का सिंचाइ गरियो । त्यसपछि आकासे पानीको भरमा छोडियो । एक बिरुवामा २८ वटा गाँज आएको छ । बिरुवाको उँचाइ ५ फिट र बाला १० इन्च रहेको छ ।

तस्वीर २. कागुनो (क) बेर्ना रोपेको २ महिनाको (ख) बेर्ना रोपेको ८० दिनको (बाली भित्र्याउने बेलाको)

तालिका ३. कागुनोको बेर्ना राखेदेखि फल प्राप्त हुँदासम्मको समग्र विवरण

बेर्ना राखेको	विरुवा सारेको	बाला देखिएको	बालाको लम्बाई	गाँजको संख्या	उचाई	प्रति बोट अन्न
२०८०/०२/०९	२०८०/०३/०८	२०८०/०४/०६	१० इन्च	२८	५ फिट	३५ ग्राम

सामा (Barnyard Millet)

सामामा पोषण प्रति १०० ग्राममा नायसिन १.५ मिलिग्राम, रिबोफ्लोविन ०.०८ मिलिग्राम, थायमिन ०.३१ मिलिग्राम, फलाम २.९ मिलिग्राम, क्याल्सियम ०.०२ ग्राम, फस्फोरस ०.२८ ग्राम, प्रोटीन ६.२ ग्राम, खनिज ४.४ ग्राम, कार्बोहाइड्रेड ६५.५ ग्राम, रेशा (फाइबर) १० ग्राम पाइनुका साथै विशेषगरी कलेजो सफा गर्ने भएकाले कलेजो सम्बन्धी रोगमा फाइदा पुर्याउँछ ।

सामाको ब्याड २०८० जेठ ९ गते राखियो र ३२ दिनपछि २०८० असार ८ गते बिरुवा रोपियो । यसलाई पनि २ फिटको बेडको केन्द्रमा बिरुवादेखि बिरुवाको दूरी १ फिटको फरकमा रोपियो । दुईवटा बेडको बिचमा १.५ फिटको नाला बनाईएको छ । जसबाट लाईनदेखि लाईनको दूरी ३.५ फिट र बिरुवादेखि बिरुवाको दूरी १ फिट हुनगयो । बिरुवा रोपेपछि २ दिन हल्का सिंचाइ गरियो । त्यसपछि आकासे पानीको भरमा छोडियो । एक बिरुवामा ९ वटा गाँज आएको छ । बिरुवाको उँचाइ ६ फिट र बाला १० इन्च रहेको छ ।


तस्वीर ३. सामा (क) बेर्ना रोपेको २ महिनाको (ख) बेर्ना रोपेको ८० दिनको (बाली भित्र्याउने बेलाको)

तालिका ४. सामाको बेर्ना राखेदेखि फल प्राप्त हुँदासम्मको समग्र विवरण

बेर्ना राखेको	विरुवा सारेको	बाला देखिएको	बालाको लम्बाई	गाँजको संख्या	उचाई	प्रति बोट अन्न
२०८०/०२/०९	२०८०/०३/०८	२०८०/०४/१३	१० इन्च	९	६ फिट	२४ ग्राम

धान कोदो (Little Millet)

धान कोदोमा पोषण प्रति १०० ग्राममा नायसिन १.५ मिलिग्राम, रिबोफ्लोविन ०.०७ मिलिग्राम, थायमिन ०.३ मिलिग्राम, फलाम २.८ मिलिग्राम, क्याल्सियम ०.०२ ग्राम, फस्फोरस ०.२८ ग्राम, प्रोटीन ७.७ ग्राम, खनिज १.५ ग्राम, कार्बोहाइड्रेड ६५.५ ग्राम, रेशा (फाइबर) ९.८ ग्राम पाइनुका साथै प्रजनन प्रणालीमा विशेष फाइदा पुर्याउँछ।

धान कोदोको ब्याड २०८० जेठ ९ गते राखियो र ३२ दिनपछि २०८० असार ८ गते बिरुवा रोपियो। यसलाई पनि २ फिटको बेडको केन्द्रमा बिरुवादेखि बिरुवाको दूरी १ फिटको फरकमा रोपियो। दुईवटा बेडको बिचमा १.५ फिटको नाला बनाईएको छ। जसबाट लाईनदेखि लाईनको दूरी ३.५ फिट र बिरुवादेखि बिरुवाको दूरी १ फिट हुनगयो। बिरुवा रोपेपछि २ दिन हल्का सिंचाइ गरियो। त्यसपछि आकासे पानीको भरमा छोडियो। एक बिरुवामा ३८ वटा गाँज आएको छ। बिरुवाको उँचाइ ५ फिट र बाला १२ इन्च रहेको छ। यसको काण्ड कमजोर भएको कारण हावाहुरी थेग्न नसकी ढल्न गयो। जसले गर्दा उत्पादनमा कमी हुन गयो।


तस्वीर ४: धान कोदो। (क): बेर्ना रोपेको २ महिनाको (ख): बेर्ना रोपेको ८० दिनको (बाली भित्र्याउने बेलाको)

तालिका ५. धान कोदोको बेर्ना राखेदेखि फल प्राप्त हुँदासम्मको समग्र विवरण

बेर्ना राखेको	विरुवा सारेको	बाला देखिएको	बालाको लम्बाई	गाँजको संख्या	उचाई	प्रति बोट अन्न
२०८०/०२/०९	२०८०/०३/०८	२०८०/०४/१३	१२ इन्च	३८	५ फिट	१७ ग्राम

बाँसपाते कोदो (Browntop Millet)

बाँसपाते कोदोमा पोषण प्रति १०० ग्राममा नायसिन १८.५ मिलिग्राम, रिबोफ्लोविन ०.०२७ मिलिग्राम, थायमिन ३.२ मिलिग्राम, फलाम ०.६५ मिलिग्राम, क्याल्सियम ०.०१ ग्राम, फस्फोरस ०.४७ ग्राम, प्रोटीन ११.५ ग्राम, खनिज ४.२१ ग्राम, कार्बोहाइड्रेड ६९.३७ ग्राम, रेशा (फाइबर) १२.५ ग्राम पाइनुका साथै शरीरमा भएका हानिकारक र विषाक्त तत्वहरूलाई हटाई शारीरिक शुद्धतामा विशेष फाइदा पुर्याउँछ। बाँसपाते कोदोको खेती पनि कोदी, कागुनो, सामा, धान कोदो खेती गरेजस्तै विधि, समय र हावापानीमा गर्न सकिन्छ।

निष्कर्ष

माथिको तथ्यको आधारमा हेर्दा लुम्बिनी प्रदेशमा उल्लिंखाति कोदोजन्य बालीको खेतीको राम्रो सम्भावना देखिन्छ। उर्वरा शक्ति कम भएको, पाखो जमीन तथा सिंचाइ सुविधा कम भएको स्थानलाई सदुपयोग गर्न सकिन्छ। रासायनिक मल तथा विषादिको प्रयोग नगर्दा पर्यावरण जोगिनुका साथै श्रीअन्नको सेवनबाट मानवमा आरोग्यता प्राप्त हुने भएकाले बिरामी भएर हुने आर्थिक क्षतिबाट पनि बच्न सकिन्छ। अहिलेका मानिसहरू स्वास्थ्यप्रति सजग छन् र उचित खाद्यान्नको खोजीमा छन्। यस्तो अवस्थामा स्थानीय र प्रदेश सरकारले आफ्नो क्षेत्रमा भएका जमीनको अध्ययन र वर्गीकरण गरी सम्भावित स्थानका किसानहरूलाई अग्रसर गराउनु पर्छ। आवश्यक तालिम, उत्पादन र बजारीकरणमा विशेष जोड दिनुपर्छ। यसबाट बेरोजगारीको समस्या समाधान गरी आर्थिक रुपले सम्बृद्ध बन्न सकिन्छ।

सन्दर्भ सामग्रीहरू

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नेपालमा कागुनो बालीको महत्त्व तथा खेती प्रविधि

कृष्ण हरि घिमिरे

राष्ट्रिय बाली प्रजनन् तथा आनुवंशिक अनुसन्धान केन्द्र, नेपाल कृषि अनुसन्धान परिषद, खुमलटार, ललितपुर; इमेल: ghimirekh@gmail.com

सारांश

नेपालमा वैदिक कालदेखि खेती गरिंदै आएको कागुनो वा काउनो वा कागुनी विश्वका अति प्राचीनतम अन्नबालीहरू मध्येको एक बाली हो। यो कोदोजन्य बालीहरू अन्तरगत विश्वको जुनेलो र बाजापछिको तेस्रो साथै नेपालमा कोदो र चिनो पछिको तेस्रो बाली हो। नेपालमा कर्णाली प्रदेशका पहाडी जिल्लाहरूमा मुख्यत: र अन्य पहाडी जिल्लाहरूमा कताकति यसको खेती हुने गरेको पाइन्छ। कागुनो बिभिन्न पौष्टिक तत्वहरू जस्तैः प्रोटीन, चिल्लो पदार्थ र खनिज पदार्थ आदिले भरपुर बाली भएकोले यसलाई धान र गहुँ भन्दा स्वस्थकर बाली मानिन्छ। नेपालको सबै किसिमको हावापानीमा खेती गर्न सकिने यो बालीको उत्पादन बढाई खाद्य परिकारमा विविधिकरण गरी बजारको सुनिश्चित गर्न सकेमा कागुनोलाई प्रवर्धन गर्न सकिन्छ। हालसम्म अनुसन्धानबाट कागुनोको एकमात्र रैथाने जात लमजुङ जिल्लाको बरियो कागुनो पन्जीकरण गरिएको छ। यस बालीमा अत्यन्त कम मात्र अनुसन्धान भएकोले यसको उन्नत खेती प्रविधिको बारेमा कृषक तथा आम सर्वसाधारणलाई जानकारी दिनु यो लेखको प्रमुख उद्देश्य रहेको छ।

महत्त्वपूर्ण शब्दहरू: कागुनो, कोदोजन्य बाली, खाद्य परिकारमा विविधिकरण, खेती प्रविधि, पन्जीकरण।

कागुनो बालीको परिचय

बानस्पतिक विवरण

कागुनो एक स्वयंसेचित बाली हो, जसमा नौ जोडा ($2n=2x=18$) क्रोमोजोम रहेका हुन्छन्। यो पनि कोदो जस्तै घाँस परिवारको एकवर्षिय बाली हो जसमा गुच्छेदार मसिना जराहरू रहेका हुन्छन्। यसको बोट लगभग धान जस्तै हुन्छ तर डाँठ छिप्पीएपछि कडा हुन्छ। यसको बाला फ्याउरोको पुच्छर जस्तो आकारको हुने हुनाले अंग्रेजीमा यसलाई 'फक्सटेल मिलेट' भनिएको हो। यसको डाँठ मसिनो र ठाडो बढ्ने, बोट १००-२०० से.मी. सम्म अग्लो, पाकेको बोट प्रायः बालाको भारले नुहेको, पातहरू साँगुरा लाम्चा र मध्यनशा प्रष्ट देखिने मसिना रौँहरूले भरिएका, बालाहरू १०-३५ से.मी. सम्म लम्बाइका लामा वा छोटा झुसहरूले ढाकिएका तथा दानाहरू मसिना (२ मि.मी. सम्मका) अण्डाकारका सेतो, पहेंलो, सुन्तले, रातो, वैजनी, खैरो, कालो आदि रंगमा हुन्छन्। दानालाई चिल्लो र कडा खोस्टाले ढाकेको हुन्छ।

कागुनो बालीको हालको अवस्था

पूर्वी, दक्षिणी तथा पश्चिमी एशिया, दक्षिणी युरोप, उत्तरी अफ्रिका र उत्तरी अमेरिकाका देशहरूमा कागुनोको धेरै खेती हुन्छ। चीन विश्वको सबैभन्दा ठुलो कागुनो उत्पादक राष्ट्र हो भने त्यसपछि जापान, दक्षिण कोरिया र भारत पर्दछन्। चीनमा कागुनो धान र गहुँपछिको महत्त्वपूर्ण खाद्यान्न बाली हो। एशियामा मुख्यतः खाद्यान्न बालीको रुपमा तथा यूरोपमा चाराबालीको रुपमा कागुनोको खेती गरिन्छ।

नेपालमा बिशेष गरी कर्णाली प्रदेशका हिमाली जिल्लाहरू जुम्ला, हुम्ला, मुगु, डोल्पा, कालिकोट, जाजरकोट; सुदुर पश्चिम प्रदेशका हिमाली जिल्लाहरू बाजुरा र बझांग; गण्डकी प्रदेशका लमजुङ, गोरखा, तनहुँ र कास्की तथा बागमती प्रदेशका रामेछाप, काभ्रे, ओखलढुंगा आदि जिल्लाहरूमा असिन्चित, कमसल, सीमान्त वा रुखो जग्गामा यसको खेती गर्ने गरेको पाइन्छ। नेपालमा कागुनोको उत्पादन र क्षेत्रफल बारे आधिकारिक तथ्यांक उपलब्ध छैन, तर औसतमा करिब ८००-९०० के.जी./हेक्टर उत्पादन हुने बिभिन्न प्रतिवेदनहरूले देखाएका छन्। खुमलटार, ललितपुरमा गरिएको परिक्षणमा अधिकतम ३१०० के.जी./हेक्टरसम्म कागुनोको उत्पादन रेकर्ड भएको छ (घिमिरे २०७२)। कागुनो हाम्रो नेपालमा कोदो र चिनो पछिको तेस्रो कोदोजन्य बाली हो तथापी विविध कारणहरूले गर्दा हालका दिनहरूमा यसको क्षेत्रफल घट्दो क्रममा रहेको छ।

महत्त्व तथा प्रयोग

कागुनोको दानामा ९-११% प्रोटीन, ४.६% चिल्लो पदार्थ, ६६% कार्बोहाइड्रेट, ८.८% रेसा तथा २.८% खनिज तत्वहरू पाइन्छ। प्रति १०० ग्राम कागुनोबाट ३५२ मि.ग्रा. फस्फोरस, ७.१ मि.ग्रा. क्याल्सियम, ३.७ मि.ग्रा. फलाम, ०.६ मि.ग्रा. थायामिन, ०.११ मि.ग्रा. राइवोफ्लाभिन र ३४६ किलो क्यालोरी शक्ति प्राप्त हुनुका साथै यसमा पोलिफिनोल्स, ट्यानिन्स, स्यापोनिन्स, अल्कोलोइड्स, फ्लाभोनोइड्स जस्ता क्यान्सर निरोधक रसादिहरू पाइन्छन् (साउद २०६७)। अन्य आडिलो खाना पचाउन नसक्ने व्यक्तिका साथै ग्याष्ट्रिक, मधुमेह, उच्च रक्तचाप आदिका बिरामीको निम्ति पनि कागुनोको भात राम्रो मानिन्छ। कोदो जस्तो धेरै ठुलो क्षेत्रफलमा खेती नगरिने भएकोले यसले हाम्रो राष्ट्रिय अर्थतन्त्रमा त्यस्तो ठुलो हिस्सा ओगटेको छैन तापनि कर्णाली प्रदेशको उच्च हिमाली जिल्लाहरूको खाद्य तथा पोषण सुरक्षामा यसले महत्त्वपूर्ण भूमिका खेलेको छ। कोदोजस्तै कागुनो पनि कम वर्षा हुने, कम उर्वर भूमिमा, सिञ्चित र असिञ्चित दुबै अवस्थामा कम लागत मै उब्जिन सक्ने बाली भएकोले सीमान्त कृषकहरूको लागि यो बालीको आर्थिक महत्त्व छ। छोटो समय (करीब ३-४ महिना) मा नै पाक्ने बाली भएकोले यसलाई अन्य बाली असफल भएको अवस्थामा पनि पूरक बालीको रुपमा खेती गर्न सकिन्छ। यो प्रतिकूल समयमा पनि धेरथोर उत्पादन दिने भएकोले हामीलाई भोकमरीबाट बचाउन सक्ने बाली हो। यसको माग हिजोआज शहरी क्षेत्रमा बढेर गएको हुँदा उच्च पहाडी भेगका कागुनो खेती गर्ने किसानहरूको लागि यो बाली आय आर्जनको एउटा राम्रो स्रोत बन्न सक्ने देखिन्छ। कागुनोको सांस्कृतिक महत्त्व पनि रहेको छ। यसको चामल कोदो वा अन्य अन्नबालीहरू जस्तो बिटुलो नमानिने भएकोले चोखो अनाजको रुपमा लिइन्छ। पुजाआजामा प्रसादको रुपमा यसको लड्डु चढाउने पनि चलन छ भने ब्रत-ब्रतादिमा चोखो खानको लागि पनि कागुनोको चामल प्रयोग हुन्छ। यसबाट कोदोमा मिसाएर उच्च गुणस्तरको मदिरा पनि बन्ने भएकोले खासगरी गुरुङ, मगर, तामाङ जस्ता आदिबासी जनजातीहरूले कुलदेवतालाई यसको रक्सी चढाउने परम्परा पनि रहेको छ। नेपालको पर्यटन प्रबर्धनको लागि कोदोको ढिंडो जस्तै कागुनोको खीर, सेलरोटी, स्थानीय मदिरा र स्थानीय कुखुराको मासु कतिपय होमस्टेले आफ्नो मेनुमा राख्न थालेका छन् (घिमिरे २०७६)। नेपालमा कागुनोबाट भात, खीर, रोटी, ढिंडो आदि परिकार बनाएर खाने गरिन्छ भने पशुपन्छीलाई आहाराको रुपमा पनि प्रयोग यसको गरिन्छ। कागुनो फलेर भुस हटाएपछि भात वा खीर पकाउन वा पिनेर रोटी वा ढिंडो बनाएर खान उपयोग गरिन्छ। यसको दाना पशुपन्छीको चाराको लागि पनि प्रयोग हुन्छ भने हरियो तथा सुकेको नल राम्रो पशुआहारा हो।

परिकार विविधिकरण र बजारीकरण

परम्परागत रुपमा कागुनोको मुख्यतः खीर र भात खाइन्छ तर हिजोआज यसका मूल्य अभिबृद्धि गरिएका परिकारहरू शहरी उपभोक्ताहरूको खोजीमा पर्दछन्। बिभिन्न वेकरी उद्योगहरूबाट कागुनोको पिठो प्रयोग गरी केक, विस्कुट, चाउचाउ, पाउरोटी, उत्पादन हुन थालेको छ। कोदो जस्तै कागुनोको पनि मूल्य अभिबृद्धि गरी विविध उत्पादनहरू बजारमा लैजान सके कृषकहरूको आय आर्जनमा बृद्धि भई यसको प्रवर्धनमा पनि टेवा पुग्न जान्छ। कागुनो उत्पादन हुने क्षेत्रमा घरेलु तथा साना उद्योगको रुपमा यी परिकार तयार गरी बिक्री वितरण गर्न सकिन्छ। यसको पिठोमा पनि कोदोमा जस्तै ग्लुटिन भन्ने तत्व नहुने भएकोले पिठो मुछेर गहुँको जस्तो डल्लो बनाउन सकिँदैन। तर कागुनोको पिठोमा गँहुको पिठो र थौरै ग्लुटिनको समिश्रणबाट बिस्कुट, कुकिज, पाउरोटी, केक, आदि बनाउन सकिन्छ (खाद्य अनुसन्धान महाशाखा २०७१)।

बिस्कुट

कागुनोबाट बिस्कुट बनाउनको लागि ४०० ग्राम कागुनोको पिठो, ६०० ग्राम गहुँको पिठो, ३०० ग्राम धुलो चिनी, १०० ग्राम घिउ, १० ग्राम नुन, १० ग्राम धुलो दुध, १० ग्राम ग्लुकोज, २० ग्राम बेकिंग पाउडर, १५ ग्राम अमोनियम बाइकार्बोनेट र ४०० मि.लि. पानी आवश्यक पर्दछ। उल्लेखित मात्राको गहुँको पिठो र कोदाको पिठोलाई मिसाई राम्रोसँग मैदा चाल्ने जालीमा चाल्ने, आधा भाग पानीमा चाहिने मात्राको बेकिङ्ग पाउडर, एमोनियम बाइकारबोनेट र आधा चिनी हाली फिँज आउने समयसम्म राख्ने, घिउलाई पगालेर आधा चिनी, धुलो दुध र ग्लुकोजको क्रिम बनाउने, चालेको पिठोमा नून, एमोनियम बाइकारबोनेट, बेकिङ्ग पाउडर घोलेको र बाँकी पानी राखेर मुछ्ने, मुछेको पिठोको डल्लामा अघि बनाएको क्रिम राखी पुनः राम्रो सँग मुछ्ने, डल्लोलाई रोटी बेल्ने बेल्नामा राखी बेल्ने र ठिक्क साईजको (४-५ मि.मि. बाक्लो) रोटी बनाई बिस्कुट बनाउने साँचोद्वारा काटी बिस्कुटलाई २२० डिग्री सेल्सियस तापक्रम हुने गरी १७-२२ मिनेट ओभनमा राख्ने र ओभनबाट झिकेर चिसो भएपछि पोलिथिन वा कागजमा उचित लेवल सहित प्याकिङ्ग गरी सफा तथा सुख्खा ठाउँमा भण्डारण गर्नु पर्दछ।

केक

कागुनोको केक बनाउनको लागि आवश्यक सामग्रीहरूमा ४०० ग्राम कागुनोको पिठो, ६०० ग्राम गहुँको पिठो, ७०० ग्राम चिनी, ५०० ग्राम घिउ, १० वटा अण्डा, २० ग्राम बेकिङ्ग पाउडर र ३७० मि.लि. पानी रहेका छन्। माथि दिईएको पिठोमा आधा भाग चिनी राखी राम्रोसँग मिसाउने, चाहिने मात्राको बेकिङ्ग पाउडरमा एक चम्चा पिनिएको चिनी राखी पानीमा घोल्ने, चाहिने मात्राको घिउलाई पगालेर चिनी राखी क्रिम बनाउने, अण्डालाई फुटाएर राम्रोसँग फिटेर तयार गरेको क्रिममा फिट्ने, क्रिम बनिसकेपछि उक्त पिठोलाई मिसाई राम्रोसँग मुछ्ने, यसरी बेकिङ्ग पाउडर घोलिएको पानी पनि राख्दै राम्रोसँग फिटी केकको व्याटर तयार गर्ने, ब्याटरलाई केकको आकार भएको कचौरामा आधा भाग ओगट्ने गरी हाल्ने,

२१० डिग्री सेल्सियस तापक्रममा (३०-३५ मिनेट) पाक्ने गरी बेकिङ्ग गर्ने, यसरी पाकेको केकलाई सेलाएर कचौराबाट निकाल्ने र उचित लेवलिङ्ग सहित प्याकिङ्ग गर्ने गर्नुपर्छ। आफ्नो स्वाद अनुसार विभिन्न प्रकारका चकलेट, फलफुल, आदि राखेर पनि आकर्षक केक तयार पार्न सकिन्छ।

खीर

कागुनोको खीर हाल लमजुङ, कास्की, जुम्ला र हुम्ला जिल्लाका हरेक होम-स्टेहरूको अनिवार्य मेनु जस्तै भएको छ। यो तयार गर्नको लागि कागुनोको चामल ५०० ग्राम, दुध ५ लिटर, चिनी १५० ग्राम र आवश्यकता अनुसार ल्वांग, सुकुमेल वा अलैंची, काजु वा बदाम, छोकड़ा, नरिवल, दाख आदि आवश्यक हुन्छ। खीर बनाउनको लागि बाक्लो पींध भएको फराकिलो भाँडोमा दुध तताउने, दुध उम्लेपछि चामल राखेर थोरै तापक्रममा चलाउँदै चलाउँदै पकाउने, चामल पाकिसकेपछि मसिनो गरी काटेको नरिवल, छोकड़ा, काजु, दाख, अलैंची, ल्वांग र सबै चिनी राखेर चलाउने। खीर लेदो वा अर्ध तरल भएपछि चुलो बन्द गर्ने र खानको लागि सेलाउन राख्ने, खीरलाई हल्का खानाको रुपमा वा खानापछिको डेजर्टको रुपमा लिन सकिन्छ।

बजारीकरण

पहिले पहिले कागुनोको भात वा चाडपर्वमा खीर खाने चलन थियो तर हाल यसको उत्पादन कम हुँदै गएको र बदलिंदो खाद्य आनीबानीका कारण ग्रामीण भेगमा भन्दा शहरी क्षेत्रमा यसको माग तथा उपयोग बढ्दो क्रममा रहेको छ। कम शारीरिक श्रम गर्ने शहरी जनसंख्या उच्च रक्तचाप, मधुमेह, कोलस्टेरोल जस्ता समस्याबाट पीडित हुन थालेकाले र शहर-बजारका होटल-रेष्टुरेन्टमा समावेश भएको मेनुको कारणले पनि हिजोआज कागुनोको खपत गाउँघर भन्दा शहरबजारमा धेरै छ। नेपालको कागुनो एक पूर्ण प्रांगारिक बाली भएकोले पनि सचेत नागरिक तथा तारे होटलका पाहुनाहरूले समेत यसको खीर, ढिंडो, केक, स्वीट वा डेजर्ट लगायतका परिकारहरू खोज्न थालेका छन्। तसर्थ गाउँघरमा प्रति के.जी. रु. ८०-१०० सम्ममा बिक्री हुने कागुनोको चामल ठूला डिपार्टमेन्टल स्टोरहरूमा प्रति के.जी. रु. २५०-३५० सम्ममा सहजै बिक्री हुने गरेको छ (घिमिरे २०७९)। नेपालमा विदेशबाट कति कागुनो आयात हुन्छ भन्ने यकिन तथ्यांक नभेटिए तापनि ठुला शहरी व्यापारिक घराना तथा होटेलहरूमा यसको माग अत्यधिक रहेको छ। शहरका व्यापारीहरूले उत्पादक किसानहरूसँग सोझै सम्पर्क गरी वा स्थानीय व्यापारीहरू मार्फत् कागुनोको चामल खरिद गरी आफ्नो लेवलमा प्याकेजिंग गरी बेच्ने गर्दछन्। कागुनो उत्पादन हुने हिमाली र पहाडी जिल्लाहरूमा स्थानीय र जिल्ला स्तरमा संचालित कोसेली घरहरूमा कृषक समुहको आफ्नै लेवलमा कागुनोको चामल किनबेच हुने गरेको छ। यसले पनि स्वदेशमै पर्याप्त उत्पादन गर्न सके कागुनो खेतीलाई बजारको कुनै समस्या छैन भन्ने देखिन्छ।

कागुनो खेती प्रविधि

हावापानी

कोदो जस्तै कागुनो पनि बर्षायाममा खेती गरिने बाली भएको हुँदा यसले न्यानो हावापानी मन पराउँछ। तथापी यो बाली विविध प्रकारको हावापानी भएको क्षेत्रमा उब्जनी हुन सक्दछ। यसको खेती उष्ण, उपोष्ण र समशितोष्ण क्षेत्रहरूमा गर्न सकिन्छ। समुद्र सतहदेखि ३००० मि. सम्मका क्षेत्रहरूमा कागुन खेती सफल हुन्छ। यस बालीलाई यसको जीवन अवधिभर मध्यम तापक्रम चाहिन्छ। वार्षिक ५०-१०० से.मि. वर्षा हुने क्षेत्रमा कागुन खेती सफल हुन्छ। कागुनो उम्रन र उचित वृद्धि विकासको लागि १५-२७ डिग्री सेल्सियस तापक्रम उपयुक्त हुन्छ। फुल फुल्ने बेलाको न्युनतम तापक्रम १० डिग्री सेल्सियसभन्दा कम भएमा बाला ननिस्कने वा निस्के पनि दाना नलाग्ने हुन्छ भने अधिकतम तापक्रम ३० डिग्री सेल्सियसभन्दा धेरै भएमा पनि परागकणहरू सुकेर सेचन हुन सक्दैन र बाला भुस्सिने हुन्छ। यसको खेती सिंचाई सुविधा नभएको र कम वर्षा हुने क्षेत्रमा वर्षे बालीको रुपमा गर्न सकिन्छ। वर्षाकालिन र छोटो अवधिमा पाक्ने बाली भएकोले यसले चिस्यानको अभव प्रायः सहनु पर्दैन। सिंचित क्षेत्रमा बसन्त गृष्मकालिन बालीका रुपमा पनि कागुनो उब्जाउन सकिन्छ। कागुनो पनि कोदो जस्तै धेरै सुख्खा सहन सक्ने बाली हो।

जातीय संरक्षण

कागुनो आफैँमा एक लोपोन्मुख बाली हो। खेती गर्ने किसानहरूले पनि यसलाई अति सीमान्त वा कम मलिलो, असिंचित र फालिएको जग्गामा खेती गर्ने गरेका छन्। दिनानुदिन कागुनो खेती घट्दै जान थालेकाले यसका स्थानीय जातहरू र सम्बन्धीत परम्परागत ज्ञान पनि लोप हुने खतरामा रहेका छन्। जातीय संरक्षणबाट हाम्रा रैथाने विविधता जोगाउन सकिन्छ, जसले किसानहरूलाई छनौटको विकल्पहरू वृद्धि हुन्छन् र जलवायु परिवर्तनबाट सिर्जित जैविक तथा अजैविक समस्याहरूसँग जुध्ने क्षमता बढाउँछ। हाम्रा यी स्थानीय जातहरूमा धेरै फल्ने, स्वाद मिठो हुने, छिटो पाक्ने, चामल धेरै पर्ने, लगायत अन्य बिशेष औषधीय गुणहरू रहेका हुन्छन् जुन बाली प्रजनन् मार्फत् नयाँ जातहरूमा सार्न सकिन्छ। स्थानीय जातहरूमा भएका यी अमुल्य गुणहरूलाई संरक्षण गर्न कृषक समुदायसँग मिलेर जातीय सुधार गर्नु अति आवश्यक छ। कागुनो खेतीमा लागेका संरक्षक कृषकहरूलाई राज्यले बिशेष अनुदानको व्यवस्था गर्नुपर्ने देखिन्छ।

खुमलटार स्थित राष्ट्रीय जीन बैंकमा नेपालमा पाइने करिब ५५ वटा कागुनोका स्थानीय जातहरू संकलन गरी सयौं बर्षसम्म सुरक्षित रहने किसिमले नियन्त्रित वातावरणमा संरक्षण गरिएको छ। संरक्षित जातहरू अध्ययन अनुसन्धान र उत्पादनको लागि कृषक, बिद्यार्थी र अनुसन्धानकर्तालाई निशुल्क उपलब्ध हुन्छन्। तपाईं हामी पनि हाम्रो आ-आफ्नो क्षेत्रमा खेती गरिंदै आएका बिशेष गुणयुक्त स्थानीय जातहरूलाई आवश्यक पासपोर्ट डाटा सहित राष्ट्रिय जीन बैंकमा संरक्षण गर्न सक्छौं। हरेक पालिकाहरूमा अनिवार्य सामुदायिक बीउ बैंकको स्थापना गर्ने, स्थानीय जैविक विविधताको संकलन तथा अभिलेखिकरण गर्ने, सामुदायिक बीउ बैंकहरू मार्फत् गुणस्तरीय बीउ उत्पादन गर्ने साथै उत्पादित अनाजको प्रशोधन तथा खाद्य परिकार विविधिकरणमा जोड दिने आदि कार्यहरू गरेमा यो बालीको संरक्षण गर्न सकिन्छ। कागुनो खेतीको प्रवर्धन तथा जातीय संरक्षणको लागि नेपाल सरकार, कृषि अनुसन्धान तथा विकास संस्थाहरू तथा कृषक समुदाय मिलेर संयुक्त संस्थागत पहल हुन जरुरी छ।

जातहरू

नेपालमा हालसम्म कागुनो बालीको कुनै पनि उन्नत जातहरू सिफारिस गरिएका छैनन् तर लमजुङको रैथाने जात 'बरियो कागुनो' हालैमात्र राष्ट्रिय बीउबिजन समितिबाट पन्जीकरण गरिएको छ (**तालिका १**)। नेपालका स्थानीय रैथाने जातहरूमा बोटको उचाई, बालाको साइज, पात र दानाको रंग, झुस र टुंडोको आधारमा प्रशस्त विविधता पाइन्छ। नेपालमा खेती गरिने स्थानीय जातहरूमा कालो कागुनो, सेतो कागुनो, रातो कागुनो, पहेंलो कागुनो, खैरो कागुनो, सानो कागुनो, ठुलो कागुनो, आदि छन् (घिमिरे र साथीहरू २०७४)।

तालिका १. नेपालमा खेती गरिने केही कागुनोका स्थानीय जातहरू र तिनका मूख्य मूख्य गुणहरू

जात	महत्त्वपूर्ण गुणहरू	चित्र
बरियो कागुनो	ठुला ठुला आकर्षक हल्का खैरो बाला, घिउ रंगको दाना, बोटको औसत उचाई: १६७ से.मी., फूल फुल्ने अवधि: ६५ दिन, पाक्ने अवधि: १०० दिन, औसत उत्पादन: २-२.५ टन/हेक्टर, बालाको औसत लम्बाई: २५-३० से.मी., सुख्खा सहने, नढल्ने, मरुवा रोग अवरोधी; मध्य पहाडी क्षेत्रको लागि उपयुक्त २०७७ सालमा पंजीकरण गरिएको लमजुङ जिल्लाको रैथाने जात	
कालो कागुनो	आकर्षक गाढा खैरो बाला, कालो रंगको दाना, बोटको औसत उचाई: १७५ से.मी., फूल फुल्ने अवधि: ७५ दिन, पाक्ने अवधि: ११० दिन, औसत उत्पादन: २.५ टन/हेक्टर, बालाको औसत लम्बाई: २५ से.मी., सुख्खा सहने, नढल्ने, मरुवा रोग अवरोधी; कर्णाली प्रदेशको हिमाली क्षेत्रको लागि उपयुक्त हुम्ला जिल्लाको रैथाने जात	

स्रोत: घिमिरे र साथीहरू (२०७५), गुरुङ र साथीहरू (२०७६)

माटो

कागुनो पनि कोदो जस्तै रुखोदेखि ज्यादै मलिलो माटोमा पनि खेती गर्न सकिन्छ। यसका लागि नयाँ, डँडेलो लगाएको, राम्रो जल निकास भएको दोमट वा चिम्टाइलो दोमट माटो राम्रो हुन्छ। पहाडमा रातो दोमट, पाँगो वा अन्य प्रकारका माटोमा पनि यसको खेती हुन सक्छ तर ढुङ्गयान वा पत्थरिलो माटो त्यति उपयुक्त हुँदैन। कागुनो खेतीको लागि पि.यच. (pH) मान ५.५-७.० सम्म भएको माटो उपयुक्त हुन्छ। कागुनो उम्रनको लागि माटोमा पर्याप्त मात्रामा चिस्यान हुनु अति आवश्यक हुन्छ।

बाली चक्र र खेती प्रणाली

कागुनो बालीलाई स्थान अनुसार एकल, मिश्रित, घुसुवा वा अन्तरबालीको रुपमा खेती गरिन्छ । भौगालिक अवस्था, खेती प्रणाली र सामाजिक अवस्थाले कागुनो खेतीको बाली-चक्रमा अन्तर ल्याउँछ । वर्षे बालीको रुपमा कागुनो लगाइएको भए त्यसपछि जौ, गहुँ, चना, केराउ, आलस, तोरी आदि लगाउन सकिन्छ भने बसन्ते कागुनो पछि कोदो वा धान लगाउन सकिन्छ । कर्णाली प्रदेशमा कागुनो प्राय: कोदो, चिनो वा मार्सेसँग मिश्रित खेती गरिन्छ भने तल्लो पहाडमा प्राय: घैया धान, मकै, बदाम, मुङ, तिल आदिसँग मिश्रित खेतीको रुपमा लगाउन सकिन्छ ।

जमिनको तयारी

कागुनो रोप्नका लागि धेरै खनजोत गर्नु जरुरी छैन । मनसुन सुरु हुनअघि एकपटक माटो पल्टाउन हलोले जोताई गर्नुपर्छ र वर्षायाम शुरु भएपछि दुई पटक ह्यारोले या स्थानीय हलोले जोतेर जमिनको तयारी गर्नुपर्छ, साथै पाटा लगाएर डल्ला फुटाएर माटो बुर्बुराउँदो बनाउनुपर्छ।

मलखाद

कागुनो रोप्नुभन्दा करिव एक महिना पहिले राम्ररी कुहेको गोवरमल वा कम्पोष्टमल ५-१० टन प्रति हेक्टरका दरले राखी माटोमा मिलाउनु पर्छ । गड्यौली मल २-३ टन/हे. का दरले वा पीना वा अन्य प्रांगारिक पदार्थ जमिनको अन्तिम तयारीको बेलामा प्रयोग गर्न सकिन्छ । प्राङ्गारिक मल हाल्नाले माटोको जलधारण क्षमता बढ्छ । यस बालीलाई रासायनिक मल पनि दिनु लाभदायक हुन्छ । रासायनिक मल कति हाल्ने भन्ने कुरा कागुनोको जात, माटोमा उपलब्ध प्रांगारिक पदार्थ, बाली लगाउने तरीका आदिले फरक पार्दछ । माटो जाँचका आधारमा माटोमा अपुग खाद्यतत्वहरू मात्र सन्तुलित मात्रामा दिनु उत्तम मानिन्छ । माटो विश्लेषणको नतिजा उपलब्ध नभएमा सामान्यतया सिंचित क्षेत्रमा २०-३० के.जी./हेक्टरका दरले नाइट्रोजन, ३०-४० के.जी./हेक्टर फस्फोरस र २०-३० के.जी./हेक्टर पोटास जग्गा तयारीको बेलामा प्रयोग गर्नु पर्छ भने २०-३० के.जी./हेक्टर नाइट्रोजनले पहिलो गोडाईको बेलामा टपड्रेस गर्नु पर्छ ।

बाली लगाउने समय

सामान्यतया बर्खे बाली (बैशाख-जेठमा रोपी भदौमा काट्ने) भएपनि सिंचित तल्लो पहाडी क्षेत्रमा यसलाई बसन्ते बाली (फागुनमा रोपी जेठ-असारमा काट्ने) को रुपमा पनि खेती गर्न सकिन्छ । बर्खे बालीको रुपमा ११०० मिटरसम्मको तल्लो पहाड र बेसीमा जेठ मसान्तसम्म, ११००-१८०० मिटरसम्मका मध्य पहाडमा जेठ पहिलो हप्तासम्म र १८०० मिटरभन्दा माथिका उच्च हिमाली भेगमा बैशाखको तेस्रो हप्तासम्ममा कागुनो रोप्नुपर्छ । माटोमा पर्याप्त चिस्यान भएको बेला रोपण गरेमा अंकुरण राम्रो हुन्छ र उब्जनी बढी हुन सक्छ । माटोमा चिस्यानको उपलब्धता ख्याल नगरी रोपेमा कागुनको बीउ राम्ररी नउम्रन सक्छ ।

बीउको दर र रोप्ने तरिका

मसिनो दाना हुने भए तापनि कोदो जस्तो धेरै गांज नहाल्ने भएकोले कागुनोलाई पनि कोदो जत्तिकै बीउ दर आवश्यक हुन्छ । जस अनुसार छरुवा तरिकाले खेती गर्दा प्रति हेक्टर १० के.जी. र लाईनमा छर्दा प्रति हेक्टर ८ के.जी. का दरले कागुनोको बीउ प्रयोग गर्नुपर्छ । बीउलाई सुख्खा माटोमा या बालुवामा मिसाई छर्न सकिन्छ । बीउ छर्नु भन्दा पहिले भाईटाभ्याक्स २.५ ग्राम प्रति के.जी. बीउका दरले बीउ उपचार गरेमा ढुसी जन्य रोगहरूबाट बच्न सकिन्छ । बीउ रोप्दा एकैनासले वितरण हुने र बीउ करिब २-३ से.मी. गहिराईमा पर्ने गरी छर्नुपर्छ भने लाईनमा छर्दा लाईन-लाईनको दूरी २५ से.मी. कायम गरी २-३ से.मी.को गहिराईमा बीउ छर्नु उपयुक्त हुन्छ । छरेको २५-३० दिनमा बाक्लो उम्रेका विरुवा उखल्नुपर्छ । यदि लाईनमा छरेको भए बाक्लो उम्रेका विरुवाहरू उखलेर छाँटी बोटदेखि बोटको दूरी १० से.मी. कायम राख्नुपर्छ ।

सिंचाइ

वर्खे कागुनो बालीलाई सिंचाई प्राय: आवश्यकता पर्दैन । तर लामो अवधिसम्म खडेरी परेमा आवश्यकतानुसार पहिलो गोडाईपछि एक पटक र बाला निकाल्नु अघि एक पटक सिंचाई दिन सकेमा उब्जाउ राम्रो हुन्छ । यो बालीले खेतमा पानी जमेको अवस्था सहन नसक्ने भएको हुनाले निकासको राम्रो व्यवस्था मिलाउनु पर्छ ।

गोडमेल

पाखो बारीमा एकल वा मिश्रित बालीको रुपमा कागुनो खेती गर्दा बालीको प्रारम्भिक अवस्थामा नै झारपात नियन्त्रणको लागि गोडमेल जरुरी हुन्छ । कुटे, हाते वा पाङग्रे दाँतेद्वारा पनि गोडमेल गर्न सकिन्छ । बर्षेबाली भएकोले कागुनो बाली भित्र झारको प्रकोप निकै हुन्छ । समयमा झारपात नियन्त्रण गरिएन भने उत्पादनमा कमी हुन्छ । लाईनमा छरेको बाली गोडमेल गर्न सजिलो हुन्छ । समयमै गोडमेल गरिएमा मुसा तथा रोगको प्रकोप पनि कम हुन्छ ।

बाली संरक्षण

कागुनो बालीमा पनि रोग र कीराले उल्लेख्य क्षति पुयाउँछन् तर किसानहरूले रोगकीराको व्यवस्थापनमा त्यति ध्यान दिएको पाइन्न। कागुनो बालीमा लाग्ने मूख्य मूख्य रोग, कीराहरू र अन्य शत्रुजीबहरू साथै तिनको पहिचान वा क्षतिको लक्षण र व्यवस्थापनका उपायहरू निम्नानुसार दिइएको छः

कालोपोके (Loose smut)

यो रोग *अस्टिलागो क्रामेरी* भन्ने ढुसीको कारणले लाग्दछ। यसका जीवाणु बीउको सतहमा टाँसिएर बसेका हुन्छन् र उम्रदा सँगसँगै बोट भित्र प्रवेश गरी फुल फुलेपछि बालामा रोगका लक्षण प्रकट हुन्छन्। रोग ग्रस्त विरुवाको बृद्धि कम हुन्छ, यसले बालाका अधिकांश दानामा प्रभावित गर्छ र बाला कालो धुलो पाउडरले भरिएको हुन्छ। बाली परिपक्व हुने बेलामा कालोपोका फुटेर हावाको सहायताले टाढाटाढासम्म फैलिन्छन्। यो रोगको व्यवस्थापनको लागि घुम्ती बाली प्रणाली अपनाउने, धुलो नझर्दै रोगी बोटहरू उखेलेर खाडल खनी गाडिदिने वा जलाउने, रोगी बोटहरू पशुहरूलाई नखुवाउने, भाइटाभ्याक्स वा थिराम २.५ ग्राम प्रति के.जी. बीउका दरले बीउ उपचार गर्ने जस्ता उपायहरू अवलम्बन गर्न सकिन्छ।

मरुवा रोग (Blast)

यो रोग *पाइरिकुलेरिया सेटारी* भन्ने ढुसीको कारणले लाग्दछ। यसले कागुनोका पातहरूमा अत्यधिक क्षती गर्छ, पातमा आँखा वा डुङ्गा आकारका किनारा पहेंलो र मध्य भाग खरानी रङ्गका दाग देखिन्छन्। यो रोग बालीको शुरु अवस्थादेखि नै लाग्न थाल्छ (मानन्धर र साथीहरू २०७३)। रोग अवरोधक जातहरू तथा स्वस्थ बीउमात्र रोप्ने, बीउ रोप्नुपूर्व क्याप्टान/कार्बेन्डाजीम २.५ ग्राम/के.जी. बीउका दरले उपचार गरेर मात्र बीउ रोप्ने, खेतमा रोपिसकेपछि रोगको आक्रमण भएमा ढुसीनाशक विषादी १५ दिनको फरकमा एक दुईपटक छर्ने, रोग ग्रस्त बालीबाट बीउ नलिने जस्ता उपायहरू अपनाउन सके यो रोगबाट बच्न सकिन्छ।

गभारो किरा (Stem borer)

कागुनो बालीमा गुलावी गबारो र धर्के गवारोले बाला निकाल्ने समयमा दुख दिन सक्छ। लाभ्रेले डाँठलाई छेडी भित्र पसी गुवोलाई खान्छ। बालीको बृद्धि अवस्थामा आक्रमण भएमा बालीको बृद्धि रोकिन्छ वा गाँज कम निस्कन्छ भने बालीको पछिल्लो अवस्थामा आक्रमण भएमा सेतो बाला (White head) निस्कन्छ र बाला सुक्छ। किराको आक्रमण थोरै मात्र विरुवामा भए गुभो मरेका विरुवाहरू उखेलेर नष्ट गर्ने, राम्रोसँग गोडमेल वा बारीको सरसफाई गर्ने, किराको प्रकोप धेरै भएको खण्डमा नयाँ बिषादी फर्टेरा (०.४% दानेदार) ३०-४० के.जी. सक्रिय पदार्थ प्रति हेक्टरका दरले माटोमा प्रयोग गरेमा गभारो किराको व्यवस्थापन गर्न सकिन्छ।

पतेरो कीरा (Bug)

कागुनोको बालामा दुध भरिने समयमा पतेरो कीराले आक्रमण गर्ने सम्भावना हुन्छ। पतेरोले आक्रमण गरेका दानाहरूमा खैरो दाग देखिने, दानाहरू फोस्रा हुने हुने गर्दछ। यसको व्यवस्थापनको निम्ति प्रकाशको पासोको माध्यमबाट वयस्क कीरालाई मार्ने, खेतबारीको झारपात गोडमेल गरी पतेरोको वैकल्पिक आश्रयस्थल नष्ट गर्ने, डर्टी ट्रयापको प्रयोग गर्ने जसको लागि गाईभैंसीको ताजा पिसाबमा कपडा वा जुटको बोरालाई भिजाएर एउटा घोचोको एक छेउमा बाँध्ने र उक्त घोचोलाई बारीको बिचमा लगेर गाड्ने, ट्रयापमा आकर्षित भएका पतेरोहरूलाई बाहिरबाट प्लास्टिकको झोलाले छोपी संकलन गरी मार्ने जस्ता उपायहरू अवलम्बन गर्न सकिन्छ।

चरा (Bug)

कागुनो चराको अति प्रिय खाना भएकोले बाली पाक्ने समयमा तोप चरा भन्ने भंगेराजस्तै एक प्रकारको सानो चराले दुख दिन्छ। यसको व्यवस्थापनको लागि सकेसम्म रुख, बुट्यानहरूको नजिकमा कागुनो नरोप्ने, धैरै छिटो वा धेरै ढिलो पाक्ने खालका जातहरू नलगाउने, ठुलो क्षेत्रफलमा कागुनो लगाउने, चरा धपाउने यन्त्रको प्रयोग गर्ने आदि उपायहरू अवलम्बन गर्न सकिन्छ।

मुसा (Rodents)

अन्य अन्नबालीमा जस्तै कागुनो बालीमा पनि मुसाले दुख दिन्छ। बाली पाक्न थालेपछि मुसाले बाला काटेर लैजान्छ। यसको व्यवस्थापनको लागि झारपात तथा ठुटाठुटिहरू हटाई खेतबारीको सरसफाई गर्ने, धैरै छिटो वा धैरै ढिलो पाक्ने खालका जातहरू नलगाउने, मुसाको प्वालहरू टाल्ने, खन्ने तथा नष्ट गर्ने साथै मुसाको प्रकोप धैरै नै भएमा बिषयुक्त चाराको प्रयोग गरेर मुसा नियन्त्रण पनि गर्न सकिन्छ।

बाली भित्र्याउने समय

खेती गरिएको स्थान र लगाइएको जात अनुसार रोपेको ३-४ महिनामा कागुनो बाली भित्र्याउनको लागि तयार हुन्छ। तराई र भित्री मधेशमा भन्दा उच्च पहाडमा कागुनो ढीलो पाक्दछ। बालाहरू सुकेपछि आँसीको सहायताले बाला टिप्न वा बाला सहित बोटहरू जमिनको सतह नजिकबाट काट्न सकिन्छ। तर अधिकांश कृषकहरूले पहिला बाला टिप्ने र त्यसपछि नल काटने गर्छन्। काटेको बाली केही दिन घाममा सुकाएर लौरो वा मुङ्ग्रोको सहायताले चुटी सफा गर्ने र राम्ररी सुकाएर राम्रोसँग बन्द गर्न सकिने टिनको भकारी वा अन्य उपलब्ध भाँडामा ओस नलाग्ने ठाउँमा मात्र भण्डारण गर्नुपर्छ।

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चिनो खेती र बीउ उत्पादन प्रविधि

बाल कृष्ण जोशी, कृष्ण हरि घिमिरे, प्रदिप थापा र मुकुन्द भट्टराई

राष्ट्रिय जीन बैंक, खुमलटार, ललितपुर; इमेल : joshibalak@yahoo.com; ghimirekh@gmail.com; pradip.thapa876@gmail.com; mukundab_7@yahoo.com

सारांश

साना दाना हुने खाद्यान्न बाली चिनो वा चिनु भातको रुपमा खाने गरिन्छ। नेपालको उच्च पहाडी भेगमा करिब ३,५०० मि. उचाइसम्म वर्षायाममा यसको खेती गरिन्छ। चिनोका स्थानीय जातहरूमा कालो चिनो, रातो चिनो, दूधे चिनो, हाडे चिनो, कटिबडे चिनो, सनवा चिनो, समई चिनो, झुमारु चिनो आदि छन्। दुधे चिनो २०७७ सालमा दर्ता गरी सिफारिस गरिएको जात हो, जसको औषत उत्पादन ११५-१२० के.जी./रोपनी छ। चिनोले सुक्खा सहने, नढल्ने, र यसको परिकार पोषिलो र आडिलो हुने हुँदा यसको खेती विस्तार गर्नु अति आवश्यक देखिन्छ।

परिचय

चिनो वा चिनु (Proso millet: *Panicum miliaceum* L.) साना दाना हुने खाद्यान्न बाली हो। चिनु प्राचीनतम खाद्यान्न बालीहरू मध्ये एक भएकाले कृषि प्रणालीमा यसलाई चिनो कै रूपमा लिइन्छ। यसको बोट धानको जस्तो हुने तर दानाचाहिँ कोदोजस्तो हुने भएकाले यसलाई कतैकतै 'धानकोदो' पनि भन्ने गरिन्छ। चिनो सुगा लगायत अन्य चराले मन पराउने हुँदा यसलाई 'चरीअन्न' पनि भनिन्छ। नेपालको उच्च पहाडी भेगमा करिब ३,५०० मि. उचाइसम्म वर्षायाममा यसको खेती गरिन्छ। मुख्य रूपमा कर्णाली अञ्चलका पाँचवटै जिल्लाहरू डोल्पा, मुगु, जुम्ला, हुम्ला, कालिकोटका साथै ओखलढुङ्गा, धादिङ, बाजुरा र बझाङ जिल्लामा पनि यसको खेती गरिएको पाइन्छ। नेपालमा चिनोको सरदर उत्पादन प्रति हेक्टर ८१८ के.जी. छ। यसलाई विभिन्न किसिमको हावापानी तथा माटामा खेती गर्न सकिन्छ।

महत्त्व

यसका दाना फलेर भुस हटाई भात वा खीरका साथै दाना भुटेर वा पिठो बनाएर विभिन्न परिकार खाने गरिन्छ। चिनोको दानामा ११.९% पानी, १२.५% प्रोटीन, १.१% चिल्लो पदार्थ, ७०.४% कार्बोहाइड्रेट पाइन्छ। यसमा गहुँ र धानमा भन्दा प्रोटीन र फलाम तत्त्व बढी पाइन्छ तर ग्लुटिन भने हुँदैन। ग्लुटिन गहुँ वा जौ मा पाइने प्रोटीनको मिश्रण हो, जसले गर्दा रोटीलाई पातलो हुने गरी बेल्न/तन्काउन सकिन्छ। यो एकदम छिटो पाक्ने (६०-९० दिन) र सबैभन्दा माथिल्लो भेगसम्म लगाउन सकिने बाली हो। यसको खेती गर्न सजिलो हुनाको साथै धेरै कम लगानीमा नै उत्पादन लिन सकिन्छ। अन्य बालीहरू भन्दा चिनो कमसल जग्गामा पनि खेती गर्न सकिन्छ। मकैजस्तै चिनो बालीले पनि ओसेप मन पराउँदैन तर पारिलो ठाउँमा यसले धेरै प्रकाश संश्लेषण गर्छ र बढी उत्पादन दिन्छ। अन्नबाली मध्ये सबैभन्दा कम पानी चाहिने भएको हुनाले सुक्खाग्रस्त क्षेत्रमा एउटा भरपर्दो सहायक बालीका रूपमा तथा सिञ्चित क्षेत्रमा सघन बाली-प्रणालीमा सामेल गर्न उपयुक्त बालीका रूपमा यसको महत्त्वपूर्ण स्थान छ। कहिले काहीँ अनावृष्टि भएर वर्षाकालीन मकैबाली असफल भएको स्थितिमा पनि सुक्खा सहने र चाँडै उत्पादन दिने भएकोले चिनो खेती गरेर खडेरीको मार न्यून गर्न सकिन्छ। आपतकालीन भोकमरी र अभावका समयमा र मुख्य बाली लाउने समय बितिसके पछिको अवस्थामा पनि चिनो खेतीबाट खाद्यान्नको समस्या टार्न मद्दत मिल्छ।

विविधता

चिनोको उत्पत्ति उत्तर-पूर्वी एसियामा भएको मानिन्छ र यसको खेती पूर्वी एसियाबाट शुरु भएको हो। नेपालमा थुप्रै किसिमको चिनोका रैथाने जातहरू पाइन्छन्। विशेष गरेर चिनोको उचाइमा, बीउको रङमा, पात तथा डाँठमा हुने झुसमा, बालाको आकारमा, गाँज आउने क्षमतामा विविधता पाइन्छ। दानाको रङको आधारमा सेतो, रातो, पहेंलो, खैरो, कालो, नौनी रङको दाना भएको पाइन्छ। दाना साना भए पनि पात र डाँठ ठूला-ठूला

हुन्छन् अनि यसका पात र डाँठमा प्रशस्त मात्रामा झुस हुन्छ। मुख्यतः चिनोका बालामा बढी विविधता देखिन्छ। बाला ठूला, लामा र कस्सिएका वा खुकुला खाले पाइन्छन्। बालाको आकारका आधारमा चिनोलाई ३ समूहमा विभाजन गर्न सकिन्छ, जस्तैः १. खुकुला र एकतर्फ लार्किएका बाला २. ठाडा बाला र ३. सबैतर्फ फिँजारिएका बाला। चिनो छिटो पाक्ने बाली भए पनि पाक्ने अवधि (जात, ठाउँ, मौसम हेरी ६० देखि १०० दिन) मा पनि विविधता पाइन्छ। सूक्ष्म रूपमा हेर्दा बीउको आकार र बनोटमा पनि विविधता पाइन्छ। नेपालमा चिनोको विभिन्न स्थानीय जातहरू पाइन्छन् र स्थानीय जातभित्र पनि विविधता देखिएको छ तर हालसम्म एकमात्र रैथाने जात हुम्ला जिल्लाको 'दुधे चिनो' राष्ट्रिय बीउबिजन समितिबाट पन्जीकरण गरिएको छ। चिनोका स्थानीय जातहरूमा कालो चिनो, रातो चिनो, दूधे चिनो, हाडे चिनो, कटिबडे चिनो, सनवा चिनो, समई चिनो, झुमारु चिनो आदि छन्।

खेती प्रणाली

चिनो ग्रीष्मकालीन र वर्षाकालीन बालीका रूपमा उब्जाइन्छ। यो छोटो अवधिको बाली भएकाले यसलाई कम साधन स्रोत वा उच्च सघन बालीचक्रहरूमा सजिलै सामेल गर्न सकिन्छ। सिञ्चित क्षेत्रमा अपनाइने बालीचक्रहरू यसप्रकार छन्: क) धान–गहुँ–चिनो (ख) धान–मुसुरो–चिनो (ग) मकै–आलु–चिनो (घ) मकै–गहुँ–चिनो (ङ) मकै–तोरी–गहुँ–चिनो (च) मकै–तरकारी/केराउ–गहुँ–चिनो (छ) चिनो–गहुँ–फापर (जुम्लामा)।

जातहरू

दुधे चिनो (२०७७ सालमा दर्ता गरी सिफारिस गरिएको)
बाली लगाउने समय : जेठ १५ देखि असाढ
पात : धान जस्तै हरियो, लामो र मसिनो झूसले ढाकेको पात
फुलको रंग : सेतो
बाला : धानको जस्तै नुहेको वाला
दानाको आकार प्रकार/ रंग : सानो दुध जस्तो सेतो रङको दाना
जात छुट्याउने मुख्य गुणहरू : बोट र बाला धान जस्तो र दाना चाही धानको भन्दा सानो, बाला पाक्ने बेलामा पहेंलो भएता पनि दाना दुध जस्तो सेतो
बोटको औषत उचाई : १४५-१५५ से.मि.
५०% फुल फुल्ने समय : ३७-४५ दिन
बाली पाक्ने समय : ७८-९३ दिन
प्रति बोट बाला संख्या : १
प्रति बाला दाना संख्या : ९८३-१५५० दाना
औषत उत्पादन : ११५-१२० के.जी./रोपनी

हाडे चिनो **जातको पहिचान** : ठुला बाला, हल्का रातो, र कडा दाना **बोटको औषत उचाई :** १०५-११५ से.मि. **५०% फुल फुल्ने समय :** ८५-९५ दिन **बाली पाक्ने समय :** ११५-१२५ दिन **अन्य गुण** : सुक्खा सहने, नढल्ने, पोषिलो र आडिलो	
रातो चिनो **जातको पहिचान** : सेतो बाला, लामो झुस, चम्किलो हल्का रातो दाना **बोटको औषत उचाई :** १५५-१६० से.मि. **५०% फुल फुल्ने समय :** ४५-५० दिन **बाली पाक्ने समय :** ८०-८५ दिन **अन्य गुण** : सुक्खा नसहने, पोषिलो र आडिलो	

बीउदर र रोप्ने तरिका

चिनोको बीउ कडा हुने भएकाले रोप्नुपूर्व रातभर भिजाउनुपर्छ। त्यसपछि आवश्यक परेमा बीउको उपचार गर्नु पर्छ। भिजेको बीउ छायाँमा सुकाएर अलि ओभाएपछि मात्र रोप्नुपर्छ। स्वस्थ र रोगरहित बीउमात्र रोप्नुपर्छ। पङ्क्तिमा रोप्दा एक हेक्टरका लागि ८-१० के.जी. चाहिन्छ भने छरुवा तरिकाले रोप्दा १०-१२ के.जी. बीउ चाहिन्छ। तर पङ्क्तिमा रोपेको बाली गोडमेल गर्न सजिलो हुन्छ। पङ्क्ति देखि पङ्क्तिको दूरी २५ से.मी. र बिरुवादेखि बिरुवाको दूरी करिब १० से.मी. कायम गर्नु पर्छ भने बीउ ३-४ से.मी. गहिराइमा रोप्नुपर्छ।

बालामा विविधता

दानामा विविधता

रुखो ठाउँमा चिनो

चराले चिनो खाँदै

जग्गा छनोट

चिनो घाम मन पराउने (C-4 plant) बाली भएकाले यसलाई छाया पर्ने ठाउँमा खेती गर्नुहुँदैन। चिसो सहन नसक्ने हुँदा तुसारो पर्ने समय तथा ठाउँमा यसको खेती गर्नुहुँदैन। चिनोको खेती गर्दा जोतेका ठाउँमा भन्दा नजोतेका ठाउँमा खेती गर्दा बढी उत्पादन भएको पाइन्छ। चिनोलाई चराहरूले धेरै दुःख दिने भएकाले बीउ उत्पादनका लागि जग्गा छनोट गर्दा सकभर रूखहरूको नजिक छान्नुहुँदैन। बीउ उत्पादनको निम्ति सकेसम्म अघिल्लो वर्ष चिनो नलगाएको जग्गा छान्नुपर्दछ।

बीउ छनोट

चिनोको फूल र बाला झट्ट हेर्दा धानका जस्तै तर त्यस भन्दा केही ठूला हुन्छन्। चिनोमा आंशिकरूपले परपरागसेचन हुन्छ। बोटमा फूलहरू करिब एक हफ्तासम्म फुलिरहन्छन्। एकै जातभित्र पनि विविधता भएकाले छनोट प्रक्रियाबाट जातीय सुधार गर्न सकिन्छ। छनोटका लागि निरोगी बोट, धेरै गाँजिएको, ठूलो र लामो बाला, धेरै दाना भएका बाला, ठूलो र ढाडा पात भएको, ठूला दाना, स्वस्थ र रोगरहित बीउ, आँख्लामा हाँगा नभएको, दरिलो काण्ड र ठाडो भएको छान्नुपर्छ। दानाको छनोट गर्दा, बालाको माथिको भागबाट छान्नुपर्छ। बालामा दाना एकैचोटि नपाक्ने हुँदा दाना झर्ने समस्या धेरै जसो जातमा देखिन्छ। जातीय सुधार गर्दा दाना एकैचोटि पाक्ने खालका बोटहरू छान्नुपर्छ।

रोगकीरा व्यवस्थापन

चिनोमा ढुसी रोग, कालोपोके, डढुवा रोग, आदि रोग तथा डाँठ गभारो, गुभामा लाग्ने झिँगा, आदि कीरा लाग्छन्। सकेसम्म रोग कीरा अवरोधक बोटबाट बीउ छनोट गरी जातीय सुधार गर्दै जानुपर्छ। चिनोलाई चराबाट बचाउनुपर्छ।

कटानी/चुटानी

बालामा दानाहरू कडा र चमकदार भएपछि र बिरुवाका पातहरू पहेंला एवं खैरा भएपछि काट्न तयार हुन्छ। बालामा दानाहरू एकै चोटि नपाकी बालाका टुप्पाबाट पाक्दै आउँछन् र फेदतिरका दाना सबैभन्दा ढिला पाक्छन्। सबै दाना पाक्न दिंदा टुप्पातिरको दाना झर्ने हुनाले बालाको माथिल्लो आधा भाग पाकेपछि चिनो काट्नुपर्छ। चिनो काटेपछि बालाको तलको भागको दाना पाक्नका लागि केही दिन एकै ठाउँमा थुपारेर राख्नु पर्छ र पानीबाट बचाउनुपर्छ। हँसियाका सहायताले पहिले बालाहरू मात्र कटाइ गरेर ल्याई खलामा सुकाउने र पछि पराल कटाई गर्ने गरिन्छ। सुकेका बाला लौराले ठटाएर वा दाइँ गरेर चुट्न सकिन्छ। बत्ताएर एवं निफनेर दानाहरू सफा गरेपछि घाममा सुकाई बीउलाई कुटुक्क टोकिने (१२-१३% चिस्यान हुने) बेलासम्म सुकाएर राम्रोसँग बन्द गर्न सकिने टिनको भकारी, सुपर ब्याग/बोरा वा अन्य उपलब्ध भाँडामा सही सङ्केत पत्र (लेबल) सहित कम ओसिलो ठाउँमा भण्डारण गर्नु पर्दछ।

सन्दर्भ सामग्री

थापा प्रदिप, बाल कृष्ण जोशी, कृष्ण हरि घिमिरे, नीराजन पुडासैनी, सन्तोष श्रेष्ठ, श्रीप्रसाद न्यौपाने र देवेन्द्र गौचन। २०७९। उपयोग मार्फत संरक्षणको लागि सिफारिस भएका बालीका रैथाने जातहरूको सन्क्षिप्त परिचय। राष्ट्रिय कृषि आनुवंशिक स्रोत केन्द्र, खुमलटार।

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यो लेख निम्न प्रकाशित लेखबाट लिइएको हो

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जुनेलो खेती प्रविधि

सुमन ढकाल

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सारांश

नेपालमा जुनेलो बिगतमा परम्परागत रुपमा खेती हुँदै आएको देखिन्छ। अन्न बालीको रुपमा भन्दा पनि चारो बालीको रुपमा यसको खेती गरिने गरेको छ। यो बालीको खेतीको क्षेत्रफल, उत्पादन, उत्पादकत्व सम्बन्धी आधिकारिक तथ्यांक उपलब्ध रहेको छैन। गहुँको मैदाको विकल्पको रुपमा जुनेलोको पिठोलाई लिन सकिन्छ र यसको पिठो बेकरी प्रयोजनमा केक, कुकिज, पाउरोटी तयार गर्नका लागि उपर्युक्त मानिन्छ। पछिल्लो समय जुनेलोलाई विभिन्न होटेल एवं रेस्टुरेन्टमा समेत विभिन्न परिकार बनाउनका लागि प्रयोग भएको पाईन्छ। जुनेलो खेतीको आधार क्षेत्र निर्धारण, खेतीको लागि प्रोत्साहन, बीउको सहज उपलब्धता र बजारीकरणको उचित व्यवस्थापन गर्नु पर्ने देखिन्छ।

सामान्य बानस्पतिक चिनारी

हेर्दा मकैको बिरुवा जस्तै देखिने जुनेलो ०.५ देहि ४ मिटरसम्म अग्लो हुन्छ। मसिनो जरा हुने यो बालीको अधिकांश जरा माटोको माथिल्लो १५ से.मी. तहमा फैलिन्छन्। मकैमा जस्तै यसमा पनि टेवा दिने जराहरू माटोको नजिकमा रहेको डाँठको आँख्लाबाट निस्किन्छन्। ठोस डाँठमा जात अनुसार ८-२४ वटा पात हुन्छन्। लामो र च्याप्टो पात हेर्दा मकैको जस्तै देखिन्छ। बाला १० देखि ५० से.मी. सम्म लामो भेटिन्छ जुन खुकुलो वा कसिएको हुन सक्दछ। स्वपरागसेंचन हुने यस बालीको दाना सानो हुन्छ। दानाको एउटा छेउ अलिक तिखो र अलि खाल्टो परेको हुन्छ भने यसको रंग सेतो,गुलाबी,पहेंलो वा खैरो-पहेंलो हुन्छ।

बालीको हालको अवस्था

नेपालमा हाल जुनेलोको खेती निकै नै कम रहेको छ। अन्न बालीको रुपमा भन्दा पनि चारो बालीको रुपमा यसको खेती नेपालमा गरिने गरेको छ। यो बालीको खेतीको क्षेत्रफल,उत्पादन,उत्पादकत्व सम्बन्धी आधिकारिक तथ्यांक उपलब्ध रहेको छैन। बिगतमा पहाडका अधिकांश स्थानहरूमा यसको खेती गरिने भएतापनि हाल भने यसको खेती अत्यन्त न्यून रहेको छ। यसको उत्पादनको विविधिकरण हुन नसकेको, पौष्टिक महत्त्व, बाली चक्रमा यसको महत्त्वको सम्बन्धमा आवश्यक जानकारी प्रचार हुन नसकेको कारण पनि पहिलेको तुलनामा हाल यो बालीको क्षेत्रफल र उत्पादन दुवै न्यून रहेको पाईएको छ।

महत्त्व तथा विशेषता

९-११ प्रतिशत सम्म प्रोटीन प्राप्त हुने जुनेलो विश्वमा एक महत्त्वपूर्ण खाद्यान्न बालीको रुपमा चिनिन्छ। अन्न र पशुचाराको रुपमा यसको प्रयोग गर्ने सम्भावना प्रचुर रहेको छ। बढी सुक्खा सहन सक्ने बालीको रुपमा परिचित जुनेलोले अधिक पानी पनि सहन सक्छ। मकैको जत्तिकै उत्पादकत्व रहेको जुनेलो चाराबालीको रुपमा र साईलेज तयार गर्न पनि उत्तिकै लाभदायक हुन्छ। हाल नेपालमा व्यवसायिक पशुपालन बढ्दै गएको अवस्थामा चाराको लागि यो बाली निकै नै महत्त्वपूर्ण हुने देखिन्छ र यो सँगै मानिसहरूमा पौष्टिक चेतना समेत बढ्दै गएको हुँदा बालीको उत्पादन विविधिकरण मार्फत पनि बजार विस्तार हुने देखिन्छ। धार्मिक कार्य, पुजाआजा, अनुष्ठानमा प्रसादका साथै भोजनका लागि समेत प्रयोग गरिने जुन्लेओ औषधि बनाउन समेत प्रयोग गरिन्छ। जुनेलोले पित्त, मुत्र एवं पेट सफा हुनुका साथै स्फूर्ति बढाउन समेत उपयोगी हुन्छ। मुटु रोग एवं पत्थरी सँगै दम रोगको लागि पनि जुनेलो लाभदायी मानिन्छ। जुनेलोको सुप, रोटी एवं ढिडो तयार गरी प्रयोग गर्न सकिन्छ। गहुँको मैदाको विकल्पको रुपमा जुनेलोको पिठोलाई लिन सकिन्छ र यसको पिठो बेकरी प्रयोजनमा केक, कुकिज, पाउरोटी तयार गर्नका लागि उपर्युक्त मानिन्छ। पछिल्लो समय जुनेलोलाई

विभिन्न होटेल एवं रेस्टुरेन्टमा समेत विभिन्न परिकार बनाउनका लागि प्रयोग भएको पाईन्छ । यस्तोमा आगामी दिनहरूमा प्रशस्त सम्भावना भएको बालीहरूमा यो बाली पनि अग्र स्थानमा रहेको देखिन्छ ।

पहाडको भिरालो, खोरिया र रुखो बारीमा समेत सहजै उत्पादन गर्न सकिने भएपछि जुनेलोलाई न्युन मेहनतका साथ् उत्पादन लिन सकिने बालीमा पर्दछ । बाली रोपिएको करिब ६० दिनमै उत्पादन दिने र सिँचाइ सुविधा कम भएको र चिस्यान कम भएको माटोमा समेत सहज उत्पादन गर्न सकिने हुँदा पहाडमा बाँसो रहेको बारीको उपयोग र पौष्टिक सुरक्षाको दृष्टिकोणले समेत यो बाली उत्कृष्ट विकल्पको रुपमा लिन सकिन्छ ।

जुनेलोको बाला

जुनेलोको दाना

जुनेलोको आधुनिक उत्पादन

खेती प्रविधि

नेपालमा जुनेलोको बिगतमा परम्परागत रुपमा खेती हुँदै आएको देखिन्छ । विभिन्न धार्मिक कार्य एवं घरको पौष्टिक सुरक्षामा यो बालीको बिशेष महत्त्व रहेको कारण हरेक घरमा यसको थोरै भए पनि उत्पादन भएको देखिन्थ्यो तर पछिल्लो चरण यो प्रवृत्ति विस्तारै कम हुँदै गएको पाईन्छ । न्यानो हावापानी मन पराउने यो बालीलाई मकैको बैकल्पिक बालीको रुपमा बारीमा उत्पादन गर्ने गरिन्थ्यो । उन्नत बीउ बिजनको अभाव, उन्नत खेती प्रविधिको अभावले यसको उत्पादन अपेक्षाकृत रुपमा वृद्धि नहुँदा विस्तारै यसको खेती कम हुँदै गएको देखिन्छ तथापि हालको अवस्थामा सुधारिएको खेती पद्धति मार्फत यसको खेती गर्न सकेको खण्डमा उत्पादन वृद्धि मात्र होइन उत्पादित जुनेलोको बजारको समेत सहज बजारीकरण गर्न सकिने देखिन्छ । यसको लागि निम्न लिंखाति बुँदाहरूमा ध्यान पुर्याउनु पर्ने हुन्छ ।

हावापानी

न्यानो हावापानी रुचाउने जुनेलो समुन्द्री सतह देखि १५०० मी. उचाईसम्म खेती गर्न सकिन्छ । २५-३५° से. तापक्रम यसको वृद्धि बिकासको लागि राम्रो मानिन्छ । सुख्खा र बढी तापक्रम सहन सक्ने भएतापनि वार्षिक १०० से.मी. भन्दा अधिक वर्षा हुने क्षेत्रमा जुनेलो राम्रो हुँदैन र आद्रता बढी हुँदा पातमा रातो थोप्ले रोग लाग्ने सम्भावना रहन्छ ।

जातहरू

बालाको आकार र छाँट, दानको रंग र आकार र अन्य केहि गुणहरूका आधारमा जुनेलो मुख्यतय डुरा, कफिर, मिलो,शालु,काओलियाँग र फेटेरीटा गरी ६ प्रकारको हुन्छ । नेपालमा हालसम्म जुनेलोको जात सिफारिस गरिएको छैन तथापि केहि भारतीय जातहरू चारा बालीको लागि खेती गरिने गरेको छ ।

माटो

मलिलो दोमट वा चिम्टाईलो माटो जुनेलो खेतीको लागि उत्तम मानिन्छ । सिँचाइ नभएको स्थानमा पनि यसको खेती गर्न सकिन्छ । मकैको तुलनामा खेतमा पानी जमेको अवस्था पनि यसले सहन सक्छ तर लामो समयसम्म पानी जम्ने स्थान जुनेलोको लागि उपर्युक्त मानिदैन । राम्रो जलधारण क्षमता भएको माटोमा जुनेलोको राम्रो उब्जनी प्राप्त गर्न सकिन्छ ।

बाली चक्र र खेती प्रणाली

अन्नको लागि जुनेलो बर्खे बालीको रुपमा खेती गरिन्छ। जुनेलोसँगा अन्तरबालीको रुपमा मुंग,रहर,मास वा भटमास आदि प्रयोग गर्न सकिन्छ। निम्न लिंखाति बाली चक्र प्रमुखत: भेटिने गर्दछ।

- जुनेलो-गहुँ/जौ/चना/केराउ लगायत अन्य हिउँदे बाली
- जुनेलो-आलु/तोरी
- जुनेलो-गहुँ-मुंग/बोडी
- जुनेलो-हिउँदे बाली-सूर्यमुखी/बदाम

जमिनको तयारी

जुनेलो खेतीको लागि माटोको तयारी राम्ररी खनजोत गरी पाटा लगाई तयार गर्नु पर्दछ। एक पटक गहिरो जोताई पश्चात ३-४ पटक डल्ला फुट्ने गरी ठाडो र तेर्सो गरी जोतेमा बुर्बुराउँदो माटोमा जुनेलो मज्जाले लगाउन सकिन्छ। खनजोतको क्रममा झार नियन्त्रण पनि महत्त्वपूर्ण रहन्छ।

मलखाद

माटोबाट प्रशस्त मात्रामा खाद्यतत्व लिने बाली भएको हुँदा जुनेलो खेती गर्दा पर्याप्त परिमाणमा मलखाद दिनु आवश्यक छ। सिंचित जमिनमा २००-२५० क्विन्टल प्रति हेक्टर र असिन्चित जमिनमा १५०-२०० क्विन्टल प्रति हेक्टरको दरले राम्ररी पाकेको गोठे मल वा कम्पोस्ट मल बाली लगाउनु भन्दा लगभग १ महिना अगाडि जस्तो माटोमा हाल्नु पर्दछ। रासायनिक मल प्रयोग गर्नु पूर्व बर्षमा कम्तिमा एक पटक माटो परिक्षण गरी सो को आधारमा मात्र मलखाद प्रयोग गर्दा राम्रो हुन्छ। जाँचको सुविधा नभएको खण्डमा सिंचित अवस्थामा १००-१२०:५०:४० के.जी. नाईट्रोजन, फस्फोरस र पोटास प्रति हेक्टरको दरले प्रयोग गर्नु पर्दछ। सिफारिस मात्रको ५०% नाईट्रोजन र पूर्ण फस्फोरस र पोटास रोप्ने बेलामा हाल्नु पर्दछ भने बाँकी ५०% नाईट्रोजन रोपेको ३०-३५ दिनमा टपड्रेस गर्न सकिन्छ। मलखाद प्रयोग गर्दा माटोमा चिस्यान हुनु अत्यन्त आवश्यक हुन्छ। बीउ रोप्ने ड्रिल प्रयोग गरेको खण्डमा बीउ छर्ने बेलामै बीउ र मल एकनासले सामान गहिराईमा लगाउन सकिन्छ।

बाली लगाउने समय

अन्न बालीको रुपमा जुनेलो लगाउने समय भनेको असार महिना हो। ढिला गरी बाली लगाउँदा रोग किराको प्रकोप सँगै अर्को बाली लगाउने समय पनि ढिला हुन जान्छ। असिन्चित क्षेत्रमा मनसुन सुरु भएको हप्तादिनमा बाली लगाई सकेको हुनु पर्दछ।

चाराको रुपमा जुनेलो फाल्गुन देखि श्रावण सम्म लगाउन सकिन्छ। सिँचाइको सुविधा भएको क्षेत्रमा फाल्गुन चैत्र मै लगाउन सकिन्छ भने बर्खे चारा बालीको रुपमा भने असारमा लगाउनु पर्दछ। एकपटक भन्दा बढी कटानी दिने जातहरू सिँचाइको सुविधा सहित फाल्गुन चैत्रमा खेती गर्दा बढी मुनाफा लिन सकिन्छ।

बीउको दर र रोप्ने तरिका

उत्पादनको पहिलो र प्रमुख शर्त भनेकै गुणस्तरीय बीउ हो। गुणस्तरीय बीउको प्रयोगबाट उत्पादन २०-२५% सम्म वृद्धि गर्न सकिन्छ। त्यसैले खेती गर्नु पूर्व भरपर्दो स्रोतबाट बीउ प्राप्त गर्नु पर्दछ। रोप्नु पूर्व ढुसीनासक विषादी (२-३ ग्राम प्रति किलो बीउका दरले) बीउ उपचार गर्नु पर्दछ। लाईनमा रोप्दा १२-१५ के.जी. बीउ प्रति हेक्टरको दरले प्रयोग गर्नु पर्ने हुन्छ। हार देखि हारको दूरी ४०-४५ से.मी. कायम गरी २-४ से.मी. गहिराईमा बीउ रोप्नु पर्दछ। बोट देखि बोटको दूरी १५ से.मी. कायम गर्नु पर्दछ। लाईनमा रोप्नको लागि सिड ड्रिलको प्रयोग गर्न सकिन्छ जसले बीउ र मल एकनासले एकैपटकमा खेतमा राख्न सक्दछ। यसका अतिरिक्त हलोको पछाडी बीउ खसाल्ने विधि पनि धेरै प्रयोग हुने गर्दछ। समग्रमा राम्रो उत्पादनको लागि डेड लाख बिरुवा प्रति हेक्टर कायम गर्न सक्नु पर्दछ। बिरुवा संख्या बाक्लो भएको खण्डमा छटाई गर्न पनि सकिन्छ। चारा बालीको हकमा बीउको दर दुई देखि तीन गुना बढी प्रयोग गर्नु पर्दछ। चारा बालीमा छटाई आवश्यक हुँदैन।

सिँचाइ

बसन्ते बालीको रुपमा लगाइने जुनेलोको लागि सिँचाइ एक प्रमुख शर्त हो भने बर्खे जुनेलो आकाशे पानीकै भरमा खेती गरिन्छ। बसन्ते जुनेलोमा १५-२० दिनको अन्तरालमा माटोको चिस्यान हेरी सिँचाइ गर्न सकिन्छ। फुल फुल्ने बेला र दाना भर्ने बेलामा माटोमा चिस्यान नभएको खण्डमा सिँचाइको अनिवार्य व्यवस्थापन गर्नु पर्दछ, अन्यथा यसले उत्पादनमा निकै नै ह्रास ल्याउन सक्छ। बर्खे जुनेलोमा खासै सिँचाइको आवश्यकता नभए पनि निकासको उपर्युक्त व्यवस्थापन गर्नु जरुरी हुन्छ।

गोडमेल

बर्खे जुनेलोमा झारको प्रकोप तुलनात्मक रुपमा बसन्ते जुनेलोमा भन्दा बढी हुने गर्दछ। साँघुरो पाते र चौडा पाते दुवै झारहरूको प्रकोप बर्खे जुनेलोमा उच्च हुने गर्दछ। समयमै झार नियन्त्रण हुन नसक्दा यसले जुनेलो सँग प्रकाश,पानी,खाद्यतत्व र क्षेत्रफलको लागि प्रतिस्पर्धा गरी उत्पादनमा ह्रास ल्याउने हुँदा समयमै झारपातको उचित गोडमेल आवश्यक रहन्छ। झार नियन्त्रणको लागि गृष्मकालीन गहिरो जोताई निकै नै लाभदायक मानिन्छ। दुई देखि तिन पटक सम्म गहिरो गरी जोत्दा झारको प्रकोप कम हुन्छ। खडा बालीमा झार नियन्त्रणको लागि रोपेको ३ देखि ४ हप्तामा कुटोको माध्यमले गोडमेल गर्न सकिन्छ। विषादीको रुपमा Atrazin (०.५ देखि १ कि.ग्रा. सक्रिय पदार्थ प्रति हेक्टर) ६००-८०० लिटर पानीमा मिसाएर बीउ रोपेको २-३ भित्रमा छरेमा धेरै झारहरू नियन्त्रण गर्न सकिन्छ। माटोमा पर्याप्त चिस्यान र खेतमा कम आवतजावत हुँदा विषादीको प्रभावकारिता बढी हुन्छ।

बाली संरक्षण

जुनेलो बालीमा धेरै रोगहरू लाग्ने गर्दछ। बिरुवा डढुवा,सेते रोग,पात थोप्ले र कालो पोके जुनेलोमा लाग्ने प्रमुख रोगहरू हो। ढुसीले गर्दा हुने यी रोगहरू नियन्त्रणको लागि बीउको ढुसीनासक विषादीले उपचार गरेमा धेरै हद सम्म रोगको नियन्त्रण गर्न सकिन्छ तथापि खडा बालीको हकमा ढुसीनासक विषादीको प्रयोग स्प्रे मार्फत सिधै बिरुवामा गर्न सकिन्छ।

गुभो खाने किरा,गभारो,लाही,पात बेरुवा,झुसिलकिरा, फट्यांग्रा लगायतका किराहरूको प्रकोप पनि जुनेलोमा धेरै देखिन्छ। यसको नियन्त्रणको लागि चुसेर खाने किराको हकमा मेटासिस्टक (२५ ई.सी. एक मी.ली. प्रति लिटर पानीमा) प्रयोग गर्न सकिन्छ भने पात खाने किराको हकमा साईपरमेथ्रिन/डेल्टामेथ्रिन (१-२ मी.ली. प्रति लिटर पानीमा घोलेर) प्रयोग गर्न सकिन्छ। एक हेक्टरको लागि ८००-१००० लिटर घोल आवश्यक पर्दछ। गभारोको लागि खेतमा सरसफाई सँगै लार्भा नस्ट गर्ने र कर्बीरिल/इन्डोसल्फान प्रयोग गर्न सकिन्छ। दानादर विषादी ३-४ दाना सिधै गुबोमा पर्ने गरी प्रयोग गर्नु पर्दछ।

खेतीमा अन्य समस्या र व्यवस्थापन

जुनेलो खेतीमा अन्य विकराल समस्या खासै देखिएको छैन तथापि बसन्ते जुनेलोमा सिँचाइको स्रोत सुनिस्चित गरेर मात्र खेती गर्नु पर्दछ अन्यथा बालीबाट अपेक्षाकृत लाभ लिन सकिदैन।

बाली भित्राउने समय

सामान्यतय: अन्नबालीको रुपमा लगाइएको जुनेलो १००-१२० दिनमा तयार हुन्छ भने चारा बालीको रुपमा लगाइएको जुनेलो ७०-८० दिन पश्चात कटानी गर्न सकिन्छ। दानाहरू सार्हो भई चिस्यानको मात्रा २५% भन्दा कम रहेको अवस्थामा जुनेलो कटानीको लागि राम्रो मानिन्छ। बाला मात्र वा पुरै बोट सहित कटानी गर्न सकिन्छ। कटानी पश्चात बालालाई राम्रो सँग सुकाएर लौरो वा थ्रेसरको सहायताले चुटाई गर्न सकिन्छ। दानालाई ५-७ दिन सम्म घाममा राम्रो सँगै सुकाएर चिस्यान १३% भन्दा कम गराएर भण्डारण गर्नु उपर्युक्त हुन्छ।

मूल्य अभिवृद्धि, परिकार विविधिकरण र बजारीकरण

जुनेलोको दानालाई पिसेर पिठोको रुपमा वा सग्लो दानालाई मकैको जस्तै फुलाको रुपमा प्रयोग गर्न सकिन्छ। यसका अतिरिक्त जुनेलोलाई सिरपको रुपमा पनि प्रयोग गर्न सकिन्छ। जुनेलोको सिरप अरु विभिन्न प्रशोधित उत्पादनमा मिठास भर्न पनि प्रयोग हुने गरेको छ। १०० ग्राम जुनेलो मार्फत ३२९ ग्राम क्यालोरी,११ ग्राम प्रोटीन, ७ ग्राम फाइबर, ७२ ग्राम कार्बोहाइड्रेट प्राप्त हुन्छ। यो सँगै भिटामिनको राम्रो स्रोतको रुपमा पनि जुनेलोलाई लिने गरिन्छ। बेकरीमा यसको पिठोलाई ग्लुटिन रहित उत्पादनको लागि व्यापक प्रयोग गरिन्छ। ग्लुटिन अलर्जी भएकाहरूलाई जुनेलोको परिकार राम्रो विकल्प हुने गरेको छ। व्यापक प्रचार र यसको पौष्टिक महत्त्व बुझाउन सकेमा जुनेलोको बजार राम्रो रहेको छ।

जातिय संरक्षणको महत्त्व एवं उपायहरू

कुनै पनि बिरुवाको बिकासको लागि जातीय संरक्षणको निकै नै ठुलो महत्त्व हुन्छ। हाइब्रिड जातको विकास, खोजेको गुण विकास देखि रोग किरा सहन सक्ने जातको विकाससम्मका कार्य जातीय संरक्षण बिना असम्भव प्राय हुन्छ। तसर्थ हाल नेपालमा रहेका जुनेलोको जातीय संरक्षण सँग सँगै जातीय विकासको कार्य अगाडि बढाउन आवश्यक देखिन्छ। यसको लागि जुनेलो खेतीको आधार क्षेत्र निर्धारण, खेतीको लागि प्रोत्साहन, बीउको सहज उपलब्धता र बजारीकरणको उचित व्यवस्थापन अनिवार्य सर्तहरू हुन्।

सन्दर्भ सामग्री

नेपालका बालीनाली र तिनको दिगो खेती, नरबहादुर साउद। २०६७। साझा प्रकाशन, पुल्चोक, ललितपुर।

आधारभूत बाली संरक्षण, सुलभ पौडेल, राजेन्द्र आचार्य। २०७२। हेरिटेज पब्लिसर्स एण्ड डिस्ट्रिब्युटर्स प्रा.ली. भोटाहिटी, काठमाडौँ।

वैज्ञानिक बाली उत्पादन, एन. पी. सिंह, आर. ए. सिंह, कल्याणी पब्लिशर्स, भारत।

बाली उत्पादनको आधुनिक विधि, चिद्धा सिंह, १९८३, अक्शफोर्ड र आई.बि.एच. पब्लिशिंग को., नयाँ दिल्ली, भारत।

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Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Evaluation of Sorghum Mutants with Respect to Sowing Dates and Row Spacings in the Central Mid-Hill of Nepal

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Abstract

Sorghum, an important drought tolerant crop, is less important and understood millet in Nepal but can be a vital crop species in the drought prone areas for food, feed and nutritional security. With the objective of exploring agronomy of sorghum, field experiments were conducted in the research block of National Agronomy Research Centre, Khumaltar, Lalitpur during the summer of 2019 and 2020. The experiment was laid in split-split plot design with two mutant sorghum varieties (Pahat and Samurai) assigned to main-plots, four sowing dates in sub plots (14th May, 24th May, 3rd June and 13th June) and two row spacings (45 cm and 60 cm) in sub-sub plots. The results of the experiments revealed that the two mutant varieties were high yielding (6.5 to 8.5 t/ha). Pahat was taller than Samurai. Sowing sorghum from May to June has either same or increasing yield advantage. Sowing from May to June first week had around 8 t/ha of yield in 2019 and in 2020 even delaying the sowing up-to mid of June could improve yield and associated traits of mutant sorghum. Therefore, mutant sorghum in the central mid-hill can be planted from May to June with relatively larger planting window. This finding implies that rainfed mid-hills of Nepal could possibly be benefitted with sorghum planting even if the monsoon starts earlier or gets delayed. Also, the evaluated mutants responded well up-to the plant population of about 1,50,000 per hectare ie, in the narrower row spacing of 45 cm.

Keywords: Drought tolerant, optimum sowing time, sorghum, plant population, row spacing, underutilized

Introduction

Sorghum (Sorghum bicolor L.) is one of the millets grown across the mid-hills and terai part of Nepal. Sorghum is also known as “Junelo” in Nepal. Production and area information of sorghum is difficult to find as national records covers only millets which accommodates all the millets produced in the country. Sorghum is one of the important food grains that has tremendous potential to be future smart food and occupies an important place to feed the ever-growing population along with its multiple uses. Sorghum is drought and salinity resistant crop adaptive to various soils and climate with very low maintenance demand along with multiple uses (Taylor, 2019). Not only its use in food and nutritional security, sorghum is considered one of the best among climate smart crops that is supposed to endure the demand of food in future covering the arid and semi-arid areas into its cultivation (Prasad and Staggenborg, 2011). Sorghum is fourth most important food grains in the world (Dong et al 2017) and third in India, however, it is neglected or underutilized food crops in terms of importance to Nepal. Sorghum is grown across the country in the marginal areas especially as livestock feed. Most of the cultivars grown are popping type and some are of fodder type. Nepal Gene bank has 15 accessions of sorghum preserved (Ghimire et al 2017). It is one of the neglected and underutilized crops in Nepal which is very aloof from the limelight of agricultural research and development despite being the super food and abilities to respond well to stressful climatic condition. Therefore, sorghum falls under less explored and understood millets in terms of Nepalese agriculture perspective although it has a prominent space in the rural households of Nepal. Unlike other millets, finger millet, foxtail millet and proso millet, it has meager information and exploration.

Seeds of Indonesian mutant sorghum varieties (Pahat and Samurai) were received for research purpose from the International Atomic Energy Agency's (IAEA) Mutation Breeding project under Nepal Agriculture Research Council (NARC) and were evaluated for agronomic characteristics. Crop growth and development is influenced by changes in temperature and water regimes, subsequently affecting yield. Therefore, efficient crop production requires understanding the response of sorghum under various management practices which would allow optimizing the use of all environment-plant resources to minimize yield gaps (Ciampitti et al 2019). The received mutant sorghum varieties were evaluated with respect to sowing dates and row spacings.

Materials and Methods

Field experiments were carried out during the summer of 2019 and 2020 in the upland research block of National Agronomy Research Centre, Khumaltar to evaluate the sorghum mutant varieties under different sowing dates and row spacings. The experimental plot is situated in the central mid-hills at an altitude of 1360 masl and is predominated with silty clay loam type of soil. The experiment was laid out in split-split plot design with three replications. Initial idea was to accommodate one local variety from Nepal but it required the huge experimental set up or the other factor needed to be omitted so we finally settled with only two mutant sorghum varieties. The experiments were conducted in two different plots in successive years. In the first year, we acquired the marginal plot just by the side of the terrace containing tall trees while in the second year we managed proper plot. Two sorghum mutant varieties (Pahat and Samurai) assigned to main plots, four sowing dates (14th May, 24th May, 3rd June and 13th June) in sub plots and two row spacing (45 cm and 60 cm) in sub-sub plots. Sorghum seeds were planted continuously in rows and later plants were thinned out at 15 cm apart. Plot size was 3.6 m X 3 m. Chemical fertilizer was used @ 90:45:45N:P2O5:K2O kg/ha. One third dose of nitrogen and all phosphorus and potash were applied as basal dose and remaining nitrogen was applied in two splits (one at the time of knee height stage and another prior to tasseling). Nitrogen was applied through urea, phosphorus through DAP and potash through MOP. All the recommended agronomic practices were carried out for all the treatments. Randomly five plants were selected for data collection of plant height, panicle length and panicle weight. Grain yield and straw dry matter were calculated from the net plot area (2.7 sq. m in 45 cm spacing and 3.6 sq. m in 60 cm row spacing). Grain yield per hectare was adjusted to 14% moisture content. The data obtained were analyzed using MSTAT-C statistical package.

Picture 1. Sowing Sorghum in rows

Picture 2. Sorghum germination

Meteorological data during the experimental period

The highest mean maximum temperature (29.8 °C) was observed during the month of June in 2019 while it was observed during August in 2020 (28.8 °C) (**Figure 1**). The lowest mean minimum temperatures (10.1 and 7.5 °C) were observed during the month of November in both the years. The year 2020 received 1212.5 mm of rainfall throughout the growing period while the year 2019 received only 1050.8 mm of rainfall. Minimum monthly rainfall of 68.1 mm was recorded during the sowing time in June in 2019 while in 2020 the minimum monthly rainfall during the sowing time was during May (151.2 mm). The year 2020 observed 3 more number of rainy days compared to 2019 (94) during the growing period of sorghum.

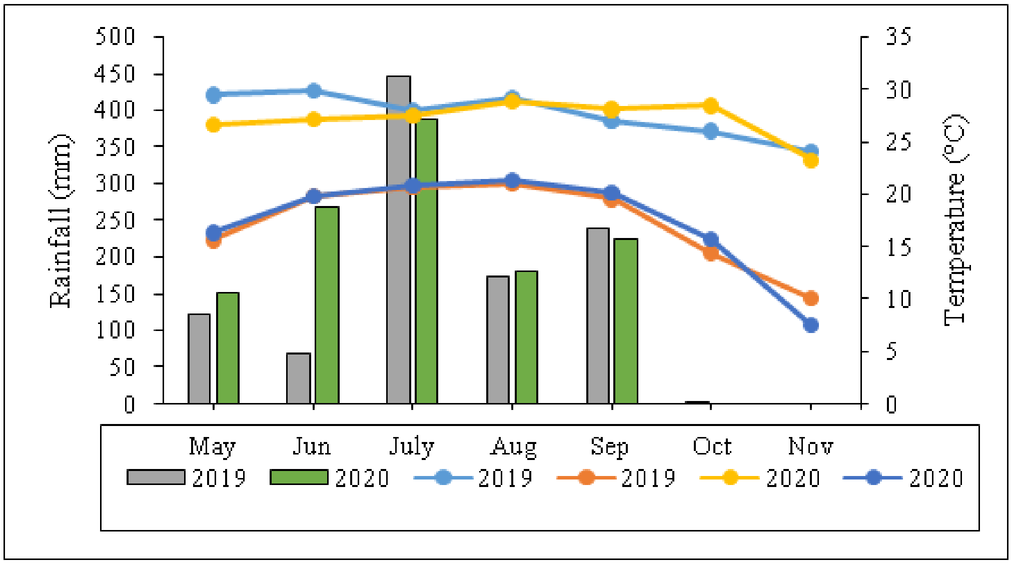

Figure 1. Mean monthly maximum/minimum temperatures and total monthly rainfall recorded during 2019 and 2020

Soil Properties

Table 1. Physico-chemical properties of soil of experimental site

Soil parameters	Value/Class	Remarks
pH	5.98	slight acidic
Total Nitrogen	0.14%	Medium
Available Phosphorus	478.6 kg/ha	High
Available Potassium	160.5 kg/ha	Medium
Texture	Silty clay-loam	

The soil of the experimental site was slight acidic, silty clay-loam and was not low to very low on any macro nutrient.

Results and Discussion

Plant height

Plant height was significantly influenced due to varieties but not due to sowing date and row spacing in both the years 2019 and 2020. Also, no interaction effect among the factors was observed in plant height (**Table 2**). Pahat was observed to be the taller among the two mutant sorghum varieties where it grew 326 cm than Samurai (224 cm) however, in 2020 Pahat was 285 cm and Samurai was only 191 cm. On the other hand, sowing dates had non-significant effect on the plant height but the trend of plant height tend to decrease with subsequent delay in sowing dates in 2019 but it was found to increase slightly with the delayed sowing date in 2020. Similarly, the plants were found to be slightly taller in 45 cm spaced plots in 2020 but no such effect was observed in 2019.

Panicle length

Panicle length was significantly influenced by varieties and sowing dates in 2019 but in 2020, sowing dates only influenced the panicle length significantly (**Table 2**). The three factors did not have any significant interaction effect in 2019 but varieties and sowing dates had only significant interaction effect in 2020.

Panicle length of Samurai (30 cm) was found to be significantly longer than that of Pahat (24 cm) in 2019 while the difference was non-significant in 2020 but still Samurai had longer panicles. Significantly the longest panicle was recorded in 3rd June sowing followed by 13th June, 14th May and 4th May, respectively, in 2020 while in 2019 13th June sowing recorded significantly the smallest panicle (24 cm) compared to other sowing dates which were statistically at par with each other.

Panicle weight

Sowing dates significantly affected the panicle weight in both the years but row spacing influenced panicle weight only in 2019 while it remained uninfluenced due to varieties (**Table 2**). Samurai recorded highest panicle weight of 104 g while Pahat recorded only 79 g in 2019 but in 2020 the panicles of both varieties were smaller but of similar weights.

In 2019, the first three sowing dates recorded similar panicle weights but 13th June sown sorghum observed drastic reduction in the panicle weight (56.7 g).14th May sown sorghum had the highest panicle weight (108 g). However, in 2020 the panicle weight was found to increase with subsequent delay in sowing from 53 g to significantly the highest in sowing done in 13th June (103 g). Similarly, panicle weight was found significantly higher in 60 cm spaced rows (96 g) compared to 45 cm spaced rows (86 g) in 2019 but in 2020, there was non-significant difference in panicle weight due to row spacing although 65 cm spaced rows sowed slightly heavier panicles.

Picture 3. Sown on May end, 45 cm row spacing

Picture 3. Sown on May end, 60 cm row spacing

Table 2. Plant height, panicle length and panicle weight of sorghum as influenced by varieties, sowing dates and row spacings

Treatments	PTH		Plgt		Pwgt	
	2019	2020	2019	2020	2019	2020
Variety (A)						
Pahat	326	285	26	27	79	72

Treatments	PTH		Plgt		Pwgt	
	2019	2020	2019	2020	2019	2020
Samurai	224	191	30	28	104	72
LSD (<0.05)	63	28.15	1.24	ns	ns	ns
Sowing Dates (B)						
14 May (Baisakh 31)	281	234	29	26	108	53
24 May (Jestha 10)	276	235	29	27	101	57
3 June (Jestha 20)	275	231	29	29	100	75
13 June (Jestha 30)	269	252	24	28	56.7	103
LSD (<0.05)	ns	ns	1.74	0.74	12.77	16.43
Row Spacing (C)						
45 cm	275	241	28	28	86	71
60 cm	276	235	28	27	96	73
LSD (<0.05)	ns	ns	ns	ns	4.70	ns
A*B	ns	ns	ns	1.04	18.05	ns
A*C	ns	ns	ns	ns	ns	ns
B*C	ns	ns	ns	ns	ns	ns
A*B*C	ns	ns	ns	ns	ns	ns
CV, %	3.28	7.13	5.49	5.55	8.41	13.18
Grand Mean	275	238	28	27.5	91	72

PTH: Plant height (cm), Plgt: Panicle length (cm), Pwgt: Panicle weight (g),

Harvest index

Varieties significantly influenced harvest index in both the years but sowing dates had significant influence in 2019 only and row spacings did not influence harvest index in both the years (**Table 3**). Samurai had significantly higher harvest index than Pahat provided its better grain production per unit biomass accumulation. Harvest index slightly improved with the successive sowing dates but reduced with 13th June planting in both years.

Thousand grain weight

Thousand grain weight remained unaffected due to varieties sowing dates and row spacing in both years except in 2019 where sowing date had significant difference in thousand grain weight (**Table 3**). The grain size shrank with successive delay in sowing in 2019 but no such effect was observed in 2020.

Grain yield

Grain yield of sorghum was significantly influenced by varieties, sowing dates and row spacings in 2019 but in 2020 varieties did not significantly influence the grain yield of sorghum (**Table 3**). Interaction effect of varieties and sowing date was significant in 2019 but all other interactions remained insignificant in both the years. Mean grain yield of Samurai was significantly higher (8.66 t/ha) than that of Pahat (6.46 t/ha) in 2019 but in 2020 both varieties were similar in yield. Grain yield of sorghum was statistically at par in the first three sowing dates (around 8.5 t/ha) but grain yield reduced to 4.2 t/ha when sowing was delayed or done on 13th of June in 2019 but the grain yield showed the trend of increment with the successive sowing dates in 2020. Significantly the highest grain yield was obtained with 13th June planting (8.96 t/ha) followed by 3rd June (7.56 t/ha), 24th May (5.87 t/ha) and 14th May (5.25 t/ha), respectively. Grain yield was significantly higher in 45 cm spaced rows compared to 60 cm spacing in both the years. 22-26% more grain yield was obtained with narrow spaced rows than widely spaced rows. More number of plants per unit area in narrow spaced rows led to more grain yield.

Straw dry matter

Straw dry matter was significantly influenced by varieties, sowing dates and row spacings in both the years. Interaction effect was significant for variety and row spacing as well as sowing date and row spacing in 2019 but none in 2020 (**Table 3**). Pahat accumulated significantly the higher dry matter than Samurai. Samurai was sort statured and thereby bore less biomass than Pahat. The trend of straw dry matter with different varieties, sowing dates and row spacings were similar to that of grain yield in both years.

Picture 5 and **6**. Sorghum during grain filling stage

Table 3. Harvest index, thousand grain weight, grain yield and straw yield of sorghum as influenced by varieties, sowing dates and row spacings

Treatments	HI		TGW		Gyld		SDM	
	2019	2020	2019	2020	2019	2020	2019	2020
Variety (A)								
Pahat	0.17	0.23	21.07	25.12	6.46	6.88	27.61	19.05
Samurai	0.24	0.28	20.90	23.68	8.66	6.94	23.34	15.68
LSD (<0.05)	0.04	0.03	ns	ns	2.18	ns	2.14	1.73
Sowing Dates (B)								
14 May (Baisakh 31)	0.19	0.24	23.21	24.83	8.63	5.25	31.15	14.68
24 May (Jestha 10)	0.23	0.26	21.35	23.91	8.97	5.87	25.95	14.23
3 June (Jestha 20)	0.24	0.26	20.70	24.17	8.39	7.56	23.48	17.79
13 June (Jestha 30)	0.15	0.25	18.67	24.75	4.24	8.96	21.32	22.76
LSD (<0.05)	0.09	ns	1.68	ns	1.39	1.32	6.41	3.68
Row Spacing (C)								
45 cm	0.21	0.25	21.07	24.51	8.32	7.7	28.26	19.25
60 cm	0.20	0.25	20.89	24.29	6.78	6.1	22.69	15.48
LSD (<0.05)	ns	ns	ns	ns	0.74	0.31	2.14	1.15
A*B	0.05	ns	2.37	ns	1.96	ns	ns	ns
A*C	ns	ns	ns	ns	ns	ns	3.03	ns
B*C	0.04	ns	ns	ns	ns	ns	4.28	ns
A*B*C	ns	ns	ns	ns	ns	ns	ns	ns

Treatments	HI		TGW		Gyld		SDM	
	2019	2020	2019	2020	2019	2020	2019	2020
CV, %	13.82	9.84	3.75	4.26	16.01	7.45	13.75	10.83
Grand Mean	**0.20**	**0.25**	**20.98**	**24.40**	**7.56**	**6.9**	**25.48**	**17.38**

Gyld: Grain yield (t/ha), SDM: Straw dry matter (t/ha), HI: Harvest index, TGW: Thousand grain weight (g).

Varietal characteristics

Characteristics	Pahat	Samurai
Plant height (cm)	285-326	191-224
Panicle length (cm)	26-27	28-30
Panicle weigh (g)	72-79	72-104
Maturity days	130-145	130-145
Grain yield (t/ha)	6.5-6.9	7-8.5

Samurai was short in stature, almost a meter shorter than Pahat. Pahat, however, was taller and highly susceptible to lodging during grain filling stage. Grain yield of Samurai was higher than that of Pahat as it had larger and heavier panicles.

Optimum planting dates of sorghum or any crops differs with the growing season, region and cropping system. Optimization of planting dates are important to receive satisfactory yield, avoiding the stressful environmental conditions, diseases and pests. Crop growth and development changes with temperature and available soil moisture, therefore it is imperative to understand the crop biology, varietal potential and site-specific optimum sowing time and optimum plant population per unit area to realize the maximum yield from crops. The results of the experiment showed that delayed sowing has either similar yield or increased yield in both the years but during 2019, 13th June sowing showed drastic reduction of the yield and yield components. During 2019 the experimental plot was near to the tree lines on the southern side. The length of the day starts decreasing. As we know that after June, position of sun changes towards the southern part of sky which reduces the length of the day and again goes to the northern side after December which increases the length of the day. Therefore, the 13th June sown sorghum which showed drastic reduction of yield might not have received the enough sunlight and accumulate sufficient temperature for its proper growth and development, intercepted by the tree lines on south of experimental plot. But in the second-year where proper plot was used for experiment with no shading trees nearby, delayed sowing showed improvement in the yield and associated traits of sorghum. Therefore, in Nepal there lies sufficient and wider window for sorghum plantation starting from May to June. Azrag and Dagash, 2015 in a study in Indonesia observed that sowing from mid-July to first week of August as optimum time of sowing grain sorghum. But another research in Missouri indicated that planting date had a small and inconsistent effect on grain sorghum yield, and a rather wide planting date window was found (Conley and Wiebold, 2003). Awopety 1995 observed decline in grain yield of sorghum on subsequent delayed sowing dates from 16 June to 30 July in Nigeria.

Grain and straw yield were significantly higher in 45 cm row spacing which was mainly due to higher number of plant population per unit area (33% more) than that of 60 cm row spacing. 60 cm row spacing had larger panicles which might be due to lower inter plant competition than 45 cm row spacing. Optimum plant population of sorghum depends upon the choice of variety (hybrid, short or long duration) and growing conditions. Early maturing and dwarf varieties may respond up to 300000 plants per hectare in medium fertile soils while in high fertile soils medium maturing varieties can be accommodated to 150000 plants per hectare (LAAS, 1988, Han et al 2021).

Conclusion

The results indicate that both the hybrids are well performing and in the environment of central mid-hills. The optimum sowing time for mutant sorghum was found to be wide window from May to June when the accumulative temperature avails for growth and development of sorghum. More number of sowing dates in the further research is required to demark the length of the seasonal window for sorghum growth and development. The plant population for mutant sorghum can be as high as 150000 per hectare in narrower row spacing of 45 cm without compromising the yield.

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Seed Quality Control of Millets in Nepal

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Summary

Nepal is adopting two types of seed quality control mechanism ie, certification system and truthful label system. Seed certification system requires the mandatory engagement of seed certifying agencies of government to certify the seeds, whereas truthful label system of seed certification does not require the mandatory engagement of seed certifying agencies. In case of millets, the seed certification directive of Nepal, 2017 has included the certification standards for finger millet only. As of now, seed certification standards for other species of millets like proso millet, foxtail millet etc have not been covered in the existing seed certification policies in Nepal. General and specific seed certification standards have been provisioned to certify the finger millet seed in Nepal. The isolation distance for producing foundation and certified seeds of finger millet is 5 meters. The two inspections before or during flowering and at the maturity stage are mandatory in finger millet seed production. The minimum physical purity and germination percentage are 97% and 75% for both foundation and certified seeds whereas 96% and 70% for the improved seeds of finger millet. The maximum allowed inert matters is 3% for both foundation and certified seeds whereas the maximum allowed offtype plants is 0.1% and 0.2% to certify foundation and certified seeds, respectively. It is suggested to review the exiting quality control mechanisms in finger millet and also develop the quality control mechanisms though defining the seed and field standard for other millet species being cultivated at commercial scale in Nepal.

Keywords: Certification, certified seed, foundation seed, millets, seed quality, truthful label

Background

The use of quality seeds of improved varieties is crucial to increase crop productivity and income of small-holder farmers. According to Gauchan et al 2014, sufficient quantity of quality seeds of high yielding varieties has the potential to increase crop yields by 15-25%. Quality seed is considered as the basic, critical and cheapest input for enhancing productivity (Sapkota et al 2011). To a large extent, the quality of seed determines the success of crops in terms of yield (and yield stability) and product quality, and thus its contribution to food security and the value of crop products in the market (Louwaars and de Boef, 2012). Seed quality control and assurance is the combined efforts and activities undertaken to ensure that the seeds that are being produced for the end users (farmers) conform to minimum quality standards. The main goal of quality control is to ensure that clients have access to seeds which are genetically pure, free from seed borne diseases, free from weed seeds and pests and produced in conformance of minimum requirements in terms of physical purity, germination and moisture content (WCDI, 2020).

As in many other developing and least-developed countries of Africa, Asia and other regions, Nepal's seed sector is also divided into formal and informal seed systems (Adhikari, 2016). The government's "National Seed Vision 2013- 2025: Seed Sector Development Strategy" (hereafter Seed Vision) recognizes the presence of formal and informal seed systems in the country. The informal seed system is characterized by farmers producing and preserving their own seeds for subsequent planting. Often, they exchange this small quantity of seed with other farmers as gift, and for both monetary and non-monetary value. Most traditional and local landraces are product of such selection and maintenance process. In addition, these landraces are important genetic resources for modern plant breeding. The formal seed systems are characterized by a vertically organized production and distribution of tested and released/registered varieties by public and private organizations using agreed quality control mechanism (NSV, 2013).

Quality control mechanism of seed in Nepal (including notified varieties of millets)

The existing seed policies and legislations have basically focused on creating a supportive policy environment for the formal seed system. As of now, none of the seed related policies are under implementation to deal with the informal or customary seed system. The government's sole focus is on introducing strategic plans and measures for expanding the use of formal seeds of high-yielding varieties, including hybrids. Such an expansion is generally made possible by designing seed extension programs to increase the replacement rates of formal seeds of both cereal and vegetable crops (Adhikari, 2016). Although the Seed Vision recognizes that there are limited number of farmer-preferred improved varieties developed, released and maintained through the formal seed system and that the formal seed system contributes less than the informal seed system to address farmers' requirements of crop seeds in Nepal, the scientific and the appropriate seed quality control mechanisms for land races and indigenous seeds has not been formulated and implemented in Nepal. However, the issue of formulating the appropriate policy to regulate the quality of seeds of farmers' variety has been raised in recent times. Hopefully, it will get materialized at the earliest in Nepal.

Quality control is an essential component of a viable and dependable seed development program. Quality seed is ensured and guaranteed through checks, ie field inspections to establish genetic/varietal purity and laboratory tests to record physical purity, germination, vigor, moisture content and seed health (Rana, 1997). The purpose of seed certification is to make the high-quality seed available to farmers with high physical and genetic identity to increase productivity and production of crops. As per the existing seed regulation, Nepal is adopting two types of seed quality control mechanism (GoN 2013) as stated below:

Certification system

Seed certification is a comprehensive quality control system, in which quality control agency is responsible for monitoring and supervision of different agricultural activities related to seed production for maintaining quality of seed from sowing to marketing. This is accomplished through field inspections and laboratory testing by the staffs of authorized seed certification agency. The activities engaged would be the field inspection, harvesting, threshing and storage, inspection, seed sampling and testing, processing, treating, bagging and issuing of certificates to suitable seed lots and testing of seed lots before marketing. Seed certification system needs high level government resources in terms of equipment, infrastructural facilities and trained manpower (Rana and Raut, 1997). Seed classes under this system are:

- Breeder seeds
- Foundation seeds
- Certified seeds
- Improved seeds

Truthful label system

In truthful labeling system, seed producers are free to produce and sell their seeds by their own quality control mechanism through filed inspection and laboratory testing. However, seed producers/traders are responsible for maintaining minimum quality of seed and are also compelled for labeling of container to bring the seeds in the market. Notified seed inspector will draw the enforcement samples and if the seed offered for sale could not meet the minimum seed standard, then seed producers or seller are not allowed to sale seeds in the market. This system does not need the direct engagement of quality control agencies. The quality parameters of this system should exactly comply with what is mentioned for seed certification system (GoN 2017). The seed classes for this system are:

- Breeder Seeds
- Source Seeds
- Label Seeds
- Improved Seeds

For developing countries like Nepal, where quality control wing is still suffering from enough resources and manpower crunch, truthful labeling could be one of the most practical and cost-effective quality control systems to ensure the good quality seed for seed market.

Seed Certification Standards of Millets

In Nepal, Seed Certification Directive, 2017 has been in place to regulate the overall seed certificate process of seeds of various crops. The seed standards and field standards of seeds of various crops grown in Nepal has been mentioned in the directives and seed certifying agencies of Nepal have to strictly follow the provision of this directive while certifying the seeds. However, the directive seems quite incomplete and inadequate as it does not include the seed and field standards for many land races and indigenous crops which are still abundantly grown in Nepal. As discussed in previous section, this directive basically focusses on provisioning the quality standards of seeds that have been produced from formal seed system.

However, neighboring country India has established a well framed seed certification system for various types of millets. India is the one of the major producers of millets in the world. They are often grown in diverse soils, climates and harsh environments. Seed production stages are: Breeder seed, Foundation seed and Certified seed. India has developed the standard of different millets which are mentioned below in the table.

Table 1. Field and seed standard of Foundation and certified seeds in India

Standard	Crop						
	Pearl millet	Finger millet	Kodo millet	Foxtail millet	Proso millet	Little millet	Barnyard millet
No. of inspection	3	2	2	2	2	2	2
Isolation distance	FS (400 m) CS (200m)	3m	3m	3m	3m	3m	3m
Physical purity %	98	97	97	97	97	97	97
Innert matter %	2	2	2	2	2	2	2
Germination %	80	75	75	75	75	75	75
Moisture content %	5-12 %	12	12	12	12	12	12

Source: Mahalinga (2013)

In case of millets, the seed certification directive of Nepal has only included the certification standards for finger millet. As of now, seed certification standards for other types of millets like proso-millet, fox tail millets etc. have not been covered in the directive. However, the initiative has recently taken by National Seed Board to develop the seed certification standards of those crops which are not included in current directive, including landraces. The following section highlights the seed certification standards of finger millet in Nepal.

General seed certification standards to certify seeds of millets (finger millet) describes verification of seed source, seed class, validity period of seed, and minimum area of seed crop for certification, eligible varieties and seed certification sequence. Specific seed certification standards include minimum field standards, minimum crop standards and minimum seed standards of produced seed to maintain the high physical and genetic integrity of the finger millet seed.

General seed certification standards

Verification of source seed and seed classes

Millet (finger millet) seed producers should apply for seed certification with prescribed format to the certification agency along with relevant evidence about the source seed, such as certification tags/or tags issued by commodity program for breeder seed. Such evidences are necessary to confirm that source used for seed production is obtained from the source approved by seed certification agency and from research station in case of breeder seeds. If such evidences are not supplied during the application period, then those must be made available during first field inspection instant.

Validity period of seed certification

According to Seed Regulation 2013, if seed is properly and safely stored, the validity period of seed remains for six months. However, validity period can be extended continuously for six more months as long as it meets minimum prescribed seed standards during revalidation tests. With this rule, validity period of certified millet (finger millet) seed also remains for six months and it can be extended following revalidation.

Minimum area and eligible varieties for seed certification

Minimum area of finger millet crop shall be at least one hectare in Tarai and five ropani in hills for seed certification. This area may belong to one farmer or group of farmers. Only finger millet varieties released or registered from National Seed Board are eligible for seed certification.

Seed certification sequence

The whole sequence of seed certification can be summarized as below:

- Receipt and scrutiny of application.
- Verification of seed source, class and other requirements of seed, used for raising seed crop.
- To verify land requirement whether it meets seed certification standards or not.
- Field inspection to verify the isolation distance and minimum prescribed field standard.
- Supervision of harvesting and threshing to avoid mechanical mixing..
- Inspection and sampling of seed lot as prescribed procedure.
- Inspection and sampling of seed lot as prescribed procedure.
- Analysis of seed sample in laboratory to verify the prescribe seed standards.
- Supervision of processing, treating, bagging and sealing of seed lot..
- Supervision of processing, treating, bagging and sealing of seed lot.
- Issuing of certification tags to suitable seed lot (See figure 2 for tag details).
- Sampling and testing of seed lot again to verify the minimum prescribed seed standard before marketing of seed.

Figure 1. Steps of millet seeds certification

Specific seed certification standard

Minimum field Standard

Land requirement: Land to be used for seed production of millet (finger millet) shall be free from volunteer plants.

Isolation distance: Finger millet is self-pollinated crop. So, seed production field of finger millet producing foundation and certified seeds shall be isolated by at least 5 m from the field of other finger millet variety or field of same variety but not conforming varietal purity.

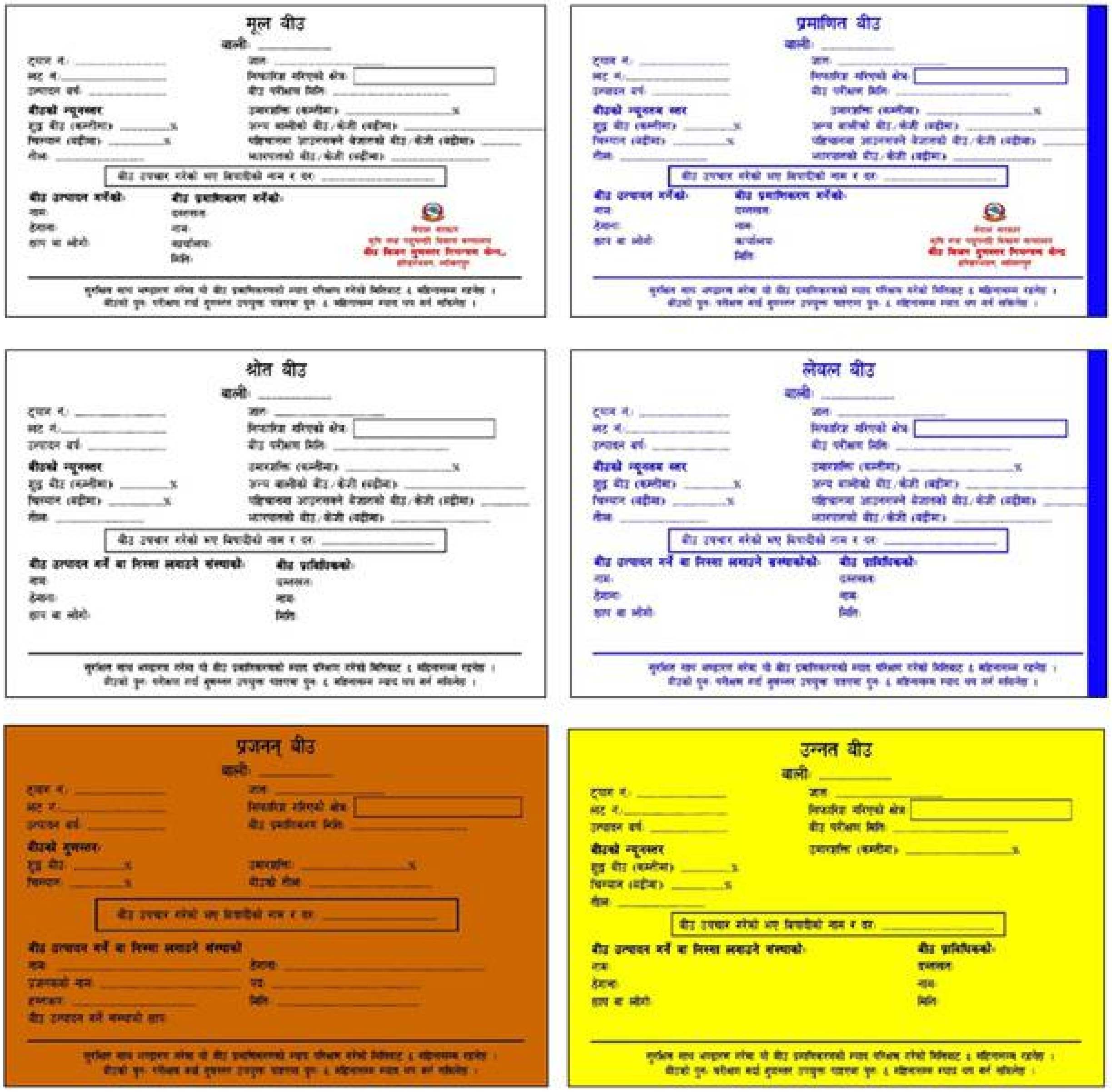

Figure 2. Tag color and descriptions for seeds of different classes under certification and truthful label system

Field inspection standard: To assure minimum crop standards, field inspection is carried out at different crop stages to determine the extent of off type plants, other crop plants, weed plants (general and designated both) and diseased plants in field, which shall be responsible to deteriorate the quality of the finger millet seed. Farmers should remove these contaminants before the visit of crop inspector through the process of rouging. Rouging can be done several times as far as possible to remove the contaminants and other doubtful and dissimilar plants from the field. However, a minimum two times rouging, one in pre-flowering stage and another in before maturity of the crop, is necessary to maintain the varietal as well as physical purity of the finger millet seed. All off-types and objectionable weed plants (weed plants that produce the seeds which are similar in shape and size of crop seed and it is very difficult to remove through economical way of processing) should be removed before second or final inspection.

In case of seed production of finger millet, two field inspections are mandatory ie, during or just before flowering and second during maturity of the crop. At first inspection during or just before flowering, source seed used for seed production and isolation distance are verified. Suggestions about rouging, weed control and other required operations for improving quality of seed crop are given to seed producer in prescribed format during first inspection time. The second inspection is performed during maturity of the crop. During this time, critical factors, such as off type plants, weed plants, diseased plants that could influence the seed quality of produced seed, are recorded. These contaminants are completely removed from the field before final inspection. If present, contaminants are to be within prescribed standard. However, if recorded contaminants are above than prescribe standards, then opportunity for maximum one re-inspection can be provided to seed producer due to self-pollinated nature of finger millet. Contaminants can be recorded by taking actual counts in field from different random places. Minimum thousand plants/ear heads are taken in each count and number of counts depends on area of seed crop (**Table 2**).

Table 2. Minimum counts for field inspection

Area of seed crop	Number of minimum counts
Up to 2 ha.	5
Above 2 to up to 4 ha	6
Above 4 to up to 6 ha	7
Above 6 to up to 8 ha	8
Above 8 to up to 10 ha	9
More than 10 ha	10

Source: GoN (2017)

Count taking method in the field: Arms span and foot step method is used for taking count. The numbers of plants/ear heads that come under each arm span after one foot step are counted from different random places of field to determine average number of plants/ear heads in each step. Then, walking towards the different directions for taking counts to represent the whole field by following arms span and foot step method is done. Contaminants that are encountered during walking are recorded but those contaminants far from crop inspector or the contaminants out of walking path are not to be recorded during field inspection. After performing required number of counts, contaminants of specific categories are added, and average number of contaminants is calculated to determine the percentage of specific contaminants by its number. Field count results are compared with the field certification standards prescribed by NSB and decision is made whether to certify the seed crop or not. Standards for off-types are checked during final inspection. Crop inspector shall provide final inspection report to farmers in prescribed format. The maximum off-type plants for foundation and certified in finger millet are 0.1% and 0.2%, respectively.

Seed standards

Standard of finger millet seed is verified by routine test (physical purity as well as other seed determination by number test, germination and moisture tests) in laboratory before seed certification. The minimum seed standards for finger millet (GoN 2017) are presented in **Table 3**. Seed production field and/or seed lot not meeting the crop standard and seed standard shall not be qualified for certification of finger millet seed.

Table 3. Seed standards for finger millet seeds

SN	Components	Foundation seed	Certified seed	Improved seeds
1	Pure seed (minimum)	97 %	97%	96%
2	Inert matter (maximum)	3%	3%	-
3	Other crop seeds (maximum) (grain/kg seed)	10	20	-
4	Weed seeds (maximum) (no. of grain/kg seeds)	10	20	-
5	Germination (minimum)	75%	75%	70%
6	Moisture (maximum) (kept in general container)	11%	11%	-
7	Moisture (Maximum) (Kept in closed container	8%	8%	-

Conclusion

The seed is the key to success in cultivation. Seeds are crucial and essential inputs to increase crop yields per unit area. Quality seed is described as varietal purity with a high percentage of germination, free from disease and pest, and with a proper moisture content and weight. Quality seed ensures strong germination, rapid growth and robust crop development. In Nepal, the existing seed certification directive mainly focusses on regulating the quality of seeds produced through formal seed system. The current provisions on seed certification in Nepal is insufficient and inadequate for seed certification of millets as it has included the field and seed standards for finger millet only. The directive fails to include the quality standard of seeds of other types of millets. The cultivated area and the production of millet in Nepal is 2,67,071 ha and 339462 ha in Fiscal year 2978/079, respectively. However, the minimum area required for certification of seeds of cereal crops is 1 ha and, 25 ha in terai and hills respectively. It seems very difficult to find such a large seed production plots of millets to certify. So, the minimum area required to certify the millets seems quite impracticable in Nepal. Similarly, the minimum area required to certify the millets seems quite impracticable in Nepal. The seed standards for all cereals including millets should not be kept in the same basket while defining the minimum areas to certify the seed plot. Thus, this is the high time to develop the quality control mechanisms though defining the seed and field standard for other types of millet species like proso-millet and fox-tail millet as soon as possible and also revise the existing seed certification directive to make it more scientific.

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D. Traditional Tools, Mechanization, and Post Harvest Management

घ. परम्परागत औजार, यान्त्रिकीकरण र फसल पछिको व्यवस्थापन

नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक)। २०८०। राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ।

कोदोजन्य बाली उत्पादन देखि प्रशोधन सम्मका कार्यमा प्रयोग हुने परम्परागत औजार तथा उपकरणहरू

निर्मला कुमारी बुढा, रामकृष्ण श्रेष्ठ र भगवती आचार्य

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सारांश

कोदोजन्य बालीहरूको खेती गर्ने क्रम घटे सँगै उत्पादन देखि भण्डारण सम्म प्रयोग हुने विभिन्न प्रकारका औजार तथा उपकरणहरूको उपयोग पनि कम भएको छ । ति मध्ये कतिपय त्यस्ता औजार, उपकरण तथा सामग्रीहरू त लोपोन्मुख अवस्थामा पुगेका छन् । यस लेखमा त्यस्ता औजार, उपकरण तथा सामग्रीहरू बनाउने तरिका र उपयोगबारे उल्लेख गरिएको छ।

परिचय

कोदोजन्य बालीहरूको उत्पादन देखि प्रशोधन सम्मका विभिन्न चरणहरूमा विभिन्न औजार, उपकरण तथा सामग्रीहरूको आवश्यक हुन्छ। नेपालमा ति चरणहरूमा आधुनिक यन्त्र तथा उपकरणको प्रयोग प्रायः कम नै रहेको पाइन्छ। कोदोजन्य बालीहरूको उत्पादन लागत घटाउन यान्त्रिकिकरणको अहँ भूमिका हुने भएता पनि घट्दो खेती गर्ने क्रम, पहाडी भू धरातलको बाहुल्यता एवं दुर्गमता, साना टुक्रामा विभाजित एवं छरिएर रहेको जमिन लगायतका कारण आधुनिक यान्त्रिकरणले अपेक्षित गति लिन सकेको छैन। पछिल्लो समय जोत्नको लागि हाते ट्याक्टर र चुट्नको लागि थ्रेसरको प्रयोग गर्ने क्रम बढ्दै गएको देखिन्छ। तथापी, मूलतः उत्पादन देखि प्रशोधन सम्मका विभिन्न कार्यहरूमा परम्परागत औजार तथा उपकरणहरू नै प्रयोग हुने गरेको पाइन्छ। हालका दिनहरूमा बढ्दो आयातित वस्तुको बजारमा सहज उपलव्धताले यस प्रकारका कतिपय घरेलु प्रविधि एवं औजार तथा उपकरणहरू लोप हुने अवस्थामा पुगेका छन् । यस आलेखमा त्यस्ता परम्परागत औजार तथा उपकरणहरू र तिनको उपयोगबारेको जानकारी समावेश गरिएको छ।

कोदोजन्य बाली उत्पादनको लागि खनजोत तथा गोडमेलका औजार तथा सामग्रीहरू

१. हलो

हलो खेतबारी जेत्नका लागि प्रयोग गरिने एक प्रमुख औजार हो। जोत्नको अलावा माटो खुकुलो बनाउन पनि हलोको प्रयोग गरिन्छ। हलो बनाउन बलियो काठलाई बासोले ताछेर तलको भाग सिधा चाक्लो र माथि बिचमा डाँडो पारि ताछिन्छ। अगाडिको मुख भागमा फलामको फाली ३-५ सेमि चौडा र ३०-३५ सेमि लामो अड्किने प्वाल पारिन्छ। हलोको बिच भागमा बर्गाकार प्वाल पारिन्छ जहाँ गोरुसँग जोडिने बाँध अड्याईन्छ र त्यसैको छेउमा मान्छेले समात्न सजिलो आधा टी आकारको लैरो राखिन्छ। बलियो बनाउन छेउबाट साना बलिया काठका टुक्रालाई ठोकी बनाईन्छ।

तस्विर १. काठको हलो
(स्रोतः गंगा बुढा)

तस्विर २. काठको हलो
(स्रोतः नवराज बडुवाल)

२. कुटो र कोदालो

कोदालो बाली लगाउँदा माटोलाई खुकुलो बनाउन र छेउछाउ खाली रहेको बाँसो जग्गा खन्न प्रयोग गरिन्छ भने कुटो बाली गोडमेल गर्न प्रयोग गरिने गरिन्छ। लाईनको दूरी र बोटको दूरी थेरै हुने बालीमा कुटोको प्रयोग गरिन्छ भने बढी दूरी बालीको लागी कोदालोको प्रयोग गरिन्छ । कुटो एक हातले समातेर गोड्ने र अर्को हातले झार उखल्ने गरिन्छ भने कोदालो खालि रहेको जग्गा खन्ने गरिन्छ।

कुटो बनाउँदा दुईओटा हाँगा एउटै मुख (४५-६० डिग्री जतिको हाँगा बिचको दूरी) भएको काप नचुडिने वा नछुट्टिने बलियो रुखको हाँगालाई ताछेर समाउने भाग अलि लामो र फलामबाट बनेको तिखो कुटो राख्ने भाग ६-१० सेमि लामो चिप्लो गरी ताछेर बनाईन्छ। कुटोको लागि मसिनो हाँगा र कोदालीको लागि मोटो हाँगा आवश्यकता पर्दछ।

तस्विर ३. कोदालो

तस्विर ४. कुटो कोदाली
(स्रोतः टेकराज गिरी)

कोदोजन्य बाली कटानी तथा चुटानीमा प्रयोग हुने औजार, उपकरण तथा सामग्रीहरू

१. हँसिया

हँसिया कोदोजन्य बाली तयार भए पछि वा पाके पछि काट्न वा टिप्न प्रयोग गरिन्छ। यो काठ र फलामबाट बनेको हुन्छ। समात्ने बिँड काठको सानो गोलो हुन्छ भने हँसियाको एक भाग चुच्चो बनाई बिँडमा दह्रो किसिमले घुसाइन्छ। काट्ने भाग केहि हद सम्म अर्ध चन्द्रमा आकारको धारिलो हुन्छ।

तस्विर ५. खापमा हँसिया राखेको
(स्रोतः गंगा ओली)

२. कोदो गुम्स्याउने प्रविधि

कोदो चुट्नका लागि सहजरुपमा चुट्न सकियोस भनेर परम्परागत रुपमा अपनाईने यो प्रविधिलाई गुम्साउने प्रविधि भनिन्छ । यो गुम्साउने प्रविधि कोदो खेती हुने नेपालको प्रायः सबै ठाउँमा प्रचलनमा रहेको पाइन्छ । यस प्रविधिबाट कोदो चुट्दा कोदो सजिलै नलबाट छुट्याउन सकिनुका साथै कोदोको गुणस्तर लामो समय सम्म कायम राख्न सहयोग पुग्दछ ।

कोदो राम्रो सँग पाकि सके पश्चात झुप्पा काटेर थुन्सेमा राखिन्छ । कोदोको झुप्पा काट्नका लागि खुरुङ्गी (एक प्रकारको सानो हँसिया) को प्रयोग गरिन्छ । झुप्पा झुप्पामा फल्ने कोदो झुप्पाबाट निकाल्न अत्यन्तै गाह्रो हुने हुँदा टिपिएको कोदोको झुप्पाहरूको थुप्रोलाई थुन्सेमा नै राम्रो सँग माथिबाट बोराले छोपेर ४-५ दिन गुम्साईन्छ । ४-५ दिन पश्चात कोदोलाई खल्यान वा आँगनमा राखेर स्थानीय ठाउँ अनुसार ग्याब्री, मुङ्गग्रो, लठ्ठी लगायतले चुटने काम गरिन्छ । यसरी चुट्दा कोदोको झुप्पाहरूबाट कोदोको गेडा राम्रो सँग छुट्टिन्छ त्यसैले यसलाई गुम्साउने प्रविधि भनिएको हो । यो विधीबाट कोदो चुट्दा कोदोको सामान्य प्रशोधन हुन गई गुणस्तर कायम राख्न पनि सहयोग पुग्दछ ।

तस्विर ६. कोदो टिप्दै गरेको
(स्रोतःभगवती आचार्य)

तस्विर ७. बोरामा गुम्स्याएको कोदो सुकाउन फिँजाइँदै
(स्रोतः बालकृष्ण जोशी)

३. ग्याब्री/जाल लौरो

सिधा हातले मुठ्ठि पारि सामत्न मिल्ने डेढ मिटर जति लामो लौरो छनोट गरी अलि मोटो टुप्पोमा प्वालपारि अर्को बिस देखि तीस से.मी.लामो लौरो एक भाग नफुत्किने गरी मोटो राख्ने र टुप्पो दुब्लो बनाई घुसाउने । पाँच देखि सात वटा बलिया तिस देखि पैंतीस से.मी.लामो भाटा लिई मोटो भागको टुप्पोमा तेस्रो सिधा राखेको लौरो छिर्ने प्वाल पारि सिधा लौरोमा एक एक गरी घुसाई डोरिले बाँधेर बनाईएको हुन्छ। यसलाई हातले समालेर घुमाई कोदो चट्ने लगायत अन्यबाली (गँहु र जौ) पनि चुट्ने गरिन्छ । यसको प्रयोग जुम्ला, मुगु, डोल्पा, हुम्ला, बाजुरा लगायतका जिल्लाहरूमा गर्ने गरेको पाइन्छ ।

तस्विर ८. ग्याब्रीले/जाल लैरोले कोदो चुट्दै गरेको
(स्रोतः प्रेम महत)

तस्विर ९. तयारी कोदो
(स्रोतः देवकी बुढथापा)

तस्विर १०. ग्याब्री/जाल लौरो
(स्रोतः पदम रोकाय)

तस्विर ११. ग्याब्री/जाल लौरो
(स्रोतः पदम रोकाय)

तस्विर १२. ग्याब्रीले कोदो चुट्दै गरेको
(स्रोतः रमेश वि. क.)

४. डिङ्ग्रो

डिङ्ग्रो (लैरो/मुङ्ग्रो) कोदो चुट्न प्रयोग गरिन्छ। यो बाँस, गुराँस, खर्सु आदि रुखका बलियो काठ/हाँगालाई बासोले ताछेर दुई हातले समात्न मिल्ने गोलो बिँड राखि चुट्ने भाग चेप्टो/चारपाटे आकारमा बनाईएको हुन्छ।

कोदो बाली टिपी ३ -४ घाममा सुकाईसकेपछि यो डिङ्ग्रोलाई दुई हातले समाती घुमाएर चुट्ने गरिन्छ। कोदोको दानाबाहिरको भुस तथा ठुटाहरू बलियो हुने हुदा यसले बेस्सरी चुटेमा राम्रो सँग चुटिने दाना निक्लिने हुन्छ र धैरै चुटेमा फलिने पनिहुन्छ। यो बिशेष गरी कालिकोट जिल्लामा प्रयोग गर्ने गरिन्छ भने कर्णालीका अन्य जिल्लाहरूमा पनि प्रयोग गरेको पाइएको छ ।

तस्विर १३. लैरो/मुङ्ग्रो/डिङ्ग्रो
(स्रोतः नवराज बडुवाल)

तस्विर १४. लैरो/मुङ्ग्रो/डिङ्ग्रो
(स्रोतः रुपक बम)

५. सुपो/नाङ्लो

सुपो/नाङ्लो कोदो बाली केलाउन तथा सफा बनाउन प्रयोग गरिने एक सामग्री हो। सुपो निगालोको चोया निकाली बुनेर बनाएको हुन्छ र यसलाई समात्न सजिलो होस् भनेर लचिलो/चाम्रो खालको काठको मसिनो हाँगाको बार लागाई डोरीले बाँधेर बानाईएको हुन्छ। यो दुई तरिकाले चित्रमा देखाए जस्तै गरी हात्तिका कान आकार र गोलो आकारमा बनाउने गरिन्छ। यो चिनो, कागुनो चुटिसकेपछि भुस, ठुटा फाल्न/बत्ताउन प्रयोग गरिन्छ।

तस्विर १५. सुपो
स्रोतः टेकराज गिरि

तस्विर १६: नाङ्लो
स्रोतःखेमराज शर्मा

६. चाल्नी/चाल्नु

चाल्नी कोदो, चिनो र कागुनो चुटिसकेपछि दाना र ठुटा छुट्याउन प्रयोग गरिन्छ । सानो/मसिनो प्वाल भएको चाल्नीले घट्टमा पिसेको पिठो चाल्ने गरिन्छ भने ठुलो प्वाल भएकोले कोदो, चिनो र कागुनो चुटिसकेपछि दाना छुट्याउन चाल्ने र ठुटा निकाल्ने गरिन्छ। मार्सि तथा घरेलु चामललाई कुट्दा धुलिने/टुक्रिने वा बाहिर रहेको भिटामिनयुक्त भाग नष्ट हुने हुँदा आधा कुटिएका चामललाई बियाँ छुट्याउन पनि प्रयोग गरिन्छ।

चाल्नी बनाउँदा मरेका जनावर जस्तै भेडा, बाख्रा, च्याङ्ग्रा, भैँसिको छाला निकाली त्यसमा भएका रौँ लाई निकालेर चिल्लो पारेर नखुम्चिने गरी सुकाइन्छ । त्यस पछि लचिलो/नरम घुमाउँदा नभाँचिने खालको काठको गोलो गरी बार बनाई त्यसमा छालालाई छेडेर सिलाईन्छ। त्यसमा झीर/तिखो मोटो चामलको दाना छिर्ने जत्तिको मोटो फलामलाई तताई प्वाल बनाईन्छ भने अर्को सानो प्वाल पनि बनाईएको हुन्छ।

तस्विर १७. चाल्नी/चाल्नु
(स्रोतःडिल्ली सार्की)

तस्विर १८. चाल्नी/चाल्नु
(स्रोतःरमेश विक)

७. मान्द्रो/मोट्टो

मान्द्रो/ मोट्टो कोदो सुकाउनका लागी प्रयोग गरिने एक सामग्री हो। यो सामान्यतयाः निगालोको चोयाबाट बनाईएको हुन्छ ।

तस्विर १९. मान्द्रो/मोट्टो
(स्रोतःअनिल सहकारी, कालीकोट)

कोदोजन्य उत्पादन भण्डारणमा प्रयोग हुने औजार, उपकरण तथा सामग्रीहरू

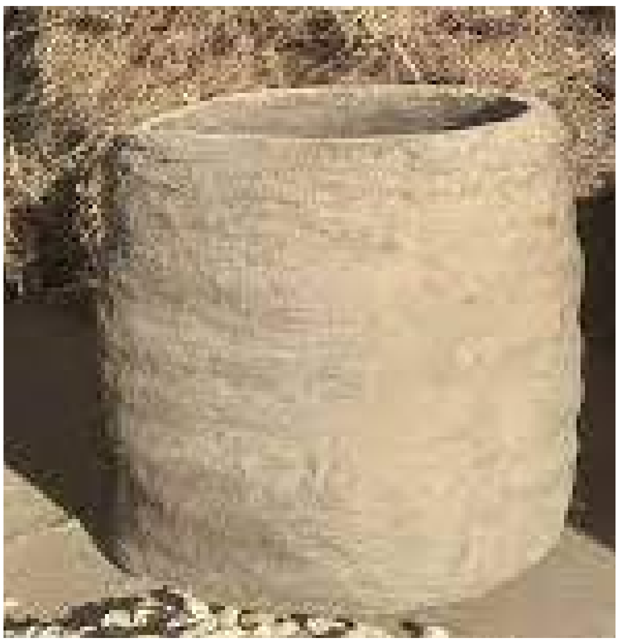
१. कुरु

कुरु नेपालको पहाडी ग्रामिण क्षेत्रमा विभिन्न प्रकारका अन्नहरू भण्डारण गर्नका लागि प्रयोग गरिने परम्परागत प्रविधिमा आधारित एक प्रकारको भकारी हो । मूख्य गरी खाद्यान्न, दलहन, तेलहन बालीहरू भण्डारणका लागि यसको प्रयोग गरिन्छ । साथै बीउ जोगाउनका लागि यो महत्त्वपूर्ण हुन्छ । चोया (बाँसका सामग्रीहरू निर्माण गर्नका लागि बाँसको पातलो बाहिरी निकालिएको) र माटोको प्रयोग गरी निर्माण गरिने यस भकारीमा भण्डारण गर्दा भण्डारित वस्तुहरूलाई विभिन्न प्रकारका किरा, रोगहरूबाट जोगाउन सकिन्छ । यसले प्राकृतिक रुपमा नै तापक्रम तथा आद्रताको नियन्त्रण गर्न सक्ने हुँदा अन्नलाई रोग किराहरूबाट सुरक्षित राख्न सकिन्छ । अन्नलाई राम्रो सँग घाममा सुकाएर यसमा भण्डारण गरिएको खण्डमा लामो समय सम्म गुणस्तर कायम राख्न सकिन्छ । कुरु बनाउन निङ्गालोको चोया, खुर्पा वा खुकुरी र मुछेको गोबर माटोको जरुरत पर्दछ।

- कुरु बनाउन निम्न बमोजिम गर्नु पर्दछ:
- सर्वप्रथम चोयाको भकारी बुन्ने । यसरी बुन्दा थुन्से जस्तो मसिनो सँग नभई केही खुकुलो गरी बुन्ने । यसको साईज आफ्नो आवश्यकता अनुसार निर्माण गर्न सकिन्छ ।
- तयार भएको चोयाको भकारीलाई गोबर माटोको हिलो बनाई भित्र बाहिर राम्रो सँग बाक्लो गरी पोतिन्छ ।
- करिब १०-१२ दिनमा हिलो सुक्छ र केही स्थानमा माटो फुटेर चिरा परेको स्थानमा अलि पातलो गोबर माटोको घोल बनाएर पुनः पोत्ने ।
- यसरी पोतेको करिब १ महिनामा यो अन्न भण्डारणका लागि तयार हुन्छ । यसलाई भण्डारण स्थानमा राखी खाद्यान्न भण्डारण गर्न सकिन्छ ।

तस्विर २०. कुरु बुन्दै
(स्रोतः भगवती आचार्य)

तस्विर २१. कुरुमा माटो लगाउदै
(स्रोतः भगवती आचार्य)



तस्विर २२. तयारी कुरु
(स्रोतः भगवती आचार्य)

तस्विर २३.
कुरु (स्रोतःप्रेम महत)

२. डालो

निगालोको चोया निकालि प्वाल नै नदेखिने गरी बुनेर बिभिन्न आकारमा बानाईएको भाँडो हो। यो बिभिन्न आकारमा गोलो, चारकुने सानो, चारकुने ठूलो गरी विभिन्न आकारमा बनाईएको हुन्छ। डालो बनाउँदा नभाचियोस भनेर पानीमा भिजाई चारकुना र टेक्ने खुट्टा बलियो बनाउन अलि चाम्रो भाटालाई चार वटा खुट्टा बनाईन्छ। चोया बुन्दा भित्र बाहिर पारेर अड्काएर हालिन्छ। यसमा सानो मसिनो प्वाल हुने हुँदा बाहिर भित्रबाट गोबर र माटोको मिश्रणले पोतेर प्वाल टालिएको हुन्छ जसले गर्दा सानो दाना प्वालबाट छिर्न पाउँदैन र खेर जानबाट जोगिन्छ।

माटो र गोबरले पोतेको ठूलो डालो कोदो बाली टिप्नका लागि प्रयोग गरिन्छ। सानो खालको डालोमा रोटी तथा अन्य खाद्य परिकार राख्न सकिन्छ । यस्तो सानो खालको डालो माटो वा गोबरले पोतेको हुँदैन। खेतबारिमा काम गर्ने बेला खेताला/कामदारलाई खाजा/अर्नी बोक्न पनि प्रयोग गरिन्छ । साथै पुजा पाठमा पुजाका सामान राख्न तथा कोसेली दिन परेमा यसैमा राखेर पनि दिने गरिन्छ।

कोदोबाली किनबेच तथा पैंचो दिन परेमा यसलाई नापोको रुपमा पनि प्रयोग गर्ने चलन रहेको छ। यो बुनि सकेपछि सानो भए माना र ठुलो भएमा पाथिको नापोको रुपमा पनि प्रयोग गर्ने गरिन्छ।

तस्विर २४. डालो
(स्रोतःखेमराज शर्मा)

तस्विर २५. डालो
(स्रोतःगंगा ओली)

३. थुन/थुन्से

निगालोको चोया निकालि घुमाउँदा नभाचियोस भनेर पानीमा भिजाई प्वाल नै नदेखिने गरी बुनेर बिभिन्न आकारमा बनाईएको भाँडो थुन हो । यो तल चारपाटे साँगुरो र माथि खुल्ला गरी बुनेको हुन्छ । चारकुनामा बलियो घुमाउँदा नभाचिने सजिलो सँग नुगिने एक बिटबाट अर्को बिटसम्म पुग्ने बलियो अलि चाम्रो भाटो वा बाँसलाई छेउमा तिखो बनाएर बुनेको चोयालाई भित्रबाहिर पार्ने गरी अड्काएर हालेको हुन्छ जसले भुईमा राख्दा राम्रो सँग अड्किने हुन्छ ।

कोदो बाली पाकि सकेपछि कोदोको बाला टिपेर यसमा राख्ने गरिन्छ । थुनमा भरि कोदोको बाला भएमा यताउति सार्न गह्रौं हुने हुँदा डालोमा टिपि यसमा राख्ने गरिन्छ । यसमा कोदो बाला भरिसकेपछि बारीबाट घरसम्म ल्याउने गरिन्छ । यो थुन अन्न भण्डारण गर्नमा पनि प्रयोग गरिन्छ ।

तस्विर २६. भण्डारणको लागि तयारी थुन
(स्रोतः गंगा ओली)

तस्विर २७. तयारी थुन
(स्रोतः खेमराज शर्मा)

४. बोरा/थैलो/कोल्था

खास गरी कोदो बाली तथा अन्न बाली चुटि सफा दाना निकाली सकेपछि यसमा राख्ने गरिन्छ । अन्न नसुकुन्जेल सुकाउने र ओसार पसारको लागि पनि यसको प्रयोग गरिन्छ । यो बिभिन्न साईजमा बनाईएको हुन्छ सानो साईजको थैलो भन्ने गरिन्छ भने घट्ट पिस्न सानो थौलोमा अन्न राखि पिठो पिस्ने गरिन्छ भने ठुलोमा खेतबाट अन्न भित्र्याउने बेला खेत वा आगान/खलोबाट बाली चुटिसकेपछि यसमा दाना राख्ने गरिन्छ ।

बोरा वा थैलो बनाउँदा भाँगो तथा अल्लोको डाँठ सुकाई त्यसबाट रेसा निकालिन्छ । निकालिएको रेशालाई मुङ्ग्रोले चुटे पछि रेशामा भएको खस्रो बोक्रा जान्छ र मसिनो धागो बन्छ । त्यसै धागोलाईबाटेर/कातेर डोरी बनाई बुनेर यो तयार पारिन्छ । यो विभिन्न साईजमा बनाईएको हुन्छ । सानो साईज भएकोलाई थैलो भन्ने गरिन्छ जुन घट्टमा पिसेको पिठो राख्न वा अन्य अन्न राख्न प्रयोग गरिन्छ । ठुलो बोरामा आँगन वा खलोबाट बाली चुटिसके अन्न ओसार्ने वा यसमा राखि नापो गर्ने तथा भित्र्याउने गरिन्छ ।

ठूलो बोरा वा कोल्था १.५-३ क्विन्टल सम्म राख्न सक्ने गरी बनाईएको हुन्छ भने घट्ट पिस्न बनाईएकोमा २०-३५ केजि अट्ने सम्मको बनाएको हुन्छ। यो कोल्था कालिकोट जिल्ला लगायत कर्णाली प्रदेशका अन्य जिल्लाहरूमा प्रयोग गर्ने गरेको पाइन्छ । अहिले प्लास्टिकका बोरा आएपछि घट्ट पिस्ने कोल्था प्रायः लोप हुने अवस्थामा पुगेको छ भने भण्डारण तथा नापोमा प्रयोग गरिने कतै कतै मात्र भेटिन्छ ।

तस्विर २८. अन्न राखिएको बोरा/थैलो/कोल्था
(स्रोतःटेकराज गिरि)

५. मुदुस/भकारी

मदुस बलियो काठलाई ताछेर फल्याक बनाई काठकै किला बनाएर जोडेर बनाएको हुन्छ। अरु सबै ठाँउमा बन्द हुने र माथिको भाग फल्याक लाई उठाई सामग्री राख्न सकिने गरी बनाईएको हुन्छ। यसमा सबै काठका सामग्री मात्र जोडेर बनाईएको हुन्छ। प्रायः आयाताकारमा बनाउने या सानो र ठुलो आकारमा बनाउने गरिन्छ। सानो आकारको लाई मुदुस र ठूलोलाई भकारी भनिन्छ । ठूलोमा २-३ क्विन्टल र सानोमा ५० केजि देखि १ क्विन्टल सम्म भण्डारण गर्न सकिन्छ। यो जंगलमा बस्ने राउटे समुदायले जंगलका बलिया काठलाई ताछेर यस्तै मदुस लगायतका सामग्री बनाई गाँउघरमा खाने अन्नसँग साट्ने गरेको पाइन्छ।

कोदो, चिनो, कागुनो लगायत अन्य बालीको भण्डारणमा तथा अन्य सामग्री राख्न प्रयोग हुने गरेको छ। यो सानो र ठुलो साईजमा बनाईएको हुन्छ। सानोलाई बीउ भण्डारण र ठूलोलाई खाद्यान्न भण्डारणमा प्रयोग गर्ने गरेको पाइन्छ। यसमा १-२ क्वीन्टल राख्न सकिन्छ। गाँउ घरमा सानो साईजकोमा पहिला पहिला भोटबाट ल्याइएको ढिक्का नुन राख्ने गरेको पाईछ।

तस्विर २९. मुदुस/भकारी
(स्रोतः डिल्ली सार्की)

तस्विर ३०. मुदुस/भकारी
(स्रोतःपदम रोकाय)

६. कोठो/ठुगिलो

कोठो/ठुगिलो कोदो जन्य बाली भण्डारणको लागी प्रयोग गर्ने गरिन्छ। यो मुख गोलो सानो हुन्छ भने बिचको भाग फुकेको र तल्लो भाग मुख भन्दा अलि ठुलो हुन्छ। यो ठुलो साईजको भए कोठो र सानो साईजको भए ठुगिलो भन्ने गरिएको छ। ठुलो कोठोमा खायन अन्न भण्डारण गर्ने गरिन्छ भने सानो ठुगिलो बीउ भण्डारण गर्न प्रयोग गर्ने गरिन्छ।

कोठो/ठुगिलो निगालोको चोयाबाट तयार पारिन्छ। निगालोको चोया निकालि घुमाउँदा नभाचियोस भनेर पानीमा भिजाई प्वाल नदेखिने गरी बुनेर बिभिन्न आकारमा बनाईएको हुन्छ। यसमा साना-साना प्वाल हुने हुँदा दाना बाहिर ननिस्कियोस र किराहरू नलागुन भनेर माटो तथा गोबरले बाहिरबाट बाक्लो गरी पोतिदिने र भित्र परेको माटोलाई कुचोले झाडु लगाएर सफा गरी घाममा घोप्टोपारी सुकाउने गरिन्छ। राम्रोसँग सुकिसके पछि चिस्यान बढी नहोस् तथा धमिरा नलागोस् भनेर राख्ने ठाँउमा भुईँमा कोठो/ठुगिलो अट्ने गोलो ढुङ्गा राखिदिनु पर्छ। किरा नलागोस भनेर कमेरो माटोले भित्र बाहिर छिपिदिने चलन पनि छ। यसमा अन्न वा बीउ राखिसकेपछि यसको मुखमा गोलो ढुङ्गा तथा गोलो काठ बनाई छोपेर माटो तथा गोबरले पुरै पोतेर राखिन्छ।

तस्विर ३१. कोठो/ठुगिलो
(स्रोतः टेकराज गिरि)

७. ढरो

साविकको कर्णाली अञ्चलका जिल्लाहरूमा कोदो कागुनो, चिनो भण्डारण गर्न प्रयोग गर्ने गरिन्छ। ढरोमा अन्य बालीका उत्पादनहरू पनि भण्डारण गरिन्छ। यो बिभिन्न आकार तथा साईजमा माटोबाट बनाईन्छ। यसको मुख छोप्नका लागी माटोबाट नै ढकनि वा काठ र ढुंगाको पनि प्रयोग गरिन्छ। यसमा अन्न राखिसके पछि ढकनी लगाई बाहिरबाट माटो र गोबरले पोतेर राखिन्छ।

तस्विर ३२. ढरो
(स्रोतः हर्कबिर रावल)

तस्विर ३३. ढरो
(स्रोतः हर्कबिर रावल)

८. डोजो

डोजो बाँसको काठबाट स्थानीय प्रविधि तथा शिपको प्रयोग गरी विभिन्न प्रकारका खाद्यान्न भण्डारणका लागि देशको विशेषत पहाडी भेगमा तयार गरिने स्थानिय खाद्यान्न भण्डारण गर्ने प्रविधी हो । यसको प्रयोग विशेषत सुदुरपश्चिम क्षेत्रको पहाडी भेगमा गरिन्छ । यसमा खाद्यान्न भण्डारण गर्दा खाद्यान्नको सम्पूर्ण पौष्टिक तत्वको सुरक्षा हुनुका साथै विभिन्न प्रकारका हानिकारक किरा मुसा आदिबाट समेत जोगाउन सकिने र घर भित्र सजिलै सानो ठाउँमा पनि व्यवस्थापन गर्न सकिने हुँदा ग्रामिण क्षेत्रमा यसको महत्त्व ठूलो रहेको छ । साथै यसमा सामान्यतयाः आगलागी नहुने तथा वर्षाको भेल समेत पस्न नसक्ने हुँदा खाद्यान्न सुरक्षित राख्न सकिन्छ । यसको निर्माणका लागि बाँसको राम्रो छिप्पिएको काठको प्रयोग गरी स्थानीय प्रविधिको प्रयोगद्धारा गरिन्छ।

डोजो निर्माण गर्दा देहाय बमोजिम गर्नु पर्दछ:

- राम्रो सँग छिप्पिएको २ मिटर लम्बाईको बाँसको मुढा लिने ।
- मुढालाई एक तर्फबाट छिनोले प्वाल पार्दै ढुङ्ग्रो जस्तो बनाउने जसमा एका तर्फ बन्द र अर्को तर्फ खुला राख्ने ।
- बाहिरी पत्र २ ईन्च जति बाक्लो राखेर सोही अनुरुप भित्र ठाउँ बनाउने ।
- राम्रो सँग काठको काम सकिए पश्चात गोबर माटोले राम्रो सँग भित्र बाहिर लिप्ने ।
- राम्रो सँग सुकाउने । सुके पश्चात ठाडो बनाई राख्ने ।
- भण्डारण गर्न तयार गरिएको खाद्यान्नलाई केही परिमाण (१ क्विन्टल खाद्यान्नमा २ माना) खरानी मोलेर राख्ने ।
- माथिल्लो खुला ठाँउ बराबरको ढुंगाको ढकनी तयार गर्ने र मुख छोप्ने ।
- ढुँगाले मुख छोपे पश्चात गोबर माटोले राम्रो सँग सिल हुने गरी लिप्ने ।

यसरी भण्डारण गरिएको खाद्यान्न लामो समय सम्म सुरक्षित राख्न सकिन्छ । ग्रामिण क्षेत्रमा प्राय घरहरू काठ, खरबाट निर्माण हुने हुँदा गर्मीको समयमा आगलागी र वर्षाको समयमा पानीबाट खाद्यान्न जोगाउन ठुलो समस्या हुने गर्दछ । डोजो आगलागी तथा पानीबाट पूर्ण सुरक्षित हुने हुँदा ग्रामिण क्षेत्रमा खाद्यान्न कटानी पश्चात हुने क्षती कम गर्न यसको ठूलो महत्त्व रहेको छ । यसले विभिन्न प्राकृतिक विपत्तिका साथै रोग किराहरूबाट समेत खाद्यान्न जोगाउने हुँदा ग्रामिण क्षेत्रको खाद्य सुरक्षणमा यसको महत्त्वपूर्ण स्थान रहेको छ ।

तस्विर ३४. डुजो
(स्रोतः प्रेम महत)

तस्विर ३५. डुजो
(स्रोतः प्रेम महत)

९. गोलो/माटोको गाग्री

गोलो/गाग्री मसिनो माटोबाट बनाईएको हुन्छ। पहिला माटोका भाडाँ कुँडा चलाउने चलन अलि बढी नै थियो जस मध्यको यो गोलो एक प्रमुख हो । बिशेष महत्त्व भएको यो भाडोमा पानी र विभिन्न बालीका अन्न राख्ने गरिन्छ। यस भाँडोमा गर्मी समयमा पानी राख्दा चिसो हुने पिउन आनन्द हुने हुँदा यस भाँडोमा बिहान पानी भरी राख्ने र दिनभरी पानी पिउने गरिन्थ्यो। गाउँघरमा आफ्ने घरमा यो भाँडामा नहुँदा छिमेकिको घरमा भए पनि पानी पिउन त्यो घरमा जाने गरिन्थ्यो। प्रायः यो गोलो सानो र ठूलो गरी दुई साइजमा बनाईएको हुन्छ। सानो गोलो २० लिटर जती अट्ने बनाईएको हुन्छ भने पिसेको पिठो राख्न अलि ठुलो ३० केजी अट्ने वा दुबै साइजमा बनाईएको हुन्छ। घट्टबाट पिसेर ल्याएको पिठो गोलोमा राखिने र आवश्यकता अनुसार यसबाट निकालेर पकाउने गरिन्छ।

तस्विर ३६. गोलो/माटोको गाग्री
(स्रोतः टेकराज गिरी)

१०. कोसी

मोटो बलियो बाझँ, खर्सु, गुराँस, साल आदी रुखका काठलाई कोत्रेर वा खोपेर/ताछेर गोलो बनाईएको एक प्रकारको काठको भाँडो हो । यो सानो, मझौला र ठुलो गरी तिन साईजमा बनाईएको हुन्छ । यो भाँडो बिशेष गरी कर्णाली प्रदेशका सुर्खेत, दैलेख, कालिकोट, जुम्ला, मुगु, हुम्ला लगायतका जिल्लाहरूमा राउटे समुदाय बस्ने ठाँउमा प्रयोग गरेको पाइन्छ । जंगलमा बस्ने राउटे समुदायले जंगलमा यस्तै विभिन्न बलिया रुखलाई काटेर तयार गर्ने र आफूले प्रयोग गर्ने तथा गाँउ गाँउमा गएर खाद्यान्नसँग साट्ने गर्छन ।

यसलाई पिसिएको पिठो राख्न प्रयोग गरिन्छ । त्यसै गरी रोटी पकाउने तथा थुप्का पकाउने पिठो मुछने र हलुवा बनाउन पिठो तयार गर्ने काममा पनि उपयोग गरिन्छ । साथै अन्य तरकारी राख्न, गाई बस्तुलाई कुँडो खुवाउन लगायत सानोतिनो सामान राख्न समेत प्रयोग गर्ने गरेको पाइन्छ । यसमा दाना राखि नापोको रुपमा पनि प्रयोग गर्ने गरिन्छ ।

तस्विर ३७. कोसी
(स्रोतः खेमराज शर्मा)

कुटानी तथा पिसानीमा प्रयोग हुने औजार, उपकरण एवं साधनहरू

१. ओखल

ठूलो र बाक्लो ढुङ्गालाई गोलो गरी खोपेर बनाईएको हुन्छ। यसमा कोदो,चिनो, कागुनो बालीमा भएको भुसनिकाल्न मुसलले कुटेर फाल्ने गरिन्छ जसलाई फल्ने भनिन्छ। धानको भुस निकाल्न पनि यस ओखलको प्रयोग गरिन्छ। मुसल बलियो/साह्रो काठबाट बनेको हुन्छ। यस प्रकारको मुसलमा बिचमा साँघुरो र तल माथिको भाग अलि मोटो गरी ताछेर बनाईएको हुन्छ र छिटो भुस/बोक्रा निक्लोस भनेर मुसलको एक मुखमा /एक पट्टी फलामलाई मुसलको गोलाई अनुसारको आकारमा धेरै धार नबनाई पातलो गरी २-३ सेमि जति चौडाईमा बनाईएको फलाम सामुलाई ठोकेर राख्ने गरिन्छ जुन फलाम सामु हो। सामो राखिएको (मुख /एक पट्टी) भित्र फलामबाटै बनाईएको अलि तिखो/चाख्लो २-३ सेमि लामो र १ सेमि जति चाख्लो फलामको दाँत अडेकाएर राखिएको हुन्छ जस्ले बोक्रा छिटो निकाल्न मदत हुन्छ।

ठूलो र बाक्लो ढुङ्गालाई गोलो गरी खोपेर बनाईएको हुन्छ। यसमा कोदो, चिनो, कागुनो बालीमा भएको भुस निकाल्न मुसलले कुटेर फाल्ने गरिन्छ जसलाई फल्ने भनिन्छ। धानको भुस निकाल्न पनि यसको प्रयोग गरिन्छ । मुसल बलियो/साह्रो काठबाट बनेको हुन्छ। यस प्रकारको मुसलमा बिचमा साँघुरो र तल माथिको भाग अलि मोटो गरी ताछेर बनाईएको हुन्छ र छिटो भुस/बोक्रा निक्लियोस भनेर मुसलको एक मुखमा/एक पट्टी फलामलाई मुसलको गोलाई अनुसारको आकारमा धेरै धार नबनाई पातलो गरी २-३ सेमि जति चौडाईमा बनाईएको फलाम सामुलाई ठोकेर राख्ने गरिन्छ जुन फलाम सामु हो। सामु राखिएको (मुख/एक पट्टी) भित्र फलामबाटै बनाईएको अलि तिखो/चाख्लो २-३ सेमि लामो र १ सेमि जति चाख्लो फलामको दाँत अड्काएर राखिएको हुन्छ जस्ले बोक्रा छिटो निकाल्न मदत गर्छ।

तस्विर ३८. ओखल
(स्रोतः डिल्ली सार्की)

तस्विर ३९. मुसल
(स्रोतः टेकराज गिरी)

तस्विर ४०. ओखलमा कोदोको भुस फाल्दै
(स्रोतः टेकराज गिरी)

तस्विर ४१. ओखलमा बेडो लगाई चिनोको भुस फाल्दै
(स्रोतः शिवकृष्ण के. सी.)

२. दुम्चे/दुङ्चो

यो बलियो काठबाट बनाईएको खाल्डो आकारको भाँडो हो । यो बिशेष गरेर कोदो, चिनो र कागुनोको भुस फाल्नको लागी प्रयोग गरिने र कुटेर तयार पारिने चिज यसमा कुटेर बनाईन्छ । यो विशेषगरी कर्णालीका जुम्ला, मुगु , हुम्ला, डोल्पा लगायत अन्य ठाउँमा पनि प्रयोग हुने गरेको पाइएको छ ।

तस्विर ४२. दुम्चे/दुङ्चो
(स्रोतःडिल्ली सार्की)

तस्विर ४३. फल्दै गरैको दुम्चे/दुङ्चो
(स्रोतः शिवकृष्ण केसी)

३. पानी घट्ट

कोदोको पिठो बनाउनको लागी पानी घट्टमा पिसिन्छ । यो एक प्रकारको पानीबाट चल्ने मेसिन हो । सुधारिएको र नसुधारिएको गरी दुई प्रकारको घट्ट पाइन्छ । सुधारिएको घट्टमा फलाम र पाईप राखिएको हुन्छ भने नसुधारिएकोमा काठको प्रयोग बढी हुन्छ । सामान्यतया यसमा सिधै पकाएर खान नमिल्ने अन्नलाई पिसेर विभिन्न परिकार बनाएर खाने गरिन्छ । पानी घट्ट ढुङ्गा, माटोको गारो र जस्ता वा खरको छाना मिलाएर सानो घर आकारमा निर्माण गरिएको भवनमा राखिन्छ । पानी घट्टमा फेदडो घट्ट (ढुङ्गाकोबाट बनेको पाथार) र कोठो पदालोको बिशेष भूमिका हुन्छ ।

सुधारिएको घट्टमा फोदडो फलामको र नसुधारिएकोमा काठबाट बनाईएको हुन्छ । फलामा वा काठलाई प्लेट आकारमा बनाई बिच डण्डीमा नफुत्कने गरी जोडिएको हुन्छ र त्यो सिधै घट्ट सँग जोडेको हुन्छ । जुन फेदडोमा पानी पर्छ र घट्ट घुम्नलाई मदत गर्छ । घट्ट (ढुङ्गाकोबाट बनेको पाथार) जाँतो जस्तै बलिया बाक्लो ठूलो ढुङ्गालाई कुदेर बनाईएको हुन्छ । जसमा अन्न दाना पसि पिसिने हुन्छ वा पिठो बनाउँछ । कोठो काठमुडा खोपेर भित्र खाली बनाई वा फल्यक जोडेर बनाईएको हुन्छ जहाँ पिसिने अन्न दाना राख्ने गरिन्छ । यो ३०-५० केजि जति अट्ने हुन्छ । माथी खुल्ला र तल दाना निस्कने ठाउँमा साँगुरो बनाईएको हुन्छ । यसको एक छेउमा सानो काठको पाता घट्ट सँग छुने गरी राखेको हुन्छ जसले घट्ट घुम्दा कोठोलाई हल्लाई दाना तला सार्न मद्दत गर्दछ ।

तस्विर ४४. निर्माणधिन घट्ट
(स्रोतः अनिल सहकारी)

तस्विर ४५. सुधारिएको घट्टको तल्लो भाग फेदडो
(स्रोतः अनिल सहकारी)

तस्विर ४६: कोदो पिस्दै घट्ट
(स्रोतःटेकराज गिरि)

तस्विर ४७. कोदो लगाएत अन्य अन्न पिस्न राखिएको घट्ट
(स्रोतःटेकराज गिरि)

४.जाँतो

जाँतो कोदोजन्य बालीका दाना र अन्य अन्न पिस्न प्रयोग गरिन्छ। आजकल जाँतो विभिन्न काममा प्रयोग गरिने भएतापनि पहिले गाँउमा घट्ट नहुँदा वा टाढा हुँदा आउन जान समयलाग्ने र कामको बोझले गर्दा जाँतोमा नै कोदो पिस्ने गरिन्थ्यो। यसरी जाँतोमा पिसी रोटी/ढीँडो/हलुबा बनाई खाने चलन थियो। जाँतो दाल पिस्ने लागायत अन्य दालजन्य गेडागुडी फक्लेटा पार्नको लागि पनि यसको प्रयोग गरिन्छ।

जाँतोमा दुई भाग हुन्छ। माथि पट्टिको भाग गोलो बाक्लो ढुँगा कोत्रेर विचमा अन्न पास हुने र तिखो मसिनो काठ वा फलाम (वियो) पस्न सक्ने प्वाल पारिन्छ। तल्लो भाग त्यस्तै बाक्लो कोतरिएको ढुङ्गा हुन्छ जस्को विचमा काठ वा फलामको वियो नहल्लने गरी जोडिन्छ। जाँतो घुमाउनलाई एक छेउमा हातले सामाउने डन्डी अड्काउन प्वाल पारिन्छ। उक्त प्वालमा जाँतो घुमाउन हातले समाउन काठको आधा फिट जतिको डण्डी प्रयोग गरिन्छ। वियोलाई सानो वा ठूलो बनाई साँघुरो वाकेहि खुल्ला प्वालबाट थोरै वा धेरै कोदो पठाइ पिठो आवश्यकता अनुसार मसिनो वा खस्रो बनाउने गरी पिस्न सकिन्छ।

तस्विर ४८. जातो
(स्रोतःखेमराज शर्मा)

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Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Post-harvest Engineering Technologies for Millet Production

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Abstract

Millets are considered to be nutritious and climate-resilient crops that are appropriate for the marginal environment of the hills and mountainous region of Nepal. However, cultivated area of millets is declining due to present labor-intensive cultivation and post-harvest practice resulting high cost of cultivation and increased drudgery to the farmers (mainly women farmers). To reduce the cost of cultivation and drudgery of women farmers by increasing the efficiency in post-harvest operations, there is a need for research and development to increase the access of farmers on the appropriate post-harvest technologies of millets. In this context, National Agricultural Engineering Research Centre (NAERC) has made efforts in the development of different post-harvest technologies for the millet cultivating farmers in Nepal for the last two decades. It has become successful in developing and commercializing some post-harvest technologies for finger millet, proso millet, foxtail millet and sorghum. This paper highlights the research and development efforts and the innovations of NAERC in the development and promotion of post-harvest technologies for threshing, pearling, cleaning, and grinding of millets in Nepal.

Keywords: Millet, thresher, pearler, dehusking machine, post-harvest technology

Background

Millets are an underutilized but very important food crop cultivated in the subsistence and marginal environment with significant contribution to the food security of the mid and high-hill region of Nepal (Ghimire et al 2017). Different millet such as finger millet (Kodo), foxtail millet (Kaguno), sorghum millet (Junelo), and proso millet (Chino) etc are cultivated across different agro-climatic zones in Nepal. Millets are cultivated in 267,071 ha producing 339,462 mt and it accounts for 3.15% of total edible cereal grain produced in Nepal during 2021/22 (MoALD 2023). Finger millet is the dominant crop among millets and is generally grown in marginal lands as monocrops in the lower hills or as a relay crop following maize in the mid hills, high hills and mountains to best utilize the residual nutrients and soil moisture of late August and September in Nepal. Similarly, proso millet is cultivated largely as the main cereal grain in the mountain regions of mid and far-western Nepal especially Karnali province while foxtail millet is grown around higher hilly regions of the country (Joshi et al 2019). Importantly, millet has the potential to become one of the few resilient crops of the future to cope with food insecurity for developing countries because it can adapt well to future climate change conditions better than other cereals, in the context of increasing drought, soil salinity and high temperatures and tougher climates (Khatri et al 2021, Ghimire et al 2017, ICRISAT 2021, Singh and Prasad 2020). Millets are edible to consume as a staple food for humans in different forms such as boiled, roasted or popped grain, porridge and flour as bread (Roti and Dhindo), cookies, muffins, cakes, etc. Finger millet grains are also used to brew local alcoholic beverages (Raksi). Besides, millet stover serves as an important source of dry-season fodder and feed for livestock, especially in

Asian countries. Importantly, millet is gluten-free, nutritious, rich in trace elements, fibers, rare amino acids, and vitamins and contains more protein, calcium and iron. (Tripathi et al 2021). Currently, millets are gaining popularity, especially in cities due to their health-promoting properties for consumers. For instance, nonacid-forming millet grains stabilize blood sugar, lower cholesterol, prevent the growth of human colon tumors, combat malnourished diseases, manage obesity, and have other health-promoting benefits (Dekka et al 2023).

Despite having multiple uses, the cultivation and promotion of millet are still in a low and declining stage due to the constraints associated with labor-intensive agronomic cultivation practices including post-harvest processing. It is estimated that 250 labor days are required to cultivate millet in 1 ha (Shrestha, 2011). Transplanting, weeding, and harvesting are considered to be labor-intensive operations in millet cultivation. Similarly, threshing, pearling, and cleaning/ winnowing are labor-intensive post-harvest operations. For the promotion of these millets, mechanized post-harvest and processing technologies are to be developed and promoted (Balasubramanian et al 2007, Palaniswamy 2018). In this context, National Agricultural Engineering Research Centre (NAERC) under Nepal Agricultural Research Council (NARC) have made serious efforts to develop and promote appropriate post-harvest technologies for millets. This paper describes the millet post-harvest technologies developed and promoted by NAERC, NARC.

Major Traditional Post-harvest Technologies Used in Millet

Traditionally harvesting and post-harvest operations of millets (especially threshing and cleaning) are performed using traditional tools in Nepal (Pudasaini et al 2002). Harvesting of the millets is performed by cutting the individual heads by sickle manually. Threshing of millets is performed by using the traditional tools viz stick, Flail (galbi/ Jaal lauro) in Nepal (Pudasaini et al 2002). The pearling/ dehusking of the millets is performed by using pounder (Dhiki or Okhal) and cleaning is performed by using Winnowing tray (Nanglo or Supo). Generally, wooden Dhiki consists of a fulcrum having two short poles and a long thick plank of wood with a small vertical extension that goes into a hole made in the ground. One person presses and release the plank at regular interval, while the other person near the Okhal (hole) keep grain in the hole. Similarly, pearling or dehusking operations are conducted in wooden pounder (Okhal). Threshing, dehusking/ pearling and cleaning are the most drudgeries activities mainly performed by women. Very low output of the traditional threshing/pearling operation of millets ie, this is reported to be as low as 1 kg per hour (for foxtail and proso millet). Besides, low output and grain losses due to spillage, kernel damage, incomplete removal of grains from the heads and grain contamination with soil, stones and other impurities is another demerit of those practices (Khatri et al 2021). Likewise, most of the rural villages of Nepal were dependent on traditional milling and grinding tools such as traditional water mills (Paani Ghatta), rotary quern (Janto), pounder (Okhal) for most of the cereal crops. The grinding capacity of a traditional water mill ranges from 10-20 kg per hour while its frequency of repair and maintenance is substantially high. Proso millet and foxtail millet) are traditionally de-husked mostly by women through pounding in wooden pounder (Okhal). Women can dehusk 2-3 kg of proso millet and foxtail millet per hour (ie 20-30 kg in a day) by two women through traditional methods (NAERC 2018). In this context, to promote millet production, the inefficient and drudgerous traditional post-harvest process should be improved and replaced by comfortable, efficient and cost-effective appropriate post-harvest technologies in millet processing.

Effort of NAERC to Develop Millet Post-harvest Technologies

To address the drudgery of the women farmers in threshing and pearling of millet, the first author of this paper visited Vivekanand Mountain Agriculture Research Centre (Vivekananda Parbatiya Krishi Ansundhan Shala (VPKAS)) and studied the Vivek millet thresher cum pearler developed by this center in 2002. Later Dr Raj Kumar Gupta, Regional Facilitator, Rice Wheat Consortium supported for obtaining a prototype of the Vivek millet thresher and pearler to the Agricultural Engineering Division (AED) [presently AED is renamed as National Agricultural Engineering Research Centre (NAERC), Nepal Agricultural Research Council (NARC)]. The Vivek millet thresher cum pearler was tested, modified and promoted in the farmer's field. To address the farmer's needs a new pedal-operated thresher was developed, promoted and commercialized in Nepal. In additions, several efforts were made to develop other post-harvest operations for foxtail millet, proso millet and sorghum. In the following section of this paper, the NAERC's efforts in the development of millet post-harvest technologies are elaborated.

Modification of Electrically Operated Millet Thresher cum Pearler

The Vivek millet thresher cum pearler (**Figure 1**) is electrically operated and it consists of a threshing cylinder and a winnowing fan (ICAR 2002). After testing of Vivek millet thresher cum pearler at AED, Khumaltar, it was found that the capacity of the thresher was 30-35 kg per hour with threshing efficiency of 96%. After several tests following shortcomings of the thresher were found,

- Small hopper to feed and lack of control of the feed.
- High wind speed blew the grain along with chaff while pearling/ threshing and about 0.4% of grain was lost along with the chaff.
- Choking of the screen while threshing/ pearling

The Vivek thresher is modified with a hopper with a controlled feeding sliding valve, a controlling mechanism to control the winnowing fan air, a damper to avoid blowing of grain by the winnower, brush to clean the screen (Shrestha 2003). The capacity of the modified thresher (**Figure 2**) is 35-40 kg per hour and the threshing efficiency is 98%. In addition, a negligible grain loss was observed in the modified thresher. After the successful testing of the modified millet thresher cum pearler, 10 prototypes were replicated with the support from the rice-wheat consortium and tested in the farmer's field in different locations in 2004. After several tests following findings were observed.

The farmers found that the millet thresher performed well and was appropriate in the villages where there was an electricity facility. In Nepal, millet is mainly grown in the mid-hills and in the majority of the mid-hills, electricity connections were not available. In addition, there was frequent load shedding even up to 18 hours per day during those years. Hence, the farmers requested to develop pedal operated millet thresher cum pearler.

Development of Pedal-operated Millet Thresher cum Pearler

To address the needs of the farmers, a pedal-operated millet thresher cum pearler (**Figure 3**) was designed and developed by the authors at the Agricultural Engineering Division (AED) of the Nepal Agricultural Research Council (NARC) in 2005 (Shrestha 2011). Pedal thresher is composed of the following components (CSAM 2016)

- Hopper: where the millet panicles are fed into the threshing drum. It is made of sheet metal and has a height of 27 cm.
- Threshing chamber: where the millet grains are beaten out of the panicles and separated from the bulk of the straw. It is made of a sheet metal drum of diameter 45 cm. It consists of a beater pegs of mild steel bar with canvas sheet and a stationary concave grid.
- Threshing drum: it is made of sheet metal, and it is housed inside the threshing chamber. It accommodates the shaft on the concave with a clearance of 3 mm.
- Cleaning chamber and grain collector: it is made up of a single sieve that undergoes to-and-fro motion and grain is collected in the chamber by gravity.
- Drive and driven assembly: Pedal operated.

Pedal thresher has a threshing and pearling capacity of 40-60 kg/hr for finger millet with threshing efficiency and pearling efficiency of 97% and 98% respectively and the grain loss was less than 0.5% (CSAM 2016). With the initiation and support from the social worker cum veteran journalist Mr Bhairav Risal and politician Mr Jeevan Bahadur Shahi (Current chief minister of Karnali Province), 5 pedal operated millet threshers cum pearler were distributed in the villages of Humla in 2007. Similarly, NAERC, NARC promoted the developed thresher in several villages in Kavre, Dolakha and Sindhu Palchowk districts. After obtaining the demand from the farmers, the Department of Agriculture and NGOs also promoted NAERC, NARC developed pedal operated millet thresher. The pedal operated millet thresher cum pearler can also be run by electrical motor of 1 hp.

NAERC pedal-operated millet thresher is widely accepted by Nepalese farmers for threshing finger millet, particularly in the hilly region. The technology has already reached finger millet-growing districts (Sindhuli, Humla, Jumla, Dhading, Gorkha, Dolakha, Kaski, Kalikot, Lalitpur, Kavrepalanchok, Baglung, Parbat, Sindupalchok, Achham, Makawanpur etc). Pedal millet thresher developed by AED/NARC and tested by LI-BIRD found that it has reduced women farmers' workload in threshing and pearling millet by about 65-85 per cent. Among the users, a total of 83 percent of respondents (94.7 percent of women) found pedal threshers to be an important alternative to manual threshing. Farmers found pedal thresher effective for easy grain separation, cleaning and removing husk while they reported that the pedal thresher requires less time and effort to operate, and most importantly it avoids injuries on feet and reduces backache compared to manual threshing (LI-BIRD 2015). In addition, the farmers realized that this technology significantly reduces the workload, drudgery and time for postharvest processing of millets and is ergonomically sound compared to the traditional method of threshing. To meet the increasing demand for this pedal-operated thresher NAERC, NARC has made an agreement with the private workshop for the commercial production of this thresher.

In addition, this pedal millet thresher was also evaluated for threshing sorghum. The average threshing capacity of the thresher for sorghum was obtained as 28.2 kg/hr with a threshing efficiency of 93.36% and concave clearance of 6 mm, respectively while that of stick beating (manual method) was 12.2±0.2 kg/hr (Khatri et al 2021). The average broken grain losses of 5.00±1.19% and 6.8±0.9% were found in machine threshing and manual threshing. Considering economic perspectives, a labor saving of 46.41% was achieved by the use of pedal thresher (47.85 man-hr/t) compared to manual threshing (103.9 man-hr/t).

Figure 1. Vivek millet thresher cum pearler

Figure 2. Modified millet thresher cum pearler (Electrically operated)

Figure 3. NAERC developed pedal operated thresher

Figure 4 First Model of proso millet dehusking machine (Abrasive stone model)

Figure 5. Second Model proso millet dehusking machine (Dehusking drum type, Chino kutak) (Bhandari et al 2020)

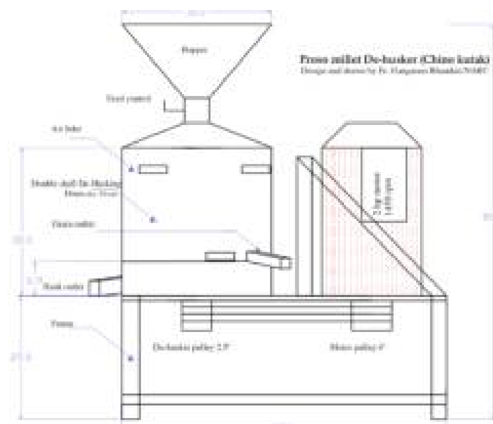

Figure 6. Third model of proso millet dehusking machine (Centrifugal type) (Bhandari et al 2020)

Figure 7. Combine mill

Figure 8. Multi crop seed cleaner

Efforts in the Development of Proso and Foxtail Millet Dehusking Machine

Dehusking is one of the primary operations needed for the removal of the outer husk layer of proso and foxtail millet to make the grains edible to the user. Traditional dehusking such as pounding in wooden mortar is a drudgery, time-consuming and more labor-intensive method. Thus, mechanized post-harvest operations can reduce the rural women's workload and drudgery in dehusking operations. Considering those aspects, the Agricultural Engineering Division has put efforts into developing different models of motorized dehusker machines for the purpose of proso millet dehusking. The first model (**Figure 4**) is an abrasive stone roller drum type which follows the principle of abrasion like a rice polisher. In this type of machine, there are three components ie, feed hopper, emery stone roller and electric motor. The performance of the first model was not satisfactory so the second model (**Figure 5**) was developed which consists of a dehusking drum type with replaceable canvas flat belt strips (this is called Chino Kutak). Similarly, the third model (**Figure 6**) was developed which is a double shell drum type having a rubber cylinder working on centrifugal force and impact principle. The second and third model is fabricated through the financial support and facilitation of GEF UNEP Local Crop Project (Bhandari et al 2020). The developed dehusker can dehusk 30 kg of proso millet (model 2) and 52 kg (model 3) per hour at 10-12% moisture content (NAERC 2018). These two models were promoted in Karnali Province under the name of the Chino Kutak machine.

Adaptation of Combine-mill for Dehusking Proso and Foxtail Millet.

Combine-mill (**Figure 7**) is a popular grain processing mill for dehusking rice and grinding grains in Nepal. NAERC also evaluated a combine-mill with a modified sieve for dehusking proso millet and foxtail millet. Based on experimental observations, combine mill has a dehusking capacity of 56 kg/hr and 75 kg/hr for proso millet and foxtail millet respectively at 12% moisture content (NAERC 2021). Similarly, the dehusking efficiency is 81% and 66% for proso millet and foxtail millet, respectively at 12% moisture content. Based upon the performance and multipurpose application of combine-mill, NAERC recommends combine-mill with modified sieves for dehusking proso and foxtail millets.

Use of Seed Cleaner for Millet Cleaning

Cleaning and grading are important operations during the processing of vegetable seed and cereal grain. Hand-operated multi-grain seed cleaner (**Figure 8**) is designed, developed and tested to enhance the quality of seed and reduce the drudgery of women. Apart from cleaning the seed, this cleaner can also separate the bold grain seed and shriveled grain. The seed cleaning mechanism was designed and fabricated using a centrifugal blower with a wind velocity 3-7 m per second at 800 rpm. It has two outlets to collect seeds of different weights and fine particles are blown away. The capacity of the hopper is 10 kg fitted with a feed control mechanism and agitator to break the bridging effect. The velocity of the air blown is controlled by changing the outlet area of the blower. It also consists of adjustable baffles with a knob to control the output in outlets. The capacity of seed cleaner is 60-85 kg/hr for smaller and larger seed respectively with a cleaning efficiency of 99% (AED 2011). The machine with an adjustable height mechanism is ergonomically sound for women of different heights. This kind of seed cleaner is already commercialized through local fabricators. NAERC has also modified manual seed cleaners to electrically operated seed cleaner to increase efficiency and capacity.

Combine-mill for Millet Grinding

Combine-mill is found to be popular machine for dehusking rice and grinding grains in the rural areas of mountainous and hilly regions of Nepal (Khatri et al 2020). The multi-functional combined mill is composed of two compartments named rice mill compartment (Rice huller) and the flour grinding compartment (disc mill). The Rice Mill consists of one alloy steel rice roller and one stainless steel rice screen, matched with an air blower device. It can remove rice husk and bran. Similarly, a disc mill (grind) compartment has one rotating disc and a fixed casing. It can be used to grind or crush the grain into flour. The grain grinding capacity and grinding efficiency of this mill are 120 kg/hr and 88 % respectively (Khatri et al 2020, NAERC 2021a).

Conclusion

The millet is an important crop for the food security and livelihoods of the marginal environment of the hills and mountain region of Nepal. The millets can withstand various biotic and abiotic stress and are considered to be climate-resilient crops. In addition, these millets are found to be high nutritional crops rich in micronutrients (viz. calcium and iron) with high dietary fiber, rare amino acids, antioxidants and vitamins. To address the nutritional requirements and livelihoods of the people in this region with the serious threat of climate change, there is a need of the promotion and commercialization of millets. One of the major challenges of the promotion of millets is the present labor-intensive and drudgerous cultivation and post-harvest operations of the millet production process. Mechanization in post-harvest operations for millets is essential for not only the reduction of drudgery of women but also to reduce the cost of cultivation for the promotion of millets in Nepal. In this context, NAERC, NARC has developed the millet thresher, foxtail and proso millet dehusker and seed cleaner for the post-harvest mechanization of millets. In addition, NAERC, NARC has also adapted the combine-mill for dehusking the fox tail and proso millet dehusking and grinding. These technologies are preferred by the farmers but there to be made more affordable and further improved to address the needs of the farmers in this region. Hence, more thrust is to be given to research, development and extension of millet post-harvest technologies for better access to the appropriate post-harvest technologies by the farmers in the region to promote the climate resilient and nutritionally important millet crops (Himalayan super food) for the sustainable development of this region.

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Millet Thresher Adoption and Consumption Pattern of Finger Millet in Nepal

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Abstract
Finger millet is the fourth major cereal crop in Nepal and an important food crop for hilly and mountainous regions. The import of millet has been increasing over the past 20 years. Its' productivity is far below as compared to other countries. It is labor-intensive crop and farmers experience drudgery from planting to threshing. This study analyzed the adoption of millet thresher and consumption pattern of millet in Nepal. A household survey of 448 samples was conducted using multistage proportionate random sampling from five major finger millet growing districts comprising Sindhupalchowk, Makwanpur, Kaski, Dolakha and Baglung. The probit model was used to identify the factors influencing adoption of millet thresher. Among the 14 explanatory variables used in the model, membership, foreign migration, training received, subsidy received, millet sold status of farmers and adjacent district to millet thresher suppliers were statistically significant. The finger millet was utilized for home consumption (48%), beverage making (33%), livestock feeding (17%), and 2% for other purpose including seed. The study showed that about 26% of farmers had adopted thresher for finger millet threshing which reduced labor and drudgery, particularly to female farmers. Finger millet thresher adopter farmers save about Rs. 1245 per ropani as compared to non-adopter farmers. To increase the adoption of finger millet thresher, extension strategy should focus on awareness about thresher and provide subsidy in millet thresher to the farmers' group. The introduction of millet thresher along with better crop management practices is important in the reduction of labor and drudgery, and increased production in the country.

Keywords: Consumption, drudgery, labor-intensive, productivity, thresher

Introduction
Finger millet is the fourth major cereal crop in Nepal, cultivated in 267,071 hectares with average productivity of 1.27 tons per hectare (MoALD 2023). Nepal imported 22,226.38 tons finger millet in 2021 (FAOSTAT 2021). The imported quantity of finger millet is doubled within five years. The import value is increasing rapidly with an average of 14.62% per annum in the last decade indicating the current production is not able to satisfy the demands (Gairhe et al 2021). There are many problems in millet farming in Nepal. Among them, labor constraint and processing difficulty were the reasons for the farmers' declining interest in finger millet cultivation (Devkota et al 2016, Ghimire et al 2017, Gauchan 2019). Farmers are not interested in finger millet cultivation because of its tedious and labor-intensive agronomic practices and post-harvest operations (Devkota et al 2016). Due to labor- intensive crop, it also creates more than 90% of workload to women farmers in finger millet cultivation in Nepal (Adhikari 2012, RESMISA 2012).

This is because of the increased migration of male household members to inside as well as outside the country, which has resulted in the feminization of agriculture (Gartula et al 2010). Labor requirement for finger millet production was found to be higher than other crops. The high labor requirement for transplanting and separating threshing of heads and straw (Upreti et al 1991). Labor outmigration in Nepal in the last decade has created a chronic shortage of agricultural labor (Gauchan 2018). This situation has also contributed to increase wage rate in rural areas (Wang et al 2016). Therefore, there is a need to introduce machinery to substitute human and animal labor and which help to reduce the cost of cultivation (Gauchan et al 2018). To address the labor shortage in finger millet, the National Agricultural Engineering Research Centre (NAERC) of Nepal Agricultural Research Council (NARC) has developed a finger millet thresher in 2010, which is being manufactured by the J.B. workshop Gwarko, Lalitpur. Further, Nepalese farmers are facing problems in the separation of threshing of millet grain which is very tedious and drudgery and also required more labors. This thresher helps to reduce cost, improve efficiency, and minimize women drudgery (Gauchan and Shrestha 2017). Likewise, millet thresher is effective for grain separation, grain cleaning, and husk removal and make free from dust and other inert material (Devkota et al 2016). Although millet thresher has a significant role in cost and drudgery reduction, its adoption among the Nepalese farmers is very low and its economic impact is unknown to the concern stakeholders. This study analyzed drivers of adoption which help to further scale up this technology rapidly and its impact on cost reduction is also analyzed.

Methodology

Study districts were selected based on the adoption of millet thresher and cultivated area of millet in the district. The selected districts were Dolakha, Sindhupalchowk, Makwanpur, Kaski and Baglung. In the district, two millet growing municipalities were identified with the consultation of the Agricultural Knowledge Centre and local municipality. We employed multistage proportionate random sampling method. A household survey was conducted from February to April 2023 with 448 households that involved 115 millet thresher users (adopters) and 331 non-users (non-adopters) from five districts. Adopter farmers were identified with the consultation of key informants and 60% of the target population was selected using the proportionate to the size sampling technique. Non- adopter farmers were selected randomly from the same locality from where millet thresher users were selected. A structured interview schedule was used to collect the data from household survey. One focus group discussion with key farmers in each selected municipality was conducted for the validation of cost related data. The survey collected information on household demographics, the quantity of inputs used, millet cultivation practices, thresher adoption status, cost reduction, consumption behavior, advantages of millet thresher, problems of millet farming and outputs obtained.

Factors influencing in the adoption of thresher

A probit model was used to determine the factors influencing millet thresher. A probit model is appropriate for modelling dichotomous dependent variable which takes value 1 for adopters and 0 for non-adopters. The Logit model is also used in the discrete model which produces the same results as the probit model. The difference between logit and probit model is only in the distribution of the errors. The logit model has a standard logistic distribution of errors whereas the probit model has a standard normal distribution of errors (Gujrati, 2004). The estimated parameters in the probit model are between 50% and 60% smaller value than the corresponding parameter estimates in the logit results.

In this study, adoption of thresher was based on an assumed underlying utility function. The difference between the utility from adopting thresher (UiA) and the utility from not adopting thresher (UiN) may be denoted as Ui*, such that a utility-maximizing farm household, i, will choose to adopt new technology if the utility gained from adopting is greater than the utility from not adopting (Ui*=UiA –UiN > 0).

Prob (U^*_i) = $\sigma_0 + \Sigma\, \delta_n X_i + \varepsilon_i$ .... Equation 1
Prob (Adopt=1) = $U' K + \varepsilon_i$ .... Equation 2
Where,

U^*_i = A latent variable representing the propensity of a farm household i to adopt thresher (1 if farmer adopt thresher and 0 otherwise)

X_i = K = the vector of farm households' asset endowments, household characteristics and location variable that influence the thresher adoption decision

$\sigma_{0,}\ \delta_n$ = parameters to be estimated

ε_i = error term of the ith farm households

Findings and Discussion

Description of socioeconomic characteristics

Table 1 shows the descriptive statistics of millet thresher adopters and non-adopter farmers. About 26% of the sample households adopted millet thresher. Farmers adopted single-crop and multi crop millet threshers. Single crop millet thresher was developed by the National Agricultural Engineering Research Centre (NAERC) of Nepal Agricultural Research Council (NARC) thresher in 2010 and is being manufactured by the J.B. workshop, Gwarko, Lalitpur and other suppliers. Multi-crop millet thresher is imported from India and China.

There were about 72% male farmers (**Table 1**). The average formal education of household heads was 3.78 years, adopters had modestly higher education (3.96 years) than non-adopters (3.72 years). Overall, about 50% of the farmers were members of an agriculture-related organization of cooperatives/groups and that involvement in the agriculture-related organization was noticeably higher (61%) in adopters than non-adopters (46%). The average years of farming experience were 33.2 years, but finger millet thresher adopter farmers were less experienced in farming (31.95 years) than non-adopter farmers (33.63 years). Adopters had less family members involved in agriculture (2.3) than non-adopters (2.5). The average millet cultivating land was about 3.87 ropani, however, finger millet thresher adopter farmers had a higher farm size (4.22 ropani) than non-adopter farmers (3.74 ropani).

Table 1. List of explanatory variables included in the probit model

Variable	All (N=448)		Adopters (N=115)		Non-adopters (N=333)	
	Mean	SD	Mean	SD	Mean	SD
Gender (1-Male; 0-Female)	0.72	0.45	0.71	0.45	0.72	0.45
Education (years)	3.78	4.41	3.96	4.41	3.72	4.41
Membership in organization (1-Member; 0-Otherwise)	0.50	0.50	0.61	0.49	0.46	0.50
Farming experience (years)	33.20	28.48	31.95	14.39	33.63	31.94
Farming member (number)	2.46	1.39	2.30	1.34	2.5	1.41
Total millet cultivated land (Ropani)	3.87	2.72	4.22	2.84	3.74	2.68

Variable	All (N=448)		Adopters (N=115)		Non-adopters (N=333)	
	Mean	SD	Mean	SD	Mean	SD
Foreign employment (1- Migrated; 0-Otherwise)	0.34	0.48	0.26	0.44	0.37	0.48
Access to extension services (1-Yes)	0.10	0.30	0.17	0.37	0.08	0.28
Access to agricultural credit (1-Yes; 0-Otherwise)	0.10	0.30	0.15	0.36	0.084	0.28
Training attended (1-Yes; 0-Otherwise)	0.06	0.23	0.10	0.30	0.04	0.20
Subsidy received (1-Yes; 0-Otherwise	0.08	0.28	0.15	0.36	0.06	0.24
Intercropping (1-Yes;0-Otherwise)	0.79	0.41	0.74	0.44	0.80	0.40
Millet sold status (1-Yes; 0-Otherwise)	0.35	0.48	0.59	0.49	0.27	0.44
District (1- Adjacent to supplier)	0.35	0.48	0.69	0.47	0.24	0.43

Overall, migration of a family member for employment was about 34% of the total farmers, but in comparison, it was higher in non-adopters (37%) than adopters (26%). On an average, only 10% of farmers have access to extension service, but the accession to extension service was more than doubled among adopter farmers (17%) than non-adopters (8%). Likewise, overall, 10% of farmers had access to credit and its percentage was nearly two times higher among thresher adopters (15%) than non-adopters (8%). Moreover, on average, only 8% of farmers received subsidy in millet farming, the thresher adopter farmers received markedly higher (15%) subsidy than non-adopters (6%). On average, 79% farmers cultivated finger millet with maize, soybean and other pulses and the remaining 21% of farmers cultivated finger millet as a sole crop. Furthermore, overall, more than one-third of the millet-growing farmers (35%) sold millet to the market, but more adopters (59%) sold millet than non-adopters (27%). Lastly, among the surveyed farmers about 35% of households were from adjacent districts to millet suppliers. The districts which are near millet thresher suppliers are Sindhupalchowk and Makwanpur, while other districts such as Baglung, Kaski and Dolakha are far from the suppliers. Among the adjacent district from suppliers, about 69% of farmers adopted millet thresher.

Probit regression results to identify the factors affecting millet thresher adoption

Table 2 presents the estimated parameters for the adoption of millet thresher. In the probit model, a discrete latent variable of millet thresher adopter is generated, taking on a value of 1 if the farmer adopted thresher and 0 if the farmers didn't adopt thresher. The result for the probit regression shows that the model is significant at a 1% level based on Likelihood Ratio (LR) chi-square value of 115.96 with 14 degrees of freedom. The value of pseudo R2 of the model is 0.227, with 82.37% of the responses predicted correctly. The area under the ROC curve for the probit regression is 0.81 which reveals that the model presents adequate discrimination. The average value of VIF is 1.35 with none of the variable's VIF value exceeding 2.57, which confirms there was no multicollinearity between explanatory variables. In **Table 2**, the marginal effect (dy/dx), represents the percentage change in millet thresher adoption per percentage change in each of the independent variables. Among the 14 explanatory variables used in the model, membership, foreign migration, training received, subsidy received, millet sold status and adjacent district were statistically significant.

Table 2. Probit model estimation of millet thresher adoption

Variables	Coefficient	SE	z-value	p>| z |	dy/dx
Gender	0.071	0.169	0.42	0.677	0.017
Education	0.016	0.018	0.90	0.369	0.004
Membership	0.279*	0.158	1.76	0.078	0.069
Farming experience (years)	-0.000	0.003	-0.09	0.932	-0.000
Agricultural members	-1.069**	0.055	-1.94	0.052	-0.026
Total millet cultivated land	-0.028	0.028	-0.99	0.323	-0.007
Foreign migration	-0.340**	0.158	-2.15	0.032	-0.084
Access to extension services	0.370	0.371	1.00	0.318	0.091
Access to agricultural credit	-0.456	0.367	-1.24	0.215	-0.113
Training attended	0.559*	0.315	1.77	0.077	0.138
Subsidy received	0.539**	0.268	2.01	0.044	0.133
Intercropping	0.010	0.179	0.06	0.956	0.002
Millet sold status	0.505***	0.163	3.10	0.002	0.125
District	1.191***	0.159	7.47	0.000	0.294
LR chi^2 (14)	115.96				
Prob > chi^2	0.000				
Pseudo R^2	0.227				
Log likelihood	-197.18				
Goodness of fit test	Pearson chi^2 (429) = 453.33 prob >chi^2 = 0.201				
Correctly predicted percent	82.37				

Participation of membership of an agriculture-related organization had a positive effect on millet thresher adoption and it is significant at a 10% level of significance. Holding other factors constant, farmers who were members of agriculture-related organizations; the probability of the adoption of millet thresher was increased by about 7%. Farmers who were members of agricultural organization; the probability of adoption of new agricultural technology was increased (Adhikari et al 2018, Mutale et al 2017).

The number of family members involved in agriculture had a negative significant effect on the adoption of millet thresher adoption decisions. This suggests that households with more members involved in agriculture were less likely to adopt millet thresher than fewer family members involved in agriculture. The result showed that with an increase of one farming member in a household, the probability of adoption decreased by 2.6%. This result indicates that households with higher number of agricultural members involve in threshing and cleaning activities of millet, that's why they may neglect to adopt millet thresher.

Another significant variable is outmigration, which had a negative effect on millet thresher adoption decisions. The result indicates that households with members migrating outside had 8.4% less probability of adoption than non-migrant households. As the migrant households have regular income sources such as remittance, they are more likely to have less focus on farming and also abandon the farming land which can affect the adoption of millet thresher. Land abandonment due to labor shortage due to outmigration is a big issue for the sustainability of farming in Nepal (Gauchan 2018).

In terms of participation in training related to millet production, the chances of adoption of millet thresher were increased by 13.8% for those farmers attending training, and it is statistically significant at 10% level of significance. Farmers who have received training related to millet farming may gain knowledge, awareness and exposure about the millet thresher which motivate farmers to adopt it. Nyanga (2012) found training had a significant positive effect on conservation agricultural technology adoption. Similarly, subsidy-receiving households had a significant positive impact on the adoption decision of millet thresher. Farmers who received subsidy in seed, fertilizer and machineries had a 13% more chance to adopt millet thresher than subsidy non receiving farmers. Adhikari et al (2023) also found that initial subsidy had a positive impact on improved lentil varieties adoption.

Furthermore, farmers who sold millet had a 12.5% more probability to adopt millet thresher than farmers' who did not sell millet to the market and it is significant at 1% level of significance. Farmers' who sell millet have ability to adopt millet thresher and they may seek and interested about new technology adoption. Lastly, the location variable showed a statistically significant and positive relationship with millet farmers' decision to adopt thresher. This means that farmers from adjacent districts from millet thresher suppliers tended to adopt millet thresher more than nonadjacent districts.

Advantages of millet thresher over manual method of threshing

The manual method of millet threshing is very tedious, drudgery and time-consuming. Farmers experienced multiple advantages of millet thresher over the manual method of threshing. Farmers found the millet thresher effective for grain separation, husk removal and cleaning. Farmers perceived that the millet thresher required less effort and faster which reduced back pain and less injury. In the manual method, labour is required for threshing and cleaning, which is replaced by millet thresher.

Table 3. Experiences of advantages in the use of millet thresher

Advantages	Index value	Ranking
Less time	0.990	I
Less labour	0.986	II
Grain separation easily	0.980	III
Less effort	0.979	IV
Husk removal easily	0.975	V
Less back pain	0.973	VI
Less cleaning required	0.966	VII
Less injury	0.959	VIII
Less dust	0.927	IX

Cost and labor saving by millet thresher

Most of the threshing and cleaning activities of millet are performed by female farmers. The manual threshing is time consuming, drudgery and painful to the female farmers. Therefore, the introduction of a thresher for the reduction of drudgery, time, effort and cost is necessary. **Table 4** shows male and female labor used for millet threshing and cleaning. According to the survey, about 0.53 male and 1.11 female labor for one ropani are required for the manual method of threshing while in the case of cleaning, 0.21 male and 1.05 female labor are required. **Table 4** also shows cost reduction by the use of thresher. Thresher adopter farmers are saving Rs. 1,245 per ropani by the replacement manual method of threshing practices.

Table 4. Cost comparison between manual and machine threshing per ropani

Item	Male	Female
Threshing (Number)	0.53	1.11
Cleaning (Number)	0.21	1.05
Wage rate (NRs.)	815	490
Total cost required for manual method of threshing (NRs.)	1,639	
Total cost required for millet thresher (NRs.)	394	
Cost reduction due to thresher (NRs.)	1,245	

Utilization of millet

Table 5 presents the millet consumption and sold status among the surveyed households. Out of total millet production, the highest percentage (32%) of millet is utilized for home consumption. After that, about 17% of millet is utilized for livestock feeding and 15% of millet is used for beverage making for home consumption. About 3% millet grain is utilized for other purposes such as seed and gifts to relatives and neighbors. More than one-third (34%) of the millet is sold to the market by the farmers. Among the sold quantity, about 18% were sold for beverages and about 16% sold for home consumption.

Table 5. Millet consumption status by district (%)

Millet consumption status	Sindhupalchowk	Makwanpur	Kaski	Dolakha	Baglung	Total
Home consumption for food	20	22	41	36	47	32
Livestock feeding	19	3	14	28	26	17
Home consumption for beverage	14	21	14	11	13	15
Other utilization	3	2	3	3	2	3
Sold for beverage	24	23	11	19	7	18
sold for consumption	19	28	16	3	5	16

Problems in millet farming

Farmers have several problems in millet farming. From the survey conducted among millet farmers, planting was ranked as the first problem followed by threshing, land preparation, animal attacks and weeding. Likewise, cleaning, nursery preparation, labor availability and marketing were the sixth, seventh, eighth and ninth problems respectively according to the farmers experiences. Most of the surveyed farmers cultivated millet with maize intercropping. Farmers stated that it is very tedious and difficult to perform planting, land preparation and weeding practices of millet in between maize plants.

Table 6. Farmers' perception on problems in millet farming

Problem	Index value	Ranking
Planting	0.786	I
Threshing	0.733	II
Land preparation	0.727	III
Animals attack	0.716	IV
Weeding	0.702	V
Cleaning	0.682	VI
Nursery preparation	0.627	VII
Labor	0.618	VIII
Marketing	0.466	IX

Conclusion

This study analyzed factors affecting millet thresher adoption, its advantages, cost reductions and consumption patterns. The probit model result showed that factors membership, foreign migration, training received, subsidy received, millet sold status and adjacent district were the major factors that influenced the millet thresher adoption. The major advantages of millet thresher are less time, labor saving, easy to separate grain, less effort and easy to separate husk. Likewise, farmers also experienced less back pain, less cleaning, less injury and less dust. Moreover, for one ropani of land, about 0.53 male and 1.11 female labor are required for the manual method of threshing while in case of cleaning, 0.21 male and 1.05 female labor are required. The cost reduction by the use of millet thresher is Rs. 1245 per ropani as compared to manual method of threshing practices. Furthermore, the highest quantity of millet was utilized for home consumption (48%), beverage making (33%), livestock feeding (17%), and 2% for other purpose including seed. The major difficulties encountered in millet farming include planting, threshing, land preparation, animal attacks and weeding. For the scaling of millet thresher, concerned stakeholders should focus on awareness and motivate farmers' groups through subsidy to purchase millet thresher. Further, there should be promotion of better crop management practices for the reduction of cost and drudgery in millet cultivation and increase production.

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Post-Harvest Management of Millets

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Summary

Millet, a climate-resilient crop with a long history in Nepal, plays a vital role in the food and nutritional security of smallholder farmers. However, challenges in millet production and post-harvest practices have hindered its potential. Traditional methods like manual threshing and winnowing are time-consuming and labour-intensive, contributing to significant post-harvest losses. The absence of modern technology and infrastructure further compounds these issues. Efforts have been made to introduce improved post-harvest technologies, including mechanical threshers and better storage facilities, which have enhanced processing efficiency and reduced losses. Value addition initiatives are emerging, with millet-based products like flour, bread, cookies, and snacks creating new market opportunities and increasing the crop's value. Storage pests pose a threat to millet storage, thus hermetic storage bag is recommended for safer grain storage. Challenges persist in proper storage and scaling up value-added products. To support the growth of the millet sector, it is crucial to provide post-harvest management training for farmers and develop niche-specific technologies and storage facilities. Thus, sustainable, and competitive millet production requires continued investment in infrastructure, training, and awareness programs, from production to post-harvest.

Keywords: Post-harvest, processing, storage, pest management, value addition

Introduction

Millet, often referred to as "KU ANNA (bad cereal)," has been a staple food in Nepal for centuries, playing a crucial role in the country's food security and agricultural sustainability. Nepal, a diverse and predominantly agrarian nation, has a rich tradition of cultivating and processing various types of millets, such as finger millet, foxtail millet and proso millet. In addition, there are other millets such as little millets, and sorghum which are not widely cultivated in Nepal. These hardy and nutritious grains have not only been a dietary staple for millions but have also been integral to the nation's cultural and agricultural heritage.

Millet processing techniques in Nepal have evolved over generations, with deeply rooted traditional methods. These processes often passed down through practices, include techniques for dehusking, milling, and turning millets into a variety of food products like flour, porridge, and fermented beverages. Millet-based dishes, such as Dhido and Roti, are not only delicious but also nutritious, contributing to the overall well-being of the consumers. However, farmers in Nepal continuously leaving millet farming because of the tedious post-harvest practices. Additionally, due to the lengthy process of post-harvest operations, and males seeking employment both abroad and domestically, females are responsible for conducting post-harvest activities (Devkota et al 2016). In recent years, millet processing in Nepal has gained renewed attention due to strenuous traditional milling practices and the realization of its importance in nutritional aspects. This encourages national efforts to promote millets as part of a sustainable and healthy diet, especially in regions facing food insecurity and malnutrition challenges. This article explores the traditional and contemporary millet storage and processing practices in Nepal. It also identifies challenges and opportunities associated with millet storage and processing in the country. This article is based on the review of various literatures and consultation with five millets growers from Kalikot, Sindhipalchowk and Makwanpur on their post-harvest practices over the telephone.

Millet's Processing and Milling Practice in Nepal

Major millets are generally harvested during October-November in Nepal. In Karnali region, especially in Kalilot district, millets are generally transplanted or sown during June/July and harvested in October. When finger millet reaches maturity, its earheads exhibit a curved shape, indicating readiness for harvest. Typically, finger millets are suitable for harvesting approximately 35-40 days after flowering. Millet grains are typically gathered when their moisture content ranges between 15% to 20%. Farmers collect the earheads and place them in bamboo baskets or bags. These harvested earheads are then sun-dried for 3-4 days to reduce moisture content in the grains. Drying is done to reduce their moisture level to an ideal range of 10% to 12% for optimal storage. Some farmers may store the harvested bags for up to 15 days before threshing. It's worth noting that sun-drying the grains is preferred over air-drying, as it results in superior flour quality. The harvested heads are emptied to the floor and are beaten with wooden sticks for threshing *(chutne).* The large size wooden stick is usually preferred because it also removes the husk from the grain. If a grain possesses a husk, it necessitates a dehusking *(falne)* process. Dehusking is done mainly by beating in *Dhiki*. After threshing farmers usually kept the grain in storage. The quality of these grains during storage is greatly influenced by factors such as temperature, relative humidity, and moisture content. Maintaining a clean and dry storage environment is crucial as it safeguards the grains against issues like pest infestation, contamination by foreign materials, and unintended grain germination. Conversely, a hot and humid storage environment can lead to increased moisture absorption and the proliferation of insect pests and fungi. Farmers usually stored millet grain either in, bamboo mat (bhakari) the mud pots, wooden pots or sacks. When farmers need food, they take the millet from storage and mill the grain. In the Karnali region, milling operations are conducted utilizing water mills referred to as "Paani Ghatta." These mills can process between 5 to 10 kilograms of millet into flour within one hour.

The leader farmers from Sindhupalchowk and Makwanpur districts reported that when the millet is harvested either threshing is done after 2-3 days of drying or store the harvested heads until 1-1.5 months and then threshed. Some farmers used wooden sticks for threshing while others used millet thresher machines. Storing for a few days is beneficial for better hauling. However, farmers have suggested temperature can be increased in the storage and millets could have a chance of fermentation, therefore it should be checked from time to time. The fermented grains get discoloured and are not palatable. In contrast, in the Kalikot district hauling is usually done on the local rice hauling mills. In the Sindhupalchowk and Makwanpur districts, farmers stored grain in conventional bags or hermetic bags. Farmers also reported that they were able to store for more than 6-7 months in hermetic bags compared to conventional bags. They used to store in earthen or wooden pots for long time, this practice almost did not exist in Sindhupalchowk and Makwanpur. Moreover, milling was done in the local flour mills. It was observed that millet is mostly consumed as bread (*roti*) and wine (*rakshi*), however, it lacks value-added products. In urban areas like Kathmandu and Pokhara, bread and cookies are occasionally found in supermarkets. In addition, millet dumplings (*momo)* are on the menu of some resultants. The sequential process of the harvesting to consumption is presented in Figre 1. In the studied areas post-harvest practices were mostly done by women. A study by Rokaya (2022) showed that two-thirds of agriculture activities in the Mugu districts are performed by women. Gender inequality was an issue in the millet-growing areas. The prevalence of women's drudgery could be due to tradition, culture or the absence of males in search of jobs in foreign countries. Spending more time in agricultural works having dust and dirt may have an impact on the women's health and life expectancy. However, the relationship between women's drudgery and their health issues was not well studied.

Figure 1. Activities performed from harvesting to consumption

Various Practices of Millet Storage

Traditional storage

Millet is commonly grown in Asia and Africa where various traditional storage practices can be observed. Millet panicles are gathered to make a bundle and suspended on the walls in homes, trees, or wooden poles in India and Africa (Mobolade et al 2019). This is useful for short-term storage; indeed, grain might be damaged by the rain during long-term exposure outside. Additionally, Mobolade et al (2019) also reported in some African region farmers used 1-meter-high bamboo or straw mats that are supported with hard wooden sticks. Furthermore, sometimes they also left the grain on the floor or on the timber to keep them dry. Besides the temporary structures, several long-term storage structures are made from soil or wood, such as earthenware pots, and metal or wooden pots. They vary in shape and volume based on the requirements of the farmers.

Figure 2: Traditional earthen pot used for millets and other grain in Kalikot district of Nepal

Bin/silo storage

Nowadays metal bins are commonly used for food grain storage in Nepal. These circular bins are generally made of galvanized aluminum sheets, and used for storage of grains inside the house. These bins are fire and moisture-proof. The bins have long durability and can be used for various types of grains. The capacity ranges from 100 to 1 ton are most commonly used in Nepal (Kandel et al 2021). Silos can be constructed from various materials such as reinforced concrete, plain or corrugated galvanized sheets, mild steel black sheets, aluminium sheets, fibre glass, ferro-cement, asbestos sheets, and more (Sahay and Singh, 1996). Among these options, concrete, bricks, and metal are the most commonly used. Metal silos offer greater flexibility in terms of construction and operation but require protection from corrosion through processes like galvanization or the application of paint. Concrete silos, on the other hand, require less maintenance and are resistant to water and fire, but may develop cracks that result in moisture penetration and the loss of fumigants. Another drawback is carbonation, which is the reaction between carbon dioxide and calcium hydroxide in concrete, leading to the corrosion of reinforcing steel. While metal silos are typically used for storing large quantities of grains and are often seen as expensive for small-scale storage, efforts have been made to develop smaller metal bins for efficient storage in rural areas (Sundaramari et al 2011). However, in Nepal, silos are rarely used for millet storage which might be due to low volume of production or less availability.

Hermetic Storage

Hermetic storage is a sealed atmospheric storage in low oxygen and high carbon dioxide conditions (Caliboso and Sabio 1998). Hermetic storage is an alternative to traditional storage methods because it protects moisture, is chemical-free, free from insect attack and no refrigeration required. Grain stored in hermetic bags has better grain quality compared to the grain stored in conventional bags. Specifically, the seed viability loss was 3.6 times higher, 42 times more insects present, physical damage was 11 times more prevalent, and the weight loss of the grain was 23 times greater in traditional storage compared to hermetic bag storage (Ngoma et al 2023). In the case of storing millet, hermetic storage methods have proven to be highly efficient. A study conducted by Preethi et al (2016) assessed the efficacy of hermetic storage in controlling rice weevils (*Sitophilus oryzae*) in sorghum and pearl millet. They employed two methods to create hermetic conditions, namely, PVC bins and SuperGrainbag™, over 90 days. It was observed that the PVC bin method was more successful in establishing rigorous hermetic conditions. When considering insect mortality, a crucial factor contributing to their demise was the depletion of oxygen levels to 7% from their initial values. Furthermore, a study by Kandel et al (2021) shows that hermetic bags have contributed to food security in rural Nepal because of low insect infestation during storage and longtime storage.

Storage Pest Management

Insects are the major pest of millet causing both quantitative and qualitative loss. The primary pest feeds on the whole grain while the secondary pest feeds on the cracked or damaged grains or flour. The major storage insects of finger millets are discussed below.

Indian meal moth (*Plodia interpunctella* Hubner)

Symptoms: *Plodia interpunctella* is an external-feeding insect species. Its larvae consistently produce a silk-like web both inside and on the surface of grains, where they consume their food. This webbing contains larval waste (frass) and sheds skins (exuvia), emitting an unpleasant odour in the affected product. In some cases, the infested product may even be coated with a dense layer of this silk web (ICRISAT, 2023).

Management: Infected materials should be promptly disposed of, consumed, or subjected to a method of decontamination. These decontamination methods include using either high or low temperatures to eliminate any larvae and eggs present in the contaminated items. To use cold treatment, infested items should be placed in a deep freezer for at least two to three days. Enhancing the effectiveness of cold treatment can be achieved by alternating between freezing and allowing the items to return to room temperature for a few days. High-temperature treatments involve heating the items in an oven at temperatures ranging from approximately 120 to 140 degrees Fahrenheit for 20 minutes. If the treated items are bulky and require longer periods to reach the desired internal temperature, slightly longer intervals may be necessary. It's important to note that excessively high-temperature treatments can potentially damage the quality of the food (CSU, 2017). Furthermore, chemical treatment can be done by fumigation with methyl bromide @ 32 g/m3 for 4 hrs (ICRISAT 2023).

Larger grain borer (*Prostephanus truncatus* Horn.)

The following systems and management practices for larger grain borer and red flour beetle given by LC (2023) are described below.

Symptoms: Adults often bore into stored seeds that still have their protective sheaths intact, typically entering at the base of the seed. They create tidy, circular holes as they tunnel through the grains, producing significant amounts of grain dust along the way. Female adults lay their eggs in the chambers of the tunnels.

Management: To maintain a pest-free storage environment between harvests, clean the store thoroughly, dispose of infested remains through burning, soak grain sacks in boiling water, eliminate any wooden elements, and use of fumigation can be done as needed. Also, ensure that only uncontaminated materials are chosen for storage. Placing food items into airtight plastic containers creates an environment for low oxygen and higher carbon dioxide level thus less infestation occurs. In locations with facilities, both prolonged freezing and a 24-hour heating process have demonstrated their effectiveness in managing stored product pests. Various combinations, including pirimiphos-methyl and permethrin, deltamethrin and pirimiphos-methyl, or fenitrothion and fenvalerate, have proven effective for safeguarding stored grain on farms. Another successful mixture, "Nimpyr," comprises neem and pyrethrum and is effective against pests like LGB and grain weevils. Large-scale grain storage can be protected from fumigation using phosphine or methyl bromide, which is highly efficient. Since pesticides are toxic, it is crucial to strictly adhere to the safety instructions provided on their labels.

Red flour beetle (*Tribolium castaneum* Herbst)

Symptoms: Adult beetles infesting granular food products can be easily detected through the tunnels they create on the grain. The damage is most problematic in processed grains that have had their outer layers removed. When the infestation is severe, these products transform into a greyish yellow colour, develop mould, and emit a strong smell. You may also notice adult beetles on the surface of the grains as a sign of infestation.

Management: Other management practices are similar to the larger grain borer. In chemical management practices, various chemicals like organophosphates, pyrethroids, and fumigants have been employed to manage the red flour beetle in Pakistan. Tetrachlorvinphos was the effective insecticide utilized against this pest, with diazinon, malathion, azinphos-methyl, and dichlorvos also being used. However, the red flour beetle has developed resistance to multiple insecticides in several countries. Therefore, chemical control should be used with a greater level of precaution.

A B C

Figure 3. Larger grain borer A, Indian meal moth B and Red flour beetle C
(Photo source: https://cropgenebank.sgrp.cgiar.org)

Post-harvest Treatments of Millets

In the millets thermal treatment is done to increase the milling efficiency. Hydrothermal treatment is done by soaking grains in water at room temperature for approximately 8 hours, followed by a 20-minute steaming step at normal atmospheric pressure, and drying (Dharmaraj and Malleshi 2011). In the little millets, the treatment to 70°C for 3 hours and steam heating at 110°C for 20 minutes to enhance milling and cooking quality (Mannuramath and Yenagi 2015). Hydrothermal treatment enhances decortication efficiency. This treatment involves steaming, which causes starch to gelatinize, starch granules to swell, and proteins to denature, resulting in a modified texture of the millet endosperm with minimal visible cracks. Additionally, drying the steamed kernels further increases digestibility (Shobana and Malleshi, 2007). Hydrothermal treatment enhances the digestibility of carbohydrates and proteins, possibly because of the partially gelatinized starch found in treated millet. The reduction in polyphenols contributes to better protein digestion (Dharmaraj and Malleshi 2011). There are many other methods for post-harvest treatment of millets dry heat treatment and irradiation etc which are not in practice in Nepal.

Conclusion

In conclusion, post-harvest management plays a critical role in determining the quality, shelf-life, and marketability of crops. While millets are one of the staple crops for smallholder farmers, traditional post-harvest practices, such as manual threshing and winnowing, have been labour-intensive and time-consuming. The absence of modern technology and infrastructure has led to significant post-harvest losses. However, there have been notable efforts to address these challenges. The introduction of improved post-harvest technologies, such as mechanical threshers and enhanced storage facilities, has not only increased efficiency but also reduced losses, thereby improving the income and food security of farmers. In addition, milling efficiency can be increased by thermal treatment. Moreover, the promotion of value-added millet products, including flour, bread, cookies, and snacks, has opened up new market opportunities and enhanced the overall value of millet crops. These innovations not only contribute to food security but also offer economic benefits to smallholder farmers.

Nevertheless, challenges persist, particularly in the proper storage and scaling up of value-added products. To foster the growth of the millet sector in Nepal, it is imperative to provide post-harvest management training to farmers, develop technology tailored to specific niches, and establish robust storage facilities. Sustainable and competitive millet production and value chains in Nepal necessitate ongoing investment in infrastructure, training, and awareness programs that span from production to post-harvest stages. Furthermore, traditional practices and cultural aspects related should be documented.

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E. Soil, Manure and Irrigation

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Nutrient Management Studies in Maize/Millet System in Nepal

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Summary

Finger millet (*Eleusine coracana L.* Gaertn) is the fourth most important cereal crop in terms of area and production after rice, maize and wheat in Nepal. It plays an important role in the livelihood of mid hills people. The objective of this paper is to comprehensively review the literatures related to yield responses of finger millet and maize/millet system to inorganic fertilizers, organic manures, green manures, crop residue. The review also describes the impact of these inputs on soils and cropping systems and finger millet varieties. The review evaluates the benefits and challenges associated with maize/millet system and integrated nutrient management. We conclude by identifying research gaps related to nutrient management in finger millet and maize/millet system, and provide recommendations to increase the yield and sustainability of finger millet and millet-based system as a guide for subsistence farmers.

Keywords: Finger millet, inorganic fertilizer, millet-based system, nutrient management, sustainability

Introduction

Finger millet (*Eleusine coracana* L. Gaertn) is a major food crop of the semi-arid tropics of Asia and Africa (Goron 2015, Kerr 2014, Pokharia et al 2014). Its name is derived from the floral head, which has the shape of human fingers. Locally, the crop is called *Ragi* (India); *Kodo* (Nepal); *Dagussa, Tokuso, Barankiya* (Ethiopia); *Wimbi, Mugimbi* (Kenya); *Bulo* (Uganda); *Kambale, Lupoko, Mawale, Majolothi, Amale, Bule* (Zambia); *Rapoko, Zviyo, Njera, Rukweza, Mazhovole, Uphoko, Poho* (Zimbabwe); *Mwimbi, Mbege* (Tanzania); and *Kurakkan* (Sri Lanka) (NRC 1996, Thilakarathana and Raizada 2015). The crop was domesticated in the highlands of Ethiopia and Uganda 5000 years ago, but reached India 3000 years ago (Dida et al 2005, NRC 1996). Finger millet is ranked fourth globally in importance among the millets, after sorghum, pearl millet, and foxtail millet (Gupta et al 2012). It is cultivated in more than 25 countries, mainly in Africa (Ethiopia, Eritrea, Mozambique, Zimbabwe, Namibia, Senegal, Niger, Nigeria, and Madagascar) and Asia (India, Nepal, Malaysia, China, Japan, Iran, Afghanistan, and Sri Lanka) (Chandrasekar 2010, Dass et al 2013). In Eastern Africa, the major producers are Uganda, Ethiopia, and Kenya (Midega et al 2010).

In Nepal, Finger millet (*Eleusine coracana* Gaertn) is the fourth most important cereal crop in terms of area and production after rice, maize and wheat. It plays an important role in the livelihood of mid hills people. The area of cultivation of finger millet in Nepal was 265,401 ha, with a production of 326,443 metric tons and the yield of 1.23 ton/ha (MoALD 2022). Agro-ecologically most of the finger millet growing areas are under mid hill which accounts 77% of the total area of finger millet followed by mountain (20%) and very limited area in terai which covered only 3%. Among the seven provinces, Gandaki province has 33.17% of Nepal's total finger millet coverage, followed by Koshi Province (26.68%), Bagmati province (22.61%), Karnali province (7.14%), Sudurpaschim province (5.92%), Lumbini province

(3.85%) and Madhesh province (0.62%) (MoALD 2022). Out of the total area under millet cultivation, 85% is relayed with maize in Nepal (Karki et al 2014).

It is pre-dominantly grown under maize/millet relay system in mid-hills of western, central and eastern regions where as in the hilly areas of mid and far western region, it is grown as mono crop. It is very important in subsistence farming systems, where it is cultivated in marginal land without external inputs and provides a sustaining diet for rural people. People mainly consume it as thick porridge, pancakes and roasted thick breads. About one-fourth of the domestic production is utilized in beverage production (Ghimire et al 2017). Most of the imported finger millet are used in city and mainly for beverage production as its other food items are not popular in urban areas.

Maize and finger millet relay intercropping is an old practice in Nepal and it is the predominant combination found in hill agriculture. This system has helped maintain food and nutritional security from 500-1800m since time old. Maize/millet system is advantageous to farmers because of reduced land preparation and more efficient utilization of moisture, nutrient, and labor resources. The system sustained for several years being advantageous to the farmers but this system of cropping exhibits some challenges as well which needs to be minimized to uplift the productivity as well as the fertility of soil. In maize/millet relay system, 30–60 days old seedlings are transplanted under the standing maize in between tasseling stage and grain filling stage at lower altitudes, whereas, at higher altitudes, it is transplanted at knee high stage. The overlapping period of relay cropping becomes longer between maize and finger millet at higher altitude (Subedi 2001). Finger millet develops with minimal competition after maize is removed and the exploitation of the available moisture after maize removal is a key to intensify this system (Paudyal et al 2001). The duration of overlap of maize and finger millet in the relayed system increases from 30-40 days at 1000 m to 70-80 days at 1500 m (Subedi 1990). Evidently, the competition between the maize and finger millet crops is mainly determined by the period that both crops are grown together.

Millet is grown on the residual fertility of maize crop and farmers apply about 10-25 (ton/ha/annum) manure to maize (Sthapit and Subedi 1990). Soil fertility of maize based farming in Nepal is gradually declining (Rajbhandari 2000). Finger millet is almost grown on residual nutrients applied to maize so, regardless of the quantity of manure applied, it is of poor quality. Both crops being cereal and having same root system, it seems nutrient exhaustive, depleting available nutrients from the soil. From the study of Shakya et al (1991), farmers indicated that the declining fertility of soil as a factor constraining millet yields. According to Khadka (1990), maize/millet system exhausted the nutrients from soil more rapidly than any other cropping patterns.

The productivity of finger millet in farmer's field is very low and one of the factors for low yield is associated with nutrient management. Location and variety specific nutrient management is necessary to harness production potential. There is lack of collective information regarding the available technologies on nutrient management in finger millet or millet-based system. A summarized and compiled report of available technologies on nutrient management in finger millet based on studies carried out in Nepal would help for the farmers, extension personnels, researchers and other stakeholders for sustainable soil management to increase the production of finger millet.

Long-term soil fertility study in maize/millet relay system in Nepal

A long-term soil fertility experiment was initiated by Shakya et al (1999) in Kabre, Dolakha since 1993-1998 (**Table 1**). The main objective of the study was to determine the effects of continuous applications of organic and inorganic fertilizers on crop yields in a maize/millet cropping pattern. For finger millet, the highest grain yield (1689 kg/ha) was obtained with recommended rates of organic manure (30 ton/

ha FYM). By contrast, the highest maize grain yield (5284 kg/ha) was obtained with recommended rates of inorganic fertilizers (120:60:40 kg/ha N:P_2O_5:K_2O). Overall decreasing yield trend was found in maize yield over years. The highest combined (maize + millet) total grain yield was obtained from 120:60:40 kg/ha N:P_2O_5:K_2O (6501 kg/ha) followed by 80:60:40 kg/ha N:P_2O_5:K_2O) and 10 ton/ha FYM + 60:30:20 kg/ha N:P_2O_5:K_2O (5949 kg/ha). The overall five years data revealed that the higher dose of chemical fertilizer ie 120:60:40 kg/ha N:P_2O_5:K_2O was found to be more effective in sustaining high maize yield, whereas FYM application at 30 ton/ha with N top dressing was found to be more effective in millet production. Thus, they concluded that the use of compost with chemical fertilizers 10 ton/ha compost advisable to increase yield and maintain long-term sustainability in maize/millet system.

Based on a simulation model used to explore the long-term impact of different fertilizer management scenarios for maize-millet systems in Nepal, Matthews and Pilbeam (2005) observed that application of FYM reduced the decline in rates of soil C and N compared to the application of inorganic fertilizer alone.

Table 1. Five years (1993-1998) mean grain yields of maize/millet and other attributes of long-term soil fertility experiment conducted at HCRP, Kabre, Dolakha.

Treatments	Finger millet yield (kg/ha)	Maize yield (kg/ha)	Total maize and millet yield (kg/ha)
Control	1032	2198	3230
10 ton/ha FYM	1295	3500	4795
20 ton/ha FYM	1585	2422	4007
30 ton/ha FYM	1689	4258	5947
10 ton/ha FYM + 20 kg N/ha top dressing	1503	3387	4890
20 ton/ha FYM + 20 kg N/ha top dressing	1656	2895	4398
30 ton/ha FYM + 20 kg N/ha top dressing	1196	3395	5051
10 ton/ha FYM + 60:30:20 kgha N:P_2O_5:K_2O	1572	4753	6325
80:40:30 kg/ha N:P_2O_5:K_2O	1217	4883	4455
120:60:40 kga N:P_2O_5:K_2O	1430	5284	6501
Mean	1153	3778	5208
F-test	**	**	**

*=Significantly different at $p \leq 0.05$, **=significantly different at $p \leq 0.01$
Source: Shakya et al (1999)

Sherchan et al (1999) carried out six years' long-term soil fertility management study on maize/millet system in eastern mid hills of Nepal at Agricultural Research Station, Pakhribas during 1989 to 1994. The results showed that yields of maize were higher where manure was applied at land preparation and a top-dressing of 30 kg/ha was applied at the knee-high stage. Millet yields were always lowest when inorganic fertilizer alone was applied to the maize, and highest when maize was manured at the highest rate (25 ton/ha) and also received a top dressing of 30 kg/ha N. Averaged over years, maize yielded significantly more (563 kg/ha) when manure and fertilizer were applied than when manure alone was applied. Manured maize crop yielded significantly more (307 kg/ha) than maize receiving inorganic fertilizer alone. Similarly, yields of millet were increased by 631 kg/ha or 705 kg/ha respectively when either manure and fertilizer or manure alone were applied to maize, rather than inorganic fertilizer. Top dressing maize with 30 kg N/ha at the knee-high stage following a basal application of manure increased yields by 797 kg/ha compared with maize yields without top-dressing. Yields of maize but not of millet were significantly greater (418 kg/ha) at the higher rate of manure. The result suggested that chemical fertilizer 120:60:30 kg/ha N:P_2O_5:K_2O

alone cannot maintain maize/millet productivity so combine application of both compost and inorganic fertilizer is necessary to maintain productivity in long run.

Pilbeam et al (2002) found that during the monsoon only 50% of applied fertilizer remained as mineral N (that is, plant available N) four days after application, and by ten days after application less than 20% of the fertilizer remained in mineral-N forms. Consequently, fertilizers may provide a more available source of nutrients to crops such as wheat grown in the cold dry winter than to crops such as maize grown in the wet summer, whereas organic materials may provide a more available source of nutrients in the wet season when decomposition is more rapid. Nevertheless, the simultaneous provision of both organic and inorganic sources of nutrients to maize in an integrated nutrient package resulted in yields which were significantly greater than when either source of nutrients was applied alone. However, for the millet crops grown on residual nutrients, integrated nutrient treatments yielded more than fertilizer applications alone, and slightly less than treatments with manure alone. According to Sherchan et al (1999), on average, integrated nutrient management (INM) treatments yielded 35% more for both crops in a maize/millet rotation compared with the treatments where inorganic fertilizer alone had been applied.

Response of N, P, K fertilizer on maize/millet system

Application of the correct level of N fertilizer is important to obtain optimum yield of finger millet and thus make its cultivation profitable. Many of the soils where finger millet is grown are deficient in N. Earlier research work revealed that finger millet responded to graded levels of N. According to KC (1990) fertilizer trials were conducted at Khumaltar, Kabre, Kakani, Surkhet and Rampur under mono cropping of different finger millet varieties in 1985, 1986 and 1987. In 1985 different N levels were tested where P and K level kept constant. The highest grain yield was recorded at 125 kg/ha N at Khumaltar and Kabre. In 1987, six different fertilizer treatments were tested at Kakani, Kabre, Rampur and Surkhet. The highest grain yield (2186 kg/ha) was given by 60:40:30 kg/ha N:P_2O_5:K_2O followed by 30:40:30 kg/ha N:P_2O_5:K_2O + Azotobacter level (2080 kg/ha). In Kabre, in 1988, 60:40:30 kg/ha N:P_2O_5:K_2O gave the highest grain and fodder yield by 28% and 60% more yield increase over the control. The ratio of 60:40:30 kg/ha N:P_2O_5:K_2O was seen optimal for mono cropping condition.

KC (1990) reported that fertilizer trial on response of NPK and compost on finger millet conducted in 1989 at Kabre, Dolakha showed that grain yield increased by 100 kg/ha in each 10 kg/ha N from 0 to 80 kg/ha N level while grain yield at control was 1275 kg/ha and reached maximum 2044 kg/ha. On the same study, the grain yield increased from 1229 kg/ha (without P application) to 1786 kg/ha when 30 kg/ha P_2O_5 applied. Increase of P_2O_5 from 30 kg/ha to 60 kg/ha did not significantly increase grain yield. Similarly on the same study application of Potassium as 20 kg/ha K_2O did not significantly increase grain yield in comparison to without K application.

According to Sthapit et al (1988) application of nitrogenous fertilizers (40-120 kg/ha N) on the nursery raising of finger millet did not improve the millet yield but application of 40 kg/ha N basal and 40 kg/ha N top dressing along with compost at the time of millet transplanting produced 14.1% higher grain yield over 10 ton/ha compost. They concluded that the optimum time of applying nitrogenous fertilizers was at the time of transplanting. KC et al (1991) conducted fertilizer response experiment on grain yield of finger millet in mono cropping as well as in maize/millet relay system at Kabre, Dolakha during 1991. They found that high level of N (60 and 80 kg/ha) hastened maturity and low level of N (without N application) delayed maturity. Only application of compost delayed maturity than compost with chemical N fertilizer application under both mono and relay system. Application of 60:30:20 kg/ha N:P_2O_5:K_2O gave significantly higher grain yield (2871 kg/ha) and straw yield (6.1 ton/ha).

A study carried out by Gurung et al (1991) on plant population and fertilizer level at Pakhribas Agricultural Centre, Dhankuta during 1990 showed that 60:30:0 kg/ha $N:P_2O_5:K_2O$ and 10 ton/ha compost were similar from nutrient supplying point of view for maize and increase in finger millet plant population without adverse effect of maize yield reduction. Chemical fertilizers at the rate of 60:30:0 kg/ha $N:P_2O_5:K_2O$ was found better than 10 ton/ha compost for millet grain yield in maize/millet system but 30 kg/ha N should be top dressed for millet. KC and Baniya (1992) conducted fertilizer trial on maize/millet system and found that application of 100:30:0 kg/ha $N:P_2O_5:K_2O$ and 30 ton/ha compost produced higher total grain yield and earlier maturity. Finger millet grain yield was higher in 20:20:0 kg/ha $N:P_2O_5:K_2O$ and 30 ton/ha compost.Shakya et al (2002) conducted fertilizer experiment to recommend fertilizer dose for maize/millet relay system at HCRP, Kabre during 2000-2001. The treatment comprises of four level of N doses 0, 40, 80, 120 kgha and three level of P doses 0, 40 and 80 kgha. The role of N was high in maize grain yield and combination of 120:40 kg/ha $N:P_2O_5$ produced highest yield while in finger millet higher dose of N was detrimental and higher yield was obtained at 80:40:30 kg/ha $N:P_2O_5:K_2O$. Role of P was negligible in both maize and millet (**Figure 1** and **2**).

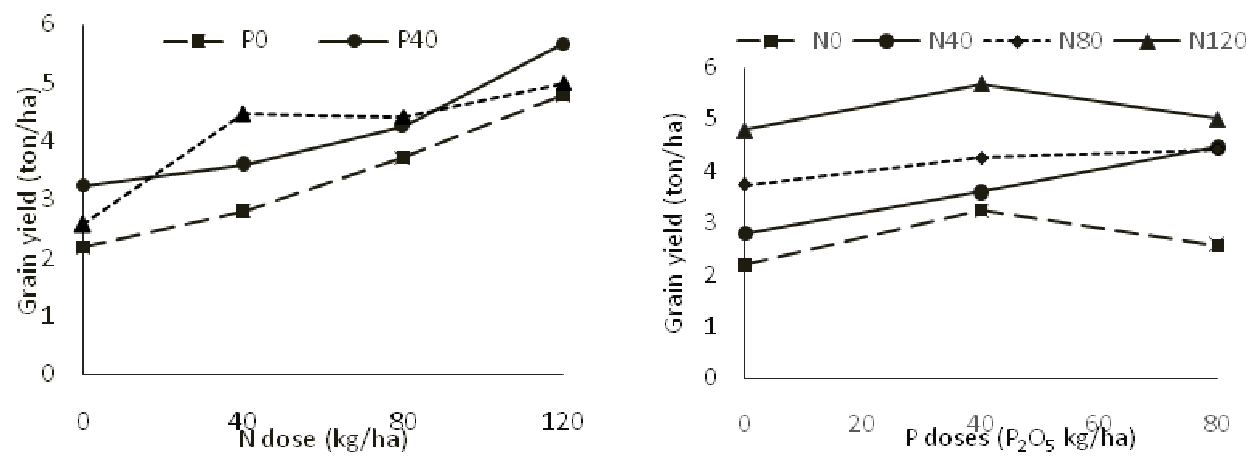

Figure 1. Maize grain yield as a function of N and P doses in maize millet system at HCRP Kabre during 2000 to 2001
Source: Shakya et al (2002)

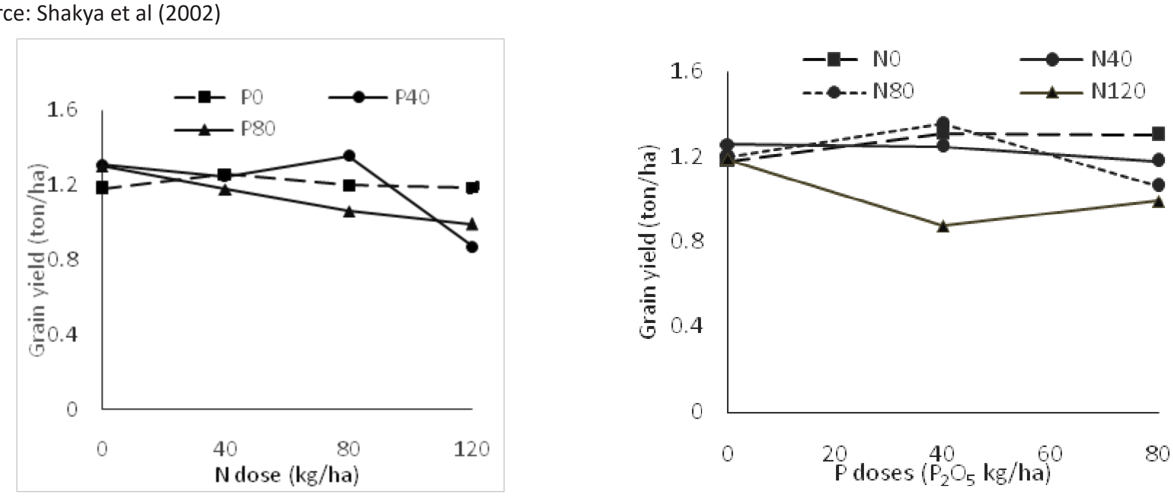

Figure 2. Millet grain yield as a function of N and P doses in maize millet system at HCRP, Kabre during 2000 to 2001
Source: Shakya et al (2002)

Effect of integrated nutrient management on maize/millet grain yield and soil properties

A Field experiment on maize and finger millet system was carried out by Acharya et al (2001) in the *Bari land* in farmers' field of Tanahun from 1997-1999 with the objective to find out the effect of organic manure and inorganic fertilizer application alone and in combination directly on maize grain yield and residual effects on succeeding crop (finger-millet) as well as on soil properties. The farmers' practice of fertilizer application determined through the survey in farmers' field was 90:30:30 kg/ha N:P_2O_5:K_2O for maize and its residue for finger millet was tested at different levels and sources under maize/millet system. The farmers' practice of inorganic fertilizers gave the highest grain yield of 2224 kg/ha. But the yield was in decreasing trend over years. Finger millet responded to residual of organic manures to produce significantly high grain yield but there was no residual effect of inorganic fertilizers on finger millet under maize-finger millet system. The total N and organic carbon decreased in all the plots including control. The available phosphorous increased more with the application of manure and less with the inorganic fertilizers. The exchangeable potassium and pH also increased in all the plots including control.

An experiment was conducted at ARS Lumle from 1997 to 2000 by Shrestha et al (2001) to develop suitable crop rotation and utilize their crop residues for maintaining soil fertility in maize based cropping system. The specific objectives were to find out the response of organic and inorganic fertilizers on crop yields and to measure the changes in soil fertility in response to manure, fertilizers, crop residues and legumes in crop rotation. Three years study revealed that under strongly acidic condition, high dose of inorganic fertilizers alone could not sustain both maize and finger millet yields but application of manure alone or 50% through manure and 50% through inorganic sources could sustain the yields of maize and finger millet yields. Application of 3 ton/ha lime is necessary when soil pH is less than 5.0.

Pilbeam et al (2002) investigated the effect of different nutrient sources applied at three rates (0, 45, 90 kg/ha N:P_2O_5:K_2O) on crop yields in a maize-millet rotation at two locations (Pakhribas and Dordor Gaun) in the mid-hills of Nepal and measured the recovery of ^{15}N-labelled urea applied as a top-dressing to maize at three rates (11.25, 22.5, 45 kg/ha N). Grain and straw yields of maize were greater following the application of fertilizers either alone or in combination with manure, rather than manure alone. Millet yields were unaffected by the rate or form of N inputs to maize. Little (<25%) of the applied fertilizer was recovered in the maize crop, with only a further 3% recovered by the subsequent millet crop. On average, 58% of the applied fertilizer was recovered in the 0- to 60 cm soil layer at maize harvest, mainly in non-mineral N forms. Transformations and movement of applied fertilizer N were shown to be rapid, occurring within seven days of application. Approximately one-third of the applied fertilizer was unaccounted for in the crop-soil system at maize harvest. It was concluded that fertilizer was rapidly immobilized and that its subsequent rate of turnover was low so that an application of fertilizers to one crop made no substantial contribution to the nutrition of the next.

An experiment was conducted by Shakya et al (2002) to identify the optimum time of N application for maize/millet system during 2000 to 2001 at HCRP, Kabre, Dolakha. Nitrogen at the rate of 60 kg/ha was applied on different stages in addition to 10 ton/ha compost. The maize grain yield was significantly varied with N application timing but millet yield was not affected. The highest maize grain yield was recorded when 50% N applied at basal and 50% N applied at knee high stage of maize.

An experiment was conducted by Munakarmy and Thapa (2002) to identify the effect of sources and level of nutrient on maize/millet system at Pakhribas, Dhankuta during 1997 to 1999. Two levels and three sources (inorganic, organic, and combination of half organic and half inorganic) of nutrients were evaluated: full dose nutrients (90:30:30 kg/ha N:P_2O_5:K_2O) from inorganic sources, 90 kg/ha N equivalent from organic sources, and the half dose (45:15:15 kg/ha N:P_2O_5:K_2O) from inorganic sources. Maize and millet grain yield increased with increased nutrient levels. Net negative balance of N and K was observed under all levels but not P. Combined application of organic and inorganic nutrient sources minimized organic matter depletion rate.

During 2003, finger millet mono system with plant density and fertilizer trial conducted at Khumaltar using Kabre Kodo-1 as a test variety (HCRP 2004). The results are presented in table 2 and showed that the highest grain yield (2384 kg/ha) was obtained when finger millet transplanted at the spacing of 10 cm X 10 cm with the fertilizer application of 15 ton/ha FYM plus 0:30:30 kg/ha N:P_2O_5:K_2O. Similarly in a study on a fertilizer cum spacing study, application of chemical fertilizer @50:30:30 kg/ha N:P_2O_5:K_2O with spacing 10 cm X 10 cm produced highest grain yield of 3.67 ton/ha (NARC 2008).

Table 2. Effect of density and fertilizer dose on grain yield of finger millet in mono cropping at Khumaltar, Lalitpur condition during 2003

Treatment	Density	FYM (ton/ha)	N kg/ha	P2O5:K2O kg/ha	Grain yield (kg/ha)
1	10 cm x 10 cm	0	0	30:30	2291
2	10 cm x 10 cm	15	0	30:30	2384
3	10 cm x 10 cm	0	30	30:30	2273
4	10 cm x 10 cm	7.5	15	30:30	2246
5	20 cm x 20 cm	0	0	30:30	1125
6	20 cm x 20 cm	15	0	30:30	1310
7	20 cm x 20 cm	0	30	30:30	1374
8	20 cm x 20 cm	7.5	15	30:30	1454
LSD					246.4

LSD=Least significant difference at 5% level of probability
Source: HCRP (2004)

Acharya et al (2001) carried out a field experiment on maize and finger millet system in the *Bari land* in farmers' field of Tanahun from 1997-1999. The objective was to find out the effect of organic manure and inorganic fertilizer application alone and in combination directly on maize grain yield and residual effect on succeeding crop (finger-millet) as well as on soil properties. The farmers' practice of fertilizer application determined through the survey in farmers' field was 90:30:30 NPK kg/ha for maize and its residue for finger millet was tested at different levels and sources under maize-millet system. The farmers' practice of inorganic fertilizers gave the highest grain yield of 2224 kg/ha. But the yield was in decreasing trend over years. Finger millet responded to residual of organic manure to produce significantly high grain yield but there was no residual effect of inorganic fertilizer on finger millet under maize-finger millet system. The total N and organic carbon decreased in all the plots including control. The available phosphorous increased more with the application of manure and less with the inorganic fertilizers. The exchangeable potassium and pH also increased in all the plots including control.

Tripathi and Shrestha (2003) reported that, under low fertility acidic soil in rainfed marginal upland with high rainfall occurring areas like Lumle, even high doses of balanced chemical fertilizers gave very poor yield of maize and finger millet (**Table 3**). Application of 120 kg/ha N through organic manure and or combination of 60 kg/ha N through organic manure plus 60:30:20 kg/ha N:P_2O_5:K_2O through inorganic sources produced 1.68 to 1.71 ton/ha maize grain yield. Organic manure alone or a combination of organic and inorganic fertilizers produced better yield of finger millet grain (0.57 -0.69 ton/ha) in maize than inorganic fertilizer alone (0.36-0.44 ton/ha).

Table 3. Effects of integrated nutrients management on maize/finger millet grain yield in infertile and fertile soil at Lumle, Kaski during 1997 to 2000.

SN	Treatments	Pooled maize grain yield (ton/ha) in infertile soil of 4 years	Pooled finger millet grain yield (ton/ha) of 4 years in infertile soil	Maize grain (ton/ha) in fertile soil
1	Maize /finger millet-fallow minus residue (FYM equivalent to 60 kg/ha N)	1.14	0.60	4.24
2	Maize/finger millet-fallow minus residue (FYM equivalent to 120 kg/ha N)	1.71	0.66	4.12
3	Maize/finger millet-fallow minus residue (60:30:20 kg/ha $N:P_2O_5:K_2O$)	0.37	0.36	5.56
4	Maize/finger millet-fallow minus residue (120:60:40 kg/ha $N:P_2O_5:K_2O$)	0.24	0.44	6.69
5	Maize/finger millet-pea minus residue (FYM equivalent to 60 kg/ha N	0.95	0.57	6.01
6	Maize/finger millet-pea plus residue (FYM equivalent to 60 kg/ha N)	1.07	0.64	5.15
7	Maize/bean-finger millet minus residue (FYM equivalent to 60 kg/ha N)	0.97	0.56	5.17
8	Maize/bean-finger millet plus residue (FYM equivalent to 60 kg/ha N)	1.03	0.69	4.62
9	Maize/finger millet-fallow minus residue (FYM equivalent to 30 kg/ha + 30:15:10 kg/ha $N:P_2O_5:K_2O$)	0.66	0.50	3.45
10	Maize/finger millet-fallow minus residue (FYM equivalent to 60 kg/ha N + 60:30:20 kg/ha $N:P_2O_5:K_2O$)	1.68	0.59	5.32
	Mean	0.98	0.56	5.03
	F-test	**	**	NS
	LSD	0.5	0.17	

LSD=Least significant difference at 5% level, *=significantly different p ≤0.05, **=significantly different at p≤ 0.01
Source: Tripathi and Shrestha (2003)

Baral et al (2023) conducted a field experiment to study the response of finger millet variety Kabre Kodo-2 on different fertilizer doses at HCRP Kabre, Dolakha. The experiment was conducted during 2019, 2020 and 2021. The highest mean grain yield was obtained from 90:60:30 kg/ha $N:P_2O_5:K_2O$ but not significantly different from 90:30:30 kg/ha $N:P_2O_5:K_2O$, 60:30:30 kg/ha $N:P_2O_5:K_2O$ and 60:60:30 kg/ha $N:P_2O_5:K_2O$. Kabre Kodo-2 variety of finger millet significantly increased grain yield up to 60 kg/ha N (**Table 4**). Similarly, the highest mean stover yield was obtained from 90:60:30 kg/ha $N:P_2O_5:K_2O$ followed by 90:30:30 kg/ha $N:P_2O_5:K_2O$. Increased nitrogen dose (90 kg/ha) had significantly increased stover yield. Every increase in the nitrogen level significantly increased grain and straw yield of finger millet. The increased uptake at higher levels of N application helps in improved production of photosynthates due to sufficient assimilation of nutrients which in turn results in vigorous plant growth and synthesizes carbohydrates and translocate them to the developing ear heads. This makes in better filling and more grain weight at increased levels of N application leading to increased yield attributes and grain yield (Krishna et al 2019). In addition, there was positive correlation on plant height and stover yield, no. of heads/m^2 and grain yield, grain yield and thousand grains weight, stover yield and grain yield (**Figure 2**).

Table 4. Effect of fertilizers application on grain yield and stover yield of finger millet at HCRP, Kabre, Dolakha during 2019 to 2021

Treatments	Grain yield (ton/ha)				Stover yield (ton/ha)		
	2019	2020	2021	Mean	2019	2021	Mean
FYM @5 ton/ha	3.586	3.00	3.074	3.220	6.094	2.955	4.525
30:30:30 kg/ha N:P_2O_5:K_2O	4.722	4.37	3.401	4.164	8.675	3.764	6.220
30:60:30 kg/ha N:P_2O_5:K_2O	4.814	3.50	3.913	4.076	7.133	3.428	5.281
60:30:30 kg/ha N:P_2O_5:K_2O	4.964	5.10	4.835	4.966	9.155	4.45	6.803
60:60:30 kg/ha N:P_2O_5:K_2O	4.906	4.85	4.32	4.692	8.394	4.522	6.458
90:30:30 kg/ha N:P_2O_5:K_2O	4.944	5.20	4.422	4.855	9.322	5.602	7.462
90:60:30 kg/ha N:P_2O_5:K_2O	5.711	4.70	4.546	4.986	10.488	6.052	8.270
Grand Mean	4.806	4.40	4.073	4.426	8.466	4.396	6.431
P value	0.002	<0.05	0.003		0.002	0.006	
LSD (0.05)	0.729	0.88	1.08		1.707	1.47	
CV%	8.5	11.30	15		11.3	18.9	

LSD=Least significant difference at 5% level, CV%=Coefficient of variance
Source: Baral et al (2023)

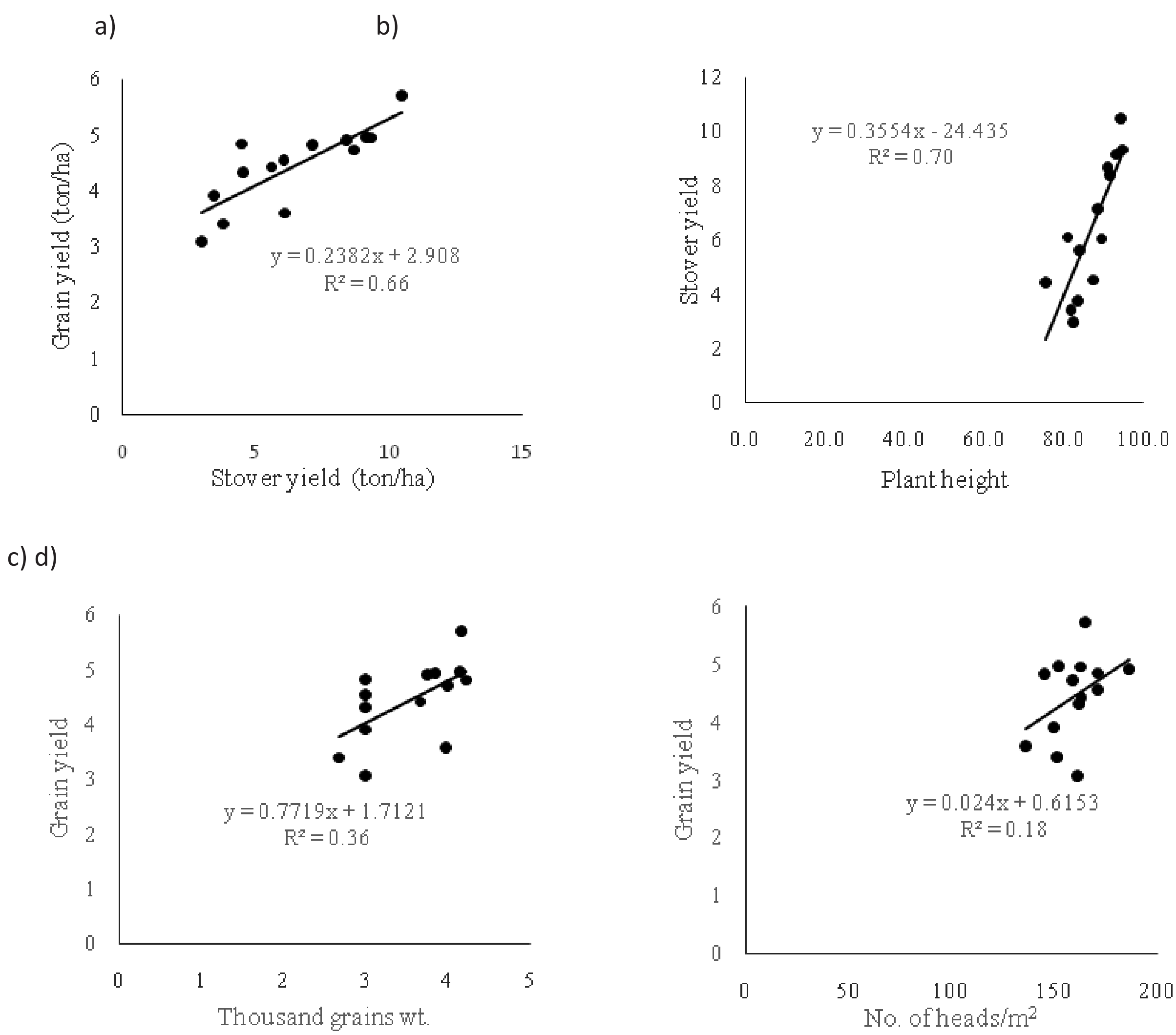

Figure 2. Correlation among growth parameters, yield attributes of finger millet a) grain yield and stover yield b) plant height and stover yield c) thousand grains wt. and grain yield d) no. of heads/m² and grain yield at HCRP, Kabre during 2019 to 2021

Conclusion

Maize and Finger millet are the major food crops for the people of hill area. The relay cropping of maize and finger millet is a common practice in the hills of Nepal. Nutrient management studies were carried out both mono cropping as well as maize/millet relay system. The long-term soil fertility management studies were carried out on maize/millet system but only very few locations. The results of long term as well as other maize/millet relay system studies showed that only chemical fertilizer alone or organic fertilizer alone cannot sustain maize/millet system. Application of both organic and inorganic fertilizers in combination gave sustainable yield of both crops. There was residual effect of organic manure applied to maize on finger millet yield but no residual effect of inorganic fertilizers on succeeding finger millet grain yield. There is lack of site-specific recommendation for the nutrient management on maize/millet system. The results were very old and recent studies on maize/millet system are limited. There are very limited literatures available on residual effect on succeeding millet grain yield. This paper has mainly focused to reveal the studies carried out in maize/finger millet system as well as finger millet mono crops carried out in Nepal. Most of the findings for relay system were old and may not fit in current soil fertility and varieties conditions. However, the results suggest some guidance for nutrient management for millet and maize/millet system for hill ecological zone of Nepal.

Research Gap and Recommendation

Based on the literature review, it is clear that very limited research carried out for nutrient management of finger millet and finger millet-based system in Nepal for the last twenty years, most of the literatures are very old and may not relevant in present soil and cropping system context. An integrated nutrient management approach appears to have the best potential to reduce the yield gap between potential yield and actual yield of finger millet farmers. For the sustainability of maize and finger millet system and harness production potential following issues and recommendation should be followed by the farmers as well as concerned stake holders:

- There is a lack of information available regarding N fertilizer recovery by finger millet. Therefore, research needs to be conducted to evaluate and improve N use efficiency rather than a simple focus on increasing the amount of inorganic N applied.
- One of the major constraints related to soil P is its low availability for plant uptake. Little research has been conducted to evaluate the importance of P in finger millet and how to improve P availability in finger millet cropping systems. Therefore, research on how to increase P solubility in soil using different P solubilizing bacteria, endophytes, and mycorrhizae may be beneficial, in addition to efforts to breed varieties that secrete organic acids from roots.
- There has been limited attention paid to K management in finger millet. Lack of K fertilizer application and removal of crop residues by farmers have decreased soil K levels. Most of the finger millet growing areas are located on marginal lands, which suffer from drought stress. As K improves the drought resistance of plants, finger millet can benefit from K fertilizer. Furthermore, application of K along with N fertilizer can also improve N use efficiency.
- There is a need to evaluate the effects of other micronutrients (B, Zn, Fe, Mn, Cu, Mo) and secondary macronutrients (S, Mg, Ca) on finger millet growth and yield.
- A significant amount of research has been conducted to evaluate the importance of FYM and alternative sources of organic matter on finger millet growth. However, there is a need to explore different sources of organic manure for finger millet farmers.

- An optimal nutrient balance is necessary to obtain higher yields of finger millet. The current literature suggests that application of NPK along with FYM (10–30 ton/ha) increases finger millet yield. As soil fertility varies from field to field, fertilizer recommendations based on a soil test will be ideal in order to maximize yield while enhancing fertilizer use efficiency. Best-management fertilizer practices, which involve the identification of the right source, right place, right timing, and right application method will also lead to more efficient management of fertilizers in finger millet systems.
- The suitable varieties of maize and finger millet should be selected for intercropping so that, the yield of both crops reach its potential. For this, the suitable varieties are to be developed and disseminated to the farmers.
- Imbalance use of chemical fertilizers should be discouraged. IPNM based farming system should be developed.
- The loss of soil fertility and nutrients should be minimized for the long run.

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Soil Fertility Management for Millets in Nepal

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Abstract
Soil is the source for nutrition of crops and soil fertility management is critical for healthy growth and production of crops. Millets are drought-resistant and hardy crops, but they still require adequate soil fertility for optimal growth and yield. The fertilizer requirement of millets varies with the crop type, management practices, varieties and soil properties. In Nepal, the nutrient management for millets is met through soils inherent productive capacity and mostly organic sources of nutrients has been the key for nutrient management in millet. The practice of cultivating millet varies with domain in Nepal. National Soil Science Research Centre (NSSRC) recently, has updated for cereal crops and based on the review, research and modelling, the fertilizer recommendations for millets have also been addressed. However, the application and rate are based on soil test values.

Keywords: Soil management, soil fertility, fertilizer requirement

Introduction
Soil is the source for nutrition of crops and soil fertility management is critical for all the crops for healthy growth and production, and it is equally crucial for growing healthy millet crops. Millets are drought-resistant and hardy crops, but they still require adequate soil fertility for optimal growth and yield. The fertilizer requirement of millets varies with the crop type, varieties and soil properties. Since time immemorial, the nutrient management for millets is met through soils inherent productive capacity and only organic sources of nutrients has been the key for nutrient management in millet. Over time, it has been changing and now only few commercial growers are applying chemical fertilizers for supplementing nutrients.

Ecology and Cropping System
The practice of growing millet varies with agricultural domain in Nepal and hence the soil fertility management practices vary with the cropping practices. Nepal has been divided into five physiographic regions (**Figure 1**) and three ecological belts (**Figure 2**). With varying ecological belt, soil properties, management practices and cropping system vary. Hence the fertility management system also differs. In eastern part of Nepal, in general, millets are grown as relay crop and are transplanted whereas in western Nepal, they are grown as main crop and are directly seeded. The soil fertility management system in relay crop and main crop obviously varies depending upon the cropping system. In eastern Nepal, farmers assume that the nutrient requirement for millets are met from the nutrient applied for main crop. However, in western Nepal, farmers generally apply farm yard manure and compost to meet the demand of nutrient requirement.

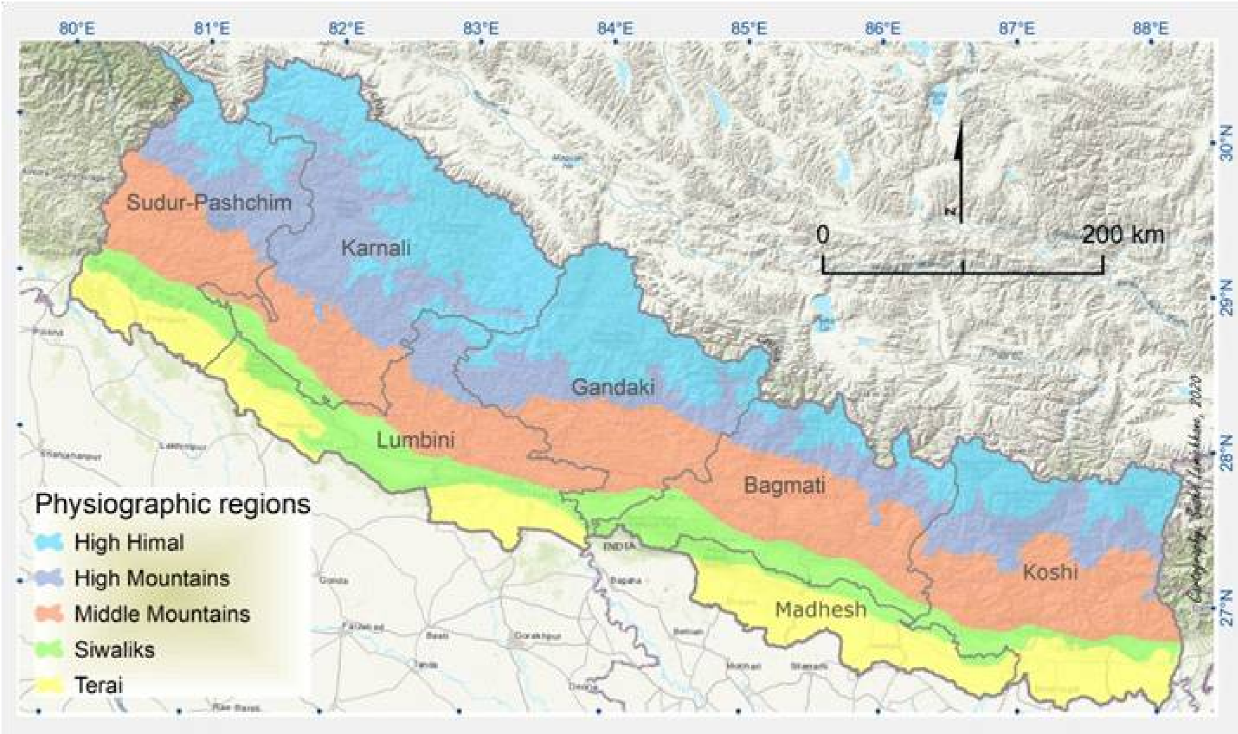

Figure 1. Physiographic regions of Nepal

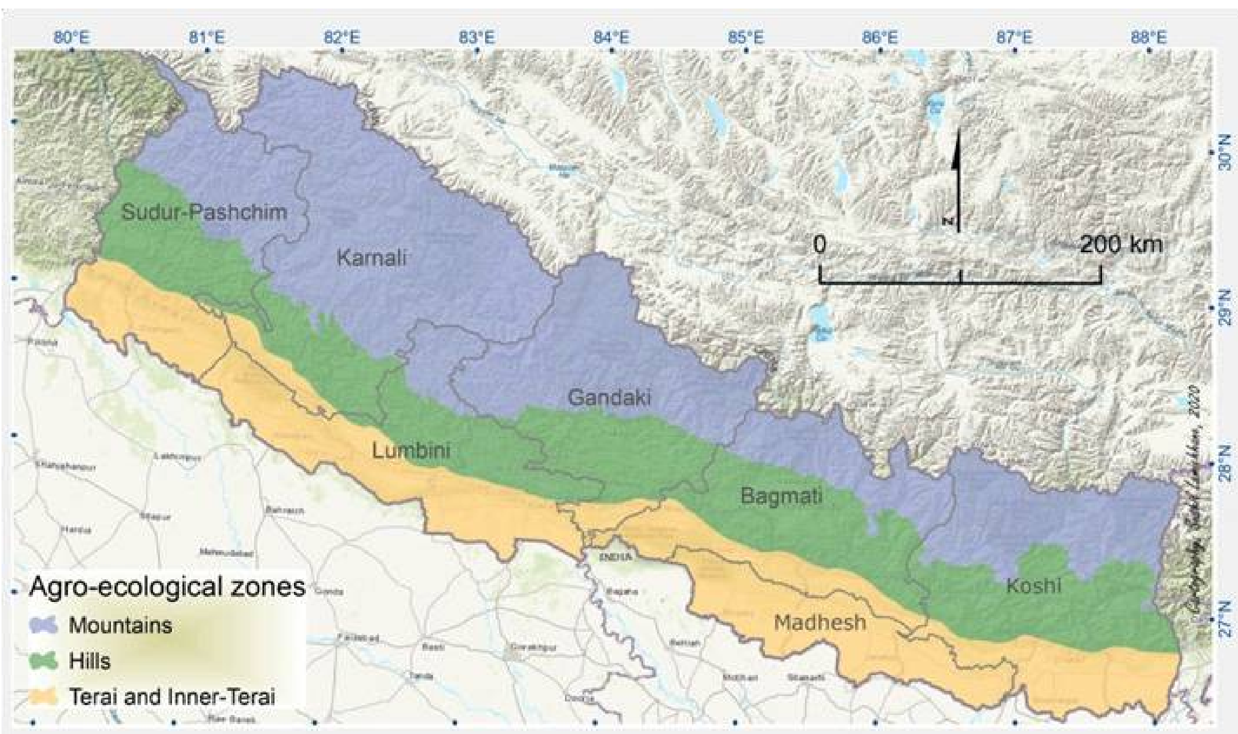

Figure 2. Ecological belts of Nepal

Soil Fertility Management Practices

Soil management and conservation is important for sustaining crop production and livelihood. Millets are highly resilient to dry and arid conditions. They can survive and thrive in low-water environments, making them ideal for regions facing water scarcity. Their deep root systems help them access water from deeper soil layers, reducing soil erosion. The extensive root systems of millet crops bind the soil together, minimizing erosion caused by wind and water. Their growth habits also create a protective cover for the soil, preventing it from being exposed to erosion agents. Millets, like other plants, absorb carbon dioxide from the atmosphere. Through this process, they contribute to reducing greenhouse gas emissions and play a role in mitigating climate change. Millets are relatively low-input crops, thereby, require lower amount of fertilizers compared to other cereals like wheat and rice. This characteristic reduces the risk of nutrient runoff and pollution of nearby water bodies.

The fertilizer dose for millets in Nepal, like in any other region, can vary based on factors such as soil fertility, crop management practices, and specific regional conditions. It is essential to determine the nutrient status of the soil and then tailor the fertilizer application accordingly. Farmers generally assume that the inherent soil capacity is enough to supply nutrient requirement and some farmers apply organic manure only, while other few farmers apply little urea. The recommended dose of fertilizer for millet is never fulfilled. Among the recommended fertilizers, millet responds well to phosphorus fertilization but due to high content of phosphorus in soil of Nepal, generally farmers do not apply phosphorus fertilizer. It should be noted that the deficiency symptoms of nutrients in millet is similar to other crops and there is no any specific symptom for millets crop.

Nutrient Management Research and Recommendations for Millets

Nutrient management research on millets is limited to fertilizer trials in Nepal. Several research has been done on nutrient requirement by Hill Crop Research Program, National Soil Science Research Centre, Agriculture Research Stations, etc. The researches have indicated varying nutrient requirement as per the location and cropping system. Application of 90: 60: 30 N:$P_2O_{5:}K_2$ kg/ha resulted higher grain yield in 2017 and 2019 (HCRP 2017 and 2019). Whereas, research conducted by NSSRC at Dolakha and Doti on application of different doses of N, P and K did not have significant effect on yield of finger millet (NSSRC 2022). Application of 100 kg N and 45 kg P_2O_5/ha have been recommended for maximum crop yield and net monetary returns under rainfed condition of Gujarat (Bhuva et al 2018). Though many researches have been conducted globally for nutrient requirements for millets, all recommendations cannot be replicated everywhere. It depends on inherent nutrient supplying capacity of soil, climatic parameters, crop types, management systems, etc. Despite of having different fertility gradient across Nepal, NSSRC has recently adopted fertilizer recommendation considering various parameters such as soil type, cropping system, climatic parameters, soil moisture regimes, irrigated or rainfed, availability of fertilizers, socio-economic parameters, etc. Based on these factors, QUEFT (Quantitative Evaluation of Fertility of Tropical Soil) model has been used for estimating fertilizer recommendations for all crops.

Based on the research, experience and modelling, the fertilizer recommendation has been revised and updated. It is imperative to update the fertilizer recommendation periodically. Till date, among the millets in Nepal, the fertilizer recommendation for finger millet only has been recommended and it was 50:20:20 kg/ha of N, P_2O_5 and K_2O respectively. However, it has been revised and the new fertilizer recommendation for millets is summarized in the **Table 1**.

Table 1. Recommended fertilizer doses for millets

Crop	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	Organic Manure (t/ha)
Finger millet	50	30	30	6-10
Foxtail millet	30	10	10	6-10
Proso millet	30	10	10	6-10
Barnyard millet	30	10	10	6-10
Little millet	30	10	10	6-10
Pearl millet	40	20	20	6-10

It is always encouraged to apply high rate of organic manure as far as possible. Since the zinc content in the soils of Nepal is very low, it is also recommended to apply 10kg/ha of zinc sulphate. To correct the zinc deficiency in standing crop, spray of 0.2% $ZnSO_4$ at tillering to pre-flowering stage is recommended. Under prolonged dry spell, it is advised to skip top dressing of N and go for spraying with 2% normal urea. It should be noted that the nutrient requirement is higher in case of higher density and more seed rate.

The rate and application of fertilizers is based on the soil test values of the specific location. The exact fertilizer dose calculation per unit area can be estimated using the soil fertility status of the area following the guidelines given in **Table 2**.

Table 2. Basis of fertilizer recommendation based on soil test values

Nutrient Status/Category	Soil type	Recommended fertilizer dose
Very low	All	125 % of N, 125% of P_2O_5 and 125 % of K_2O
Low and Medium	All	100 % of N, 100% of P_2O_5 and 100% of K_2O
High	Light	80 % of N, 70% of P_2O_5 and 70% of K_2O
High	Heavy	75 % of N, 60% of P_2O_5 and 60% of K_2O
Very High	All	25 % of N, 25% of P_2O_5 and 25% of K_2O

Source: Vista et al 2023

Improving Soil Fertility for Millet Production

All crops are highly responsive to higher or increased soil fertility and millet is also not an exceptional. Since millets are predominantly grown under rainfed condition in Nepal, incorporation of high amount of organic manure is always encouraged. Use of biofertilizer (such as Azospirillum and PSB) can economize nitrogenous and phosphatic fertilization. Instead of applying mineral fertilizer, which includes costs and may increase the risk of moisture stress to the crop, it is advisable to incorporate FYM to the soil, and integrate leguminous crop in the cropping system. In case of sloping area, suitable soil conservation practices should be adopted in order to check top soil losses through erosion. The soil should never be kept barren/naked.

Intercropping is also highly encouraged to maintain soil fertility. Crop rotation should be properly followed. Practicing green manuring crop in the crop rotation is highly encouraged to maintain or improve soil fertility.

In very acidic soils, application of lime should be done two months prior to sowing millet but in the case of relay cropping, it should be done before planting the first crop. The quantities of lime to apply depend on the amount of acid to neutralize in the soil (or the target pH to be reached after liming). Advice on this is best based on laboratory analyses.

Synthesis on Soil Fertility Management for Millets

Soil fertility management is crucial for crop production and integrated nutrient management strategy would be one of the best options for managing soil fertility in Nepal. Proper soil management aspects should be considered and since, millets are mostly grown under rainfed condition, adequate use of organic manure and biofertilizers would be beneficial from the perspective of nutrient as well as soil health management. Intercropping, crop rotation, cover cropping and integration of legumes in the cropping system is highly encouraged and soil should never be kept naked. Proper soil erosion measures should be practiced in hilly and slopy areas of Nepal for maintaining soil fertility.

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F. Crop Protection

च. बाली संरक्षण

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Insect Pests of Millets and their Management in Nepal

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Summary
Millets play a vital role in Nepal's agriculture and food security, providing essential sustenance and livelihood support to a significant portion of the population. However, various insect pests constantly threaten the successful cultivation of millet crops, leading to substantial yield losses and significant economic implications. Nominal information is available in research publications regarding entomological issues for millet crops like insect diversity, abundance, bio-ecology, damage, and management. Considering the increasing trend of insect pest infestation in millet crops in Nepal, judicious management strategies can be developed following Integrated Pest Management (IPM) strategies that primarily rely on cultural practices, growing resistant varieties, use of botanical extracts and biopesticides, and use of green chemicals. By providing a comprehensive overview of the insect pests affecting millets in Nepal and the associated management approaches, this study serves as an essential resource for researchers, extension workers, students, and farmers.

Keywords: Bio-ecology, botanicals, integrated pest management, economic threshold level

Introduction
Millets are a highly varied group of small-seeded, fast-growing cereal plants grown majorly in the semiarid tropical region of Asia and Africa. They belong to the Poaceae family, which was first cultivated about 7,500 years ago in Asia (Cherfas 2015). More than 97% of millets are produced in developing countries (McDonough 2000). Millets can be easily grown in marginal, less fertile lands with minimum application of fertilizers. They are highly tolerant of heat (up to 64 degrees Celsius) and are grown in low and high altitudes.

Millets have many health benefits, including helping to reduce blood sugar and cholesterol levels, and are gluten-free giving better digestive health. The millet contains 7-12% protein, 2-5% fat, 65-75% carbohydrates, and 15-20% dietary fibre (Dayakar Rao et al 2018). The top millets producing countries in the world include India (13.21 million tonnes), China (2.70 million tonnes), Niger (2.15 million tonnes) whereas, Nepal is in 14th rank with (0.33 million tonnes) (FAOSTAT 2023). Millets are considered the future crops in the context of climate change as they have huge potential to deal with food insecurity worldwide.

Mainly three species of millets such as finger millet, foxtail millet and proso millet are grown across various agroclimatic zones of Nepal. Finger millet is the fourth most important crop after rice, maize, and wheat in terms of area and production (MOALD 2022). Millets are important food sources and are also used to make different alcoholic beverages such as *Rakshi* and *Tongba*, distilled liquor where millets are used as a base ingredient (Ghimire et al 2023). In the last few decades, the production of millets has seen a significant decline due to a reduction of agricultural lands, but still, we have seen a significant increase in the number of insect pests in millets. Globally, approximately 150 different insect species have been documented as hampering millet crops (Nwanze and Harris 1992) whereas the number of pests found in Nepal has not been reported yet as very nominal information is available on the status of insect pests of millets.

Although we know the economic importance of millet pests, knowledge of control measures in rural areas is limited due to a lack of research in such parts. The objective of writing this review paper is mainly to provide a comprehensive and critical analysis of the various pests affecting millets in Nepal and there is no better time to write this as it is International Year of Millets 2023. This paper aims to provide proper information on major insect pests of millets, present IPM strategies for each insect pests and ultimately serve as a valuable resource for researchers, agricultural practitioners, and policymakers in Nepal.

Methodology

This review paper adopts literature-based research to comprehensively analyse the effect of insect pests on millets in Nepal. The search for relevant literatures was conducted using academic databases from the internet, and careful selection was made based on their relevance to the objective of the study. Research articles, scientific journals, conference papers, and reports were among the sources selected. Moreover, personal observations were also conducted during field visits and interaction with researchers to supplement the literature-based findings with practical knowledge and experiences. However, it is acknowledged that certain data gaps may exist due to variations in pest occurrences across different agri-ecological regions and limited accessibility to certain information.

Results

The study on insect pests of millets in Nepal revealed a diverse amount of pest species impacting millet crops across different regions of the country. The pests were categorized mainly into five categories which were foliage pests, internal borers, sucking pests, ear head pests and soil-dwelling insects. Stem borers and shoot flies were causing issues during the early growth stages, head feeders, such as caterpillars and bugs, posed a significant threat to the developing grains in the panicles, leading to grain losses and reduced crop quality. After proper research and analysis, the major pests infesting millets are listed in **Table 1**.

Table 1. Economically important insect pests of millets in Nepal

Common name	Scientific name	Family	Crop infested	Occurrence	Category	Reference
Shoot fly	*Antherigona spp. Rondani*	Muscidae	Finger millet, Proso millet, Foxtail millet, Barnyard millet	Regular	Internal borer	CAB (2007)
Aphids	*Rhopalosiphum maidis Fitch; Sitobion miscanthi Takahashi*	Aphididae	Barnyard millet, Finger millet	Regular	Sucking pests	CAB (2007)

Common name	Scientific name	Family	Crop infested	Occurrence	Category	Reference
Fall armyworm	*Spodoptera frugiperda*	*Noctuidae*	Sorghum millet, Pearl millet	Regular	Foliage pests	J.E. Smith Bhusal and Chapagain (2020)
Grasshopper	*Hieroglyphus spp. Krauss*	Acrididae	Finger millet, Proso millet, Foxtail millet, Barnyard millet	Regular	Foliage pests	Subedi and Bhaskar (2023), Sultana and Lecoq (2019)
Hairy caterpillar	*Spilosoma obliqua Walker*	Erebidae	Finger millet, Proso millet, Foxtail millet, Barnyard millet	Occasional	Foliage pests	Gurung et al (2019)
White grubs	*Anomala dimidiate Hope*	Scarabeidae	Finger millet, Proso millet, Foxtail millet, Barnyard millet	Occasional	Soil dwelling insects	GC (2006)
Rice ear bug	*Leptocorisa oratoria Fabricius*	Alydidae	Finger millet, Proso millet, Foxtail millet	Regular	Ear head pests	Soti et al (2020)
Rice ear head cutting caterpillar	*Mythimna separata*					
Walker	*Noctuidae*	Finger millet, Foxtail millet, Proso millet	Regular	Ear head pests and Foliage pests	CAB (2007)	
Stripped borer	*Chilo partellus Swinhoe*	Crambidae	Finger millet, Foxtail millet	Regular	Foliage pests	CAB (2007)

Insect pests

Shoot fly (Antherigona spp.)

Shoot flies infest various millet crops. The maggot of the shoot fly feeds on the growing tip, causing the central shoot to wither and display early symptoms of a dead heart (**Figure 1**), followed by abundant side tillering at a later stage, which is also affected (IIMR 2016). The maggot itself measures around 3.2-3.8 mm in length and bears a dark grey appearance similar to that of a housefly (Pont and Magpayo 1995). The pupation occurs in the plant base, and the entire life cycle lasts approximately 17 to 21 days (Sajwan et al 2022). The egg of the shoot fly is cigar-shaped and whitish. Studies have revealed that these flies can cause yield losses of 20-50% in pearl millet (Kishore 1996), 36% in proso millet (Natarajan et al 1974), and 39% in small millet (Selvaraj et al 1974).

Management of Shoot fly

Sorghum shoot fly management can be efficiently achieved by implementing adjustments to cultural practices, such as altering the sowing time, optimizing seed rates, adopting crop rotation, refining tillage operations, and optimizing fertilization methods (Mote 1983).

- When planting is conducted within 7-10 days of the commencement of the monsoon rains, the crop stands a better chance of avoiding shoot fly infestation. In the post-rainy season, choosing to plant between the last week of September and the first week of October has been observed to result in a relatively lower level of shoot fly damage (Balikai 1999).
- The application of nitrogen and phosphorus at a rate of 80 and 40 kg/ha, respectively, has been shown to be more effective in reducing shoot fly infestation compared to lower dosage levels. (Bhanderi and Patel 2016).
- Intercropping proves to be a significant factor in decreasing the population of sorghum shoot flies. The inclusion of garlic or onion intercrops, alongside paired row planting of sorghum, has been identified as an effective method for shoot fly management without compromising plant population. (Karibasavaraja et al 2005).
- When shoot fly damage reaches a threshold of 5 to 10% of the plants exhibiting dead hearts, it is advisable to apply Cypermethrin 10 EC at a rate of 750 ml/ha or Quinalphos 25 EC at a rate of 400 g a.i./ha for crop protection (Prasad et al 2015).

Figure 1. Shoot fly larvae and associated damage symptoms
(Photo: RP Mainali, Nepal Genebank, NARC)

Aphids (Rhopalosiphum maidis; Sitobion miscanthi)

In various regions of Nepal, aphids are commonly observed as pests in finger millet crops. These aphids form colonies that are dark bluish-green and somewhat ovate in shape (**Figure 2a**). They measure approximately 1.7-3 mm in length and have distinguishing black legs, cornicles, and antennae (Blackman and Eastop 2000). Both the adult aphids and nymphs feed on sap from the tender leaves and can spread across the entire plant. The presence of aphid colonies is common in the central leaf whorl and stems of millet plants. The sucking of plant juices by young and adult aphids often leads to yellowish mottling of the leaves and necrosis along the leaf margins (**Figure 2b**). Each female aphid lays approximately 30-35 eggs, usually depositing 6-10 eggs in each floret. The generational cycle takes about a week (IIMR 2016).

Figure 2a. Rhopalosiphum maidis adults and nymphs (Bugwood.org)

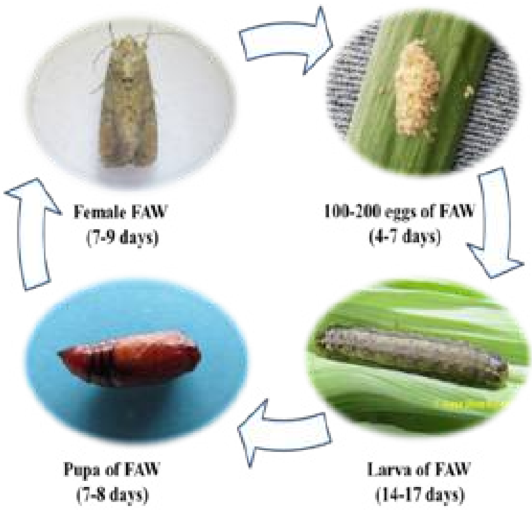
Figure 2b. Nature of damage of Aphids in finger millet (Photo: KH Ghimire)

Management of Aphids

- Install yellow sticky traps for monitoring the occurrence of winged aphids (Paneru and Giri 2011).
- Release biocontrol agents like larvae and adults of ladybirds, lacewing larvae, soldier beetles and syrphid fly larvae in the field (Rana et al 2017, Rana et al 2020, Nayak et al 2023).
- Applying a dusting of wood ashes onto plant foliage during the morning hours (Sharma 2004). Similarly, wood ash and soap solution (at the rate of 1:4 ratio wood ash and water for 12 hours then filtrate mixed with soap at a rate of 10 g per litre) (NARC 1999).
- Spray neem fruit extract of 50 g fruit dust overnight soaked in 1 litre water or tobacco decoction (200 g dried tobacco + 30 g soap + 4-litre water boiled for 30 mins) (Duwadi et al 1993) or chinaberry fruits extract of 1 kg of chinaberry fruits dusts 24 hours soaked in 10-litre water (Joshi 1994).
- In cases where the use of chemical insecticides is necessary, consider spraying Malathion 50% EC at a rate of 2 ml or Dimethoate 30% EC (Rogor) at a rate of 1 ml per litre of water for a rapid reduction in aphid populations (Entomology Division 2002).

Fall armyworms (Spodoptera frugiperda)

Armyworms have a host range that includes sorghum, millet, and pearl millet. During their larval stage, they predominantly feed on leaves, especially in nurseries, leaving behind a skeletal structure after scraping the green matter of the leaf tissue. Initially, young armyworms feed on plants without severing the stems or leaves (Sisay et al 2019). However, as they grow, they begin to cut off the foliage, particularly tender stems of young and developing plants. During the daytime, the larvae seek shelter in the soil and become active in the evening, often causing extensive damage to leaves, sometimes consuming entire leaves. The adult armyworms have a brownish colouration (IIMR 2016). The feeding phase of fall armyworm larvae typically spans 2-3 weeks, after which they enter the pupation stage, lasting approximately 2 weeks (Nyupane et al 2023). Mature larvae pupate in the soil, and the pupae exhibit colours ranging from reddish brown to dark brown. After mating, the female adults can lay up to 1000 eggs (Williams 2017). This pest is potential pest for millet too. The lifecycle and associated nature of damage of fall armyworm, by taking an example of the maize crop is depicted in **Figure 3**.



Damage symptoms in leaf

Damage symptoms in leaf whorl

Figure 3a. Life cycle of Fall Armyworm (Nyupane et al 2023), **Figure 3b**. Nature of damage (Photo: RP Mainali).

Management of Fall army worm

- If you encounter only a small number of armyworms, manually remove them from the grass blade or plant. Place them in a container with soapy water and employ other fundamental cultural methods for management.
- Physical control methods include manual crushing of larvae and eggs of the insect pest and application of charcoal, soil ash and fine sand in the whorls of the attacked crops in order to suffocate the larvae of the fall armyworm (Nayak et al 2023).
- Natural enemies like predators or parasitoids or even bacterial pathogens can suppress pests effectively (Bhusal and Chapagain 2020).
- Extracts such as azadirachtin (derived from neem) and pyrethrins (obtained from pyrethrum) have demonstrated efficacy in controlling armyworms. Additionally, the application of a mixture of ash and detergent has proven to be an effective method for armyworm control (Badhai et al 2020).
- Emamectin benzoate (5 SG, 0.4 g/lit.), Spinosad (45 SC, 0.3 ml/lit.), Chlorantraniliprole (18.5 SC, 0.4 ml/ lit.) etc. are recommended as most effective if applied at early larval stages (Gebreziher 2020).

Grasshoppers (Hieroglyphus spp.*)*

Various millet crops are susceptible to the impact of grasshoppers. Both nymphs and adult grasshoppers create marginal holes in the leaves, and in severe infestations, they can defoliate entire plants, giving the field a grazed appearance. As they primarily feed on foliage, grasshoppers pose a considerable threat to millet crops, causing crop destruction (IIMR 2016). Adult female grasshoppers deposit their egg pods in the soil bunds. When the early rains arrive, small nymphs emerge from these pods and move by jumping from one location to another. A single female has the potential to produce four to five egg pods, with each pod containing anywhere from 7 to 99 eggs (Sultana and Lecoq 2019). Usually, these eggs are laid in September or October and hatch in June or July of the subsequent year, although they can remain viable for up to three years (Sajwan et al 2022). Eggs then go through nymphal and adult stage subsequently. The management and biology of locust is also similar to that of Grasshoppers.

Management of Grasshopper and Locust

- Grasshoppers and locusts can be picked out and destroyed from the crops by the use of a hand net. This method is applied when they are in large numbers and easily accessible to the picker.
- Farmers often favour the use of poison baits, ULV spraying, or ground applications over biological control agents due to their proven effectiveness (Maiga et al 2008).
- Several insect-eating birds, including swallows, are well-known predators of grasshoppers. Additionally, other animal species such as praying mantises, small snakes, and toads consume grasshoppers and locusts. Raising chickens can also prove to be a useful strategy in this regard (Texas A&M AgriLife Extension Service in 2023).
- Furthermore, the application of three entomopathogenic fungi, namely B. bassiana, M. anisopliae, and Nosema locustae Canning, has been observed to cause significant mortality in grasshopper populations (Maiga et al 2008).
- Products for the control of grasshoppers and locusts in non-crop areas adjacent to millet fields include acephate and Dimilin.

Hairy caterpillar (Spilosoma obliqua)

The hairy caterpillar is known to affect different types of millet crops. This species is not limited to Nepal but is also found in other countries such as India, Myanmar, Pakistan, and China (Kabir and Khan 1968, Singh and Seghal 1992). Identifying features of the caterpillar include a black head, clusters of black hairs behind it, and additional tufts of yellow hairs on the rest of the body. The adult's wingspan measures around 23 mm (approximately 0.9 inches) and displays a pale brown colour with small black specks forming a distinct pattern additionally, the abdomen is red (Maxwell-Lefroy 1909). The female of the species lays up to 1000 eggs on the undersides of leaves in multiple batches. Upon hatching, the larvae initially scrape the leaf's underside but eventually transition to feeding on the leaf edges, resulting in a net-like appearance. If the caterpillars are present in large numbers, they can completely defoliate the plant (Selvaraj et al 2015). All stages of the soyabean hairy caterpillar is presented in **Figure 4**.

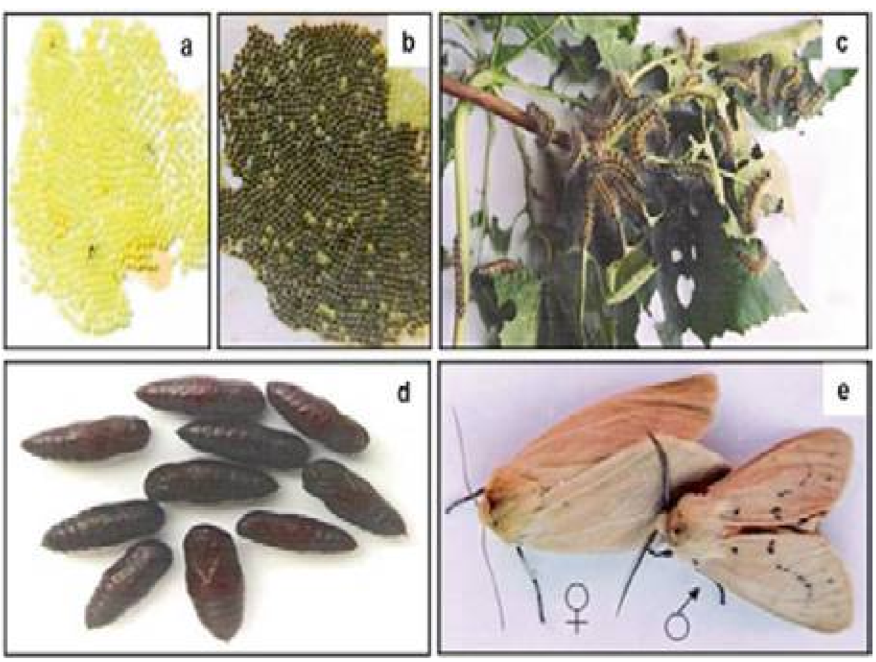


Figure 4a. Various life cycle stages of Spilosoma obliqua a) Fresh eggs; b) Eggs near to hatch; c) Larva; d) Pupa; e) Adult (Photo: Aslam Khan)

Management of Hairy caterpillar

- Performing deep ploughing before the monsoon (typically two to three times) can effectively expose hibernating pupae to sunlight, making them vulnerable to predatory birds.
- Hand-picking of larvae, collection of egg masses, bonfire, and poison baiting is effective against hairy caterpillar (TNAU 2015).
- Install light traps, which can be either gas lanterns or electric bulbs, along the field bunds to draw moths towards the light source.
- Quinalphos 2% powder should be added to the trench at a rate of 25 kg per acre (Nayak et al 2023).
- Apply either Indoxacarb 14.5 SC at a rate of 0.5 ml per liter or Emamectin Benzoate 5% SG at a rate of 0.4 g per liter of water through spraying (NIPHM 2014).

White grubs (Anomala sps*)*

Figure 5. Different stages of White grubs and it's nature of damage (IIMR-ICAR)

Various species of millets are susceptible to infestations by white grubs. *Anomala dimidiata* Hope and *Anomala varicolor* (Gyllenhal) are the dominant species in the high-hill and mid-hill of Nepal (Khanal et al 2012). These grubs are typically found near the base of the millet clusters and are characterized by their fleshy, 'C' shaped bodies with a yellowish hue. The adult stage of these grubs is dark brown in colour. The pupal stage can last anywhere from one to six weeks. White grubs cause damage by cutting the roots of millet plants, leading to wilting in certain patches and, in severe cases, the death of the affected plants. Infested plants often display stunted growth. Generally, the eggs take around 1-3 weeks to hatch, and the grubs undergo development over a period of 8-22 weeks. The pupal stage lasts for 1-8 weeks, after which 13-20 mm long beetles emerge (Prasad et al 2015). A study from Parbat, Tanahu, Nawalparasi, and Chitwan districts in Nepal reported a total of 78 white grub species, but the specific species responsible for damaging individual crops have not been studied yet (GC 2006). White grub and associated damage is presented in the **Figure 5**.

Management of white grubs

- Maintaining a healthy field is essential for culturally managing pest issues in any setting. This entails thorough soil preparation before establishing turfgrass, selecting the appropriate turfgrass variety for the site, ensuring proper installation, and adhering to recommended management practices to ensure a robust lawn (Forrester 2018).
- Insect parasitic nematodes, also known as entomopathogenic nematodes, stand out as effective biological controls for white grubs. Specifically, *Heterorhabditis bacteriophora* nematodes have demonstrated their efficacy in white grub control (Mathias 2019). Other beneficial fungus including *Metarhizium anisoplie* and *Beauveria bassiana* can be applied as a biopesticides.
- Neem oil products, such as Ecoworks EC, serve as valuable foliar sprays and soil drenches. Additionally, garlic-based solutions like Garlic Barrier, derived from garlic juice, can act as repellents, dissuading insects from laying eggs in your lawn vicinity and near your plants (Dekker 2023).

Seed treatment can be accomplished by using imidacloprid 17.8SL at a rate of 2.0 ml or chlorpyriphos 20EC at a range of 6.5-12.0 ml per kilogram of seed. Drenching within the root zone is recommended, with options such as chlorpyriphos 20 EC at 4.0 litres per hectare or quinalphos 25EC at 3.2 litres per hectare, to be carried out three weeks after adult emergence (Nayak et al 2023).

Rice ear bug (Leptocorisa oratoria)

The host crop of rice ear bugs is finger millet, foxtail millet and proso millet. Adults of this species are characterized by their elongated bodies, measuring between 14-17 mm in length and 3-4 mm in width (**Figure 6**a). They typically exhibit a light-yellow green to yellow-brown coloration (Corbett 1930). When these insects are disturbed, they emit an unpleasant odor as a defensive mechanism. Females are responsible for laying approximately 100-200 eggs within the plant's leaves (Tjahjadi 2001). These eggs eventually hatch into nymphs with a green hue, gradually transitioning to brown as they mature into adulthood. They feed on the developing ear of the millet reducing the yield and crop quality (**Figure 6**b).

Management of Rice ear bug

- Preventing rice bug populations from reaching damaging levels can be achieved by removing alternate hosts, especially graminaceous weeds. This is because these bugs rely on wild hosts for feeding and reproduction before migrating into rice fields in early spring (Serrano et al 2014).
- Effective irrigation management is essential to avoid excessive humidity. Corbett (1930) suggested that nymphs and adults may be attracted to trap crops consisting of grasses or early-planted rice, where insects can be collected before the main crop flowers.
- For managing rice bugs at lower densities, capturing them with nets during the early morning or late afternoon can be effective, albeit labour-intensive. Encouraging the presence of biological control agents, such as wasps, grasshoppers, and spiders that prey on rice bugs or their eggs, is also a valuable strategy.
- When considering the use of insecticides, several factors should be taken into account, including the availability of application equipment, the cost of the insecticide, and the experience of the applicator. The decision to use insecticides should weigh the benefits of pest control against the potential risks to human health and the environment (http://www.knowledgebank.irri.org /training/fact-sheets/pest-management/insects/item/rice-bug).

6a Adult rice ear bug

6b Damage symptoms associated with rice ear bug

Figure 6. Rice ear bug and associated damage symptoms, location: Nepal Gene Bank, NARC, Khumaltar (Photo: RP Mainali)

Rice ear head cutting caterpillar (Mythimna separata)

The rice ear head-cutting caterpillar is a pest that can be found in finger millet, proso millet, and foxtail millet. The complete life cycle of this insect, spanning from egg to adult, typically spans approximately 29-39 days. The eggs are typically off-white in colour and are often laid in clusters on the lower sections of leaves, frequently found between the sheaths or on the leaf blades. On average, each female lays around 996 eggs (Sharma et al 2002). When young, the caterpillar appears green, while older larvae take on a brownish colour with a thin pale dorsal line and a dark lateral line on each side. The head of the caterpillar displays a light and dark brown pattern. The pupa, characterized by its brown colouration, is commonly located in surface litter or within the soil. Adult moths exhibit a pale to brick-red or pale brown appearance and possess a highly hairy body adorned with dark specks and patches. These moths typically boast a wingspan ranging from approximately 35 to 50 mm (Hampso n 1896). The caterpillars of these moths predominantly feed on leaf tips and margins. In cases of severe infestation, they can consume entire leaves or even entire seedlings, thereby presenting a substantial menace to millet crops. Different stages of rice ear head caterpillar and associated damage are depicted in **Figure 7**.

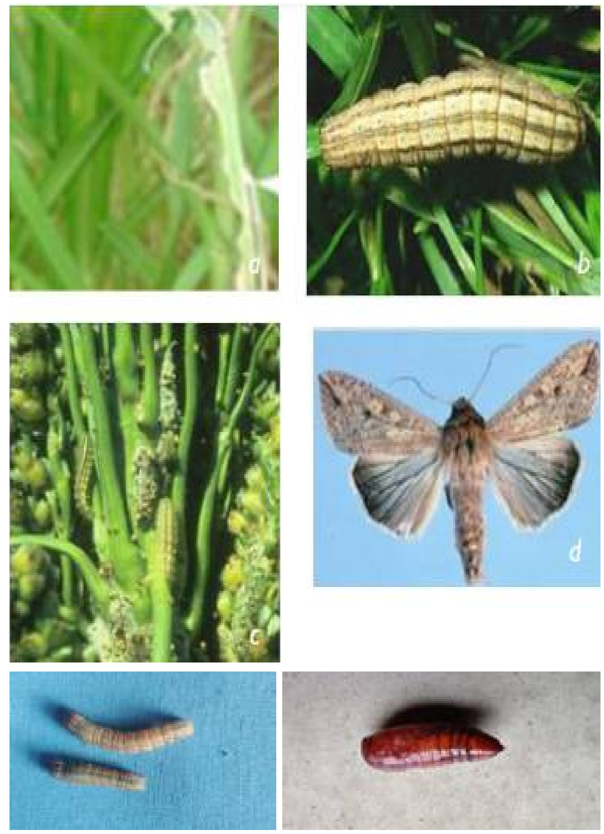


Figure 7. Damage symptoms and different stages of Mythimna separata a, b, c & d (IIMR-ICAR) (Caterpillar-RP Mainali) (Pupa-Sony Bhattarai)

Management of Rice ear head-cutting caterpillar

Egg masses or larvae can be manually collected by hand from seedbeds or young crops as a control measure.

- Farmers are advised to refrain from rotating host crops to minimize the pest's impact.
- For effective control, raising the water level when the population is in the pupal stage can drown the insects.
- The cultivation of high-tillering cultivars and the implementation of sound crop management practices have been shown to mitigate the issue (Paneru and Giri 2011).
- Use of biological pesticides such as Nuclear Polyhedrosis Virus 250 Liter/hac and *Bacillus thuringiensis* 2 gm/Liter by mixing it in water and spraying in the field is useful for control against *Mythimna separata* (Mainali et al 2015).
- In case of outbreak of this pest, Emamectin Benzoate is the most viable option (Mainali et al 2014).

The striped borer primarily feeds on finger millet and foxtail millet. Their eggs are flat and oval in shape, appearing creamy white and measuring about 0.8 mm in size. Pupae can reach lengths of up to 15 mm, featuring a slender and shiny appearance, with colors varying from light yellow-brown to dark red-brown. As adults, they manifest as small moths with wing lengths spanning from 7 to 17 mm and a wingspan that typically measures between 20 and 25 mm. Eggs are laid in batches, mostly on the leaves of the plant. The number of eggs per batch can be as high as 170 but the mean number of eggs per batch is usually between 35 and 40 (Deep and Rose 2014). Larvae of Chilo partellus feed within the leaf whorls, creating distinct scars and holes in the leaves. When seedlings are infested, it can lead to the demise of the growth point, resulting in what is known as 'dead hearts.' These dead central leaves subsequently take on a characteristic appearance, especially in young plants (Lella and Srivastav 2013). The appearance of spotted stem bore and associated damage symptoms is depicted in **Figure 8**.

Stripped borer (*Chilo partellus*)

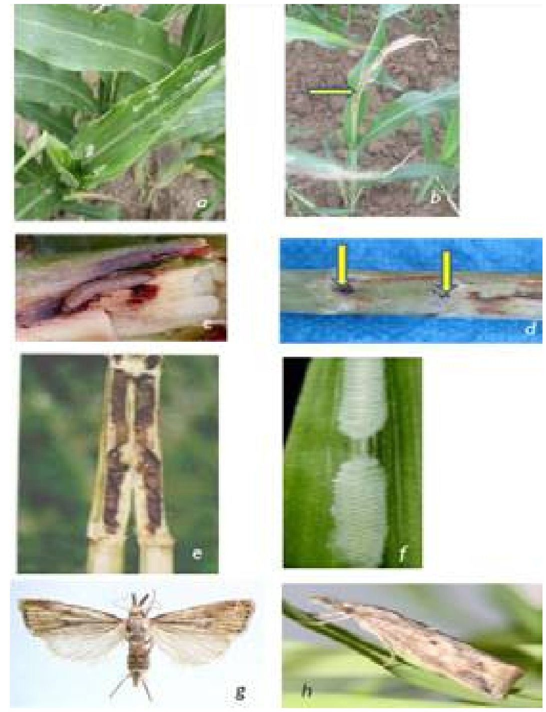


Figure 8. Spotted stem borer and its damage symptoms (IIMR-ICAR)

Management of Stripped borer

- To prevent the incidence of insects in the upcoming year, it is advisable to collect and eliminate all crop stubbles during the initial ploughing after harvest.
- The installation of light traps in the field can help reduce the moth population (Neupane 2002).
- Trimming the tips of seedlings to a length of 2.5-3 cm just before transplanting is an effective measure to prevent egg deposition on the main field. Moths tend to lay eggs near the leaf tips.
- Taking prompt action, such as uprooting dead hearts, destroying egg masses, and removing infested seedlings from the nursery, is crucial to hinder population buildup in subsequent generations (Paneru and Giri 2011).
- Spray *Bacillus thuringiensis* (Bt) based @ 3 g per litre water during evening hours in 10-day intervals (NARC 1999).

Potential millet crop threats

Emerging millet crop pests pose a looming threat to the agricultural landscape of our country. As climate patterns shift and ecosystems evolve, previously benign pests may adapt and become significant menaces to millet crops. These millet pests are already found in our neighbouring countries of southeast Asia. The identification and tracking of these potential threats have become paramount in safeguarding our nation's millet production, a vital component of our food security. These pests might already exist in Nepal so proper research is required for the identification of these pests. Here we will be discussing two pests that are quite significant outside our country and might soon be posing a threat to our millet crops if not surveyed properly. These pests are:

Millet stem borer (Coniesta ignefusalis)

The host crop of the millet stem borer includes finger millet, proso millet, barnyard millet, sorghum millet and pearl millet. Millet stem borer is a major pest of millets that are found in high-hill areas and other parts of our neighbouring country India (Sajwan et al 2022).

Management of Millet stem borer

- Application of neem-based products at the onset of the growing season, before the larvae penetrate the plant's stem, is recommended.
- To disrupt the pest's life cycle, consider implementing crop rotation with a non-host crop like legumes and utilizing resistant millet varieties (CABI 2018).
- Tillage techniques, such as deep ploughing at a depth of 20-23 cm, have been demonstrated to effectively decrease the pupal population (Nwanze 1991).
- Additionally, you can combat the infestation by applying dust or granules to the whorl leaves of affected plants or by conducting a field-wide spraying with Fenvalerate or Cypermethrin (0.5 ml per litre of water) (Prasad et al 2015).

Rice stink bug (Oebalus pugnax)

The rice stink bug is seen in proso and foxtail millets. Similar to rice ear bugs these are also found commonly in rice but also on other crops including millets near various parts of Nepal but out of country's current territory.

Management of Rice stink bug

- Cultural practices such as planting schedule, sanitation of field, trap cropping, and removal of weeds, can be useful.
- A parasitic wasp belonging to the Scelionidae family, known as Telenomus podisi (Ashmead) (Hymenoptera), has been documented as a natural enemy that parasitizes eggs of the rice stink bug (Ingram 1927). When eggs are parasitized by T. podisi, they undergo a colour change, turning black and ultimately failing to hatch.
- Additionally, neonicotinoid dinotefuran has demonstrated effectiveness against O. pugnax and may offer longer-lasting residual toxicity when compared to pyrethroids (Blackman et al 2015).

Conclusion

The study of insect pests affecting millet crops in Nepal is of paramount importance for sustainable agriculture and food security in the region. Through this comprehensive review, we have highlighted the diversity of insect pests that afflict millet crops in Nepal, ranging from well-known and widely studied pests to lesser-known, emerging threats. Collaborative efforts among researchers, farmers, and policymakers are essential to develop and implement strategies that safeguard millet production in Nepal. By implementing effective pest management strategies and promoting sustainable agricultural practices, Nepal can secure its millet production, enhance food security, and improve the livelihoods of its farming communities. It is our hope that this review will serve as a valuable resource for researchers, policymakers, and stakeholders working towards the sustainable cultivation of millets in Nepal.

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Invertebrate and Vertebrate Pest Management in Millets: A Systematic Review

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Abstract

Millets are the fourth-ranked crop in terms of area, production and productivity after paddy, maize, and wheat in Nepal. These crops are considered a staple food for the rural poor farmers and are valued crops by the urban people. Millet grains, foliage and stems are also used for cattle and poultry feed. Millets are infested by various categories of invertebrate and vertebrate pests. Invertebrate pests are insect pests and common vertebrate pests are monkeys, birds and rodents. There are 150 insect pests recorded on different crop growth stages and storage conditions in millet crops. 10-20% yield losses have been recorded by insect pests in millet crops in normal situations but that can reach up to 50% in severe situations. If we consider the damage from vertebrate pests in millet crops, the loss could be much higher than the loss from invertebrate pests. White grub, shoot fly, leaf folders, stem borers, hairy caterpillars, grasshoppers, green bugs, blister beetles and thrips are considered the economically important insect pest of millets. There are very few insect pests and crop-protection-related research in Nepal because of considering this crop as a minor and low crop value. Moreover, such kind of research in the case of vertebrate pests are almost nil or negligible. Hence, there is a need for a more systematic review of both invertebrates as well as vertebrate pests focusing on millet crops. Pests biology, habitat, damage nature and integrated pest management (IPM) packages focusing on millet crops should be systematically reviewed and studied. Hence, this review is done to study the details of invertebrates as well as vertebrate pest and their common management practices. These informations are useful to the policymakers, researchers as well as extension personnel who are involved in promoting the millets as well as other indigenous crops in their locality.

Keywords: Birds, insect pest, integrated management, millets, monkey, pearl millet, vertebrate and invertebrate pest

Introduction

Millets are used as staple food crops in many countries. Eight millet species are grown worldwide. Pearl millet, *Pennisetum glaucum*, finger millet, *Eleusine coracana*, foxtail or Italian millet, *Setaria italica*, proso millet, *Panicum miliaceum*, little millet, *Panicum sumatrense*, barnyard millet, *Echinochloa colona*, fonio millet, *Digitaria* spp., brown top millet *Brachiaria ramose* are common millet species grown in the world (Gahukar and Reddy 2019). Among all species, pearl millet is the most important crop in the semi-arid regions of Asia and other similar countries. Millets are good food for rural people and are also rich in vitamins, minerals and many other anti-metabolites. There are 150 insect species recorded in millet crops (Nwanze and Harris 1992). Among them, 160 species are recorded in India (Kishore 1996). Some of them are soil-inhabiting insects, some are seedling insects, some are defoliators and some are sap-sucking insects (Gahukar and Reddy 2019). Among all invertebrates, grain-eating birds are considered an important crop-limiting biotic agent. Birds normally damage the crops during seed formation or millet ripening stage. Common species are pigeons, weavers, parrots, house sparrows, golden sparrows, blue-tailed starlings, quelea, mourning doves, and red bishops. Birds alone damage the crop equal to 78% (Sharma and Davies 1988). Pigeons almost destroy about 10-100% pearl millet at sowing. Rodents are another group of vertebrate pests. Rodents damage the crops in significant amounts both in field or storage conditions. Bandicoota indica, Mus musculas, and Rattus rattus are the common rodent species in South Asia. It has been reported that their damage in millet reached up to 20% in severe situations (Sharma and Davies 1988). Hence this review is made to collect both the invertebrate and vertebrate pests that frequently damage or cause a significant crop loss both in standing or storage conditions. In this review, basic information about insect pests, their biology, habitats and brief information and common vertebrate pests such as monkey, birds and rodents and their management are included and discussed systematically.

Invertebrate Pests in Millet and Integrated Management

Table 1. Insect Pest of Millet with Potential Millet Hosts

SN	Scientific name	Common name	Order	Family	Millet hosts	References
1	*Holotrichia consanguinea*	White Grub	Coleoptera	Scarabaeidae	Pearl millet, Finger millet, Proso millet	(Choudhary, Tandi, & Singh, 2018)
2	*Atherigona approximate, A. varia soccata*	Shoot fly	Diptera	Muscidae	Sorghum, finger millet, pearl millet, proso millet, kodo millet, fox tail millet, barnyard millet, lile millet	(Sajjan & Biradar, 2018)
3	*Geromiya Penniseti,*	Grain midge	Diptera	Cecidomyiidae	sorghum, pearl millet and wild graminaceous plants	(Gahukar, 1990)
4	*Chilo partellus*	Stem borer	Lepidoptera	Crambidae	Sorghum	(Gahukar & Jotwani, 1980)
5	*Acigona ignefusalis*	Stem borer	Lepidoptera	Crambidae	Sorghum	(Sasmal, 2015)
6	*Sesamia inferens*	Pink borer	Lepidoptera	Noctuidae	Sorghum, Finger millet, Proso millet	(Sasmal, 2015)
7	*Schizaphis graminum*	Green bug	Hemiptera	Aphididae	Sorghum, Pearl millet, Barnyard millet	(Akthar et al., 2012)
8	*Calocoris angustatus*	Ear Head Bug	Hemiptera	Miridae	Sorghum	(Sharma & Lopez, 1992)

SN	Scientific name	Common name	Order	Family	Millet hosts	References
9	*Psalydolytta fusva*	Blister beetle	Coleoptera	Meloidae	Pearl millet, Finger millet	(Zethner & Lawrence, 1988)
10	*Stenadiplosis sorghicola*	Sorghum midge	Diptera	Cecidomyiidae	Sorghum	Gahukar & Reddy, 2019; Sajwan et al., 2022
11	*Saluria inficita*	Whiteborer	Lepidoptera	Pyralidae	Finger millet	Gahukar & Reddy, 2019; Sajwan et al., 2022
12	*Spodoptera exigua*	Cutworm	Lepidotpera	Noctuidae	Finger millet	Gahukar, 1989; Sajwan et al., 2022
13	*Sitotrogra cerealla*	Earhead caterpillar	Lepidoptera	Gelechiidae	Finger millet	Gahukar, 1989; Sajwan et al., 2022
14	*Tetraneura nigriabdominalis*	Root aphid	Hemiptera	Aphididae	Finger millet	Gahukar & Reddy, 2019; Sajwan et al., 2022
15	*Colemania sphenarioides, Hieroglyphus nigrorepletus, H. daganensis, Oedaleus senegalensis, O. nigeriensis, Schistocerca gregaria, Locusta migratoria*	Grasshoppers	Orthoptera	Acrididae	Pearl millet, finger millet	Gahukar, 1989; Gahukar & Reddy, 2019; Sajwan et al., 2022
16	*Bagrada cruciferarum, Agonoscelis pubescens, Nezara viridula*	Stink bug	Hemiptera	Pentatomidae	pearl millet	Gahukar & Reddy, 2019; Sajwan et al., 2022
17	*Chaetocnema basalis, Chaetocnema pusaensis*	Flea beetle	Coleoptera	Chrysomelidae	finger and barnyard millet	Gahukar & Reddy, 2019; Sajwan et al., 2022
18	*Blissus leucopterus*	Chinch Bug	Hemiptera	Blissidae	finger and barnyard millet	Gahukar, 1989; Sajwan et al., 2022

Description of Major Insect Pests of Millet

White grub, *Holotrichia consanguinea* (Coleoptera: Scarabaeidae)

A common white grub species, *Holotrichia consanguinea* Blanch (Coleoptera: Scarabaeidae), is a widespread pest of pearl millet (Choudhary, Tandi and Singh 2018). This species damages the roots of seedlings causing seedlings to wither and die. The larval period is 8-22 weeks, pupal period lasts for 1-8 weeks and beetles emerge in November -December if climatic conditions are favourable (Jotwani and Butani 1978, Sajwan et al 2022)

Shoot fly, *Atherigona approximate* (Diptera: Muscidae)

Almost all millet species are the main hosts of shoot fly (*Atherigona approximate)*. This pest damages the millet crop during the seedling stages. Maggot feeds on the growing tip causing wilting of leaves and cause a dead heart symptoms (Singh and Jotwani 1973). Shoot flies lay the eggs beneath the leaves, the larva hatches in 2-3 days from eggs, larval periods last in 7-12 days and adults emerge in 3-4 weeks. Dead heart and chaffy heads or white heads are the major damage symptoms of shoot flies. Their damages recorded up to 20–50% in pearl millet, 36–36% in common millet and 39% in small millets (Sajwan et al 2022).

Pearl Millet Midge or Grain Midge, *Geromyia penniseti* (Diptera: Cecidomyiidae)

Major hosts are sorghum, pearl millet and wild graminaceous. Maggots damage young grains, developing seeds and making the grain chaffy. Their damage recorded up to 90%. Adult midge or fly lays eggs in flowering spikelets, hatches in 2-3 days, and maggot lasts in 7-12 days, pupal period is 2-4 days and adult fly can survive for one week (Gahukar 1989).

Pink Borer, *Sesamia inferens* (Lepidoptera: Noctuidae)

Sorghum, maize, rice, wheat, sugarcane, pearl millet and ragi are the important hosts of pink borer. The damage is severe in the winter months in finger millet (Sasmal 2018). The pink larvae are gregarious, congregate inside the leaf whorls, and feed on the central leaves, causing typical 'pinhole' symptoms. The typical damage symptom of pink borer is 'dead heart' and 'white head'. They have egg, larva, pupa and adult stages.

Stem borer, *Chilo partellus* (Lepidoptera: Crambidae)

Sorghum, Pearl millet, finger millet, sugarcane, and rice are the major hosts of stem borer (Samsal 2018). The adult moth is straw brown in colour and lays eggs in masses on the undersurface of the leaf near the midrib which hatch to produce larva. This pest damages the crop from 2nd week after sowing to the crop maturity. 'Dead heart' and 'white head' symptoms are major damaging symptoms of stem borer (Sajwan et al 2022).

Green bug or aphid, *Schizaphis graminum* (Hemiptera: Aphididae)

Green bug or aphid is a sporadic pest that greatly damages pearl millet crops in seedling stages (Akthar et al 2012). They directly give the nymphs or lay the eggs according to the outside environment. They can also produce wings aphids to move from one place to another. Throughout the summer, nymphs can mature into wingless or winged adults, and each adult can give birth to 50-60 other nymphs. This pest sucks the fluids from seedlings and damage the plant. They can also carry the virus and transmit the virus from healthy to unhealthy crop seedlings (Davidson and Peairs 1996).

Ear head bug, *Calocoris angustatus* (Hemiptera: Miridae)

This pest damage the sorghum and finger millet. Male adults are green, and female adults are green with brown borders. Adult females lay the blue cigar-shaped eggs under the panicles or flowers. Egg hatches in a week. Nymphs last in 10-14 days. Both nymphs and adults suck the ear heads of millet and damage the grain. The infestation is higher during the milky stage of grain (Sajwan et al 2022).

Blister Beetles, *Psalydolytta fusva* (Coleoptera: Meloidae)

Major hosts of blister beetles are barnyard millet, finger millet and pearl millet (Ramamurthy et al 1970). Adult blister beetles are metallic blue, green, black, reddish-yellow, or brown colours. Female adults lay the eggs in the soil, grub damage the seedlings in the soil and pupation also takes place in the soil. Adult only emerges during summer. Adults feed the inflorescences, which results in impoverished seed germination. Adults eat stigmas, pollen, or whole flowers, which stops grains from developing. Their damage was reported up to 4 to 48% (Gahukar 1989).

Grasshoppers

Many species of grasshoppers damage the millet. Common species are *Colemania sphenarioides, Hieroglyphus nigrorepletus, H. daganensis, Oedaleus senegalensis, O. nigeriensis, Schistocerca gregaria, Locusta migratoria, Chrotogonus* spp., *Kraussaria angulifera.* Female grasshopper lay their eggs in pods in soil, have 5-7 nymphal stages and take about 150-170 days to emerge in adult stages. Nymphs and adults damage the leaf by making holes and grazing appearance during severe infestations (Kalaisekar, Padmaja and Patil 2019).

Integrated Management of Invertebrate Pests

For pest management in millet in a compatible manner, more emphasis is given to a proper Integrated pest management package which utilizes all suitable techniques such as cultural practices, physical methods, mechanical methods, biological control methods and application of botanical insecticides (cake or water extract) (Samraj 2023, Karuppuchamy and Venugopal 2016). In case of severe damage, sensible use of soft chemicals can be applied as an emergency measure (Hurley and Sun 2019).

Cultural Methods

Cultural methods include the manipulation of crop production and management techniques to minimize or avoid pest damage to crops. Cultural practices make an unfavourable environment for the insect pests ensuring a favourable environment for natural enemies (Devi, Mandal, Dadarao and Kumar 2023). The most common means of field sanitation are weeding, intensive tillage, water flooding, and collection and destruction of stubbles from the field (Bajwa and Kogan 2004). To reduce the incidence of stem borers in millets, the stubbles and chaffy ear heads can be collected and burnt before the onset of monsoon. Likewise, soil-dwelling insects can be exposed to predatory birds and scorching sun by practising deep ploughing one month before planting (Samraj 2023). Destruction of alternate host plants lowers the incidence of shoot fly, stem borer and head bug in millet (Devi, Mandal, Dadarao and Kumar 2023).

Early sowing of millet can be done to reduce the density of eggs of shoot fly and minimize the level of infestation of shoot fly in millet. Similarly, early and synchronous sowing of millet can control shoot fly and head bug damage (Samraj 2023, Devi, Mandal, Dadarao and Kumar 2023). Crop rotation with cotton, groundnut or sunflower was found to be effective in pest management in millets (Samraj 2023).

Intercropping millet with cowpea, bean, onion, garlic or coriander at a ratio of 1:1 is found to be effective against shoot fly (Sathish, Manjunatha and Rajashekarappa 2017). Stem infestation by millet stem borer can be lowered by intercropping millet with peanut at the ratio of 1:1 and intercropping millet: cowpea in a ratio of 4:1 is found to reduce infestation of the stem along with an increase in grain and straw yields (Samraj 2023). Intercropping of groundnut with pearl millet enhances the parasitic activity of *Goniozus* sp. which helps in lowering the incidence of thrips, jassids and leaf miners (Devi, Mandal, Dadarao and Kumar 2023).

Mechanical Methods

Mechanical methods are the pest management tools for sustainable agricultural production (Karuppuchamy and Venugopal 2016). Noctuid moths can be monitored and reduced by setting up light traps in the millet field (Samraj 2023). Similarly, *Spodoptera* spp. and *Helicoverpa* spp. can be reduced by installing pheromone traps.

Physical Methods

Physical methods of insect pest management involve altering the environment so that insect pests cannot grow and develop (Angon et al 2023). For the control of millet borer, destruction of plant residue or burning of stems or sun drying of stems in plastic bags after harvest destroyed larvae and pupae (Gahukar 1990).

Biological Control Methods

Biological control methods are an important component of Integrated Pest Management (IPM) that enables to cultivate of environmentally friendly, sustainable pest management practices ensuring favourable habitats for natural enemies in the agroecosystem (Khursheed et al 2022, Hajjar, Ahmed, Alhudaib and Ullah 2023).

Predators such as ants, earwigs, mirid bugs, spiders, carabid beetles, an anthocorid bug, and various coccinellid beetles help in reducing the pests population in millet (Sow et al 2018). Coccinellids (*Coccinella transversalis* F., *Cheilomenes sexmaculata* F.) predator and larval parasitoids (*Halticoverpa* sp., *Trichopria* sp.) were found to reduce the infestation level of pests in millet (Sathish, Manjunatha and Rajashekarappa 2017). The tenebrionid beetle, *Pimelia senegalensis* Olivier and mite, *Eurombidium* sp. are important natural enemies that can suppress the population of grasshoppers (Jago, Kremer and West 1993). Also, entomopathogenic fungi, *Beauveria* bassiana, *Metarhizium anisopliae* and *Nosema locustae* were found to be effective against grasshoppers in millet fields (Maiga, Lecoq and Kooyman 2008).

Parasitoids such as the egg parasitoids *Trichogrammatoidea* spp., *Trichogrammatoidea armigera* Nagaraja, *Telenomus sp.*, the egg-larval parasitoid, *Copidosoma primulum* Mercet, the larval parasitoids *Schoelandella sahelensis* Huddleston and Walker and *Habrobracon (Bracon) hebetor* Say, and the pathogens Aspergillus spp. have a significant role in reducing the pests population in millet (Karimoune, Ba, Baoua and Muniappan 2018). Larval parasitoid, *Neotrichoporoides nyemitawus* Rohwer was reported to decrease the incidence of shoot fly in millet (Sileshi 1997). Egg parasitoids, *Trichogramma chilonis, Platytelemus* sp. and the larval parasitoid, Syzeuctus sp. were reported to be common parasitoids that can reduce the population of millet borer (Youm and Gilstrap 1993, Harris 1962). For reduction in the incidence of grain midge in millet, the parasitoid, *Tetrastichus* sp. and the predatory bug, *Orius* sp. are reported to have a significant role (Coutin and Harris 1968). The conservation of biological control agents and their augmentation is of prime importance (Geedi and Reddy 2022). Periodic augmentative releases of *Habrobracon hebetor* can be done to control millet head miner in millets (Ba et al 2014).

Botanical Management Methods

Botanical pesticides are an essential component of IPM easily biodegradable and are user-friendly in sustainable agriculture (Chattopadhyay, Banerjee and Mukherjee 2017). Products derived from plants have pesticidal properties against a range of insect pests with their ability to modify insect behaviour and antifeedant properties (Singh, Kataria and Kumar 2012, Tembo et al 2018). A water extract of *Nicotiana* sp. leaf powder (3 kg in 500 litres water/ha) and neem seed powder extract (3 kg in 500 litres water/ha) can be effective in suppressing the larval population of shoot fly in millet. Also, seed cakes of neem, castor, and rice shell ash can lower shoot fly fecundity and eventually lower the infestation of shoot fly in millet (Sathish, Manjunatha and Rajashekarappa 2017). Both the Earhead bug and Sorghum midge population can be controlled by using 5% neem seed kernel extract and 1% Azadirachtin (Samraj 2023).

Chemical Methods

Judicious use of synthetic pesticides are suggested in pest control packages (Jago, Kremer and West 1993). The most effective pesticides for IPM are reported to be those which has little to no effect on the natural enemies while being effective against the target insect pests (Bueno and Bueno 2012).

The pesticide applications can be recommended in areas with high endemic pressure from white grubs and during pest outbreaks (Gahukar and Reddy 2019). Seed treatment with imidacloprid 600 FS at 10–12 ml/kg is effective in reducing white grubs in millets (Choudhary, Tandi and Singh 2018). Also, soil drenching with imidacloprid 17.8 SL at 300 ml/ha or mixing chlorpyriphos 20 EC and quinalphos 25 EC at 4.0 litres/ ha along with irrigation 3 weeks after seedling emergence (WAE) was found to be equally effective against white grubs (Kalaisekar, Padmaja, Bhagwat and Patil 2017). When a high infestation of gall midge is noticed in the millet field, cypermethrin 25 EC at 250 ml/ha can be sprayed. Also, it is reported that Cypermethrin 10 EC at the rate of 0.5 ml/ litre of water can be sprayed at 50 per cent flowering in millet for controlling midges in millet. When damage to Shoot fly is observed to reach about 5 to 10 %, it is recommended to spray Cypermethrin 10 EC at the rate of 750 ml/ ha (Samraj 2023).

Monkey in Millet and Integrated Management

Monkey is a primate belonging to the pravorder Catarrhini (Old World monkey) and Platyrrhini (New World monkey) (Schrago and Russo 2003). Monkeys are frugivorous and feed on seeds, flowers, leaves and bark by foraging in the wild habitat. This species inhabits in wide geographic ranges in tropical and subtropical areas with fragmented populations (Ghimire and Chalise 2019b). In countries of southeast Asia-Nepal, Bhutan, north-eastern India, and Thailand, *Macaca assamensis* is found along the foothills of the Himalayas. However, in Nepal, the same species is found at varying altitudes from 284 m in Tanahu, 1607 m in Api Nampa Conservation Area and 2350 m above mean sea level in Langtang region (Chalise 2013).

In Nepal, Rhesus macaque (*Macaca mulatta*, Zimmerman 1780), Hanuman Langur (*Semnopithecus entellus*, Dufresne 1797) and the Assamese macaque (*Macaca assamensis*, McClelland 1839) are common and cause harm to agricultural crops (Rijal 2015, Paudel 2016, Ghimire and Chalise 2019b).

Monkey feeds on fruits like banana and maize close to harvest. In the mid-hills, species of Rhesus, Langur and Assamese causes damage to various crop like maize (*Zea mays*), fruits, wheat (*Triticum aestivum*), millet (*Eleusine coracana*), rice (*Oryza sativa*), potato (*Solanum tuberosum*), lentil (*Lens culinaris*), mustard (*Brassica nigra*), pumpkin (*Cucurbita maxima*), bread, brown lentil, broad beans (*Vicia faba*), sesame, black pulses (*Vigna mungo*), dal, cauliflower, tomato (*Lycopersicum esculentum*), and gram (*Cicer arietinum*) (Ghimire & Chalise 2019b). In Budhigandaki River, damage caused by monkeys was highest in maize (58.43 %) and 0.67 % in millet (Ghimire and Chalise 2016a); however much higher damage was caused in millet (10.84%) in Kaligandaki River Basin (Paudel, 2016).

Integrated Management of Monkey

Maintaining a minimum distance of 500 meters from the agricultural field in a forest area is crucial to reducing the damage to cultivated crops (Naughton-Treves, Treves, Chapman and Wrangham 1998). Beating drums or firecrackers, and using bananas and biscuits mixed with red chillies are some common traditional practices to keep them away from fields. Domestication of well-trained and big-body-sized barking dogs can scare the monkeys (Reddy 2018).

Maintaining natural habitats with fruit-bearing vegetation and deploying human guards in buffer zones can reduce their damage (Reddy 2018). Creating scary or irritating noise and smoking machines can scare monkeys from agricultural areas. Planting a monkey puzzle tree (*Araucaria araucana*) on the sides of an agricultural field can reduce monkey's damage to crops (Reddy, 2018). Utilizing information technologies such as Radio Frequency Identification Device (RFID) modules and Global System Mobile (GSM) to locate animals by injecting RFID tags inside the skin of animals and sending SMS to farmers are other practices, this is common practices in some states of India (Santhiya et al 2018).

Birds in Millet and Integrated Management

Birds are key components of agro-ecosystems and their dual role in agriculture is well documented. Certain bird species also damage crops and are considered as pest (Issa and El-Bakhshawngi 2018). Birds damage millet crops at germination, tillering, milky, dough, grain maturity, and harvesting (Patel 2011). Blue rock pigeons and Indian ring dove are granivorous birds and they damaged sown seeds of sesamum, sorghum and pearl millet. House crows and Jungle crows feed on millet grains during the seeding, germination, and grain maturing stages. Baya weavers feed on insect larvae of millet crops (Patel 2011).

The severity of their damage is determined by the season, local weather, harvest time, etc (Abbasy et al 2012). Birds can damage the crops from seed sowing to crop establishment and normally affect the grains of millet (Lubadde et al 2016). The common bird species that damage the millet crops are Rose-ringed Parakeet, *Psittacula krameri*, House Crow, *Corvus splendens*, Jungle crow, *Corvus macrorhynchos*, Baya Weaver, *Ploceus philippinus*, Common Myna, *Acridotheres tristis*, Bank Myna, *Acridotheres ginginianus*, Common babbler, *Turdoides caudate*, Rosy pastor, *Pastor roseus*, Blue rock pigeon, *Columba livia*, Indian ring dove, *Streptopelia decaocto*, Red-billed quelea, *Quelea quelea* and many others.

Integrated Management of Birds

There are various management practices for birds in the world. Some management practices which are particular to millet crops are the use of scarecrows in cultivated fields, the manual distraction of birds by producing sound, creation of sheltered bays or lagoons (Soliman Desoky 2014). Spray the extracts of leaves of *Azadiracta indicus, Momordica foetida, Veronica amygdaline, and Gliricidia sepium* are known to repel bird pests. Some other practices are the use of anti-perching tools such as sharp spikes, wire barriers and electrified cables. Exclusion via netting can be used to protect crops and roost trees, although the practice is often labour-intensive and expensive. Methyl anthranilate (MA) and anthraquinone are avian repellents. MA acts as an irritant to birds. Anthraquinone (AQ) causes nausea in birds feeding on treated food, leading to a learned avoidance in a variety of species (Klug et al 2019).

Rodents in Millet and Integrated Management

Among the vertebrate pests, rodents can cause considerable loss by damaging the growing tillers and also by consuming and hoarding the ear heads of millets (Naik et al 2015). Rodents are critical vertebrate pests and are regarded as a major biotic problem as they cause damage to food items in farmlands, orchards, range lands, godowns, storehouses, poultry units, and urban dwellings (Sridhara 2006, Witmer and Singleton 2010). Rodents infest almost every crop in the field and have affected food security on a global scale (Brown et al 2006). Crops like cereals, pulses, vegetables, and oilseeds are damaged at crucial stages of the crop and are responsible for 5-10% losses annually during production, processing, storage and transport. The common rodent species that damage the millet crops are *Bandicota bengalensis*, *Tatera indica and Mus platythrix*.

The signs of Infestation of rodents on the field are well-defined runways, an unpleasant musky odour, prints of feet on the dusty floor, marks of dragging tails over the dusty floor, the presence of gnawed holes and a heap of loose soil in cultivated lands.

Integrated Management of Rodents

Maintaining a clean environment in the field and storage area can reduce rodent infestation. Storage bins or sacks should stored off the floor, remove all grass, trash, and all branches touched to windows and roofs can reduce rodent infestations (Namala 2021, Singleton, Brown and Jacob 2004). Millets should be stored in rodent-proofing structures such as local mud bins, concrete bins or steel bins. These bins should be placed at least 1 m above the ground level because almost all rodents can't jump more than 90 cm high. Windows or doors in the storage house should be closed (Namala 2021).

There are many traps available in the market. Traps can be very effective if properly placed and used. Traps are also much safer in places very near to stored grains, in houses and storage buildings. However, trapping is generally useful to reduce their infestations. Various rat traps are available in the market such as Pot Trap, Snap Trap, Steel Trap, Box/Cage Trap etc. While placing the traps, it should be noted that baited traps should be established very near the rodent runways, holes, nests and burrows. For roof rats and mice, traps should be set on shelves, beams, pipes and other high places (Makundi and Massawe 2011). Rearing a cat is the natural control method for rats in the house. Cats are very effective predators of rats. One house and one rat campaign can reduce rodent damage in the community. Some plant products have been found to possess anti-rodent properties. Crude cottonseed oil (5%) possesses anti-fertility effects on bandicoots (Singla et al 2008). Among the botanical extracts garlic extract+ castor oil (1:1) was found effective for control of rodents in the field. Baits containing Datura, Nerium and Jatropha have caused significant mortality at 20% concentration. Nowadays several rodenticides are available in the market. They are being used irrespective of their effectiveness by farmers and urban people for controlling rodents. Zinc Phosphide (Zn_3P_2) is the most widely used acute poison. However, precautions should be taken while using Zinc Phosphide since it is highly toxic to human beings and animals (Singleton, Brown and Jacob 2004).

Conclusion

Millets are important ingredients in human diets in mountain or rural areas of Nepal. These crops are considered as underutilized grain crops in Nepal. Millets are normally cultivated in poor soils with little or no inputs. However, these crops have the potential to give a maximum yield even in extreme environmental and biotic stress conditions. These crops have the potential to feed millions of poor people living in rural areas in the world as well as in Nepal. Millets are comparatively free from insect pests and diseases than other cultivated crops such as rice, wheat, and maize. However, several biotic and abiotic constraints are prevalent in all stages of crop development. Biotic constraints are invertebrate and vertebrate pests. Invertebrate pests are stem borers, aphids, bugs, caterpillars, gall midge, white grubs, ear-head bugs, sorghum midge, blister beetles etc. Some of them are economically important and are considered a major pest and some of them are only encountered or visitors in millets. In certain circumstances, some local pests reach epidemic situations from time to time. Similarly, in certain circumstances, monkeys, birds, rodents and many other vertebrate pests cause a considerable yield loss. In general pest problems in millets are underestimated and very little attention has been paid to their integrated management. On the other side, in the literature very little information about vertebrate and invertebrate pest are available and such information are not well compiled and reviewed. Hence, this systematic review is done to compile all vertebrate and invertebrate pests together with a short description of their habitat and appropriate integrated management.

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Millet Diseases and their Management Practices in Nepal

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Abstract

Within Nepal's unique landscape, millet crops play a decisive role in ensuring food security and livelihoods for marginalized rural population. Despite their climate-smart and resilient nature, millets encounter significant challenges posed by climate change, as they are increasingly susceptible to various pathogens that can trigger diseases, resulting in substantial yield losses. This review summarizes major findings on millet pathogens in Nepal, including disease prevalence across key millet species and effective management practices. The study reports 16 diseases in finger millet, 13 in proso millet, 12 in foxtail millet, 22 in sorghum, 19 in pearl millet, 16 in Kodo millet, 12 in barnyard millet, and 6 in little millet, with significant impacts on millet yield. Out of 116, most of the reported diseases are fungal (85), few are bacterial (11), virus (11), nematode (7) and plant parasites (2). In response to the challenges posed by millet diseases, a thorough exploration of disease management practices is presented. This encompasses a multi-faceted approach that combines cultural, biological, chemical, and integrated strategies. Traditional practices are evaluated alongside modern methods involving resistant cultivars and innovative biocontrol agents. Additionally, the judicious use of chemical interventions is examined, considering both their benefits and associated environmental concerns. Furthermore, the implications of climate change on millet disease dynamics and management are explored, emphasizing the need for adaptive strategies. In conclusion, this review focused on dissemination of knowledge to ensure the resilience of millet crops in the face of evolving pathogen pressures and changing agricultural landscapes.

Keywords: Disease management, millet, pathogens, resilience, yield loss

Introduction

Nepal's agricultural landscape is a rich of diverse crops, each contributing to the country's food security and cultural heritage. Among these treasures, millet crops are pivotal for their remarkable diversity and invaluable contributions to nutrition and sustainability (Baniya et al 1992). Millet crops, encompassing various species such as finger millet (*Kodo*), foxtail millet (*Kaguno*), proso millet (*Chino*), sorghum (*Junelo*) kodo millet (*Dhan Kodo*), little millet (*Kutki Sama*), barnyard millet (*Sama*) and pearl millet (*Bajra, Ghoge*) have been nurtured on Nepalese soil for centuries. These crops are true survivors, flourishing in regions with challenging agro-climatic conditions, often unforgiving to other major cereal crops. Millets have earned the title of "smart crops" due to their exceptional resilience to drought, heat, and poor soils, making them a lifeline for many rural communities (Subedi 2023).

The nutrient-dense grains of millet crops have earned it a place as a dietary staple, particularly in combating malnutrition, especially in children (Upadhyaya et al 2010). Beyond its nutritional value, millet species plays a critical role in addressing dietary deficiencies. This is especially significant given its richness in calcium, iron, and dietary fiber, contributing to overall health. Millet crops in Nepal exhibit remarkable diversity (Ghimire et al 2017), thriving across varied agro-ecological zones, ensuring food security even amid changing climatic conditions. While millets have cultural and religious significance in Nepal (Upadhyay and Joshi 2003), the modernization of agriculture and changing dietary preferences have posed challenges (Luitel et al 2020). Advocacy for millet revival is essential for their conservation and their ongoing contributions to nutrition and sustainability. In the context of millet diseases, understanding their prevalence, impacts, and advancements in management strategies is crucial. Recent advances in millet pathology science have led to more effective disease control measures, ensuring the continued productivity and viability of millet crops in Nepal.

Crop diseases and pests represent significant challenges leading to substantial yield losses, particularly in the context of millet production in Nepal. The deficiency in the release of new high-yielding millet varieties, combined with limited access to such varieties, has become a pressing issue for farmers, hindering the expansion of millet cultivation. Moreover, there has been a notable absence of research attention directed towards the pathological aspects of millet crops in Nepal (Subedi 2023). With the looming specter of climate change, these challenges are poised to exacerbate in the future. Millet crops in Nepal face an array of major diseases, including grain mould, downy mildew, blast, smut, rust, ergot, leaf spot, brown spot, and sporadically, viral and bacterial diseases (**Table 1**). Farmers residing in the mid and high hill regions have engaged in the cultivation of millet for generations, demonstrating its historical significance as a staple crop (HCRP 2019). However, the limited availability of millet varieties has been a bottleneck, with only five released and one registered landrace of finger millet, one registered landrace of proso millet, and one of foxtail millet currently accessible (HCRP 2020). This limited selection does not cater to the diverse agro-ecological zones present in Nepal. Furthermore, the sustainability of these existing varieties and landraces is not assured indefinitely. Adding to the complexity of the situation is the dearth of a consistent supply of high-yielding, disease-resistant new millet varieties that could effectively address the multifaceted challenges faced by farmers. In light of these circumstances, it becomes increasingly imperative to bridge the gap between research and practice, fostering innovation in millet breeding and crop management to ensure food security and agricultural sustainability in Nepal.

The comprehensive assessment of major millet diseases and their prevalence across diverse agro-ecological regions is meticulously documented in **Table 1**. The inception of millet disease investigation in 1980 marked a pivotal milestone, especially considering the absence of any improved millet varieties within the country at that time (Batsa and Tamang 1983). This pivotal research endeavour was launched in tandem with a plant disease survey conducted by the National Maize Development Program based in Rampur, Chitwan, Nepal (Batsa and Tamang, 1983).

While a spectrum of millet diseases were documented, only few were economically significant to loss the crop yield. The primary approach to managing these major diseases has predominantly revolved around the development and deployment of resistant varieties. This review critically addresses the major millet diseases, which represent formidable hurdles to millet productivity and production in Nepal.

Table 1. List of millet diseases, etiology and their status in Nepal

Disease	Type	Etiology	Disease prevalence	Status
Fingermillet (*Eleusine coracana* (L.) Gaertn. (कोदो)				
Blast	Fungal	*Pyricularia grisea* (Cooke.) Sacc. [Perfect stage: *Magnaporthe grisea* (Herbert) Barr]	High, mid and foot hill/ terai and inner terai	Major
Cercospora leaf spot	Fungal	*Cercospora eleusinis* Munjal, Lall & Chona	Mid and foot hill/ terai and inner terai	Major
Banded sheath blight	Fungal	*Rhizoctonia solani Kuhn*. [Basidial Stage: *Thanatephorus cucumeris* (Fr.) Donk.]	Mid and foot hill/ terai and inner terai	Major
Grain Smut	Fungal	*Melanopsichium eleusinis* (Kulk.) Mundk. & Thirum. [Syn. *Ustilago eleusines* Kulk.]	High, mid and foot hill	Major
Brown Spot (Seedling Blight or Leaf Blight)	Fungal	*Drechslera nodulosa* (Berk. & M.A. Curtis ex Sacc.) Subram. & B.L. Jain [Syn. *Helminthosporium nodulosum* Berk. & M.A. Curtis ex Sacc.] [Perfect stage: *Cochliobolus nodulosus*].	High, mid and foot hill/ terai and inner terai	Major
Leaf Spot	Fungal	*Curvularia lunata* (Wakker) Boedijn [Syn. *Acrothecium lunatum* Wakker]	Mid and foot hill/ terai and inner terai	Minor
Downy Mildew or Crazy Top	Fungal	*Sclerophthora macrospora* (Sacc.) Thirum. [Syn. *Sclerospora macrospora* Sacc.]	Mid and foot hill/ terai and inner terai	Minor
Foot Rot	Fungal	*Sclerotium rolfsii* Sacc. [Perfect Stage: *Athelia rolfsii* (Curzi) C.C. Tu & Kimbr.]	Mid and foot hill/ terai and inner terai	Minor
Rust	Fungal	*Uromyces eragrostidis* Tracy.	High, mid and foot hill/ terai and inner terai	Minor
Bacterial Leaf Spot	Bacterial	*Xanthomonas eleusinae* Rangaswami, Prasad, Eswaran	Mid and foot hill/ terai and inner terai	Minor
Bacterial Blight	Bacterial	*Xanthomonas axonopodis* Starr and Garces pv. *coracanae* Desai, Thirumalachar and Patel [Syn. *Xanthomonas coracanae* Desai, Thirumalachar and Patel]	Mid and foot hill/ terai and inner terai	Minor
Leaf stripe	Bacterial	*Pseudomonas eleusinae*	Mid and foot hill/ terai and inner terai	Minor
Severe mosaic	Virus	*Sugarcane mosaic virus*	Mid and foot hill/ terai and inner terai	Minor
Mottle streak	Virus	*Mottle streak virus*	Mid and foot hill/ terai and inner terai	Minor
Finger millet streak	Virus	*Eleusine strain of maize streak virus*	Mid and foot hill/ terai and inner terai	Minor
Cyst nematode	Nematode	*Heterodera gambiensis*	Mid and foot hill/ terai and inner terai	Minor
Rotylenchulus nematode	Nematode	*Rotylenchulus reniformis Linford and Oliveira*	Mid and foot hill/ terai and inner terai	Minor
Proso millet (*Panicum miliaceum* L.) (चिनो)				
Blast	Fungal	*Pyricularia grisea* (Cooke.) Sacc. [Perfect stage: *Magnaporthe grisea* (Herbert) Barr]	High and mid hill	Major

Disease	Type	Etiology	Disease prevalence	Status
Grain smut	Fungal	*Sphacelotheca sorghi* (Ehrenb. ex Link) G.P. Clinton [Syn. *Sporisorium sorghi* Ehrenb. ex Link.; *Tilletia sorghi* (Ehrenb. ex Link) Tul. & C. Tul., ; *Ustilago sorghi* (Ehrenb. ex Link) Pass.; *Sphacelotheca sorghi* (Ehrenb. ex Link) Speg.]	High and mid hill	Major
Leaf Spot (Blight/seedling rot)	Fungal	*Bipolaris panici-miliacei* (Y. Nisik.) Shoemaker [Syn. *Helminthosporium panici-miliacei* Y. Nisik.; *Drechslera panici-miliacei* (Y. Nisik.) Subram. & B.L. Jain]	High and mid hill	Major
Leaf stripe	Fungal	*Helminthosporium oryzae* Breda de Haan [Syn. *Bipolaris oryzae* (Breda de Haan) Shoemaker; *Drechslera oryzae* (Breda de Haan) Subram. & B.L. Jain]	High and mid hill	Minor
Sheath rot or banded sheath blight	Fungal	R*hizoctonia solani* Kuhn [Basidial Stage: *Thanatephorus cucumeris* (Fr.) Donk.]	High, mid and foot hill	Minor
Rust	Fungal	*Uromyces linearis* Berk. & Broome [Syn. *Caeomurus linearis* (Berk. & Broome) Kuntze; *Ustilago linearis* (Berk. & Broome) Petch]	High, mid and foot hill	Minor
Downy mildew	Fungal	*Sclerospora graminicola* (Sacc.) J. Schröt.	High, mid and foot hill	Minor
Udabatta	Fungal	*Ephelis oryzae* Syd. [Teleomorph: *Balansia oryzae* (Syd.) Naras. & Thirum.]	High, mid and foot hill	Minor
Bacterial stripe	Bacterial	*Pseudomonas syringae* Van Hall pv. panici [Syn. Bacterium panici]	High, mid and foot hill	Minor
Nematode disease	Nematode	*Aphelenchoides besseyi*	Mid and foot hill	Minor
Wheat streak virus	Virus	*Wheat streak virus*	Mid and foot hill	Minor
Rice dwarf or stunt virus	Virus	*Rice dwarf or stunt virus*	Mid and foot hill	Minor
Leaf streak virus of maize	Virus	*Leaf streak virus of maize*	Mid and foot hill	Minor
Foxtail millet (*Setaria italica* (L.) Beauv. (कागुनो)				
Blast	Fungal	*Pyricularia setariae* Y. Nisik. [Syn. *Pyricularia oryzae* Cavara]	High, mid and foot hill	Major
Smut	Fungal	*Ustilago crameri* Körn.	High, mid and foot hill	Major
Leaf Spot or Blotch	Fungal	*Cochliobolus setariae* (S. Ito & Kurib.) *Drechslera ex Dastur*, [Syn. *Bipolaris setariae* (Sawada) Shoemaker; *Drechslera setariae* (Sawada) Subram. & B.L. Jain; *Helminthosporium setariae* Sawada; *Helminthosporium setariae* Lind; *Ophiobolus setariae* S. Ito & Kurib.]	High, mid and foot hill	Major
Banded sheath blight	Fungal	*Rhizoctonia solani* Kuhn [Basidial Stage: *Thanatephorus cucumeris* (Fr.) Donk.]	High, mid and foot hill	Minor

Disease	Type	Etiology	Disease prevalence	Status
Downy Mildew or Green Ear	Fungal	*Sclerospora graminicola* (Sacc.) J. Schröt.	High, mid and foot hill	Minor
Rust	Fungal	*Uromyces setariae-italicae* Yoshino	High, mid and foot hill	Minor
Leaf and sheath brown spot	Fungal	*Bipolaris australiensis* (M.B. Ellis) Tsuda & Ueyama [Syn. *Helminthosporium australiense* Bugnic.; *Drechslera australiensis* (Bugnic.) Subram. & B.L. Jain; *Drechslera australiensis* M.B. Ellis]	High, mid and foot hill	Minor
Udabatta	Fungal	*Ephelis oryzae* Syd. [Teleomorph: *Balansia oryzae* (Syd.) Naras. & Thirum.]	High, mid and foot hill	Minor
Bacterial blight or spot	Bacterial	*Pseudomonas alboprecepitans* Rosen.	High, mid and foot hill	Minor
Bacterial brown stripe	Bacterial	*Acidovorax citrulli Williems et al* [Syn. A. *avenae subsp. citrulli* Williems et al; *Pseudomonas setariae* (Okabe) Savulescu]	High, mid and foot hill	Minor
Seed rot	Fungal	*Aspergillus flavus, A. terreus, Penicillium citrinum, Alternaria alternata, Curvularia lunata, C. maculans, Fusarium sp. Rhizopus sp. and Mucor sp.*	High, mid and foot hill	Minor
Wheat streak virus	Virus	*Wheat streak virus*	Mid and foot hill	Minor
Sorghum (*Sorghum bicolor* (L.) Moench (जुनेलो)				
Grain mould	Fungal	*Fusarium moniliforme, Curvularia lunata, Alternaria alternate and Phoma sorghina*	Mid and foot hill/ terai and inner terai	Major
Anthracnose	Fungal	*Colletotrichum sublineolum*	Mid and foot hill/ terai and inner terai	Major
Downy mildew	Fungal	*Peronosclerospora sorghi*	Mid and foot hill/ terai and inner terai	Major
Ergot/sugary disease	Fungal	*Claviceps sorghi; C. sorghicola; C. africana*	Mid and foot hill/ terai and inner terai	Major
Rust	Fungal	*Puccinia purpurea*	Mid and foot hill/ terai and inner terai	Minor
Leaf blight	Fungal	*Bipolaris turcica*	Mid and foot hill/ terai and inner terai	Minor
Sooty stripe	Fungal	*Ramulispora sorghi*	Mid and foot hill/ terai and inner terai	Minor
Zonate leaf spot	Fungal	*Gleocercospora sorghi*	Mid and foot hill/ terai and inner terai	Minor
Grey leaf spot	Fungal	*Cercospora sorghi*	Mid and foot hill	Minor
Target leaf spot	Fungal	*Phyllachora sacchari*	Mid and foot hill/ terai and inner terai	Minor
Loose smut	Fungal	*Sporisorium cruenta*	Mid and foot hill/ terai and inner terai	Major
Covered smut	Fungal	*Sporisorium sorghi*	Mid and foot hill/ terai and inner terai	Major
Head smut	Fungal	*Sporisorium reilianum*	Mid and foot hill/ terai and inner terai	Major

Disease	Type	Etiology	Disease prevalence	Status
Long smut	Fungal	*Tolyposporium ehrenbergii*	Mid and foot hill/ terai and inner terai	Minor
Charcoal rot	Fungal	*Macrophomina phaseolina*	Mid and foot hill/ terai and inner terai	Minor
Pokkahboeng	Fungal	*Fusarium moniliforme var. subglutinans*	Mid and foot hill/ terai and inner terai	Minor
Fusarium stalk rot	Fungal	*Fusarium moniliforme*	Mid and foot hill/ terai and inner terai	Minor
Pythium root rot	Fungal	*Pythium arrhenomanes*	Mid and foot hill/ terai and inner terai	Minor
Bacterial leaf stripe	Bacterial	*Pseudomonas andropogonis*	Mid and foot hill/ terai and inner terai	Minor
Bacterial leaf streak	Bacterial	*Xanthomonas axonopodis pv. holcicola*	Mid and foot hill/ terai and inner terai	Minor
Bacterial leaf spots	Bacterial	*Pseudomonas syringae pv. syringae*	Mid and foot hill/ terai and inner terai	Minor
Viral diseases	Virus	*Maize stripe virus, maize mosaic virus*	Mid and foot hill/ terai and inner terai	Minor
Kodo millet (*Paspalum scrobiculatum* L.) (धान कोदो)				
Head Smut	Fungal	*Sorosporium paspali-thunbergii* (Henn.) S.Ito [Syn. *Sorosporium paspali* Mc Alp.]	Mid and foot hill/ terai and inner terai	Major
Leaf blight	Fungal	*Alternaria alternata* (Fr.) Keissl. *Trichometasphaeria turcica* Luttrell [Syn. *Helminthosporium turcicum* Pass.]	Mid and foot hill/ terai and inner terai	major
Ergot (Sugary)	Fungal	*Claviceps paspali* Stevens & Hall	Mid and foot hill/ terai and inner terai	Major
Rust	Fungal	*Puccinia substriata* Ellis & Barthol. [Syn. *Uredo paspali-scrobiculati* Syd.]	Mid and foot hill/ terai and inner terai	Minor
Udbata	Fungal	*Ephelis oryzae* Syd. [Teleomorph: *Balansia oryzae* (Syd.) Naras. & Thirum.] or *Ephelis japonica* P. Henn.	Mid and foot hill/ terai and inner terai	Minor
Sheath rot	Fungal	*Sarocladium oryzae* (Sawada) W. Gams & D. Hawksworth [Syn. *Acrocylindrium oryzae* Sawada; *Sarocladium attenuatum* W. Gams & D. Hawksw.]	Mid and foot hill/ terai and inner terai	Minor
Kodomillet poisoning	Fungal	*Phomopsis paspali, Aspergillus flavus, A. tamari, Sorosporium paspali*	Mid and foot hill/ terai and inner terai	Minor
Leaf spot	Fungal	*Trichometasphaeria holmii* Luttrell [Syn. *Drechslera holmii* (Luttrell) Subram. & Jain (*Helminthosporium holmii*), *Drechslera victoriae* (Meehan & Murphy) Subram. & Jain	Mid and foot hill/ terai and inner terai	Minor
Sheath blight	Fungal	*Rhizoctonia solani Kuhn*	Mid and foot hill/ terai and inner terai	Minor
Bacterial leaf streak	Bacterial	*Xanthomonas species.*	Mid and foot hill/ terai and inner terai	Minor
Bacterial leaf blight	Bacterial	*Xanthomonas campestris* (Pam.) *Dowson pv. oryzae* Uyeda & Ishiyama	Mid and foot hill/ terai and inner terai	Minor

Disease	Type	Etiology	Disease prevalence	Status
Phanerogamic Partial Root Parasite	Parasite	*Striga asiatica* (L.) Kuntze and Striga densiflora Benth.	Mid and foot hill/ terai and inner terai	Minor
Nematode disease	Nematode	*Meloidogyne incognita* (Kofoid & White), *Tylenchorhynchus vulgaris, Rotylenchulus reniformis*	Mid and foot hill/ terai and inner terai	Minor
Little millet (*Panicum sumatrense* Roth.ex.Roem.& Schult.) (कुट्की सामा)				
Grain smut	Fungal	*Macalpinomyces sharmae* Vanky [Syn. *Tolyposporium sp.*]	Mid and foot hill/ terai and inner terai	Major
Rust	Fungal	*Uromyces linearis* Berk. & Broome [Syn. *Ustilago linearis* (Berk. & Broome) Petch]	Mid and foot hill/ terai and inner terai	Major
Udbatta	Fungal	*Ephelis oryzae* Syd. [Teleomorph: *Balansia oryzae* (Syd.) Naras. & Thirum.]	Mid and foot hill/ terai and inner terai	Major
Leaf blight	Fungal	*Cochliobolus nodulosus* Luttrell *Drechslera nodulosa* (Berk. & Curt.) Subram. & Jain (*Helminthosporium nodulosum* Berk & Curt. apud Sacc.), *Cochliobolus miyabeanus* (Ito & Kuribayashi) Drechsler ex Dastur= *Drechslera miyabeanus*, (*Helminthosporium oryzae* Breda de Hann.)	Mid and foot hill/ terai and inner terai	Major
Sheath blight	Fungal	*Rhizoctonia solani Kuhn*	Mid and foot hill/ terai and inner terai	Minor
Nematode disease	Nematode	*Helicotylenchus dihystera, H. abunaamai, Meloidogyne incognita, Tylenchorhynchus vulgaris, Heterodera delvi*	Mid and foot hill/ terai and inner terai	Minor
Barnyard millet [Echinochloa crusgalli (L.) P.B.] (सामा)				
Head smut	Fungal	*Ustilago crus-galli* Tracy & Earle	Mid and foot hill/ terai and inner terai	Major
Grain smut	Fungal	*Ustilago panici-frumentacei* Bref.	Mid and foot hill/ terai and inner terai	Minor
Kernel smut	Fungal	*Ustilago paradoxa* Syd., P. Syd. & E.J. Butler	Mid and foot hill/ terai and inner terai	Minor
Leaf spot or blight	Fungal	*Helminthosporium monoceros* Drec. [Syn. *Helminthosporium crusgalli* Nisikado and Miyake]	Mid and foot hill/ terai and inner terai	Minor
Sheath blight	Fungal	*Rhizoctonia solani* Kuhn	Mid and foot hill/ terai and inner terai	Major
Brown or sharp eye spot	Fungal	*Pellicularia filamentosa*	Mid and foot hill/ terai and inner terai	Minor
Leaf sheath rot	Fungal	*Sclerotium hydrophyllum*	Mid and foot hill/ terai and inner terai	Minor
Leaf spots	Fungal	*Curvularia lunata, Helminthosprium nodulosum, H. Oryzae, Brachysporium senegalense, Cercospora echinochloe, C. Sorghi*	Mid and foot hill/ terai and inner terai	Minor
Virus disease	Virus	Wheat Streak Virus, Sugarcane Mosaic Virus, *Eleusine* virus 2	Mid and foot hill/ terai and inner terai	Minor

Disease	Type	Etiology	Disease prevalence	Status
Nematode disease	Nematode	*Heterodera morioni*	Mid and foot hill/ terai and inner terai	Minor
Pearl millet [*Penisettum glaucum* (L.) R. Br.] (बाजरा/घोगे)				
Downy mildew	Fungal	*Sclerospora graminicola*	Mid and foot hill/ terai and inner terai	Major
Blast	Fungal	*Pyricularia grisea*	Mid and foot hill/ terai and inner terai	Major
Ergot	Fungal	*Claviceps fusiformis*	Mid and foot hill/ terai and inner terai	Major
Smut	Fungal	*Moesziomyces penicillariae*	Mid and foot hill/ terai and inner terai	Major
Rust	Fungal	*Puccinia penisetti (P. substriata var. indica)*	Mid and foot hill/ terai and inner terai	Minor
Top rot	Fungal	*Fusarium moniliforme*	Mid and foot hill/ terai and inner terai	Minor
Head mould	Fungal	*Various fungi*	Mid and foot hill/ terai and inner terai	Minor
Bipolaris leaf spot	Fungal	*Bipolaris setariae*	Mid and foot hill/ terai and inner terai	Minor
Cercospora leaf spot	Fungal	*Cercospora penniseti*	Mid and foot hill/ terai and inner terai	Minor
Curvularia leaf spot	Fungal	*Curvularia penniseti*	Mid and foot hill/ terai and inner terai	Minor
Dactuliophora leaf spot	Fungal	*Dactuliophora elongata*	Mid and foot hill/ terai and inner terai	Minor
Drechslera leaf spot	Fungal	*Drechslera dematioidea*	Mid and foot hill/ terai and inner terai	Minor
Myrothecium leaf spot	Fungal	*Myrothecium roridum*	Mid and foot hill/ terai and inner terai	Minor
Phyllachora leaf spot	Fungal	*Phyllachora penniseti*	Mid and foot hill/ terai and inner terai	Minor
Zonate leaf spot	Fungal	*Gloeocercospora sorghi*	Mid and foot hill/ terai and inner terai	Minor
Exserohilum leaf blight	Fungal	*Exserohilum rostratum*	Mid and foot hill/ terai and inner terai	Minor
Phyllosticta leaf blight	Fungal	*Phyllosticta penicillariae*	Mid and foot hill/ terai and inner terai	Minor
Rhizoctonia blight	Fungal	*Rhizoctonia solani; Rhizoctonia zeae*	Mid and foot hill/ terai and inner terai	Minor
Southern blight	Fungal	*Sclerotium rolfsii*	Mid and foot hill/ terai and inner terai	Minor

Finger Millet

Finger millet, scientifically referred to as *Eleusine coracana* (L.) Gaertn, from family Poaceae and sub family Chlorodoideae (Chromosome 4x, 2n=36) originated from the Ethiopian highlands and found its way into South Asian region around 4000 years ago. Itis a nutrient dense, culinary, easily digestible and processed with nutraceuticals quality, climate smart cereal crop cultivated in the semi-arid regions of Africa and South Asia (Amadou et al 2011). It is rich in calcium (0.34%), dietary fiber (18%), protein (6-13%), minerals (2.5-3.5%), phytates (0.48%) and phenolic compounds (0.3-3%) and also valued for its nutraceutical effects like anti-diabetic, anti-tumorigenic, antioxidant and antimicrobial properties (Nakarani et al 2020). The unique composition of nutraceuticals found in this crop has led to the development of innovative food products with higher market value, making it an attractive crop for farmers and food processors alike (Ghimire et al 2022). The crop occupies around 10% of the total millet area, which is 34.18 million ha in the world (FAO 2019). Globally, it ranked fourth among millet crops after sorghum, pearl millet and foxtail millet (Upadhyaya et al 2007). It is extensively grown in over 25 countries across Africa (especially in the eastern and southern regions) and Asia, spanning from the Near East to the Far East. Predominantly cherished as a staple food grain, its major producers include Uganda, India, Nepal, and China. This versatile crop boasts a substantial yield potential, capable of exceeding 10 metric tons per hectare under optimal irrigated conditions, and it demonstrates excellent grain storage capabilities. This robust grain exhibits remarkable adaptability to elevated terrains and thrives in the Himalayan region, flourishing at altitudes of up to 2500 meters. One of its most notable attributes lies in its exceptional capacity for long-term storage, making it a critical resource during periods of scarcity and food insecurity.In Nepal it is the fourth most important crop of after rice, maize and wheat and cultivated in an area of 267,071 ha, with the production and productivity of 339,462mt and 1.27mt/ha respectively (MoALD 2023). The major finger millet producing districts in the country are Khotang, Baglung, Sindhupalchok, Kaski, Syangja and Gorkha (MoALD 2023).

There is a wide yield gap in finger millet. The attainable (experimental) yield is 3.99 t/ha while the on-farm yield with the improved package of practices is 3.07 t/ha. The national average yield of finger millet is 1.19 t/ha in Nepal. So, the gap between attainable and national yield is about 2.8 t/ha (Subedi 2023) (**Figure 1**). The major factor for the wide yield gap is limited varietal options for varied agro-ecological domains; Biotic, abiotic and socio-economic constraints; Low adoption of improved package of practices and neglected marginal crop. There are various biotic and abiotic yield limiting factors in millet of which diseases and poor crop management are important ones. Finger millets are affected by wide range of pathogens with fungal and bacterial diseases being the most important in Nepal (**Table 1**).

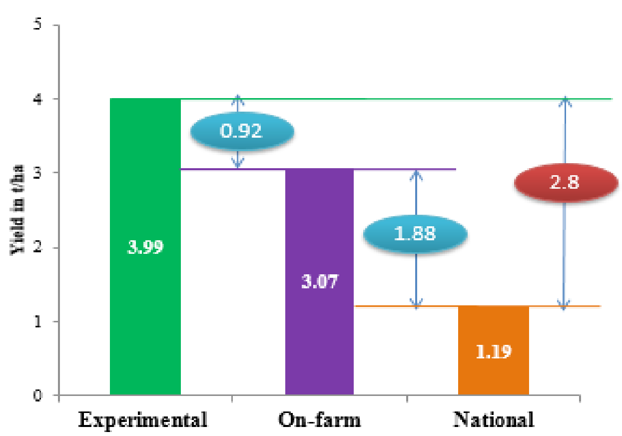

Figure 1. Yield gap of finger millet in Nepal

Blast (मरुवा)

Blast caused by *Pyricularia grisea* (Cooke) Sacc. [teleomorph: *Magnaporthe grisea* (Hebert.) Barr.] is a serious and widespread fungal disease that poses a significant threat to finger millet production worldwide, leading to substantial economic losses for farmers (Babu et al 2014; Das et al 2021; Dida et al 2020). Blast is prevalent in Dolakha, Ramechhap, Kaski, Gorkha, Tanahu, Syangja, Khotang, Baglung and Sindhupalchok districts of Nepal (HCRP 2020). The disease can cause severe damage to the crop, resulting in reduced yield and poor grain quality, which has a direct impact on the livelihood of many smallholder farmers who rely on finger millet as a staple crop. It is a seed-borne disease that damages the foliage, neck, and finger developing three types of symptoms leaf blast, neck blast and finger blast respectively at multiple stages of crop growth, hibernates in infected crop trash, and manifests itself during the rainy season (Manandhar et al 2016). Leaf blast is characterized by the appearance of small brown spots with grey centers that are elliptical or diamond-shaped, on the leaves while neck blast, on the other hand, appears in the neck region of the plant as brown lesions that can girdle the neck, leading to sterility and reduced grain yield (Kiran Babu et al 2013). Finger blast is characterized by browning, followed by either partial or complete drying of the fingers, which causes spikelet sterility (Manandhar et al 2016). The attack of neck and finger blasts before milking stage, significantly reduce grain yield, which is to be around 28 to 36% in Asia each year (Nagaraja et al 2007), but the yield loss might reach as high as 80 to 100% (Prajapati et al 2013). The lower temperature with more than 70% humidity is conducive to spread this disease. Anilkumar et al (2004) conducted a comprehensive analysis of the finger millet blast pathogenic population, revealing a remarkable degree of diversity, quantified by the Shannon diversity index (H) of 0.98. This observation suggests that nearly every individual within the population can be classified as a distinct pathotype.

Leaf blast Neck blast Finger blast

Photo: Subash Subedi, NARC

The initial inoculum of the pathogenic fungus predominantly originates from infected seeds. Furthermore, the fungus may endure in plant remnants and in seeds derived from afflicted grains. The introduction of a single infected seed has the potential to trigger an epidemic of the disease (Pall 1988). Favorable climatic conditions for disease progression encompass a minimum temperature range of 15-25° C, relative humidity surpassing 85%, coupled with intermittent precipitation (Pall 1987). The severity of the disease is contingent on a myriad of factors including genotype susceptibility, sowing time, and corresponding climatic parameters. A study by Anil Kumar et al (2004) conducted in Coimbatore and Paiyur highlighted the paramount influence of relative humidity on disease incidence among various weather parameters. Elevated relative humidity during the early hours of the day proved conducive for pathogen infiltration and expeditious development. Conversely, higher mean maximum temperatures and lower mean minimum temperatures were found to be detrimental, as indicated by negative correlation coefficients. Nonetheless, the highest incidence of the disease has been recorded in crops sown during the second fortnight of July to the first fortnight of August (Nagaraja et al 2007).

Management

Currently, the cultivation of varieties endowed with inherent resistance, complemented by judicious applications of fungicides and bioagents, stands as the most cost-effective strategy for disease control. The utilization of blast-resistant varieties in combination with carbendazim seed treatment at a rate of 2g/kg seeds? has demonstrated the potential to augment yields by 50-100%.Out of the 300 finger millet accessions evaluated, 95 accessions were having less score of finger blast compared to the best released variety Kabre Kodo-2. Among them, accessions viz. NGRC04798, NGRC03478, NGRC05765, NGRC03539, NGRC06484, NGRC01458 and NGRC01597 are found the resistant genotypes for finger as well as neck blast (Ghimire et al 2022). Genotypes ACC#6408, Coll#DR-6, ACC#2707, ACC#6375 and ACC#2811 were high yielding and showed combined resistance to leaf, neck and finger blast in mid hill conditions of Nepal (Subedi 2023). The sources of genetic resistance in finger millet genotypes against blastdisease (Subedi 2023) are shown in **Table 2**.

Table 2. Identifying sources of genetic resistance in finger millet against leaf, neck and finger blast in mid hill conditions of Nepal

Fingermillet –Hill set			
Year	**Leaf Blast resistant**	**Neck Blast resistant**	**Finger blast resistant**
2017	ACC#6373, ACC#2374, ACC# 530	ACC#458, ACC# 530, ACC# 2385, ACC#2752, KLE-298, GPU-025	ACC# 519, ACC#530, ACC#2639, ACC#2752, ACC#6022, SailungKodo
2018	Coll#DJ-2, GE-322 Acc#6359, Acc#6376, Acc#6438, Acc#6414, Acc#6523	Acc#2811, Acc#519, Acc#504 Coll#DJ-2, Acc#6446, Acc#6603, DJ-4	Acc#2289, Acc#6562, GE-322, Acc#511, Acc#425, Acc#6587 Acc#466, DH2
2019	Acc#152, Coll#DJ-7 Acc#6533, Acc#2289 Acc#6386, Acc#6537 VL-149	Acc#152, Coll#DJ-7, Acc#2289, Acc#6537, Acc#2777, VL-149, Acc#6587	Acc#500, Acc#530, Acc#436 Acc#6564, Acc#2723
2020	Acc#152, Acc#2843, Acc#2432, Coll#DJ-7, DH1	Acc#152, Acc#2843, Acc#6515, Acc#6573, Acc#6527	Acc#152, Acc#2843, PR-202, Acc#6515, Acc#2372, Acc#2707, Acc#2670, Acc#6573, Acc#6527
Finger millet –Mountain set			
Year	**Leaf Blast resistant**	**Neck Blast resistant**	**Finger blast resistant**
2019	Kabre Kodo-1, Acc#456	KLE-216, Acc#6407, Acc#2326, Acc#2646, Acc#1509, Acc#1512, Acc#2692,	Acc#6407, Acc#6575, Acc#2646, Acc#1509, Acc#1512,
2020	Acc#2326, Acc#2963-1, Acc#1515, Acc#2452	Acc#6526, KLE-2339 KLE-216, Acc#444	Acc#2326, KLE-216, Acc#6407, Acc#444

The leaf, neck and finger Blast disease of finger-millet was effectively controlled in the plot sprayed with Tricyclazole 75%WP @ 2 g/l of water and produced grain yield of 4.6 t/ha (Gurung et al 2022). Seed treatment involving *Trichoderma harzianum* or *Pseudomonas fluorescens* at 6g/kg, combined with two applications of *Pseudomonas fluorescens* at 0.3% initially at the onset of flowering, followed by a subsequent application 10 days later has proven highly effective in managing leaf, neck, and finger blasts (Patro et al 2008). In the absence of varieties with innate resistance, fungicidal sprays are recommended to mitigate disease incidence. Two applications of Saaf (0.2%), carbendazim (0.05%), or tricyclazole (0.05%) with the first application at 50% flowering and the second 10 days thereafter have demonstrated efficacy (Madhukeshwara et al 2004).The adoption of the resistant variety GPU 28 garnered widespread acceptance among farmers in Tamil Nadu and Karnataka, whereas in Uttarakhand, VL149 emerged as the most suitable choice (Madhukeshwara et al 2005; Kumar 2011).Remarkably, finger and neck blast incidence remained low for the GPU 28 variety, irrespective of the amount and type of fertilizer applied (Nagaraja et al 2008).The adoption of a varietal mixture at a 1:1 ratio of PRM 1 (susceptible) and VL 149 (resistant) has proven to be an economically viable strategy for blast disease management in Uttarakhand (Kumar and Kumar 2011).Nagaraja et al (2012) proposed that finger millet blast can be effectively managed through the selection of a resistant cultivar combined with seed dressing using Carbendazim (2g/Kg) or a bioformulation of *Pseudomonas fluorescens* (6g/kg of seed).

Cercospora leaf spot (सर्कोस्पोरा पात थोप्ले)

Cercospora leaf spot is second most important after blast and notable foliar disease affecting finger millet in Nepal, although its prevalence was being confined to specific geographical regions. Cercospora leaf spot manifests at various developmental stages of finger millet, spanning from seedling emergence to the grain-filling phase. If infection arises immediately post-heading, it can induce a substantial yield reduction of up to 40 percent and diminish the 1000-seed weight by 21 percent (Pradganang 1994). Notably, when the disease incidence remains around 25 percent, there is no substantial yield loss (Pradganang and Abington 1993). The disease is prominently observed in the Himalayan foothills and mid-hill regions of Nepal. Additionally, Muyanga (1995) documented Cercospora leaf spot as a highly destructive malady afflicting finger millet in Zambia. The causative agent of Cercospora leaf spot is *Cercosporaeleusinis* Munjal, Lall & Chona. Munjal et al (1961) conducted an extensive study based on specimens collected by J. N. Kapoor from Kathgodam, Nainital, Uttarakhand. They provided comprehensive descriptions and nomenclature for this newly identified species, designating it as *Cercospora eleusinis*. However, it's worth noting that Wallace and Wallace (1947) had previously reported *Cercospora fusimaculans* Atk. as the causative agent of leaf spot in Tanganyika. Fungal growth becomes evident within lesions after infected leaves are subjected to incubation in a moist chamber for 36-48 hours at 25°C. The fungus produces stroma, from which conidiophores and conidia emerge. Conidia germinate from both ends or from multiple cells along the length of the conidia. Conidiophores are characterized as white, thread-like structures, ranging from straight to mildly curved, with 3-12 septa. The average dimensions of 25 conidia are 1.5 µm (range 1-1.7 µm) x 69.6 µm (range 50-95 µm) (Kumar 2005).

Cercospora leaf spot in finger millet
Photo: Subash Subedi, NARC

Finger millet is susceptible to Cercospora leaf spot across all growth stages, from the seedling stage through grain formation. Under natural conditions, infection typically initiates in mid-June for early-sown crops. The initial symptoms manifest as reddish-brown specks encircled by a yellow halo. At this stage, these lesions can be easily mistaken for those caused by Helminthosporium leaf spot. As the disease progresses, these specks coalesce to form larger lesions surrounded by a yellow halo. In periods of elevated humidity, the fungus sporulates, producing a grayish-white growth at the center of the lesions. These lesions can expand to form eye-shaped spots, measuring up to 15 x 3 mm, resembling those observed in blast disease. Leaves afflicted in this manner exhibit a burnt appearance. Towards the end of August, severely infected leaves become completely necrotic, shriveling and drying. At this stage, the entire plant appears blighted. Such symptoms can also manifest on the stem, leaf sheath, peduncle (neck), and finger segments.

In Nepal, Cercospora leaf spot is predominantly confined to mid-hill regions characterized by a mean daily temperature not exceeding 20°C and abundant rainfall. The disease typically exhibits its most severe manifestations in June, particularly in early-sown crops. In Uttarakhand area of India, the disease is a significant concern in mid and high-altitude regions, occurring at elevations ranging from 850 m to over 1900 m (Kumar et al 2007). Notably, disease intensity is relatively low in lower hill regions.

Management

Management strategies for Cercospora leaf spot encompass field sanitation practices and the application of Carbendazim at a concentration of 0.05% at 15-day intervals. These measures have been reported to mitigate infection to a certain extent (Kumar et al 2007).

Banded Sheath Blight (धब्बे फेद डढुवा)

The emergence of banded sheath blight in finger millet was initially documented in a severe form in Vellayani, Kerala, India (Lulu Das and Girija 1989). Subsequently, the disease manifested severely in experimental plots at Birsa Agricultural University, Ranchi, with a particular prevalence among exotic genotypes (Dubey 1995).

Banded sheath blight in finger millet
Photo: Subash Subedi, NARC

In Nepal, it was reported in severe form during crop season in many finger millet genotypes at Hill Crops Research Program, Kabre, Dolakha located in altitude of 1740 masl (HCRP 2019). The disease was first time reported in Pokhara region of Kaski district during 2015 (Manandhar et al 2016). It's noteworthy that the pathogen responsible for banded sheath blight, *Rhizoctonia solani* AG1, can infect the finger millet crop; however, it does not exhibit the same capability to infect rice, in contrast to the rice sheath blight pathogen, *Rhizoctonia solani* (Kannaiayan and Prasad 1978). The causative agent of banded sheath blight in finger millet is identified as *Rhizoctonia solani* Kuhn, with its basidial stage being *Thanatephorus cucumeris* (Fr.) Donk. The pathogen is a soil-dwelling organism, and its proliferation is facilitated by high humidity levels (above 80%) and moderate temperatures (around 26 ± 2°C) (Dubey 1995). Banded sheath blight is characterized by the presence of oval to irregular lesions that range in color from light grey to dark brown, predominantly located on the lower leaf and leaf sheath. As the disease progresses, the central portions of these lesions transform into a white coloration, accompanied by a narrow reddish-brown border. In later stages, these spots irregularly distribute across the leaf lamina. Disease development is favored by temperatures ranging from 23-30°C and a relative humidity exceeding 80%, leading to the rapid expansion of lesions, which ultimately coalesce to cover extensive portions of the sheath and leaf lamina. At this advanced stage, the disease exhibits a distinctive appearance characterized by a series of copper or brown-colored bands spanning across the leaves. Mycelial growth, accompanied by the presence of white to brown sclerotia, becomes apparent on and around the lesions. Eventually, the affected leaves desiccate, imparting a blighted appearance to the plants. In severe cases, symptoms extend to peduncles, fingers, and glumes, presenting as irregular to oval, dark brown to purplish-brown necrotic lesions. Early peduncular infection mimics neck rot, resulting in suboptimal grain filling. Infected glumes produce smaller and shriveled grains. The distinctive feature of this disease lies in its ability to manifest symptoms across all parts of the plant, creating a characteristic banded appearance, hence its designation as banded blight (Dubey 1995). Notably, early-maturing varieties tend to be more susceptible than their late-maturing counterparts, as the latter have a higher likelihood of avoiding disease due to the lower autumn temperatures, which spare the upper leaves from damage. Additionally, tall varieties with fewer tillers typically exhibit lower infection rates compared to shorter varieties with a profusion of tillers (Patro et al 2008).

Management

The twice spraying of Propiconazole @ 1ml/L of water at an interval of 10 days was found effective for managing the banded sheath blight pathogen in finger millet (HCRP 2020). Additionally, practices such as clean cultivation, effective drainage to eliminate excess water, and the removal of grassy weeds from bunds have been found to be preventative measures against the disease (Patro 2008).

Brown Spot (Seedling Blight or Leaf Blight) (खैरो थोप्ले/ फेद डढुवा/ पात डढुवा)

Brown spot, also known as Seedling Blight or Leaf Blight, poses a substantial threat to finger millet, ranking third important disease in terms of both severity and prevalence in Nepal (HCRP 2019). The causal agent of Brown Spot is *Drechslera nodulosa* (Berk. & M.A. Curtis ex Sacc.) Subram. & B.L. Jain, previously known as *Helminthosporium nodulosum* Berk. & M.A. Curtis ex Sacc. In its perfect stage, it is referred to as *Cochliobolus nodulosus*. The pathogen exhibits a broad host range, infecting several plant species including *Setaria italica, Eleusine indica, Dactyloctenium aegyptium, Echinochloa frumentacea, Panicum miliaceum, Pennisetum typhoides, Sorghum vulgare*, and *Zea mays* (Mitra 1931; Pall et al 1980).

Butler (1918) first observed the disease causing foot rot, seedling blight, or leaf blight in finger millet. In India, it is prevalent across various regions (Govindu 1982, Misra 1979, Pall and Sharma 1976, Mitra 1931, Thomas 1940, Narain et al 1975). The disease intensifies in cases of prolonged drought or nutrient deficiency. Brown spot can manifest sporadically throughout the field or in well-defined patches, affecting all parts of the plant including the base, culms, leaf sheath, leaf blade, neck, and fingers. In instances where infected seeds are used for sowing, there may be pre or post-emergence rotting. When healthy seedlings are exposed to external inoculum, characteristic symptoms include the appearance of brown to dark brown spots on the leaf lamina. Symptoms can also be observed on the leaf sheath, particularly in older plants, where a woolly growth of the fungus becomes apparent at the center of the lesion, especially under high humidity conditions. Infection on the neck and fingers, particularly in high humidity conditions, can lead to neck breakage and hanging on the plant. Severe infection results in chaffiness and discoloration of the seed, causing a considerable reduction in yield.

Grewal and Pal (1965) reported that the disease is seed-borne, with the spores on the seeds remaining viable for up to one year (Narasimhan 1933). The primary infection is initiated by the pathogen through the seed, and the fungus becomes systemic from the early stages. The pathogen also maintains viability on stubbles and plant debris. Vidhyasekaran (1971) noted that the pathogen can persist in the soil for 18 months. Secondary dissemination occurs through airborne conidia. The optimal temperature for infection ranges from 30-32°C, with infection possible between 10 and 37°C. Initial signs of infection emerge within 24 hours, followed by the formation of lesions in four days. Small seedlings may succumb within three days, while older seedlings are susceptible for up to 15 days.

Management

The need based application of Mancozeb (0.2%) through spraying has been found effective in mitigating the disease (HCRP 2020). Additionally, Patra (1996) observed that the use of cuman (0.3%) applied once at flowering and again 15 days later contributes significantly to brown spot disease control.

Grain Smut (कालोपोके)

Grain Smut has since become a notable concern in millet cultivation after documented by Kulkarni (1922) in 1918 within the princely state of Kolhapur India. Reports of this disease in Mysore state were contributed by Coleman (1920), McRae (1924), Narasimhan (1933), Mundkur (1939), and Venkatarayan (1947). While the damage caused by Grain Smut is generally minimal, Mantur (1994) notes that under epidemic conditions, as many as 200 grains per ear may be infected. Although traditionally associated with the summer crop, recent observations have sporadically recorded its presence during the kharif season as well. The fungus of this disease was initially named as *Ustilago eleusines* by Kulkarni, it was later reclassified by Mundkur and Thirumalachar (1947) under the genus *Melanopsichium*, denoted as *M. eleusinis*. The spores exhibit a globose or subglobose morphology, adorned with echinulations and measuring 7-11µm, with a mean diameter of 9.5µm. Upon germination, the spores give rise to septate promycelium, generating both lateral and terminal sporidia. The promycelium initially emerges as a small papilla, gradually elongating. Transverse septa form, segmenting the promycelium into three to four cells. These cells give rise to both terminal and lateral sporidia. Primary sporidia quickly produce secondary sporidia through budding.

Grain smut in finger millet
Photo: Subash Subedi, NARC

The presence of smutted grains becomes apparent a few days after flowering, with affected grains appearing randomly scattered within the ear. The impacted ovaries undergo a transformation into velvety, greenish, gall-like structures, significantly larger than healthy grains. Over time, the outer tunica of the sorus changes from greenish to pinkish green, ultimately darkening to a dirty black upon drying. The affected grains are often solitary, occasionally clustered in patches of varying sizes, and frequently localized to one side, or towards the base or apex of the head, showing signs of rupture at multiple points (Thirumalachar and Mundkur 1947). Ganapathi (1971) further characterizes distinct symptoms of the disease. In certain instances, the inflorescence remains markedly reduced and withered, with a complete absence of spike or spikelet development, replaced instead by greenish, globular to elongated sac-like structures containing sooty teliospores. In other cases, sori are found to encircle the inflorescence's main rachis stalk, presenting as galls either scattered or coalesced, housing an abundance of teliospores on the same ear. These sori are small, rounded, and elongated sac-like structures, resembling phyllody rather than developing into normal grains. Infection of flowers occurs through airborne spores. Thirumalachar and Mundkur (1947) achieved successful infection by applying sporidial suspension to the ears at the time of emergence. However, comprehensive studies on the disease cycle remain limited.

Management

Given the airborne nature of the pathogen, chemical control is neither cost-effective nor recommended. Nevertheless, Mantur et al (1995) conducted trials on various fungicides, both individually and in combination, applied as sprays to the inflorescence. The lowest incidence was observed when two sprays were administered: the first with Difolatan at panicle initiation, followed by a second spray with mancozeb at flowering.

Proso millet

Proso millet (*Panicum miliaceum* L.), also known as Chino in Nepal, is a tetraploid (2n=4x=36) species in the Poaceae family and Panicoideae subfamily with great potential to combat food insecurity and is regarded as a future climate smart crop (Ghimire et al 2018). It is a predominantly self-pollinating crop; however, there is the potential for natural cross-pollination to occur at rates exceeding 10%. It is regarded as "Future Smart Food" due to its potential for food and nutritional security for a growing population and climate resilience capability (Gauchan et al 2020). Proso millet is high in protein (12.5%), fat (1.1%), carbohydrate (70.4%), fiber (2.2%), and minerals (1.9%) such as iron, zinc, copper, and manganese (Saud 2010, Saha et al 2016), all of which have antipyletic, antioxidant, and antibacterial properties (Kumar et al 2016). In Nepal, it is the second most important crop after finger millet among millet crops. Proso millet exhibits a remarkable adaptability, thriving in regions further north than other millets and demonstrating resilience in plateau environments and high elevations. It can be found at impressive altitudes, reaching up to 1200 meters in the former USSR and up to 3500 meters in Nepal and India.

Proso millet landraces
Photo: Subash Subedi, NARC

The major districts producing proso millet are Mugu, Dolpa, Humla, Jumla, Kalikot, Bajura, and Jajarkot of the Karnali region (Shrestha et al 2020), with an average area of 2000 ha and a productivity of 0.81 t/ha (Ghimire et al 2018). This cereal crop typically reaches maturity within a span of 60 to 90 days, making it a favorable choice for regions characterized by poor soil quality and hot, arid climates. Its ease of cultivation is accentuated by its compatibility with rudimentary agricultural practices. One of the most distinguishing features of proso millet is its minimal water requirements, possibly ranking as the cereal with the lowest water requirement per unit of yield. This efficiency in water usage is not solely attributed to drought resistance but is primarily a consequence of its abbreviated growth cycle. Proso millet has evolved to swiftly convert available water resources into dry matter and grain, making it an excellent choice for regions where water conservation and efficient resource utilization are paramount considerations. Although proso millet is adapted to a wide range of soils and has a unique climate resilience ability, biotic stress can cause heavy loss, damaging the entire crop (Sathiyabama and Manikandan 2016). Porso millet is affected by wide range of pathogens with fungal and bacterial diseases being the most important in Nepal (**Table 1**).

Blast (मरुवा)

Blast in proso millet
Photo: Subash Subedi, NARC

Among various biotic stresses that affect proso millet, the incidence of blast caused by *Pyricularia grisea* (Cooke) Sacc [teleomorph: *Magnaporthe grisea* (Hebert) Barr.] is the most important disease (Gauchan et al 2020). This fungus exhibits hyaline, septate hyphae. As the fungus ages, the hyphae transition to a brown coloration. Under high humidity conditions, a profusion of conidiophores and conidia is produced, imparting a dirty brown tint to the lesion. The conidiophores are uncomplicated and septate, with the basal portion appearing relatively darker. The conidia are three-celled, pyriform, with the upper cell pointed and the middle cell wider and darker. Conidia measurements fall within the range of 29.9-39.9 x 9.1-11.6µm (with a mean of 33.6 x 9.5µm). The pathogen's survival is facilitated by collateral hosts, and airborne conidia serve as the primary mode of infection on proso millet. Additionally, the pathogen can persist through seeds, as noted by Mishra (1983).

Blast incidence is evident in all growth stages, producing elliptical leaf spots or whitish centers with reddish brown margins that infect the foliage, neck, and head of the crop, causing yield and biomass reduction in Nepal (Manandhar et al 2016). Prajapati et al (2013) reported significant losses in grain yield and fodder yield of 35.78 and 43.72%, respectively, with an average yield loss of around 28.36% (Nagaraja and Mantur 2007), with severe cases reporting up to 100% yield loss (HCRP 2020). Simmonds (1948) reported a substantial yield reduction ranging from 20-60% attributable to this disease.

Lower temperatures and higher humidity are ideal for disease progression, leading to epidemics of leaf, neck, and head blast (Manandhar et al 2016). Although blast can be efficiently controlled by using chemical fungicide (Prajapati et al 2013), it possesses an environmental hazard and is not economical, especially for underutilized and neglected crop species (Subedi et al 2020). Hence, sustainable management of blast can be obtained through host-plant resistance, which means utilization of the plant's own defense mechanism in management of pest and diseases, particularly the rapid localized cell death, also known as hypersensitive response (Bhatta et al 2017).

Management

Genotypes C04654, Humla-239, and C04651 were found to have lower blast severity and produce higher grain yields. Genotype C04654 was found as resistant with 34.6% disease severity and high yielding (2.6 t/ha), followed by Humla-239 and C04651 as moderately susceptible with 44.8 and 45.9% disease severity resulting grain yields of 2.5 and 2.4 t/ha, respectively at Kabre Dolakha, Nepal (Subedi et al 2022).

Head Smut (कालो पोके)

Head Smut, a disease prevalent in millet-growing regions across Europe and Asia, has been documented in countries such as Bulgaria, Kazakhstan, Japan, Poland, Nepla and India (Sinha and Upadhyay 1997). In Nepal, this disease was first recorded in Humla district (Manandhar et al 2016). *Sporisoriumdestruens* (Schltdl.) Vánky Syn. *Sphacelothecadestruens*is the causative agent of Head Smut, representing a loose smut pathogen. The primary source of inoculum is externally seed-borne. Chlamydospores, present on the seed, germinate and infect the host during the seedling stage. The mycelium subsequently becomes systemic, manifesting symptoms exclusively upon ear emergence. Optimal conditions for spore germination have been reported at temperatures ranging between 22-30°C. However, germination can occur within a broader range of 10-35°C (Lovik and Dahlstrem 1936). Shirokov and Maslenkova (1983) identified two races and biotypes of the pathogen, indicating some variability within the species. Infected plants exhibit notable distinctions from healthy ones, appearing taller and displaying a vivid green hue. The emergence of smut sori aligns with the panicle's development. These sori encompass the entire inflorescence, enclosed by a conspicuous greyish-white membrane. As the plants mature, this membrane ruptures, unveiling a dark-brown spore mass and the vascular tissues of the smutted panicle.

Management

Given that the disease is primarily externally seed-borne in the form of teliospores, effective control hinges on fungicidal seed treatment (Kovacs et al 1997). Sharma and Sugha (1991) conducted studies highlighting the efficacy of Carboxin and Benomyl in smut control. These treatments led to a substantial reduction in smut incidence by 99% and 95%, while concurrently increasing yields by 136% and 119%, respectively.

Grain Smut (कालो पोके)

Grain smut, also referred to as covered or kernel smut, is a fungal disease of millet. The causal agent is *Sphacelotheca sorghi* (Ehrenb. ex Link) G.P. Clinton, previously categorized under various synonyms including *Sporisorium sorghi* Ehrenb. ex Link, *Tilletia sorghi* (Ehrenb. ex Link) Tul. and C. Tul., *Ustilago sorghi* (Ehrenb. ex Link) Pass., and *Sphacelotheca sorghi* (Ehrenb. ex Link) Speg. The pathogen primarily persists through contaminated seeds. Affected grains undergo a distinctive transformation, appearing as white-greyish sacs known as smut sori. These structures are slightly pointed to oval in shape and contain a black powdery substance known as chlamydospores.

Grain smut in proso millet
Photo: Subash Subedi, NARC

Management

Effective management strategies for grain smut include early identification and removal of diseased ears followed by their controlled burning. Additionally, implementing a crop rotation strategy over a period of 2-3 years can help mitigate the disease's impact. Seed treatment with fungicides like thiram (3 g/kg) or copper-based seed dressings has been demonstrated to significantly reduce disease incidence in main crops.

Leaf Spot or Blight (पात थोप्ले/डढुवा)

Leaf spot or blight stands out as the sole significant disease affecting this crop, manifesting in various stages from seed infection causing seed rot, coleoptile spotting, to seedling blight (Lee-DuHyung 1997). The causal agent is *Bipolarispanici-miliacei* (Y. Nisik.) Shoemaker, previously referred to as *Helminthosporium panici-miliacei* Y. Nisik. or *Drechslera panici-miliacei* (Y. Nisik.) Subram. & B.L. Jain. The olive-colored conidiophores of the pathogen are 2-8 septate and measure 131-296 x 3-6µm (with a mean of 186.3 x 4.2µm). The slightly curved conidia exhibit round end cells, are 3-6 septate, and measure 34-87 x 9-12µm (with a mean of 54.2 x 11.3µm) (Misra 1973). The disease's onset is marked by the appearance of small, oval brownish spots, measuring approximately 2.5 mm in length, on the leaf lamina. These spots subsequently darken to black. In cases of rapid disease progression, the spots may coalesce, leading to extensive blighting. The symptoms are not particularly damaging during the initial stages but can escalate to severe levels under certain conditions. Besides the leaf lamina, symptoms may also manifest on the culm, leaf sheath, and leaf blade.

Leaf spot/blight in proso millet
Photo: Subash Subedi, NARC

The disease primarily spreads through externally seed-borne inoculum, with the pathogen also capable of surviving on infected plant debris. Some grasses serve as reservoirs for the pathogen, contributing to its survival and acting as the primary source of inoculum for the primary crop. Secondary disease dissemination occurs through air-borne conidia.

Management

Given its seed-borne nature, disease incidence can be reduced through seed treatment with appropriate fungicides. Additionally, spraying with carbendazim at a rate of 0.05 percent during flowering is recommended to curb secondary infections (Sinha and Upadhyay 1997). Notably, the variety RAUM-7 exhibits high resistance to this disease.

Foxtail millet

Foxtail millet [*Setaria italica* (L.) P.Beauv.], is a diploid (2n=2x=18) species in the Poaceae family and Panicoideae subfamily believed to have originated in China, stands as one of the earliest cultivated crops globally. Among millets, it holds the second-highest planting prevalence worldwide and bears paramount importance in East Asia (Kumari et al 2011; Ning et al 2015; Sheikh and Singh 2013; Xiaomei et al 2016; Zhang et al 2014). Locally referred to as Kaguno in Nepal, it is also known by various names like Italian millet, German millet, or Hay millet. The nutritional composition of foxtail millet grains is noteworthy, containing 12.3% protein, 4.3% fat, 60.9% carbohydrates, 14.0% dietary fiber, and 3.3% minerals. It surpasses major staple crops like rice and wheat in essential elements, boasting 31g calcium, 290 mg phosphorus, 5mg iron, and vital vitamins (Saha et al 2016; Saud 2010).In Nepal, Kaguno holds the position of the third most significant millet crop, cherished for its diverse applications. Cooked as bhat (rice), utilized in dhindo (porridge), or crafted into kheer (resembling rice pudding), its versatility in culinary traditions is noteworthy. What distinguishes foxtail millet is its nutritional richness and health-enhancing attributes, thriving even in low-input agricultural setups and demonstrating resilience to harsh environmental conditions, notably drought. Recent recognition for its medicinal benefits, such as regulating blood glucose levels and managing cholesterol, further elevates its stature among both regular consumers and those grappling with diabetes (Goron and Raizada 2015). In the face of a changing climate, foxtail millet emerges as a crop of promise, poised to address food insecurity in remote regions of the country.

Foxtail millet (Humla 252)
Photo: Subash Subedi, NARC

Despite its status as a traditional climate-resilient and nutritionally dense crop in Nepal, various factors have contributed to its declining cultivation and use. These encompass shifts in land use, population migration, evolving social norms, altered dietary preferences, diminishing traditional knowledge, and a dearth of research initiatives and formalized seed distribution systems. Policy support mechanisms, such as subsidies on food imports and financial credits, have been lacking, thereby exacerbating these trends (Gurung et al 2017, Parajuli et al 2017, Palikhey et al 2017, Bisht et al 2006). Noteworthy districts for foxtail millet cultivation include Mugu, Kalikot, Humla, Jumla, Bajhang, Bajura, Dolpa, Lamjung, Gorkha, Ramechhap, Kavre in Nepal. It is grown either exclusively or intercropped with other crops like finger millet, proso millet, beans, amaranths, and sorghum. Nepal stands as a center of diversity for foxtail millet, boasting high genetic variation in this crop (MoFSC 2002), yet comprehensive research on its status remains limited. Foxtail millet is also affected by wide range of pathogens with fungal and bacterial diseases being the most important in Nepal (**Table 1**).

Blast (मरुवा)

Blast, caused by the fungus *Pyriculariasetariae* (Y. Nisik.), is a significant disease affecting foxtail millet. The disease was first reported in Japan in 1917 and Tamil Nadu in 1919, and subsequent observations have extended its geographical presence to various regions (Sinha and Upadhyay 1997; Kumar 2013). In its severe form, blast can lead to substantial losses in grain yield, accounting for up to 30-40 percent reduction (Nagaraja et al 2007). The causal agent, *Pyricularia setariae*, also known as *Pyricularia oryzae* Cavara, exhibits diverse physiological races, distinguished by pathogenicity, cultural, physiological, and morphological characteristics (Kulkarni and Patel 1956). Notably, the isolate infecting foxtail millet has been identified as distinct from those affecting rice, pearl millet, and Fingermillet, wheat (Gaikwad and D'Souza 1987; Viswanath and Seethram 1989).

Blast in foxtail millet
Photo: Subash Subedi, NARC

The disease primarily affects young plants up to 40 days old. Initial symptoms manifest as small, water-soaked, yellowish dots on the leaves, which quickly progress to form circular or oval-shaped spots with a greyish center surrounded by a dark brown margin. These spots typically measure 2-5 mm in diameter and may coalesce, resulting in the drying up of affected leaves. Notably, the disease symptoms do not appear on the neck or peduncle of the plant (Palaniswami et al 1970). The disease primarily spreads through external seed transmission. Research indicates that seeds inoculated with a spore solution demonstrated high rates of infection under conducive environmental conditions. However, the fungus's viability and infectivity are significantly reduced after prolonged storage of infested seeds (Palaniswami et al 1970). While the potential for natural seed transmission between growing seasons remains uncertain, the pathogen can persist in infected plant residues and, to some extent, in the soil. Survival through collateral hosts is also plausible. Various factors, including susceptible plant varieties, inoculum availability, nitrogen fertilization practices, and specific weather conditions (cloudiness, drizzle, and dew), influence the severity of blast epidemics. Night temperatures between 15-24°C and high relative humidity above 90 percent are particularly conducive to disease development. Additionally, neutral pH levels (7.0) and temperatures between 28-30°C provide optimal conditions for fungal growth (Ramakrishnan 1971).

Management

Effective measures for blast management include the cultivation of resistant varieties, prudent nitrogen application, and the removal of weeds and crop debris. Genotypes C03474, Humla-219, and Humla-163 were found to have lower blast severity and produce higher grain yields at Kabre Dolakha, Nepal (Subedi 2023).Early detection of blast spots necessitates immediate fungicidal intervention using effective agents like Carbendazim 50 WP, Ediphenphos 50 EC, or a combination product of Carbendazim + Mancozeb. Top dressing of nitrogen should be implemented following fungicidal treatment to ensure optimal crop health and development.

Smut (कालो पोके)

Smut, a widespread disease, poses significant threats to foxtail millet crops across various regions, including South Asia, China, Europe, and Manchuria. In particularly susceptible areas like Romania, the impact of this disease on crop yields is notably severe. Studies in China and Manchuria have reported losses of up to 50 percent due to smut. Disturbingly, inhalation of spores during threshing operations has been linked to respiratory issues, such as asthma, among laborers (Fischer 1953; Sundararaman 1921).

Smut has been documented in several regions of Nepal and India. These areas have experienced varying degrees of infestation, necessitating vigilant disease management strategies (Ramakrishnan 1971; Kumar 2011). The causal agent of smut in foxtail millet is identified as *Ustilago crameri*Körn. The spores generated by this pathogen are characterized by their dark brown coloration, angular or round shape, and smooth-walled texture, measuring 7-10µm in diameter. A distinctive characteristic of smut is its comprehensive infestation of grains within an ear, although the terminal section of the spike may sometimes escape infection. The sori, or spore-producing structures, are observable in the flowers and basal portions of the palea. These sori exhibit a pale greyish hue and measure approximately 2-4 mm in diameter. Upon maturation of the crop, the sori rupture, giving rise to a dark powdery mass of spores. While primarily transmitted through seeds, there have been reports of soil-borne infection in arid regions. Spores germinate during seed germination, infiltrating the mesocotyl region before establishing a systemic presence, predominantly towards the apical portions. Upon flowering, invading hyphae replace the ovaries, culminating in the formation of septate hyphae, which subsequently evolve into chlamydospores. These spores adhere to the seed surface during harvesting and threshing, ultimately reaching the soil during sowing. Disease severity is significantly influenced by environmental conditions, with lower temperatures and higher relative humidity levels providing an ideal breeding ground for smut in its more severe form.

Smut in foxtail millet
Photo: Subash Subedi, NARC

Management

Mitigating the impact of smut necessitates a multifaceted approach. This includes cultivating resistant varieties, diligent removal of infected ears, and treating seeds with Carbendazim at a rate of 2g/kg to safeguard against further infection. By implementing these strategic measures, farmers can protect their foxtail millet crops from the devastating effects of smut, ensuring robust yields and food security in affected regions.

Leaf Spot or Blotch or Blight (पात थोप्ले/धब्बे/डढुवा)

This disease was first recorded in Japan and Farmosa in 1906, and later on gained prominence in New Jersey (Haenseler 1941). Under favorable weather conditions, it can cause substantial losses in grain yield. Notably, cool weather is conducive to the incidence of this disease. The causal agent *Cochliobolus setariae* (S. Ito &Kurib.) Drechsler ex Dastur, also known by its synonyms *Bipolaris setariae* (Sawada) Shoemaker, *Drechslera setariae* (Sawada) Subram. and B.L. Jain, *Helminthosporium setariae* Sawada, *Helminthosporium setariae* Lind, and *Ophiobolus setariae* S. Ito &Kurib. The conidiophores, which play a crucial role in the pathogenic cycle, are simple, erect, cylindrical, brown structures, slightly swollen at the base, and geniculate at the apex. These elements measure within the range of 72-199µm in length and 5.6-9µm in width. Conidia, on the other hand, are acrogenous ellipsoid to obclavate, fusoid, and may exhibit slight curvature. They range in color from pale to moderately dark brown and feature thin walls. These spores

Leaf spot/blotch/blight in foxtail millet
Photo: Subash Subedi, NARC

measure between 39-120µm in length and 10-18µm in width. With four to ten septa present, there is no interconnection at the septum. The disease was characterized by brown lesions that progressively enlarge, coalesce, and eventually cover the entire leaf blade, this disease also manifests as blotches. The affected leaves ultimately desiccate. Additionally, secondary roots may experience rotting, further exacerbating the damage (Sprauge 1950).

Management

Given its seed-borne nature, disease incidence can be reduced through seed treatment with appropriate fungicides. Additionally, spraying with carbendazim @ 0.05% during flowering is recommended to limit secondary infections (HCRP 2019).

Sorghum

Sorghum cultivation thrives predominantly in the Tarai, inner Tarai, and mid-hill regions of Nepal during the summer months. Sorghum, one of the world's major food grains, holds a crucial role in the lives of millions of people across Africa, serving as a staple food source. In recent times, the versatile sorghum crop has also found application as a biofuel in developed nations. Its origins can be traced back to central Africa, specifically in the vicinity of Ethiopia or Sudan. Sorghum plants boast impressive heights, often reaching up to an impressive 4 meters, bearing a resemblance to maize. While sorghum stands as the third most significant crop among India's food grains, its importance in Nepal is comparatively less pronounced (Ghimire et al 2017). In Nepalese agricultural landscape, sorghum is cultivated in terrace bonds, fulfilling dual roles as a valuable source of both food and fodder. However, it's worth noting that the diversity within Nepalese sorghum accessions is not notably extensive, a factor that warrants consideration for future agricultural endeavors. The global significance of sorghum as a food grain cannot be overstated, particularly in regions where it plays a vital role in ensuring food security and economic stability. Furthermore, its adaptability for alternative applications, such as biofuel production, underscores its value in addressing evolving agricultural and energy needs on a global scale (Ghimire et al 2017).

Fungal diseases exert the most significant toll on sorghum, closely trailed by viral and bacterial infections. The economic impact of a particular disease fluctuates depending on factors like geographical location, prevailing climate, cropping timetable, and the specific varieties of sorghum. A roster of common disease includes grain mould, anthracnose, downy mildew, ergot, smut, leaf blight, and leaf spots, presenting a common occurrence. Among these, grain sorghum mostly suffered with grain mould, downy mildew, anthracnose, and ergot during the rainy season (**Table 1**). Conversely, post-rainy periods usher in the specter of root and stalk rot, alongside a slew of viral diseases. Incidental appearances of rusts, leaf spots, pokkahboeng, and smuts are not uncommon. For forage species of sorghum, foliar diseases like leaf spots, sooty stripes, leaf blight, downy mildew, anthracnose, and rust take precedence. Specific agro-climatic settings bring forth the significance of other conditions like viral infections, sugary disease, and mould. While the sorghum family susceptible with fungal, viral, and bacterial diseases, it's crucial to acknowledge that not all of these diseases bear the same economic weight.

Grain mould (अनाजको ढुसी)

Grain mould poses a significant challenge to producing high-quality sorghum grain. It is a prevalent issue in many countries across Asia, Africa, North and South America. This disease mainly affects improved short- and medium-duration sorghum varieties that mature during the rainy season in humid climates. Late-maturing sorghums tend to avoid grain mould. In India, the problem is particularly severe due to the widespread cultivation of white grain, bold-seeded hybrids, and varieties (Das and Patil 2013). Grain mould greatly impacts grain quality and yield. The affected grain loses its shine and fetches a lower market price compared to healthy grain. Losses occur due to reduced seed size and weight, as well as grain rotting. Mouldy seeds also have lower germination rates, further affecting their value. Depending on the variety and weather conditions, production losses can range from 30% to 100(Singh and Bandyopadhyay 2000). This translates to economic losses of around US$130 million in Asia and Africa, and US$50-80 million in India (Das and Patil 2013). Apart from economic consequences, grain mould has significant effects on human and livestock populations, as well as cropping patterns. It diminishes the nutritional value of both food and feed, and impairs cooking quality. Moreover, the mycotoxins found in mouldy grains are harmful to humans, animals, and poultry (Norred 1993). In India, there have been cases of acute disease outbreaks, linked to the consumption of fumonisin-contaminated mouldy sorghum and maize (Chatterjee and Mukherjee 1994). Livestocks are also at risk when fed with mouldy grains, which can lead to various health issues (Bhat et al 1997).

Grain mould in Sorghum
Photo: S. Ramesh

Grain mould can be caused by various fungi, some weakly parasitic, pathogenic, or saprophytic in nature. Among the parasites/pathogens, *Fusarium moniliforme, Curvularia lunata, Alternaria alternate*, and *Phoma sorghina* are the most common. Many saprophytic fungi can also colonize mature grain under high humidity conditions (Thakur et al 2006). The first visible sign of mould infection is a change in color in the spikelet tissues, including the anthers and filaments. Under humid conditions, the infected grain can be covered with fungal growth even before it matures, and such grains break apart easily. This is referred to as 'pre-mature seed rotting'. The color of infected grains varies depending on the fungus species, ranging from whitish, pinkish, greyish, to shiny black. Sprouting of grains may also occur due to fungal colonization, making the grains soft.

Management

Preventing grain mould is best achieved by using cultivars that mature during a period of little or no rainfall. However, this may not always be feasible with erratic rainfall patterns. Using mould-tolerant cultivars and ensuring the crop is harvested at the right time, followed by thorough drying of the grain, is the next best option. Developing grain mould-resistant cultivars is a challenge, as various resistance mechanisms are at play (Mansuetus et al 1988, Esele et al 1993, Audilakshmi et al 1999, Aruna and Audilakshmi 2004, Rodriguez-Herrera et al 2006, Katile et al 2010). Disease-escape mechanisms, such as choosing long-duration cultivars that mature during rain-free periods, can also be effective. Chemical sprays may help, but they may not be cost-effective due to the low price of sorghum grain and the high cost of chemicals and labor. For high-value seed production, treating panicles with fluorescent pseudomonas may be considered to reduce grain mould severity and enhance seed quality.

Anthracnose (कोत्रे)

Anthracnose, initially identified in Togo, West Africa in 1902 (Sutton 1980), has since spread across various regions worldwide. Prevalent in numerous countries across Africa (Nigeria, Kenya, Togo, Mali, Zimbabwe, Ethiopia, South Africa), North America (South, Central, and North America), South America (Brazil, Argentina, Guatemala), and Asia (India, Nepal, China, Thailand), it manifests in different forms affecting seedlings, leaves, stalks, and ear-heads. In India, forage sorghum is particularly susceptible, with moderate to severe infestations, while grain sorghum experiences sporadic occurrences. Notably, forage sorghum in Northern and Western India, and grain sorghum in Central and Southern India, bear the brunt

Anthracnose in Sorghum
Photo: A. Martinez

of anthracnose. Anthracnose inflicts economic losses of up to 50% in severe outbreaks, escalating to 70% in highly susceptible cultivars (Harris et al 1964, Thomas et al 1995, Mathur et al 2002). Although quantifying monetary losses is intricate and lacks precise data, the impact on human and cattle populations is significant. *Colletotrichum graminicola* (Synonym: *C. sublineolum*) is the causative agent of anthracnose, with *Glomerellagraminicola* being its perfect state. The fungus produces grey to olivaceous mycelium, which is septate and sparingly branched in culture. Acervuli yield numerous erect, hyaline, non-septate conidiophores bearing conidia terminally. While more than 40 races/pathotypes have been reported worldwide (Nakamura 1982, Casela and Ferreira 1988, Prom et al 2012), including nine from India (Pande et al 1991), the host specificity and range remain debated (Mathur et al 2002). Anthracnose adversely affects seedlings and adult plants alike, causing small circular spots on leaves, distinguished by a central straw-colored region surrounded by a wide margin. In favorable conditions, these spots amalgamate, leading to a blighted appearance. The fungi generate acervuli, small black dot-like structures at the center of the spots, producing creamy to pinkish spore masses. Severe cases may lead to plant defoliation, stunting, yellowing, and even death. Infection can occur below or just above ground level, with early and severe cases leading to pre-emergence damping-off. Crop residues and wild sorghum species serve as primary inoculum sources, dispersed by wind or rain. Conidia germinate, forming germ tubes that develop into appressoria, penetrating epidermal layers or stomata. The pathogen establishes itself within leaf tissue, resulting in visible symptoms. Warm, humid conditions exacerbate the disease, with conidia maturing in about 14 hours at 22°C (Frederiksen 1986). Survival mechanisms include mycelium in host residue, wild sorghum species like Parasorghum, Heterosorghum (*Sorghum laxiflorum* Bailey), Chaetosorghum (*S. macrospermum* Garber) and Stiposorghum (*S. angustum* S.T. Blake, *S. ecarinatum* Lazarides, *S. extans* Lazarides, *S. intrans* F. Muell. ex Benth., *S. interjectum* Lazarides, *S. stipoideum* (Ewart and Jean White) C. Gardener and C.E. Hubb.), and some weeds, as well as conidia or mycelium in seeds, with viability extending up to 10 months in buried plant debris (Mishra and Siradhana 1979).

Management

Management strategies involve cultural practices, crop rotation, clean cultivation, and the use of resistant cultivars. Effective elimination of inoculum sources and reducing infection likelihood can be achieved through the collection and destruction of crop residues. Leveraging available resistant sources for cultivar development against distinct pathotypes is pivotal. Different genes confer resistance to leaf, stalk, and grain anthracnose, controlled by single dominant or recessive genes, contingent on the crosses (Mehta et al 2005, da Costa et al 2011). Various molecular markers, such as Random Amplified Polymorphic DNA (RAPD) (Boora et al 1998), Restriction Fragment Length Polymorphism (RFLP) (Perumal et al 2009), Single Sequence Repeat (SSR) (Murali Mohan et al 2010), and Single Nucleotide Polymorphism (SNP) (Upadhyaya et al 2013), have been employed for identifying resistance genes, contributing to the genetic enhancement of anthracnose resistance.

Downy Mildew (पाते ढुसी)

The inception of downy mildew in sorghum, as documented by Butler in India in 1907, marked the genesis of a persistent agricultural challenge (Butler 1907). Since its discovery, this pernicious disease has made its presence felt in numerous tropical and subtropical regions worldwide. Its origin lies in Africa and Asia, later extending its reach to the Americas in the late 1950s (Frederiksen 1980). Systemic infection of sorghum plants results in barren inflorescences, while local infections impede the productive leaf area. Under favorable conditions, the disease can escalate into an epidemic, with estimated crop losses ranging from 2 to 20%. In some parts of India, annual yield reductions of up to 0.1 million tonnes have been reported (Payak 1975). Notably, in a single season, a downy mildew outbreak in Texas, United States, resulted in staggering losses estimated at US$2.5 million (Frederiksen et al 1969). The repercussions of downy mildew extend to livestock populations as well, especially due to the loss of stover yield, leading to significant income reductions for poor farmers in crop-livestock production systems. The seed-borne nature of this pathogen further compounds the challenges and imparts quarantine significance to the disease.

The causal agent of this devastating disease is *Peronosclerospora sorghi* (Synonym: *Sclerospora sorghi*). This obligate parasite necessitates living tissue for growth and typically does not thrive in artificial media. However, there is a report of successful *P. sorghi* growth in dual culture with host tissue on a modified White's medium (Kaveriappa 1980). Oospores are generated in the mesophyll tissue between vascular bundles. These oospores are spherical, hyaline to yellow, and enclosed in an irregularly thickened wall. *Peronosclerospora sorghi* endures as oospores in soil and plant debris, disseminating through oospores in the glumes of sorghum seeds and in plant debris. Conidia are fragile and do not contribute significantly to long-distance dissemination. Although the pathogen may be present as mycelium in infected seeds, the mycelium is inactivated upon seed drying. Consequently, seed-borne infection seems to have negligible importance in disease spread. *Peronosclerospora sorghi* also exhibits the capacity to infect grasses such as *Euchlaena, Panicum, Pennisetum*, and *Zea* spp., generating conidia and oospores on them. These collateral hosts serve as reservoirs of inoculum for sorghum crops. Pathotypes have been identified in *P. sorghi* isolates from various geographic regions, including the United States, Brazil, Honduras, Zimbabwe, and India. Additionally, SSR markers have been developed from Peronosclerospora genomic DNA to differentiate isolates within several species of oomycetes causing downy mildew diseases (Perumal et al 2008).

Sorghum downy mildew manifests two distinct sets of symptoms, stemming from systemic and local infections. Systemic infections originate from apical meristematic tissue, leading to the development of pale yellow or light-colored streaking or mottling on the leaves. Affected plants exhibit chlorosis, stunted growth, and premature demise. In humid conditions, the undersides of leaves become enveloped in a white, downy growth comprising conidia and conidiophores. As the disease advances, leaves emerging from the whorl display parallel stripes of green and white tissue, which eventually wither, resulting in a shredded appearance. Notably, systemically infected plants typically fail to produce earheads. However, on occasion, a plant may recover and yield earheads (Singh and Milliano 1989). Conidia produced in infected plants become airborne, causing local infections on leaves. These local lesions initially appear as rectangular, pale yellow areas that later turn brown. Systemic infection of young seedlings may occur either from oospores in the soil or from conidia produced on early-infected plants. Infection typically takes place a week after emergence. The fungus grows internally, infecting meristematic tissues and yielding systemic symptoms. Both conidia and oospores germinate via a germ tube. Conidia production, dispersal, and infection processes are contingent upon specific temperature and relative humidity conditions (Pande et al 1997). Optimal conditions for conidia production are around 18°C. Oospores necessitate low soil temperature (around 10°C) and low soil moisture for infection. Production of conidia and infection processes are favored by a cool environment and high humidity.

Management

Cultural practices, including deep plowing, rouging of infected plants, adjusting sowing dates, and crop rotation, are recommended for effective disease management. The use of disease-resistant cultivars represents the most effective strategy, with current cultivars displaying a moderate level of field resistance. However, resistance can be compromised due to the emergence of pathogen races and repeated use of resistant cultivars. Thus, ongoing efforts are essential to develop resistant cultivars with novel sources of resistance (Kamala et al 2002). Notably, many Australian accessions have exhibited immunity to downy mildew.

In circumstances conducive to disease development, chemical spray interventions become necessary to control downy mildew. Seed treatment with Ridomyl-MZ followed by a spray of Ridomyl-MZ has proven effective in reducing downy mildew incidence. Careful use of metalaxyl is advised to mitigate the risk of resistance development against this fungicide. It is worth noting that *Peronosclerosporasorghi* isolates from the downy mildew outbreak region in Texas exhibited resistance to metalaxyl fungicide, which had been employed as an effective seed treatment for many years (Perumal et al 2008).

Ergot or Sugary Disease (अरगोट/चिनी रोग)

The initial documentation of ergot in sorghum dates back to 1917 in India (McRae 1917) and later in Australia in 1996 (Ryley et al 1996). Since then, this pathogenic fungus has proliferated across continents, establishing a foothold in Asia, Africa, South America, North America, and Australia. Its detrimental effects on seed yield, quality, germination, and the subsequent rejection of seed lots due to ergot contamination are profound. Hybrid seed production is particularly susceptible to ergot, with estimated production losses ranging from 10 to 80% in India and South Africa (Bandyopadhyay et al 1996). Even popular varieties are not spared when environmental conditions favor the disease, leading to wide-spread damage. Ergot's repercussions extend beyond immediate agricultural losses, as the disease carries quarantine implications. Seeds harvested from infected fields often face rejection in trading. The manifestation of ergot infection is characterized by the exudation of honeydew-like droplets from infected florets. These exudates harbor both micro- and macro-conidia of the causal fungus. The severity of infection determines whether this symptom is observed on a single floret, a few, or all florets within a panicle. Subsequently, honeydew droplets falling onto leaves foster the growth of saprophytic fungi, resulting in the darkening of the affected foliage.

Ergot /Sugary disease in Sorghum
Photo: A. Martinez

Claviceps africana, a prominent species of *Claviceps*, is consistently found in association with *sphacelia*. Their physical association renders differentiation between the two challenging. Sclerotia, typically elongated, hard, and black, surpass the size of sorghum seeds. In various parts of the world, three different *Claviceps* species are responsible for ergot. The distribution of *C. africana* spans continents, including Southern and Eastern Africa, South America, Australia, Southeast Asia, and India. On the other hand, *C. sorghi* is confined to India (Kulkarni et al 1976) and Southeast Asia, while *C. sorghicola* is prevalent in Japan (Tsukiboshi et al 1999). Macroconidia produced by *C. africana* yield copious secondary conidia, which become airborne, facilitating infection. These macroconidia are oval to oblong, slightly constricted at the center, and contain two polar vacuoles. They germinate to produce pear-shaped secondary conidia outside the surface of sticky honeydew. Sclerotia function as resting spores and exhibit a wide range of characteristics, including color, shape, size, and mass. These attributes are contingent on genotypes, climate, and stage of development. Upon germination, sclerotia generate one or more elongated, pigmented stipes. Each stipe gives rise to a sub-globose capitulum, within which perithecia develop. These perithecia house asci, which upon maturity produce filiform and hyaline ascospores.

Infected florets cease grain production, giving rise to a wart-like fungal structure termed a sclerotium, which gradually replaces the grain. Sclerotia exhibit variations in shape, size, color, and compactness, influenced by host genotype and environmental conditions. In sorghum, the sclerotium emerges later from within the sphacelium and typically remains attached to a remnant of the sphacelium. In warm and dry conditions, sphacelia solidify, forming dense, solid sclerotia known as ergot. Primary ergot infections occur through either ascospores or conidia. Conidia are produced on collateral grass weeds, wild sorghums, infected panicles, or on plant debris in the soil. Honeydew originating from infected florets contains numerous macroconidia and secondary conidia, contributing to the secondary spread of the disease. Multiple conidial cycles unfold in a season, with conidia disseminated by wind, rain, and insects. Low night temperatures (around 90%) or cloudy weather create favorable conditions for ergot disease development (Tonapi et al 2002). The pathogen endures via infected panicles left in the field or through sclerotia. Collateral hosts such as *Pennisetum typhoides, Ischaemumpilosum,* and *Panicum maximum* also play a role in survival.

Management

Initiating early sowing serves as a preventive measure against the occurrence of the sugary disease (Anahosur and Patil 1982). Removing collateral host plants from the field aids in reducing pathogen inoculum and disease. Mechanical removal of sclerotia from seeds, accomplished through washing in 30% salt water followed by three rinses in plain water before sowing, minimizes seed-contaminated infection. Ensuring synchronization of flowering between A and R lines averts disease occurrence in seed production plots. Spraying panicles with fungicides (Bavistin/Tilt/Mancozeb) serves as an effective strategy in disease mitigation (Nagarajan and Saraswathi 1971; McLaren 1994). The initial spray should be conducted at the initiation of flowering, followed by two additional sprays at 10-day intervals.

Smut (कालो पोके)

Sorghum cultivation worldwide encounters four distinct smut types, commonly prevalent across diverse sorghum-growing regions. Currently, these smuts inflict minimal economic damage. In India and Nepal, their impact is sporadic, rendering them of marginal significance, a trend further mitigated by the introduction of seed-treatment fungicides. The four variants encompass covered smut (*Sporisorium sorghi*), loose smut (*Sporisorium cruenta*), head smut (*Sporisorium reilianum*), and long smut (*Tolyposporium ehrenbergii*).

Smut in Sorghum

Photo: eagri.org

Covered smut manifests as sori replacing healthy grains, where a majority of the grains in an infected ear succumb to smut sori. The membranous structure veiling the spore masses typically endures until threshing. Conversely, loose smut impairs affected plants, inducing stunted growth, slender stalks, increased tillering, and earlier flowering compared to their healthy counterparts. All spikelets on an infected earhead exhibit malformation and hypertrophy. The membrane encasing the spore masses ruptures shortly after head emergence.

In head smut, a sori, shrouded in a grayish-white membrane, emerges from the boot leaf in lieu of the inflorescence. Upon complete emergence, the fungal membrane ruptures, liberating spore masses into the air while leaving filamentous vascular tissues of the host exposed. Long smut, characterized by a whitish to dull yellow, relatively thick membrane, extends significantly beyond the sori observed in the other two smut types.

Management

Both loose and covered smuts are externally seed-borne, amenable to effective control through seed dressing with sulfur (@ 4 g/kg of seed). The collection of smutted heads in cloth bags, followed by immersion in boiling water to eliminate the pathogen, proves efficacious in reducing inoculum potential for subsequent year's crops. Long smut, however, employs airborne dissemination, rendering control measures challenging. Adjusting sowing dates emerges as a viable strategy in circumventing the disease's impact.

Kodo Millet

A total of 16 diseases have been reported in Kodo millet. Among them fungal diseases is more likely to attck this crop. Nine fungal diseases, 2 bacterial, 3 nematode and 2 phanerogamic root parasites are the major biotic constraints of kodo millet. Among fungal diseases head smut, rust, ergot, leaf blight and udbatta diseases were more prominent to cause yield loss and reported in Gorkha, Lamjung, Dhading, tanahu and far western Tarai regions of Nepal (HCRP 2019). Kodo millet poisoning is also a major problem characterized as a toxic syndrome which has been reported from the kodo millet growing areas caused health hazard to humans and cattles. For the management of this poisoning, harvested heaps should be protected from rains. Traditional practice of threshing by pre-moistening the plants should be avoided and only dried harvest should be threshed. Unripe or pre mature grains should not be harvested. Use of some anti dotes like juice of banana stem, astringent juice of guava or the leaves of tamarind, butter milk and pickles are recommended to combat with this poisoning. The integrated disease management practices including cultivation of resistant cultivars and timely with proper application of fungicides as described above in previous chapters of this review for the major diseases were effective to handle the pathogen pressure in this crop.

Little Millet

Few fungal pathogens (5) and nematode (1) were reported in little millet in far western belts of Nepal up to the altitude of 2000-2500 masl (HCRP 2020). Grain smut, rust, sheath blight, udbatta and leaf blight were the major fungal diseases, likely to cause the yield loss in little millet. For the management of these fingal diseases, disease resistant cultivar along with proper application of the fungicides that were described above in the previus chapters of this review should be followed.

Barnyard Millet

Most of the pathogens belonging to group fungi (8), few viruses (3) and nematode (1) were reported in barnyard millet. In karnali and Sudurpaschim province of Nepal, barnyard millet was grown as a substitute for rice when the paddy crop fails. The crop is also used as a fodder. The major fungal diseases smut, leaf spot/blight and sheath blight were reported in Gorkha, lamjung, Tanahu, Jumla and Humla districts (HCRP 2020). To control these diseases, integrated disease management practices including host resistance and proper application of fungicides were effective. Disease management practices were not so adopted by the farmers for this crop in Nepal.

Pearl Millet

Pearl millet is mostly attacked by fungus. Out of 19 fungal diseases, blast, downy mildew, smut, ergot and rust were the major diseases reported in plain area of far western region, Dhading and Nuwakot of Nepal (HCRP 2020). In Nepal very limited cultivation of this crop was found mainly in Tarai and lower hill side. Apart form food items, farmers used this crop for cattle fodder and make beverages also. The detailed management practices of above mentioned major diseases of this crop were discussed in previous chapters.

Conclusion

The diseases mentioned above have a significant impact on millet production, both in Nepal and globally, as they are prevalent in areas where millet is cultivated. These diseases lead to substantial economic losses and pose potential risks to both humans and animals. Furthermore, thorough exploration and accurate disease identification are essential for gaining a deeper understanding of these ailments before implementing interventions. A comprehensive approach that encompasses agronomic, nutritive, and chemical controls should be embraced for successful disease management. Additionally, the development of resistant millet varieties, employing both traditional and biotechnological techniques, is imperative in mitigating these persistent diseases, which continue to challenge agricultural communities even years after their initial discovery. It is evident that there is a significant gap in research pertaining to the epidemiology, diagnosis, yield loss, and management of millet diseases (excluding host resistance), and this area requires focused attention.

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Weed Management in Millets

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Summary
Millets are the important small seeded cereal crops of Asia and Africa in terms of food and nutritional security. It includes commonly cultivated crops like finger millet, pearl millet, sorghum, foxtail millet, and proso millet. They were regarded as minor and disrespected crops by people in the past. However, due to their high potentiality to cope with climate change and health benefits, they are now renamed as super food, *su-anna* and *shree anna* in different parts of the world. After rice, maize and wheat, finger millet is the fourth most important crop in Nepal. Millets occupy the important position in the cropping system of Nepal. They are grown in the hills and mountains with sloppy and marginal lands where there is food shortage. Millets suffers from both biotic and abiotic stresses during their growth period. Weeds are the prime yield-limiting biotic constraints that compete with millets for moisture, nutrients and sunlight causing yield loss up to 40% or more. All the three types of weeds narrow weeds, broadleaf and sedges weeds) infest millets. The most common weeds species in millet worldwide are: *Cynodon dactylon*, *Echinochloa colona, Echinochloa crus-galli, Eleusine indica, Sorghum halepense, Oxalis corniculate, Digitaria sanguinalis, Cyperus rotundus, Ageratum conyzoides, Amaranthus spinosus*, *Bidens philosa*, *Oxalis latifolia*, *Dactylectum aegyptiacum* and *Eragrostis tenu.* Weeds can be managed through different approaches such as mechanical, chemical and integrated methods. The most common method in Nepal is hand weeding and hoeing.

Keywords: Biotic constraints, hand weeding, hoeing, millets, sedges, weeds

Introduction
Millets are important and highly varied group of small-seeded cereal crops belong to the poaceae family. The grains are used as human food and straw as fodder for livestock (Joshi et al 2023). They are also known as *ku-anna* due to less popularity and social respect. However, these days realizing the nutritional and health benefits from millets, they are known by various names such as *su-anna* (Nepal), super food (Europe and US) and *Shree-anna* (India). Millets are grown as major cereals in many parts of Asia and Africa. More than 25 nations in Asia and Africa are involved in the cultivation of millets. India is the largest country for the production of millets followed by Ethiopia (Gebreyohannes et al 2021). After rice, maize, and wheat, finger millet is the fourth most significant crop in Nepal and the production of millets are the essential component of the farming system in Nepal's mountainous terrain where agricultural land is scarce and food shortage is an issue (Adhikari 2012). The total area, production and yield of millets (finger millet) in Nepal is 265,401 ha, 326,443 mt and 1.23 t/ha, respectively (MOALD 2022). Among the millets, finger millet is the most important crop in Nepal in terms of area and production followed by proso millet and foxtail millet. Besides, Sorghum, barnyard millet, pearl millet, little millet and kodo millet are

also grown in different parts of the country (Ghimire et al 2017). Proso millet (Chino) is the second most important crop for food security among a group of millets in Nepal that have a wide range of culinary uses (Ghimire et al 2018).

Losses Due to Weeds

Weed has been a significant factor contributing the crop loss in many of the cereal crops. One of the major problems with which a farmer must deal is the presence of weeds which prevents from obtaining maximum yield (Winifred 1917). Weeds successfully compete with the crop, harbour insect pests, and create problems at harvest (Zimdahl 1988, Ottman and Olsen 2009). They compete with crop plants for nutrients, water, sunlight and space, thereby inflict huge loss in soil nutrients and crop yields. The extent of yield loss depends upon the weed flora, time of infestation, soil type, and rainfall and management practices followed. Weed infestation in a unmanaged condition significantly reduces the crop yield between and 15 to 83% in sorghum, 16 to 94% in pearl millet, and 55 to 61% in finger millet depending on crop cultivars, nature, and intensity of weed infestation, management practices, and environmental condition (Mishra et al 2018). Millets are generally grown in rainy season which favours abundant growth of weeds. All types of weeds, *viz*. grasses, sedges and broad-leaved infest the millet crops during their early phase of growth. The weed flora and their intensity of competition with the crop varies with the geographic regions, soil, weather conditions and crop management practices (Stahlman et al 2000, Mashingaidze et al 2012).

The millets are relatively poor competitors against weeds especially during the early growth stages. During the initial growth phase, millets grow very slowly. Only when the crop reaches the mid growth phase, millets attain canopy cover enough to shade the weeds and suppress its growth (Mishra 2015). Weeds also act as an alternate host of pest and diseases of millets. The rust, smut, ergot and downy mildew pathogens of various millets infect weed species like *Cynodon dactylon*, *Sorghum halepense, Oxalis corniculate, Digitaria marginata, Pennisetum* sp. and *Eragrostis tenuifolia* and help them overwinter (Marley 1995, Reed et al 2002).

Weeds are the prime yield-limiting biotic constraints that compete with finger millet for moisture, nutrients and light. Grain yield of finger millet decreases linearly with increase in weed population (Nanjappa and Hosmani 1985). The weeds cause varying yield loss of about 34 to 61 per cent in finger millet (Prasad et al 1991). Weeds are a major constraint and limit productivity as initial slow growth of the finger millet favors growth of weeds competing for sunlight, nutrient and water in early stages of growth (Lall and Yadav 1982, Pradhan et al 2010, Mishra et al 2018). To reduce the cost of finger millet production, intensive applications of weed control methods should be optimized (Fryer 1997).

Weed infestation in pearl millet is one of the major causes for low productivity. Initial slow growth with wider spacing of the crop causes severe infestation of weeds in pearl millet. The major weeds of pearl millet are *Trianthema protulacastrum, Tribulus terrestris*, *Cyprus rotundus, Amaranthus sp, Echinochloa Colona, and Cynodan dactylon,* etc. Infestation by weeds in pearl millet severly reduces the grain and stover yield of the crop up to 40% and more (Girase et al 2017).

Common Weeds in Millets

Commonly growing weeds in millet fields belong to families poaceae, convolvulaceae, asteraceae, amaranthaceae, commelinaceae, compositae, nyctaginaceae, apparridaeceae, portolacaceae, ehphorbiaceae, tiliaceae, alizoaceae, zygophyllaceae, oxalidaceae, asclepiadaceae, cyperaceae and scrophulaceae (Janjit 1990, Mishra et al 2018). Among the grassy weed; *Echinochloa colona* (L.) Link. (Jungle rice), *Echinochloa crus-galli* (L.) Beauv. (Barnyard grass), *Eleusine indica* (L.) Gaertn. (Goose grass), *Digitaria sanguinalis* (L.) Scop. (Crab grass) and *Sorghum halepense* L. Pers. (Johnson grass), among broad-leaved weed; *Amaranthus palmeri* S. Wats (Palmer amaranth), *A. retroflexus* L. (Redroot pigweed), *Celosia argentea* L. (white cock's comb)*, Trianthema portulacastrum* L. (horse weed), *Tribulus terrestris* L. (puncture vine), *Boerhaavia diffusa* L. (hog weed), *Acanthospermum hispidum* DC (Bristly starbur) and among sedges; *Cyperus rotundus* L. are the most common weeds of millets worldwide.

In sorghum, grasses *Echinochloa, Panicum, Digitaria*, and *Sorghum halepense* are considered to be the most common and troublesome weeds (Limon-Ortega *et al* 1998; Peerzada *et al* 2017). *Trianthema portulacastrum* (Carpet weed) was also reported to be the dominant (more than 28%) weed in pearl millet (Deshveer and Deshveer 2005). Grassy weeds like *Cynodon dactylon, Brachiaria eruciformis*, broad-leaved weeds like *Parthenium hysterophorus, Commelina benghalensis, Celosia argentea, Panicum isachne, Amaranthus viridis, Euphorbia microphylla, Phyllanthus niruri, Alternanthera triandra*, and sedge *Cyperus rotundus* were recorded in pearl millet (Girase et al 2017). *Ageratum conyzoides*, *Eleusine indica*, *Echinochloa colona*, *Commmelian bengalensis*, *Cynadon dctylon*, *Oxalis latifolia*, *Setaria* sp. and *Cyperus rotundus* Wefrre the common weeds in finger millet (Janjit 1990).

Critical Period of Crop-weed Competition

Critical period of weed control (CPWC) is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses. The CPWC is useful for making decisions on the need for and timing of weed control (Knezevic et al 2002). Identifying the CPCWC in crops is one of the first steps in designing a successful integrated weed management (Rao and Nagamani 2010, Mishra 2015, Rao et al 2015). The critical period of weed competition is 2 to 6 weeks after transplanting in finger millet (Nanjappa et al 1987). Initial growth period of finger millet is subjected to heavy weed infestation resulting into higher competition and drastic reduction in yield (Pradhan et al 2012, Patil et al 2013). The CPCWC for the finger millet varied from 25-60 days after sowing (DAS) (Yathisha et al 2020). In respect of irrigated transplanted finger millet, critical period for weed competition has been identified to be first 4-6 weeks from planting (Nanjappa and Hosmani 1985, Mishra 2015). Under rainfed conditions, finger millet should be kept weed-free during the first 5 weeks to prevent losses in yield (Sundaresh et al 1975, Hedge et al 1983). In finger millet/soybean inter-cropping system, 4-5 weeks after sowing was the most critical period of competition (Mohapatra and Haldar 1998).

Weed Management Practices

Effective weed management practices are very important to prevent the weeds from using the costly inputs and attaining the growth and yield of the crops. Therefore, appropriate weed management practices are important in improving the productivity and input use-efficiency of the millet. The mechanical and cultural methods are the most commonly used and efficient weed control methods. Hand weeding and hoeing is the most common method in Nepal. The unavailability of labor and increasing labor wages have made the farmers to seek alternate method of weed management in millet.

Integrated Weed Management

Integrated weed management is system approach for sustainable weed management with an objective to reduce the selection pressure for the development of resistance in weeds (Shaner 2014, Chauhan et al 2017). Lamichhane et al (2017) reported that integrated weed management was more effective than any single method in controlling weeds. The common strategies in IWM are cultural methods, physical, biological, allelopathy, chemical and biotechnological methods.

Cultural method

Cultural practices like tillage, crop rotation, using of competitive crop varieties, reducing row spacing, increasing seed rate, mulching, timing of fertilizer application and application techniques, early application of nitrogen and its placement near to plants can help in increasing vigor of the crop and exert smothering effect on weeds.

Row spacing

Narrow rows (<30 cm) are beneficial in reducing weed competition and increasing yield of foxtail and proso millets (Nelson 1977, Agdag 1995).

Intercropping

Growing of mungbean, groundnut, cowpea, soybean etc. as intercrops in sorghum/pearl millet could exert suppressing effect on weeds. Intercropping of black gram and green gram in pearl millet significantly reduced the density as well as biomass of weeds and also realized higher net returns, B: C and income equivalent ratio in comparison to sole crop of pearl millet (Mathukia et al 2015). Maize-relay cropping also significantly reduce weed infestation.

Mulching

Crop residue mulching in millets is an effective method to control the annual weeds. Mulching with rice straw or shredded coconut waste significantly reduced the weed density and weed dry weight in finger millet (Vishalini et al 2020).

Mechanical method

Mechanical weed management is one of the effective weed management practices followed in cultivation of millet crops. The mechanical weeding involves handheld tools to the most advanced vision-guided hoes (Hussain et al 2018). However, the hand weeding or inter-row cultivation are the most widely practiced methods for millet cultivation. Hand hoeing and blade harrowing are the most effectively followed method for weeding in pearl millet. First weeding should be done at 20-25 DAS and should be repeated every two weeks up to 45 DAS for effective weed control (Yadav 2012). In barnyard millet (*Echinochloa frumentacea*) the weeds could be effectively controlled by using a mechanical weeder integrated with hand weeding under rain-fed conditions (Shamina et al 2019). Mechanical harrowing can control the weeds in grain pearl millet and forage pearl millet, when weeds are at 3-5 leaf stage (Cuerrier et al 2010).

Hand weeding

In general practice, hand weeding can be practiced couple of times at 20 and 30 DAP is considered as one of the best efficient methods for the weed control in finger millet which produces significantly higher yields and weed control efficiency (Bhargavi, 2016). Hand weeding twice with narrow spacing was the best weed management practice for WCE (Weed Control Efficiency), higher productivity and profitability in line sown rainfed barnyard millet (Shamina *et al* 2019). Higher weed density recorded in paired row planting might be due to more space between two rows which resulted in better environment for germination and growth of weeds (Kauri and Singh 2006). The integration of hand weeding with 2, 4-D resulted in higher yields of finger millet (Prasad et al 1991).

Chemical method

Chemical control is effective if the crop is sown in assured rainfall or irrigated areas. Since finger millet is grown in marginal areas as a rainfed crop, the seed is broadcasted in the dry soils, and grains germinate whenever rains happen. The chemical weed control may not be feasible in finger millet (Sood and Babu 2016). Application of butachlor @ 1.5 L /ha as pre mergence found to be effective in controlling weeds with highest weed control efficiency (77 %) and grain yield 1.91 kg/ha (Ranjit 1989). Pre-emergent (PE) application of bensulfuron methyl 0.6 g and pretilachlor at 600 g/ha and early post emergent (PE)application of bispyribac sodium at a dose of 25 g/ha is a remunerative method for controlling weeds and supports yield enhancing in transplanted finger millet under sodic soil (Reddy et al 2007). Pre-emergent application of Nitrofen at the rate of 0.5-1.0 l/ha has been recommended for sole finger millet crop and pendimethalin as 0.75- 1.5 l/ha as pre application can give good control to a wide spectrum of weeds. Post application of 2,4-d ethyl at the rate of 1.0-1.5 l/ha is effective against broad leaf weed (Shubhashree et al 2019).

In pearl millet, PE application of atrazine 0.5 kg/ha followed by(fb) hand weeding at 35 DAS and atrazine at the rate of 0.4 kg/ha as PE at 20 DAS fb hand weeding at 35 DAS appeared to be the best integrated weed management practice (Girase et al 2017). In kodo millet, isoproturon @ 500 g/ha PE followed by hand weeding at 40 DAS found to be effective in reducing the density of weed species in irrigated kodo millet (Vinothini and Arthanari 2017). In barnyard millet, bensulfuron-methyl @ 60 g + pretilachlor @ 495 g/ha as PE on 3 DAS was found effective (Thambi et al 2021).

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In-vitro Efficacy of Bioagents and Fungicides against Pearl Millet Downy Mildew caused by *Sclerospora graminicola* (Sacc.) Schoret

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Abstract

Pearl millet is popularly known as Bajra in India. India is the largest producer of pearl millet, both in terms of an area, production and productivity. Downy mildew incited by Sclerospora graminicola (Sacc.) Schroet is the most widespread and destructive disease of pearl millet in India. The efficacy of eight bio-control agents with 1 x108 CFU/ml and nine fungicides were evaluated against Sclerospora graminicola, in screen house conditions during Kharif season of 2019. In case of bioagent, seeds treated with the bioagent were sown in earthen plastic pots filled with autoclaved soil, sand and manure in the ratio 2:1:1. While in case of fungicides, seed treatment and foliar application of fungicides to inoculated plants was made on 7th and 15th day after emergence. Three replications per treatment were arranged in a randomized complete block design. Seedlings were maintained at 25–300C with 95% relative humidity. Two -day-old seedlings were whorl-inoculated with S. graminicola zoospore suspension. The disease incidence was recorded after 30 days of sowing. Among biocontrol agents seed treatment of Pseudomonas fluorescens @ 8 g/kg seed (4.00%), Trichoderma harzianum (ST) @ 8 g/kg seed (5.33 %) was found effective. While among fungicides, foliar application of Azoxystrobin 23% SC @ 2ml/L (5.33%), Provalicarb 5.5% + Propineb 61.25% w/w WP (@ 1 g/, Trifloxystrobin WG 50 @ 1ml/L (6.66%), and Kresoxim-methyl WG 50% (7.33%) significantly reduced the incidence of downy mildew disease.

Keywords: Downy mildew, pearl millet, sclerospora graminicola, bio agents, fungicides

Introduction

Pearl millet (*Pennisetum glaucum* (L.) belongs to family *Poaceae* and it is a major warm-season climate resilient cereal crop, largely grown under rainfed conditions in India. It is popularly known as bajra in India. The photosynthesis efficiency of pearl millet crop is higher than C3 crops (Wang et al 2012). Pearl millet reinforces fight against food insecurity in the arid and semi-arid environments (Bailey et al 1979; Buerkert et al 2001). Pearl millet is grown in the ecologies of characteristically challenged by low or erratic rainfall, high mean temperature (Serba et al 2020). Pearl millet is major millet considered nutricereal in terms of high levels of energy, dietary fiber, proteins with a balanced amino acid profile, essential minerals, vitamins and antioxidants and occupies first position among all the millets in India. Among many constraints in pearl millet production, disease is the most important yield reducing factor. The major diseases occur in pearl millet are downy mildew, ergot,smut, blast and rust which are most important constraint in reducing grain yield. Downy mildew caused by *Sclerospora graminicola*, is a highly destructive and widespread disease in most pearl millet growing areas of Asia and Africa. The disease spreads in more than 20 countries all over the world (Safeeulla, 1976). The mean annual loss the downy mildew pathogen was first reported on pearl millet in India in 1907 (Butler, 1907). A comprehensive data set for grain yield loss in pearl millet due to downy mildew disease is suggested 45% in Allahabad, India (Mitter and Tandon 1930) and 0-50% in other western African countries (Selvaraj 1979, Saccas 1954).

Downy mildew was quite severe in Ahmednagar, Jalgaon, Aurangabad and Jalna districts of Maharashtra state (India) with mean disease incidence of 56%, 40%, 35% and 32%, respectively (Sharma et al 2012). The average downy mildew incidence in different districts of Rajsthan viz, Bikaner, Jodhpur, Sikar, Jaipur and Alwar varied from 9.87 to 17.95 per cent (Saini et al 2020). There is hazardous effect of repeated application of fungicides due to their non-target effects, some of them are losing their effectiveness, because of development of resistant strains of pathogens and contribute to greater production costs and environmental pollution therefore integrated disease management is the only key for effective long term control of downy mildew disease of pearl millet to avoid all inherent ill effects viz, environmental pollution, residual toxicity, development of resistance by the pathogen, cost ineffectiveness etc.

Material and Methods

The present study was conducted at National Agriculture Research Project, Aurangabad, Maharashtra during Kharif season of 2019. This site lies between latitude and longitude 19.8762 N and 75.3433 E, respectively.

Efficacy of bio-control agents against *Sclerospora graminicola*

A greenhouse experiment was conducted to find out the effect of seed treatment with bio-control agents viz., *Trichoderma asperallum*, *T. harzianum*, *T. hamatum, T. koningii, Aspergillus niger, Bacillus subtilis, Pseudomonas fluorescence, Pseudomonas striata* against *Sclerospora graminicola*, causing pearl millet downy mildew was assessed under screenhouse condition during Kharif 2019. on the incidence of downy mildew.

Treated seeds (treatment details are given below) with the bioagent (collected from Department of Plant Pathology, College of Agriculture, Parbhani) were sown in earthen plastic pots filled with autoclaved soil, sand and manure in the ratio 2:1:1. There were three replications per treatment. These were arranged in a complete block design. Seedlings were maintained at 25–30^{0}C with 95% relative humidity. Seedlings were watered when required with appropriate fertilization. Two-day-old seedlings were whorl-inoculated with *S. graminicola* zoospore suspension. Pots were maintained in greenhouse conditions and the disease incidence (thenumber of plants showing the typical symptoms of downy mildew disease such as stunted growth, sporulation, malformation etc) were recorded after 30 days of sowing.

Treatment details

T1	Seed treatment with *Trichoderma asperellum** (8 g/Kg of seed)
T2	Seed treatment with *Bacillus spp*. *(8 g/kg seed)
T3	Seed treatment with *Pseudomonas fluorescence* *(8 g/kg seed)
T4	Seed treatment with *Trichoderma harzianum* (8 g/kg of seed)
T5	Seed treatment with *Trichoderma hamatum* (8 g/kg of seed)
T6	Seed treatment with *Trichoderma koningii* (8 g/kg of seed)
T7	Seed treatment with *Aspergillus niger* (10 g/kg of seed)
T8	Seed treatment *Pseudomonas striata* (8 g/kg of seed)
T9	Control (untreated)

*= 1 x10^8 CFU/ml for fungi and 1 x10^6 CFU/ml for bacteria

Inoculum preparation

Leaves of infected pearl millet plants and infected leaves from pot-grown plants of 7042-S in the greenhouse were collected in the evening hours and washed in running tap water to remove pre-existing sporulation and blot-dried and placed in moist chamber for sporulation and incubated in darkness at 21°C for 6 hours. The incubation temperature was reduced to 2-3°C after 6 hours in order to inhibit release of zoospores from mature sporangia until spores were used as inoculum. Fresh sporangia were collected the next morning and zoospores using a soft brush in ice- cold sterile distilled water, and the spore concentration was adjusted to 1 x 105 sporangia/ml in distilled water using a haemocytometer and used as inoculum for all the experiments (Safeeulla 1976).

Efficacy of fungicides against *Sclerospora graminicola*

The efficacy of nine fungicides viz, Provalicarb 5.5% + Propineb 61.25%, Mancozeb 75%WP, Metalaxyl 75% WS 35 WS, Azoxystrobin 23% SC, Pyraclostrobin5%+Metiram 55%, Kresoxim-methyl 50% WG, Amectoctradin 27% + Dimethomorph 20.27% SC, Cymoxanil 8%+Mancozeb 64% WG, Trifloxystrobin 50% WG were evaluated against Sclerospora graminicola, causing pearl millet downy mildew in screen house conditions in 2019. Seed were sown in earthen/ plastic pots filled with autoclaved soil, sand and manure in the ratio 2:1:1. Foliar application of fungicides to inoculated plants was made on 7thand 15th day after emergence. There were three replications per treatment. These were arranged in a randomized complete block design. Seedlings were maintained at 25–30^{0}C with 95% relative humidity. Seedlings were watered when required with appropriate fertilization. Five-day-old seedlings were whorl- inoculated with *S. graminicola* zoospore suspension. Seed treated with fungicides were sown in earthen potsand foliar spray with fungicides to inoculated plants will made on 7thand 15th day after emergence Pots were maintained in greenhouse conditions and the disease incidence (the number of plants showing the typical symptoms of downy mildew disease such as stunted growth, sporulation, malformation etc) were recorded after 30 days of sowing. Disease incidence was recorded when plants at 30 days old.

Treatment details

T1	Foliar application Provalicarb 5.5% + Propineb 61.25% w/w WP
T2	Foliar application of Mancozeb @ 75 % WP 0.2%
T3	Seed treatment Metalaxyl 35% WS 6 g/ kg seed
T4	Foliar application Azoxystrobin 23%SC 250 g/l
T5	Foliar application Pyraclostrobin 5% + Metiram 55 % 20 g/10L water
T6	Foliar application Kresoxim-methyl 50% WG w/w
T7	Foliar application Cymoxanil 8% + Mancozeb 64% WG
T8	Foliar application Trifloxystrobin 50% WG
T9	Seed treatment Amectoctradin+Dimethomorph 20.27 SC (0.4 ml/500ml
T10	Control (untreated)

The percent disease incidence was calculated as per formula, percent disease incidence = (Number of infected plants/ Total number of plants observed) x 100

Result and Discussion

The results (**Plate 1**, **Table 1** and **Figure 1**) revealed that, percent seed germination ranged from 90.00 to 74.67 as against 71.67 in untreated control. However, it was significantly highest with T3: *Pseudomonas fluorescens* (ST) @ 8 g/ kg seed (90.00 %), followed by T4: *T. harzianum* (ST) @ 8 g/ kg seed (87.33 %), T1:

T. asperellum @ 8 g/ kg seed (81.00%) and T7: *A. niger* (ST)@ 8 g/ kg seed (80.67%). Rest of the treatments recorded seed germination in the range of 77.00 to 74.67 percent. Downy mildew incidence ranged from 4.00 to 11.33%, as against 14.00% in untreated control. However, it was significantly least with T3: Pseudomonas fluorescens (ST) @ 8 g/kg seed (4.00%) which was on par with T4: *T. harzianum* (ST) @ 8 g/ kg seed (5.33%), followed by T7: *A. niger* (ST) @8 g/ kg seed (7.33%). Rest of the treatments recorded the disease incidence in the range of 8.00 to 11.33%, while percent disease reduction over control in different treatments ranged from 71.42 – 19.07% as against 0.00% in untreated control. However, it was highest with T3: *Pseudomonas fluorescens* (ST) @ 8 g/ kg seed (71.42%) followed by T4: *Trichoderma harzianum* (ST) @ 8 g/ kg seed (61.92%), T7 *Aspergillus niger* (ST) @ 8 g/ kg seed (47.64%) and T1: *T. asperellum @* 8 g/ kg seed (42.85%) and rest of the treatments ranged from 38.14 to 19.07%.

Plate 1. In-vitro efficacy of bioagents against *Sclerospora graminicola,* causing pearl milletdowny mildew

Table 1. In-vitro efficacy of bio-agents against ***Sclerospora graminicola,*** causing pearl millet downymildew, during ***Kharif*** 2019

TrN	Treatment	Conc. (g/kg seed)	% Seed germination*	% DM incidence* at 30 DAS	PDC at 30DAS
T1	*Trichoderma asperellum*** (ST)*	8	81.00 (64.17)	8.00 (16.34)	42.85
T2	*Bacillus subtilis*** (ST)	8	76.67 (61.12)	10.00 (18.37)	28.57
T3	*Pseudomonas fluorescence ** (ST)*	8	90.00 (71.56)	4.00 (11.53)	71.42
T4	*Trichoderma harzianum*** (ST)	8	87.33 (69.16)	5.33 (13.29)	61.92
T5	*Trichoderma hamatum*** (ST)	8	75.67 (60.44)	9.33 (17.75)	33.35
T6	*Trichoderma koningii* **(ST)	8	77.00 (61.34)	8.66 (17.09)	38.14
T7	*Aspergillus niger* **(ST)	8	80.67 (63.92)	7.33 (15.46)	47.64
T8	*Pseudomonas striata*** (ST)	8	74.67 (59.78)	11.33 (19.64)	19.07
T9	Control (Untreated)	8	71.67 (57.84)	14.00 (21.93)	--
S.E.±			0.67	1.04	
CD (P=0.01)			1.93	3.12	

* Mean of three replications; DAS-Days after sowing; ST: seed treatment, PDC: Percent disease control; DM-Downy mildew. Figure in parenthesis denoted Arc sign transferred values. **, 1×10^8 (CFU/ml) for fungi and 1×10^6 (CFU/ml) for bacteria.

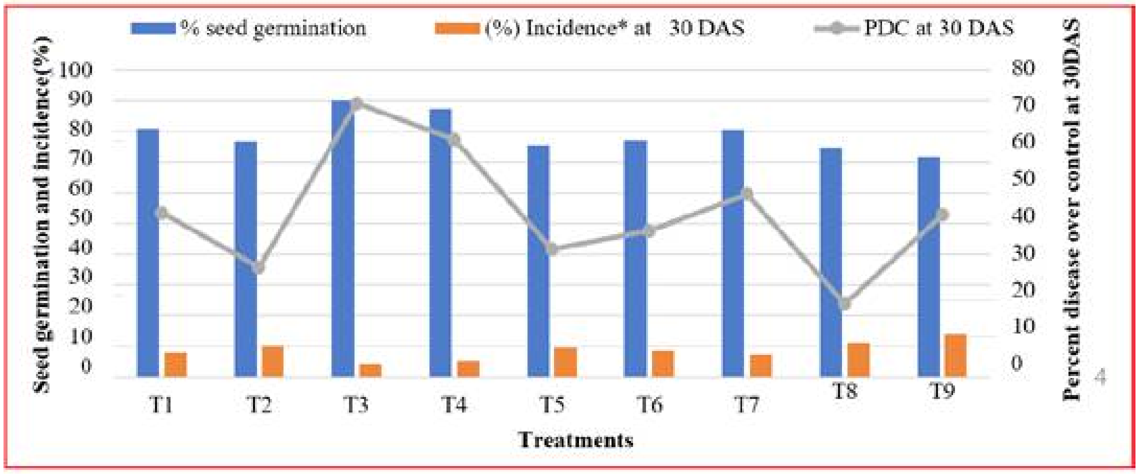

Figure 1. In-vitro efficacy of bio-agents against *Sclerospora graminicola* causing pearl millet downy mildew, during *Kharif* 2019

These results of the present study are in consonance with earlier findings of the several workers, who reported that Trichoderma asperallum, T. harzianum, T. hamatum, T. koningii, Aspergillus niger, Bacillus subtilis, Pseudomonas fluorescence, Pseudomonas striata etc. as potential biocontrol agents against many plant pathogens. Similarly, the bioagents viz, T. asperellum, T. harzianum, T. hamatum, T. koningii, Aspergillus niger Bacillus subtilis, Pseudomonas fluorescence and Pseudomonas striata is antifungal against pearl millet downy mildew were also reported by the following research workers, Raj et al (2005), Latake and Kolase (2007) evaluated the bioagents viz., Trichoderma viride, T. harzianum, T. hamatum, Pseudomonas fluorescens in sick plot for their effectiveness in controlling downy mildew disease of pearl millet and reported that, seed treatment along with spray of T. harzianum recorded the least downy mildew incidence (18.60, 39.60 and 52.40%) at 20, 30 and 60 DAS respectively. Raj et al (2011), Nandini et al (2013), Randhwa (2015), Sangwan and Kushal Raj (2016a).

Chauhan (2018), Sasode et al (2018) and Saini (2019) studied antagonistic effect of *Trichoderma viride, T. harzianum,* and *Pseudomonas fluorescens* biocontrol agents against *Sclerospora graminicola* under glasshouse and recorded least disease incidence (11.23%) with seed treatment of *T. viride* @ 6g/kg seed + spray of *Pseudomonas fluorescence* @ 1 x 10^8 cfu/ml over untreated control (40.43%), followed by seed treatment with *T. harzianum* + spray of *P. fluorescence* (13.56%), Alone seed treatment with *T. viride* (15.89%), seed treatment with *Trichoderma harzianum* (17.34%) and *P. fluorescence* (19.45%).

The results (**Plate 2**, **Table 2** and **Figure 2**) revealed that, pearl millet percent seed germination ranged from 86.00 to 70.67% as against 69.67% in untreated control. However, it was significantly highest with T_8: Trifloxystrobin 50% WG (FA) @ 1ml/L (86.00 %), followed by T_4: Azoxystrobin 23 % SC (FA) @ 2ml/L (85.67 %) and T_1: Provalicarb 5.5% + Propineb 61.25% WP (FA) @ 1 g/L (85.33%). Rest of the treatments were recorded seed germination in the range of 80.67 to 70.67%.

Downy mildew disease incidence was ranged from 5.33 to 26.66%, as against 30.00% in untreated control. However, it was significantly least with T4: Azoxystrobin 23% SC (FA) @ 2 ml/L (5.33%) and was on par with T1: Provalicarb 5.5% + Propineb 61.25% w/w WP (FA) @ 1 g/L, T8: Trifloxystrobin 50 WG FA @ 1ml/L (6.66% each) and T6: Kresoxim-methyl 50% WG (FA) (7.33%). Rest of the treatments had recorded disease incidence in the range of 7.33 to 26.66%. While the percent disease reduction over control ranged from 82.23-11.13%. However, it was the highest with T4: Azoxystrobin. 23% SC (FA) 2 ml/L (82.23 %), followed by T_8: Trifloxystrobin 50% WG (FA) @ 1ml/L and T_1: Provalicarb 5.5% +Propineb 61.25% WP (FA) @ 1 g/L (each 77.80%). Rest of the treatments ranged from 75.56 to 11.13%.

Plate 2. In-vitro efficacy of fungicides against *Sclerospora graminicola,* causing pearl millet downy mildew

Table 2. In-vitro efficacy of fungicides against ***Sclerospora graminicola,*** causing pearl millet downymildew, during *Kharif* 2019

TrN	Treatments	Conc.	% Seed germination*	(%) DM Incidence* at 30 DAS	PDC at 30DAS
T1	Provalicarb 5.5% + Propineb 61.25% w/w W (FA)	1 g/L	85.33 (67.49)	6.66 (14.79)	77.80
T2	Mancozeb 75% WP (FA)	0.2%	74.67 (59.78)	22.00 (27.94)	26.66
T3	Metalaxyl 35 % WS (ST)	6 g/ kg	80.67 (63.92)	11.33 (19.64)	62.23
T4	Azoxystrobin 23% SC (FA)	2 ml /L	85.67 (67.75)	5.33 (13.29)	82.23
T5	Pyraclostrobin 5% + Metiram55 % (FA)	2.0 g/L	80.33 (63.68)	8.00 (16.42)	73.33
T6	Kresoxim-methyl 50% WG w/w(FA)	2ml/L	75.33 (60.68)	7.33 (15.67)	75.56
T7	Cymoxanil 8% + Mancozeb 64% WG (FA)	2.5 g/L	70.67 (57.21)	26.66 (31.07)	11.13
T8	Trifloxystrobin 50 % WG (FA)	1ml /L	86.00 (68.02)	6.66 (14.79)	77.80
T9	Amectoctradin 27, %+ Dimethomorph 20.27% SC(ST)	2 g/kg	74.67 (59.78)	17.33 (24.56)	42.23
T10	Control (untreated)		69.67 (56.58)	30.00 (33.19)	-
SE±			0.62	0.98	
C.D. (P=0.01)			1.82	2.93	

* Mean of three replications, FA: Foliar application; ST: Seed treatment, PDC: Percent disease control. DM-Downy mildew. Figure in parenthesis denoted Arc sign transferred values.

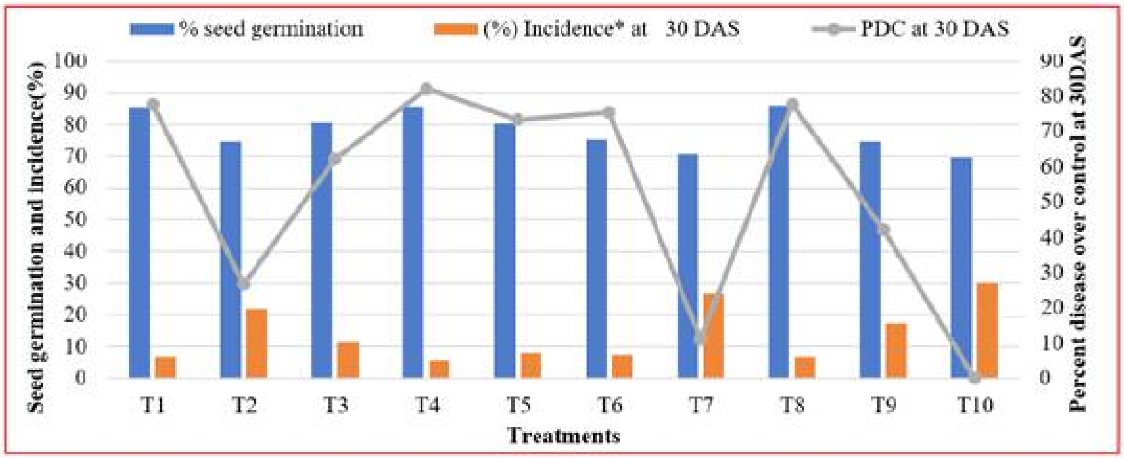

Figure 2. In-vitro efficacy of fungicides against *Sclerospora graminicola*, causing pearl milletdowny mildew, during *Kharif* 2019

The results of present study are in conformity with earlier findings of following workers, Pandya et al (2000), Zarafi et al (2004), Deepak et al (2004) evaluted in-vitro and in-vivo two fungicides *viz* Provalicarb 5.5% + Propineb 61.25% WP and Metalxyl 35 WS against *S. graminicola* (Pearl millet downy mildew) and reported that foliar application as most effective. Similarly, fungicide Metalaxy35 % WS pearl millet downy mildew. Sudisha et al (2005) tested three formulations of Strobilurin, Azoxystrobin, Kresoxim-methyl and Trifloxystrobin each at @ 0.1 to 2 ug ml-1 concentration and reported that these fungicides inhibited sporulation, zoospores release and mobility. Seed treatment with Azoxystrobin, Trifloxystrobin, and Kresoxim-methyl showed significant protection of 66, 59, and 46%, respectively. while seed treatment with these fungicides followed by foliar spray resulted highly significant protection of 93, 82, and 62% respectively. Sudisha et al (2010) evaluated the efficacy of three commercial formulations of strobilurins, viz., Trifloxystrobin, Kresoxim-methyl, and Azoxystrobin against *Plasmopara halstedii* (Sunflower downy mildew) and reported that seed treatment at various doses with strobilurins enhanced the sunflower seed germination and seedling vigour and also provided excellent disease control over untreated control. Sangwan and Kushal (2016b) , Sasode et al (2018), Saini (2019) reported that seed treatment of Metalaxyl 35 % WS(@ 6g/kg seed + spray of Fosetyl-Al (@ 0.25% resulted with highest plant stand (45.33%), followed by seed treatment with Metalaxyl 75% WS 35%WS @ 6g/kg seed + spray of Propiconazole 25% EC (@ 0.25% (41.66%), seedtreatment with Metalaxyl 35% WS (@ 6g/kg seed+ spray of Carbendazim @ 0.25% (39.33%), seed treatment with Metalaxyl 75% WS 35% WS (@ 6g/kg seed + spray of Chitosan @ 0.25% (38.66) and seed treatment with Metalaxyl 75% WS35 % WS (@ 6g/kg seed + spray of Initium @ 0.25% (35.66). Jiaswal (2018) reported that Mancozeb 75%WP seed treatment was significantly superior with the seed dressing with Amectoctradin + Dimethomorph @ 0.4 ml/ 500 ml water

Conclusion

The efficacy of eight biocontrol agents viz. *Trichoderma asperallum, Bacillus subtilis, Pseudomonas fluorescence, Trichoderma harzianum, Trichoderma hamatum, Trichoderma koningii, Aspergillus niger, Pseudomonas striata* were evaluated against *Sclerospora graminicola* in greenhouse condition and found that, it was highly significant with *Pseudomonas fluorescens* (ST) @ 8 g/kg seed (4.00%), over control and at par with Trichoderma harzianum (ST) @ 8 g/kg seed (5.33%) reduced the downy mildew incidence. While the efficacy of different fungicides viz. Provalicarb 5.5% + Propineb 61.25% w/w, Mancozeb 75% WP, Metalaxyl 75% WS, Azoxystrobin 23% SC, Pyraclostrobin 5%+ Metiram 55%, Kresoxim-methyl WG 50% Amectoctradin 27% + Dimethomorph 20.27% SC WG 50%, Cymoxanil 8% + Mancozeb 64%,Trifloxystrobin

50% WG were evaluated against *Sclerospora graminicola* in green house condition and Azoxystrobin 23% SC (FA) 2ml/L (5.33%) is highly significant over control (30.0%) and it is at par with Provalicarb 5.5% + Propineb 61.25% w/w WP (FA)@ 1 g/, Trifloxystrobin WG 50 (FA)@ 1ml/L (6.66 %), and Kresoxim-methyl WG 50% (FA) (7.33%).

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G. Food, Nutrition and Health

छ. खाद्य, पोषण र स्वस्थ

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कोदोबाट तयार गरिने परम्परागत खाद्य परिकारहरू

भगवती आचार्य[१], रामकृष्ण श्रेष्ठ[१] र निर्मला कुमारी बुढा[१]

[१] कृषि विभाग, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र, श्रीमहल ललितपूर

साराशं

कोदोको परम्परागत परिकारहरू बच्चा देखि गर्भवति, सुत्केरी र अन्य सवै उमेर समूहका व्यक्तिहरूको लागि विगतमा पोषिलो खानाको रुपमा उपभोग गर्ने गरिन्थ्यो । तथापी, कोदोको उत्पादन र उपभोग घटे सँगै यसबाट बन्ने ति परिकारहरू पनि लोप हुने अवस्थामा पुगेका छन् । यस लेखमा त्यस्ता केहि प्रचलित परिकारहरूको पोषण महत्त्व र परिकार तयार गर्ने विधि समेटिएको छ ।

परिचय

नेपालमा कोदोजन्य बाली अन्तर्गत कोदो सवै भन्दा धेरै उत्पादन र उपभोग गरिने बाली हो । विगतमा आम रुपमा नेपाली भान्सामा कोदोको विभिन्न परिकारहरू बन्ने र परिवारमा सवै उमेर समूहका सदस्यहरूले उपभोग गर्ने गरेकामा आधुनिकता सँगै धेरै नेपालीको खानेबानीमा परिवर्तन आइ कोदोको परिकारको उपभोग गर्ने क्रम घट्दै गएको पाइन्छ । आजकल सिमित रुपमा कोदोको पाउरोटी, कुकिज् लगायतका आधुनिक परिकार बजारमा पाइने भएता पनि अझै पनि परम्परागत परिकारकै बाहुल्यता रहेको पाइन्छ । तर कोदोको ढिँडो र रोटी जस्ता परिकारहरू बाहेक अन्य परम्परागत परिकारहरूको उपभोग निकै कम हुँदै गएको सन्दर्भमा त्यस्ता परम्परागत परिकारहरूको संरक्षण र आम उपभोक्तालाई जानकारी प्रदान गर्न यो लेख तयार पारिएको हो ।

१. कोदे फाँडो

क. परिचय

धेरै खाद्य तत्व तथा औषधिय गुण भएको कोदोको पिठोबाट अहिले विभिन्न खाद्य परिकार तयार गरि विभिन्न क्षेत्र एवं समुदायका वासिन्दाहरूले उपभोग गर्ने गरेका छन् । त्यस्ता परिकार मध्ये कोदे फाँडो एक हो । कोदे फाँडो कोदोको पिठो, चामल र मसला मिसाई बनाइएको खाने परिकार हो । विषेश गरेर कर्णाली प्रदेशको कालिकोट जिल्ला लगायतका जिल्लाहरूमा चिसो तथा रुघाखोकी लागेमा यो परिकार बनाएर खाने चलन छ । यो परिकारमा टिमुर र खुर्सानी अलि धेरै राखि पिरो-पिरो बनाई तातो-तातो पसिनै पसिना बनाउँदै खाने अनि घाममा सुते रुघाखोकी सन्चो हुने र जीउलाई आराम मिल्ने मान्यता कर्णाली बासीमा पाइन्छ । विगतमा बाटोघाटो र नजिक तथा पायक पर्ने स्थानमा स्वास्थ संस्थाहरू नभएका अवस्थामा सामान्य रुघाखोकी ज्वरो आउँदा यो परिकार बनाई खाने तथा खुवाउने गरिन्थ्यो जुन अहिलेपनि सामान्य अवस्थामा बनाएर खाने चलन छ । केहि स्थानीयबासीहरूले आफूसँग पिठो नभएपनि पैंचो/सापटी मागेर पनि पकाई खाने गरेका पाइन्छन ।

ख. आवश्यक सामाग्री

कोदे फाँडो बनाउन आवश्यक सामग्रीहरू यस प्रकार रहेका छन् । १. कोदोको पिठो, २. चामल, ३. टिमुर, ४. नुन, ५. खुर्सानी, ६. लसुन, ७. धनिया, 8. जिरा, ९. घिउ, १०. पानी, ११. कराही/खुल्ला भाँडो

ग. बनाउने तरिका

१. एक लिटर पानी कराही वा कुनै खुल्ला भाँडोमा उमाल्ने ।
२. उम्लेको पानीमा २५० ग्राम चामल राखि पकाउने । चामल पाकिसके पनि पानी अलि बढीनै हुने हुँदा गिलो हुन्छ ।
३. यसरी पाकिसकेको गिलो भातमा टिमुर र खुर्सानी अलि धेरै राखि पिसेको मसला (टिमुर, लसुन, धनिया, खुर्सानी, जिरा, बेसार,नुन आदि) राखि मजाले चलाउने ।

४. कोदोको पिठोलाई चाल्नीले चालेर सफा पिठो राख्ने ।
५. चालिएको कोदोको पिठो ८०-१०० ग्राम वा पकाउन राखिएको चामलको ३०-४० प्रतिशत पिठो मन तातो पानीमा राखि गिलो/पातलो/लेदो बनाउने अनि बनाइएको पातलो पिठो पाकेको गिलो भातमा राखि राम्रो सँग चलाउने र चलाइ सकेपछि पानीको मात्रा कम भएमा मनतातो पानी आवश्यकता अनुसार थप्न सकिन्छ ।
६. पाँच-दश मिनेट थालले छोपेर पकाउने । फतफती पाकिसकेपछि आगोबाट निकाल्ने अनि तातो-तातो हुँदै खानुपर्छ ।
७. यो अलिकति गिलो वा जाउलो जति गिलो हुनेगरि पकाईएको हुनुपर्छ र यो फतफती पाक्दा अलि घिउ राखेर पानि पकाउन सकिन्छ वा पाकिसकेपछि घिउ राखेर खान पनि सकिन्छ ।
८. यसरि पाकेको खाँदा टिमुर र खुर्सानीको पिरोले गर्दा जीउ तथा अनुहारमा पसिना-पसिना बनाउँछ । जसले चिसो लागेको तथा रुघाखोकी लागेको ठिक बनाउँछ ।

घ. विषेशता /महत्त्व

१. चिसोलागेको बेला यो परिकार बनाएर खाँदा ज्यान तातो हुने र शक्ति दिने हुन्छ ।
२. सानो बच्चालाई खुबाउन सजिलो हुने तथा पोषिलो र खान मन पराउने तातो हुने गर्दछ ।
३. बुढा बुढीलाई रोटी खान अलि गाहो हुने हुँदा खानाको रुपमा खान सकिने ।
४. सुत्केरी महिलालाई पिरो अलि कम गरि घिउ बढी राखि खान दिदा पोषिलोका साथै दुध आउन सहयोगि हुने ।



फोटोः टेकराज गिरी सान्नी त्रिवेणी गा.पा. कालीकोट

२.कोदोको थुक्पा

क. परिचय

कोदोको थुक्पा कर्णाली अञ्चलका हुम्ला, जुम्ला, मुगु लगायतका जिल्लाहरूमा खाने चलन छ । यो कोदोको पिठो भटमास, आलु, काउली, बन्दा तथा तरकारी बालीका परिकार र मासु मिसाई पकाएर खाने गरिन्छ । भटमास र पिठो, तरकारी र पिठो ,मासु र पिठो मिसाई छुट्टा छूट्टै पनि पकाएर खाने गरिन्छ । यो चिसो लाग्दा दिउँसो नास्ता/अर्नी (खाजा) वा खानाको रुपमा पनि खाने गरिन्छ । शरिरमा पानीको मात्रा कम हुने हुँदा यस्तो झोलिलो परिकार बनाएर खाँदा पानीको मात्रा बढ्ने, चिसो हट्ने र पोषिलो मात्रा थपिन्छ भन्ने मान्यता छ । यसलाई जुम्लामा रामजाडे/फाँडो/थुक्पा र हुम्लामा थुक्पा भन्ने गरिन्छ ।

ख. बनाउन आवश्यक सामाग्री

कोदोको थुक्पा बनाउन आवश्यक सामग्रीहरू यस प्रकार रहेका छन् ।

१.कोदोको पिठो,२.भिजेको/भुटेको भटमास, ३.टिमुर, ४.नुन, ५.खर्सानी, ६.लसुन, ७.धँनिया, 8.जिरा, ९.घिउ, १०.पानी, ११.कराही/खुल्ला भाँडो, ११.काउली, १२.बन्दा, १३.साग, १४.मासु

ग. बनाउने तरिका - एक

१. सर्वप्रथम सय ग्राम जति कोदोको पिठोलाई चाल्नीले चालेर सफा पिठो तयार पार्ने ।
२. आगो बालेर कराहीमा पानी तताउन बसाउने । पानी तातिसकेपछि कोदोको पिठो तातोपानीमा हाली राम्रो सँग चलाउने र तेल/घिउ पनि अलिकती राख्ने जसले पिठोको डल्ला नपर्नमा सहयोग गर्छ । यसलाई चलाई राख्न पर्छ, नचलाउँदा डल्ला पर्ने हुन्छ ।
३. यसलाई तेलमा पिठो भुटेर पछि पानी हाली पकाउन पनि सकिन्छ । यदि भुटेर पकाउने हो भने ठिक्क तेल/घिउ राखि तातिसकेपछि पिठोलाई हालि रातो हुन्जेल सम्म भुट्ने । भुटिसकेपछि मनतातो पानी हाल्ने र छिटो छिटो चलाइ डल्ला पर्न नदिने ।
४. पिठो राम्रो सँग पानीमा घोलिसकेपछि पिसेको मसला (टिमुर, लसुन, धनिया, खुर्सानी, जिरा, बेसार, नुन आदि) राखि राम्रोसँग चलाउने ।
५. भिजेको भटमास/पकाइएको भटमासलाई पनि राखिदिने र चलाउने । चलाईसकेपछि एकछिन छोप्ने र पाक्न दिने ।
६. यो अलिकति झोल/सुपमै बनाइने हुँदा आवश्यकता अनुसार मनतातो पानी थपि चलाइ पकाउन सकिन्छ ।
७. पिठोको डल्ला पर्ने हुँदा पाकुन्जेल पनि चलाई राख्नु पर्ने हुन्छ ।
८. स्वादको लागी चिल्लो तथा पिरो आवश्यकता अनुसार राख्न सकिन्छ ।
९. पाकिसकेपछि यसलाई तातो-तातो हुदै खानु पर्छ ।

घ. बनाउने तरिका - दुई

१. कोदोको पिठो एक कप रोटी बनाउने जति साह्रो गरि मुछेर राख्ने ।
२. तरकारीमा आलु ,बन्दा, काउली, साग धोई पखाली ठीक्क गरि काटेर राख्ने ।
३. आगो बाली कराहीमा तेल राखि बसाउने ।
४. तयार पारिएको/काटेको तरकारी राम्रोसँग भुटेर मनतातो पानी तरकारी डुब्ने गरि राख्ने ।
५. पिसेको मसला (टिमुर, लसुन, धनिया, खुर्सानी, जिरा, बेसार, ज्वानो, नुन आदि) राखि राम्ररी चलाउने र छोपिदिने ।
६. तरकारी पाकिसके पछि मुछेको पिठोलाई सानो डल्लो बनाई हातमा लिई कान्छी औला जतिको मोटो र लामो लिङ्का/गोलो टुक्रा बनाई उम्लेको तरकारीमा राख्दै चलाउँदै गर्ने वा मुछिएको पिठोलाई अली बाक्लो रोटी बनाएर कान्छी औंला जति मोटो र लामो गरि साना -साना टुक्रा पारि काट्ने र एउटा एउटा गरि उम्लेको तरकारीमा राख्दै चलाउँदै गर्ने । यो सँगै राख्दा टाँसिने हुँदा एउटा -एउटा गरि राख्ने र चलाउँदै रहने । नचलाएमा पिठो टासिने र डल्लो हुने हुनाले नपाकुन्जेल सम्म बेला बेला चलाउँदै राख्ने ।
७. पाकिसकेपछि निकाली तातोतातो खान सुरु गर्ने ।
८. पहिलो तथा दोस्रो तरिकाले बनाइएको थुक्पामा मजाले सिठी लागाएर पाकेको मासु राखि केहि बेर पकाइ खान पनि सकिन्छ । यसरि पकाइएको खानमा मिठो र स्वादिलो हुन्छ ।

ङ. फाइदा एवं विषेशता

१. यसरि तयार पारेको थुक्पा विशेष गरि रुघाखोकि लागेको बेला तातोतातो खाँदा फाइदा हुन्छ ।
२. पखाला धेरै लागेको भए पनि यो खाँदा बिसेक हुने हुन्छ ।
३. सुत्केरी महिलालाई खुवाउँदा जिउ बलियो, तातो र पोसिलो तथा दह्रो हुनुको साथै आमाको दुध बढी आउने हुन्छ ।
४. सामान्य सबैले खाँदा खानाको काम पनि गर्ने र जिउ पनि बलियो तथा दह्रो हुने हुन्छ ।



फोटोः डिल्ली सार्की खार्पुनाथ गा.पा. हुम्ला

३. कोदोको लगड/माडे रोटी

क. परिचय

लगड कोदोको पिठोबाट बनाइने एक परिकार हो । यो आफ्नो खाने स्वाद अनुसार खाना वा नास्ता/अर्नि (खाजा) को रुपमा खाइने परिकार हो । विषेश गरेर अर्नि पछि खानाको रुपमा खाइने लगड गिलो पिठोबाट बनाइएको हुन्छ । साधारणतयाः सबैलाई खान मन पर्छ र खाने गरिन्छ तर बच्चा र बुढाबुढी अवस्थामा सारो चपाई खानालाई गाह्रो हुने हुनाले यो खुवाउन राम्रो मानिन्छ ।

ख. बनाउन आवश्यक सामाग्री

लगड बनाउन आवश्यक सामग्री निम्न रहेका छन् ।

१. पिठो, २.पानी, ३. घिउ, ४. मह/चिनि

ग. बनाउने तरिका

१. कोदोको पिठोलाई राम्रो सँग चालेर राख्ने ।
२. चालेको पिठोमा अलिकति मह/चिनि राखि मनतातो पानीले गिलो पिठो बनाउने र एकछिन छोपेर राखिदिने ।
३. आगोमा तावा बसाउने । तावा तातिसकेपछि घिउ राखेर हात वा कचौराले गिलो पिठो राख्ने र हात वा डाडुले गोलो पातो हुने गरि पिठोलाई मिलाउने र थालले एक छिन छोपि फर्काउने ।
४. फर्काएको लगडमा माथिबाट अलिकति घिउ राखिदिने र ओल्टाई पल्टाई गरि राम्रोसँग पाक्न दिने । पाकिसकेपछि निकालिदिने ।

४. पेडुला

क. परिचय

"पेडुला" कोदो र गेडागुडी मिसाइ तयार पारिने एक परिकार हो । यो जुनसुकै दाल तथा गेडागुढीमा कोदोको पिठो मुछेर मुछेको पिठोलाई स साना मटेङ्ग्रा जस्तो डल्ला बनाई बुढीं औंला र चोर औंलाको सहयोगले थिच्दै पकाउन राखेको दालमा राख्दै जाने र दाल पाकिसके पछि तयार हुने खाद्य परिकार हो । यो परिकार कोदो प्रसस्त मात्रामा खेती गरिने नेपालको मध्य पहाडी क्षेत्रमा प्रायः खाने चलन छ ।

ख. आवश्यक सामाग्री

पेडुला बनाउन आवश्यक सामग्रीहरूः १. उपलव्धता अनुसार चना, रहर, मसुरो, मास, मस्याङ्ग, सिमि, बोडी र भटमास आदिको दाल आवश्यकता अनुसार । २. कोदोको पिठो । ३. दाल तयारी गर्नका लागि आवश्यक प्याज, लसुन, नुन, घिउ आदि सामाग्री । ४. पकाउने भाडाँकुडाँहरू तथा अन्य आवश्यक सामाग्री ।

ग. बनाउने तरिका

१. कोदोको पिठो सुख्खा रोटी पकाउने गरी मुछ्ने ।
२. दाल पकाउन भाडा तयार गर्ने ।
३. भाडा तातिए पश्चात घिउ वा तेल (भुटुन) आवश्यकता अनुसार राख्ने ।

४. भुटुन राम्रो सँग तातिए पछि जिरा, मेथी राखेर पड्काउने ।
५. अब तयार दाललाई राख्ने र राम्रो सँग चलाउदै एक छिन भुट्ने ।
६. दुई मिनट जती भुटी सके पश्चात तातो पानी आवश्यकता अनुसार राख्ने तर धैरै पातलो हुने गरी नराख्ने ।
७. आवश्यकता अनुसार नुन, बेसार, मसला, लसुन अदुवाको पेष्ट आदि राखेर पकाउने ।
८. दाल राम्रो सँग उम्लिन थाले पश्चात मुछेको पिठोको स साना डल्लाहरू बनाउने र डल्लालाई बुढी वा कान्छी औलाले थिचेर उम्लिएको दालमा राख्दै जाने ।
९. यसरी राख्दै जादा दालको परिमाण अनुसार पकाउन मिल्ले गरी राख्ने ।
१०. यसरी पाक्दै गरेको दाल पिठोलाई राम्रो सँग चलाउदै राख्ने राम्रो सँग पकाउने ।
११. राम्रो सँग पाके पश्चात पेडुला खानको लागि तयार भयो ।
१२. राम्रो सँग पाकेको पेडुलाका पुक्क पुक्क फुलेको हुन्छ ।

घ. फाइदा एवं महत्त्व

यो स्वादिलो, स्वस्थकर तथा सजिलै पचाउन सकिने हुँदा बच्चा देखी बृद्ध सम्मले मन पराउँछन । शरिरलाई आवश्यक पोषण उपलव्ध गराउन तथा जाडोमा शरिर गरम राख्न यो महत्त्वपूर्ण छ । खाना तथा खाँजा दुबैको रुपमा प्रयोग गरिने यस परिकार तर अहिले आधुनिक खाद्यवस्तुहरूको सहज उपलव्धता सँगै संकटमा परेको छ ।

५. खोचा (डल्ला)

क. परिचय

खोचा लुम्वनी तथा कर्णाली प्रदेशका पहाडी जिल्लाहरू रोल्पा, रुकुम, प्यूठान, सल्यान तथा सुदुरपश्चिम क्षेत्रका केही पहाडी जिल्लाहरूमा खाना तथा खाजा (अर्नी) को रुपमा प्रयोग गरिने एक रैथाने परिकार हो । कोदोको पिठोको डल्लो बनाई पकाइखने हुँदा यसलाई सुदुरपश्चिम क्षेत्रमा डल्ला पनि भनिन्छ । रैथाने सिपको प्रयोग गरी तयार गरिने यस परिकार प्रयाप्त पौष्टिक तत्वले भरिपूर्ण र स्वस्थवर्द्धक हुन्छ । सबै उमेर बच्चा देखि लिएर बुढापाकाहरूले सजिलै सँग पचाउन सक्ने तथा स्वादिलो हुने हुँदा यसलाई सबैले मन पराउछन् ।

ख. आवश्यक सामाग्री

डल्ला बनाउन आवश्यक सामग्री यस प्रकार रहेका छन् ।
१. कोदोको पिठो, २. घिउ वा तेल, ३. सख्रर वा चिनी, ४. बाटा वा आरी, ५. पानी, ६. केरा तथा भर्लोको पात, ७. पटुवाको डोरी वा स्थानियश्रोतमै उत्पादीत डोरी, ८. कसौंडी वा ताउली, ९. थाल वा भाडाकुडा साथै अन्य आवश्यक सामाग्री ।

ग. बनाउने विधी : (१ के.जी.पिठोको लागि)

१. पिठोलाई राम्रो सँग चालेर मसिनो बाटामा राख्ने ।
२. पिठोमा सानो चम्चाको ५ चम्चा घिउ राखेर राम्रो सँग मोल्ने ।
३. गुलियो मन पराउने भएमा स्वाद अनुसार सख्खर मसिनो बनाएर राख्ने ।
४. साहो डल्लो हुने गरी राम्रो सँग पानी मिसाइ पिठो मुछने ।
५. मुछेको पिठोको डल्लोलाई लोहरो आकारको बनाउने ।
६. केरा तथा भर्लोको पातमा नौनी घिउ लगाई चिल्लो पार्ने
७. लोहरो आकारको पिठोको डल्लोलाई केरा वा भर्लोको पातमा राख्ने र त्यही पातले राम्रो सँग बेर्ने ।
८. बेरेको पातलाई पटुवाको डोरीले चारै तिरबाट बाध्ने ।
९. ताउली तथा कसौडीमा १ लिटर पानी राखि कसौडीको माथी टिनको प्वाल पारेको पाता राखी त्यस माथी पातमा बेरिएको डल्लाहरूलाई चाङ्ग मिलाएर पकाउने भाडोमा राख्ने र बाफ नजाने गरी ढकनीले छोप्ने ।
१०. यसरी पानीको बाफद्धारा करिब ३० मिनेट पकाउने । ३० मिनेट पकाए पश्चात खोचा खानको लागि तयार हुन्छ ।

यसरी तयार गरिएको खोचालाई टिमुर मिसाईएको भाँगोको छोप सँग मनतातो मै खाँदा मिठो हुन्छ । बासी खोचा बचेमा पातै सँग आगोको कोईलामा तताएर पनि खाने चलन छ ।

खोचा बनाउदै गरेको फोटोहरू


खोचा पकाउन पिठो तयार गर्दै

खोचा पकाउदै

तयारी खोचा

फोटो तथा जानकारी संकलक: जगत बहादुर विष्ट, बाजुरा

६. लेटे

क. परिचय

"लेटे" दुध र कोदोको पिठोबाट बनेको एक प्रकारको खाद्य परिकार हो। आम रुपमा बच्चाले खाने लिटो जस्तो भान हुने यस परिकार सबै उमेर समूहका व्यक्तिहरूले उपभोग गर्न मिल्ने पोषिलो परिकार हो। सुदुरपश्चिम र कर्णाली भेगका कोदो उत्पादन हुने क्षेत्रमा यसको उपभोग खाजा (अर्नी) को रुपमा प्रयोग गरिन्छ।

ख. लेटे बनाउने सामाग्री

लेटे बनाउन आवश्यक सामाग्रीहरू यस प्रकार रहेका छन्।

१.कोदोको पिठो, २.गाई वा भैसीको दुध, ३.कराई वा कशौडी, ४.पन्यू वा डाडु तथा अन्य आवश्यक भडाकुँडा

ग. लेटे बनाउने तरीका:

१. लेटे बनाउँदा गाई अथवा भैसिको जुनसुकै दुधमा पनि बनाउन सकिन्छ। शुरुमा दुधलाई तताउने। दुध ताते पश्चात त्यसमा २५० ग्राम कोदोको पिठो थोरै थोरै राख्दै विस्तारै चलाउँदै जाने। पिठो थोरै थोरै राख्दै पन्यू वा डाढुले चलाउँदै गर्नु पर्दछ।
२. सबै पिठो राखिसके पछि आगो सानो बनाउने फतफत पकाउने साथै लगातार चलाउदै जाने।
३. पाक्दै जाँदा यो बाक्लो हुँदै जान्छ।
४. यत्ती बेला गुलियो मन पराउनेहरूले स्वाद अनुसार सख्खर राख्न पनि सकिन्छ।
५. यो पाकिसके पछि मिठो बासना आउँछ र पाकिसकेपछि रङ्ग पनि खैरो देखिन्छ।
६. अब लेटे खानलाई तयार यो चिसो नबनाई ताततातै खाने चलन छ।

घ. फाइदा एवं महत्त्व

यो परिकार नेपालको सुदुरपश्चिम तथा कर्णाली क्षेत्रका ग्रामिण भेगका सबै उमेर समूह र वर्गका मानिसहरूको लागि पौषिक पदार्थको प्रमूख श्रोत हो। यसले कुपोषणबाट जोगाउनुका साथै धैरै शारीरिक श्रम गर्नु पर्ने समय, गर्भवती, सुत्केरी अवस्थाका व्यक्तिहरूलाई धैरै फाईदाजनक हुन्छ।

लेटे पकाउन तयार कोदोको पिठो


लेटे पकाउन तयार गरिएको दुध


पाक्दै गरेको लेटे

खान तयारी लेटे

७. गजगजे

क. परिचय

गजगजे एक किसिमको कोदोको पिठोमा दुध, घिउ, सख्खर मरमसला आदी मिसाई तयार पारिएको एक किसिमको खाद्य परिकार हो। यो प्राय: नेपालको सुदुर पश्चिमको पहाडी जिल्ला अछाम र बाजुरा तथा कर्णाली प्रदेशका केही जिल्लामा खाजाको (अर्नी) रुपमा प्रयोग गरिन्छ। यसको प्रयोग सँधै नगरी विशेष पाहुनाको स्वागतका लागि गरिन्छ भने सानातिना चाडपर्वमा विशेष परिकारको रुपमा पनि पकाएर खाने चलन रहेको छ। कोदोको पिठोबाट स्थानीय शिपको प्रयोग गरी तयार गरिने यस परिकारले सो क्षेत्रका बासिन्दाहरूको पौष्टिक आवश्यकता पूरा गर्न तथा सांस्कृतीक पहिचान कायम राख्न योगदान पुर्याएको छ।

ख. आवश्यक सामाग्री:

गजगजे बनाउन आवश्यक सामग्रीहरूः १. कोदोको मसिनो पिठो, २. तेल वा घिउ, ३. सम्भव भए र पाएसम्म नरिवल, छोयडा, जस्ता मसलाको मसिनो धुलो, ४. सख्खर स्वाद अनुसार, ५. मेथी, सौफ र जुवानो, ६. चेप्टो भाडो कराई वा तावा, ७. डाडु, ८. पन्यू

ग. बनाउने विधी:

१. कोदोलाई राम्रो सँग केलाएर त्यसमा भएको अखाद्य वस्तुहरू हटाउने।
२. केलाएको कोदोलाई आ आफ्नो सुविधा अनुसार मिल, घट्ट वा जाँतोमा राखेर मसिनो सँग पिस्ने र पिठोलाई चाल्नीले चालेर मसिनो पिठो छुट्याउने।
३. दुई चम्चा घिउ, स्वाद अनुसारको चिनी वा सख्खरको धुलो पिठोमा मिसाउने।
४. उपलव्ध भए सम्म मनतातो दुध र सो नभए मनतातो पानीले गिलो रोटी पकाउने भन्दा अली साह्रो हुने गरी पिठो मुछने।
५. मुछेको पिठोलाई १५ मिनट राम्रो सँग छोपेर राख्ने।
६. १५ मिनेट पश्चात कराहीमा ३०० ग्राम घिउ राखेर राम्रो सँग ताते पश्चात जुवानो, सौफ, मेथी फुराउने र तयार गरिएको पिठोलाई एकै पटक कराहीमा हाल्ने।
७. एक छिन पश्चात पिठो पाक्दा पाक्दै डाढु वा पन्यूले खुडेर मसिनो बनाउने।
८. अब पाक्न पाक्न लाग्यो भन्ने बेलामा तयार गरिएको १०० ग्राम नरिवल र छोकडाको मसला धुलो (उपलव्ध भए सम्म) मिसाउने।
९. मसलाको धुलो राखेको करिब ५ मिनेट पकाई सके पश्चात खान तयार हुन्छ। यो परिकार मन तातो हुँदा नै खान राम्रो मानिन्छ।

घ. फाईदा एवं महत्त्व

१. सुत्केरीलाई खुवाउँदा पाठेघर कस्ने काम गर्दछ भन्ने जनविश्वास रहेको छ।
२. स्तनपान गराउने महिलालाई पोषिलो हुने हुन्छ।
३. चिसो तथा वर्षादको समयमा चिसोबाट जोगिन यसको उपयोग गर्ने चलन रही आएको छ।
४. प्राय गरी पश्चिमी पहाडी ग्रामिण समाजमा यसको सेवनबाट शरिरको चिसो भाग्छ भन्ने विश्वास चली आएको छ।
५. यसको सेवनले कब्जियत हुनबाट जोगाउने विश्वास गरिन्छ।
६. सबै उमेर र समूहका व्यक्तिको लागि वा दाँत झरेका बुढा पाकाको लागि पनि खान र सजिलरी पचाउन सक्किने हुन्छ।

फोटोहरू


खलमा कोदो फल्दै गरेको


फलेको पिठो जाँतोमा पिस्दै


तयारी पिठो


पिठो मुछ्दै गरेको


नरिवल छोकडा वा मसलाको


भाडोमा घिउ तताउदै


पकाउन तयारी गरेको


तयारी गजगजे

फोटो संकलकः जगत बहादुर विष्ट, बाजुरा

८. बेसार पाते रोटी

क. परिचय

“बेसारपाते” कोदोको पिठोलाई साधारण रोटी पकाउने झै मुछेर बेसारको पातमा राखेर रोटी बनाई बेसारको पातै सँग ताबामा राखेर पकाईने एक रैथाने परिकार हो। कोदोको पिठोलाई बेसारको पातमा राखेर पकाईने हुँदा यसलाई बेसारपाते रोटी भनिएको हो। विशेष गरी देशको पूर्वी पहाडी भेगमा खाजाको रुपमा यसको व्यापक प्रयोग गरिन्छ। यस परिकार स्थानीय सामाग्री तथा शिपको प्रयोग गरी तयार गरिने साथै स्वादिष्ट, स्वस्थकर वास्नादार, नरम तथा सजिलै पचाउन सकिने हुँदा बृद्ध देखि बालबालीका सम्म लोकप्रिय छ।

ख. आवश्यक सामाग्री

बेसारपाते रोटी बनाउन आवश्यक सामाग्रीहरूः १. कोदोको पिठो आवश्यकता अनुसार, २. चुलो वा ग्यास, ३. तावा, पिठो मुछ्ने भाडा, ढकनी आदि आवश्यक भाडाकुँडा

ग. बनाउने तरीका

१. आवश्यकता अनुरुप कोदोको पिठो लिने।
२. पिठोलाई गहुँको सुख्खा रोटी पकाउने भन्दा अलि गिलो गरी मुछ्ने।
३. मुछेको पिठोलाई १५ मिनेट कुनै भाँडोले राम्रो सँग छोपेर राख्ने। गिलो पिठो छोपेर राख्दा रोटी नरम हुन्छ।
४. सफा र नच्यातिएको चिल्लो बेसारको पात लिने। पातलाई बिचबाट दोबारेर बराबर गराउने।
५. दोबारेको आधा भागमा मुछेर राखिएको पिठोको डल्लो लिई हातले बिस्तारै थिच्दै रोटी बनाउने।
६. तयार भएको रोटीलाई बाँकी आधा पातले छोपेर ताबामा पातै सँग पकाउन राख्ने।
७. ताबामा यसरी पातै सँग राखिएको रोटीलाई पुनः माथीबाट थाल, प्लेट वा कुनै ढकनीले ढाकिदिने।
८. त्यसैगरी एकपट्टी पाकिसकेपछि अर्को पट्टी फर्काएर पकाउने। यसरी रोटी पकाउँदा बेसारको पात सँग सँगै पकाउनुपर्ने हुन्छ।
९. रोटी सँग पात बराबर चाहिने हुँदा प्रत्येक रोटीमा एउटा पात आवश्यकता पर्ने हुन्छ।

१०. अब बेसारपाते रोटी तयार भयो। यो खाँदा बेसारको स्वादसँगै आउने बासनादार रोटी बन्छ।

११. तयारी रोटी मनतातो नै अचार, तरकारी, चिया सँग खाँदा स्वादिलो हुन्छ।

घ. महत्त्व तथा फाईदाहरू

१. स्थानीय सामाग्री र शिपको प्रयोग गरी तयार गर्न सकिने।

२. सजिलै पचाउन सकिने हुँदा बच्चा देखी बृद्ध सम्म उपयोगी।

३. शरिरलाई चिसोबाट जोगाउन तथा रुघाखोकीको घरेलु औषधीको रुपमा समेत प्रयोग गर्न सकिने।

४. गर्भवती तथा सुत्केरी महिलाको लागि अत्यन्त लाभदायिक खाजाको रुपमा प्रयोग गर्न सकिने।


पिठो मुछदै गरेको


बेसारको पात तयार गरिदै

बेसारको पातमा रोटी थिच्दै


तावामा राखेर रोटी पकाउदै

धकनीले छोपेर पकाउदै

पाकी सकेको रोटी


खानको लागि तयारी रोटी

फोटो संकलक: आर. बि. थुलुङ्ग, सुलुखुम्बु।

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Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Revitalizing the Importance of Millet Crops for Food and Nutrition Security in Nepal

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Summary

Millets are fourth important staple food of Nepal after rice, wheat and maize and, very important summer crops of *bari*-dominated mid and high hills of the country. Finger millet is the major one among more than eight millet crops grown in Nepal in terms of area coverage and total production followed by proso millet, foxtail millet, pearl millet, sorghum, barnyard millet, kodo millet and little millet. This paper has reviewed the importance of millets in Nepalese context considering their valuable characteristics in regard to climate resilience, well adapted to marginal land/soil, wide adaptation in terms of geographic locations, growing seasons and fitting well in various cropping systems and their contribution in food and nutrition security of growing population in the country. More importantly, nutritive value of millets has been reviewed in greater extent comparing with the nutritive value of major staple food of the country such as rice, wheat and maize. This paper has concluded that the millets particularly finger millet is a miracle crop, a superfood and millets as a whole are the hope of future in constantly changing climate conditions. Considering all these, the paper has suggested to give priority towards increasing the area and productivity of millets and consumption of various millet products so that the goal of achieving food and nutrition security of the country could be much easier.

Keywords: Climate resilience, food and nutrition security, hope of future, marginal land, millets, superfood, wide adaptation

Introduction

The millets are a group of small seeded cereal crops (members of the grass family) and are grown for food, feed and forage (Ghimire et al 2017, Gairhe et al 2021). Major millet crops grown in Nepal are finger millet (*Eleusine coracana*), proso millet (*Panicum miliaceum)* and foxtail millet (*Setaria italica)*. Other millets such as barnyard millet (*Echinochloa frumentacea)*, sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum typhoides*) etc are also grown in the country. Similarly, little millet (*Panicum sumatrense*) and kodo millet (*Paspalum scrobiculatum*) have also been reported to be grown in a small scale in Nepal (Ghimire et al 2017). Finger millet is the major one among various millets grown in Nepal in terms of area coverage and total production followed by proso millet and foxtail millet (Ghimire et al 2017).

Millets are the fourth most important food crops of Nepal after rice, wheat and maize in terms of area coverage and total production. Area covered by millets in the country is 267,071 hectares with an annual production of 339,462 metric tons and average productivity of 1.27 t/ha (MoALD 2023). Millets are underutilized but important food crops for rural poor farming communities living under subsistence and marginal environments of Nepal. They are also known as Himalayan Super-foods due to their nutrient-dense nature. This paper highlights the importance of millets from various dimensions focusing more on the nutritional aspect, comparing with major staple foods common in the daily diets of the vast majority of the country's population. Considering the important nutritional value and health benefits of the millets, this paper suggests some of the possible options to increase the total production, productivity and increased consumption of millets in the country. This paper has prepared based on the review of literatures and experiences from the field.

Importance of Millets

Millets are very important crops of Nepal from various dimensions such as (i) climate resiliency, (ii) very good adaptation to drought and biotic and abiotic stresses, (iii) wide adaptation in terms of growing season, soil type and fertility, (iv) very short growing period in warm/hot weather and can fit well in different cropping systems, (v) highly nutritious for both human and animal etc. These are briefly described below:

Climate resilient crops

Millets particularly finger millet is reported to be one of the oldest crops and has been domesticated for last 5000 years, which was started in the East African highlands (de Wet 1984). It also has been said that "Millets were the first crops" and "Millets are the future crops"(IIMR 2018), meaning millets are the hope for the changing climate context of subtropical region of the world. Nepal is considered a secondary centre of millet diversity with diverse types of varieties grown by smallholder farmers across different altitudes, farming systems, and locations in the country (Baniya et al 1992, Ghimire et al 2017; 2020, Gairhe et al 2021). Those might have contributed to develop good adaptation to various environments and stress conditions such as marginal/poor soils, drought stresses, tolerance to pest and diseases etc. Altogether it makes possible to grow millets under stress conditions which are considered as resilience to changing climate environments (Ghimire et al 2020). Primarily these crops are considered as climate resilient due to its short to very short crop duration, tolerant to drought, grow satisfactorily in marginal land or in poor soil fertility conditions with acidic to slightly acidic soils compared with other crops like rice and wheat, and can produce very good yields in better soils and/or in better management conditions; their good root system/network is helpful to conserve soil erosions.

Wide adaptability

Millets are important crops of *bari* (rain-fed upland)-dominated mid and high hills (900-2200m) though it is cultivated from plain area to mountain region (as high as 3100m above sea level) ie at Buranse village of Humla near Simikot (Baniya et al 1992, Ghimire et al 2017). However, planting time differs with altitude; usually it is seeded in April in case of mountain area (above 2200m); it is seeded during May in the high hills; May-June in the mid hills (900-1800m), and June-July in the low hills and *terai* (<900m). Mostly direct seeding is done in high hills and mountain area and transplanting is common in mid-hills and lower altitude areas. Similarly, finger millet is grown in spring season as well in certain pockets of *terai* region where seeding is done in late February to mid-March and transplanting in late March to early April. Though millets are considered as drought-tolerant and rain-fed crop, finger millet production as spring crop in *terai* is done only in irrigated condition. Seedlings are transplanted in puddled field (like rice transplanting) and additional three, four irrigations are given during the crop period.

Millets in marginal land and poor soils

Most of the millet crops, if not all, are C4 crops. They have high photosynthetic efficiency meaning efficient users of water and nutrients for crop growth (IIMR 2018) and high adaptation to drought and other biotic and abiotic stresses. In other words, they are highly efficient in absorbing and using carbon dioxide. Generally, they are rain-fed crops grown in areas with low rainfall and thus resume greater importance for sustained agriculture and food security. General characteristics of soil in the hills and mountains of Nepal are light textured, shallow soil depth, acidic nature of most of the parent materials and millets are mostly cultivated in sloppy land with very minimal or no use of manures. They are very fragile and very difficult to maintain the soil fertility condition of such soils. Soil acidity is increasing due to improper farming practices such as imbalance use of chemical fertilizers in maize and other crops where millets are also grown. On the other hand, millets (particularly finger millet) can be grown well in slightly acidic and acidic to neutral soils (4.5 to 7.5 pH). Foxtail millet and barnyard millet can also be grown in pH 5.5 and above. That means millets are well adapted in acidic and slightly acidic to neutral soils which is common in Nepal. All these reveal that millets could be the last hope to produce food for future generations without much destroying the environment in the hills.

Nutritive value and health benefits

Looking into the nutritive value and health benefits, millets are considered most nutritious and healthy food among cereal/staple crops (Mishra et al 2022, Maharajan et al 2021). Millets are important staple food in parts of mid/high hill areas of Nepal. Health-conscious people have considered millets particularly finger millet as super-food and prestigious crops from food and nutrition point of view. Millets are gluten-free, nutrient-dense containing rich micronutrients, dietary fibres, amino acids, vitamins, and account for higher protein, calcium, and iron. They are highly nutritious and good for people with diabetics and high level of cholesterol (Mishra et al 2022, Maharajan et al 2021). Experiences of farmers suggest that the biomass/straw of finger millet is a good forage for animals and grains are very nutritious feed.

Though finger millet is highly nutritious and has many health benefits it is considered as an inferior staple food (*Kuanna*) and not allowed in the worship/rituals of god/goddess (*Debkarya*) and rituals related to demised/deceased parent/family members (*Pitrikarya*). Also, people of certain community (particularly *Brahmin-Chhetri*) are conscious for not to eat millet products during rituals and fasting[1]. However, *Nirnaya Sindhu (Dharma-sastra*) do not restrict eating millet products in normal occasions. More importantly *Dharma-sastra* restrict even eating rice products in *Ekadasi* ('the Eleventh Day,' which occurs twice in a lunar month - once each on the 11th days of the bright and dark fortnight respectively)[2]. So, there is no surprise to see restriction of eating millet products for few days in a month, as nutritious millet products can be eaten most of the other days. On the other hand, foxtail millet is considered an important food item for the day of fasting and rituals.

Others

Greenhouse gases (GHG) emission and fossil fuel depletion are ever-increasing challenges of global industrial development. Bioethanol is considered at the moment as one of the most promising substitutes for petroleum products and millets (not only the grains but also biomass) can be one of the possibilities to produce bioethanol production from renewable organic matter (Yemets et al 2020). This is however under study whether this will be economically viable or not.

1 Nirnaya Sindhu of Prof. Dr. Benimadhav Dhakal, page 48-49 has explicitly mentioned restriction of eating finger millet and sorghum along with many other food crops during rituals and fasting.

2 Nirnaya Sindhu of Prof. Dr. Benimadhav Dhakal, page 107-108

Millets and Nutrition

Millets are known to have enormous nutritive values in comparison to rice and wheat. In addition, presence of gluten free proteins with high dietary fibres and richness in bioactive compounds make millets a very healthy food (Mishra et al 2022). Millets are gluten-free, mineral rich (mainly calcium, potassium, magnesium, iron and zinc), vitamin rich (mainly Thiamine-B1, Riboflavin-B2, Niacin-B3), high in amino acids, dietary fibres and account for higher protein and phytochemicals that include phenolic compounds as compared to major staples such as rice, wheat and potato (Mishra et al 2022, Maharajan et al 2021) (**Table 1**, 2 & 3**)**. That means millets are nutritionally very superior to common staple food such as rice, wheat and maize. In other words, crops like rice and wheat contribute for food security, but nutrition security is not possible from these crops. Food as well as nutritional security is possible from millets. More importantly millets grain can be stored for three or more years without insect damage that makes it a valuable crop for famine hit areas.

All millets and in particular finger millet are good for (i) diabetes, (ii) lowering blood cholesterol so good for people with high blood pressure, (iii) strong bones, and (iv) good for nursing mothers. Similarly, it helps to overcome anemia, slow down the aging process, helps in weight loss and it is one of the best non-dairy sources of calcium so people with lactose intolerance can consume finger millet for calcium instead of milk etc (Rao et al 2017). However, excess intake can increase the amount of oxalic acid in the body. So, finger millet is not recommended for kidney patients. Similarly, excessive intake of finger millet can cause kidney stones as it is a rich source of calcium (Zotezo 2022).

The major mineral nutrient composition of millet crops comparing with staple food (rice, wheat and maize) is summarized in **Table 1**. The vitamin A and B content of various millets are given in **Table 2**.

Table 1. Major mineral content (mg/100g of edible part) of various millets comparing with major cereal crops

Crop	Ca (Mg)	Fe (mg)	Na (mg)	K (mg)	Mg (mg)	Zn (mg)
Finger millet	344-350	3.9	11.0	408.0	137.0	2.3
Foxtail millet	31.0	2.8	4.6	250.0	81.0	2.4
Proso millet	14.0	2.1	2.0	170	84.0	2.7
Sorghum	25.0	4.1-5.4	7.3	131.0	171.0	1.6
Pearl millet	42.0	8-11	10.9	307.0	137.0	3.1
Barnyard millet	20-22	5.0-18.6	-	-	82.0	3.0
Kodo millet	35.0	1.7	-	-	-	-
Little millet	17.0	9.3	8.1	129.0	133.0	3.7
Buckwheat†	31	3.8	2.5	378	167	1.7
Amaranth†	135	7.6	2.5	396	233	3.0
Maize†	7.0	2.7	35	287	127	2.2
Wheat	23-30	2.7-3.5	20.0	315.0	132.0	2.2
Rice	10-33	0.7-1.8	-	-	90.0	1.4

Source: Mishra et al 2022, and †https://fdc.nal.usda.gov/

Table 2. Vitamin A and B content (µg/100g of edible part) of various millets comparing with major cereal crops

Crop	Carotene (µg)	Thiamine B1 (µg)	Riboflavin B2 (µg)	Niacin B3 (µg)
Finger millet	42.0	0.42	0.19	1.1
Foxtail millet	32.0	0.59	0.11	3.2
Proso millet	-	0.15	0.05	2.0

Crop	Carotene (µg)	Thiamine B1 (µg)	Riboflavin B2 (µg)	Niacin B3 (µg)
Sorghum	47.0	0.37-0.38	0.13-0.15	3.1-4.3
Pearl millet	132	0.33-0.38	0.21-0.25	2.3-2.8
Barnyard millet	0	0.33	0.1	4.2
Kodo millet	-	0.15	0.09	2.0
Little millet	0	0.30	0.09	3.2
Buckwheat‡	0	0.24	0.16	3.84
Amaranth‡	-	0.06	0.17	0.75
Maize‡	90	0.38	0.21	3.6
Wheat	25.0	0.12-0.41	0.07-0.10	2.4-5.1
Rice	0	0.06-0.41	0.04-0.06	1.9-4.3

Source: Mishra et al 2022, and ‡https://fdc.nal.usda.gov/

Ranking of various millets for their major minerals, vitamins and macronutrient content comparing with common staple food of Nepal (rice) has given in Annex-I and II.

Among eight millets and rice, finger millet ranked first for Ca, K and Na content (Annex-I). Barnyard millet ranked the first for Fe content followed by pearl millet and little millet. Similarly, little millet ranked the first for Zn content followed by pearl millet and little millet (Annex-I). Foxtail millet ranked the first for thiamin content followed by finger millet and sorghum, whereas pearl millet ranked the first for riboflavin content followed by finger millet and sorghum (Annex-II). Similarly, barnyard millet ranked the first for niacin content followed by sorghum and foxtail millet (Annex-II).

Table 3. Macronutrient contents (g/100g of edible part) of various millets comparing the macronutrient contents of major cereal crops

Crop	Protein (g)	Carbo (g)	Fats (g)	Crude fiber (g)	Total energy (Kcal)
Finger millet	7.3-7.7	71.5-72.0	1.3-1.5	3.6	328-336
Foxtail millet	11.2-15.0	60.9-67.3	3.3-4.3	6.7-8.2	352-391
Proso millet	10.0-13.0	67.1	3.09	8.5	352
Sorghum	10.4-10.82	70.7-72.9	1.9-3.1	1.6-2.0	329-349
Pearl millet	11.4-11.8	67-69	4.87-5	2.1-2.3	361-363
Barnyard millet	6.2-13.0	55.0-65.5	2.2-3.9	9.8-13.6	300-307
Kodo millet	8.3-10.0	63.8-66.6	3.0-3.6	5.2-8.2	349-353
Little millet	6.2-15.0	60.9-67	4.7-5.2	7.6	329-341
Buckwheat#	8.9	75	2.5	11.4	334
Amaranth#	13.2	68.8	6.2	7.2	384
Maize#	9.4	74.3	4.7	7.3	365
Wheat	11.6-13.8	69.9-73.9	0.9-2.8	0.3-1.8	348-438
Rice	4.9-7.9	78.2-82.8	0.5-1.9	0.2-1.6	345-369

Source: Mishra et al 2022; and #https://fdc.nal.usda.gov/

Finger Millet and Calcium

Calcium is the fifth most abundant element present in human body after oxygen, hydrogen, nitrogen and carbon, it accounts for up to 1.9% of the body weight in adults. That means we need comparatively high amount of calcium for our daily life. Finger millet is the main food crop among staples that contains highest amount of Ca. Finger millet is very rich in calcium (>300 mg/100 g flour) when compared with major cereal crops. For example, the Ca content in finger millet (347 mg/100 g) is almost 16-times higher than rice (21.5 mg/100 g); 13 times higher than wheat (26.5 mg/100 g) (Mishra et al 2022) and three times higher than milk (Kumar et al 2016). From the Ca content point of view finger millet is a miracle crop and it is also called as superfood. Among eight millets and rice, finger millet ranked the first followed by pearl millet and *Kodo* millet for the Ca content and rice is the least or ninth (Annex-I). Finger millet also ranked first for K and Na content (Annex-I).

The Ca deficiency can cause low bone density, osteoporosis, colon cancer etc, so calcium is very important for a healthy life (Mishra et al 2022, Rao et al 2017). General observations in the hills of Nepal revealed that finger millet might have helped to alleviate the Ca and other micronutrients deficiency of hill population where consumption of finger millet was high.

It is evident from **Table 1** that finger millet is only one staple food that contains very high Ca. Finger millet and Calcium looks like synonym and regular consumption of finger millet supports for strong bones and teeth, blood clotting, regulation of heart beat, muscle contraction, nerve signalling etc (Maharajan et al 2021, Puranik et al 2017).

Calcium is required for various basic regulatory functions in human body; it is important for development of fetal skeleton, increasing birth weight, prenatal hypertension and avoidance of preeclampsia in pregnant women (Maharajan et al 2021). Ca deficiency is a serious health problem both in the developing countries of Asia and Africa (Sharma et al 2017). Elderly population is mostly affected by Ca deficiency predominantly in the form of osteoporosis and osteopenia (Puranik et al 2017). The onset of bone decalcification and demineralization leads to reduction in bone mass causing the osteoporosis among above 50 years old men and menopausal women (Michaelsson et al 2005).

The World Health Organization (WHO) considered that osteoporosis as the next main public healthcare concern globally, after cardiovascular diseases afflicting almost 75 million people in Europe, the United States of America and Japan. Hypocalcaemia disease occurs in human body when Ca levels are low in the blood (Maharajan et al 2021).

Milk and dairy products are one of the major sources of Ca in human diets. Consumption of one liter of milk per day is required to get the recommended amount of Ca (1000–1300 mg) (Thorning et al 2016). But most poor people in Nepal cannot afford to buy and consume a liter of milk per day and average consumption is <500 ml of milk per day. Unavailability of recommended amount of milk among poor population and person with lactose intolerance led to Ca deficiency (Maharajan et al 2021). In such case high Ca content in finger millet can help to alleviate Ca deficiency in developing countries including Nepal. In other words, finger millet can be a very good source of Ca also for poorer people as it can be available in cheaper price than other calcium rich commodities.

Finger Millet Yield and Its Consumption

Review of many literatures reveal those millets particularly finger millet is highly nutritious and has many more health benefits. However, productivity of these crops in farmers' fields is low or very low in Nepal mainly due to (i) its cultivation in marginal land with low soil fertility, (ii) mostly grown without manure and fertilizers or with residual nutrients applied in maize crop, (iii) very minimal use of improved seed, (iv) lack of proper weed management practices in most cases etc. This is linked with their cultivation in rain-fed sloppy *bariland* (cultivation without irrigation) and moisture stress during reproductive phase of the crop. These millets are labour intensive crop and farm-gate price is low or very low, as a result farmer do not like to grow millets as far as other less labour-intensive crops are available. On the other hand, consumer price of millets in urban area is high or very high; similar to medium or high-quality rice. Lack of awareness on the nutritive value of millets and their health benefits and also prevailing taboos have hindered the consumption of millets in Nepal. All these major hurdles are causing low productivity and very less consumption of millets that need to be properly resolved for increased consumption of millets in the country.

Way Forward

Looking into all the benefits of millets, it is very important to increase (i) the area under millets particularly finger millet, proso millet and foxtail millet in the country, (ii) their productivity and (iii) awareness at various level from grassroots' general people to high level planner/policy makers and administrators of the country regarding the nutritive value of finger millet and their health benefits, ways and means to increase the production and productivity and to increase the consumption of this miracle crop.

At least following steps/actions need to be taken to increase the area and productivity of millets so that its total production and consumption can be increased substantially:

- Increase the irrigated area in spring season (which is most-driest period of the year) and promote finger millet cultivation in spring season under partial irrigation facility in Khetland. This is in case of terai-Madhesh, river basin and low hills only. At least three irrigations (at transplanting, tillering and flowering time) are essential for spring crop,
- Finger millet should not be confined only in marginal soils of sloppy bariland under rainfed condition and this should also be promoted in irrigated khetland of low hills (<900m) and terai-Madhesh where irrigation and improved production practices can be adopted and crop can be harvested before transplanting of normal rice. This has been practiced in few places of Dhanusha district and yield reported is 2.4-3.0 t/ha, which is very high if compared with national average yield in Nepal (1.27 t/ha),
- Improved package of practices needs to be promoted/supported to farmers particularly in case of spring season crop where at least partial irrigation is possible,
- Threshing of millets is the most tedious, labour intensive and/or expensive task. Threshing and weeding are two major hurdles particularly in finger millet production that have contributed to reduce the area under finger millet in recent years. Hence, there should be a provision of subsidy for thresher machine appropriate for terai-Madhesh and for the hills,
- Provision of improved seeds – seed production at local level should get priority and improved seeds should be available locally so that general farmers can afford for improved seeds. It would be good to provide improved seeds at least on 50% subsidy to millet growers,
- Necessary support to producer groups or cooperatives for grinding/milling, packaging, labeling (branding) of various millets and provision of increased monetary value of millets so that farmers will be further motivated for millet production,
- Millets in general and particularly finger millet is a miracle crop and a superfood in developing countries like Nepal. So, the nutritive value and its health benefits should be communicated/ disseminated through various mass media, street drama, campaign etc so that consumption of finger millet food items can be increased. This will certainly contribute much on food and nutrition security of the country along with the reduction of rice consumption in the longer term.

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Annexes

Annex-I. Ranking of various millets for their major minerals content comparing with common staple food of Nepal (rice)

Crop	Ca (Mg)	Fe (mg)	Na (mg)	K (mg)	Mg (mg)	Zn (mg)
Finger millet	**I**	V	**I**	**I**	II	VI
Foxtail millet	IV	VI	V	III	VIII	V
Proso millet	VIII	VII	VI	IV	VI	IV
Sorghum	V	IV	IV	V	**I**	VII
Pearl millet	II	II	II	II	II	II
Barnyard millet	VI	**I**	-	-	VII	III
Kodo millet	III	VIII	-	-	-	-
Little millet	VII	III	III	VI	III	**I**
Rice	IX	IX	-	-	IV	VIII

Source: based on the data presented in **Table 1** above

Annex-II. Ranking of various millets for their vitamin A and B and macronutrient content comparing with common staple food of Nepal (rice)

Crop	Carotene (µg)	Thia B1 (µg)	Ribo B2 (µg)	Nia B3 (µg)	Protein	Carbo	Fats	Crude fiber	Energy (Kcal)
Finger millet	III	II	II	VII	VII	II	VIII	VI	VIII
Foxtail millet	IV	**I**	IV	III	**I**	VII	III	IV	**I**
Proso millet	-	VII	VII	VI	III	V	V	II	IV
Sorghum	II	III	III	II	IV	III	VII	VIII	VI
Pearl millet	**I**	IV	**I**	V	II	IV	**I**	VII	II
Barnyard millet	0	V	V	**I**	V	IX	VI	**I**	IX
Kodo millet	-	VII	VI	VI	VI	VI	IV	V	V
Little millet	0	VI	VI	III	IV	VIII	II	III	VII
Rice	0	VIII	VIII	IV	VIII	**I**	IX	IX	III

Source: based on the data presented in **Table 2** & 3 above

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Comparative Nutrient Evaluation of Finger Millet and Proso Millet with Rice, Wheat and Maize

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Abstract

The research aims to investigate disparities in nutritional attributes among finger millet, proso millet, and common cereals such as rice, wheat, and maize. A total of five finger millet varieties, two proso millet varieties, two rice varieties, two wheat varieties, and two maize varieties were sourced from various research stations affiliated with the National Agricultural Research Center (NARC). These selections exclusively comprised of registered or released varieties and landraces. Purposive sampling was conducted across three distinct plots. Proximate analysis was carried out, encompassing the quantification of mineral content, including iron, calcium, phosphorous, zinc, sodium, and potassium, across these crops. Zinc, sodium, and potassium levels in these cereal crops were assessed via atomic absorption spectroscopy. The results revealed that the protein content in proso millet and wheat exhibited a statistically significantly higher ($p<0.05$) compared to other crops. Meanwhile, the ash and fiber content within the millet group and wheat also displayed a significant elevation ($p<0.05$) when contrasted with the rice and maize varieties. Calcium content in the millet group was found to range from 207.68 to 319.41 mg/100 g, demonstrating a significantly higher ($p<0.05$) in comparison to other crops, which ranged from 14.16 to 78.24 mg/100 g. Iron content in wheat closely mirrored that of the millet group and was significantly higher ($p<0.05$) than in rice and maize. Similarly, zinc, sodium, and phosphorous content in maize paralleled that of the millet group, with significantly higher levels ($p<0.05$) than those found in rice and wheat. This research highlights millet groups as a rich source of essential minerals. However, further investigation is warranted to assess the bioavailability of these nutrients.

Keywords: Calcium, crude fiber, principal component analysis, millet, protein, sodium, zinc

Introduction

Cereals constitute the primary dietary staple on a global scale, with rice being the predominant choice, closely followed by maize and wheat (FAO 2021). Lesser-known cereals such as finger millet, proso millet, and buckwheat remain underappreciated in both kitchens and markets, primarily due to a lack of awareness regarding their exceptional nutritional benefits (Drewnowski et al 2020). Efforts are currently underway by the Nepal Agricultural Research Council (NARC) to develop various millet varieties based on their agro-economic performance. Furthermore, they are actively working on the creation of value-added technologies that can be easily adopted by small and medium-scale entrepreneurs (NARC 2021).

Nevertheless, the convenience and established dietary habits have led individuals to prefer readily available cereals such as rice and wheat.

Millet, due to its impressive root penetration capability in soil, requires less water in comparison to staple crops such as wheat and rice, rendering it a highly resource-efficient option. Additionally, millet contributes to the enhancement of soil biodiversity and health, as indicated by Sing et al (2014). Furthermore, millet demonstrates remarkable adaptability, thriving in acidic and saline soils, and exhibiting resistance to temperatures as high as 46°C, making it a resilient crop, as observed by Saleh et al (2013). Millet boasts a substantial content of essential minerals, fibers, and compounds with diverse health-enhancing properties, including anti-inflammatory, radical-scavenging, anti-diabetic, and anti-cancer attributes, as reported by Kumar et al (2016) and Shobana et al (2013). These properties hold significant potential for utilization and warrant exploration through awareness programs aimed at improving nutritional status and addressing food security issues in rural areas. This, in turn, can reduce the population's reliance on rice, wheat, and maize while promoting overall health. The unique culinary diversity of millet in Nepal encompasses various dishes such as *haluwa*, *dhido*, *nimki*, *pan cake*, *khir*, and *puwa*. The incorporation of millet into flour for the production of bakery items like bread, biscuits, pizza, cake, and doughnuts not only enhances the nutritional value of these products but also introduces culinary diversity, as suggested by Ojha et al (2020). This approach has the potential to encourage the utilization of underutilized crops, ultimately leading to improved health and a better society. The nutritional value, particularly micronutrient content, varies across different types and varieties of cereals (Ojha et al 2020). This research endeavors to investigate the nutritional profile of millet and make a comparative analysis with the currently available varieties of rice, wheat, and maize.

Materials and Methods

Materials

The study involved the collection of five different finger millet varieties: Dalle Kodo 1, Sailung Kodo 1, Okhle Kodo 1, Kabre Kodo 2, and Kabre Kodo 2. These varieties were sourced from the Hill Crops Research Program, Dolakha. Additionally, two proso millet varieties, Dudhe Chino and Hade Chino, were obtained from the Agriculture Research Station, Jumla. The study also included two rice varieties (Hardinath 6 and Bahuguni 1), two wheat varieties (Gautam and Bijaya), and two maize varieties (Rampur Composite and Arun 2), which were acquired from the National Paddy Research Program, Dhanusa, the National Wheat Research Program, Bhairawa, and the National Maize Research Program Chitwan, respectively.

Research design and data analysis

The design was completely randomized design. Grains were collected from three distinct locations. To achieve homogenization, we combined samples from the three plots, aiming to create a consistent and uniform mixture wherein the unique characteristics of each plot merged to form a representative composite sample. By amalgamating and homogenizing the original samples, our objective was to obtain a more comprehensive and representative dataset for analysis. This methodology ensures that our findings accurately portray the overall conditions and properties of the entire study area, minimizing the influence of localized variations. We conducted triplicate analyses, performing each analysis three times for each sample, and expressed the results as the mean and standard error of the mean. To discern differences between treatments, we employed the Student-Newman-Keuls test using SPSS software version 26. The nutrient profiles are categorized under cereals, and we've presented the data in a pie chart format to facilitate a common understanding of nutrient distribution among various cereal groups. The principal component analysis and cluster analysis were carried out by using the software JMP Pro version 17.

Proximate analysis

The moisture content was determined using the hot-air oven method, involving drying the sample at 105°C until a constant weight was achieved, following the AOAC method number 930.15 (AOAC 2005). For cereals, the protein content was calculated based on the nitrogen content, which was measured using the Kjeldahl method as outlined in the AOAC method number 920.152 (AOAC 2005). The fat content of the cereals was determined through solvent extraction using a Soxhlet apparatus with petroleum ether as the solvent, in accordance with AOAC method number 991.36 (AOAC 2005). To determine the crude fiber content of cereals, the AOAC method number 934.01 was employed. The total ash content of the cereals was determined following the AOAC method number 945.46 (AOAC 2005). Total carbohydrate content (Ranganna 2002) was calculated by the difference method as below:

$$Carbohydrate\ (\%\ dry\ basis) = 100 - (crude\ protein + total\ ash + crude\ fiber + crude\ fat)$$

Mineral analysis

The calcium, iron, and phosphorous content of cereals were determined in accordance with the method outlined by AOAC (2005) by using Cary UV-Vis spectrophotometer, Agilent, USA. Sodium, potassium, and zinc levels within the food matrix were quantified using Flame Atomic Absorption Spectroscopy (Agilent AA 240FS) following the AOAC (2005) protocol.

Results

Proximate analysis of cereals

The proximate analysis of cereals was conducted, and the results, expressed on a dry basis, are presented in **Table 1**. Notably, among the cereals, 'hade chino' exhibited a significantly higher ($p<0.05$) protein content (14.34%). Following this, 'dudhe chino' and wheat also displayed significantly higher ($p<0.05$) protein content, when compared to rice, maize, and finger millet. In terms of fat content, 'proso millet' had a significantly higher ($p<0.05$) amount closely followed by maize. Conversely, finger millet and rice showcased the lowest ($p<0.05$) fat content. Moving on to ash content, 'proso millet' exhibited the highest value ($p<0.05$). This was followed by wheat and millet, while the lowest ash content was found in rice and maize. In the realm of crude fiber, the millet group displayed the highest content ($p<0.05$), followed by wheat and maize. Conversely, rice exhibited the lowest ($p<0.05$) crude fiber content. Notably, carbohydrate content was found to be significantly higher ($p<0.05$) in rice and millet, whereas it was notably lower in wheat and proso millet.

Table 1. Proximate composition (g/100 g dry matter) of cereals

Cultivar	Protein	Fat	Ash	Crude fiber	Carbohydrate
Dalle kodo 1	8.83±0.26[c]	1.27±0.07[d]	2.56±0.03[bc]	4.71±0.02[b]	82.63±0.17[cd]
Sailung kodo 1	8.34±0.12[c]	1.09±0.08[d]	2.49±0.03[bc]	2.96±0.11[d]	85.12±0.24[ab]
Okhle kodo 1	8.96±0.11[c]	1.26±0.04[d]	2.70±0.08[bc]	4.08±0.06[cb]	83.01±0.21[cd]
Kabre kodo 2	8.63±0.20[c]	1.22±0.05[d]	2.37±0.18[c]	4.05±0.08[cb]	83.72±0.32[bc]
Kabre kodo 1	8.22±0.14[c]	1.09±0.03[d]	2.68±0.07[bc]	4.43±0.07[cb]	83.58±0.19[bc]
Dudhe chino	12.01±0.49[b]	5.07±0.14[a]	3.97±0.07[a]	3.92±0.21[c]	75.03±0.52[e]
Hade chino	14.34±0.11[a]	5.11±0.25[a]	3.90±0.12[a]	5.47±0.18[a]	71.17±0.49[f]
Hardinath 6	9.53±0.16[c]	1.03±0.06[d]	0.62±0.02[e]	1.10±0.26[e]	85.42±0.49[a]
Bahuguni 1	9.57±0.11[c]	0.81±0.01[d]	0.53±0.02[e]	1.12±0.16[e]	85.67±0.21[a]

Cultivar	Protein	Fat	Ash	Crude fiber	Carbohydrate
Gautam	13.04±0.06^{b}	1.81±0.07^{c}	2.80±0.04^{b}	2.61±0.33^{d}	79.73±0.31^{e}
Bijaya	13.05±0.07^{b}	1.80±0.05^{c}	2.45±0.03^{bc}	2.49±0.12^{d}	80.21±0.22^{e}
Rampur composite	8.78±0.95^{c}	4.60±0.01^{b}	0.14±0.01^{e}	2.76±0.26^{d}	83.72±0.85^{cb}
Arun 2	9.41±0.54^{c}	4.34±0.23^{b}	1.66±0.14^{d}	2.84±0.16^{d}	81.76±0.73^{d}

Note: All the results were expressed on a dry basis. The value after ± is the standard error of mean determined from series of triplicate analysis. The value represented by different letters in the same column is significantly different at a 5% level of significance.

The proximate components (protein, fat, ash, and crude fiber) of cereals are depicted in **Figures 1.1** through **1.4**. The results indicate that the highest protein content was observed in proso millet (13.18%) and wheat (13.05%), with rice (9.55%), maize (9.1%), and finger millet (8.6%) following in descending order. In terms of fat content, proso millet had the highest percentage (5.09%), followed by maize (4.47%), wheat (1.18%), finger millet (1.19%), and rice (0.92%). The ash content was most prominent in proso millet (3.94%), followed by wheat (2.63%), finger millet (2.56%), maize (0.9%), and rice (0.58%). Crude fiber content was found to be highest in proso millet (4.7%), followed by finger millet (4.05%), maize (2.8%), wheat (2.55%), and rice (1.11%). In conclusion, the proximate analysis demonstrates that proso millet ranks as the superior cereal among those examined, while rice lags behind in terms of nutritional composition.

The data presented by Rao et al (2017) demonstrates that the protein content of proso millet surpasses that of wheat, rice, maize, and other millets. In contrast, the fat content of proso millet, as indicated by Rao et al (2017) data, was higher. This variation can be attributed to the use of whole proso millet flour in their research. However, the nutrient content of other cereals closely aligns with the findings of Rao et al (2017). In their review, Kalsi and Bhasin (2023) reaffirmed that proso millet outperforms other cereals in terms of protein, fat, and fiber content.

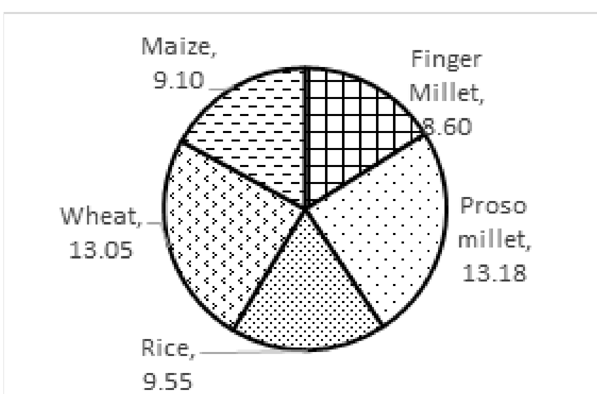

Figure 1.1. Protein content of cereals

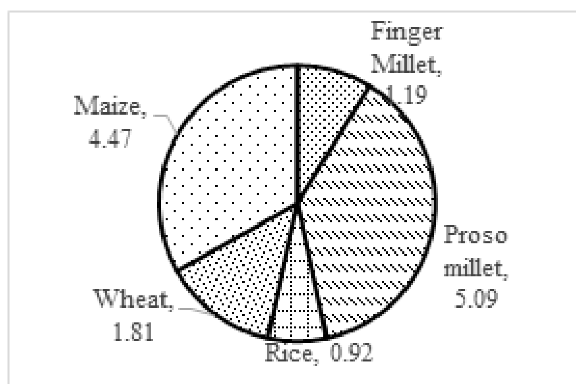

Figure 1.2. Fat content of cereals

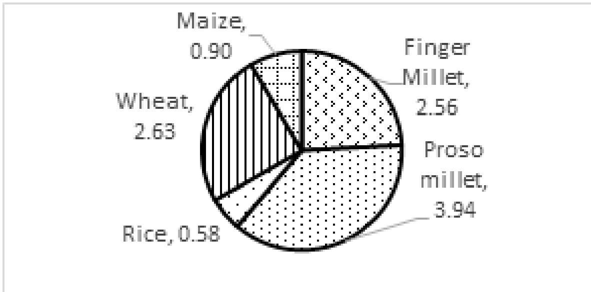

Figure 1.3. Ash content of cereals

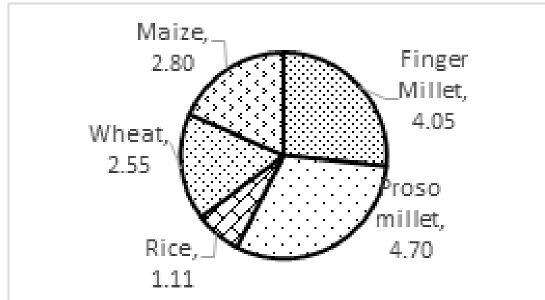

Figure 1.4. Crude fiber content of cereals

Mineral content of cereals

The analysis focused on six minerals (iron, calcium, phosphorous, sodium, potassium, and zinc) within the collected cereal samples, as outlined in **Table 2**. Results are expressed in milligrams per 100 grams of dry matter. Among these cereals, Hade Chino exhibited a significantly higher ($p<0.05$) iron content (6.4) when compared to the other crops. Proso millet and Dalle Kodo 1 displayed significantly higher ($p<0.05$) calcium content compared to other varieties. On the contrary, the finger millet group exhibited significantly higher ($p<0.05$) calcium content compared to rice and maize. The phosphorous content was significantly higher ($p<0.05$) in Hade Chino (434) compared to other cereals, followed by Dudhe Chino, millet, and maize. In terms of sodium content, Okhle Kodo 1 and Rampur Composite demonstrated significantly higher ($p<0.05$) values in comparison to other cereal varieties. Hade Chino and Kabre Kodo 2 exhibited significantly higher ($p<0.05$) potassium content when compared to other crops, with rice displaying the lowest ($p<0.05$) potassium content. The zinc content was found to be significantly highest ($p<0.05$) in Kabre Kodo 2 and significantly lowest in rice ($p<0.05$).

Table 2. Mineral content (mg/100 g dry matter) in varieties and landrace of cereals

Cultivar	Iron	Calcium	Phosphorous	Sodium	Potassium	Zinc
Dalle kodo 1	4.38±0.27^{bc}	305.05±19.98^{a}	278.86±3.47^{b}	4.72±0.09^{ab}	493.56±2.85^{bc}	2.42±0.02^{c}
Sailung kodo 1	4.94±0.26^{b}	265.21±12.73^{b}	270.27±5.26^{b}	4.72±0.09^{ab}	489.95±2.80^{bc}	2.62±0.06^{c}
Okhle kodo 1	3.66±0.14^{bcd}	212.31±3.59^{c}	278.38±7.37^{b}	5.04±0.03^{a}	497.62±2.37^{b}	2.53±0.05^{c}
Kabre kodo 2	4.41±0.21^{bc}	251.36±9.78^{b}	270.82±5.04^{b}	4.57±0.08^{bc}	511.33±5.77^{a}	3.38±0.08^{a}
Kabre kodo 1	3.25±0.08^{bcd}	207.68±6.71^{c}	272.88±5.51^{b}	4.82±0.06^{ab}	485.33±3.06^{c}	2.90±0.03^{b}
Dudhe chino	4.14±0.15^{bc}	319.41±7.3^{a}	319.84±17.04^{b}	4.31±0.16^{c}	464.45±3.00^{d}	2.43±0.08^{c}
Hade chino	6.40±0.38^{a}	311.56±14.37^{a}	434.76±22.72^{a}	4.75±0.09^{ab}	507.00±0.24^{a}	2.62±0.05^{c}
Hardinath 6	3.57±0.40^{bcd}	16.53±2.38^{e}	66.28±18.66^{d}	2.40±0.02^{e}	134.39±0.66^{h}	1.29±0.02^{e}
Bahuguni 1	2.89±0.23^{cd}	14.16±1.15^{e}	136.96±10.35^{c}	2.66±0.04^{d}	140.85±1.56^{h}	1.34±0.02^{e}
Gautam	3.36±0.05^{bcd}	78.25±0.61^{d}	160.51±3.25^{c}	2.32±0.05^{e}	351.70±2.36^{e}	2.16±0.06^{d}
Bijaya	3.60±0.11^{bcd}	75.70±1.34^{d}	172.97±6.96^{c}	2.21±0.01^{e}	350.07±1.44^{e}	2.15±0.01^{d}
Rampur composite	2.23±0.02^{d}	16.42±2.14^{e}	263.83±8.77^{b}	4.94±0.06^{a}	326.44±1.45^{f}	2.60±0.02^{c}
Arun 2	3.03±0.35^{cd}	15.86±2.18^{e}	274.13±26.10^{b}	4.57±0.03^{bc}	318.39±1.64^{g}	2.55±0.03^{c}

Note: All the results were expressed on a dry basis. The value after ± is the standard error of mean determined from triplicate analysis. The value represented by different letters in the same column is significantly different at a 5% level of significance.

The mineral content of cereals, specifically iron, calcium, phosphorous, sodium, potassium, and zinc, is presented in **Figures 2.1** through **2.6**. The data reveals that the iron content was most abundant in proso millet at 5.27 mg/100 g, followed by finger millet at 4.13 mg/100 g, wheat at 3.48 mg/100 g, rice at 3.23 mg/100 g, and maize at 2.63 mg/100 g. In terms of calcium and phosphorous, proso millet exhibited the highest values, with calcium at 315.49 mg/100 g and phosphorous at 377.3 mg/100 g. Conversely, maize displayed the lowest calcium content at 16.14 mg/100 g, while rice had the lowest phosphorous content at 101.62 mg/100 g. Regarding sodium, potassium, and zinc, finger millet displayed the highest concentrations. Based on the mineral content, it is evident that both proso millet and finger millet surpass rice, maize, and wheat in terms of nutritional quality.

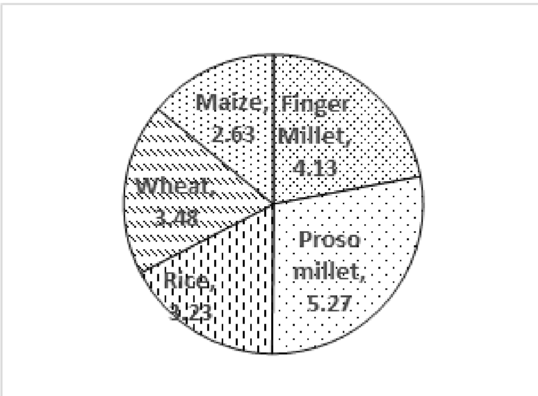

Figure 2.1. Iron content of cereals

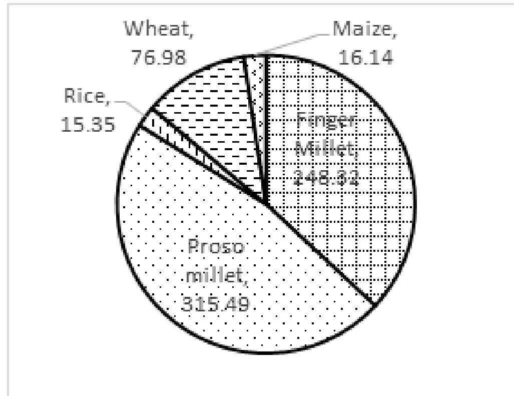

Figure 2.2. Calcium content of cereals

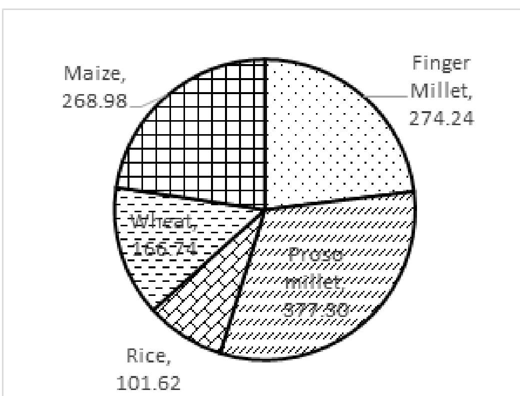

Figure 2.3. Phosphorous content of cereals

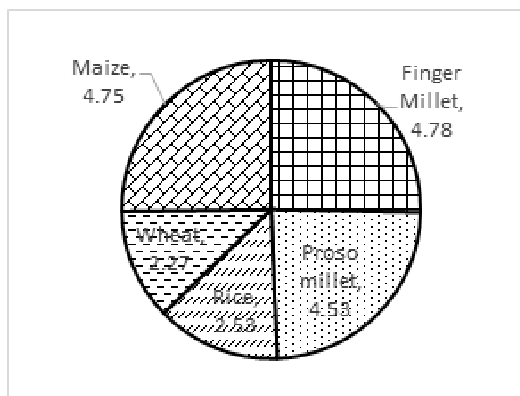

Figure 2.4. Sodium content of cereals

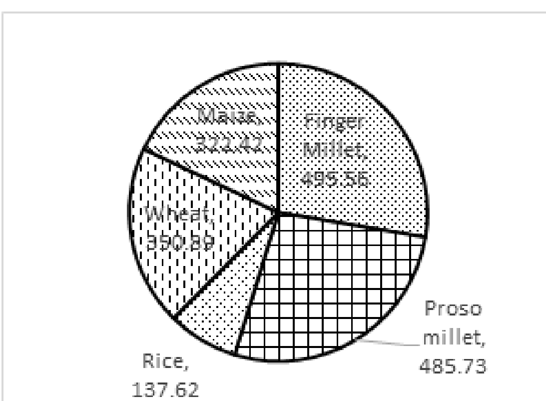

Figure 2.5. Potassium content of cereals

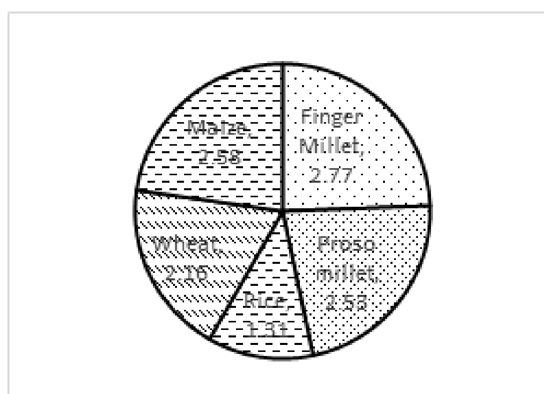

Figure 2.6. Zinc content of cereals

Rao et al (2017) reported that the calcium content in finger millet exceeded that of rice, maize, and wheat. In contrast, the iron content in millet was comparable to that of other cereals, which contradicts our findings. Our results indicate a significant disparity. Furthermore, our analysis of proso millet revealed higher mineral content compared to the figures reported by Kalsi and Bhasin (2023).

Principal component analysis

The principal component analysis was carried out based on covariances and the K-mean cluster analysis shows that the n=6 cluster is optimum. The results are shown in **Figure 3.1-3.2** and **Table 3-4**. From **Table 3**, we can say that 95% of the variance is captured by principal components 1 and 2, so another component is not considered for result interpretation.

In **Figure 3.1**, it is evident that ash, iron, and calcium are exclusively associated with the first principal component. This indicates that ash, iron, and calcium exhibit the highest loadings, characterized by strong correlation coefficients, with the first principal component. In other words, any alterations or fluctuations in these three variables contribute significantly to the variance encapsulated by the first principal component. When ash, iron, and calcium experience concurrent increases or decreases, they exert a notable influence on the value of the first component. In contrast, carbohydrate demonstrates a negative association with both the first and second principal components. An increase in carbohydrate content leads to a decrease in the values of both the first and second principal components. This implies an inverse relationship between carbohydrate content and these two components. Conversely, the remaining parameters, namely protein, fat, crude fiber, phosphorous, sodium, potassium, and zinc, exhibit positive correlations with both component 1 and component 2. An increase in the values of these variables results in a corresponding increase in the values of both the first and second components. This indicates a positive relationship between these variables and both components.

In **Figure 3.2**, cereals are classified into six distinct categories. Specifically, rice is categorized within cluster 1, wheat within cluster 2, hade chino within cluster 3, maize within cluster 4, millet within cluster 5, and dudhe chino within cluster 6. This cluster data holds potential utility for the food industry, enabling them to enhance product development and refine marketing strategies. Furthermore, the nutritional information derived from this study can be instrumental in formulating specialized diets for various demographic groups.

Table 3. Eigenvalue obtained from the PCA based on covariances

Number	Eigenvalue	Percent	Cum Percent	ChiSquare	DF	Prob>ChiSq
1	35626.75	87.467	87.467	2904.90	65.000	<.0001*
2	3121.92	7.665	95.131	2237.97	54.000	<.0001*
3	1965.85	4.826	99.958	2019.43	44.000	<.0001*
4	15.13	0.037	99.995	696.408	35.000	<.0001*
5	0.98	0.002	99.997	249.965	27.000	<.0001*
6	0.54	0.001	99.998	188.912	20.000	<.0001*
7	0.35	0.001	99.999	143.795	14.000	<.0001*
8	0.15	0.000	100.000	90.573	9.000	<.0001*
9	0.0791228	0.000	100.000	60.229	5.000	<.0001*
10	0.0340221	0.000	100.000	32.972	2.000	<.0001*
11	0.0046036	0.000	100.000	0.000	0.000	.

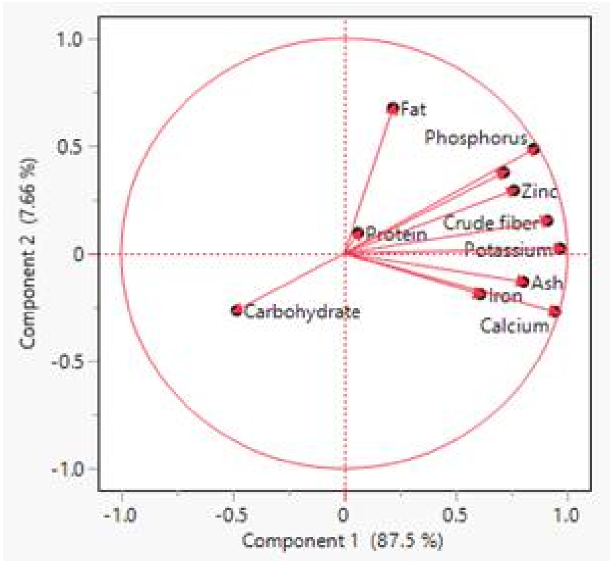

Figure 3.1. Plotting of 13 variety of crops based on the nutrient content analyzed

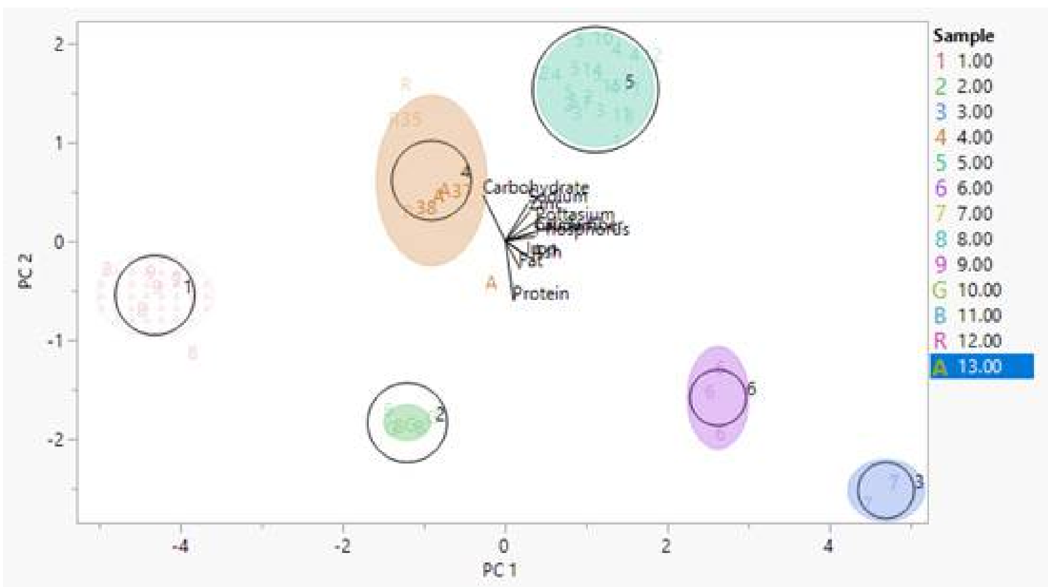

Figure 3.2. Clustering of 13 cereals variety in six cluster based on PC1 and PC2

Table 4. Mean value of nutrients in six different cluster

Cluster	Pro (%)	Fat (%)	Ash (%)	CruFi (%)	CHO (%)	Fe (mg%)	Ca (mg%)	P (mg%)	Na (mg%)	K (%)	Zn (%)
1	9.55	0.92	0.58	1.10	85.55	3.23	15.35	101.62	2.53	137.62	1.31
2	13.04	1.81	2.63	2.55	79.97	3.48	76.98	166.74	2.27	350.88	2.15
3	14.34	5.11	3.90	5.47	71.18	6.40	311.56	434.76	4.75	507.00	2.62
4	9.09	4.47	0.90	2.80	82.74	2.63	16.14	268.98	4.76	322.41	2.58
5	8.60	1.19	2.56	4.05	83.61	4.13	248.32	274.24	4.78	495.56	2.77
6	12.01	5.07	3.97	3.92	75.03	4.14	319.41	319.84	4.31	464.45	2.43

Note: Pro=Protein, CruFi=Crude fiber, CHO=Carbohydrate, Fe=Iron, Ca=Calcium, P=Phosphorous, Na=Sodium, K=Potassium, Zn=Zinc. Cluster 1-Rice, Cluster 2-wheat, Cluster-3-hade chino, Cluster-4-maize, Cluster-5-Finger millet, Cluster-6-dudhe chino

Conclusion

Proso millet and finger millet exhibit a superior nutritional profile, surpassing wheat, maize, and rice. Subsequent research reveals positive correlations among protein, fat, crude fiber, phosphorus, sodium, potassium, and zinc, while carbohydrate demonstrates a negative correlation with both principal component 1 and component 2. On the basis of nutritional attributes, the cereals can be classified into five distinct groups, further subdivided into six clusters. Notably, millet varieties emerge as rich sources of protein and fiber. Therefore, there is a compelling need to advocate for the increased consumption of finger millet and proso millet to alleviate hidden hunger, owing to their heightened mineral content in comparison to mainstream cereals such as rice, wheat, and maize. In light of the potential presence of antinutritional factors in cereals, it is imperative to conduct further research to investigate the impact of processing on mineral bioavailability.

Acknowledgements

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Effect of Germination Temperature and Time on Minerals Content in Finger Millet

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Abstract

The current study investigates the impact of germination duration and temperature on mineral content alterations in Nepalese finger millet (variety *dalle*). Germination trials were conducted at temperatures of 25°C, 35°C, and 45°C for germination periods of 0, 36, and 72 hours. Specifically, changes in key minerals, such as iron and calcium, were scrutinized. The calcium was analyzed with volumetric analysis whereas iron was determined using spectrophotometric method. The initial mineral composition of the raw finger millet was determined as follows: calcium (10.4467 ± 0.09 mg/100g) and iron (5.0806 ± 0.02 mg/100g). Upon exposing the finger millet seeds to various germination temperatures, there was significant increase in calcium and iron content post-germination, recording increments of 95.88% and 1.61%, respectively. The germination time and temperature had significant effect on iron and calcium levels. Through meticulous analysis, an optimized germination time of 72 hours at a temperature of 25°C was identified. The outcomes of this research hold practical implications for millet processing industries, furnishing them with valuable insights into optimal germination conditions to amplify the mineral content, notably calcium and iron. By adhering to the established germination time and temperature parameters, these industries can enhance the nutritional value of finger millet products, contributing to improved dietary benefits and overall consumer health.

Keywords: Mineral content, temperature, germination, iron, calcium

Introduction

Millet belongs to the group of small-seeded species of cereal crops or grains which are annual plants (Shiihii et al 2011). Millets are produced abundantly for food and fodder all over the world. As compared to most other cereals like maize, millets have the unique capacity to resist and live under severe conditions of continuous or intermittent drought. For millions of individuals, millet serves as their primary source of protein and calories. Although millets are now not considered to be a single significant item in the food baskets of North America and Europe, their significance as a component of multi-grain and gluten- free cereal products have been emphasized (Reddy et al 2019). However, millet is a common dietary ingredient in many African and Asian regions, especially among the less-affluent parts of their respective cultures. Millet is used to make bread (fermented or unfermented), porridges, and snack foods (Reddy et al 2019).

Finger millet [*Eleusine coracana* (L.) Gaertn.], proso millet [Panicum miliaceum L.], and foxtail millet [Setaria italica (L.) P. Beauv.] are the three main millets cultivated in Nepal. In addition, crops such pearl millet [Pennisetum typhoides (Burm.f.)], sorghum [Sorghum bicolor (L.) Moench], barnyard millet [Echinochlo afrumentacea Link], etc are also cultivated (Ghimire et al 2017). For rural impoverished agricultural communities in Nepal's hills that live in subsistence- based and remote situations, millets are a crucial but underutilized food crop. They are so nutrient-dense that they are also referred to as Himalayan Super-foods. National Seed Board of Nepal have registered five varieties of finger millets: Okhle-1, Dalle-1, Kabrekodo-1, Kabre kodo-2, and Sailung kodo-1. However, no further millet species variations have been released in the country (Ghimire et al 2017).

Millets are rich in protein, essential fatty acids, dietary fiber, vitamin B, minerals like calcium, iron, zinc, potassium, and magnesium, which help to regulate blood pressure, blood cholesterol, and thyroid disorders as well as the risk of developing cardiovascular disease, celiac disease, and a host of other age-related chronic diseases (Sheethal et al 2022). However, studies also reported that cereals contain “anti-nutrients”, such as phytic acid, that interfere with nutrient absorption in the human body (Sheethal et al 2022).

Materials and Methods

Cleaning

First, 250 g of millet grains were sorted using woven bamboo trays (nanglo). Husk, young grains, and light particles were removed during this phase by winnowing, while heavier particles like specks and stones were separated by gravity during the winnowing process. The millet was thoroughly de-hulled before using a grinder to turn it into powder.

Steeping and Spreading

One portion of the well cleaned millet was kept in muslin fabric bags at room temperature before being soaked in a beaker for 24 hours in millet: water (1:3) solution. The sample's light components were scraped off. To once clean the seeds, agitation was used. Steep was at room temperature. After straining the water, the steeped millet was put over the tray, with a thickness of 0.5 to 1.0 cm, and a muslin towel covering it. By sprinkling water on the muslin cloth every six hours, it was possible to keep the grain from drying out. To balance the temperature and moisture during germination, the grain was sometimes rotated and stirred.

Germination and drying

The millet grain, which had a moisture content of 37%, was spread out on a tray covered with muslin fabric, refreshed with water by spraying it every six hours, and incubated at temperatures of 25ºC, 35 ºC, and 45 ºC for a total of 0, 36, and 72 hours, respectively, in an incubator. At that time, mixing was done to balance the temperature and moisture. After 24 hours of germination, the rootlets could be seen. After 0, 36, and 72 hours, the germination stopped when the grain length of the acrospires (rootlets) was the same. The grain’s further germination was stopped by constantly drying it in a cabinet drier at 60°– 62°C until the moisture content dropped to 8% before it was pulverized in a grinder. After that, the flour was prepared for usage.

Experimental designs for germination varying temperature, time

The experimental design was designed from software called design expert 13 as is shown in **Table 1**.

Table 1. Experimental design for steeping temperature, germination temperature and time for millet

Std	A: Germination Temperature (℃)	B: Time(days)
1	25	0
2	45	0
3	25	0
4	45	0
5	25	3
6	45	3
7	25	3
8	45	3
9	25	1.5
10	45	1.5
11	35	1.5
12	35	1.5
13	35	0
14	35	3
15	35	1.5
16	35	1.5
17	35	1.5
18	35	1.5
19	35	1.5

Analytical methods

The findings of every chemical analysis were given on a dry basis after being completed in wet form. For each parameter, all samples were examined simultaneously to reduce systemmistakes.

Calcium determination

According to Rangana's (2007), the calcium content in finger millet was identified.

$$Titer = \frac{4(V_1 + V_2 + V_3)}{3} + V_4$$

V_1, V_2, V_3 = Titer of the flasks 1, 2 and 3 respesctively

V_4 = volume of consumed by filter paper

$$Ca^{++}(mg/100, drybasis) = \frac{Titer \times 0.2 \times V_T\ \ ml\ \ \times 100^{*} \times 100}{V_g\ \ ml\ \ \times wt\ of\ sample\ \ g\ \ \times dry\ matter(\%)}$$

V_T =Total volume of ash solution

V_g = Volume taken for estimation

$*$ = volume (ml) made up (in the above case,100ml)

Iron determination

According to Rangana's (2007), the iron content in finger millet was identified.

$$= \frac{\begin{array}{c} Absorbance\ of\ sample \times mg\ iron\ \ ml\ \ of\ standard\ solution \times \\ total\ vol\ of\ ash\ solution\ \ ml\ \ \times 100 \times 100 \end{array}}{\begin{array}{c} Absorbance\ of\ standard \times Aliquot\ of ash\ solution\ \ ml\ \ \times \\ wt\ of\ sample\ taken\ for\ ashing(g) \times Drymatter(\%) \end{array}}$$

Results and Discussion

Calcium

The calcium content ranged from 12.13-37.08 mg/100g dry basis (**Figure 1**). Equation-1 was selected for representing the variation of lateral expansion ratio and for further analysis,

Total calcium coded equation = $15.30+2.47A+7.24B+3.02+3.02A^2+0.3318B^2$............ (1)

Where A and B are the coded values of germination temperature (˚C) and germination time (hours) respectively. The above quadratic equation (1) total calcium had highly significant positive linear effect of germination temperature and germination time.

From the experiment, the result obtained is that the germination temperature does increase the calcium content and there is a direct association between these parameters. It was discovered that the non-germinated finger millet had calcium concentration of 10.4467mg/100g which increased by 95.88%. In recent study, calcium content of raw finger millet flour increased from 822.40 to 4,158.40 ppm after germination (Owheruo et al 2019). In another study, germination increased the Ca contents by 9.77% compared to raw finger millet ie, from 124 ± 0.16mg/100g to 147 ± 0.10mg/100g (Azeez et al 2022).

These results are comparable with those of (Suma and Urooj 2014), who reported an increase in calcium content of pearl millet on germination for 72 hours. The increase in calcium might be due to loss of organic dry matter from the grains during germination and hence increase in the percentage of calcium in the grains.

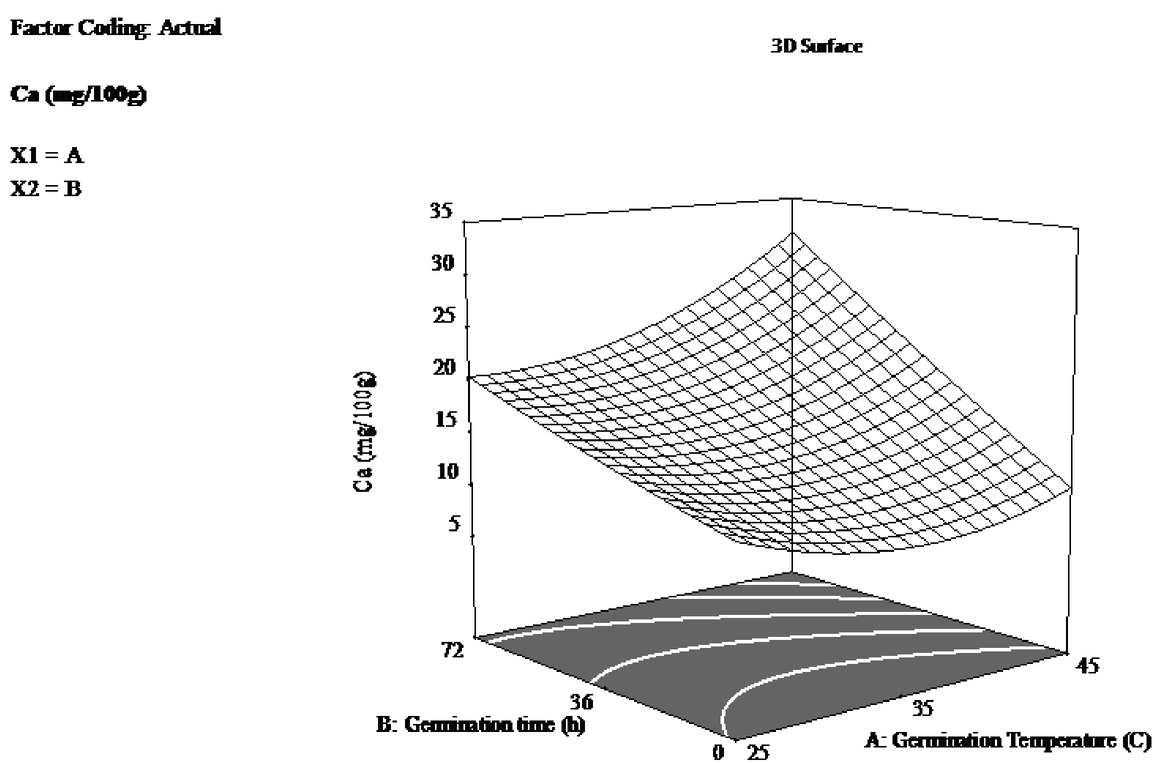

Figure 1. Response surface plot for calcium

Iron

The iron content ranged from 18.03-28.62mg/100g dry basis. Equation-2 was selected for representing the variation of lateral expansion ratio and for further analysis.

Total iron coded equation= 5.40 - 0.0296A + 0.3925B ...... (2)

Where A and B are the coded values of germination temperature (˚C) and germination time (hours) respectively. The above quadratic equation (2) total iron had highly significant positive linear effect of germination temperature (A) and germination time (B). Three- dimensional plot for the total iron as a function of germination temperature (˚C) and germination time (hours) at center value given in **Figure 2**. This graph shows with increase ingermination time and germination temperature iron also increases.

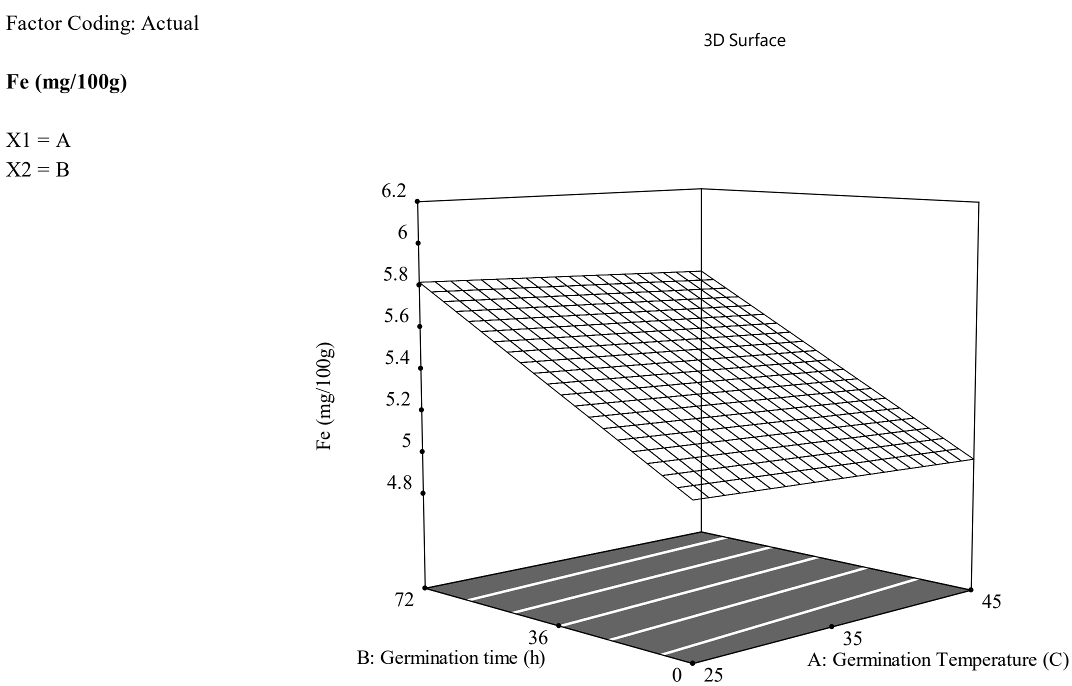

Figure 2. Response surface plot for iron

From the experiment, the germination temperature does increase the iron content and there is a direct association between these parameters. Similarly, germination time also increases the iron content and they are positively associated. It was discovered that the non-germinated finger millet had iron concentration of 5.806mg/100g which increased by 1.619015% to 5.9mg/100g. In recent study, germination increased iron content from 3.7±0.06 - 4.5±0.05mg/100g (Chauhan and Sarita 2018). The Fe contents increased from 181 ± 0.75mg/100g-406 ± 0.42mg/100g of finger millet increased by 124% after germination (Azeez et al 2022).

Optimization of parameters

A numerical multi-response optimization technique was applied to determine the optimum values of calcium and iron. The assumptions were to develop a combination of time and temperature which would germinate. Under these assumptions by design expert, the uncoded optimum conditions for the calcium and iron were found 20.452 mg/100g and 5.81 mg/100g and the level of optimization is shown in **Table 2**.

Table 2. Optimization of different parameters

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
GerminationTemperature	In a range	25	45	1	1	3
Germinationtime	In a range	0	72	1	1	3
Calcium	Maximize			1	1	3
Iron	Maximize			1	1	3

Optimized graphs

The millet was germinated in temperature and time of 25°C, and 72 hours and following graphs were obtained which is shown in **Figure 3**.

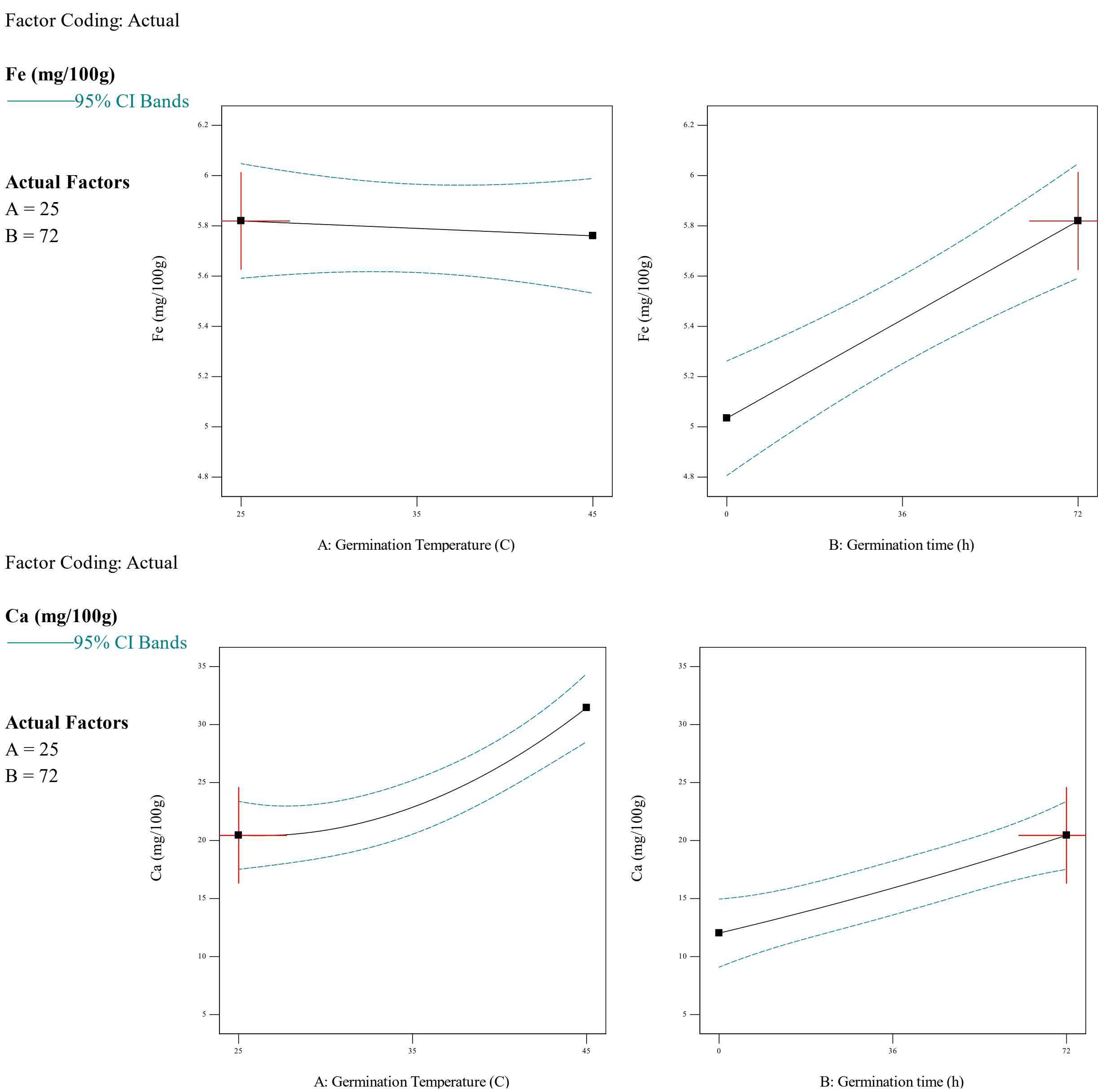

Figure 3. Optimized Iron (above) and Calcium (below) Content varying germination time and temperature (2D)

Conclusion

The effect of germination time on calcium levels was notable, with an observed increase of 95.88%. This suggests that a longer germination period can lead to significantly higher calcium content in the plants, potentially making them a richer source of this essential mineral. Additionally, the study also examined the influence of temperature on these mineral levels. The findings indicated a more modest increase of 1.61% in iron content when the germination temperature was altered. While this increase may not be as substantial as that seen with calcium, it still highlights the importance of temperature control in optimizing nutrient levels in plants. The ideal germination time was determined to be approximately 72 hours, while a temperature of 45ºC proved to be the most favorable for achieving these desired nutrient levels. These findings offer valuable insights for agricultural practices and the cultivation of plants with enhanced nutritional profiles.

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Glycemic Index of Millet Composites

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Abstract

The present study was for the quality assessment of low glycemic millet, the nutri-cereals based composites for Missi Roti. Survey revealed that Missi Roti was consumed by all the diabetic subjects, but the type of millet selected and proportion used varied. Composite flour was developed for most commonly produced and consumed millets ie bajra (BJ), maize (MZ) and foxtail millet (FT) with bengal gram (BG) in the proportion of 3:2 and with bengal gram and barley (BY) 3:1:1 after several trials of different proportions in preparing Missi Roti and its acceptability (scores>6) by panel of judges using nine-point hedonic scale. A recipe of 'Missi Roti" was standardized for its carbohydrate content (40 g/ serve), serving size, cooking time, cooked weight and water required for preparing the dough. Developed composite flour provide 63.27-73.30% energy from carbohydrate and were the good sources of fiber (2.1-6.50 g%). Protein quality of the composite flour (8.9-11.6) was better than the plain flour (1.7-7.6). Developed flour was stored in 1 kg capacity flour bags at room temperature for a period of three months. Shelf-life parameters revealed that free fatty acids and peroxides increased steadily with storage but did not exceed the safe limits. Acceptability of Roti from MZ, BJ, FT and their blends decreased significantly ($p<0.05$) with storage period. Nutritional status of the diabetic and normal subjects revealed that majority (43%) of them were in the category of overweight and obesity, waist hip ratio confirmed the abdominal obesity (> 0.85) in the females. Glucose tolerance test was conducted with 40 g glucose and test recipe of Miss Roti with chutney on diabetic and normal subjects at 0, 1/2, 1, 1 and ½, and 2 hours after feeding to determine the glycemic index (GI) of composite flour. GI was lower for composite flour than the plain flour. Blend of FT with Bengal gram was best as its GI was the lowest. The acceptability of FT+ BG+BY composite was for longer duration up to 3 months and its Gl was also the lowest, therefore, for commercial purpose this blend is recommended. Further it is suggested that diabetics may select composite flour as per their preference for the staple millet in place of plain flour.

Keywords: Composite flour, missi roti, quality evaluation, glycemic index

Introduction

Diabetes mellitus is a metabolic disorder of multiple aetiology characterizes by chronic hyper glycemic and associated with impaired carbohydrate, fat and protein metabolism. These abnormalities are the consequences of either inadequate insulin secretion or impaired insulin action or both. Diabetes has been recently reclassified into four distinct types: Type1, Type2, gestational diabetes mellitus and other specific types. Type2 diabetes mellitus until recently referred as non-insulin dependent (NIDDM) diabetes mellitus accounts for about 85-95% of diseased cases. In India crude prevalence rate of diabetes mellitus in urban area is about 9% and in rural area it has increased to around 3% of the total population. Out of these approximately 10% of the diabetic cases are Type1 and 90% are Type2.

In addition to exercise and pharmaceutical treatment, a key component of medical management of diabetes is nutrition therapy. It is considered to be the corner stone in the management of diabetes mellitus and more so in case of NIDDM in which the primary derangement of carbohydrate metabolism with secondary abnormalities of lipid and protein metabolism. Dietary management of diabetes involves reduction of postprandial hyperglycemia and good glycemic control. Data from epidemiological and human studies suggest that high glycemic index (GI) diet should be replaced by low GI diet.

Nutri-cereals are consumed as staple all over India and improves insulin response. In North India these are consumed as Roti in major meals of the day. Diabetic patients are advised a medical officer, their colleagues to consume Roti of the composite flour called "Missi Roli" Bijlani et al (1993) reported that wheat, barley and bengal gram is in equal proportion is suitable supplement for prevention and treatment and diabetes. Ancient medical text prescribed addition of barley in the traditional cereal pulse mixture for maintaining blood glucose in diabetics (Trowell 1987). However, their proportion is not suggested therefore there is a need to develop appropriate combination to prepare acceptable Roti with low GI. Although Roti is consumed in all the meals, a combination of millets and pulses having low GI has not been determined from commonly consumed millets. A preparation consumed as a major dish of the meal of a day having low GI value will definitely help in normalizing the blood glucose level. Hence the present study was planned to find out the utilization of composite flour by diabetics, to develop low glycemic composite flour based on nutri cereals consumed in Rajasthan, to find out the nutrient composition and shelf life of developed composite flour, to assess the sensory qualities of Missi Roti Prepared from fresh and stored flour and to assess the glycemic index of developed composite flour.

Materials and Methods

The information of consumption, preparation and composition of composite flour used for the preparation of Missi Roti by the diabetic patient was collected from Ratangarh of Churu District and Udaipur city of Rajasthan. A recipe of Missi Roti was standardized. Nutri-cereals were mixed with Bengal gram and /or barley. Mixed nutri cereals were grinded, packed in hand stitched packets. Developed flour was stored in 1 kg capacity of flour bags at room temperature for a period of 3 months. Flours were analyzed for physical characteristics, nutrient composition, sensory and keeping quality for a period of 3 months. Nutritional and health profile of 10 NIDDM and 10 normal subjects were assessed to measure the Gl of the composite flour. Glucose tolerance test was conducted with 40 g glucose and test recipe of Miss Roti with chutney on diabetic and normal subjects at 0, 1/2, 1, 1&1/2and 2 hour after feeding to determine the glycemic index (GI) of composite flour.

Results and Discussion

Missi roti was consumed by all the diabetic subjects, but the type of food grains selected, and proportion used was varied. Composite flour was developed for most commonly produced and consumed food grains, those were bajra (BJ), maize (MZ), foxtail millet (FT) with bengal gram (BG) in proportion of 3:2 and bengal gram and barley (BG+BY) 3:1:1. After several trials of different proportions in preparation of Missi Roti and its acceptability (scores less than 6) by panel of judges using 9-point hedonic scale. A recipe of Missi Roti was standardized for its carbohydrate content (40 g/serve), serving size, cooking time, cooked weight and water required for preparation of the dough. Developed composite flour provides 70-83% of carbohydrate and were the useful source of fiber (2.10-6.5). Protein quality of composite flour was better than the plain flour (8.9-18.3). Self-life parameter for stored flours showed that free fatty acid and peroxide value increased steadily with storage but did not exceed the safe limits. Acceptability of Roti from MZ, BJ, FT and their blends decreased significantly ($p<0.05$) with storage period.

Nutritional status of diabetic and normal subjects revealed that majority (43%) of them were in the category of overweight and obesity, waist hip ratio confirms the abdominal obesity (>0.85 in the females).

Glucose tolerance test was conducted with 40 g glucose and test recipe Missi Roti with chutney on diabetic and normal subjects at 0, 1/2, 1, 1&1/2and 2 hour to determine the Gl of composite flours. Gl was lower for composite flour than plain flour. Blends of FT with bengal gram is the best as their GI is the lowest. The acceptability of MZ blends were up to 3 months and its Gl was not found much higher (**Table 1**).

Table 1. Glycemic Index of Missi Roti

Composite flour	Diabetic	Non-diabetic	Overall
BJ	87±36.69	68±17.09	78±26.89
BJ+BG	57±8.85	50±11.20	54±10.030
BJ+BG+BY	85±33.57	63±35.32	74±34.44
MZ	89±35.28	58±9.02	74±22.15
MZ+BG	60±15.80	55±16.55	58±16.17
MZ+BG+BY	83±17.95	34±3.46	59±10.70
FT	72±18.76	53±6.07	63±12.41
FT+BG	61±15.07	37±5.18	49±10.12
FT+BG+BY	74±23.78	37±11.94	56±17.86

Geetha et al (2020) reported low glycemic index foods with 37, 48 and 53 for dosa, mudde and roti respectively with a glycemic load of 11.05, 18.43 and 18.09. However, all the three developed products showed the relatively lower glycemic index (< 55) and moderate glycemic load of < 20. Further, dietary intervention on pre diabetic subjects revealed that there was a significant reduction in FBS (120.50 ± 18.73 to 97.81 ± 20.00) and HbA1c (6.14 ± 0.30 to 5.67 ± 0.40) indicating their preferable option in the management of diabetes mellitus. Nishi et al (2012) also reported glycemic index of finger millet and pearl millet flours based cheela (36.83±1.23) and uthapam (38.72±1.879) was found to be lower than control cheela (44.07±1.67) and uthapam (39.9±1.14). The glycemic load of finger millet and pearl millet flours based cheela (12.5±0.525) and finger millet and pearl millet flours based uthapam (11.36±0.533) were found to be lower than control cheela (13.37±0.794) and control uthapam (14.72±0.418) respectively.

Conclusion

Composites are better than plain flour. The acceptability of the FT+BG+BY composite was found longer duration up to 3 months and GI was also lower therefore for commercial purpose this blend can be recommended. Further it is suggested that diabetics and obese can select composite flour as per their preference for the staple millet in place of plain millet flour.

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Millets Consumption: The Impact on Health, Environment, and Socio-cultural Aspects

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Abstract

Millets have been a staple food for millions of people for centuries. In recent years, there has been a growing interest in millet's consumption due to its numerous potential health benefits, as well as its positive impact on the environment and cultural significance. Studies have shown that millets are rich in essential nutrients, including vitamins, minerals, and dietary fiber. Regular Millets consumption has been associated with reduced risk factors for chronic diseases such as diabetes, cardiovascular disorders, and certain types of cancer. Compared to conventional cereal crops, millets require less inputs, making them an eco-friendly option. Millets have a deep-rooted cultural significance in many societies, where it is often considered a symbol of traditional heritage. The preservation and revival of Millets-based culinary traditions can promote a sense of cultural identity and pride, influencing consumer behavior positively. Factors such as taste, convenience, price, and availability play a vital role in influencing consumer behavior. Despite the potential benefits, there are several challenges to widespread millet consumption. Limited awareness and knowledge about millets, a lack of marketing efforts, and infrastructural constraints are some of the barriers that may impede consumer behavior change. Addressing these challenges is crucial for the successful integration of millets into mainstream diets.

Keywords: Fiber, food, health, human behavior, millets consumption, nutritional content

Introduction

In recent years, researchers have paid a lot of attention to the relationship between millets intake and human behavior. The small-seeded grasses known as millets have been farmed for millennia as a mainstay crop in many regions of the globe. Consumption of these products has far-reaching effects on people, affecting everything from nutrition and culture to environmental sustainability and health. This essay delves deep into the complex web of interactions between Millets eating and behavior (Thapliyal and Singh 2019).

Millets is steeped in history and tradition in many countries. Millets have been consumed by people in several Asian and African nations for hundreds of years. Millets are often used in religious and cultural ceremonies and celebrations. Dishes made with Millets are common in regional Indian cuisines and are often reserved for festive occasions, such as ragi mudde and bajra roti. The cultural significance of millets influences behavior through fostering the maintenance of long-standing eating customs and the consolidation of distinctive national identities. (Obilana and Manyasa 2002).

Millets' high nutritional content is a major factor in motivating healthy eating habits. Millets are an excellent source of energy and are packed with nutrients including protein, fiber, and antioxidants. (Yang et al 2022) They are also a great option for those who have to avoid gluten because of dietary restrictions. Incorporating millets into contemporary diets is on the rise as people become more aware of their health advantages. There has been a welcome trend toward healthy eating habits, reflected in the rising popularity of millets as a food option (Rao et al 2011).

Millets consumption has the potential to substantially affect sustainability-related actions. In comparison to other staple grains like rice and wheat, millets are drought-resistant and use fewer resources. They can be grown with less impact on the environment, leading to fewer emissions and more efficient use of water. (Majid and Priyadarshini 2020). Millets are a sustainable dietary option, and their increased popularity reflects a societal change toward more environmentally aware lifestyles as people become more concerned about the planet's future. In areas where Millets is a staple crop, its production and consumption can have important economic effects. The demand for millets may have a beneficial effect on farmers and their communities. Millets cultivation has the potential to enhance economic behavior in these areas by providing people with stable means of subsistence. The ripple effects of increased prosperity may permeate many aspects of society, from healthcare and education to transportation and housing (Himanshu et al 2018).

In areas where food scarcity and climate change are major problems, Millets consumption may help strengthen food security and resilience. Millet's capacity to thrive in a wide range of climates makes it an excellent crop for maintaining a constant supply of food. Millets-dependent communities tend to be more resilient in the face of food shortages and natural catastrophes. This encourages actions that strengthen food security and resilience over the long run (Jaybhaye et al 2019).

Millets

Numerous grass crops, including those whose seeds are harvested for human nourishment or animal feed, benefit from the name "Millets" (A Nutritive Crop). After rice, and wheat, Millets has been a staple meal in many regions of Africa and India for thousands of years. Many people, especially those who must survive in humid, tropical climates, rely heavily on millets for nourishment. Millets are a staple food in many impoverished countries because they can grow despite harsh circumstances like little rainfall. Millets provides a significant amount of protein and calories for many people in dry regions. Millets has been studied for its potential as both a food and a medicine (Tiwari 2022). Despite their high dietary value, millets are seldom used as a staple meal since few people are familiar with them. However, because of mounting evidence that they have positive effects on human health, millets have recently gained considerable attention in the field of biomedical research. Millets are tiny, spherical grains that pack a hefty nutritional punch thanks to their high proportions of crude fiber (2%-7%), protein (7%-11%), and fat (1.5-5%). Millets is gluten-free and a good source of minerals and vitamins, including zinc, magnesium, iron, calcium, and vitamin. In response to India's initiative, the United Nations has declared 2023 the "International Year of Millets." There was a prior celebration in India of the "National Year of Millets" in 2018 (Saini et al 2021). The declarations are an effort to spread awareness about millets and their positive effects on food security and nutrition, as well as to encourage the development of ecologically responsible methods of producing millets.

Table 1. Types of millets and nutrients value

Millets Type	Major Nutrients	Calories	Carbohydrates	Protein	Fats	Fiber	Key Minerals and Vitamins
Pearl Millet	Bajra	378	73g	11g	4.2g	1.2g	Iron, Magnesium, Phosphorus, Zinc
Finger Millet	Ragi	328	72g	7.3g	1.3g	3.6g	Calcium, Iron, Magnesium, B-vitamins
Foxtail Millet	Kangni/ Navane	351	63g	12g	4g	6.7g	Iron, Magnesium, Zinc, B-vitamins
Barnyard Millet	Jhangora/ Kuthiraivali	342	71g	11.2g	3.6g	10g	Calcium, Potassium, Phosphorus
Kodo Millet	Kodra/Arikelu	309	65g	8.3g	3.6g	9g	Iron, Magnesium, Phosphorus
Little Millet	Kutki/Samai	207	41g	7.7g	1.5g	7.6g	Calcium, Iron, Potassium
Proso Millet	Panivaragu/ Barri	341	74g	12g	2.9g	2.2g	Iron, Magnesium, Phosphorus, Niacin

For people who are gluten intolerant, millet can be an excellent substitute grain because it often contains no gluten. Millets are also a better option for diabetics because of their relatively low glycemic index.

There are normally seven distinct types of millets, each with its own set of characteristics including color, size, and optimal climate for growth. These small-seeded, spherical cereals, which belong to the Poaceae family, are the oldest and, presumably, the first cereal grain cultivated by humans. Millets has the sixth greatest yield of all grains. India is the world's top producer and exporter of millets. According to the United States Department of Agriculture's Foreign Agricultural Service, as of February 2023, India accounted for 39% of the world's millets production. In Table, we've outlined the millets' individual nutrient profiles (Das et al 2019).

Finger Millets

Ragi, often called finger millets, is an important staple meal for persons with low incomes and those with metabolic diseases including diabetes and obesity. Finger Millets is a nutritious and healthful alternative to rice or wheat. Minerals, fiber, protein, and carbohydrates may all be found in them in healthy amounts. Its usefulness stems from its high capacity for storing food and its high nutritional content (Bunkar et al 2021).

The high fiber content makes it a useful laxative and a preventative measure against constipation. Finger millet's high calcium content makes it a healthy option for infants, seniors, and expectant mothers. It also aids nursing moms in making enough milk for their infants, so it's a win-win (Dayakar 2017).

Foxtail Millets

Foxtail Millets is an economically significant crop grown and eaten globally, especially in India, China, and other parts of Asia, North Africa, and the Americas. Setaria is a cereal grain that belongs to the Poaceae family and the Panicoideae subfamily. Foxtail millet's high protein and low carbohydrate content facilitates the manufacture of acetylcholine, a neurotransmitter that relays impulses between muscles and neurons. Foxtail Millets is a nutrient powerhouse that sustains energy, builds strength, and protects against a wide range of potential illnesses (FAO World Food and Agriculture - Statistical Year book. 2020).

Proso Millets

Proso Millets is an environmentally friendly, gluten-free, small-grain cereal that also benefits humans. Proso Millets contains protein and micronutrients. It has long been considered a healing food, especially after difficult life events like delivery or sickness. Pellagra is a sickness caused by niacin, a kind of Vitamin B3, which may be alleviated by consuming proso Millets. Proso Millets has a very high niacin content Mathanghi and Sudha 2018). Pellagra is characterized by skin that is dry, scaly, and rough. Proso Millets has several positive qualities as a human meal. Due to its drought resistance and short growing season, proso Millets is an ideal rotating crop for winter wheat-based dry land farming systems. The most cost-effective method of producing proso Millets is to combine it with wheat and summer fallow every other year (Shashi 2017).

Kodo Millets

It has been hypothesized that India is where kodo Millets was first developed. It is estimated that Kodo Millets was initially domesticated around the year 3000 BC. Kodo Millets is a traditional meal that helps you lose weight and tastes a little like rice. It's easy on the digestive system and packed with disease-fighting antioxidants and phytochemicals that might be depleted by a sedentary lifestyle. Postmenopausal women with cardiovascular disease risk factors including hypertension and dyslipidemia might benefit from a diet rich in kodo Millets. Because of its greater antioxidant content, it helps keep blood sugar levels and diabetes under control. Among the many ailments that kodo Millets may alleviate are those associated with breathing and cardiovascular health (Ambati et al 2019).

Barnyard Millets

The ancient Millets crop known as barnyard Millets is produced in warm, temperate regions all over the globe. It has a massive fan base throughout Asia, particularly in countries like India, China, Japan, and Korea. It is the fourth most extensively produced minor Millets and a crucial source of nutrition for the world's impoverished. Barnyard Millets is mostly cultivated for human food, but it is also used as animal feed. Two of the most well-known varieties of barnyard Millets are Echinochloa frumentacea and Echinochloa esculenta, both of which are both cultivated and wild species. Barnyard Millets is a fast-growing, short-lived crop that requires very little attention and may thrive in poor conditions (Sharma and Niranjan 2018).

Little Millets

Some of the world's poor rely on the unusual minor crop known as little Millets, which is widely cultivated in the tropics. Similar to other cereals like rice and wheat, little Millets is a good source of protein, fat, carbs, and crude fiber. It also contains tannins, phenolic acids, phytates, and flavonoids. Despite its little stature, little Millets may not be as nutritionally dense as other grains. It's a good source of B vitamins and minerals including calcium, iron, zinc, and potassium. This provides the body with the needed lipids that aid in the process of losing weight. As an added bonus, its high fiber content makes it a great swap for rice in dishes like Pongal and Khee (Sharma and Niranjan 2018, Reddy 2017).

Nutritional Composition

Nutritional Composition of Millet (per 100 grams)

- Calories: 378 kcal
- Carbohydrates: 73.9 grams
- Protein: 11 grams
- Dietary Fiber: 8.5 grams

- Fat: 4.2 grams

Vitamins

- Vitamin B3 (Niacin): 4.72 mg (24% of daily value)
- Vitamin B6: 0.38 mg (19% of daily value)
- Folate (Vitamin B9): 85 µg (21% of daily value)

Minerals

- Iron: 3.9 mg (21% of daily value)
- Magnesium: 114 mg (29% of daily value)
- Phosphorus: 285 mg (29% of daily value)
- Potassium: 195 mg (6% of daily value)

Antioxidants

- Antioxidants like quercetin and curcumin, which provide a number of health advantages, are found in millet.

Glycemic Index (GI) of Millet

- GI ranges from low to moderate for millet, depending on the variety. For instance, foxtail millet has a GI of about 50, making it a decent option for folks trying to control their blood sugar levels.

Protein Quality (PDCAAS) of Millet

- Although millet's Protein Digestibility-Corrected Amino Acid Score (PDCAAS) varies, it is typically thought to be lower than those of sources from animals, such as meat or dairy. When mixed with other foods or protein sources, it can be enhanced.

Health Perspective

Millet's nutritional density suggests it may have positive health effects when consumed. As a result of its high nutritional richness, including magnesium, phosphorus, and B vitamins, millets are a popular food option. People's eating habits may be significantly influenced by this profile, as they seek out foods that provide a wide range of nutrients to promote health (Awika and Rooney 2022).

Millets may have a role in weight control, which is one of the main health advantages connected with eating it. Millets have a high fiber content, which is a key factor in making you feel full. This suggests that eating meals based on Millets might help people adopt healthy eating habits by reducing snacking and promoting satiety. Those trying to lose weight or keep their current weight under control may find this feature, which causes them to feel full after eating less, to be quite helpful. The positive effect Millets has on blood sugar regulation is also important. Millets have a low glycemic index, thus they raise blood sugar levels more slowly than high-glycemic meals. People with diabetes or those trying to maintain consistent energy levels throughout the day would benefit greatly from this quality. People may improve their blood sugar control and metabolic health by opting for millets instead of high-glycemic foods (Upadhyaya et al 2016).

Millets consumption is associated with improved health and healthier eating habits. Millets' newly-found status as a superfood has inspired people to broaden their diets and give more consideration to the substances they put into their bodies. The growing popularity of millets reflects a growing awareness of the link between diet and health, as people become more interested in making well-informed food choices (Prathyusha 2021). Millets is becoming more popular as a nutritious food option. People are more likely to engage in healthy practices as a result of its high nutritional density, appetite-suppressing qualities, and effect on blood sugar regulation. There has been a welcome movement toward emphasizing health and well-being via dietary decisions, and increasing awareness of these advantages has encouraged people to choose healthier eating choices (Arendt and Dal Bello 2017).

Health Benefits of Millet Consumption

- Due to its high fiber and magnesium content, it lowers the risk of heart disease. It also supports weight control because of its low calorie density and high fiber content, which increases satiety.
- Blood sugar management for diabetic sufferers due to the reduced GI content.
- Its lack of gluten makes it a good grain for people who have celiac disease or gluten intolerance.
- Antioxidants-rich foods may help prevent chronic illnesses.
- Due to the phytochemicals it contains, it may be able to reduce the risk of some cancers.

Environmental Impact

The positive effects of millets on both human health and the natural world have increased their popularity as a food source. Millets are very environmentally friendly crops, the production and consumption of which may strengthen the agricultural sector as a whole. Millets farming has a minimal resource impact, which is one of its main environmental benefits. Millets are resilient crops that can survive in a wide range of climates and drought situations. They are a viable option in areas with little water since they need far less water to grow than other basic cereals like rice or wheat. This water-saving feature has the potential to alter farmers' ways of doing business, making Millets an attractive crop to grow in areas with water constraint (Madhusudhana nd).

In addition, insecticides and fertilizers are generally used less sparingly on Millets fields. They can survive and even flourish in many different types of agroecological zones, which means less need for chemical pesticides and other treatments. In line with international initiatives to lessen agriculture's environmental toll, farmers are adopting more eco-friendly methods (Renganathan et al 2020).

Millet's favorable impact on the environment is bolstered by the fact that growing it results in less emissions of greenhouse gases. Carbon emissions from Millets farming are generally lower since the crop requires fewer energy-intensive operations during growing and harvest. Adopting millets at a time when the globe is struggling to adapt to climate change will help motivate people to embrace more environmentally friendly and resilient agricultural methods. An increase in Millets consumption has the potential to lessen the need for more labor- and water-intensive grains like rice and wheat. By eating a wider variety of foods, we can lessen agriculture's toll on the planet's scarce water and land resources (Sood et al 2017).

Millets intake is consistent with ecologically friendly lifestyle choices and also encourages healthy eating habits. Millets are a sustainable and ecologically beneficial alternative due to their water-efficient farming, less chemical inputs, and reduced greenhouse gas emissions. There has been a rising trend toward behavior that promotes sustainable agriculture and aids in resource conservation as more people and communities learn about the environmental advantages of Millets consumption (Pradeep and Guha 2021).

Environmental Impact Category	Millet Production (per acre or hectare)
Land Use	Low land use compared to major crops
Water Use	Moderate water requirements
Greenhouse Gas Emissions	Low greenhouse gas emissions
Biodiversity Impact	Minimal impact on biodiversity
Pesticide Use	Low pesticide use in organic systems
Fertilizer Use	Low fertilizer use in traditional systems

Environmental Impact Category	Millet Production (per acre or hectare)
Soil Erosion	Low risk of soil erosion
Energy Consumption	Low energy-intensive crop
Water Pollution	Minimal water pollution potential

Socio-Cultural Aspects

Millets consumption is intricately connected with several cultural factors, which in turn influence a wide range of regional and community-specific behaviors and ways of life (Sarita and Singh 2016).

- **Relevance to Culture:** Millets have been very important in the history, culture, and cuisine of many different communities. Millets have been used as a staple food in places like India and portions of Africa for hundreds of years. Dishes made with Millets are often served during social events, ceremonies, and festivals. One way in which this cultural bond influences behavior is through reinforcing customary dietary practices.
- **The variety of diets:** Millets are a great addition to any diet since they encourage variety. Millets are becoming more common in people's diets, and with that comes an increased interest in trying new foods. As a result, people are more likely to try new things in the kitchen, which improves the quality of their cuisine and the culture around it.
- **Safe and sufficient food supply:** Millets have played a crucial role in preventing famine, particularly in areas where this problem is compounded by climate change and other natural disasters. They are an important crop for ensuring reliable food supply since they can withstand harsh circumstances and thrive in a variety of regions. Millets are a sustainable crop that may inspire long-term thinking about food supply and community resilience.
- **Freedom and Sustainable Income Generation:** Growing and eating Millets may give people in poor areas more agency. Millets cultivation provides a living for subsistence farmers in many regions of the globe. The enhanced socioeconomic behavior that results from this economic participation opens doors to better education, healthcare, and poverty reduction.
- **The Safeguarding of Indigenous Knowledge:** Traditional farming methods are protected by the continuous use of millets in the diet. A feeling of tradition and cultural continuity is fostered via the passing on of information from one generation to the next. Traditional knowledge about farming and nutrition is more likely to be preserved in communities that place a high value on millets.
- **Creative Cooking:** Millet's adaptability in the kitchen inspires new approaches to cooking. People's culinary traditions change and grow as they try new Millets-based dishes. This kind of thinking inspires new ideas and makes people proud of their hometown food.
- **Social Integration:** Communities often work together to grow and prepare meals in areas where Millets is a staple crop. Millets intake is not only about nutritional choices but also a reflection of socio-cultural values and customs because of the ways in which it is often consumed in groups. It plays a significant part in a wide variety of cultural events and festivities, and in dietary diversity, food security, economic development, and communal connection. Millets' long cultural and social relevance is shown in their widespread popularity around the world (Vishakha 2016).

Consumer Perception and Acceptance

How Millets is portrayed and received by consumers has a significant impact on their eating habits and the market as a whole. From eating habits to shopping selections, these aspects heavily impact people's decisions. The purported health advantages connected with Millets eating are one of the key motivations of its adoption. Millets are seen by many as a healthy grain option because of their high vitamin, mineral, and fiber content. This idea coincides with the worldwide trend toward better diets, encouraging people to include millets as part of a well-rounded and healthy diet. Millets' appeal to people with food allergies or intolerances is increased by their lack of gluten, which has an impact on purchases (Hassan et al 2021).

Millets acceptability is also influenced by how common it is in people's culture. Millets have a deep cultural significance in places like areas of India and Africa, where they have been consumed by locals for millennia. Because of the positive associations that people have with Millets-based recipes, they tend to continue to prepare and eat them in the same ways as in the past. The integration of millets into rituals and festivities also contributes to their growing popularity. Millets' popularity among consumers may be attributed, in part, to their adaptability and creativity in the kitchen. Millets-based dishes are expanding as chefs and foodies try new things with this versatile grain. Consumers are inspired to try new foods thanks to this trend toward culinary experimentation, with many now actively seeking out millet-based meals in restaurants and trying to duplicate them at home (Saleh et al 2019).

Consumer perception and acceptability are shaped in large part by government regulations and awareness efforts. Changing people's habits on a social level is possible via campaigns advocating Millets use as part of sustainable and nutritious diets (Chandrasekara and Shahidi 2020). Millets may be made more desirable to consumers via subsidies, nutritional education programs, and marketing campaigns.

Millet's acceptability and popularity among consumers is a major factor in the spread of millet-based diets. Perceived health advantages, cultural familiarity, culinary innovation, and governmental activities all play a role in shaping these variables. More and more people are beginning to see millets as a healthy addition to their diets because of its nutritional richness, cultural significance, and eco-friendliness (Dong et al 2020).

Aspects of Millet Species in Nepal

Millets are a species of small-seeded grasses that are highly diverse and are largely grown as grain crops around the world, including Nepal. These grains are a staple crop in many areas because of their reputation for tolerance to drought and poor soil. Millets are cultivated in Nepal in a variety of ecological zones, from the lowlands to the high highlands, as both major and minor crops. The following are a few of the millet species grown in Nepal:

- Finger Millet (*Eleusine coracana*): Likewise referred to as "Ragi" or "Kodo" in Nepal. It is one of the main millets grown in Nepal's high and middle highlands.
- Foxtail Millet (Setaria italica): referred to as "Kauni" locally. One of the first millet species to be grown.
- Proso Millet (Panicum miliaceum): Although less frequently cultivated there, it is renowned for having a short growing season.
- Barnyard Millet (Echinochloa spp.): referred to as "Sanwa" or "Jhangora" locally. It is a millet that grows quickly and is mostly grown in Nepal's mountainous areas.
- Little Millet (Panicum sumatrense): Despite not being as well known as other millets, it is produced in some regions of Nepal.
- Pearl Millet (Pennisetum glaucum): This is mostly cultivated in the Tarai area (lowland) of Nepal and is commonly referred to as "Bajra."

These are the main millet species farmed in Nepal, however there are additional lesser-known landraces and cultivars that are grown in particular areas or by particular ethnic groups. The Nepalese cuisine has long included these millets, especially in areas where rice and wheat are less common. Additionally, millets have seen a rebound in consumption and production in recent years due to growing knowledge of their nutritional advantages.

Distribution of Millet Species in Nepal

In many areas of Nepal, especially in the steep and mountainous areas where rice production is difficult, millet is a significant traditional crop and a staple food. Depending on the altitude and temperature, different types of millet are grown in different parts of Nepal.

- Finger Millet (*Eleusine coracana*): In Nepal, this is the millet that is most often grown. Although it is farmed across the nation, the mountainous areas like Kaski, Lamjung, Gorkha, Dolakha, and Ramechhap produce the majority of the crop.
- Proso Millet (Panicum miliaceum): Although not as widespread as finger millet, this kind of millet may be found in the mountainous and Tarai areas (lowland plains in the southern portion of Nepal).
- Foxtail Millet (Setaria italica): It is cultivated in some parts of Nepal, although not as widely as finger millet.
- Barnyard Millet (Echinochloa spp.): Cultivated in the hilly regions and is used as both food and fodder.
- Little Millet (Panicum sumatrense): Despite being less often planted, this species may be found in various regions of the nation.
- Pearl Millet (Pennisetum glaucum): mostly cultivated in Nepal's western Tarai regions and a few of its highland regions.

Millets are often farmed in Nepal's diverse habitats, which range from the lowland Tarai plains to the mid-hills and high Himalayan areas. Both as a primary crop and as a crop in rotation between primary crops like maize and rice, they are grown.

Species of Millets: Duration, Time, and Circumstances

Millets are a family of tiny-seeded cereal grains that have been grown for a very long time in many different places of the world. Each species of millet has unique traits and needs for growth. A few popular millet species, their development cycles, planting times, and typical growing circumstances are listed below:

- **Pearl Millet (Pennisetum glaucum):** Pearl millet typically matures between 60 to 90 days. When the soil temperature is regularly above 65°F (18°C), which occurs in late spring or early summer, pearl millet is often seeded. It does well in hot, dry climates with well-drained soil and little water need. A crop resistant of drought is pearl millet.
- **Foxtail Millet (Setaria italica):** Foxtail millet typically reaches maturity between 60 to 90 days. When the earth has warmed up in the late spring, it is often planted. Warm temperatures and well-drained soil are favourites of this millet variety. It is drought-resistant and adaptable to a variety of climate situations.
- **Proso Millet (Panicum miliaceum):** Proso millet typically takes 60 to 100 days to develop. When the soil temperature is continuously higher than 50°F (10°C), plant proso millet in the late spring or early summer. Proso millet may grow in a variety of soil conditions and can withstand some drought. In areas with chilly evenings, it can flourish.
- **Finger Millet (*Eleusine coracana*):** Finger millet normally takes 90 to 120 days to reach maturity. The optimal time to plant finger millet is in the early summer or at the start of the rainy season.

Since it is generally resistant, finger millet can tolerate a variety of environmental conditions but prefers well-drained soils. It thrives in highland areas and is renowned for its capacity to flourish on marginal soils.

- **Little Millet (Panicum sumatrense):** Little millet takes 60 to 75 days to reach maturity. At the beginning of the rainy season or in the summer months, plant a little amount of millet. Little millet may grow in a range of soil types and climates. It may be cultivated in a variety of agroecological zones and is comparatively drought-resistant.

Barriers and Challenges

Although there are many positive outcomes associated with Millets eating, its broad acceptance and influence on behavior are hampered by a number of obstacles (Dai Xiaojun and Ma Lei 2021). These obstacles stem from a wide range of sources, including cultural biases and economic considerations.

- **Preferences and beliefs based on culture**: Millets may be met with skepticism in parts of the world where they are not historically consumed. It might be difficult to change people's ingrained preferences for certain grains. However, cultural stereotypes linking millets to squalor or anachronistic eating habits might be just as discouraging.
- **A failure to realize**: The lack of knowledge about the nutritional content and health advantages of Millets is a major obstacle to their use. The benefits of millets to the human body are still largely unknown, though, since of this misunderstanding, people may choose less healthy grains since they are more easily accessible.
- **Supply Is Very Low**: In densely populated areas or places with established agricultural networks, the lack of ready access to Millets products may be particularly problematic. Consumers' freedom of action and choice may be constrained by the lack of Millets-based items available in conventional marketplaces. Convenience plays a role in why consumers choose certain products over others.
- **Problems with Preparation and Cooking**: Due to unfamiliarity with preparation procedures, customers may find it difficult to include some kinds of Millets into their everyday meals since they need specialist processing processes. As a result, people may be dissuaded from including Millets into their diets because of the time and effort required to cook them.
- **Factors in the Economy**: Millet's higher price relative to other grains, for example, may discourage buyers. Consumers in low-income areas may be dissuaded from adding millets to their diets if the cost of doing so increases.
- **Advertisement and Publicity**: Millets' potential for widespread use is hampered by insufficient promotion and marketing. Millets may have a harder time competing for market share than more popular grains like rice and wheat.
- **Policy backing**: It may be difficult to grow and eat Millets if there are no government programs, subsidies, or incentives to do so. Producers and consumers may be dissuaded from interacting with millets if policies promote other main crops.

Although there is great potential in increasing millets intake, there are a number of obstacles that prevent people from making the switch. Educating the public about millet's health benefits, encouraging chefs to experiment with the grain, expanding distribution channels, and enacting regulations that reward both production and consumption are all necessary steps toward overcoming these challenges. Addressing these challenges can help unlock the full potential of millets as a sustainable, nutritious, and culturally diverse dietary choice (Luo 2019).

Conclusion

Millets consumption offers a viable route to improve human health, foster environmental sustainability, and enhance social and cultural aspects of human existence. However, in order to fully tap into this potential, a concerted effort is required, one that includes educational initiatives, the introduction of enabling regulations, and cross-sector partnerships. We can promote change on both the individual and social levels by removing the obstacles in the way of widespread Millets adoption. This collaborative effort is setting the way for a future that is both healthier and more sustainable by celebrating the cultural diversity and nutritional abundance that millets provide to our menus. The vital amino acids, dietary fiber, vitamins, and minerals included in millets make them nutrient-rich foods. Reduced chances of chronic illnesses like diabetes, cardiovascular problems, and some malignancies have been associated with their use. In order to accommodate persons with celiac disease or gluten allergies, they are also gluten-free. Millets are suitable for dry and semi-arid environments because they can be grown with less water and fertilizer than other main crops. They display incredible resistance to climatic changes, maintaining food security under difficult circumstances. Millets have long been a part of the diets of many nations. However, urbanization and contemporary agricultural methods have diminished their significance. A rise in millet consumption can support rural economy and protect cultural traditions. Promoting the use of millet can be a comprehensive strategy for resolving health issues, reducing environmental risks, and maintaining socio-cultural values. Millets can provide significant benefits on a number of fronts when incorporated into contemporary diets.

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक)। २०८०। राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ।

कोदोसँगको सम्झना र स्वास्थ्यमा असर

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कोदो र स्वास्थ्य

"कोदो कुअन्न हो, गरीब र केही नहुनेले मात्र खान्छन्" भन्ने चलन पहिले थियो। तर अहिले समय बदलिएको छ। केही दिन अघि पत्रिकामा "नेपालमा कोदो आयात" भन्ने समाचार पढेर मलाई याद आयो, १५ वर्षअघि मेरी छोरीले दुःखी भएर मसँग भनेकी थिइन् - "आमा, तपाईलाई त कति मान्छेले कोदे बूढी भन्छन्। तपाईंले कोदो र फापरबारे धेरै कुरा गर्ने भएकोले"। उनलाई भनेको थिएँ - "के भयो त? यस्तो कुरामा त म गर्व गर्छु। कोदो, फापर त राम्रा अन्न हुन्। यसको महत्त्व नबुझेर पो मानिसले हेपेका हुन्।" त्यो बेलाको भन्दा परिस्थिती बदलिएको छ।

मधुमेह र मुटुको रोग लागेपछि कोदो स्वस्थकर हुन्छ भन्ने चेत धेरैमा आएको छ। तर बालबालीकालाई कोदो, जुनेलो जस्तो अन्न दिन सकिन्छ भनेर विचार अझै आइसकेको छैन। अभिभावकहरूले माया गरेर बालबालीकालाई कुरमुरे, सेता पाउरोटी, चाउचाउ जस्ता मन्द विष दिँदा अति नै हानी गर्छ। किनभने प्याकेटका खानामा शरीरलाई चाहिने पौष्टिक तत्व प्रोटीन, लौहतत्व, क्याल्सियम आदि हुँदैनन्। कोदो, जुनेलो, चिनो आदिका परिकार बनाएर दिए बच्चाको स्वास्थ्य राम्रो हुन्छ।

अहिले कर्णाली र सुदूर पश्चिममा पनि कोदोको प्रयोग गर्न त्यति रुचाउँदैनन्, बरु बिस्कुट र पाउरोटी प्रयोग गर्छन्। तै पनि अहिले विभिन्न संचार माध्यममा कोदो र स्थानिय अन्न बालीहरूको बारे छलफल हुन शुरु भएकोले बिस्तारै गाउँघरमा कोदोलाई कुअन्न भन्न छाड्छन् कि भन्ने आशा लागेको छ। अब स्वास्थ्यकर्मीलाई पनि "कोदो र अन्य स्थानिय बालीहरूको प्रयोगले कुपोषणको समस्या समाधान गर्न मद्दत गर्ने भएकोले गर्भवती, सुत्केरी, वृद्धा र बालबालीकाको खानामा यो समावेश गर्नु" भनेर सिकाउनु पर्छ।

केही वर्ष अघि म मुगु गएको थिएँ। त्यहाँ होटेलमा "लौ यहाँको के स्थानिय अन्न छ त्यही ख्वाउनुस् न" भनेको त "यहाँ चामल मात्र पाइन्छ। आजकल त चिनु, कोदो, फापर त फलाउनै छोडियो। खाद्यले दिएको चामलमात्रै मीठो लाग्छ। अब त बारीमा काम गर्न पनि अल्छी लाग्छ।" भन्ने पसलमा सुनियो। यो सुनेर दुःख लागेको थियो कि कर्णालीको हावापानी अनुसारको अन्न अब बिस्तारै हराउनेछन्। मैले स्थानिय अन्नको बारेमा र त्यसको महत्त्वको बारेमा पनि २० वर्ष अघि भारतमा विभिन्न तालिम लिएपछि थाहा पाएको र रैथाने बाली/अन्नको बारेमा बोल्न अनि लेख्न थालेको थिएँ। कोदो अति नै पोषणयुक्त अन्न हो। चिसो मौसममा तातो तरकारी र दालको झोलमा कोदोको पिठो हालेर खानाले हाम्रो शरीरलाई पोषण दिन्छ। यसमा रहेका विभिन्न सुक्ष्म पोषक तत्व: म्याग्नेसियम, फस्फरस, क्याल्सियम, लौह तत्व साथै रेशादार पदार्थ पर्याप्त मात्रामा पाइन्छ। यसैले नै यो गर्भवती महिला र सुत्केरीको लागि खान योग्य छ। कोदो, जुनेलो, चिनो आदि अन्नले शरीरको आन्द्रा स्वस्थ राख्न ठूलो भूमिका निर्वाह गर्छ। यिनमा रहेको रेशादार पदार्थले आन्द्रामा रहेको असल किटाणुको रक्षा गर्छ। यिनमा रहेको रेशादार पदार्थले शरीरमा कोलेस्टेरोल (बोसो) घटाउन मद्दत गर्छ।

दस वर्षअघि अछाममा कोदोको रोटी बनाउन होटेलकी साहुनीलाई आग्रह गर्दा उनले एक पटक माथिदेखि तलसम्म हेरिन्। ""काठमाडौँबाट आएका मान्छेले पनि कोदो खान्छन् र?" उनले आश्चर्य प्रकट गरीन्। "खान्छौं नि" भनेपछि उनले कोदोको पिठोमा गहुँको पिठो मिसाएर रोटी र साग बनाईदिएकी थिइन्। त्यो स्वाद अझै मेरो जिब्रोमा छ। "प्राय: यहाँ आउनेले कोदोको पिठोको परिकार पकाउन भन्दैनन्। हामीले आफ्नो लागि मात्र केही कोदोको ढिडो बनाएर खान्छौं।" साहुनीको कुराले लागेको थियो "माल पाएर, चाल नपाउनु" भनेको यही होला।

मेरो पनि एउटा नमीठो अनुभव छ। एकजना मोटी ८० वर्षकी महिला १५ वर्षअघि "मोटोपन घटाउन के गर्ने" भनेर सोध्न आएकी थिइन्। मैले आफू स्वस्थ रहन म जे खान्छु, त्यही सिकाउँछु भन्ने विचार गरेकी थिएँ। मैले तरकारी मिसाएर कोदा र गहुँको सुप (खोले) बनाएकी थिएँ। उनलाई घरमा

बोलाएँ। उनले बटुकाको सूप हेरिन् र भनिन्, "छि दिदी, यस्तो खोले त मेरो कुकुरले पो खान्छ। " त्यसो भनिसकेपछि उनलाई थप सल्लाह दिने जाँगर पनि चलेन। उनको मोटोपन अझै घटेको छैन। उनलाई भेट्दा म त्यो घटना सम्झिरहन्छु। उनले सम्झेकी छैनन् होला। वा अब मधुमेह र उच्च् रक्तचाप भइसकेपछि उनले कोदो जस्तो स्थानिय अन्न खान थालिन् कि?

कोदो मात्र पकाएर खाँदा कतिलाई स्वाद नहुने भएकोले यसलाई विभिन्न अन्य अन्नसँग मिसाएर खान पनि सकिन्छ। चामल, कोदो, गहुँ, फापर आदिको पिठो मिसाएर बनाएको परिकार उत्तम हुन्छन्। यस्तो पिठोहरूको मिश्रणबाट सुप बनाउन सकिन्छ। त्यसमा तरकारीहरू हालेर खाँदा स्वाद र स्वास्थ्य दुबै दिन्छ। बालबालीकालाई पनि कोदो, जुनेलो, चिनो उपलब्ध हुने ठाउँमा दिन सकिन्छ। यसरी एकैचोटी दिंदा धेरै नदिएर बिस्तारै बिस्तारै दिनुपर्छ ता कि पचाउन सजिलो होस्। बच्चालाई हरेक दिन एउटै परिकार खान वाक्क लाग्छ त्यसैले थरि थरिका परिकार ख्वाउन सकिन्छ।

मलाई खुशी लाग्छ अहिले कोदोको छलफल सुनेर। 'कुअन्न' का रूपमा मानिँदै आएको यो अन्नको अहिले शहरमा पनि उपभोग बढ्न थालेको छ। यसको महत्त्व बुझेर यसलाई 'सुन अन्न' वा 'सुअन्न' पनि कतिले भन्छन्। भारतमा त कोदो, जुनेलो, आदि जस्ता अन्नलाई "श्रीअन्न" भनेर त्यहाँको सरकारले नै त्यसको प्रबर्धन गर्न लागि परेको छ। नेपालमा पनि यदि यस्तो प्रयास हुने हो भने समुदायमा कुपोषण कम हुन धेरै मद्दत पुग्ने थियो। साथै किसानको आर्थिक अवस्था पनि राम्रो हुने थियो। पहिले पहिले कोदो खाएमा जात जान्छ भनिन्थ्यो र गरीब, हरूवा-चरुवा, हली, गोठाला तथा कृषि मजदुरले मात्रै कोदोको रोटी, ढिँडो, खोले (सुप) बनाएर खाने गर्दथे। वास्तवमा उनीहरू शारीरिकरुपमा हृष्टपुस्ट भएर बलको काम गर्न यस्तो भोजनले मद्दत पुर्याएको थियो। तर अहिले समय परिवर्तन भएको छ, ढिलै भएपनि हामीलाई बुद्धि आएको छ। काठमाडौँ र ठूला शहरमा अहिले उच्च रक्तचाप, मधुमेह भएका व्यक्तिहरूको संख्या बढेपछि "पर्याप्त मात्रामा रेशादार तत्व पाइने खाना खानुस्" भनेर स्वास्थ्यकर्मिले सल्लाह दिन थालेका छन्। त्यसैले कोदो, फापरको प्रयोग शहरमा बिस्तारै बढ्न थालेको छ। अहिले नेपालमा कोदो आयात पनि हुन थालेको छ। तर यो दुःख लाग्दो कुरा हो। एकातिर नेपालका केही भागमा फलेको कोदो जस्तो अन्न वेवास्ता हुने अनि अर्कोतिर आयात हुने विडम्बना छ। म त व्यक्तिगत रुपमा लामो यात्रामा निस्कँदा पनि गहुँ र कोदाको सुख्खा रोटी बनाएर लैजान्छु। यात्रा गर्दा यस्तो खाजा आडिलो हुन्छ। बाहिरको खाजा खान पर्दैन। यसमा अन्य फाइदाहरूको बारेमा त केही भन्नै परेन। कति जनाले अहिले कोदोको सेल, पुरी, खजुरी, निम्की पनि बनाउन थालेका छन्। यसको बजार पनि भएकोले हाम्रो स्वस्थकर रैथाने बालीको उत्पादनमा ध्यान नदिएर बाहिरबाट आयात गर्ने हो भने त देशको अर्थतन्त्रलाई पनि कमजोर पार्छ। रैथाने बालीसँग हाम्रो संस्कृती पनि जोडिएको छ।

अब कसरी प्रयोग गर्ने त?

कोदोमा प्रशस्त फलाम पाइने हुनाले महिलामा, किशोरी, बालबालीकामा भएको रक्तअल्पताको समस्यालाई कम गर्न सक्छ। कोदो, जुनेलो, चिनो पाइने ठाउँमा स्कुलको दिवा खाजामा यसको विभिन्न परिकार बनाउन सकिन्छ। यस्ता स्थानिय वस्तु छोडेर बच्चाहरूले पत्रु खाना खाएपछि पोषण सम्बन्धी समस्याहरू हुन्छन् भनेर समुदायमा बुझाउनु पर्छ। स्थानिय अन्नको सट्टा महँगो खाना किन्दा पैसा बढी खर्च हुन्छ, कुपोषण हुन्छ। कुपोषण भएपछि अभिभावकको पैसा खर्च हुने, मानसिक तनाव पनि हुन्छ। तर स्वाद केका लागि? एकछिनको स्वादको लागि जीवनभर अस्वस्थ गराउने बालबालीकालाई? मैले प्राय अभिभावकहरूसँग कुराकानी गर्दा शिशु अवस्था देखि नै स्वस्थकर खाना खाने बानी लगाउनु भन्छु। किनभने कुनै पनि आमाबुबाले आफ्नो छोराछोरी बिरामी परुन्, स्वास्थ्य खराब होस् भन्ने चाहेका हुँदैनन्। तर उनीहरूलाई जानकारी नहुँदा बालबालीकाको स्वास्थ्यमा नकारात्मक असर परेको छ।

बच्चाहरूलाई स्वस्थकर खाना खान प्रेरित गर्न आमाबाबु, शिक्षक र समुदायको भूमिका हुन्छ। पत्रु खानाले स्वास्थ्यमा कसरी नराम्रो असर पार्छ भन्ने देखाउन यस सम्बन्धी फोटोहरू देखाएर, जानकारी गराउन सकिन्छ। प्राय: मानिसहरूलाई के लाग्छ भने कोदो, जुनेलो, चिनो, कागुनो आदि अन्नबाट बनाईएका खाना स्वादिष्ट हुँदैनन्। तर स्वादिष्ट बनाउन सकिन्छ। विदेशमा यस्ता अन्नबाट विभिन्न स्वस्थकर खाना बनाएर मानिसहरूले खान्छन् भने नेपालमा पनि सकिन्छ भन्ने कुरा पनि बुझाउनु जरुरी छ।

कोदो, जुनेलो जस्ता स्वस्थकर अन्नलाई नै खानाका विभिन्न परिकार बनाउन सकिन्छ। जस्तै मैदाको मःम पत्रु खाना हो। तर कोदो र गहुँको मःम बनाएर खाने हो भने त्यो स्वस्थकर हुन्छ। त्यसलाई शाकाहारी र मांसाहारी दुवै खालको बनाएर पकाउन सकिन्छ। त्यसैगरी नेपालमा युवाहरूले मन पराउने पिज्जा यस्तो स्थानिय अन्नबाट पनि बनाउँदा स्वस्थकर हुन्छ, स्वाद पनि हुन्छ। कोदो, जुनेलो जस्ता स्थानिय अन्नको बारे चर्चा परिचर्चा भएपछि जब यसलाई "रोग लागेपछि खाने होइन कि रोग लाग्ने संभावनालाई कम गर्ने गरी खान सकिन्छ, खानु पर्छ" भन्ने भावना जातृत गराउनु पर्छ। अनि 'कोदोको खोले कुकुरले मात्र खान्छ' भन्ने भावना हट्छ। नेपालमा हिमाली र पहाडी भागमा फल्ने यस्ता विभिन्न बालीहरूको संरक्षण गरेर समुदायको स्वास्थ्यमा सकारात्मक असर पार्न सकिन्छ भन्ने कुरा सरकारको उच्च पदमा बसेकाहरूले बुझे कति राम्रो हुने थियो।

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H. Environmental and Forage Values

झ. वाताबरणीय र आहारा-जन्य मूल्य

Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Millets for Livestock Feeding in Nepal

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Abstract

Livestock is an integral part of agricultural system in Nepal. Livestock is not only important for its contribution in GDP but also important for food and nutritional security and livelihood improvement in Nepal. There are 9.95 million Livestock Units (LSU) of animals that need 27,637,708 mt dry matter (DM) and 14,928,529 mt total digestible nutrient (TDN) per year whereas only 24,564,451 mt. of DM and 11,059,027 mt of TDN was available in the year 2018 resulting a deficit of 11.2 and 20.9% of DM and TDN, respectively. Millet species are important for feeding livestock but only limited research has been carried out especially about their nutrient content and feeding value for the livestock. There are 12 domesticated and 9 wild relatives of millets found in Nepal but only five among them, namely, *Eleusine coracana*, Pennisetum glaucum, Sorghum bicolor, Setaria italica and Brachiaria mutica are of high importance for livestock feeding. Millet grains and forages are taken as important feeds since long back as they are rich in some of the macro and micro-nutrients needed for livestock. Forages of millets can be conserved as hay, silage and haylage to feed them during the time of green forage scarcity. Proper treatment of the forages is helpful in making them more nutritious, palatable and digestible to the livestock. This article is a review of the available literature along with the consultation of key informants and pilot survey of some of the millet growing sites. It is concluded that millets are of high importance for feed and fodder for livestock. However, more priority has to be given in teaching, research and extension of millets for their promotion and development in Nepal.

Keywords: DM, feeds and forages, finger-millets, LSU, TDN, teaching research and extension

Background

Livestock is an integral part of agricultural farming system in Nepal. Livestock contributes about 24.01% to the agriculture gross domestic production (MoALD 2023). Livestock development is an integrated approach of its four pillars; namely, animal health, animal breeding, animal nutrition and market management. Though, all the pillars are equally important, among these components, animal nutrition is vital because of its higher contribution to the cost of the livestock products. Animal nutrition accounts up to 70% to the total cost of the livestock products (Paudel et al 2000). Therefore, to reduce the cost of production of any kind of livestock products, highest care has to be given to the animal nutrition component of the livestock development in Nepal. There are more than 7.2 million cattle, 5.3 million buffalo and 13 million goats in Nepal (AITC 2023). It has been estimated that there are more than 9.95 million Livestock Unit (LSU) of animals in Nepal. They need about 27,637,708 mt dry matter (DM) whereas available DM is 24,564,451 mt per year. Similarly, available total digestible nutrient (TDN) in the country is 11,059,027 mt and demand for the same is 14,928,529 mt per year (NPAFC 2018). It shows that there is a shortage of 11.2 and 20.9% of DM and TDN per year, respectively. It clearly shows that there is an acute shortage of livestock feed and hence livestock are underfed in Nepal. Because of the seasonality in fodder and pasture production in the country winter and summer seasons are more prone to the fodder and pasture shortage for livestock feeding in Nepal. During these seasons straws and agricultural by-products share about 80% contribution in livestock feeding. In these circumstances, straws and by-products of millets which can be available in these seasons could be the important alternatives to reduce the DM and TDN balance and other nutritional deficiencies in the areas of livestock feeds and feeding in Nepal.

Important millets in livestock feeding

Millets are of very important crops of hills and Tarai of Nepal. Since livestock feed deficit is highest in mid-hills (24.09%) followed by Tarai (18.91%), promotion of millets in these areas could be of important intervention to meet these deficits. There are 12 domesticated and 9 wild relatives of millets found in Nepal (Joshi et al 2023). Among them, important millets that can be used in feeding the livestock are briefly discussed below:

Finger millet (*Eleusine coracana*)

Finger millet is grown from Tarai to high hills of Nepal. It is transplanted in dryland in rainy season and harvested in early winter. The total area covered by finger millet was 263 thousand hectares in 2017 which was slightly increased and reached to 267 thousand in 2021. The total grain production of this crop was 314 thousand mt in 2017 and 339 thousand mt in 2021. Very limited research has been carried out in this crop especially in feeding livestock. However, a preliminary survey of this crop in some of the finger millet growing sites has revealed that the green mass production is high accounting as a ratio of 1:7 (grain to green mass). Hence, the total green matter production of finger millet in the country accounts around 2373 thousand mt per year. Assuming 60% moisture content in the green forage, about 949 thousand mt of dry matter (DM) was produced in 2023 (MoALD 2023).

Photo 1. Finger millet growing in Adguri village of Arghakhanchi district, Nepal

Bajra (*Pennisetum glaucum*)

Bajra is a warm-season grass with small edible seeds. The estimation of total area and biomass produced of bajra in the country is not available yet but this is in increasing trend in recent years. This is relished by all kinds of livestock (Banerjee 2011).

Sorghum (*Sorghum bicolor*)

Sorghums are the tall maize like grasses grow up to 2 meter high. This is also the summer season crop which is very much useful in feeding livestock during the scanty supply of green forages in Nepal. As in Bajra, the total area and related statistics of its production and use has not yet estimated in Nepal.

Setaria (*Setaria italica*)

Setaria is mainly grown as a forage crop in Nepal. Traditionally, it was taken as a weed in cultivated land but in recent years by realizing its importance and nutritive value it has been developed as an improved forage crops in Nepal (Uprety and Uprety 2013). It can be propagated either by seeds or slips during rainy season. It is a perennial crop which can be grown from terai to mid-hills and mainly harvested from autumn to winter season in Nepal.

Photo 2. Setaria at the stage of harvesting in Sandhikharka of Arghakhanchi district, Nepal

Para grass (*Brachiaria mutica*)

Para grass is an another very important millet forage crop for livestock feeding. It is also known as signal grass, buffalo grass, Scotch grass, etc. in different countries. Para grass is a rapid growing perennial forage with creeping stolons (https://en.wikipedia.org/wiki/Brachiaria_mutica) which can be harvested in summer and rainy seasons. It is also said as water loving plant which can be grown in moist areas and boundaries of ponds, tanks, ditches and canals (Ranjan 2003). Para grasses are very much liked by cattle, buffalo as well as other livestock.

Feeding values of millets to livestock

Very limited researches have been carried out so far in feeding millets for livestock in Nepal. However, some of the facts available in the literatures and common experiences and survey with the key informants in livestock farming areas have revealed that millets are very much useful in livestock feeding in Nepal. McDonald et al 1990 reported that the Crude Protein (CP) content in millets varies considerably but usually ranges from 100-120 g/kg, the oil content varies from 20-50 g/kg and the Crude Fibre content varies from 50-90 g/kg. Millets contain a high percentage of indigestible fiber owing to the presence of hulls which are not easily removed by ordinary harvesting methods. Millets are of small seeds and usually grown for feeding animals other than poultry (McDonald et al 1993).

Millets, especially finger-millets, were used to feed livestock during the time of green forage scarcity since long back in Nepal. As most of the millets are hardy in nature and grown in summer as well as winter seasons, they are of great values in feeding livestock. It is a long tradition and practice in Nepal that the green biomass of finger millet is dried on shade and prepared good hay for feeding livestock in scarce time.

It is a well-known and scientifically proven fact that hay of finger millet (millet-straw, *Nal*) is much better than rice-straw in livestock feeding. The practice of making *Dhindo* (porridge) and gruel of finger-millet and feeding to the draft animals, pregnant cows and calves has been a common tradition to supplement the macro as well as micro-nutrients to the animals for their robust health. The green forages, hay, silage and gruel are highly palatable and liked by all kinds of livestock.

Photo 3. Feeding green and dry forages of millets to the livestock by small holder farmers in Nepal

Conservation Methods of Forages of Millets to Feed Livestock

Green forages of surplus seasons can be conserved as hay and silage. Almost all millets are of good forages for hay making where as some of the millets are equally important for silage making as well.

Hay making

Green forages of millets when dried to around 85% DM that preserve most of its nutrients including carotene are called hay. It is always advised to dry the green forage under the shade for keeping the original color, reduce leaves shattering, make free of any kind of fungus, relished aroma for the animals and reduce the moisture content to below 15% to make a good hay from the millets. The prepared hay is stored in dry places so that it can be safely stored without any risk of unwanted fermentation and combustion. These hays can be fed to the animals when there is the scarcity of green forage in the farms.

Photo 4. Prepared hay of different millets for feeding livestock

Silage making

Silage is prepared under the controlled fermentation of green millet-fodder retaining the high moisture content in it. Fresh fodder after harvesting at proper stage are chopped and packed in a container or ensiled in the trench to let them ferment under the anaerobic condition. Production of volatile fatty acids of the desired aromatic condition and for preserving the forage materials for a long time keeping in mind for the minimal losses of nutrients are the preliminary conditions for the preparation of good quality silage. Millets, such as finger-millets, pearl millets, para grasses, setaria, sorghum, bajra, etc. could be taken as good crops for silage making. They are to be harvested in appropriate stage of their lives, milk or dough stage, before being hard/tough stem to ensile them. Such silage can be taken as the substitute of the green forage during the time of scarcity.

A good quality millet-silage should have a greenish yellow color, no mold growth, with acceptable aroma as their physical characteristics. pH value of 3.5-4.5, ammonium nitrogen production of 10-12% of the total nitrogen production, concentration of butyric acid of less than 0.2% and higher ratio of lactic acid, 35-40% of DM are some of the important chemical characteristics of good quality silage of the millets.

Haylage making

Haylage are the ensiled hay of grasses and legumes. Millets can be best used by mixing the legumes to prepare the good quality of haylage. Haylage should have the DM content of 30-35%. About 30-35 kg of molasses can be added per mt of green forage of millets to improve the lactic acid fermentation and making the better quality of haylage of millets.

Treatment of Millet-Straw for Better Palatability and Nutrients Availability

Straw and dried forage of millets are very poor in nutrients availability. These are particularly poor in protein and have very high percentage of crude fiber. Millet-straws are comparatively poor in available calcium, phosphorus and other trace elements but are rich in silica content. The DCP content of millet straw is also very low while TDN is about 40% (Benerjee 2011). Finger-millet straw is not used for feeding livestock in developed countries but generally used as bedding material. In Asian countries, particularly in India and Nepal, 1-2 kg of concentrate is added to the basal regime of millet-straw to make the maintenance ration. The ester linkages between lignin of such straw and the cell wall polysaccharides makes the carbohydrates more resistant to rumen microbial enzyme. Silica of the straw also resembles lignin for its digestibility. Inappropriate storage of straw, e.g., stacking in moist floor, may cause mycotoxins contamination that may cause diseases associated with *Fusarium* species. These all are the limitations of millet straw feeding to livestock (Paudel et al 2000). To overcome these limitations and to enhance the nutritive value of millet-straws, several techniques of straw treatment have been developed in last decades. Some of the important treatment methods are as follows:

Soaking of straw: Chaffing the millet-straw into smaller pieces and soaking them with equal volume of water for few hours before feeding increases the nutritive value of straw through removal of silica, oxalates and other dust and inert materials. It helps to make the straw soft and more palatable and digestible.

Urea treatment: Different methods and modalities have been introduced in rice straw treatment by using urea. Similar practices can be applied in millet-straw treatment as well. In general, 4% of urea treatment is common in practice. In this practice, 100 kg of millet-straw is mixed with a solution of 4 kg of urea in 40 liters of water. The solution is uniformly mixed/sprayed and covered with polythene sheet or with gunny bags or by banana leaves for 3-4 weeks. This treatment will make the straw more palatable, digestible and enhance the nitrogen content of straw which in turn will be used by rumen microbes for protein synthesis. The basic principle of Urea treatment of such straw is ammonia and carbon dioxide formation by the decomposition of urea in the presence of moisture and enzyme urease.

$$NH_2\text{-}CO\text{-}NH_2 \text{ (Urea)} + H_2O \rightarrow 2NH_3 \text{ (Ammonia)} + CO_2$$

Urease enzyme

Note: This means NH_2CONH_2 is Urea. Urea reacts with H_2O (water) in the presence of Urease enzymes produces $2NH_3$ Ammonia and CO_2 (Carbon dioxide).

The ammonia, as a weak alkali, thus produced acts on the bonds of lignin-hemicellulose-cellulose linkage making cellulose and hemicelluloses available. This increases the digestibility and subsequently leads to increases the body weight gain and milk production in cattle and buffaloes (Reddy 2014).

Alkali treatment of millet-straw: One liter of solution containing 1.25% of Sodium Hydroxide in water is used to one kg of straw that removes the significant amount of lignin and reduces oxalates that helps to retain normal calcium absorption to a great extent.

Ammonia treatment: Anhydrous ammonia or solution of ammonia in water is used to treat the millet-straw that increases the crude protein content of the straw. Ammonia acts as a fungicide that avoids the problems arising from alkali residues obtained with sodium hydroxide. Excess ammonia, if any, quickly volatizes when the treated materials are exposed to air (Reddy 2014).

Conclusion

Millets are moderate to poor in nutritional regimes for feeding livestock. Among 21 species of millets found in Nepal, five species are more important than others for livestock feeding. Very few researches have been carried out so far in exploring the importance and use of millets in livestock feeding in Nepal. However, there is a high potentiality to cultivate and use them in livestock feeding. Nepalese livestock are still underfed. The deficit of feed, DM and TDN, can be reduced by cultivating millets and use them by following the proper conservation and treatment measures. This may decrease the cost of production and will increase the production and productivity of livestock in Nepal. For this, high priority should be given in teaching, research and extension of millets production and use them in livestock feeding.

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I. Climate Changes and Abiotic Stresses

ञ. जलवायु परिवर्तन र अजैविक तनाव

Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Millets – Resilient Crops in the Changing Climate: A Review

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Summary

Millets, a group of underutilized and neglected indigenous cereal crops, exhibit climate-resilient attributes; however, there is a dearth of information on why and how. This is important to protect agriculture production systems and enhance food and nutrition security due to the increasing climate risk in South Asia. The study aims to document various possible factors that possess the crops that help to withstand climate extremes. A desk-study approach was used to explore and review various sources of literature and document some common attributes of possible climate resilience. Then, this information was analyzed and synthesized. The review demonstrated that millets, in comparison to other major cereal crops such as rice and wheat, have robust morpho-physiological and genetic attributes that can withstand increasing biotic and abiotic climate stresses such as rising atmospheric temperature, elevated CO_2 concentration, and decreasing water availability. The crop demonstrated water and nutrient efficiency, has efficient photosynthesis pathways, and is capable of better radiation utilization, among others, compared to C3 crops. These attributes are important for increased production as well as making the crop climate resilient. There is, however, inadequate research and development to inform the benefits of millets and utilize their morpho-physical and genetic characteristics in South Asia. Hence, more attention is required from all dimensions – policy, research, development, extension, and practice - to maximize the benefits of millets in the changing climate.

Keywords: Climate change, climate resilience, food security and livelihoods, millets

Introduction

Crop growth and productivity have largely been vulnerable to climate change (Gupta et al 2017). Temperature and rainfall are important climatic variables on which the yield of crops depends. The increase in temperature and changing pattern of rainfall in an area reliably influence the yield of crops (Luitel et al 2018). In addition, other short-term extreme climatic events such as floods, droughts, landslides, hurricanes, and severe freezes may become more common, with especially serious consequences for crops. Extreme weather events are becoming more frequent and intense (Yan and Alvi 2022).

South Asia is one of the most vulnerable regions to climate change (Barbier and Hochard 2018, Hussain et al 2019). Temperatures in Nepal increased at a rate of 0.056°C per year for the base period of 1971 to 2014. Warming occurred in all regions of Nepal, with the highest rate of increase taking place in the high mountain and Himalayas regions. Precipitation decreased in all seasons from 1971 to 2014, with the trends of decreasing precipitation observed mainly in the high mountains and high Himalayas in all seasons. Precipitation extremes are increasing. The projected climate scenario showed that Nepal's climate will warm further with increases in temperature for all seasons. Nepal will also be wetter in the future, but there will be decreased precipitation during the pre-monsoon and erratic rainfall. Nepal will experience extreme climate events in the future (GoN 2021).

Small rainfed farmers are affected more by climate change because of their limited access to financial institutions and technical ability to adapt to it (Satishkumar et al 2013). The production of cereal crops has been affected by 9–10% due to adverse climatic conditions such as drastic increases in temperature, drought, and so on (Lesk et al 2016). According to Chandio et al (2023), climatic variables, including temperature and CO_2 emissions, negatively affected crop production, suggesting that a 1% increase in temperature and CO_2 emissions reduces crop production by 1.93% and 0.32%, respectively.

Currently, one-fourth of the world's population is living in South Asia, and it will grow by 40% by 2050. In the future, feeding an ever-increasing population will be a major challenge (Yan and Alvi 2023). Because of high rates of population growth and natural resource degradation, as well as persistently high rates of poverty and food insecurity (Barbier and Hochard 2018, Hussain et al 2019). Over the past century, extreme climate events have increased in South Asia.

There are a handful of options that can reduce the stress related to climate change. Modern crop improvement techniques such as genomics-assisted breeding and genetic engineering play an important role in understanding the complexities of climate risk-related stress response and tolerance as well as in providing measures for enhanced crop productivity. However, one of the possible solutions to counter these complex challenges can be identifying and using native crops that are highly adaptive to the local climate and can efficiently withstand biotic and/or abiotic stresses (Gupta et al 2017). It is therefore important to know the climate-resilient factors while selecting the varieties in the changing context. In this context, it is difficult to find a single staple food crop that fulfills all the major criteria. The wide variety and diversity of local food crops, such as minor millets, can, however, provide a choice of such climate-resilient crops (Gupta et al 2017, Shukla et al 2015).

Climate Resilience in Agriculture

The concept of resilience originally comes from civil engineering, which has been recently used in the natural resources management sector and climate change (Khanal and Pradhan 2021). Resilience is an emergent property, and stress tolerance requires the coordinated deployment of dozens to hundreds of molecular and phenotypic changes (Bray 1997). In terms of climate change, resilience is the ability of people and ecosystems to anticipate, avoid, plan for, cope with, recover from, and adapt to climate-related risks (Khanal and Pradhan 2021). It is critical in the context of the rising frequency of extreme weather events in recent years that affect farm-level productivity and impact food security. In this context, climate resilience has become an important aspect of the agricultural sector to stabilize crop yield in the face of ever-increasing climate risks, both at present and in future. Therefore, it is of utmost importance to enhance the resilience of crops to climate change (Lenka et al 2020).

Millet - Potential Crops for Climate Resilience

Millet, a C4 plant, is a cereal grain that belongs to the Poaceae family, commonly known as the grass family. Millets can be categorized as major, ie Pearl millet (*Pennisetum glaucum*), Sorghum (*Sorghum bicolor*), Finger millet (*Eleusine coracana*), Foxtail millet (*Setaria italica*); and minor, ie Proso millet (*Pennisetum glaucum*), Kodo millet (*Paspalum scrobiculatum*), Barnyard millet (*Echinochloa frumentacea*), Little millet (*Panicum sumatrense*) etc (Gajural 2017).

Millets were domesticated and cultivated as early as 10,000 years ago in northern China (Gujral 2017). Millets are culturally and economically important across Asia and Africa (Wilson and VanBuren 2022, Khatri 2012). Millets are critical plant genetic resources for agriculture that extend food and nutrition security to deprived farmers inhabiting arid, infertile, marginal, and poor lands, especially in Asia and Africa. Millets represent a diverse group of small-seeded grasses grown for food, feed, or forage. They comprise about a dozen crop species that mainly originated in Asia and Africa and were domesticated and cultivated by small farmers in semiarid and tropical regions. Some of the predominant millets are finger millet, foxtail millet, kodo millet, proso millet, barnyard millet, and little millet, and all of them are known for their unique traits and nutritional values (Kumar et al 2016).

Millets are hardy and grow well in dry zones as rain-fed crops under marginal conditions of soil fertility and moisture. Unlike rice and wheat, which require more fertilizer and water, millets grow well in dry regions as rain-fed crops. Millets are drought-resistant and need very little water for their production compared to rice and wheat (Saxena et al 2018) and can be cultivated under non-irrigated conditions or in very low rainfall regimes (200–500 mm) (Gupta et al 2017).

Millets are superfoods that can potentially provide a solution to rising gut-related diseases and metabolic disorders. Superfoods are food items that claim to confer health benefits resulting from their exceptional nutrient density. Millets, in contrast to rice and wheat, are not only a good source of energy and major nutrients, including protein, but are also a good source of micronutrients such as vitamins, including vitamins A, B, D, E, niacin, pyridoxine, antioxidants, iron, and zinc. Millets have a high protein content (10–12.3 g/100 g), fat (1% - 5%), iron (0.5–19.0 mg) and calcium (10–410 mg) compared to rice and wheat. Millets contain plenty of protective polyphenols. These polyphenols have antioxidant activity with free radical scavenging action and anti-inflammatory activity (Jena et al 2023).

Millets have comparatively low production with other challenges such as seed shattering, lodging (Wilson and Van Buren 2022) and market acceptance. It is therefore difficult to improve the productivity of these crops immediately as needed to serve the increasing demand for food. Distinctive attributes of the millets are their adaptation to adverse climatic conditions, requirement of minimal inputs, and superior nutritional properties (Gupta et al 2017, Lata et al 2013).

Millets are also more responsive to good production options such as planting time and duration, planting density, inter/intra row spacing, nitrogen application, and irrigation (Ullah et al 2017). In addition, millets are generally thermophilic (thriving at relatively higher temperatures) (Saxena et al 2018). All millets use the optimized C4 pathway of photosynthesis, which reduces photorespiration and improves water use efficiency, allowing millets to thrive in warm, dry climates (Wilson and VanBuren 2022). Being a C4 group of cereals, millets convert more carbon dioxide to oxygen, contributing to mitigating climate change. On the contrary, wheat and paddy, being thermally sensitive crops, are the major contributors to climate change through methane emission (Gujral 2017).

Despite their several benefits, millets are ignored, especially after the green revolution, and instead concentrated on rice and wheat. Considering the increasing role of millets in the changing climate, this review explores the unique morphological and genetic attributes and highlights features that contribute to the stress tolerance and climate resilience characteristics of millets. Finally, it is argued that the promotion of millets can be a key strategy for developing climate-resilient agriculture in arid and semi-arid agro-ecozones in South Asia.

Discussion

Based on the existing literature, millets are comparatively unexplored, considering climate change and its impacts. There were few studies completed on the pattern analysis of climatic variables and their impact at regional and local levels in South Asia. The formal crop improvement is directed at so-called major cereal crops such as rice, wheat, and maize. Despite being the major food crops for food and nutrition security in semi-arid and tropical regions, with their climate-resilient properties, research and development in these crops lagged far behind (Lenka et al 2020).

The review of the paper showed that millets have some attributes that help moderate climate change risks. Millets are generally thermophilic (thriving at relatively higher temperatures) and xerophilic (can reproduce with limited water input) (Saxena et al 2018). The exceptional tolerance of millets toward diverse abiotic stresses including drought, salinity, light and heat makes them a tractable system to study their stress-responsive traits at the cellular, molecular, and physiological levels (Bandyopadhyay et al 2017). Millets possess several morpho-physiological, molecular, and biochemical traits that confer better tolerance to changing climates (Lenka et al 2020). These traits, as a result, develop some distinct characteristics that make the crop more resilient to climate change and climate variability. Due to these attributes, millets are increasingly known as climate-resilient crops. They are grown on arid lands with minimal inputs and maintenance, are tolerant or resistant to diseases and pests, and are more resilient to climate shocks than other cereals. Some of the major attributes are presented below.

Genetic and genomic attributes

Genetic and genomic resources are imperative for the improvement of any crop species, where genetic resources serve as the primary input for developing good traits that help to adapt to climate change risks (Bandyopadhyay et al 2017). Such information is still scarce in the case of millet as compared to major cereals (Bandyopadhyay et al 2017). For example, according to Zhang et al (2012) and Bandyopadhyay et al (2017), whole genome sequencing of foxtail millet and comparison of gene families among 15 sequenced plant genomes showed that 1,517 genes were specific to foxtail millet. Among these, 586 genes were annotated as 'response to water', which could be playing significant roles in conferring drought and dehydration stresses, thus facilitating the adaptation of this crop to arid and semi-arid zones.

Optimized C4 pathway of photosynthesis

High-yielding plants are essential for meeting the demands of the ever-growing population and, therefore, need to ensure that photosynthesis occurs optimally for such plants. About 85% of crop plants like rice and wheat follow the C3 pathways, whereas maize and millet follow the C4 pathways.

C4 plants are more efficient than C3 plants in photosynthesis and resource usage, particularly in hot climates, where the potential for productivity is high (Cui 2021). The C3 pathway plants follow the Calvin cycle, and, in this case, the photosynthetic efficiency is lower because of excess photorespiration. Whereas the C4 plants work on enlarged physiological functions that are directly connected with the CO_2 concentration of these plants, therefore influencing the plant's metabolism. As the cells in the C4 species are enlarged, there is always close contact between the mesophyll and bundle sheath cells, which are interconnected via plasmodesmata (see **Figure 1**). Compared to the C3 photosynthesis process, the C4 process takes one or two additional molecules of ATP per fixed particle without requiring any other reduction equivalents (Cui 2021, Wang et al 2012, Wilson and VanBurent 2022, Tadele 2016).

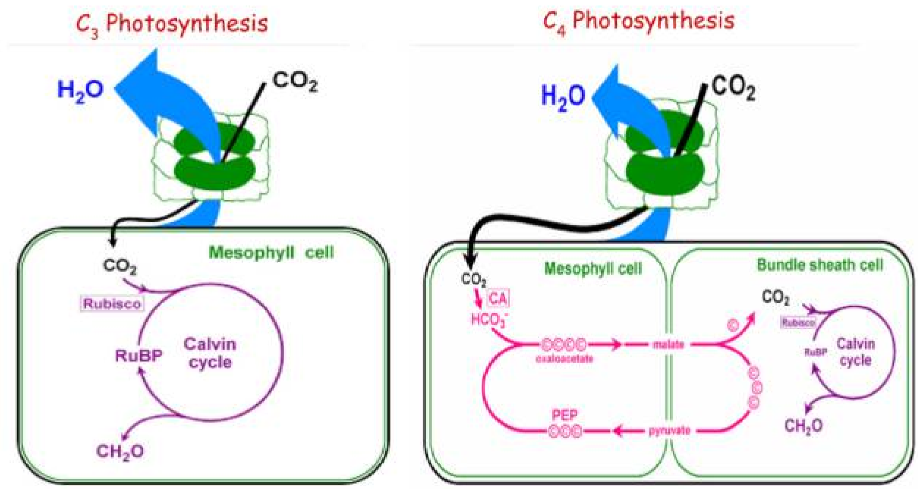

Figure 1. A schematic diagram of C_3 and C_4 photosynthesis (Wang et al 2012)

Less carbon emission

Cereal crops have significant global warming potential. Among all the major cereal crops, wheat has the highest global warming potential of around 4 tons CO_2 eq/ha followed by rice and maize (around 3.4 tons CO_2 eq/ha). These crops also have high carbon equivalent emissions of 1000, 956 and 935 kg C/ha for wheat, rice, and maize, respectively (Jain et al 2016). Whereas, the carbon footprints of other minor cereal crops, such as millets and sorghum, are comparatively lower. This is one of the primary reasons that millets could reduce the carbon footprint in the world (Prasad and Staggenborg 2009, Saxena et al 2018).

Morpho-physiological traits

Drought-resistant ability/water use efficiency

Due to the difference in genomic characteristics of millets, they are resilient to extreme environmental conditions such as drought and poor soil conditions (Tadele 2016). In addition to its resistance to drought, some millets, such as proso millet, help to escape the drought as they have a shorter growing season (ie three months). Hence, millets are considered to be crops with low water requirements (Tadele 2016, Goron and Raizada 2015, Wilson and VanBuren, 2022). Millets have comparatively deeper root systems (Bandyopadhyay et al 2017). For example, pearl millet growth and development respond to good soil moisture conditions (irrigated) and even perform reasonably in unpredicted weather conditions due to deep and rapid root penetration (Ullah et al 2017). Additionally, C4 plants can close their stomata for long periods, they can significantly reduce moisture loss through the leaves (Tadele 2016). Paired with their C4 physiology, and deep and fibrous root systems, millets can quickly enhance water availability and maintain stability during environmental changes. When combined with anatomic and physiological adaptations, these dehydration responses allow millets to survive low critical leaf water potential until conditions improve (Wilson and VanBuren 2022).

This water use efficiency is highly important with increasing drought conditions. For example, about 4000 liters of water are consumed to grow one kilogram of rice (MNI 2016), whereas the water requirement of millets is on average 2.5 times lower than that of rice.

Besides these, there is some literature that also indicates that C4 plants are more efficient than C3 plants in terms of accumulating biomass at different split of nitrogen application regimes. The C4 cereals produce higher biomass and grain yields as compared to the C3 cereal crops (Fatima et al 2018). This variation in biomass and grain yield would be due to the supremacy of C4 cereals as compared to C3 cereal crops in harnessing higher resource use efficiencies for nitrogen (Niu et al 2003). Fatima et al (2018), found that C4 summer cereals out-yielded C3 winter cereal in terms of RUE and NUE. The RUE and NUE varied from 0.90 to 2.31 g MJ^{-1} and 17.84 to 51.86 kg^{-1} for the C3 and C4 cereals, respectively.

Attributes to adapt to the changing climate

Morphophysiological and biochemical studies of millets have shown their stress adaptation strategies. Some millets can respond according to the weather (Bandyopadhyay et al 2017). For example, pearl millet adjusts flowering phenology according to the pattern of rainfall (Bidinger et al 2007), whereas Balsamo et al (2006) observed an increase in leaf tensile strength in teff during drought, and in little millet, an increase in root length was reported by Ajithkumar and Panneerselvam (2014). van der Weerd et al (2001) showed the dynamics of membrane permeability for water in pearl millet in comparison to maize for achieving better water status during osmotic stress.

Millets are also found to be a response to future climate scenarios. Sultan et al (2013) took into account 35 possible climate scenarios by combining precipitation anomalies from −20% to 20% and temperature anomalies from +0 to +6 ◦C. The simulations show that the photoperiod-sensitive traditional cultivars of millet and sorghum used by local farmers for centuries seem more resilient to future climate conditions than modern cultivars bred for their high yield potential. Photoperiod-sensitive cultivars counteract the effect of temperature increases on shortening cultivar duration and thus would likely avoid the need to shift to cultivars with a greater thermal time requirement. However, given the large difference in mean yields of the modern versus traditional varieties, the modern varieties would still yield more under optimal fertility conditions in a warmer world, even if they are more affected by climate change.

Genetic resources for future research

Each cereal and its response to climate are shaped by its unique domestication history, genetic traits, and the degree and intensity of breeding. Leading cereals such as maize, rice, and wheat were selected for optimized yield under intensive cultivation and stress tolerance, and they become susceptible to numerous abiotic stresses. Millets are an exception, and although generally lower yielding than leading cereals, they are adapted to dry conditions unsuitable for other grain crops. Millets are often referred to as orphan crops due to their low yield, are neglected as major staple crops, and are grown on marginal land. They, however, retain their climate-resilient attributes in their genes (Wilson and VanBuren 2022). These diverse genetic resources are now a great resource, which are generally not available to other major cereals to work on a molecular level such as crossbreeding, marker-assisted gene pyramiding, genome-wide selection and genome editing for improving stress tolerance in the potential climate resilient millet crops (Bandyopadhyay et al 2017 and Lenka et al 2022).

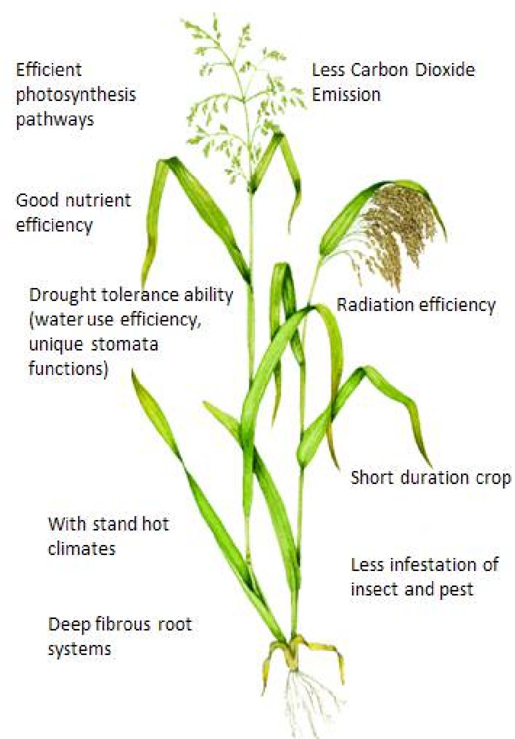

Image 2. Corresponding traits of millet for climate resilience

Millets: promising crops for the twenty-first century

Before the improvement of other high-yielding cereal crops, the advancement of chemical fertilizer, and technological improvements, millets were popular as they could be grown in rainfed and marginal lands as well. They can be cultivated in arid climates without irrigation, are tolerant to high temperatures, and are resistant to pests and diseases. They have high water and nutrient use efficiency. They do well in rotation with other crops and can be used for food, forage, and cover crop purposes. Additionally, millets require minimal fertilizer inputs and emit fewer greenhouse gases compared to other cereal grains. Because of this, millets have the potential to reduce emissions, improve soil health, and ultimately fight climate change (see **Figure 2**). They also have important genetic resources that can be used to address some climate risks (Tadele 2016, Bandyopadhyay et al 2017, Wilson and VanBuren 2022, Gupta et al 2017, Lenka et al 2020). This showed that millets are climate-resilient crops.

Conclusion

The unique resilience of millets can be traced back to their origin and domestication history. Resilience traits in millet stem from their unique evolutionary history, domestication in semi-arid regions, and continual selection for stability over yield.

Millets are known for their climate-resilient feature, including adaptation to a wide range of ecological conditions and a lower water requirement, among others. Millets possess several morpho-physiological, molecular, and biochemical traits that confer better tolerance to changing climates. Climate change is making agriculture production systems challenging with the increase in temperature and increasing water stress along with various climate extremities. Millets require less water than rice and wheat. They are very tolerant of heat, drought, and flood. The deep roots improve soil structure and water retention. The study showed that millet is a hardy, climate-smart grain crop, idyllic for environments prone to drought and heat stress.

It could not be confirmed that millets, as C4 plants, can work under elevated CO_2 levels, reduce less carbon dioxide, improve photosynthetic rates in warm conditions, and present prompt water use efficiency (WUE) and nitrogen use efficiency (NUE) than C3 photosynthesis. The short life cycle (seed to seed) in millet helps in escaping from stress. Traits responsible for evading stress conditions include short stature, small leaf area, thickened cell wall and capability to form a dense root system. Millets can grow in both low and high altitudes and across a wide latitudinal range, on arid lands, under non-irrigated conditions, in very low rainfall regimes, and have a low water footprint. Due to the availability of climate resilience attributes, there is also ample opportunity to improve stress resistance traits for breeding/crop improvement for climate resilience. With these attributes, millets are an obvious choice for farmers in an era of climate change and are considered good crops for farmers to deal with the effects of climate change.

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Genetics and Breeding Perspectives of Millets as Climate-resilient and Abiotic Stresses-tolerant Crops

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Summary

In the context of evolving climate changes and the need for climate-resilient and abiotic stress-tolerant crops, millets emerge as a promising solution. These C4 crops exhibit remarkable adaptability and resilience, attributed to their high degree of genetic variability, a localized focus on cultivation, and a strategy that minimizes environmental shock. Millets demonstrate an inherent ability to withstand a wide range of abiotic stresses, a testament to their hardiness and resource efficiency. However, it's essential to acknowledge that certain millet cultivars may have limits in their resistance to high levels of specific stresses. To harness the potential of millets for climate adaptation, genetics and breeding approaches are invaluable. Understanding the genetics of millets and the identification of tolerant genes to abiotic stresses have paved the way for the development of resilient millet varieties. Molecular tools enable precise screening of germplasm for these desirable traits. Screening techniques are typically conducted in controlled environments, laboratories, and hotspots, where different stress scenarios can be simulated and studied. The cultivation of site-specific polymorphic cultivars represents a powerful strategy to mitigate the impacts of climate change and abiotic stresses.

Keywords: Climate smart plant breeding, screening, genetic diversity, abiotic stress tolerant

Background

The world is facing an unprecedented challenge in the form of climate change, driven by the relentless impact of human activities. This rapidly changing climate has left no sphere of life untouched, including agriculture. The repercussions are profound, ranging from partial losses to the outright failure of crop production, threatening global food security (Lenka et al 2020, Assefa and Fetene 2013, Makarana et al 2019). As we navigate the unpredictable and evolving climate landscape, there is an imperative need to adapt our agricultural practices and genetic resources accordingly. This evolving environment compels us to develop dynamic strategies for preserving and enhancing agricultural genetic resources (AGRs) to ensure they remain resilient and productive in the face of these changes.

AGRs including millet crops have evolved over decades, shaped by the specific conditions of the production areas. These genetic adaptations play a pivotal role in enabling crops to cope with the challenges posed by climate change (Numan et al 2021, Chaturvedii et al 2023, Bhatt et al 2011). Genetic diversity and the occurrence of increased meiotic events underpin the potential of millets to exhibit resilience to climate variability and tolerance to abiotic stresses (Palikhey et al 2016, Parajuli et al 2016, Ghimire et al 2023b, Joshi et al 2016, 2020).

Among the myriad crops cultivated globally, millets stand out as an exemplar of hardiness and adaptability. Millets have continued to flourish in specific and diverse regions, earning them the distinction of being climate-resilient and tolerant to a wide array of abiotic stresses (Chaturvedi et al 2023, Ghimire et al 2023b, Tadele 2016). It is these qualities that have led to the nomenclature of "smart crops" (Joshi et al 2019, Lenka et al 2020). From the tropical landscapes to the alpine terrains of the Himalayas, millets have not just survived, but thrived (Ghimire et al 2023b, Palikhey et al 2016, Parajuli et al 2016, Joshi and Joshi 2002, Joshi et al 2005). Their innate ability to endure and produce under such diverse conditions makes them a subject of great interest, as they offer a valuable genetic resource for developing crops that can withstand the changing climate.

Understanding the genetics of millets is an essential foundation for breeding new varieties that exhibit climate resilience and tolerance to abiotic stresses (Srivastava et al 2022). Number of genes associated with climate changes and abiotic stresses have been identified and based on which high yielding varieties have been developed (Tiwari et al 2022, Saleem et al 2021). These genetic insights are the key to unlocking the potential for high-yielding, location-specific performance. Compared to many other crops, millets have proven to be less affected by the capricious nature of climate change and other abiotic stresses. Even in the harshest conditions, millets exhibit a remarkable capacity to perform well, which is of paramount importance in the context of both grain and forage production.

This article explores the genetic and breeding perspectives of millets in the context of climate resilience and abiotic stress tolerance. By delving into the genetic foundations of these remarkable crops, we aim to shed light on the potential of millets as a resource for developing a new generation of resilient and adaptable crop varieties that can address the challenges posed by the ever-changing climate.

Climate Changes and Abiotic Stresses

Climate changes

Over the past centuries, climate changes (**Figure 1**) in Nepal have manifested in a rising trend of temperature anomalies. The combined land and ocean temperature at the global level has witnessed a consistent increase, with an average rate of 0.08°C per decade since 1880, as reported in the 2022 Global Climate Summary by the NOAA[1]. This global warming phenomenon, primarily attributed to human activities, is estimated to have caused around 1.0°C of warming above pre-industrial levels. Projections indicate that if current trends persist, global temperatures are likely to reach the critical threshold of 1.5°C between 2030 and 2052, with far-reaching consequences for ecosystems, societies, and economies worldwide in the 2022 Global Climate Summary by the NOAA.

1 https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202213

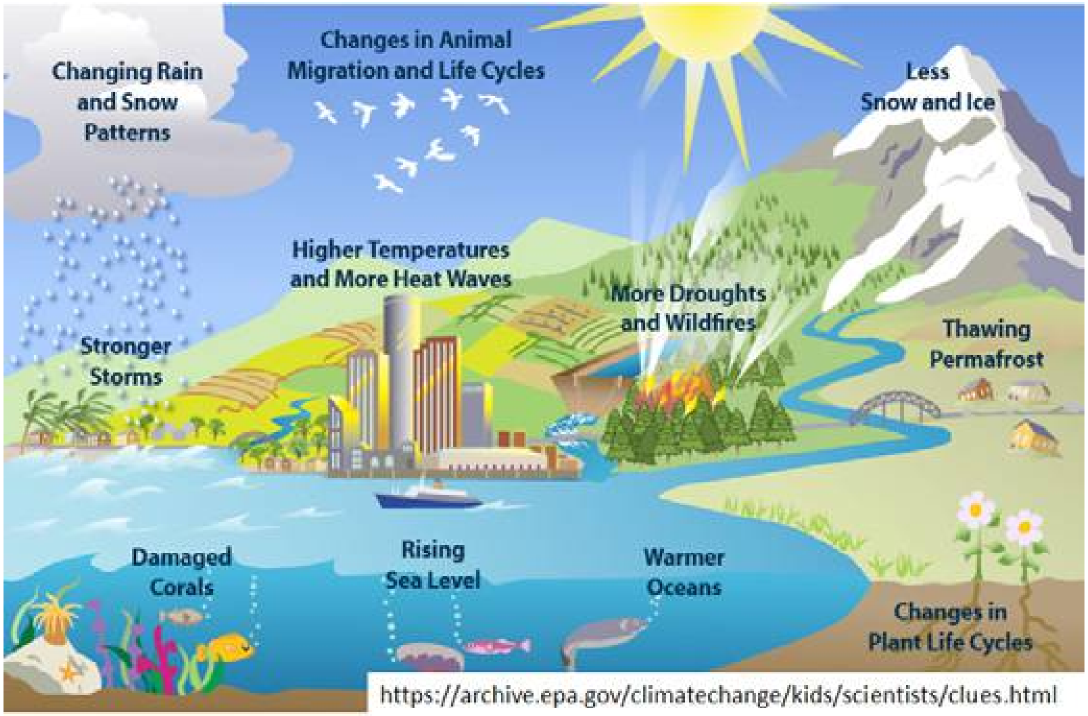


Figure 1. Understanding climate changes

In the context of Nepal, the effects of global warming are evident in the rising temperatures, erratic rainfall, etc across the country. Climate changes are generally measured through different approaches (**Figure 2**). According to data from the Department of Hydrology and Meteorology (DOHM), Nepal's average annual maximum temperature has increased by approximately 0.056 degrees Celsius (**Figure 3**). Notably, this increase varies across different regions, with the low-lying Tarai districts experiencing the lowest temperature rise, at 0.02°C, while the high Himalayan regions have witnessed the most significant increase, at 0.086°C. This regional variation underscores the need for localized strategies to address the specific challenges posed by climate change in Nepal, which range from shifts in precipitation patterns to the rapid retreat of glaciers and its far-reaching consequences on water resources and livelihoods.

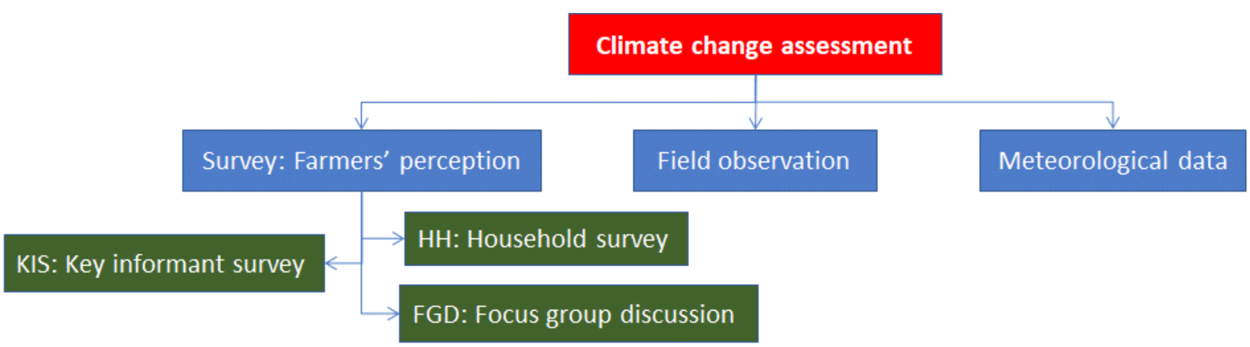


Figure 2. Assessment of climate change and their impact

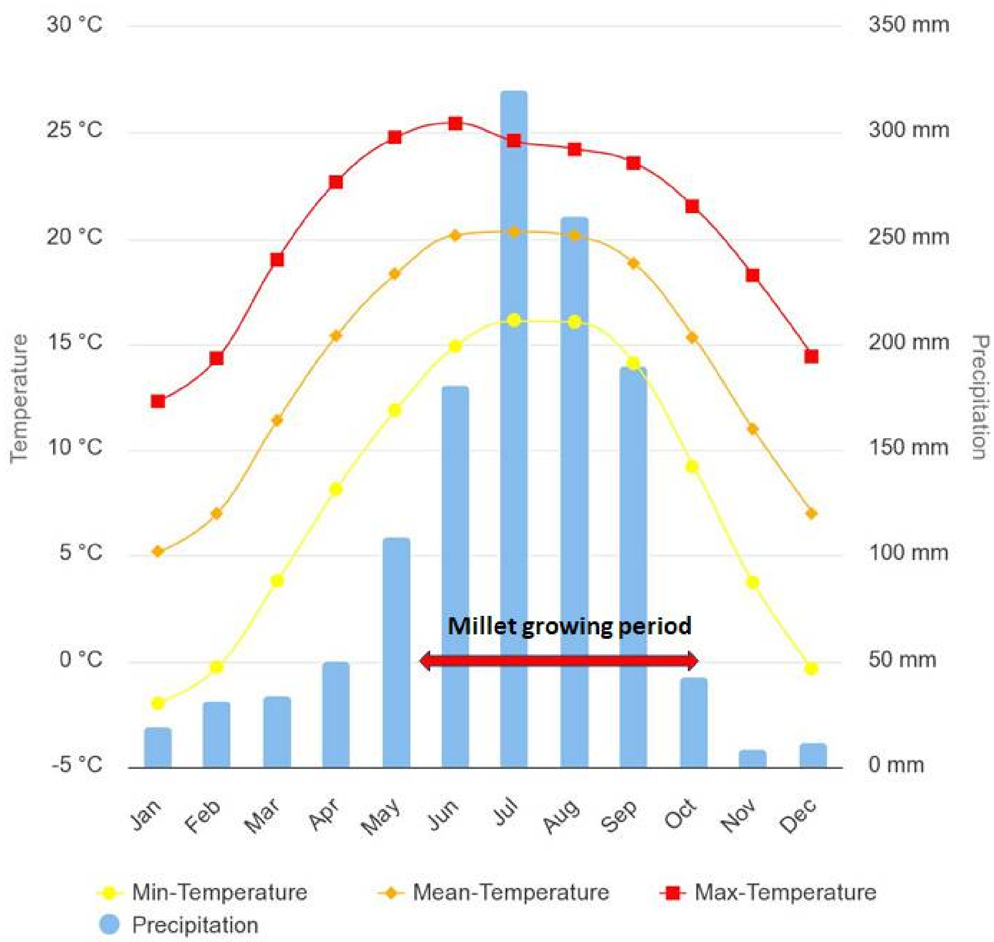


Figure 3. Monthly climatology of temperature and precipitation from 1991-2020 in Nepal
Source: https://climateknowledgeportal.worldbank.org/country/nepal/climate-data-historical, accessed at 3 Sept 2023

Abiotic stresses

Abiotic stresses in millets, as in other crop plants, are primarily attributed to non-living components of the environment that influence their growth and productivity. These factors are significantly influenced by climate changes, which are part of a dynamic, multifaceted system of alterations in environmental conditions affecting both abiotic and biotic components of the world. Abiotic stresses can be grouped into several categories (**Figure 4**).

a. Climate Change Regulated Stresses

1. **Drought:** Prolonged periods of inadequate rainfall or water availability can severely impact millet growth and yield.
2. **Heat (High Temperature):** Elevated temperatures, especially during critical growth stages, can lead to heat stress, reducing crop performance.
3. **Cold (Low Temperature):** Exposure to sub-optimal temperatures, particularly during flowering and seed formation, can hinder millet development.
4. **Flooding and Water Logging:** Excessive water in the root zone can lead to root damage and oxygen deficiency, impeding nutrient uptake and overall growth.

5. **Rainfall:** Erratic rainfall patterns can disrupt millet cultivation, affecting sowing and germination.
6. **Humidity:** High humidity can encourage the growth of fungal diseases and impact crop health.
7. **Wind:** Strong winds can physically damage millet plants, affecting their structural integrity and productivity.
8. **Light and Radiation:** Intense light and radiation can lead to photoinhibition, affecting photosynthesis and overall plant health.
9. **Hail:** Hailstorms can cause physical damage to millet plants, including leaf shredding and bruising.
10. **Elevated CO_2:** Increased atmospheric CO_2 levels can influence plant physiology and nutrient content.
11. **Sunshine Intensity:** Extreme solar radiation and UV exposure can harm millet crops.

b. Chemical-Based Stresses

1. **pH:** Soil pH imbalances can hinder nutrient uptake and affect millet growth.
2. **Salinity:** High soil salinity levels can lead to osmotic stress and ion toxicity.
3. **Heavy Metal:** Soil contamination with heavy metals can result in toxic effects on millet plants.
4. **Nutrient Stress:** Inadequate or excessive nutrient availability can disrupt millet nutrient uptake and utilization.
5. **Toxicity Stress:** Exposure to toxic substances, including pesticides or pollutants, can harm crop health.

c. Human Activities Regulated Stresses

1. **Polluted Air Stress:** Air pollution from industrial and vehicular emissions can negatively impact millet crops.
2. **Dust Stress:** Dust particles in the air can interfere with photosynthesis and overall plant health.
3. **Waste Stress:** Proximity to waste disposal sites can expose millet crops to contaminants.
4. **Polluted Water Stress:** Water pollution from various sources can affect irrigation and soil quality.
5. **Transplant Shock:** The process of transplanting millet seedlings can induce stress.
6. **Mechanical Stress:** Physical damage to millet plants caused by machinery or human activities.
7. **Herbicide Stress:** The application of herbicides can have unintended consequences on millet crops.
8. **Shade:** Insufficient light due to shading can limit millet growth and yield.

Understanding and mitigating these abiotic stresses is essential for maintaining and improving millet production, especially in the face of climate change and human activities that may exacerbate these stress factors. These stresses bring changes at molecular, biochemical and physiological levels in crops.

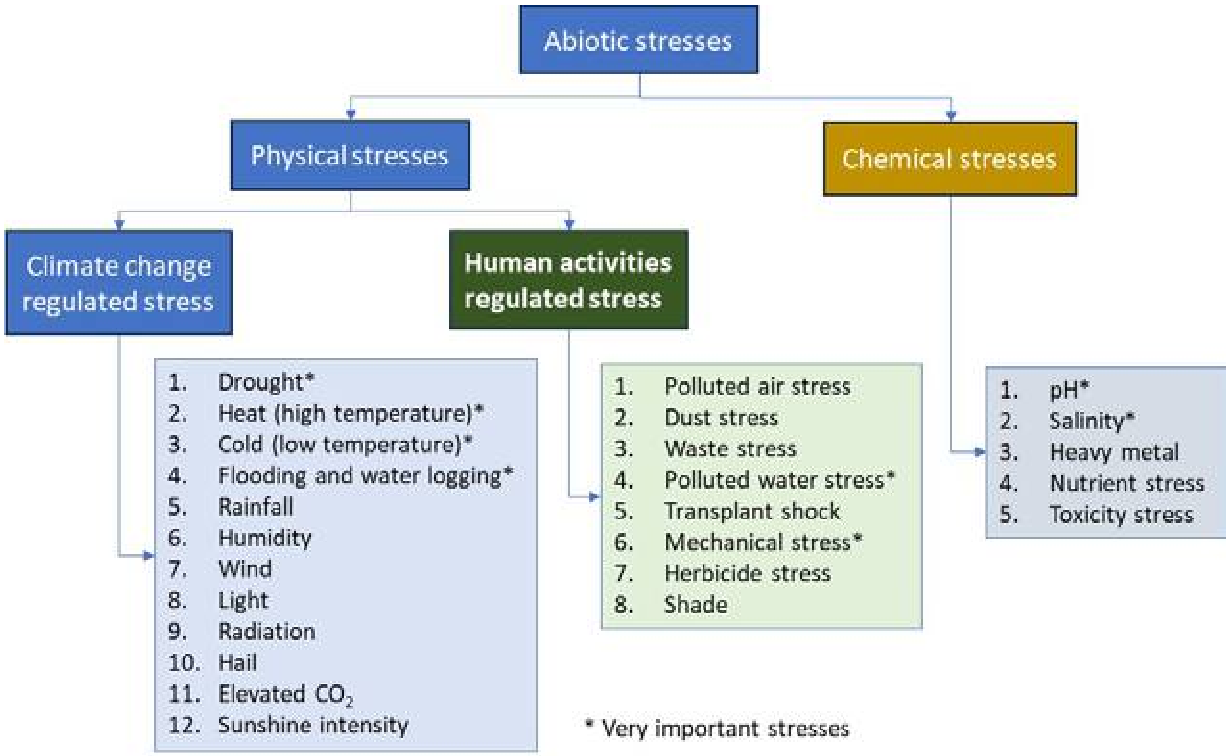


Figure 4. Grouping of abiotic stresses

These abiotic stress factors exacerbated by climate change cause osmotic and oxidative stresses in crops (Saleem et al 2021). These stresses jeopardize plant growth and productivity. Osmotic stress arises from sudden shifts in solute concentration around plant cells, disrupting water movement across cell membranes. Factors like high salinity and drought under natural conditions are primary causes of osmotic stress. In salt stress, ion imbalance and water scarcity in plant cells trigger osmotic stress, affecting normal cellular functions.

Oxidative stress occurs when crops face extreme abiotic conditions, leading to the excessive production and accumulation of reactive oxygen species (ROS). Abiotic stress conditions often accelerate ROS production, which can be harmful to plant cells when present in high concentrations. Drought-induced stomatal closure, for instance, can lead to an overabundance of ROS, resulting in oxidative stress (Saleem et al 2021, Tiwari et al 2022). This, in turn, causes lipid peroxidation and damage to other essential molecules in plant cells.

Farmers' Perceptions on Climate Changes

Farmers across diverse regions have experienced an array of negative impacts attributed to climate change. Prolonged droughts have led to dwindling soil moisture, sometimes preventing the successful germination of essential crops. Erratic rainfall patterns and temperature fluctuations have resulted in decreased crop yields, affecting staples like millet, black gram, and mustard. The emergence of new insect pests and diseases, often previously unseen in these areas, poses additional challenges to crop production. Climate-driven extreme weather events, such as excessive rainfall, have led to environmental and water pollution, with soil erosion and waterlogging becoming common issues. Moreover, livestock health has suffered due to heat stress and waterborne diseases, and earthworm populations, crucial for soil health, have declined. These climatic changes have also shortened the life cycle of crops and caused reduced fruiting in fruit trees, further impacting agricultural productivity.

While climate change presents considerable challenges, some farmers have also noted certain positive impacts. The extended farming period in regions with milder conditions allows for more crops to be cultivated over a longer duration. High-altitude areas may experience favorable conditions for the cultivation of new crop species, expanding the range of vegetables that can be grown. Reduced humidity and improved drying conditions may benefit seed storage and quality. Some traditional landraces, which possess a broad genetic base, continue to thrive in the face of changing conditions. Additionally, climate-driven natural mechanisms, such as increased predation, may automatically control certain pests, reducing the need for chemical interventions. Local fruits may enjoy improved size and taste, and in areas with multiple cropping seasons, farmers can now grow two different crops within a year, thereby increasing agricultural productivity. These positive aspects demonstrate that adaptation strategies can be explored alongside the challenges posed by climate change.

Genetics and Breeding of Millet Crops in Response to Climate Changes and Abiotic Stresses

Genetics and breeding of millet crops play a crucial role in responding to climate changes and abiotic stresses. Millets go through five major developmental stages: dormant, seedling, vegetative, reproductive, and grain filling stages (**Figure 5**). Each of these stages can be significantly influenced by climate variations, making it essential to identify and address the critical stages (**Table 1**) to mitigate the impact of these changes.

C4 millets, which are a type of millet with a unique photosynthetic pathway, tend to be less affected by climate changes and are better adapted to harsh and stressful conditions. Their specific photosynthetic mechanism allows them to perform well under adverse environmental conditions.

Landraces, which are traditional, locally adapted varieties of millets, tend to exhibit a higher degree of tolerance to climate changes due to their extensive genetic diversity (Ghimire et al 2023a). They are dynamic, evolving populations that have adapted to local conditions over time. Landraces are typically grown in the same localities throughout the entire millet production cycle, from seed production to grain production and storage, due to which they have zero environmental shock. This continuity in their environment helps them cope with climate fluctuations and minimizes the shock from changing conditions.

The performance of landraces of finger millet collected from the Tarai area displayed a notable inconsistency when cultivated in the high hill regions. This observation underscores the significance of localized adaptability in crop cultivation. It suggests that landraces originating from diverse agroecozones, such as the high hill, mid hill, and Tarai, may exhibit distinct adaptations (with specialized genetic makeup) and responses to their specific environments. This highlights the intricate interplay between local agroecological factors and the suitability of particular millet varieties, emphasizing the need for tailored cultivation strategies and varietal selection to ensure optimal performance in different agro ecozones.

It's important to note that various changes can occur in millet crops in response to climate changes, as mentioned in **Table 1**. To address these challenges, genetic and breeding efforts are focused on developing millet varieties that are more resilient to these changes, including those that can better withstand abiotic stresses and adapt to evolving environmental conditions (Srivastava et al 2022).

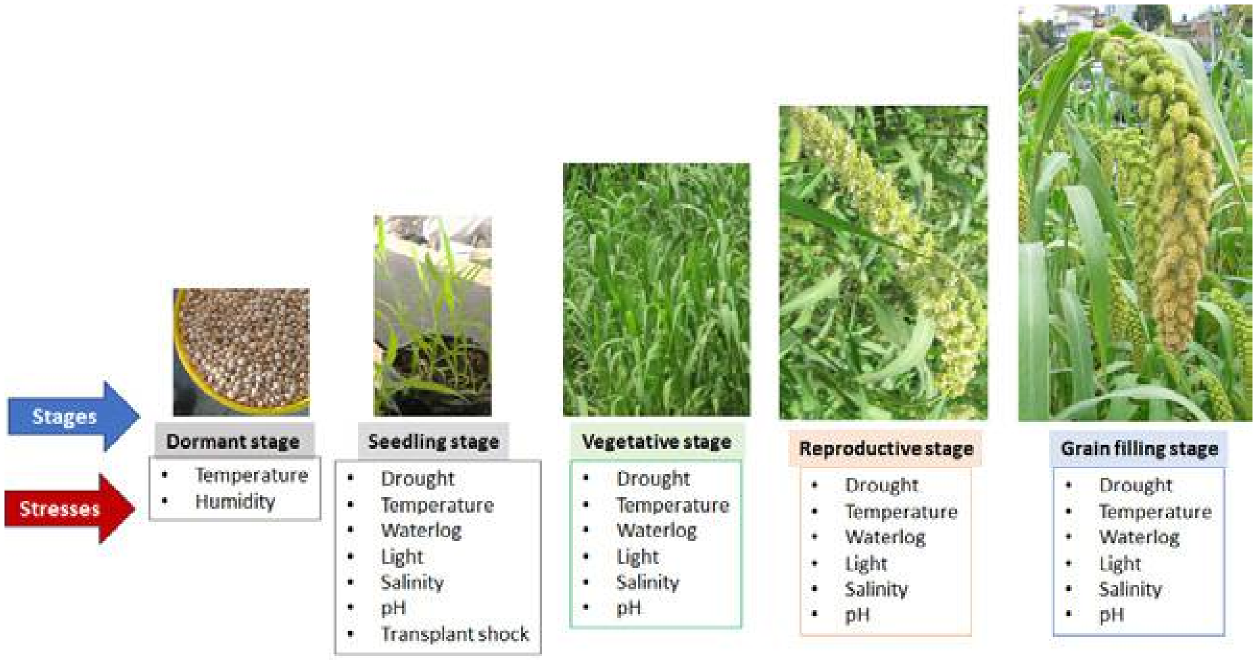


Figure 5. Growth stages of foxtail millet and stage specific abiotic stresses

Table 1. Millet crops with tolerance features and their impacts

SN	Millet	Chromosome	Stress and feature	Impact of stresses	Critical stage
1	Finger millet	2n = 6× = 36	Drought and salt tolerance	Plant height, leaf area, total dry matter, root/shoot ratio by weight, grain yield, and harvest index all exhibited declines, while the root/shoot ratio by length increased. A moderate rate of decrease in relative water content (RWC) and chlorophyll levels. A substantial decrease in leaf area, accumulation of dry matter, seed weight, radiation use efficiency, and overall yield (Bhatta et al 2011, Assefa et al 2013).	Flowering
2	Foxtail millet	2n = 2× = 18	Drought tolerance	in conditions of water stress, both root hair density and length experienced an increase. A notable decrease in shoot length occurred alongside an increase in root length. Water stress resulted in a decrease in the number of tillers and ears, as well as reduced peduncle and ear length, seed count, harvest index, and plant height. Interestingly, the findings revealed that foxtail millet demonstrated the highest yield in both stressed and non-stressed conditions when compared to other crops (Liu et al 2019, Aljithkumar et al 2014).	Before heading
3	Japanese Barnyard millet	2n = 6× = 36	Early maturity, anti-fungal		Flowering
4	Kodo millet	2n = 4× = 40	Drought tolerance		Flowering

SN	Millet	Chromosome	Stress and feature	Impact of stresses	Critical stage
5	Little millet	2n = 4× = 36	Abiotic stress tolerance	The root length exhibited a gradual increase under all drought conditions, whereas the shoot length progressively decreased (Ajithkumar et al 2013).	Before and after heading
6	Nepalese Barnyard millet	2n = 6× = 36	Early maturity	A moderate rate of decrease in relative water content (RWC) and chlorophyll levels (Tiwari et al 2020).	Flowering
7	Pearl millet	2n = 2× = 14	Drought & heat tolerance	Water stress resulted in a decrease in the number of tillers and ears, as well as reduced peduncle and ear length, seed count, harvest index, and plant height. Interestingly, the findings revealed that foxtail millet demonstrated the highest yield in both stressed and non-stressed conditions when compared to other crops. They noted a marked decrease in plant height, biomass, panicle and stalk length, leaf count, total grain count, and grain weight (Debieu et al 2018).	Flowering
8	Proso millet	2n = 4× = 36	Drought tolerance, early maturity	Water stress resulted in a decrease in the number of tillers and ears, as well as reduced peduncle and ear length, seed count, harvest index, and plant height. Interestingly, the findings revealed that foxtail millet demonstrated the highest yield in both stressed and non-stressed conditions when compared to other crops (Seghatoleslami et al 2008).	Before and after heading

Table 2 outlines various abiotic stresses, and numerous scientific studies have yielded valuable insights into the responses of millet crops to these environmental challenges. For instance, when subjected to saline stress, finger millet exhibits a range of adverse effects, including a reduction in chlorophyll content, decreased seed germination rates, lower survival rates, and impaired plant growth. Similarly, proso millet experiences significant setbacks when confronted with drought stress, leading to reduced grain yield, diminished water use efficiency, and a decline in the harvest index. These findings underscore the importance of understanding how millet crops respond to abiotic stresses, as it can guide efforts to develop more resilient and adaptable millet varieties to enhance agricultural sustainability in the face of changing environmental conditions. Responses at morphological, physiological, biochemical and molecular levels are given in **Figure 6**.

Table 2. The influence of abiotic stresses on millets

SN	Species	Stress	Impact on the plant	Reference
1	Finger millet	Saline stress was induced by exposing the samples to different NaCl concentrations (0, 50, 100, 150, 200 mM).	Salt levels exceeding 50 mM led to a reduction in chlorophyll content (both a and b), seed germination, survival rate, plant growth, as well as fresh and dry weights, while simultaneously increasing proline accumulation, leaf chlorosis, H2O2 content, and cell mortality. At concentrations exceeding 100 mM of NaCl, there was a decrease in relative water content (RWC) and a notable rise in electrolyte leakage, caspase-like activity, and the thickening of xylem vessel walls.	Satish et al 2016

SN	Species	Stress	Impact on the plant	Reference
2	Finger millet	Altering the temperature from its optimal range (32/22°C: daytime maximum/night-time minimum) to higher temperature levels, namely HT1 (36/26°C) and HT2 (38/28°C), led to the induction of high-temperature stress in the seedlings.	Elevated temperature stress caused a reduction in several key growth and yield-related parameters, including chlorophyll index, photosystem II activity, plant height, internode length, tiller count, leaf and stem dry weights, as well as harvest and grain yields. Additionally, it led to significant delays in panicle emergence (by 16 days), flowering (by 21 days), and physiological maturity (by 28 days). Notably, stress experienced during the booting, panicle emergence, or flowering stages of development resulted in the most substantial decrease in grain yield.	Opole et al 2018
3	Finger millet	The suspension of irrigation for 45-day-old plants led to water stress in the plants.	Under conditions of water stress, the plants exhibited wilted and curled leaves. There was a tenfold surge in proline leaf content and an increase in MDA content, electrolyte leakage, H2O2 concentration, and the activity of antioxidant enzymes (GR, SOD, APX, GPX, and CAT).	Bhatt et al 2011
4	Finger millet	Drought stress was applied in two regimes (fully irrigated and after drought)	Significant reduction in leaf area, dry matter accumulation, seed weight, radiation use efficiency and yield	Tiwari et al 2020
5	Finger millet	Drought stress was applied in two regimes (fully irrigated and after drought)	Results showed that reduction in plants growth, chlorophyll content due to drought stress	Aidoo et al 2016
6	Finger millet	Stress was given to plant by holding irrigation to 45-day old plants	Their results showed droopy, curling leaves, increased amount of proline, MDA, electrolyte leakage, Hydrogen peroxide and antioxidant activities.	Manivannan et al 2007
7	Finger millet and barnyard millet	Water stress was given (control, mild, medium, and severe condition	A significant reduction in chlorophyll content while MDA, proline and CAT activity increased during stress	Assefa et al 2013
8	Finger millet and barnyard millet	Water stress was given (control, mild, medium, and severe condition	Significant reduction in protein, carbohydrate, amylase and relative water content	Debieu et al 2018
9	Pearl millet	Drought stress was induced by withholding irrigation for a duration of 4 weeks, starting from the third week after germination	A substantial decline was observed in plant height, biomass, panicle and stalk lengths, leaf quantity, total grain weight, and the total count.	Debieu et al 2018

SN	Species	Stress	Impact on the plant	Reference
10	Pearl millet	Atrazine stress was induced by elevating the herbicide's concentration to various levels (0, 5, 10, and 50 mg/kg).	Elevating the herbicide concentration resulted in heightened levels of H2O2 and MDA, along with increased activity of antioxidant enzymes like APX and POD. Conversely, SOD and CAT activities decreased, and the expression of antioxidant genes was suppressed. Furthermore, photosynthesis was inhibited by the blockade of the electron acceptor protein PSII within the thylakoid membrane, leading to a disruption in electron transfer.	Erinle et al 2018
11	Pearl millet	After 3 weeks of germination drought stress was induced by ceasing water for 4 weeks	They observed a significant reduction in plant height, biomass, panicle, stalk length, no. of leaves, total grain number and weight	Maqsood et al 2006
12	Pearl millet and Finger millet	The presence of different nickel concentrations, spanning from 0 to 40 ppm, induced stress in the plants.	Elevated levels of nickel concentration led to the suppression of seed germination, inhibited root and shoot growth, and a reduction in both root and shoot dry weights. When exposed to higher nickel concentrations, the stems displayed a brownish discoloration. The activities of POD and SOD increased, while CAT activity decreased. At a nickel concentration of 40 ppm, the proline content saw a significant increase, ranging from 4.0 to 4.3-fold.	Gupta et al 2017
13	Pearl millet and sorghum	Controlled and stressed condition	Results showed that under water stress condition leaf water potential, rates of stomatal conductance, photosynthesis and transpiration decreased more in sorghum than in pearl millet	Subramanian et al 1989
14	Proso millet	Well- watered, drought stress at vegetative stage, ear emergence stage, seed filling stage and vegetative and seed filling stages	Drought stress results reduction in grain yield, Water use efficiency and harvest index	Seghatoleslami et al 2008

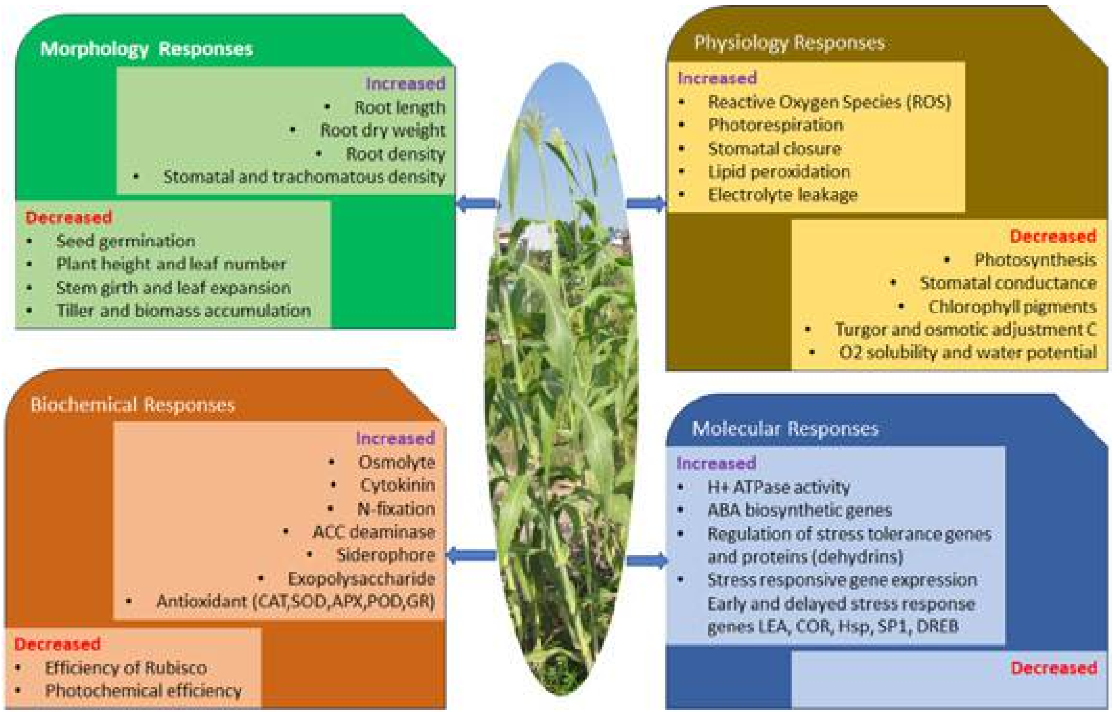


Figure 6. Responses of millet crops during drought stress
Redrawn from Tiwari et al 2022

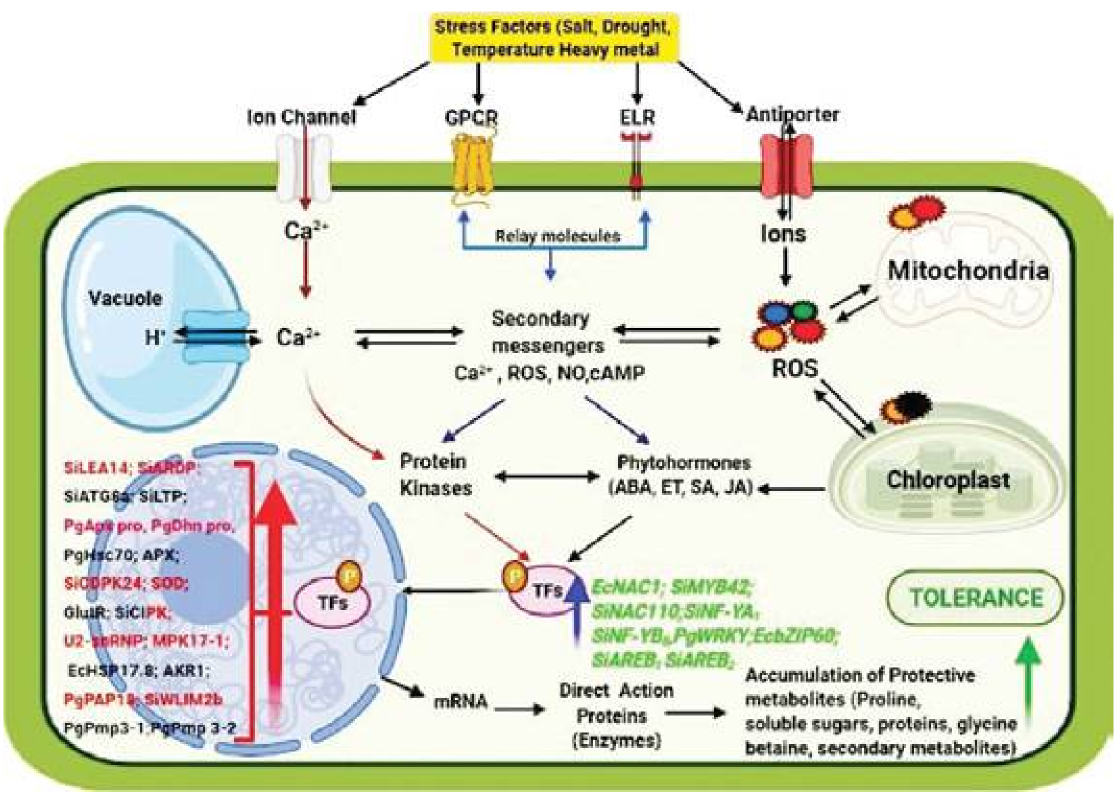


Figure 7. Molecular mechanism of adaptation in millets at the functional gene level
Adopted from Saleem et al 2021

Millet crops employ diverse adaptive mechanisms to combat abiotic stresses (**Table 3**). For example, finger millet's resilience to salinity is underpinned by the accumulation of elevated carbohydrate levels while maintaining favorable Na+/K ratios during stressful conditions. In the case of foxtail millet facing drought, adaptation involves a moderate decrease in relative water content (RWC) and chlorophyll levels, accompanied by heightened concentrations of soluble sugars and proline. Additionally, there's a notable increase in the phytohormones abscisic acid (ABA) and jasmonic acid (JA) as part of the stress response. The intricate molecular mechanisms underlying millet adaptation at the functional gene level are visualized in **Figure 7**, providing valuable insights into their ability to thrive in challenging environments. Biotechnological approaches have also been used to dissect the climate resilient traits in millets (Singh et al 2021).

Table 3. Adaptations at the biochemical and physiological levels to cope with stress in millets

SN	Species	Trait	Mechanisms of adaptation	Reference
1	Finger millet	Salinity tolerant	Accumulated elevated levels of carbohydrates while maintaining low Na+/K ratios during stressful conditions	Vijayalakshmi et al 2014
2	Finger millet	Drought tolerant	A 200% surge in ascorbate content was observed, effectively restricting the accumulation of reactive oxygen species (ROS).	Bartwal et al 2016
3	Finger millet	Drought tolerant	Notable buildup of proline, glycine betaine, and total soluble sugars was evident, accompanied by an elevated activity of antioxidant enzymes (SOD, CAT, APX, GPX).	Mundada et al 2020
4	Foxtail millet	Drought tolerant	A modest decrease in relative water content (RWC) and chlorophyll levels was observed, alongside heightened concentrations of soluble sugars and proline. Additionally, there was a substantial increase in the phytohormones abscisic acid (ABA) and jasmonic acid (JA).	XU et al 2019
5	Foxtail millet	High soil temperature tolerance	Efficient utilization and incorporation of carbon and nitrogen from the membrane, along with the accumulation of protective metabolites associated with stress (serine, threonine, valine, fructose, glucose, maltose, isomaltose, malate, itaconate) in the roots.	Aidoo et al 2016
6	Pearl millet	Salt adaptive	Accumulated a greater concentration of osmolytes, including proline and soluble proteins.	Makarana et al 2019
7	Pearl millet	Drought adaptive	Increased accumulation of secondary metabolites, including flavonoids, lignin, and terpenoids.	Shivhare et al 2019

For specific variety, see Saleem et al (2021)

Millet researchers have made significant strides in identifying genes associated with the crop's capacity to adapt to abiotic stresses, thereby enhancing its tolerance and resistance (**Table 4**). For instance, the AKRI gene found in foxtail millet is linked to pathways related to antioxidant defense. This gene plays a pivotal role in mitigating the harmful effects of oxidative stress caused by various abiotic factors. Wu et al (2023) has also demonstrated the physiological and molecular regulation on foxtail millet on salt stress condition.

In pearl millet, PgPmp3-1 and PgPmp3-2 have emerged as critical genes involved in the plant's response to cold and salt stress. These genes, when upregulated, significantly contribute to enhancing the plant's resilience in adverse environmental conditions, particularly cold and saline stress. Their activation is instrumental in fortifying the plant's defense mechanisms.

Furthermore, in foxtail millet, the SiLTP gene has been identified as a key player in bolstering salt and drought tolerance. The expression of SiLTP has been harnessed to enhance the adaptability of transgenic tobacco plants to these challenging conditions. These genetic findings provide valuable insights into the molecular mechanisms underlying millet's ability to thrive in stressful environments, offering promising avenues for crop improvement and resilience in the face of abiotic stressors.

Table 4. Genes associated with millet's ability to adapt to stress

SN	Gene	Source	Stress	Function	Reference
1	ACCase	Foxtail millet	Herbicide stress	The overexpression in transgenic maize led to heightened resistance to the herbicide sethoxydim.	Dong et al 2011
2	AKRI	Foxtail millet	Osmotic, salt stress	Involvement in pathways related to antioxidant defense.	Kirankumar et al 2016
3	Ec-apx1	Finger millet	Drought stress	Expression increased under drought	Bhatta et al 2013
4	EcbZIP60	Finger millet	Drought, salinity, oxidative stress	The expression in transgenic tobacco plants conferred tolerance to drought, salinity, and oxidative stresses. This was achieved by preserving cellular homeostasis through the upregulation of genes associated with the unfolded protein response pathway.	Babitha et al 2015
5	EcDehydrin7	Finger millet	Drought stress	Overexpression of EcDehydrin7	Singh et al 2016
6	EcHSP17.8	Finger millet	Heat stress, NaCl stress	Experienced a 40-fold upregulation during heat stress and is considered an early responsive gene associated with heat stress tolerance.	Chopperla et al 2018
7	Farnesyl pyrophosphate synthase	Finger millet	Drought stress	Induced under drought	Parvathi et al 2013
8	Farnesylated protein ATFP6	Finger millet	Drought stress	Induced under drought	Parvathi et al 2013
9	Metallothionein,	Finger millet	Drought stress	Induced under drought	Parvathi et al 2013
10	PgPmp3- / and PgPmp3-2	Pearl millet	Cold, salt stress	The upregulation of PgPm3 genes in response to cold and salt stress played a significant role in enhancing the tolerance of plants to these adverse conditions.	Yeshvekar et al 2017
11	Protein phosphatase 2A	Finger millet	Drought stress	Induced under drought	Parvathi et al 2013

SN	Gene	Source	Stress	Function	Reference
12	RISBZ4	Finger millet	Drought stress	Induced under drought	Parvathi et al 2013
13	SiARDP	Foxtail millet	Drought, salt stress, low temperature	Transgenic Arabidopsis plants exhibited improved tolerance to both drought and salt stress. It is suggested that DREB transcription factors may play a role in regulating the expression of SiARDP, contributing to this enhanced stress tolerance.	Li et al 2014
14	SiATG8a	Foxtail millet	Nitrogen starvation, drought stress	The overexpression in Arabidopsis resulted in enhanced tolerance to both nitrogen starvation and drought stress.	Li et al 2015
15	SiCDPK24	Foxtail millet	Drought stress	The overexpression in transgenic Arabidopsis plants significantly improved their resistance to drought.	Yu et al 2018
16	SiCIPK	Foxtail millet	Salt, cold, ABA stresses	Participates in stress responses and signaling pathways associated with various abiotic stresses.	Zhao et al 2019
17	SiLEA14	Foxtail millet	Salt, drought stress	The overexpression of this gene in transgenic Arabidopsis resulted in improved salt tolerance. Furthermore, when introduced into transgenic foxtail millet, it enhanced the plant's tolerance to both salt and drought stress.	Wang et al 2014
18	SiLTP	Foxtail millet	Salt, drought stress	The expression of SiLTP (a specific gene or protein) improved salt and drought tolerance in transgenic tobacco plants.	Pan et al 2016
19	SiNF-YAI and SiNF-YB8	Foxtail millet	Drought, salt stresses	Stress tolerance in tobacco was heightened by stimulating stress-related genes and enhancing various physiological traits.	Feng et al 2015
20	SiWLIM2b	Foxtail millet	Drought stress	The transgenic rice plants displayed increased resistance to drought, as evidenced by higher relative water content (RWC) and reduced cell damage.	Yang et al 2019
21	β-carbonic anhydrase	Pearl millet	Drought stress	Up-regulated when exposed to drought	Kaul et al 2011

Screening Techniques

Screening techniques in millets are fundamental in the quest to identify and cultivate climate-resilient and abiotic stress-tolerant germplasm. The process begins with the deliberate creation of stress environments, where a careful selection of stress factors such as intensity, duration, and type is essential. These screening methods encompass a wide spectrum, ranging from relatively straightforward approaches to more intricate, multi-stress assessments (**Table 2**, Ghimire et al 2023a, 2023b). They are primarily conducted in three distinct scenarios (**Figure 8**). In the laboratory, germplasm is evaluated based on its genetic makeup, without the need to subject it to the actual stressors. This genetic profiling aids in the identification of key markers associated with stress tolerance, facilitating the development of resilient millet varieties.

Controlled environments are a common and highly effective screening scenario, providing researchers with the ability to meticulously manipulate and replicate specific stress conditions (**Table 2**, Tiwari et al 2022). This controlled approach ensures rigorous assessment and the opportunity to test a wide range of millet varieties under consistent stress conditions. In addition, some screening takes place in naturally occurring stress hotspots, where specific abiotic stresses are naturally prevalent. In Nepal, for instance, conventional hotspot screening is widely employed, particularly for finger millet. While rare, controlled environments, such as greenhouses or plastic tunnels, have been used for screening, particularly when focusing on traits like drought tolerance.

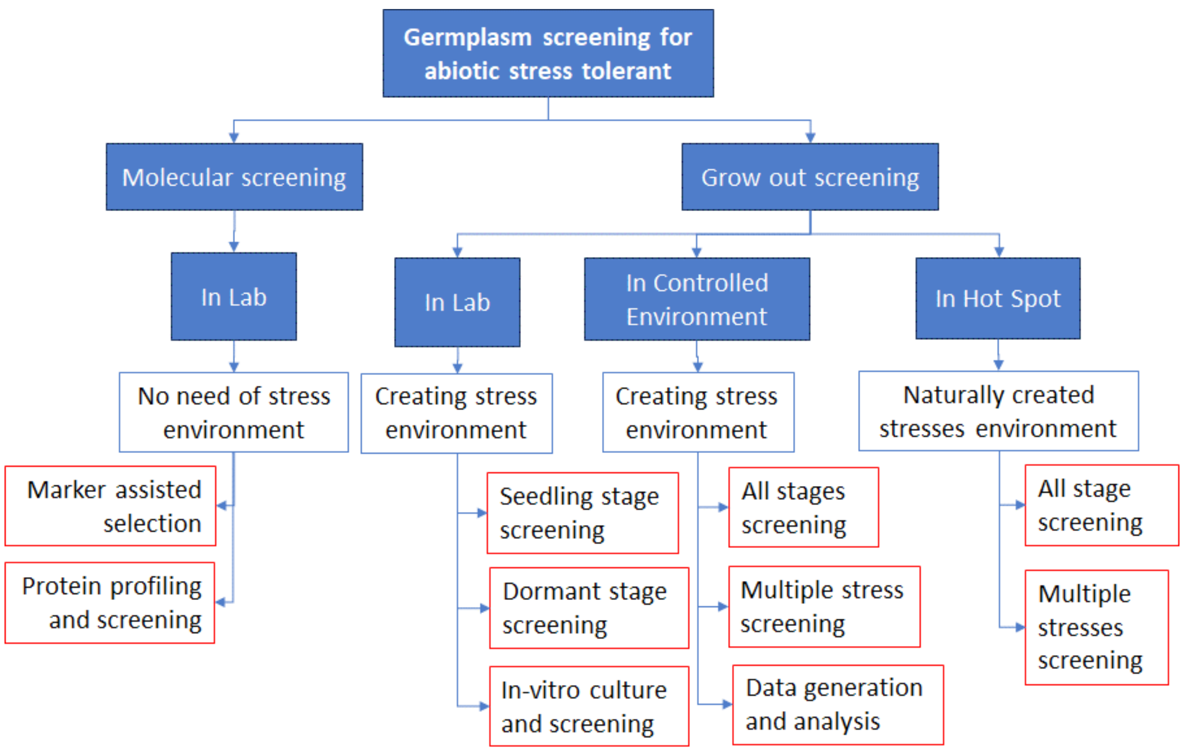


Figure 8. Screening and development of climate resilient and abiotic stresses tolerant millet cultivars

Mechanism to Cope Climate Changes and Abiotic Stresses

Coping with climate changes and abiotic stresses in millets necessitates a multifaceted approach rooted in genetics and breeding. Strategies like the utilization of plant growth-promoting rhizobacteria (PGPRs) have been employed to enhance the growth, development, and stress resilience of crops. Furthermore, the advent of next-generation sequencing technology has facilitated the application of genome editing techniques, such as the clustered regularly interspaced short palindromic repeats (CRISPR/Cas9) system, including genome-wide association studies (GWAS) in the development of stress-tolerant varieties across various crop species (Numan et al 2021, Vellaichamy et al 2022). Here's a breakdown of the key mechanisms and strategies employed:

Understanding Genetic and Breeding of Millets: Comprehensive understanding of millet genetics and breeding is the foundation. This includes exploring the genetic variation, traits, and adaptation mechanisms within various millet species.

Millet Breeding and Gene Transfer: Millet breeding programs aim to transfer desirable genes from diverse millet varieties to create new, climate-resilient cultivars. This gene transfer helps enhance specific traits, such as drought tolerance or pest resistance.

Increased Genetic Diversity: Introducing genetic diversity through breeding techniques as well as increasing the diversity in the field is crucial for developing and producing millets that can thrive in varying environmental conditions (Tiwari et al 2003, Joshi et al 2020).

Promoting Polymorphic Cultivars: The promotion of polymorphic cultivars, which have diverse genetic makeup, is an effective strategy to ensure resilience against changing climates.

Climate-Smart Breeding and Climate-Smart Germplasm: Utilizing climate analog tools helps breeders select millet varieties suited to the anticipated future climate conditions, ensuring they remain resilient (Joshi et al 2017). With the germplasm in Genebank, climate smart breeding and germplasm can be identified and promoted (**Figure 9**). Different models of stability and genotype by environment analysis help identify suitable varieties for target environment (**Figure 9**) (Joshi et al 2005, Chaturvedi et al 2023).

Molecular Breeding and Marker-Assisted Selection: These advanced breeding techniques enable the precise selection of genes associated with climate resilience and abiotic stress tolerance, expediting the breeding process.

Evolutionary Plant Breeding and Participatory Plant Breeding: These approaches involve working closely with local farmers, allowing for the development of climate-resilient varieties that align with their needs and preferences.

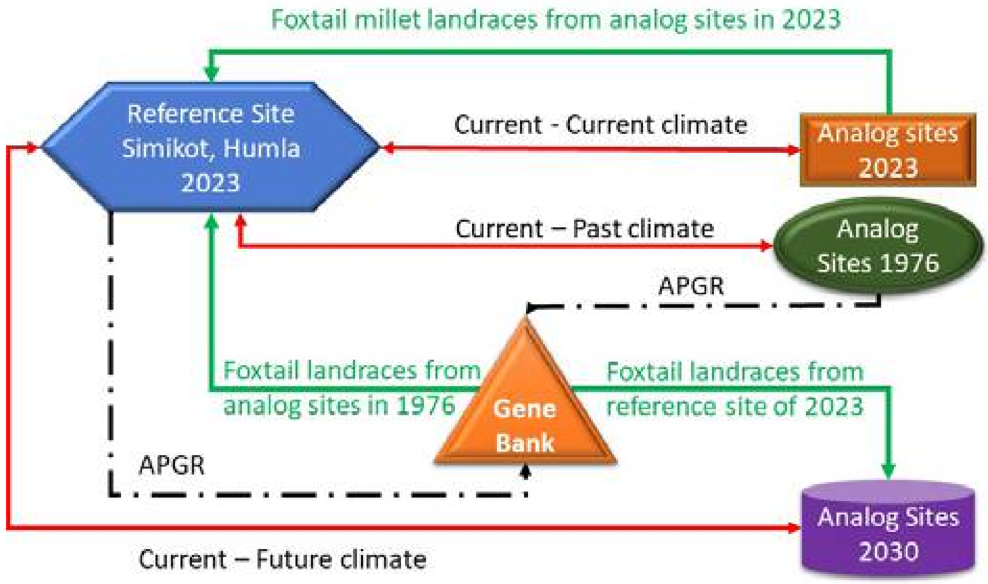
Diversity Block: Creating diversity blocks where multiple varieties of millets are grown in close proximity helps promote genetic diversity, serving as a single site to select the genotypes.

Cultivar Mixture: Planting a mixture of different millet varieties within a single field can reduce the risk associated with climate variability and stress conditions, ensuring that at least some varieties will perform well. Cultivar mixtures are designed to tackle specific challenges with tailored traits. To combat drought stress, they often include deep-rooted varieties, erect plant structures, and a variety of plant heights and leaf sizes. For optimizing space utilization, mixtures incorporate different root lengths, plant heights, and structures, ensuring resource efficiency in all dimensions. Key to their success is maintaining common traits, such as maturity, cooking methods, milling characteristics, and genetics, ensuring consistency while harnessing the benefits of diversity (Joshi et al 2020).

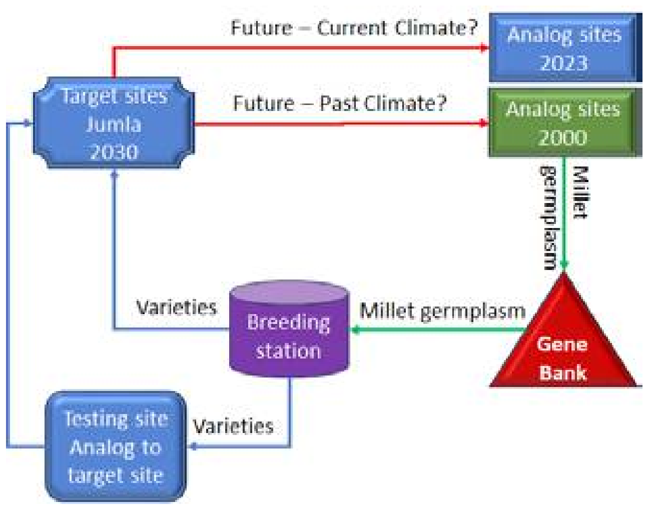
Localized Site-Specific Landraces Enhancement: Focusing on enhancing the performance of indigenous landraces in their native environments allows for climate adaptation and maintaining traditional practices.

Seeds and Grains Production in the Same Sites: Growing seeds and grains in the same locations ensures that seeds adapted to local conditions are produced, furthering climate resilience and such materials have zero environmental shock.

Agro Gene Sanctuary: Creating dynamic and evolving areas where diverse millet varieties are conserved and allows to interact all the time with environments, allows for easy access to genetic resources as well as to create new genotypes for future breeding efforts.



A. Climate smart milleet germplasm



B. Climate smart millet breeding

		Mean: High	Mean: Low
Amount of GxE	High	Potential for locally adapted lines	Potential for locally adapted lines
Amount of GxE	Low	Ideal. Potential of widely adaptive lines	Undesirable

C. Grouping of millet germplasm based on performance over different locations

Figure 9. Climate smart millet germplasm identification and development

Climate changes can be considered as climate shift, ie climate of somewhere can be found in other areas over the time (**Figure 10**). This indicates the possibilities of shifting technology from the area where climate is same, and farmers can introduce technologies from such areas. Farmers facing the challenges of climate change are implementing various adaptive strategies to protect their crops and livelihoods. These measures often involve adjusting their traditional agricultural practices in response to shifting climatic patterns. Farmers are increasingly shifting their agricultural calendars, planting and harvesting crops in accordance with altered weather conditions. They are also embracing crop rotation and diversification to mitigate risk, enabling them to better withstand extreme weather events. Some farmers have opted to change their primary crop types and varieties, transitioning from rice cultivation to more climate-resilient crops like bananas or maize. Investment in irrigation infrastructure is on the rise, offering a dependable water supply even in the face of erratic rainfall. Techniques like mulching, the increased use of compost and farmyard manure (FYM) and adopting newly released crop varieties are becoming common strategies for adapting to the changing climate. In some cases, farmers are diversifying their sources of income by venturing into alternative occupations such as the hotel business or opting for migration. Interestingly, for millet farmers, their crops offer a relatively high degree of climate resilience, often rendering traditional practices adequate, reinforcing the importance of millets in sustainable agriculture amid evolving environmental conditions.

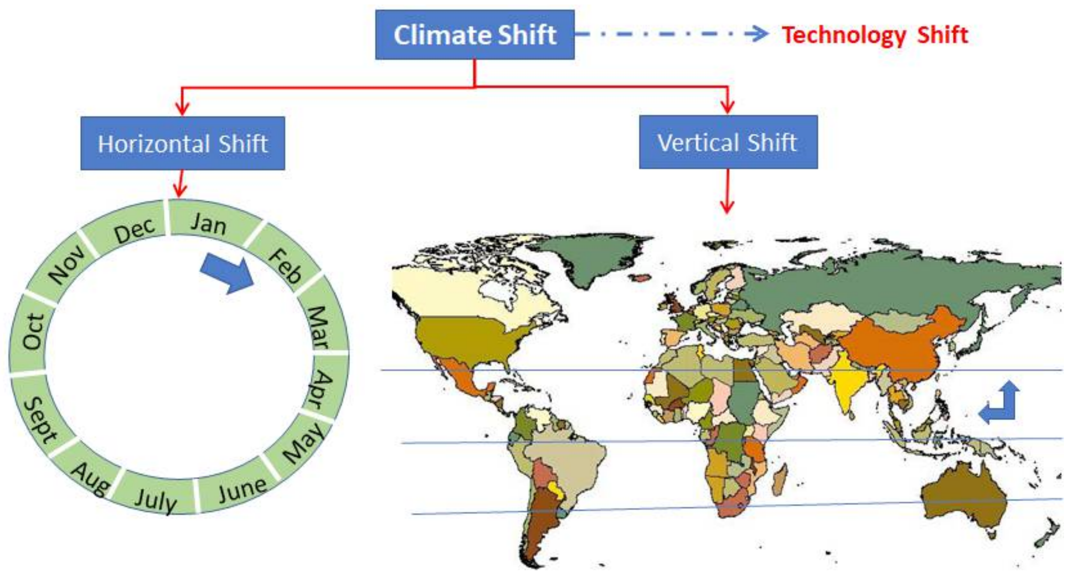


Figure 10. Climate change: Analogues perspective means climate shift and can be shifted technology accordingly

Climate Resilient and Abiotic Stresses Tolerant Cultivars

Millet crops, often referred to as the "poor man's crop," play a vital role in the diets of resource-constrained producers and consumers. Their major contributions to nutrition cannot be overstated. Millets have been a staple food for generations, providing essential nutrients to those who rely on them as their primary source of sustenance. In times of scarcity and famine, millets emerge as the ultimate "famine crops" due to their remarkable ability to ensure yields even in the most adverse conditions. These resilient ancient food crops have stood the test of time, offering sustenance and hope to communities facing food insecurity. With their rich nutritional, pharmaceutical, and nutraceutical properties, millets are not just a source of food but a lifeline for countless individuals, making them a true symbol of resilience and resourcefulness.

The dynamic evolution of millet crops extends beyond their contribution to human diets. These plants have adapted morphologically, physiologically, biochemically, and molecularly to cope with various environmental challenges. Their unique C4 photosynthesis system allows millets to thrive in semi-arid regions, efficiently utilizing limited moisture while minimizing water loss through specialized stomatal control. Furthermore, millets actively contribute to climate change mitigation by sequestering carbon, playing a crucial role in climate adaptation efforts. With their short life cycle, small leaf areas, thickened cell walls, and dense root systems, millets demonstrate remarkable stress resistance. As we confront the growing challenges of climate change, poverty, and malnutrition, millets emerge as a promising solution, offering both sustenance and hope to those who depend on them while aiding in our collective efforts to combat global challenges.

In the midst of an agrarian crisis exacerbated by the detrimental effects of climate change, crops like pearl millet, known for their remarkable drought and heat resistance, offer a ray of hope to farmers. Thriving in well-drained sands or sandy loams, pearl millet is a resilient choice for regions grappling with water scarcity and rising temperatures. Similarly, finger millet, among the millets, shines as an exemplar of stress resilience, capable of withstanding high temperatures, limited moisture, and poor soils, offering a lifeline to agricultural communities in the face of increasingly challenging environmental conditions.

Nepal is home to a rich diversity of native landraces, including finger millet, foxtail millet, proso millet, sorghum, barnyard millet, and pearl millet. These landraces have demonstrated remarkable climate resilience and tolerance to various abiotic stresses, making them invaluable genetic resources. However, it is essential to note that despite their potential, the breeding and genetics of these landraces have not been extensively explored and understood. One striking characteristic of these native landraces is the high degree of genetic variation both within and among them. This genetic diversity contributes significantly to their ability to thrive in a range of environmental conditions, making them inherently resilient to climate changes. In contrast, improved varieties, which have typically undergone extensive breeding to enhance specific traits, tend to be more uniform and lack the genetic variation necessary to adapt to varying environmental conditions.

One significant challenge is the absence of specific stress-tolerant breeding efforts in Nepal. These landraces, along with certain Indian varieties, have immense potential to be harnessed for their climate-resilient and abiotic stress-tolerant traits. However, the lack of focused breeding programs means that their full potential remains untapped. In **Table 5**, some of these landraces and Indian varieties are listed, emphasizing the need for more targeted efforts to understand and harness the genetic diversity present in these native cultivars.

Table 5. Climate resilient varieties and landraces of millets in Nepal and India

Crop	Nepal	India
Pearl millet	-	GHB-538 and GHB-719, WCC-75, RBH-177, RBH-154, RBH-173
Foxtail Millet	Bariyo kaaguno, Kalo kaguno, Seto kaguno, Pahenlo kaguno, Maal kaguno	RS-118, K-211-1, PS-4, SIA-326, Chitra, SIC 3
Finger Millet	Raato kodo, Kaabre kodo-1, Okhale-1, Dalle-1, Kaabre kodo-2, Sailung kodo-1, Dalle, Jhapre, Paaundure, Saano, Laarfre, Nangre, Nangkatuwa, Matyangre, Mudke, Lekaali, Samdhi	VR-708, HR-374, MR-1, MR-6, GPU-66, Phule Nachani, BM 1, VL 101
Sorghum	Gaazali junelo, Raato junelo, Seto junelo	CSH-5, CSH-9, CSV-4, Pant Chari 5, Pant Chari 7, Phule Chitra, M-35-1 Phule Vasudha, CSV18
Kodo millet	-	GK 1, PSC 1, TNAU 86
Barnyard millet	-	PRJ 1
Proso millet	Dhude chino, Kaalo chino, Raato chino, Haade chino	DHP 2769

Source: Lenka et al 2020, Ghimire et al 2023a, Joshi et al 2023, Palikhey et al 2016, Parajuli et al 2016, Vetriventhan et al 2020

Conclusion

The genetic and breeding perspectives of millets have provided a promising pathway towards developing climate-resilient and abiotic stress-tolerant crops. Millets, being C4 crops, inherently exhibit greater efficiency in resource utilization, making them valuable candidates in the face of changing environmental conditions. Their innate hardiness and adaptability have solidified their reputation as crops that can endure and thrive despite the multitude of abiotic stresses they face. One of the key strides in this field has been the identification of numerous genes that hold the potential for developing millet varieties that can withstand the challenges posed by climate change. Furthermore, various germplasm screening techniques and coping mechanisms have been explored to enhance the resilience of millets in the face of unpredictable climatic variations and abiotic stressors. The success of breeding strategies, such as crop improvement and evolutionary plant breeding, has emerged very important for climate-resilient millets. These approaches, when coupled with location-specific cultivation and the use of polymorphic cultivars, present a dynamic framework for addressing the diverse challenges posed by climate change. The adoption of a zero environmental shock strategy ensures a smoother transition into an era where environmental stability becomes an increasingly scarce commodity. The genetic diversity and meiotic events in millets have offered us a valuable toolbox for crafting crops that can thrive in a changing world.

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Chapter 3. Value Chain and Socioeconomics

अध्याय ३. मूल्य शृंखला र सामाजिक अर्थशास्त्र

A. Products Diversification and By-products

क. वस्तु विविधिकरण र उप-उत्पादन

Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Nepali Millets: Culinary Diversity, Nutrition and Health and its Importance for Enhancing the Sustainability of Nepali Food Systems

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Summary
This comprehensive review highlights the importance of gluten-free, nutrition-rich millet grains in Nepali food systems. Millets, a member of the Poaceae family, are vital to global agriculture, offering diverse nutritional benefits, particularly in protein and fiber content compared to rice and wheat. Notable varieties include protein-rich pearl millet, iron-zinc-rich finger millet, cholesterol, and blood-sugar-regulating foxtail millet, and nutrient-dense proso millet. These millets are referred as "future smart foods" due to their resource-efficient, climate-resilient, and adaptable nature, capable of addressing food security and nutritional challenges, notably among women and children, combating anemia, diabetes, obesity, and cardiovascular diseases. The review highlights millets' role in Nepali cuisines, inspiring culinary innovation from traditional recipes. In summary, this review explores the multifaceted world of millets, where science and culinary creativity merge for a healthier and more sustainable future in Nepali Food Systems. It also discusses the need for policy reconsideration and dispelling misconceptions about millet' integration into the food supply.

Keywords: Nutrition, traditional recipes, health, food

Diversity in Millets
Millets, a group of diminutive-seeded cereal plants within the Poaceae family, exhibit remarkable versatility in their taxonomic distribution, properties, and geographic cultivation. These unassuming grains serve as foundational staples to the people across the globe, characterized by their resilience to drought and pests, and their nutritional richness. Millets, with their abundant phytochemical repertoire and antioxidant potential, hold promise for promoting human health (Kumar et al 2016). Millets flourish in diverse climates worldwide, with pearl and finger millet being staples in Africa and Asia. Proso millet, foxtail millet, barnyard millet, little millet, kodo millet, and others are cultivated across temperate, subtropical, and tropical regions. Some of the key millet varieties are:

Pearl millet *(Pennisetum glaucum)*
Pearl millet stands out as the foremost variety among millets, particularly thriving in arid and semi-arid regions of Africa and Asia. This robust grain exhibits exceptional adaptability to various soil types and climatic conditions. Rich in protein, iron, zinc, and a variety of phytochemicals, including phytates,

phenolics, and tannins, pearl millet emerges as a nutritional powerhouse. Its credentials include the prevention of anemia, diabetes, and the mitigation of oxidative stress (Saleh et al 2013).

Finger Millet *(Eleusine coracana)*
Finger millet predominates in the agrarian landscapes of Nepal, India, and select regions of Africa. Notable for its remarkable calcium content, a rarity among cereals, finger millet boasts an impressive array of minerals especially iron, vitamins, dietary fiber, and phytochemicals such as polyphenols, phytosterols, and policosanols. This grain contributes significantly to bone health, blood glucose regulation, lipid profile management, and enhancement of antioxidant status (Shobana et al 2013).

Foxtail millet (*Setaria italica*)
Foxtail millet, tracing its historical lineage to ancient China and high hills and mountains of Nepal, has seen a resurgence in contemporary agriculture across China, India, Korea, Japan, and parts of Europe and up to some point also in Nepal. This venerable grain is rich in protein, carbohydrates, dietary fiber, minerals, and, also like other millets, an array of phytochemicals, including flavonoids, phytic acid, and phytosterols. Foxtail millet, as a bioactive grain, accolades extend to the amelioration of cholesterol levels, blood pressure regulation, and glycemic control (Saleh et al 2013).

Proso millet *(Panicum miliaceum)*
Proso millet, also known as common millet or broomcorn millet, holds cultivation dominions in China, Nepali hills, India, Russia, and parts of Europe and America. Despite its unassuming appearance, this grain unfolds its exalted stature through a substantial energy content, complemented by a mixture of protein, minerals, vitamins, and phytochemicals such as phenolic acids, flavonoids, and phytates. Proso millet stands as a commendable dietary inclusion (Kumar et al 2016), however, remained underutilized.

Barnyard millet *(Echinochloa frumentacea)*
Cultivated in India, China, Japan, and some African regions, this millet boasts the highest fiber content among all millets, along with significant levels of iron, calcium, and zinc. Its consumption is linked to preventing constipation, obesity, diabetes, and cardiovascular diseases (Singh et al 2014).

Kodo millet *(Paspalum scrobiculatum)*
Native to India and Africa, cultivated in parts of Southeast Asia, Kodo millet is known for its high protein content and low glycemic index. It also contains various phytochemicals, including phenolics, tannins, phytates, and saponins, with potential benefits in reducing inflammation, oxidative stress, and cholesterol levels.

Little millet *(Panicum sumatrense)*
Grown in India, Nepal, China, and select African regions, this millet stands out with its high iron content, moderate protein content, and presence of dietary fiber, minerals, vitamins, and phytochemicals like phenolics and phytates. Consumption of little millet may improve hematological status, glucose tolerance, and lipid profile.

Nutritional Profile of Millets

This section explores the diverse facets of millets, focusing on their nutritional composition, health benefits, processing versatility, and the challenges inherent in promoting their consumption. Millets, being hardy, drought-tolerant crops, represent a significant dietary resource, particularly in Asia and the semi-arid regions of Africa. Despite their potential for enhancing nutritional security, there has been a decline in their consumption over recent years. Millets are characterized by their rich mineral, vitamin, protein, fatty acid, fiber, and phytonutrient content. Notably, they provide a balanced profile of essential amino acids, with a particular emphasis on sulfur-containing amino acids. Additionally, millets are enriched with a spectrum of health-promoting phytochemicals, including lignans, phytosterols, polyphenols, phytoestrogens, and phytocyanins. However, the processing and milling of millets often result in the removal of germ and bran layers, which are repositories of fiber and phytochemicals. Millets also harbor antioxidants, such as glycated flavonoids and phenolic acids. Furthermore, millets serve as prebiotics, enhancing the efficacy of probiotics and their potential health benefits. The nutritional profile of diverse millet cultivars holds immense promise for the development of value-added products, aiding in the prevention of lifestyle-related ailments, including cancer, cardiovascular diseases, and metabolic disorders. Given their pivotal role in ensuring nutritional security and improving health, millets have garnered considerable attention among food scientists. Nevertheless, there is room for enhancing the nutritional quality of millets through effective processing methods, thus facilitating their utilization in the creation of high-value and nutrient-rich products. Such advancements are poised to bolster immunity, health, and socioeconomic well-being among consumers.

Proximate composition of millet varieties

Table 1 and **Table 2** furnish a detailed information of the nutrient composition in different millets grain, encompassing foxtail, proso, pearl, finger, barnyard, fonio, and little millets. This table elucidates the content of macronutrients such as protein, fat, and carbohydrates, as well as crude fiber, all presented in grams per 100 grams' dry weight for each millet variety.

Table 1. Proximate composition of different millet varieties

Types of millet	Protein (g/100 g DB)	Ash (g/100 g DB)	Fat (g/100 g DB)	Total CHO (g/100 g DB)	Crude fibre (g/100 g DB)	References
Pearl millet	14.8	1.64	4.86	59.8	12.19	Taylor et al (2010)
Finger millet	8.2	2.7	1.8	83.3	3.5	Devi et al (2011)
Proso millet	11.58	NA	4.9	80.1	0.7	Bagdi et al (2011)
Foxtail millet	11.50	0.47	2.38	75.2	NA	Kamara et al (2009)
Fonio millet	9-11	1-1.1	3.3-3.8	84-86	NA	Vodouhe et al (2003)
Little millet	12.2	3.2	3.9	56.6	24.1	Vali Pasha et al (2018)
Barnyard millet	11.3	3.7	3.4	56.4	25.2	Vali Pasha et al (2018)
Kodo millet	9.8	3.7	2.2	51.8	32.5	Vali Pasha et al (2018)

*CHO- Carhodydrate, DB- Dry weight basis

Millets are highly nutritious cereals and a staple food source for millions worldwide. The proximate composition shows millets are rich sources of protein (**Table 1**); pearl millet has the highest protein content at 14.8 g/100 g, while finger millet contains 8.2 g/100 g. The substantial protein content of millets makes them a valuable plant-based source of this essential macronutrient. Protein is vital for growth and development in children, wound healing, immune function, and preserving lean muscle mass in the elderly (Paddon-Jones and Leidy 2014). The fat content ranges from 1.8 g/100 g in finger millet to 4.9 g/100 g in proso millet. Dietary fats provide essential fatty acids and aid the absorption of fat-soluble vitamins A, D, E, and K (Gropper and Smith 2012). Carbohydrate levels vary between 51.8 g/100 g for kodo millet and 84-86 g/100 g in fonio millet. Carbohydrates are the main source of energy for the body and brain function (Nelson et al 2008). Crude fiber is highest in barnyard millet (25.2 g/100 g) and lowest in proso millet (0.7 g/100 g) (Bagdi et al 2011, Vali Pasha et al 2018). Dietary fiber reduces the risk of obesity, diabetes, heart disease, and certain cancers. It improves glucose control, lowers cholesterol, and promotes digestive health (Anderson et al 2009). Fiber is particularly beneficial for diabetics managing blood sugar levels. In summary, the balance of protein, fats, carbohydrates, and fiber make millets an excellent source of macronutrients. The nutritional profile of the different varieties can complement staple cereals and provide health benefits, especially for vulnerable groups. Such as infants, children, and pregnant and lactating mothers.

Table 2. Minerals Concentration of different millets

Types of millet	Iron (mg/ 100 g)	Calcum (mg/ 100 g)	Phosphorus (mg/100 g)	Sodium (mg/ 100g)	Potassium (mg/100 g)	Magnessium (mg/100 g)	Zinc (mg/ 100 g)	Copper (mg/ 100 g)	References
Pearl millet	9.27± 0.24	50.07± 0.31	399.23± 0.04	112.12± 0.29	325.35± 0.23	177.45± 0.04	0.09± 0.01	0.19± 0.01	Vali Pasha et al (2018) Kunyanga et al (2013)
Finger millet	3.84	281.00	280	3.70	294	66.0	0.62± 0.18	1.80± 0.43	Nassarawa Samusi et al (2011) Shashi et al (2007)
Proso millet	18.0	19±0.07	503.0±0.51	57±0.09	525±0.95	297±0.48	1.6	7.8	Bagdi et al (2011) Vali Pasha et al (2018)
Foxtail millet	30.5	20	565	58	714	259	1.4	7.7	Vali Pasha et al (2018)
Fonio millet	2.14	19.84	126.50	1.29	138.33	1.21	1.30	1.12	Belton et al (2002)
Little millet	47.9	24±0.03	617±0.54	63±0.04	472±0.36	313±0.15	1.0	11.3	Vali Pasha et al (2018)
Barnyard millet	34.1	20±0.06	617±0.43	68±0.04	792±0.78	3.08±0.19	1.1	9.0	Vali Pasha et al (2018)
Kodo millet	54.7	24±0.03	473±0.63	61±0.06	640±1.00	301±0.54	1.9	6.6	Vali Pasha et al (2018)

Similarly, the mineral analyses reveal that millets provide good amounts of essential dietary minerals (**Table 2**). Iron content varies from 2.14 mg/100 g in fonio millet up to 54.7 mg/100 g in kodo millet. Iron deficiencies are one of the most prevalent nutritional inadequacies globally, impairing cognitive development in children and immunity in all age groups (McLean et al 2009). The iron content in some millets can help combat this issue. Calcium ranges between 19-50 mg/100 g in most varieties but is markedly higher in finger millet at 281 mg/100 g. Calcium is essential for bone health, growth, and metabolism. Thus, millets can support these functions with their calcium levels (Christakos et al 2011). Phosphorus and potassium are present at levels between 126-617mg/100g and 138-792mg/100g respectively. Phosphorus aids bone formation, while potassium benefits cardiovascular health and counters hypertension (Takeda et al 2014). Magnesium content is also substantial, up to 313 mg/100 g in little millet. Magnesium assists energy production, blood pressure regulation, and bone development (Volpe 2013).

Essential amino acid content in different millet grains

Essential amino acids are critical for human health, as the body cannot synthesize them and must derive them from the diet. Each essential amino acid serves a specific function in the body, participating in processes such as tissue repair, enzyme and hormone production, and immune system support. For instance, Isoleucine is pivotal for muscle metabolism and immune function, while Leucine contributes to protein synthesis and muscle growth. Lysine plays a crucial role in bone health and collagen synthesis, while methionine is involved in the synthesis of essential compounds like creatine and glutathione. Phenylalanine serves as a precursor for neurotransmitters such as dopamine and norepinephrine, while Threonine participates in protein synthesis and glycine production. Valine is instrumental in muscle metabolism and energy generation, and Histidine plays a vital role in histamine synthesis, essential for immune function.

Table 3 details the concentration of essential amino acids in different varieties of millet. Pearl millet exhibits the highest Isoleucine and leucine content, whereas foxtail millet and finger millet register the lowest Isoleucine and leucine content. But finger millet has the highest leucine content, while Pearl millet presents the lowest content. Foxtail millet stands out for its methionine and phenylalanine content, and pearl millet and finger millet with the lowest methionine and phenylalanine content. Finger millet also leads in threonine, valine, and histidine content, while proso millet has the lowest threonine content and Pearl millet has the lowest content valine and histidine content.

Similarly, the bioavailability of proteins for human from millet is also high (0.8-2.0) compared to other cereals like wheat and comparable to legumes and beans (**Table 3**). Numerous studies have measured the "protein efficiency ratio" (PER, weight gain divided by the amount of protein consumed) of different protein sources in rodent diets. For example, protein efficiency ratios were found to lie within the 1.2–2.4 range for plant proteins (including pea flour, soy protein, and beans) and could be as low as 0.95 for wheat flour, whereas animal proteins were in the 3.1 – 3.7 range (Mariotti 2017). Finger millet has the highest and foxtail millet has the lowest PER among the millets (**Table 3**).

Table 3. Essential amino acids content of different millet varieties

Essential Amino acid	Pearl millet	Finger millet	Proso millet (Defatted grain)	Foxtail millet (Defatted flour)
Isoleucine	5.10	4.30	4.10	4.59
Leucine	14.10	10.80	12.20	13.60
Lysine	0.50	2.20	1.50	1.59
Methionine	1.00	2.90	2.20	3.06
Phenylalanine	7.60	6.00	5.50	6.27
Threonine	3.30	4.30	3.00	3.68
Valine	4.20	6.30	5.40	5.81
Histidine	1.70	2.30	2.10	2.11
Tryptophan	1.20	NA	0.80	NA
PER	1.60	2.00	1.10	0.80
Sources	Saldivar et al (2003)	Devi et al (2011)	Bagdi et al (2011), Saldivar et al (2003)	Kamara et al (2009)

*PER-Protein Efficiency Ratio

In summary, the nutritional compositions of millet can help address major public health challenges related to protein-energy malnutrition, micronutrient deficiencies, chronic diseases, and bone disorders. The protein, fiber, minerals, and macronutrients make millets a valuable sustainable food source, especially for vulnerable groups with increased nutritional needs like children, pregnant women, the elderly, and those suffering from chronic diseases.

Challenges and Opportunities in Promoting Millets

Despite their nutritional merits, millets are neglected in several regions, eclipsed by more dominant cereals like rice and wheat. Effective promotion necessitates a multi-stakeholder approach, involving farmers, researchers, policymakers, and consumers. The development of value chains, market linkages, and policy support holds the potential to enhance millet production, processing, and consumption. Such efforts align with Sustainable Development Goals (SDGs), notably SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), and SDG 12 (Responsible Consumption and Production).

Millets: Future Smart Foods

Millets are prized for attributes such as drought resistance, pest resilience, high nutrition, and gluten-free nature. Additionally, millets are rich in phytochemicals and antioxidants, offering significant potential for human health (Kumar et al 2016). Therefore, millets, often referred to as "future smart foods," combine agricultural resilience and nutritional strength to address global challenges sustainably. Here are several reasons highlighting their importance:

Ensuring food security in a changing climate

Millets have extensive root systems, enabling them to access moisture deep within the soil. This reduces their reliance on external irrigation, making them resource efficient. Millets can thrive with as little as 200 mm of rainfall annually, far less than the 500 mm needed for wheat or 1,000 mm for rice (Singh et al 2014). They also exhibit remarkable resilience to high temperatures, enduring up to 46°C, and can thrive in soils with salinity and acidity challenges (Saleh et al 2013). In a world grappling with climate change, millets offer hope to farmers facing environmental adversity.

Enhancing nutrition and health

Millets are nutritional powerhouses, providing essential macro and micro-nutrients and a range of bioactive phytochemicals. These compounds grant millets antioxidant, anti-inflammatory, anti-diabetic, anti-cancer, and anti-microbial properties (Kumar et al 2016, Shobana et al 2013). Millets can help combat anaemia, diabetes, obesity, cardiovascular diseases, osteoporosis, and cancer. They also hold promise in alleviating malnutrition and promoting health, especially among women and children, by providing essential micronutrients and bioactive compounds.

Supporting rural development and livelihoods

Millets are well-suited to and being cultivated by small and marginal farmers, offering a stable income source with minimal input requirements. Cultivating millets reduces reliance on synthetic fertilizers and pesticides, promoting sustainable farming practices. Millet cultivation also creates employment opportunities in processing and adds value to rural economies. Integrating millets into agricultural systems enhances biodiversity and soil health (Singh et al 2014).

In summary, millets, with their unique blend of agricultural resilience and nutritional richness, have the potential to revolutionize food systems. They offer solutions for food security, nutrition, and rural development, earning their title as "future smart foods."

Nepali cuisines and recipes featuring millets

Millets, in addition to their nutritional and ecological merits, have become integral to global cuisines. Their versatility and adaptability make them key ingredients in a wide array of dishes worldwide. Millets can be processed into a spectrum of food products, encompassing flour, flakes, and puffed grains. Their unique functional properties, including water-holding capacity, gelation, and foaming, render them adaptable for diverse food applications, spanning baked goods, breakfast cereals, snacks, and fermented delicacies.

From traditional staples to modern fusion creations, millets continue to inspire culinary innovation. Embracing millets in global cuisines not only enhances flavor and nutrition but also promotes sustainability and food security. Recently, these remarkable grains have gained recognition and appreciation on the global culinary stage. By blending tradition and innovation, millets enrich the gastronomic heritage of nations and contribute to a healthier and more sustainable future.

Millets are known for gastronomic delicacies from Asia, Africa, Europe, and America, delving into the culinary craftsmanship, formulation, nutritional intricacies, and inherent values of millet-based recipes that offer both delightful flavors and nutritional benefits. Each region's unique culinary traditions offer distinct perspectives on incorporating millet into both savory and sweet dishes; from the South Asian Culinary Delights from Nepalese Culinary Gems from its multicultural heritage, reveals the "Millet *Dhindo*," a symbol of simplicity, satiety, and nutrition, and the "Foxtail Millet Kheer," an indulgent blend of millet, milk, and spices (Pathak 2023, Sophie 2023). India and Pakistan offer culinary treasures like "Proso Millet *Upma*" and "Foxtail Millet *Pulao*," respectively, where millets, rich in protein and fibre, blend seamlessly with intricate flavors (Madhavi 2023, Sandhya 2023). Africa has also a rich heritage in its millet-based traditional recipes from East to West, South to North such as Ethiopian Millet *Injera*, (Sommer 2023), West African Millet Porridge with Peanut Butter and Bananas, and North African Millet *Couscous* with Vegetables (Dianne 2023). Furthermore, Millet-based European delicacies have been turned into “Fine-Dining” recipes such as Millet Risotto (Lindsay 2023), Millet Apple Cake (Barbara 2023*)* Millet Zucchini Bread (Fatsectret 2023). At the other end of the globe, North American Fusion, "Millet and Beef Stuffed Peppers" (Eva 2023) fuse millet's earthy essence with the richness of the beef, providing essential minerals, fiber, and protein, a health-conscious culinary choice. Similarly, South American Fusion, “Millet Quinoa Salad with Avocado and Lime” (Segal 2023), showcases the fusion of indigenous nutritious grains with vibrant flavors.

Thus, millet cuisines transcend borders, portraying millets not only as dietary alternatives but also as nutritionally potent grains bridging culinary creativity with health-conscious living. They epitomize nutritious and healthy dietary choices, etching their presence onto global plates and into the hearts of diverse cultures. This review paper testifies to the expanding horizons of culinary possibilities, inviting enthusiasts and scholars to explore the diverse world of millets, where culinary artistry converges with nutritional excellence. Moreover, the diverse spectrum of millets paints a vivid picture of their global prevalence and their ability to thrive in various climates and soils. While possessing distinct properties and phytochemical profiles, with their remarkable resilience and health-enhancing attributes, stand as invaluable components of the global agroecosystem, which needs some reinvigoration.

Similarly, Nepal also boasts a rich culinary heritage, characterized by a wide variety of ancient grains, among which finger millet, proso and foxtail millets hold a prominent place, spanning from breakfast to dessert. This article delves into the formulations, nutritional profiles, and gastronomic value of selected finger, proso and foxtail millets dishes, encompassing the traditional gastronomy to innovations led by Nepal Agricultural Research Council (NARC), shedding light on their significance in the cuisines of Nepal.

Finger millet *dhindo*

Millet *Dhindo*, a staple of Nepal's culinary heritage, graces tables across the hilly and mountainous regions of the country Nepal, specially Tamangs and the Sikkim and Darjeeling regions of India. This satiating thick and sticky porridge, made from millet flour, water, and ghee, is traditionally paired with lentil soup, vegetable curry, pickle, or meat gravy. Millet *Dhindo,* belonging to the realm of gluten-free and vegetarian cuisine, offers a rich nutritional profile. Enriched with fiber, iron, and antioxidants from millet flour. It combines both taste and health. Its versatility in complementing various accompaniments enhances its appeal.

Product Formulation and Nutritional Composition:

The components for Millet *Dhindo* are as follows (Pathak 2023):

Ingredients	Nutritional Profile (Approximately 250 g)
Millet flour: 2 cups (240 g)	Calories: 315 kcal
Water: 4 cups (960 g)	Fat: 9 g
Ghee: 2 tablespoons (30 g)	Saturated fat: 5 g
	Cholesterol: 19 mg
	Sodium: 12 mg
	Carbohydrate: 52 g
	Fiber: 5 g
	Protein: 8 g

Preparation steps:

- Boil the water in a large pot with salt.
- Gradually add the millet flour, stirring constantly with a wooden spoon to avoid lumps.
- Cook over medium-low heat, stirring occasionally, until the mixture becomes thick and smooth, about 15 to 20 minutes.
- Transfer the *dhindo* to a greased plate and shape it into a round or oval cake.
- Cut into pieces and serve hot with ghee, lentil soup, or vegetable curry.

Proso millet *dhindo*

Proso millet *dhindo*, deeply rooted in Nepali tradition, serves as a staple food, enjoyed as both a main course and a snack. Its gluten-free nature and ease of preparation make it a versatile and inclusive dish. Proso millet, a common ingredient in Nepali cuisine, especially in mountainous regions, finds utility in various culinary applications, including bread, porridge, and even beer. Its nutritional contributions, such as protein, antioxidants, and phosphorus, add to its significance.

Product Formulation and Nutritional Composition:

Proso Millet Dhindo, a revered Nepali staple, requires the following ingredients:

Ingredients	Nutritional Profile (Approximately 250 g)
1 cup of flour (200 g)	Calories: 136 kcal
3 cups of water (720 ml)	Protein: 4 g
Salt to taste	Fat: 1 g
	Carbohydrates: 28 g
	Fiber: 3 g
	Iron: 5% of the Recommended Daily Intake (RDI)
	Calcium: 1% of the RDI
	Magnesium: 8% of the RDI

Preparation steps

- Boil water in a large pot, adding a pinch of salt.
- Gradually add proso millet flour while stirring continuously to prevent lumps.
- Maintain the mixture over medium-low heat, stirring intermittently, until it reaches a smooth consistency, which takes about 15 to 20 minutes.
- Transfer the *dhindo* to a greased plate, shaping it into a circular or oval cake.
- Cut the *dhindo* into palatable pieces, ready to be served hot with ghee, lentil soup, or vegetable curry.

Foxtail millet *kheer*

The Foxtail millet *kheer*, with its sweet and creamy profile, stands as a dessert fit for celebrations during festivals or special occasions specially of Karnali Province. Its gluten-free composition makes it inclusive, and its vegetarian-friendly nature appeals to a diverse range of palates. Within Nepali cuisine, this cuisine offers a nutritional boost with its protein, fibre, and B vitamins content.

Product Formulation and Nutritional Composition (Sophie 2023):

Ingredients	Nutritional Profile (1 serving- 1/2 cup)
Foxtail millet: 1/4 cup (50 g)	Calories: 231 kcal
Milk: 4 cups (960 ml)	Carbohydrates: 38 g
Sugar: 1/4 cup (50 g)	Protein: 8 g
Ghee: 2 tablespoons (30 ml)	Fat: 5 g
Cardamom powder: 1/4 teaspoon (1.25 ml)	Saturated Fat: 3 g
Chopped almonds: 2 tablespoons (18 g) (optional)	Polyunsaturated Fat: 1 g
Chopped pistachios: 2 tablespoons (18 g) (optional)	Monounsaturated Fat: 1 g
	Cholesterol: 15 mg
Total servings: 3	Fiber: 3 g
	Sodium: 52 mg
	Potassium: 252 mg
	Sugar: 14 g
	Vitamin A: 198 International Unit (IU)
	Vitamin C: 0.1 mg
	Calcium: 156 mg
	Iron: 1 mg

Preparation steps:

- Rinse the foxtail millet thoroughly with clean water and allow it to soak for a minimum of 30 minutes. Drain afterward.
- In a heavy-bottomed pan over medium heat, melt ghee. Add the foxtail millet and sauté for approximately 5 minutes, stirring continuously.
- Pour in the milk and bring the mixture to a vigorous boil.
- Let the foxtail millet simmer in the milk until it softens, and the milk thickens, which takes about 40 to 50 minutes.
- Add sugar and cardamom powder, mixing well.
- Garnish the kheer with chopped nuts if desired.
- Serve the Foxtail Millet Kheer either hot or cold, according to your preference.

Millet-based weaning food

Weaning foods are generally prepared from multigrain including rice, wheat, maize, soybean, yellow split grain (*mung dal*), and chickpea along with millet. National Food Research Centre (NFRC), NARC has developed recipe for millet based weaning food, which is not only reach in energy and protein but also iron and calcium than other cereal based weaning food. The combination of these grains generally depends upon the availability and practice. Normally, all grains are roasted, ground, and mixed. It is consumed by mixing with hot water or milk.

Ingredients	Nutritional Composition (per 100 g)
Millet flour: 210 g	Protein: 13.04 g
Rice flour: 210 g	Fat: 5.30 g
Gram flour: 280 g	Carbohydrate: 69.31 g
Banana Flour or add half a banana of 1 serving: 70 g	Ash: 1.70 g
Pumpkin flour or add 1 tablespoon of cooked pumpkin: 35 g	Fibre: 4.23 g
Powdered milk or mix with milk while serving: 35 g	
Peanuts powder: 35 g	
Sugar powder: 35 g	

Product Formulation and Nutritional Composition (Ojha et al 2020)

Preparation Steps

- Panfry the grams for 15 to 20 minutes at 140 to 150°C until it turns brown, grind and sieve.
- Soak the almonds for 1 hour and panfry for 15 minutes at 150°C. Grind the fried almonds and sieve.
- Also, grind and sieve the sugar.
- The powdered form of all the dried ingredients is mixed according to the given formulation.

Packaging of Weaning Food: Weaning foods are powdered foods that absorb moisture easily. The packaging materials for the storage should have a low water vapor transmission rate. The packaging material should be a 100-micron thick plastic bottle containing an aluminum seal along with a lid, and if the packaging material is of paper, then the inner layer should be of aluminum. The options for packaging materials depend on the usage and availability. The product should be stored in a cool and dry place for a long storage time.

Procedure for serving: The weaning food can be served by mixing it with hot water or milk. Normally, the ratio of weaning food to water or milk is 3 or 4:1.

Millet pancake

NFRC, NARC has also developed recipe for millet pancakes. Pancakes are flat, thin cakes made of batter that are fried on a griddle or in a skillet. Typically, the batter is made up of eggs, flour, milk, water, and either melted butter or oil. The batter's recipe frequently changes to incorporate things like buttermilk, sugar, and sourdough starter. Regardless of their name, pancakes, griddlecakes, flapjacks, wheat cakes, or flannel cakes are among the most widely consumed foods in the country. Pancakes can be found in practically every cuisine, in one form or another.

Product Formulation and Nutritional Composition (Ojha et al 2020)

Ingredients	Nutritional Composition (per 100 g)
Millet flour: 500 grams	Carbohydrate:79.9
Egg: 2 pieces	Protein: 9.34 g
Salt: 1 teaspoon	Fat: 0.88 g
Sugar: 10 tablespoons	Fiber: 1.19 g
Oil or Ghee: 10 tablespoons	Ash: 1.2 g
Milk: 200 mL	
Water: As per requirement	
Baking powder: 1 pinch	

Preparation Steps

- Mix all the dry ingredients.
- Add milk to the dry ingredients and then add egg.
- The batter should be flowing, and let it stand for 20 minutes.
- Heat the pan, and grease it by applying a small amount of oil.
- Pour the measured amount of batter with the help of a ladle.
- Spread the batter before it turns into a solid state and then cook by flipping it.

Note: small pieces of banana, apple, and cheese can be added before the batter turns into a solid state while cooking. It can be served with jam, jelly, ghee/butter, peanut butter, and egg.

Millet based pizza

Similarly, NFRC, NARC also developed millet-based pizza (Ojha et al 2020). Pizza is a dish consisting of a flat round base of dough with a topping of tomato, mushroom, cheese, and vegetables, meat (optional).

Product Formulation and Nutritional Composition (Ojha et al 2020)

Ingredients	Nutritional Composition (100g)
Tomato sauce: 650 g	Carbohydrate: 50.54 g
Thin slice of onion: 500 g	Protein: 20.27 g
Mushroom: 300 g	Fat: 5.19 g
Cheese: 500 g	Ash: 2.01 g
Chopped cabbage: 200 g	Fiber: 3.78 g
Capsicum slice: 200 g	
Grated carrot: 300 g	

Preparation Steps

- Sieve the flour and weigh,
- For the activation of yeast, take the weighed amount of yeast in a glass of lukewarm water containing a small amount of sugar. Mix the solution and let it stand for some minutes.
- After a certain time, the yeast will start to grow.
- Also, mix weighed amount of salt in the water,
- In the weighed amount of flour add yeast, salt solution, sugar, butter, and egg to make a dough,
- The dough should be prepared until it stops sticking to our hand,
- The pizza crust will be hard if the dough is not kneaded enough,
- First fermentation: For the fermentation, the dough is allowed to stand at 28-30°C for 1.4- 2 hours. During this period, the size of the dough increases three times its original size.
- Bench time: The shape of the dough is maintained after fermentation. The dough shouldn't be kneaded or pressed hard; it should be placed softly which is known as bench time.

- Second fermentation: The shape of the dough should be made round with soft hands. Again, let the dough to stand at 28-30°C for 1 hour and cover with muslin dough. The relative humidity should be high at this stage so, water should be sprayed on the muslin cloth used to cover the dough.
- Preparation to toppings: The name of pizza is given according to the toppings used like mushroom pizza, cheese pizza, chicken pizza, etc. All the ingredients should be chopped into small pieces. In the case of meat and egg, it should be half boiled.
- Baking: The prepared round shaped dough is then baked at 180-200°C. After around 10 minutes, add all the finely chopped ingredients and then again bake for 10 minutes. The cheese used for pizza preparation should be grated before baking.
- Placement of topping: During the addition of topping on the dough, first tomato sauce is spread. Then, add thin sliced onion, capsicum, grated carrot, mushroom/ meat, grated cheese. Mozzarella cheese is known to be best for the preparation of pizza.

Millet *nimki*

Millet *nimki* is the fried snack made from millet dough, which was also developed by NFRC.

Product Formulation and Nutritional Composition (Ojha et al 2020)

Ingredients	Nutritional Composition (Per 100 g)
Millet Flour: 500 g	Carbohydrate: 79.79 g
Salt: As per required (10 g)	Protein: 9.34 g
Ghee: 100 g	Fat: 0.88 g
Oil: 25 ml	Fiber: 1.19 g
Baking powder: 5 g	Ash: 1.2 g
Thyme seed: As per required	
Water: 350-400 ml	

Preparation steps

- Mix buckwheat and refined wheat flour properly,
- Add salt and baking powder and mix well,
- Then, add ghee,
- Add water and make a tight dough,
- Make a sheet with the help of wooden roll by applying oil in it,
- Give defined shape with the help of sharp instrument like knife,
- Then, fry the small pieces of dough in hot oil (till golden brown)(Saharan and Sirohi 2020).

Millet noodles

The dough prepared from the mixture of refined wheat flour, gluten, salt, and water and then sliced with machine to give thin thread like structure, which is further dried to make noodles. To enhance the taste of noodles, egg and many different ingredients are also added. Thus prepared dried noodles are further boiled and served according to the taste (Ojha et al 2020).

Product Formulation and Nutritional Composition (Ojha et al 2020)

Ingredients	Nutritional Composition (per 100g)
Millet: 200 g	Carbohydrate: 76.90 g
Refined Wheat Flour: 800 g	Protein: 8 g
Gluten: 100 g	Fat: 0.93 g
Water: 425-475 ml	Fiber: 0.91 g
Salt: 5 g	Ash: 0.99 g

Preparation steps

- The flour should be sieved properly,
- Mix all the weighed amount of flour properly with given amount of gluten,
- Add water as per recipe,
- Make dough and let it stand for 20-30 minutes by covering with damp muslin cloth,
- Then, sheeting should be done of about 2 mm thickness, or it can be done by using noodle maker,
- The sheet is then cut into thin thread like structure with the help of knife or noodle maker can be used,
- Then, it is dried at 70-80°C, the noodles should be dried properly,
- The dried noodles are packed in an airtight polybag,
- Store the packed noodles in cool and dry place.

Finger Millet momo

Momo is one of the famous food items of Nepal. Dough, which is made by mixing millet flour with water and is rolled to make small balls of about 10 g. About 10 g of vegetable or meat is stuffed and wrapped to give a round shape. It is about 20 g dumpling, and it is the further steamed to cook. This food item is called *momo. Momo* is eaten with soup, while it is hot. It is a tasty, nutrition food item but is made by cheap.

NFRC has made a recipe that has incorporate millet flour with *maida* (refined wheat flour), which contain gluten portion for the preparation of biscuit, noodle, and bread. To make bread, biscuit and noodle from millet flour, the flour should be sieved from sieve number 70 (Bepary et al 2015).

Product Formulation (Bepary et al 2015)

Ingredient	Veg (g)	Chicken/Pork/Mutton(g)
Millet flour	100	100
Atta	400	400
Onion	100	120
Tomato	50	
Cabbage	150	100
Green chilies	30	30
Green cardamom	30	30
Hot oil	30	30
Minced meat		500

Preparation steps for veg momo

- Millet flour, Atta (white flour) is mixed with water.
- Vegetables including cabbage, onions, garlic, and ginger are cut into pieces and mixed with the vegetables. Pieces like turmeric, cumin, black pepper, salt is added as per taste.
- Millet dough is rolled and made to dumpling by adding about 15 gram of vegetable mix.
- Water is boiled and dumpling is steamed for about 20 minutes.

Preparation steps for chicken momo

- Millet flour, atta (wheat flour) is mixed with water.
- Chicken is minced and mixed with vegetables like cabbage, onion, garlic, ginger. Spices like salt, turmeric, black pepper.
- Millet dough is rolled and made to dumpling by adding about 15 grams of mix.
- Water is boiled and dumpling is steamed for about 20 minutes.

Finger Millet Cookies

Similarly, NFRC also developed millet-based cookies. Cookies are baked goods that typically contain the three elements flour, sugar, and fat, along with other minor ingredients, to make dough. Cookies is like biscuit but with soft texture than biscuit. Cookies served as snacks with tea. Millet could be used for making quality cookies. The ingredients and their proportion with barley flour for cookies making are shown in table below (Soni et al 2018):

Product Formulation and Nutritional Composition (Ojha et al 2020)

Ingredients	Nutrition Composition (per 100 g)
Wheat flour: 800 g	Energy: 660 kcal
Millet flour: 200 g	Carbohydrate: 24 g
Salt: 4 g	Protein: 5.04 g
Ghee: 300 g	Fat: 31.15 g
Sugar: 300 g	Ash: 0.78 g
Baking powder: 6 g	Fiber: 0.68 g
Milk powder: 40 g	Carbohydrate: 24 g
Egg: 100 g	Protein: 5.04 g
Water: 150 ml	Fat: 31.15 g

Preparation Steps

- Production flowchart and diagrammatic representation of cookies,
- Beat the ghee for 5 minutes at room temperature,
- Make cream (mixing granulated sugar for 10 min,
- Add baking powder, salt, and skim milk powder,
- Mix slowly by adding half of the sieved flour and little water, mix for 5-10 minutes,
- Add remaining flour and water, mix for 10 minutes,
- Leave for 10 minutes, and fill in the filler to pump the dough,
- Give the required shape,
- Bake (17^{0}C for 20-25 minutes) in baking oven,
- Cool it and pack in plastic (Good sealing).

Finger Millet doughnut

It is a delicacy prepared form either refined wheat flour or whole wheat flour. It expands to twice the size as compared to *Selroti*, which is prepared locally (Ojha et al 2020).

Required materials	Quantity (grams)
Wheat flour + millet/buckwheat flour	800 + 200 = 1000
Ghee	100
Sugar	100
Salt	10 to 15
Yeast	10 to 20
Water	600 ml

Preparation steps

- Initially, yeast is activated, or its quality is tested by mixing with sugar and warm water (37 ^{o}C to 38 ^{o}C), followed by resting for 10 to 20 minutes.
- After yeast is activated, all the materials are mixed properly.
- Dough is left for fermentation for 2 hours in a closed vessel.
- During fermentation, carbon dioxide is formed which is trapped in gluten, formed during mixing the dough. As a result, its volume doubles.
- Balls are prepared from the dough and left for 10 to 20 minutes.
- Balls are given the shape of *Selroti* and fried in ghee.

Millet cake

Developed by NFRC, it is one of a flour confectionary prepared from wheat flour, sugar, ghee, egg, water etc. Further, ingredients may be added as per your taste. The shape and taste of cake can be different according to the requirement (Ojha et al 2020).

Product Formulation and Nutritional Composition

Ingredients	Nutritional Composition (per 100g)
Millet flour: 400 g	Carbohydrate: 55.48 g
Wheat flour: 600 g	Protein: 13.74 g
Sugar: 600 g	Fat: 20.35 g
Ghee: 500 g	Fiber: 3.85 g
Egg: 10	Ash:1.28 g
Baking powder: 10 g	
Water: 350 -380 ml	

Preparation steps:

- Mix flour and half of the sugar,
- Mix the baking powder in one glass of water with 5 g sugar,
- Make cream (By mixing remaining granulated sugar in melted ghee),
- Beat the egg in cream,
- Add flour slowly in the cream with continuous mixing also add water slowly (preparation of batter),
- Add the activated baking powder in the batter,
- Pour the batter in cup to fill it half,
- Bake it in oven (190˚C for 25-30 minutes) in baking oven,
- Cool it and pack in plastic (Good sealing)

Millet bread

Another recipe developed by NFRC, millet based bread, is the finished product that has been baked in certain ovens with set baking conditions containing dough, water, wheat flour, and a tiny bit of salt(Kourkouta et al 2017). Bread is another most popular baked product generally made from hard flour (high protein content). Barley could be used for making quality bread. The ingredients and their proportion with barley flour, naked barely flour, malted barley flour, and malted naked barley flour for bread making are shown below(Ojha et al 2020).

Product Formulation and Nutritional Composition

Ingredients	Nutritional Composition (Per 100 g)
Wheat flour: 1000 g	Carbohydrate: 50.01 g
Sugar: 100 g	Fat: 4.95 g
Ghee: 50 g	Protein: 11.95 g
Gluten: 20 g	Ash: 2.25 g
Yeast: 10 g	Crude Fiber: 0.55 g
Salt: 10 g	
Water: 500 ml	

Preparation steps

- Activate the yeast (Add yeast in 100ml water containing 5 g sugar at 37 ˚C) (Leave for 30 min),
- Mix dry ingredients (salt, sugar, gluten, barley flour and wheat flour),
- Add yeast and mix properly, then again add sugar, salt and water slowly to prepared dough,
- Mix ghee, mix it for 20 minutes and leave the sough for 37 ˚C for 1.5 hour (cover with wet muslin cloth),
- Make round shape ball about 200g and leave in baking moulds for 1 hour,
- Bake at 210 ˚C for 25-30 minutes in baking oven,
- Cool it and pack in plastic (Good sealing)

Millet biscuit

Also developed by NFRC, biscuit is a product which consists of small granular grains, has compact structure and a quantity of air trapped in it. Biscuit is a product prepared from the mixture of wheat flour, sugar, ghee, salt, milk, glucose, and water. The moisture content of biscuit is comparatively low, so it can be stored for longer time. Biscuits can be made attractive by using chocolate chips, cream, flavor, and many more.

Product Formulation (Ojha et al 2020)

Ingredients	Quantity
Millet flour	400 g
Wheat flour	600 g
Sugar	250 g
Ghee	150 g
Salt	10 g
Skimmed milk powder	10 g
Glucose	10 g
Baking Powder	20 g
Ammonium Bicarbonate	15 g
Water	350-450 ml

Procedure steps

- Mix the above-mentioned flour and sieve,
- Prepare cream by mixing half of the powdered sugar, skimmed milk powder, and glucose in melted ghee,

- Add salt, ammonium bicarbonate. baking powder, and remaining sugar in the sieved flour and mix properly,
- In the above prepared mixture, add previously prepared cream and mix thoroughly,
- Sheeting of the dough is done by the help of stainless steel or wooden roller of about 4-5 mm thickness and give the required shape by using cutter,
- Bake the biscuit at 170 ˚C for 20-25 minutes,
- Cool the baked biscuits and pack in polyethylene or packaging paper,
- Store the product in cool and dry place.

Leveraging Millets for a Sustainable Future in Nepali Food Systems, Culture, Heritage, and Economy

Millets, often referred to as "nutri-cereals", play a pivotal role in addressing the challenges of food insecurity and malnutrition. These grains are rich sources of essential macro- and micronutrients (Kumar et al 2016, Nanje Gowda et al 2022, Shobana et al 2013). However, prevailing governmental policies primarily prioritize food security, inadvertently neglecting the untapped potential of millets to promote balanced diets and drive socioeconomic progress (FAO 2023). This discussion explores opportunities and strategies for utilizing millets in the production of nutrient-dense processed foods, emphasizing the need for a shift in government policies.

Millets have silently sustained communities across Nepal, South Asia, and Africa for centuries, displaying remarkable adaptability to diverse and challenging agro-ecological conditions. Thriving in regions characterized by poor soil fertility and limited resources, these hardy grains have become indispensable (Gairhe et al 2021). Nepal boasts a rich variety of millet types, including Finger Millet (*Kodo*), Proso Millet (*Chino*), and Foxtail Millet (*Kaguno*). Finger Millet, ranking fourth in Nepal's crop hierarchy, thrives in the mid-hills and high hills on marginal lands. It stands out for its higher fiber content, making it suitable for weight management, and its superior levels of calcium, iron, and phosphorus, rendering it particularly beneficial for pregnant women, diabetics, and individuals with hypertension. Proso millet, with its short growth cycle and low water and fertilizer requirements, holds promise for the future, especially given changing environmental conditions (Gairhe et al 2021).

Unleashing the full potential of millets involves value addition, processing, and innovative recipes. These approaches can extend the shelf life of millets, enhance their nutritional value, and broaden their culinary applications not only to make nutritious cuisines and recipes but also the tasty one too, which is the prime factor that decide which food the people eat. Millet flour can be utilized to create various nutritious and tasty gluten-free products, including bread and pasta, while millet flakes can be incorporated into breakfast cereals or replace rice in savory dishes. Innovative “Fine-Dining” recipes development can make millets more appealing to younger generations and niche market, facilitating their integration into modern diets (UNRIC 2023) and launch traditional Nepali Millet recipes to an international stage. This will enhance the value of our traditional recipes to an unimaginable height.

In light of the current agricultural landscape and the potential of millets, it becomes evident that numerous opportunities exist for their commercialization, particularly in the context of producing nutrient-rich and tasty processed foods. However, it is imperative to acknowledge that existing governmental policies predominantly center on the concept of food security. While this approach is undeniably crucial, it may fall short in ensuring long-term sustainability unless we broaden our perspective to consider agricultural products like millets as significant and context-specific opportunities in the realm of food-based nutritional security and the enhancement of a nation's socio-economic fabric.

The central premise here underscores the importance of product diversification, with a specific focus on the creation of millet-based products that are both delectable and highly nutritious and tasty. This approach offers a multifaceted solution to address prevalent nutritional deficiencies within vulnerable, disadvantaged, and marginalized segments of the population.

First and foremost, this approach directly tackles the pressing issue of nutritional deficiency diseases that afflict these vulnerable groups. Now, undeniable evidence suggest that millets are “nutrition powerhouses”. By harnessing millets to produce a spectrum of nutrient-rich processed foods, we can make significant strides in mitigating the prevalence of malnutrition and related health problems.

Furthermore, the strategy of developing millet-based products that are both palatable and nutritious is pivotal in fostering their widespread adoption. However, to embark on this transformative journey toward product diversification and the creation of delectable millet-based offerings, a fundamental overhaul of government policies and actions is imperative. The current policy framework, primarily centered around food security, necessitates reconfiguration to accommodate the broader vision of harnessing millets to enhance nutritional security and socio-economic well-being.

This paradigm shift in policy should encompass several dimensions. Firstly, it should incentivize and facilitate research and development efforts aimed at creating innovative millet-based products that strike a balance between taste and nutrition. Collaborative initiatives involving inter and intra-government entities, research institutions, and the private sector can be instrumental in driving this innovation forward. However, in our view, Nepal has failed to capitalize the opportunity for international collaborations and cooperation’s that was before us, provided by the countries across the globe, as United Nation has declared 2023 as “International Year of Millets”.

Secondly, policy measures should prioritize the promotion of millet cultivation and production. This entails providing farmers with the necessary resources, knowledge, and infrastructure to cultivate millets efficiently. Additionally, mechanisms for ensuring fair pricing and equitable market access should be established to guarantee that farmers receive just compensation for their millet produce. Moreover, there is a critical need for public awareness campaigns and educational initiatives to inform consumers about the health benefits of millets and the delightful options available to them. These campaigns can stimulate demand for millet-based products, driving market growth and enhancing the economic viability of millet production.

Finally, the most crucial, promoting value-added millet products can profoundly impact marginalized communities by offering new market opportunities and strengthening livelihoods. Millets, classified as low-input crops, also demonstrate resilience to diseases and pests, reducing reliance on synthetic fertilizers and pesticides. Their adaptability to challenging environmental conditions, such as heat, drought, and floods, positions millets as a critical component of climate-resilient agriculture (UNRIC 2023).

In conclusion, millets possess the potential to revolutionize food security, nutritional well-being, and socioeconomic stability, particularly in regions like Nepal. Harnessing the diversity of millets and implementing value addition and processing strategies can create a future where these ancient grains play a pivotal role in addressing the challenges of food insecurity and malnutrition. However, realizing this potential requires a fundamental shift in government policies and actions, aligning them with the vision of a millet-driven nutritional renaissance. Food is not only food but the unwavering beacon to boost wealth and showcase out culture and heritage at the world stage.

Conclusion

In this extensive review, we have embarked on a comprehensive exploration of millets, revealing their multifaceted contributions to Nepal Food Systems. Millets, recognized as gluten-free, nutrient-rich grains, hold a central role in the domains of agriculture, food science and technology, and gastronomy. Our journey has covered diverse aspects of millets, encompassing their taxonomy, properties, and global cultivation. These unassuming grains, belonging to the Poaceae family, serve as foundational elements in global agriculture.

Our investigation has underscored not only the significance of comprehending millets' taxonomy, properties, and cultivation but also the intricate tapestry of millet varieties. Pearl millet, thriving in arid regions, stands out as a nutritional powerhouse abundant in protein, iron, zinc, and phytochemicals. Finger millet, renowned for its calcium content, plays a vital role in promoting bone health and regulating blood glucose levels. Foxtail millet, rooted in ancient Nepal and China, shows promise in reducing cholesterol levels and managing glycemic control. Proso millet, unassuming in appearance, conceals a rich trove of nutrients and energy content.

Our examination has further highlighted the nutritional superiority of millets, surpassing rice, and wheat in terms of protein and dietary fiber content. Millets offer support in reducing the risk of chronic diseases, fostering digestive health, facilitating weight management, and enhancing immunity. Significantly, our review has emphasized millets' adaptability, showcasing their capacity to thrive in diverse climates. Finger millet emerge as staples in mid and high hills, while proso millet and foxtail millet flourish in temperate hilly regions. These grains play a pivotal role in addressing the challenges posed by a changing climate, providing resource-efficient, heat-tolerant, and soil-resilient solutions for enhancing food security and nutrition.

Millets, as "future smart foods," emerge as champions in addressing contemporary issues, ranging from anemia, diabetes, obesity, and cardiovascular diseases to malnutrition, with a particular focus on the well-being of women and children. Beyond health benefits, millet cultivation promotes rural development and sustainable livelihoods, advocating for biodiversity and eco-friendly farming practices.

In our culinary exploration, we have celebrated the inherent adaptability and versatility of millets, which have inspired a plethora of culinary delights. From traditional millets *Dhido* to pizza, bread, and cookies continue to fuel culinary innovation.

In summary, this comprehensive review paper has interwoven the intricate facets of millets, encompassing their taxonomy, health benefits, culinary potential, and their vital role as "future smart foods." Through the synthesis of scientific data and culinary creativity, millets emerge as indispensable grains, bridging the realms of nutrition, sustainability, and gastronomy. As we conclude our journey, we extend an invitation to scholars and enthusiasts to embrace the diverse world of millets. Within this fusion of scientific excellence and culinary ingenuity, we envision a healthier, and more sustainable future for global food systems, where millets shine as beacons of promise and possibility. The article also stressed that concept of commercializing millets to produce nutrient-rich processed foods holds immense promise. To fully unlock this potential and address the complex challenges of nutritional deficiency and socio-economic uplift, a comprehensive reevaluation of government policies and actions is indispensable. The culinary diversification, aid in processing nutritious and tasty millet-based food is crucial to change the food habit of majority of people is crucial and should be addressed. This transformative shift can pave the way for a future where millets assume a pivotal role in enhancing the nutritional landscape and socio-economic well-being of the nation, particularly benefiting vulnerable and marginalized populations.

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Traditional Fermentation Practices and Brewing Dynamics of Nepalese Millet-Based Alcoholic Beverages

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Abstract

This review provides an in-depth investigation of Nepalese ethnic alcoholic beverages, with particular reference to traditional fermentation starters and the dynamics of finger millet fermentation. Commencing with an overview of *murcha*, *mana*, *manapu* crafting methodologies (making processes), the subsequent sections delve into physicochemical and microbiological aspects, unveiling disparities in moisture, amylase activity, and microbial counts between traditional fermentation starters, *murcha* and botanicals used to prepare them. Subsequently, the chapter focuses on traditional millet-based alcoholic beverages such as *jand*, *tongba*, and *raksi*, elucidating their preparation processes and properties encompassing physicochemical, sensorial, storage, and therapeutic aspects. Additionally, it explores different finger millet varieties for high-quality malt production and potential brewing applications. Insights into the impact of fermentation containers and cereal types on chemical and sensory attributes are also discussed. The review concludes by presenting nuanced perspectives on the future trajectories of Nepalese fermentation practices, challenges in preserving biodiversity, and cultural and socioeconomic empowerment of local communities. This comprehensive overview not only enriches academic discourse on traditional fermentation but also furnishes actionable insights for optimizing Nepalese ethnic alcoholic beverage production. This review holds paramount significance for the cultural and socio-economic tapestry of Nepal and its ethnic groups. By unraveling the intricate processes of traditional fermentation, it sheds light on the cultural heritage embedded in these practices. Furthermore, the exploration of future trajectories underscores the potential for economic empowerment and sustainable development, ensuring the preservation of cultural identity amid evolving global landscapes.

Keywords: Fermentation starters, *jaad*, *toomba*, *raksi*, bentonite, brewing potential

Traditional Cereal-Based Alcoholic Beverages

Indigenous fermented foods mirror a synthesis of technology ranging from primitive to culture-specific innovations, exhibiting diverse sensory and textural qualities. The exploration of alcoholic beverages unfolds unique brewing methodologies, exemplifying the intricate dynamics between tradition and industrialization in indigenous fermented beverages. Spontaneous food fermentation intricately intertwines with climatic nuances, raw material availability, socio-cultural factors, and ethnic preferences

(Karki 2013). Fermented foods, encompassing staples, adjuncts, condiments, and beverages, stand as pivotal dietary foundations (Tamang 1998). An examination of fermented foods in diverse cultural contexts reveals a tapestry ranging from household practices to extensive commercial applications. This complexity underscores the multifaceted nature of spontaneous food fermentation, where the interplay of climatic conditions, raw materials, and cultural intricacies shapes a diverse array of fermented products, reflecting both tradition and adaptation in culinary practices across different societies.

The taxonomy of indigenous fermented foods classifies them by raw materials, predominant fermentation type, product utilization, and geographical origin. Fermented products fall into categories such as alcoholic foods and beverages, vinegars, breads, fermented porridges and snacks, and lactic acid-fermented fish products. Steinkraus (1983) refines the classification of indigenous cereal-based alcoholic foods and beverages into three categories contingent upon saccharification methodology:

Saliva as the amylolytic agent

Historically, saliva served as a source of diastase in the conversion of starch to sugars in fermented alcoholic beverages like Japanese *sake* (Kodama and Yoshizawa 1977) and South American *chicha*. The age-old practice of utilizing saliva in the *chicha*-making process persists in the Andes regions of Bolivia and Peru, originating from the pre-chewing of grains for infants.

Starch hydrolysis through malting

Malting, an age-old method of starch hydrolysis, has roots dating back to the inception of grain harvesting and storage. Malted grain, when immersed in free water, underwent fermentation by ubiquitous yeasts, yielding early beer. Examples include African *kaffir* (sorghum) beer, Egyptian *bouza* (wheat-based), and Kenyan *busaa* (maize and finger millet or a blend of finger millet and sorghum) (Karki 2013, Steinkraus 1983).

Amylolytic molds and yeasts

This category spans from primitive Thai rice wines to the refined Japanese *sake*, primarily attributed to the enzyme amylase produced by filamentous fungi to convert starch into simple sugars that are fermented by yeasts. Essential amylase producers include *Aspergillus oryzae*, molds of the genera Mucor and Rhizopus, and *Amylomyces rouxii*. Alcohol production involves yeast strains such as *A. rouxii*, *Saccharomyces cerevisiae*, *Endomycopsis burtonii*, *E. fibuligera*, *Candida lactosa*, and related yeasts (Karki 2013).

Fermentation in cereal grains involves a nuanced interplay of microbial activity leading to the reduction of carbohydrates and non-digestible polysaccharides. Simultaneously, amino acid synthesis occurs, and B-complex vitamin availability surges. The enzymatic degradation of phytate during fermentation amplifies the soluble iron, zinc, and calcium content. Fermentation also elevates protein quality and lysine levels in cereals like maize, millet, and sorghum (Karki 2013).

Thus, the spectrum of traditional cereal-based alcoholic beverages reflects the ingenuity and diversity inherent in age-old fermentation practices across the world. Only the Asia-Pacific region boasts a rich tapestry of over 200 described alcoholic beverages, with distinctions arising from preparation methods, raw materials, and the season of production (Lee and Kim 1993). Cereal fermentation across the globe includes European beer, Asian beer with rice, maize-based products in Africa and the Americas, sorghum and millet in Africa and South Asia, and rice-based fermentations in India, China, Southeast Asia, and the Far East. Wheat-centric fermentations are prominent in the Middle East, Turkey, and the Far East.

In the annals of Nepalese history, the genesis of alcoholic beverages dates back to ancient times, intricately interwoven with celebrations, festivals, and marriage settlements. Rooted in ethnic traditions, these brewing technologies have been passed down through generations, embodying a profound cultural legacy. Among the pantheon of traditional fermented beverages in Nepal, including *jand*, *toongba*, *nigar*, *hyaun thon*, and *raksi*, as well as the indispensable *murcha* and *mana*, traditional alcoholic fermentation starters, emerge as a linchpin. These libations, with their ritualistic importance deeply embedded in the cultural heritage, find resonance in various ethnic ceremonies and practices. Alcoholic beverages, such as *jand* and *raksi*, assume central roles in marriage ceremonies and religious rites, exemplifying their cultural indispensability (Regmi 2007).

Within the rich tapestry of indigenous fermented foods, Nepal stands as a mosaic awaiting meticulous exploration. Traditional fermented foods, deeply embedded in household and regional variations, contribute significantly to the nutritional landscape. These fermentation processes, acting as economic and cultural cornerstones, offer an inexpensive technology to preserve and elevate the nutritional value and sensory appeal of foods (Murty and Kumar 1995). The exploration of indigenous fermented foods in developed countries contrasts with the lacunae in Nepal, urging a more comprehensive investigation into their production, consumption, and socio-economic impact.

Finger Millet: An Essential Component in Traditional Alcoholic Beverage Production

Finger millet (*Eleusine coracana*) is the fourth most pivotal food crop in Nepal, thriving in 267,071 hectares of land. With a robust yield of 229,462 MT and a productivity of 1.27 T/ha (MoALD 2023), finger millet plays a crucial role in both relay cropping systems and mono-cultivation, mid and high hills. While not only a staple for direct human consumption, finger millet also emerges as a key player in alcoholic beverage production (Osti 2004). *Tongba*, an alcoholic beverage in Nepal, which also becomes a part of the culture of Ethnic West Bengali in India, is prepared by boiling millet seeds, cooling them, inoculating with yeast, and fermenting the concoction in bamboo sections. *Tongba* involves the extraction of juice through a cylindrical bamboo or wooden barrel, offering a unique tasting experience. *Jand*, a cereal beer derived from grains like finger millet, rice, wheat, and maize, plays a vital role in *Newar*, *Limbu*, *Tamang*, and *Rai* cultures (Rai 2006). *Nigar*, akin to *sake*, is a prized cereal wine resulting from prolonged fermentation (Rai 2006). *Rakshi*, an unaged congeneric spirit, is obtained through pot distillation of fermented cereal slurry or mash, showcasing varying alcohol contents (15-40% v/v) (Kharel et al 2009).

The global narrative of fermented beverages from millet extends beyond Nepal, finding resonance in diverse cultural milieus. In Eastern Europe, *braga*, a fermented beverage from millet is a traditional drink from Romania (Pederson 1971). Moreover, in East African countries, millet assumes a pivotal role in the malting process, enhancing its nutritional quality and palatability. This transformation, rooted in the biochemical modification of grains during malting, showcases the development of amylolytic enzymes, thereby hydrolyzing starch into fermentable sugars (Karki 2013). The advantages brought about by malting extend to reducing antinutritional factors, improving digestibility, and augmenting palatability (Nout and Davies 1982). Finger millet emerges as a malt superior to its counterparts, ranking closely to barley in enzymatic activity (Taylor et al 2006). Its malted form not only signifies a brewing revolution but also positions itself as a superior nutritional option, reducing antinutritional factors and enhancing palatability. The nuanced biochemical alterations during malting bestow upon finger millet the status of a premium brewing ingredient, embodying both tradition and innovation in its malted alcoholic beverages (Taylor 2009).

The substitution of barley malt with millet in brewing has witnessed successful endeavors in various nations. In Kenya and India, finger millet takes center stage in the traditional manufacture of malt, celebrated for its heightened enzymatic activity and distinct flavor profile (Nout 1981). Pearl millet, a staple in sub-Saharan Africa, undergoes home malting for small-scale brewing of traditional African beer, with its industrial malted variant gaining traction in commercial opaque beer production in Zimbabwe (Pelembe et al 2004).

Traditional Fermentation Starters in Cereal-Based Nepali Alcoholic Beverage Production

This section reviewed the traditional fermentation starters employed in the production of cereal-based alcoholic beverages across diverse cultures of Nepal. The study scrutinizes the methodologies, ingredients, and microorganisms involved in crafting starters like *murcha*, *manapu*, and *mana*, shedding light on their significance in the preparation of beverages such as *jand* and *raksi*.

Murcha

Murcha or *marcha* (Fig 1), a pivotal starter in the Himalayan regions, stands as a testament to the intricate artistry embedded in the preparation of *jand* and *raksi*. *Murcha*, an amylolytic fermentation starter, indigenous to Nepal, is used in the preparation of alcoholic beverages such as *jand* in Nepal, and also in the Darjeeling hills and Sikkim of India, and Bhutan (Tamang et al 1996). It is a dry, round to flattened, creamy white to dusty white, solid ball-like starter ranging from 1.9 to 11.8 cm in diameter and from 21.1 g in weight (Karki et al 2016). *Murcha* is a Nepali word. Different ethnic communities of the region call it by their own dialect such as *khesung* by *Limboo*, *bharama* by *Tamang*, *bopkha* or *khabed* by *Rai*, *phab* by *Bhutia* and Tibetans, and *buth*/*thanbum* by the *Lepcha* (Karki 2013).

Figure 1. Traditional fermentation starters of Nepal
Adapted from Karki et al 2016

Murcha is produced at home exclusively by women. This art is practiced as a hereditary trade that passes from mother to daughter, especially daughter in law (Tsuyoshi et al 2005). It has become a tradition to prepare *murcha* between September 10 and 20. There is a cultural belief that the quality of starter would be better if it is made during "*Ganesh Chaturthi*" (a famous Hindu festival), which generally falls in the month of September (Karki 2013). Its formulation involves a meticulous combination of cereals, *murcha* plant components, and indigenous spices (**Figure 2**). The subtle variations in preparation techniques contribute to the diverse sensory profiles of the final products.

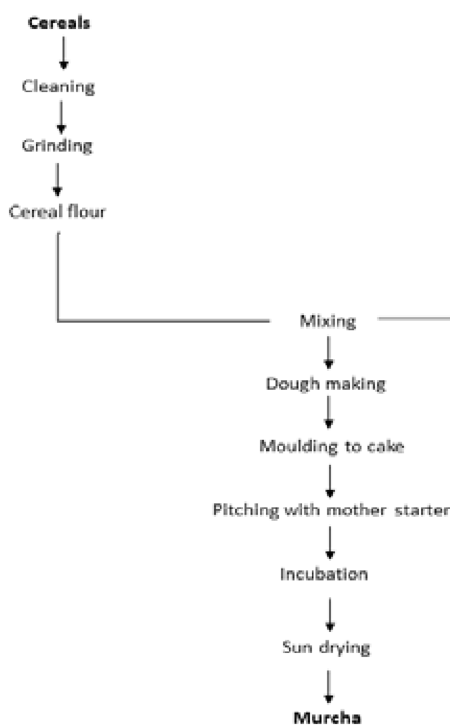

Figure 2. Murcha preparation steps
Source: Rai 1984, Karki 2013

The plants and herbs used in Nepal as a source of microorganisms are extensive. Some of them are listed in **Table 1** with their parts used for making *murcha*.

Table 1. Different botanicals used for preparation of *murcha*

Vernacular name	Scientific Name	Plant parts used
Abhijalo	*Drymaria cordata* Wild.	Whole
Adhuwa	*Zingiber officinale* Roxb.	Whole
Anaras	*Ananas comosus* (L) Mer	Leaf
Anglah lena	*Elephantopus* sp.	Root-bark
Angtellek	*Polygala* sp.	Whole
Bhatu	*Clerodendrum indicum* (L.) Kize	Root
Bhimsenpati	*Buddleja asiatica* Lour	Root
Buki Phul	*Anaphalis triplinevis*	Whole
Chabo	*Piper chaba* Hunter	Whole
Chhatre	*Inula* sp.	Whole
Chini jhar	*Scoparia dulcis* L.	Flower
Chitu	*Plumbago zeylanica* L.	Whole Tender leaf
Dhaenro	*Woodfordia fructicosa* Kurz	Root
Dudhe	*Ichnocarpus fructescens*	Bark
Gahate jhar	*Polygala abyssynica* Buch. Hum.	Whole Leaf
Ghodtapre	*Centella asiatica* L.	Tender shoot
Hide simi	*Dolichos lab-lab* L.	Root
Khareto	*Sida acuta* Burm F.	Rhizome
Khedei	*Polygala arillata* Buch.Hum.	Whole
Khursani	*Capsicum annum* L.	Whole
Kurilo	*Asparagus racemosus* Wild	Leaf and tender shoot

Vernacular name	Scientific Name	Plant parts used
Lasunpate	*Ophiopogon parviflorus* (Hook.f) Hara	Whole
Lwangta	*Spergula arvensis* L.	Leaf
Mahagagro	*Clematis grewiaeflora*	Tender leaf
Marich	*Piper nigrum* L.	Root-bark and flower Whole
Mewa	*Carica papaya* L.	Whole
Mulapate	*Elephantopus scaber* L.	Tender shoot and flower Whole
Nighare	*Vernonia* sp.	Leaf and tender shoot Fruit
Okhar	*Juglan regia* L.	Whole
Phulange	*Vernonia cinerea* (L.) Less	Fruit-stalk, leaf & bark Root
Pipla	*Piper longum* L.	Whole
Pire jhar	*Spilathus acmella* (L.) Less	Whole
Pire Unyu/ Uneu	*Christella appendiculata* (Bl.) Holtt	Whole
Pulukna	*Polygala triphyla* Buch. Hum.	Whole
Rukh Katahar	*Artocarpus heterophylus* Lamk	Fruit-stalk, leaf & bark Root
Sengreng	*Geniosporum coloratum* D. R. Don	Whole
Tite	*BrIchnocarpus* sp.	Root-tuber
Unyu	*Pteridium revolutum* (Bl.) Nakai	Whole

Source: KC et al 2001

Murcha is a mixed microbial culture and consists of saccharifying molds, fermentative yeast, and acidifying lactic acid bacteria (Karki 1986, Tamang and Sarkar 1995) responsible for different concentrations of ethanol, higher alcohols, different volatile components (aldehydes, ketones, esters, etc), and organic acids, which impart characteristic overall body, flavor, and aroma of alcoholic beverage depending on the microbial diversity and population in *murcha* used. The major microorganisms present in *murcha* are filamentous molds such as *Mucor praini,Mucor circinelloides*, *M. hiemalis*, *Rhizopus chinensis*, *R. oryzae* , *R. stolonifer* var. *lyococcus* and *Absidia lichtheimia*; yeasts such as *S. cerevisiae*,*S. fibuligera*, *S. capsularis*, *S. bayanus*,*Pichia anomala*, *P. burtonii*, and *Candida glabrata*; and LAB such as *Pediococcus pentosaceus*, *Lactobacillus bifermentans*, and *L. brevis* (Kobayashi et al 1961, Tamang and Sarkar 1995, Tsuyoshi et al 2005). Mold population in *murcha* has been detected at the level of 6 log cfu/g, whereas the load of yeasts and LAB was 8 log cfu/g, and 7 log cfu/g, respectively (Tamang 1992).

Mana

Mana (**Figure 1**) is a granular, greenish-type starter prepared from wheat flakes in Nepal (**Figure 3**). In the *Newar* community of Nepal, *mana* is further classified into three of its forms, which are based on the key substrates used. They are *Cho mana*, *Ki mana*, and *Pa mana*. Here *Cho* means wheat, and *Ki* means rice (Karki et al 2016). *Pamana* refers to *murcha* as stated above. The green mycelium development and sun-drying stages are critical, contributing to *mana*'s distinct qualities. *Mana* contains 6 log cfu/g of *Mucorales*, 7 log cfu/g of *Aspergilli*, 3 log cfu/g of *yeasts*, and 5 log cfu/g of lactic acid bacteria (Nikkuni et al 1996). *Aspergillus oryzae* and *Rhizopus* spp. are present in *mana* (Nikkuni et al 1996, Shrestha et al 2002). It is the only amylolytic starters in this region, which have *Aspergillus* significant in cereal-based alcoholic fermentation. Among the yeast, Saccharomyces cerevisiae are predominant followed by *Candida versatilis* (Karki and Shrestha 1999).

Manapu

Manapu (**Figure 1**) is an ethnic amylolytic starter from Nepal similar to *murcha* that is prepared from rice flour and millet. *Manapu* preparation is also an example of solid-state fermentation utilized in production of *koji*, fermentation starter of *sake* (**Figure 3**). It serves as a source of various groups of microorganisms that allow selective growth of desirable microflora. It is white to creamy white in color and can be of varying size. The microorganisms present in *manapu* are *S. cerevisiae*, *S. fibuligera*, *C. versatilis*, *Rhizopus* spp., and *P. pentosaceus* (Shrestha et al 2002). The load of yeast and LAB in *manapu* is 5-9 log cfu/g, and the mold population is 7 log cfu/g (Shrestha et al 2002).

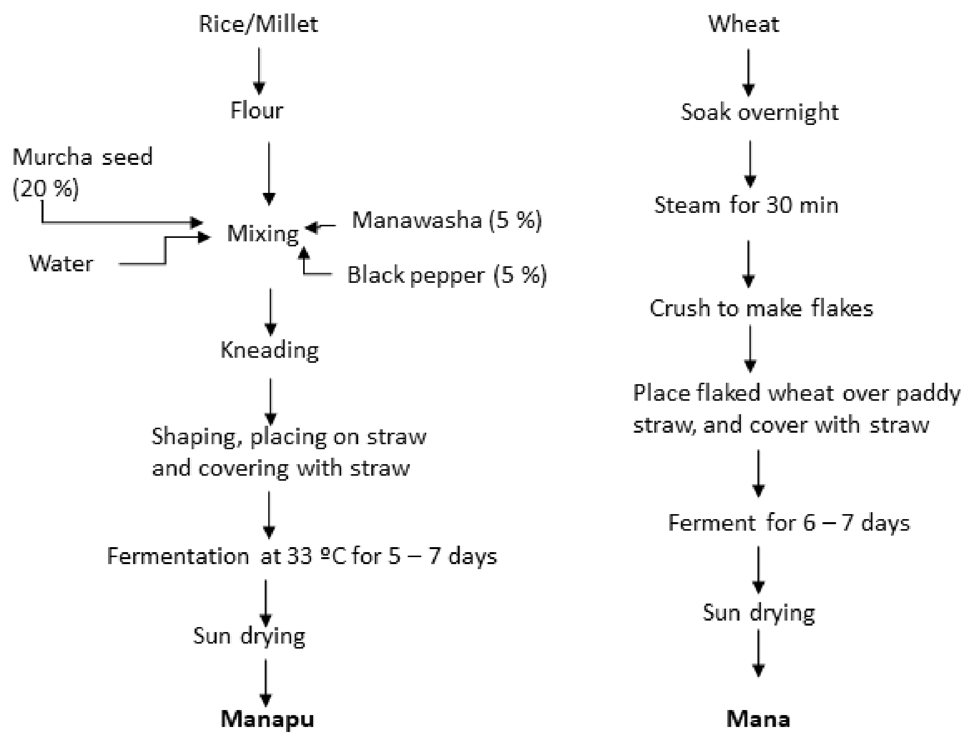

Figure 3. *Manapu* and *Mana* preparation steps
Source: Karki 2013

In conclusion, the traditional methods employed in crafting fermentation starters unveil a fascinating interplay of indigenous flora and specific preparation rituals. From the meticulous selection of plants as described above to the nuanced processes involving soaking, crushing, and sun-drying, each step contributes to the unique characteristics of the starters. The economic and cultural significance of these traditional practices cannot be overstated. *Murcha* production, often a hereditary trade passed down through generations, holds a pivotal place in the economic activities of *Matuwali* communities. The secrecy surrounding certain preparation methods further emphasizes the cultural intricacies associated with these practices.

However, the use of *murcha* as a starter culture introduces challenges due to non-uniformity in product quality and variable microflora concentrations. Research gaps exist in the physicochemical and microbiological characteristics of *murcha*. Further research interventions are necessary to enhance the scientific understanding of indigenous starters like *murcha*. While research exists on *murcha* and amylolytic fermentation, gaps persist in the preparation of starters using isolated cultures and comprehensive analyses of resulting products. Bridging these gaps is crucial for propelling traditional cereal fermentation toward improved and standardized processes. Inspiration from global examples, like Japanese *sake* and Korean *soju*, highlights the potential for Nepal to elevate its indigenous fermented foods. Recognizing the threat of indigenous practices facing extinction, efforts to preserve and harness local knowledge become imperative. Research on indigenous starters like *murcha* emerges as a crucial avenue for unlocking the full potential of Nepalese traditional alcoholic cereal fermentation

Traditional Millet Fermentation Process in Nepal

Finger millet plays a crucial role in both relay cropping systems and mono-cultivation as well as diverse ethnic alcoholic beverages. Alcohol, an age-old elixir, boasts a rich historical tapestry globally. In Nepal, where archaeological remnants date back to 7000 BCE in China, the genesis of alcohol production lacks direct evidence but is intricately woven into the cultural fabric. Imported technology from India and China shaped Nepal's alcoholic narrative, as corroborated by traditional Hindu literature Mahabharata and Ramayana (Shrestha 2023a). Diverse communities in Nepal exhibit distinct folklore: The *Limbu* credit their deity for fermentation knowledge (Shrestha 2023b), contrasting with *Gurung* folklore attributing it to a divine couple's culinary desires (Shrestha 2023d). Despite varied genesis tales, the cultural significance of alcoholic beverages unifies Nepalese ethnicities, acting as a linchpin in rituals, marriages, and even prenatal and postnatal ceremonies (Karki 2013, Shrestha 2023a,b,c,d,e).

The conventional method of finger millet fermentation in Nepal is initiated with the precise dehusking of millet using the *Okhal* or *Okhli*, and *Jato* (**Figure 4**), followed by the methodical winnowing facilitated by the *Nanglo* (woven bamboo tray) (**Figure 4**), the procedure systematically eliminates husks, immature grains, and lightweight particles. Subsequent to a thorough washing, potentially involving an overnight soak for optimal debris removal, the process discerns between red and black millet varieties (Karki 2013). The latter, recognized for yielding superior quality in products such as *jand* or *toongba*, assumes a central role (Regmi 2007). The pivotal cooking phase, integral to subsequent fermentation, manifests nuanced variations. Inclusion of coriander seeds enhances taste and aroma, with cooking durations tailored to the specific beverage—limited to rupture for *tongba*, while complete splitting is imperative for *jand* and *raksi*. The introduction of rice or wheat (10-20% by weight) intermittently enhances taste and aroma, with fully split millet noted for amplifying solid content in *jand*, even serving as a rice substitute (Nout 1981). Following cooking, the millet undergoes cooling, with the addition of powdered *murcha* preceding the spreading of the mash on a plastic sheet for fermentation. The fermented mash is consumed in two different ways. It is squeezed with added water, strained in a traditional strainer made of bamboo stripes, (*chhapani)* or aluminum strainer, and the whitish cloudy extract thus obtained is served in deep bowls, tumblers or other containers (Kharel et al 2009).

Murcha quantities are contingent upon fermentation temperature and intended product, with reduced *murcha* favored for *tongba* and elevated concentrations beneficial for *jand*. *Raksi* production advocates the highest *murcha* content, occasionally introduced a few days before completion for increased yield and strength (Pelembe et al 2004). The ensuing alcoholic fermentation and biomass development occur within vessels such as *Ghyampo* (**Figure 4**) or plastic buckets, spanning a fermentation duration ranging from 6 days to 6-12 months (Karki 2013). Traditional earthenwares, renowned for harboring beneficial microorganisms, are preferred in this process. The fermented millet tailored for *tongba* retains potential consumption until August in specific regions (Regmi 2007).

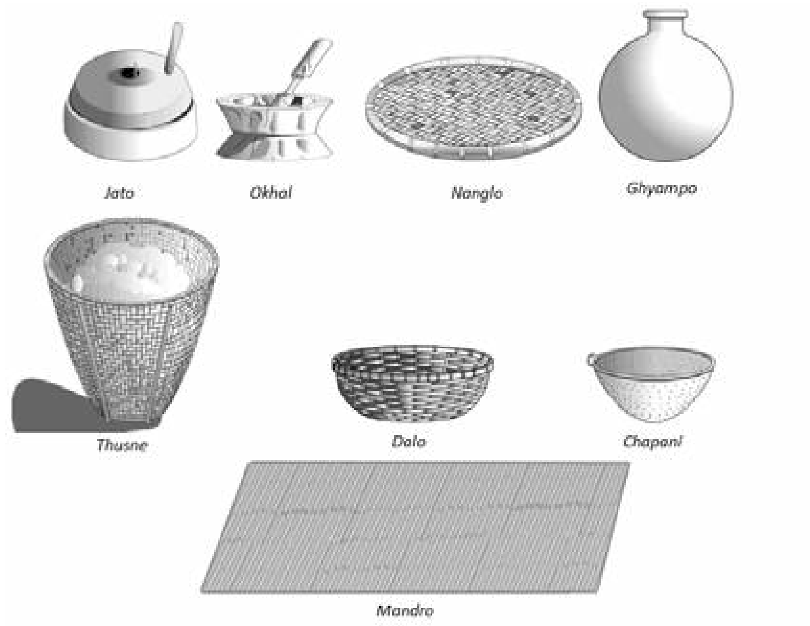

Figure 4. Traditional utensil and tools used for millet fermentation
Adapted from Kharel et al 2009

Despite the outlined method, variations occur based on locality, raw material availability, geographical factors, *murcha* types, and optional ingredients. The final beverage quality hinges on brewer expertise and raw material choices (Rai 1991, Yadav 1993). While culturally significant, traditional food fermentations pose challenges like uncontrolled processes, labor intensity, and limited economic integration. Addressing these challenges requires a focused research agenda to delineate the benefits and risks associated with specific products. Traditional brewing processes need a scientific facelift for industrialization. Prerequisites include scientific knowledge of raw materials, production processes, quality management, and hygienic packaging. The lack of scientific underpinnings in tribal brewing, relying on mixed microbial cultures, leads to inconsistent product quality.

Jand: Traditional Nepalese Noncarbonated Beer

This chapter provides a detailed exploration of *Jand* or *jnard*, a traditional sweet-sour cereal beer. The research encompasses microbial dynamics, fermentation techniques, physico-chemical attributes, organoleptic quality, and the choice of finger millet. Further, it delves into the effects of raw materials on *Jand* quality and explores the comparative impact of solid and semi-solid fermentations on chemical and sensory attributes of finger millet *Jand*s. *Jand*'s cultural ubiquity is evident in its role as a ubiquitous beverage across various ethnic groups in Nepalese and Tibetan cultures, transitioning from a homemade concoction to small-scale cottage industry production (Karki 2013). Its cultural significance extends to hospitality, rituals, dispute resolution, and appeasing deities (Shrestha 2023e). The preparation involves detailed steps, including selection, dehusking, washing, cooking, inoculation with *murcha*, and fermentation until a pleasant aroma develops (**Figure 5**). Straining results in the liquid elixir known as *Jand*.

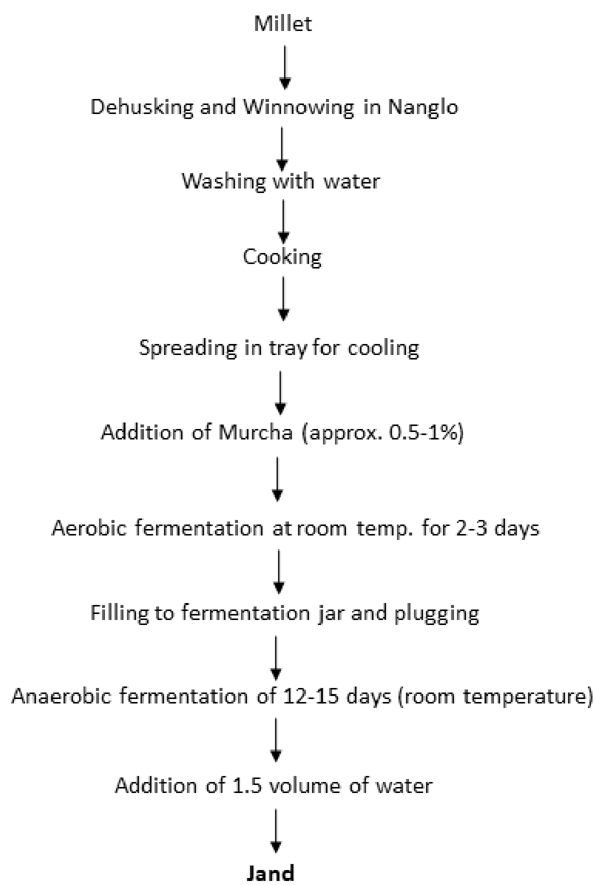

Figure 5. *Jand* Preparation Process
Source: Karki 2013

Aidoo et al (2005), offering an extensive analysis of crucial facets in the realm of *jand* production, reiterated that a focal point in *jand* fermentation is mucaraceous fungi, which facilitate the amylase production, an integral factor for starch saccharification and liquefaction during the fermentation process. The temporal dynamics of amylase activity, reaching its pinnacle on the second day of fermentation, are meticulously detailed. Aidoo et al (2005) further highlighted the diverse microbial composition found in matured *jand*, encompassing yeasts (*Pitchia anomala*, *Saccharomyces cerevisiae*, *Candida galbrata*) and LAB (*Lactobacillus bifermentans*), with concentrations exceeding 8 log cfu/g. Pederson (1971) distinguished "*chhyan*" as a millet beer brewed in Sikkim, while Venkataramu and Basapu (1993) define "*chhyang*" as a traditional fermented beverage made from *ragi* or barley, consumed in the sub-Himalayan region and Tibetan settlements. The optimal quantity of powdered *murcha* added to cooked cereal, regulated by temperature and beverage type, is systematically examined, with Yadav (1993) recommending 10 to 20 g of powdered *murcha* per 1 kg of cooked cereal.

Karki (2013) pointed out the delineating factors affecting overall *Jand* sensory quality, including raw materials, fermentation conditions, *murcha* quality, physicochemical properties, and organoleptic properties (**Table 2**).

Table 2. Factors affecting overall sensory quality of ***jand***

Factors	Components
Raw materials	Cereal substrates such as finger millet, wheat, rice, maize etc. used in the fermentation.
Fermentation conditions	Temperature, pH, aerobicity, duration of fermentation, solid-or semi-solid state of fermentation.
Murcha quality	Species and strains of the essential microorganisms (yeasts, molds, lactic acid bacteria), presence of extracellular enzymes, amylase in particular.
Physicochemical properties of jand	Alcohol, acidity, pH, reducing and non-reducing sugars, total soluble solids, esters, and other congeners.
Organoleptic properties of jand	Taste, smell mouth-feel and color

Rai's (1991) inclination towards finger millet, as a best raw material in *jand* and *toongba* production, attributed to its cost-effectiveness, low food preference, prolonged discrete state, and ability to impart a clean flavor and aroma, serves as a contextual foundation for the broader discourse.

Dynamics of biochemical transformations and microbial growth in finger millet *jand* fermentation

Finger millet fermentation represents a complex bio-physicochemical process that involves significant changes in its chemical composition. Karki (2013) meticulously documented the alterations in various parameters throughout the fermentation period. Commencing with moisture content (MC), a notable surge is observed from 56.06% on day 0 (post-cooking) to a peak of 74.69% on the twelfth day of fermentation. The accelerated increment, especially within the initial six days, signifies a rapid liquefaction process during this pivotal stage. Total Soluble Solids (TSS) experienced a significant elevation during fermentation, manifesting an average daily increment of 0.67 ^{0}Bx. The zenith, achieved on day 12 at 12 ^{0}Bx, underscores the escalating concentration of soluble solids throughout the fermentation continuum.

Total acidity (TA) embarked on a remarkable ascent from 0.12% (day 0) to 0.82% on day 6, remaining relatively stable thereafter. This surge in TA is mirrored in fixed acidity, matching TA on day 0 and reaching a pinnacle of 0.90% on day 9. Volatile acidity, absent on day 0, undergoes a substantial surge, culminating at 0.027% on day 9 and plateauing until day 12. Total reducing sugar content surged from 0.41% (day 0) to 4.49% on day 12, with a nadir on day 6. Simultaneously, sucrose content escalated from 0.37% to 0.63% (day 3), stabilizing until day 9 and dwindling to 0.27% on day 12. Glucose and fructose showcased dynamic patterns, with glucose reaching 692.8 mg/100g on day 12, and fructose peaking at 74.2 mg/100g on the same day. Starch content exhibited a consistent decline throughout fermentation, with a notable rapid decrease within the initial three days. Water-soluble protein undergone an augmentation from 0.50% (day 0) to 1.15% on day 9, maintaining stability until day 12. This protein evolution mirrored findings in finger millet fermentation by Sripriya et al (1997). Fermentation time elicits a significant impact ($p<0.05$) on antioxidant activity, intensifying from 59.88% (day 0) to a pinnacle of 81.21% on day 12. Alcohol content experienced a remarkable surge, escalating from 6.49% on day 3 to 14.58% on day 12. This alcoholic evolution aligns with reported trends in finger millet fermentation by Thapa and Tamang (2006) and Koirala (2011).

Changes in volatile constituents during finger millet fermentation are depicted in **Figure 6**. Total aldehydes (as acetaldehyde), total esters (as ethyl acetate), methanol, and fusel oil contents in 3- and 12-days fermented finger millet were found to be 1.857 and 1.089, 2.121 and 1.124, 1.753 and 1.500, and 8.028 and 4.366 g/L alcohol (alc), respectively (Karki 2013). It appeared that concentrations of these volatile constituents were higher during the initial stage of fermentation compared to the later one. Fusel oil was approximately doubled in 3 days fermented millet compared to 12 days one. Koirala (2011) also reported that total esters content in 3 and 12 days fermented finger millet were 1.404 and 1.164 g/L alc, which is analogous to findings by Karki (2013).

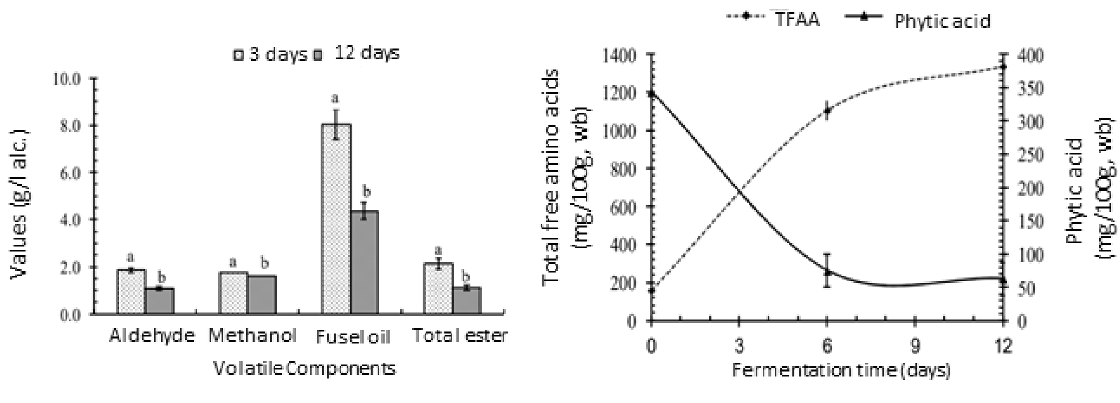

Figure 6. Changes in alcohol, volatile content (A) and phytic acid and total free amino acids (TFAAs) contents (B) during millet fermentation. Values are the means (n=3) ± SD.
Adapted from Karki 2013

Karki (2013) also explored the proximate constituents and mineral contents in the intricate processes of cooking, biomass development, and fermentation of finger millets unfolds revealing insights into the nuanced biochemical transformations. MC, a pivotal determinant of the physical characteristics of millets, experienced a notable surge. Cooked millet, with an initial MC of 55.44% (wb), witnessed an increment by 3.18% (wb) during aerobic fermentation and a more substantial increase of 17.49% (wb) during anaerobic fermentation. Intriguingly, while protein, fat, ash, and total carbohydrate content exhibited no discernible alterations during aerobic fermentation, they undergone significant transformations during subsequent fermentation. Protein content undergone a remarkable twofold increase, emphasizing the impact of microbial synthesis during growth cycles. Total carbohydrate content, however, experienced a reduction by 10.33% compared to cooked millet.

Moreover, the mineral constituents, essential for various physiological functions, engaged was in choreography of changes during both biomass development and fermentation. Phosphate content exhibited a significant ($p<0.05$) increase during biomass development, further accentuated during alcoholic fermentation. This resonates with the metabolic demands of microbial activity during the dynamic phases of fermentation. Iron content, intriguingly, undergone a decrease in biomass developed samples compared to cooked millet. However, no significant differences ($p>0.05$) manifested between fermented and cooked finger millets, presenting a nuanced perspective. Manganese content, while remaining relatively stable during biomass development, experienced a significant increase during fermentation. This corroborates with the findings of Tamang and Thapa (2006), underscoring the differential impact of fermentation on mineral constituents.

Karki (2013) also reported that sodium content exhibited a moderate increase from 19.7 mg% (dry basis, db) in cooked millet to 25.6 mg% (db) in biomass-developed millet, with no significant increment during fermentation. In contrast, potassium content remained unchanged during biomass development but underwent a substantial 100% increase during fermentation, portraying the intricate interplay of environmental factors and microbial activity. Zinc content, a critical trace element, manifested an increase during both aerobic and anaerobic fermentations. This aligns with previous reports in rice and millet by Tamang and Thapa (2006) and Thapa and Tamang (2004), albeit with values surpassing those in the study by Karki (2013).

In the intricate landscape of finger millet fermentation, Karki (2013) further reported dynamic microbial transformations unfold, notably within yeast and mold populations. **Figure 7** visually depicts these nuanced alterations, elucidating the profound impact of fermentation time on microorganism counts. Karki (2013) reported that the yeast population, a pivotal orchestrator of fermentation, engaged in a complex evolution of proliferation and decline. Initiated at 6.633 log cfu/g on day 0, counts peaked at 8.673 log cfu/g by day 4, stabilized on day 6, and gradually declined to 7.239 log cfu/g by day 10. Thapa and Tamang (2006) align with these findings, reporting a surge in yeast counts in fermenting finger millet, reaching a peak on day 2 and stabilizing until day 4. Consistently, Tamang and Thapa (2006) noted similar yeast dynamics in rice fermentation, supporting overarching patterns in microbial behavior during fermentation.

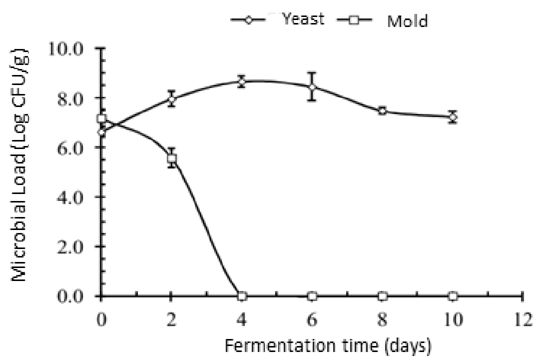

Figure 7. Changes in yeast and mold population with an increase in fermentation time
Adapted from Karki 2013

In contrast, mold counts followed a distinctive trajectory during finger millet fermentation. Starting at 7.19 log cfu/g on day 0, a rapid descent occurred, reaching 5.573 log cfu/g on day 2. Visible growth ceased from day 4 onwards, aligning with observations by Thapa and Tamang (2006) in fermenting finger millet, where mold counts declined from 4.2 log cfu/g on day 0 to 1.8 log cfu/g on day 3. Similarly, Koirala (2011) also echoed these trends in finger millet fermentation, emphasizing the ephemeral nature of mold presence during the process.

Comparative analysis of solid and semi-solid fermentation on chemical and sensory attributes of finger millet *jands*

Diverse fermentation processes, such as solid and semi-solid state fermentations, can be utilized for finger millet *jand* fermentation. Karki (2013) reported that solid and semi-solid fermentation (Semi-solid 1: sterile cool distilled water was added at the rate of 50% v/m, and Semi-solid 2: sterile cool distilled water was added at the rate of 100% v/m) induced significant alterations in TSS, pH, acidities, reducing sugars (RS), esters, and alcohol content, as well as sensory perception (**Table 3** and **Figure 8**). Semi-solid fermentations, particularly with 50% water addition, exhibited a profound impact on enhancing quality.

Table 3. Variation in physico-chemical parameters at different fermentation methods

Parameters	Solid state	Semi-solid1	Semi-solid2
Moisture (% m/v)	96.33±1.07^{a}	96.21±0.18^{a}	96.28± 0.23^{a}
Total soluble solids (ºBx)	3.27± 0.06^{a}	3.87± 0.23^{b}	4.03± 0.06^{b}
pH	4.17± 0.12^{a}	3.83± 0.23^{b}	3.37± 0.12^{c}
Titrable acidity as lactic acid (% m/v)	0.33± 0.01^{a}	0.72± 0.01^{b}	1.24± 0.01^{c}
Fixed acidity as lactic acid, (% m/v)	0.26 ±0.02^{a}	0.50 ± 0.001^{b}	1.00 ± 0.01^{c}
Volatile acidity as acetic acid (% m/v)	0.048± 0.025^{a}	0.143± 0.001^{b}	0.156 ± 0.002^{b}
Alcohol (% v/v)	6.20± 0.72^{a}	7.13± 0.3^{a}	6.91± 0.17^{a}
Reducing sugar as dextrose (mg/100 mL)	1582± 128.1^{a}	71± 6.5^{b}	69± 5.1^{b}
Esters, as ethyl acetate (mg/100 mL)	10.6± 0 0.9^{a}	13.3± 0 0.7^{b}	18.50 ± 0.4^{c}

(Source: Karki 2013)

Sensory evaluations revealed that semi-solid fermentations significantly impacted taste preferences, with panelists favoring solid-state fermented *jand*s (**Figure 8**).

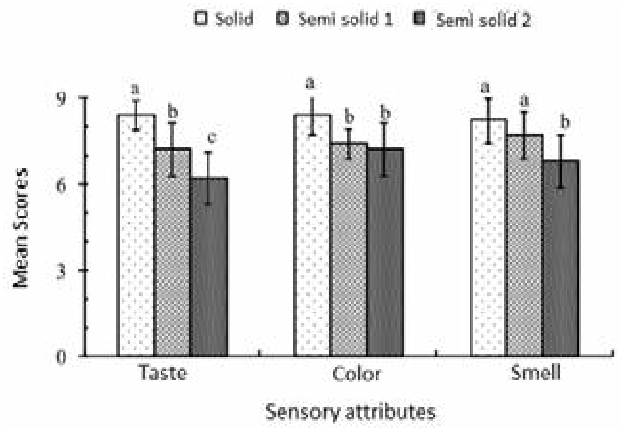

Figure 8. Variation in sensory perception of jand prepared by solid and semi-solid fermentations

Moreover, Karki (2013) also reported that storage conditions further impact chemical attributes and sensory quality, emphasizing the need for strategic storage practices. Storage conditions significantly influenced chemical attributes, with increased TSS and decreased alcohol content in room temperature-stored samples (25 ± 2 ^{0}C and 75 – 85 % RH for 90 days) compared to control (at -30 ^{0}C). Sensory evaluations demonstrated that room temperature-stored samples exhibited superior color, taste, and smell.

Impact of different fermentation containers on *jand quality*

The chemical intricacies of finger millet subjected to a 15-day fermentation process at 26 ± 2 °C within the plastic, wooden, and earthen containers were methodically assessed by Karki (2013). Intriguingly, the container type yielded no significant effect (p>0.05) on MC. However, discernible differences surfaced in TSS (^{0}Bx), titrable acidity (TA) as lactic acid (% m/m), fixed acidity as lactic acid (% m/m), volatile acidity as acetic acid (% m/m), alcohol (% v/m), total esters (g ethyl acetate /L alc), and total aldehydes (g acetaldehyde/ L alc). Notably, plastic containers imparted heightened TSS, while earthen containers exhibited elevated total and volatile acidities. The sensory evaluation provided nuanced insights. Plastic containers, lauded for ease of maintenance, yielded superior results in color, taste, and smell attributes.

Improvement of millet *jand* quality by use of fining agents

Karki (2013) also explored the impact of different fining agents on the clarification of millet *Jand*, presenting findings through visual representations in **Figure 9**. The influence of bentonite, gelatin, tannin, and tannin-gelatin combinations on *Jand* turbidity were assessed. The clarification of millet *Jand* exhibited a decrease in turbidity with increasing concentrations of both bentonite and gelatin. Notably, bentonite demonstrated a superior efficacy in reducing turbidity compared to gelatin. Statistical analysis highlighted the significant impact (p<0.05) of bentonite treatment on millet *Jand* clarification. The mean turbidity values, ranging from 143 Formazin Turbidity Units (FTUs), the measurement of turbidity via light transmission, typically measured by colorimeters or spectrophotometers with formazin as the primary reference standard, (0 g/L bentonite) to 48.33 FTUs (4 g/L bentonite), exhibit significant differences as determined by LSD. Tannin and tannin-gelatin combinations, however, led to increased turbidity with rising concentrations. Given the scarcity of literature specific to millet *Jand* clarification, a comparative discussion with a wine clarification reported by Ough and Amerine (1960) also reported the positive effects of bentonite on wine clarity, color lightening, and filter speed.

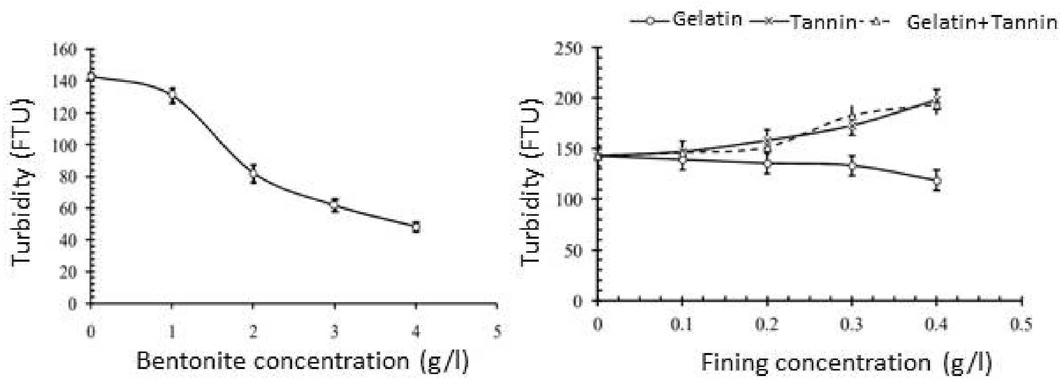

Figure 9. Effect of bentonite, gelatin, and tannin concentration on turbidity
Adapted from Karki 2013

The combined influence of bentonite concentration (0, 1, 2, or 3 g/L) and acidity levels (0.35%, 0.45%, or 0.55% as lactic acid) on millet *Jand* clarification was also depicted by Karki (2013). Both factors showed significant effects ($p<0.05$), with increasing concentrations of bentonite and acidity contributing to improved clarification. Karki (2013) also assessed the impact of holding temperature (room temperature and refrigeration) on millet *Jand* treated with bentonite. While bentonite treatment significantly reduces turbidity, holding temperature variation does not influence clarification. A decrease in turbidity with prolonged holding time was also reported. Optimal results were achieved with a 3-day holding time following pasteurization and bentonite treatment. Bentonite treatment during pasteurization significantly enhanced clarity, while post-pasteurization gravity settling failed to improve clarity.

While TSS, pH, and volatile acidity remain unaffected, reductions in total and fixed acidities, reducing sugars, sucrose, total sugars, and various nitrogenous compounds were also observed by Karki (2013). Moreover, he also reported that bentonite treatment enhances clarity without affecting total phenolics, tannin, antioxidant activity, electrical conductivity, and sensory quality. Taste, smell, and color remain unaffected, aligning with Amerine et al (1967) findings on the minimal adverse effects of bentonite on flavor and bouquet. In conclusion, bentonite emerges as a potent fining agent for millet *Jand* clarification, significantly reducing turbidity without compromising its chemical and sensory attributes. Further investigations into optimal dosages and application methods can enhance the efficacy of this fining process.

Tongba

Tongba, an indigenous fermented beverage ingrained in the cultural ethos of the Himalayan region, manifests as a beverage of choice among ethnic communities spanning Nepal, Bhutan, and selected regions of India (Dangal et al 2021). *Tongba*, steeped in centuries-old tradition, emerges as an integral facet of the Himalayan cultural tapestry, earning its place as a staple during festive occasions, weddings, and diverse social gatherings (Dangal et al 2021). Functioning as a symbol of hospitality and camaraderie, its cultural resonance extends beyond mere gustatory indulgence. This venerable libation is meticulously crafted through the fermentation of whole grains, encompassing millet, maize, or rice, subjected to partial cooking, drying, and subsequent storage within bamboo or wooden receptacles immersed in water (Majumder et al 2022, Karki 2013). The methodical consumption of *Tongba*, borrowed from traditional Nepalese culinary practices, involves placing fermented mash in wooden or aluminum cylindrical vessels (**Figure 10**). Hot water is added, and the extract is sipped through a bamboo or aluminum tube known as a *peepa* (Karki 2013). The meticulous process, aptly termed *Tongba* serving, exemplifies a ritualistic symphony where hot water addition and extraction continue until the extract is depleted.

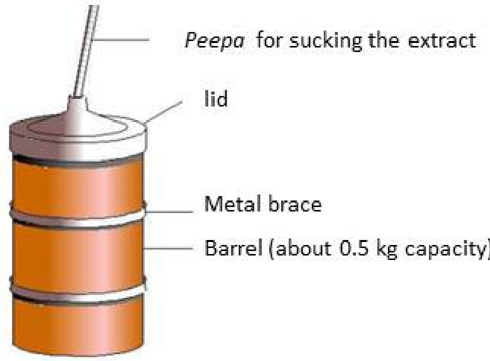

Figure 10. The traditional vessel for serving tongba
Adapted from Karki 2013

Bioactive components, therapeutic implications and health benefits

In high-altitude regions, where atmospheric moisture diminishes with elevation, the human body grapples with moisture retention challenges. The traditional Himalayan elixir, *Tongba*, emerges as a therapeutic beacon (Majumder et al 2022). Bioactive compounds, particularly the pivotal ethyl-α-EG, unravel a tale of skin moisturization, collagen augmentation, and holistic damage repair, making it an invaluable ally in high-altitude environments (Bogaki et al 2017). Contemporary interest converges on the therapeutic potential of *Tongba*, notably in mitigating high-altitude maladies such as Acute Mountain Sickness (AMS) and hypoxia (Dangal et al 2021). Scientific scrutiny elucidates *Tongba*'s bioactive composition, unveiling a rich repository of antioxidants that serve as guardians against oxidative stress and inflammation (Dangal et al 2021). Furthermore, *Tongba* reveals a diverse array of phenolic compounds, endowing it with anti-inflammatory, anti-cancer, and anti-diabetic properties, underscoring its potential as a functional beverage (Dangal et al 2021, Majumder et al 2022). *Tongba* shares a metabolomic profile akin to Japanese *sake*, prompting a comparative exploration of their respective health benefits (Majumder et al 2021). This metabolomic synergy adds a layer of complexity to *Tongba*'s enigmatic therapeutic potential.

In the pursuit of unraveling the profound ethnomedicinal properties enshrined within the traditional Himalayan libation, *Tongba*, Majumder et al (2022) embarked on a meticulous exploration of its volatile profile and employed Gas Chromatography-Mass Spectrometry (GC-MS) metabolomics and chemometrics. This endeavor aimed not only to discern the intricate metabolite composition but also to substantiate the longstanding claims of *Tongba*'s therapeutic efficacy against high-altitude maladies. The crux of their analysis lay in the GC-MS metabolite profiling, an intricate process dissecting the volatile constituents of this ethnic elixir. A comprehensive examination by Majumder et al (2022) revealed thirty-three peaks in the GC-MS chromatogram, denoting the presence of twenty-six distinct compounds. Among these, ethyl-α-D-glucopyranoside (α-EG) and cyclo(L-Leu-L-Pro) emerged as dominant constituents, collectively constituting 70.91% of the total peak areas, with α-EG alone occupying 53.95%. The metabolomic exploration of *tongba* reveals intriguing components with potential therapeutic applications.

α-EG Glucoside Dynamics: Foremost among the bioactive entities is ethyl-α-D-glucopyranoside (α-EG), spawned through the enzymatic prowess of the starter culture's α-glucosidase activity (Majumder et al 2022). This enzymatic cascade orchestrates the trans-glycosylation of maltose or maltooligosaccharides intrinsic to *Tongba*'s substrate, primarily finger millet. Maltose, the precursor of α-EG, emerges as a disaccharide derivative from starch, courtesy of the amylase activity intrinsic to amylolytic microbes inhabiting the *Tongba* milieu (Bogaki et al 2017, Dangal et al 2021). The transformative potential of α-EG lies in its profound impact on human dermal fibroblasts, stimulating collagen production—a keystone of the extracellular matrix (Majumder et al 2022). This signifies *Tongba*'s prowess in expediting the healing cascade for various bodily tissues, from skin to tendons, ligaments, bones, and muscles. A formulation enriched with α-EG becomes a therapeutic elixir, hastening recovery in high-altitude settings.

Starch Catabolism: Finger millet (kodo), constituting the cradle of *Tongba*'s biochemistry, boasts a starch content of approximately 59% (Majumder et al 2022). This starch reservoir profoundly shapes *Tongba*'s volatile profile, evident in the dominance of starch catabolites such as glucosides, sugar alcohols, and terpenoids, collectively commanding 57.95% of the chromatographic landscape.

Amino Acid Derivatives: Beyond glucosides, *Tongba* unfurls a repertoire of amino acid derivatives, encapsulating compounds of remarkable therapeutic promise. Noteworthy among these is the cyclic dipeptide, cyclo(L-Leu-L-Pro), a veritable linchpin constituting 16.96% of the total peak area (Majumder et al 2022). Renowned for its antioxidant and anti-inflammatory virtues, this cyclic dipeptide positions itself as a pivotal player in *Tongba*'s ethnomedicinal narrative (Dangal et al 2021). Supplementing the rich tapestry of amino acid derivatives are two accomplices: actinomycin C2, an antibiotic of bacterial origin, and DL-pyroglutamic acid, a metabolite with nuanced biochemical implications (Majumder et al 2022). Together, this trio commandeers 18.71% of the chromatographic expanse, underscoring the profound influence of amino acid derivatives in *Tongba*'s biochemical syphony.

Cyclo(L-Leu-L-Pro), an antifungal metabolite within *Tongba*, showcases diverse pharmacological facets such as antiviral, antibacterial, antimutagenic, and antiprotozoal properties (Acharyya et al 2021, Zhao et al 2021). The antibiotic actinomycin C2, an antioxidant with cytotoxic prowess, and pyroglutamic acid, with hepatoprotective, antidepressant, and anti-inflammatory attributes, join the ranks of *Tongba*'s metabolomic arsenal (Gazme et al 2019, Saravana Kumar et al 2014).

Cardio-Protective Fatty Acids and their Acid Derivatives in Tongba: *Tongba*'s repertoire of fatty acids, including palmitate and linoleate, emerges as a notable source of cardio-protective agents—palmitate and linoleate, boasting vasodilatory, antihypertensive, and coronary heart disease preventive virtues, aligning with the demands of high-altitude settings (Majumder et al 2021). This presents potential relief from ailments associated with high-altitude maladies. The anti-inflammatory, antioxidant, and antibiotic attributes of palmitic acid and pentadecanoic acid further enhance *Tongba*'s medicinal repertoire (Anyasor et al 2015, Venn-Watson et al 2020). This compendium of lipidic derivatives spans the realm of long-chain hydrocarbons, encompassing fatty acids, fatty alcohols, alkanes, and carboxylic acids—an ensemble enriched through the lipid reservoir inherent in the substrate, *kodo* or finger millet, boasting a lipid content of approximately 1.3% (Devi et al 2014). The identification and categorization of these lipidic entities within *Tongba*'s matrix illuminated the profound symbiosis between substrate and product. The prevalence of such derivatives aligns seamlessly with the lipidaceous endowment of the millet substrate, exemplifying the intricate biochemical conversation orchestrated during the fermentation odyssey.

Terpenoids: Terpenoids, a captivating cadre of bioactive components in *Tongba*, encapsulates a botanical overture in the form of phytosterol, beta-sitosterol, and the chlorophyll-derived phytol, accompanied by its derivative, neophytadiene (Majumder et al 2022). Noteworthy is the provenance of beta-sitosterol as a distinctive millet metabolite (Islam et al 2018), substantiating *Tongba*'s botanical resonance. The metabolomic narrative suggests a direct infusion of these terpenoids from the substrate, further elucidating *Tongba*'s holistic embrace of its botanical origins. Beta-sitosterol, phytol, neophytadiene, and farnesol, each a bioactive sentinel within *Tongba*, wield anti-inflammatory, antioxidant, antimicrobial, antiviral, antidiabetic, neuroprotective, and vasodilatory capabilities, offering a comprehensive shield against disorders linked to high-altitude adversities (Bhandari and Lee 2013, Delmondes et al 2020, Islam et al 2018).

Tyrosol: Tyrosol, a phenolic compound inherent to *Tongba*, resonates with millet's metabolic rhythm (Sun 2017). Derived through *Saccharomyces cerevisiae* activity, tyrosol validates *Tongba*'s kinship with esteemed beverages like *sake* (Ren et al 2021). It echoes the traditions of diverse cultures (Ren et al 2021, Soejima et al 2012). Tyrosol, a versatile compound, unfolds a spectrum of medicinal virtues—from antioxidant and anti-inflammatory to anticancer and antiallergic activities (Sun 2017). Meanwhile, dihydroergotamine steps forth as a potential ally against migraine disorders, presenting effective relief for individuals grappling with frequent migraine attacks (Tfelt-Hansen and Koehler 2008).

1,3-methylene-D-arabitol: The sweet 1,3-methylene-D-arabitol, a sugar alcohol, permeates *Tongba*'s symphony. Documented in various fermented foods (Kordowska-Wiater 2015), this yeast metabolite adds a signature note to *Tongba*'s metabolomic melody. Saha et al (2007) identified it as a flagship product of glucose fermentation by *Zygosaccharomyces* sp., a crucial starter in fermented beverages, including *kombucha*.

Dihydroergotamine: Dihydroergotamine, an alkaloid and secondary metabolite of ergot fungi, stands as a testament to *Tongba*'s intricate relationship with its substrate—millet (Majumder et al 2022). Emerging as a substrate-derived signature or microbial output, it reaffirms *Tongba*'s biological connectivity with its milieu (Haarmann et al 2009).

In conclusion, within the symphony of metabolites, *tongba* showcases a composition rich in anti-inflammatory compounds. Pyroglutamic acid, palmitic acid, pentadecanoic acid, phytol, neophytadiene, β-sitosterol, and tyrosol collectively respond to the challenges posed by inflammation and high-altitude afflictions. This study underscores the intricate connection between tradition, science, and therapeutic promises encapsulated in the sublime blend of *tongba*. These findings not only validate *Tongba*'s ethnomedicinal essence but also open avenues for further research into its specific health-promoting mechanisms. *Tongba* emerges not merely as a beverage but as a metabolomic symphony, orchestrating healing, inflammation alleviation, and cardiovascular fortification. This ethnobiological revelation underscores *Tongba*'s pivotal role in Himalaya's ethnoecology—a testament to the profound synergy between traditional wisdom and scientific validation. The harmonious interplay of substrate-driven metabolites and the orchestration of microbial cultures paints a vibrant portrait of *Tongba*'s biochemical richness, beckoning further microbiological inquiry to complete the narrative of this traditional Himalayan elixir.

Nigar

Nigar is the clear liquid that spontaneously accumulates during prolonged fermentation of cereal. The product likens *sake* and is highly prized by consumers (Karki 2013). *Nigar* can therefore, be classified as a cereal wine rather than a beer (Rai 2006).

Raksi Distillation: A Traditional Cultural Heritage

The artisanal production of *Raksi* unfolds through a meticulous distillation process of fermented mash, *jand*. Utilizing *Phonsi*¸ a copper still vessel filled with fermented mash, alcohol vapor condenses upon contact with a cooler surface, a process meticulously controlled through the ingenious *Paini*, *Nani,* and *Bata* setup (**Figure 11**). Fractionation ensues, categorizing *Raksi* into strong, medium, and weak alcohol content fractions, defining its market value. Following fermentation, the mash undergoes a calculated transformation. A measured amalgamation with water precedes its introduction into the *phoshi*—a vessel crafted from copper, brass, or aluminum with a flat bottom (Karki 2013, Kharel et al 2009). The *phoshi* is filled to approximately 1/3 of its volume, crowned with a *paini*—an earthen pot endowed with perforations. Nested within the *paini* is the *nani*, another earthen receptacle designated for distillate collection. Completing the ensemble is the *bata*, a condenser strategically positioned atop the *paini*. The distillation process unfolds with strategic precision. Evaporation of water and other volatiles takes place, traversing through the minute openings of the *paini*. These vapors then condense on the frigid surface of the *bata*, subsequently pooling in the awaiting *nani*. To maintain optimal conditions, periodic replacement of water in the bata is executed, especially when its temperature ascends beyond 45°C (Karki 2013). A noteworthy observation emerges: an escalating frequency of water changes correlates with a diminishing alcohol content in the resultant distillate.

Raksi, an unaged congeneric spirit, undergoes meticulous crafting through pot distillation of fermented cereal slurry. Exhibiting a notable resemblance to whiskey, this libation boasts a variable alcohol content, typically ranging from 15 to 40% (v/v). Numerous foundational studies have explored *raksi* production, utilizing diverse cereals and investigating both *murcha* and pure cultures derived from traditional fermentation starters (Bhandari 1997, Rai 1984, Shrestha 1985, Subba 1985, Yadav, 1993).

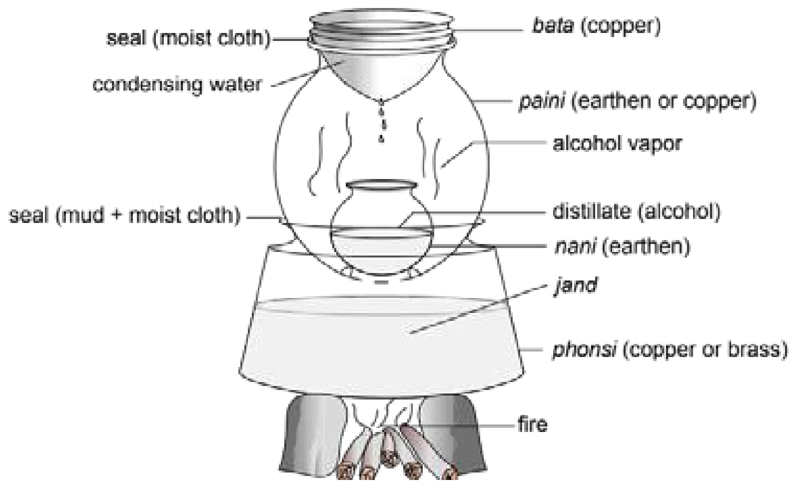

Figure 11. Traditional raksi distillation setup
Adapted from Kharel et al 2009

The intricate process of fractional distillation in the production of traditional *raksi* unfolds through sequential water changes known as *ekpanè* (first water change) and *duipanè* (second water change), each marking distinct fractions. Initially, *ekpanè* is necessitated, leading to the creation of *ekpanè raksi* (Kharel et al 2009). This process of heating persists until the demand for yet another water change surfaces, denoted as *duipanè*, resulting in *duipanè raksi*. Subsequent water changes continue up to the ninth fraction, with a gradual decline in alcohol concentration observed from the first fraction to the next. Remarkably, although fractions are discerned, they are not collected separately (Kharel et al 2009).

Practically, the first two to three fractions are amalgamated, collectively referred to as "strong," embodying a higher alcohol content. In contrast, fractions four to six are designated as "medium," while the seventh and subsequent fractions are characterized as "weak" in terms of alcohol concentration (Kharel et al 2009). The distillation process reveals a nuanced relationship between the successive water changes and alcohol concentration, shaping the categorization of the resultant *raksi*. This stratification, based on alcohol content, serves as a determinant in establishing the pricing structure for *raksi*, offering a unique perspective on the traditional distillation practices and their impact on the final product (Kharel et al 2009).

This exploration into the intricate choreography of *raksi* production underscores the amalgamation of tradition and technological precision. The nuanced distillation process, as depicted in **Figure 11**, symbolizes the delicate harmony between elements, where temperature, vessel selection, and water replacement meticulously orchestrate the final composition. This synthesis not only enriches the scientific understanding of *raksi* production but also paves the way for future research, promising advancements in the realm of congeneric spirits. While *raksi* is hailed as an empty stimulator, its excessive consumption emerges as a harbinger of compromised health and societal impropriety. A delicate balance is paramount, as the perils of premature mortality loom large, rooted in the dual challenges of excessive *raksi* intake and inadequate nutrition.

Brewing Potential of Nepali Finger Millet Varieties

The main ingredient of beer or malted whisky is malt. Barley malt is ubiquitously used for brewing. However, different variants of malt from wheat, rye, and in some cases from finger millet are also used. This section delves into the brewing potential of six Nepalese finger millet varieties: *Dalle*, *Okhle*, *Kabre*, *Juwain*, GE 5016, and GP 0025, as reported by Karki (2013). Detailed analyses of enzymatic activities, chemical properties, and malting quality were conducted by him (**Figure 12**). *Kabre kodo* millet emerged as the leader in malting quality, displaying superior enzymatic activities and chemical characteristics. The research by Karki (2013) highlighted the significance of kilning temperature, mashing methods, and gibberellic acid in influencing millet malt wort properties.

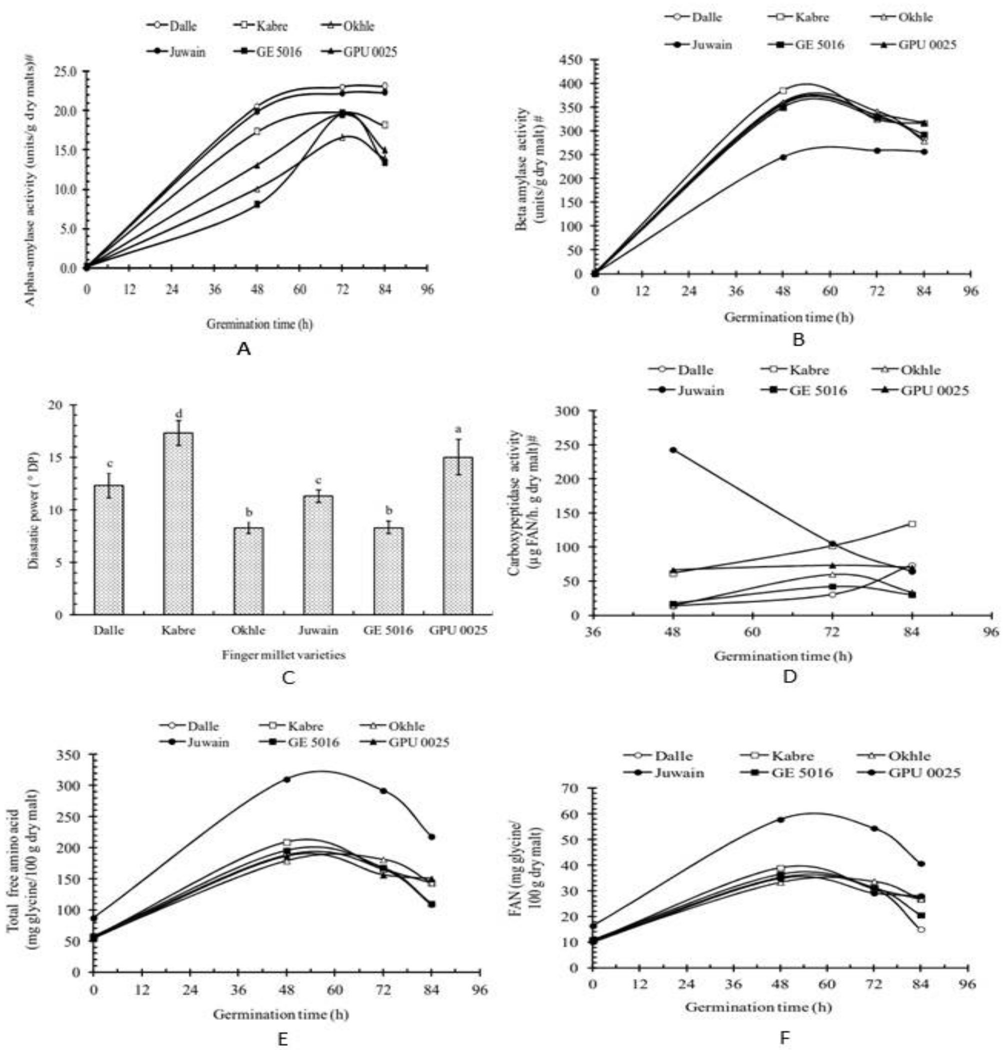

Figure 12. Malting dynamics of different Nepali millet varieties. (A) changes in alpha-amylase activity at different germination times; (B) changes in beta-amylase activity at different germination times; (C) changes in diastatic power at different germination times; (D) changes in carboxypeptidase activity at different germination times; (E) changes in total free amino acid concentration at different germination times; (F) changes in free amino nitrogen (FAN) concentration at different germination times.
Adapted from Karki 2013

Enzymatic dynamics

The enzymatic tableau, crucial in malting, unfurled complexity under the dual influence of finger millet variety and germination time. Focus extended to α-amylase, β-amylase, total diastatic activities, carboxypeptidase activities, total free amino acids (TFAAs), and free amino nitrogen (FAN) in millet malts. Alpha-amylase activity responded dynamically to the intricate relationship between varietal distinctions and germination chronology (**Figure 12** A). Ungerminated millets set a baseline, exhibiting alpha-amylase activities of 0.05 – 0.11 unit/g dry malt. A crescendo in germination time up to 72 hours significantly amplified alpha-amylase activity across all millet varieties. Beyond 72 hours, a decline surfaces in some varieties, while others exhibit resilience, showcased sustained or elevated alpha-amylase activities. The 72-hour germination epoch emerged as optimal for peak alpha-amylase activity.

Beta-amylase activity also unfolded as a dynamic interplay between millet variety and germination time (**Figure 12** B). Elevated activity at 48 hours was shared across varieties, with subsequent germination reducing activity uniformly. *Kabre* millet stands out as an epitome of beta-amylase activity. Total diastatic power (DP), a pivotal metric, surfaced as a culmination of alpha and beta-amylase activities (**Figure 12** C). *Kabre kodo* millet asserted its dominance with the highest DP of 385.0 units/g dry malt, reaffirming its eminence in fostering maximal enzymatic activity.

Similarly, proteolytic dynamics, represented by carboxypeptidase activity, also unfolded as a multifaceted interplay of millet variety and germination duration (**Figure 12** D). Again, *Kabre kodo* millet stood out with a gradual ascent in carboxypeptidase activity, emphasizing varietal-specific proteolytic dynamics. *Juwain* millet exhibited impressive carboxypeptidase activity at 48 hours, while GPU 0025 millet maintained stable activity, offering the potential for industrial-scale malt production.

Total Free Amino Acids (TFAAs) in millet malts were significantly influenced by millet variety and germination time (**Figure 12** E). Except for *Juwain* millet, TFAAs among other native millets showed no statistical difference ($p>0.05$), ranging from 53.9 to 57.9 mg glycine equivalent/100 g dry malt. *Juwain* millet exhibited the highest TFAAs content (87.1 mg glycine/100 g dry malt). TFAAs peaked at 48 h of germination, declining significantly thereafter. *Juwain* millet malt had the highest TFAAs content (310.0 mg glycine/100 g dry malt). Parallel trends were observed for Free Amino Nitrogen (FAN) FAN contents in millet malts (**Figure 12** F). FAN ranged from 10.1 to 10.9 mg glycine/100 g dry malt, except in *Juwain* millet, where it reached 16.4 mg glycine/100 g dry malt. FAN peaked at 48 h of germination, decreasing significantly thereafter. *Juwain* malt exhibited the highest FAN content. Amino acid content is pivotal for yeast growth and metabolism in malt wort.

Elevated FAN and amino acids enhance fermentability and efficiency. Increased nitrogen and amino acids with prolonged germination are attributed to extensive protein hydrolysis (Nie et al 2010). Amino acid content supports yeast nutrition (Clapperton 1971). Variations in FAN contents among millet malts highlight the need for nuanced considerations in malting processes. Comparing these finding with other studies, Morral et al (1986) reported FAN contents exceeding than reported by Karki (2013); Okolo and Ezeogu (1995) also reported higher FAN content in sorghum malts. The study contributes to the scientific foundation of brewing potential in Nepalese finger millet varieties.

Effect of millet varieties on chemical characteristics of their malt extracts

Malt is the product of the process of soaking, germinating, killing at step-wise progressively higher temperatures, and finally cleaning the cereals to increase the amylolytic and proteolytic enzymes and its action to produce fermentable sugars and characteristic flavors and aroma as well as color. The comprehensive analysis of chemical constituents of unmalted and malted finger millets was also undertaken by Karki (2013). In unmalted millets, total reducing sugar content varied. Significant differences were absent except for *Dalle*. Upon malting, total reducing sugar increased across varieties. The magnitude of increment varied, with *Juwain* millet malt showing the highest increase. Glucose content increased significantly during malting across all millet varieties. The highest increment was observed in *Juwain* millet malt. Starch content in native millets showed no significant differences. Malting significantly reduced starch content in all varieties. Amylose content decreased significantly during malting. Amylopectin content varied among native millets. Malting significantly reduced amylopectin, a highly branched starch, in most varieties. The study sheds light on dynamic changes in carbohydrate composition during malting, providing valuable insights into essential components. These findings contribute to understanding malting processes in finger millets.

Total phenolics (TPs) in native millet cultivars exhibited variability, ranging from 60.9 to 229.2 mg Gallic acid equivalent (GAE)/100 g dry matter (DM). TPs increased during malting, with the highest increase in *Juwain* malt. Total flavonoid (TFs) contents ranged from 35.2 to 141.7 mg Rutin equivalent (RE)/100 g DM in native millets. Malting increased TFs, with *Dalle* malt showing the highest increment. Tannin contents in native millets ranged from 169.9 to 566.0 mg Tannic acid equivalent (TAE)/100 g (DM). Malting decreased tannin content in most varieties. Significant variations in antioxidant activity were observed among unmalted and malted finger millets. A positive correlation between total phenolics and antioxidant activity was observed in native millets, but not in malted millets. Turbidity significantly varied among malt extracts. Extract pH showed no significant differences between specific varieties. TFAAs exhibited wide variation among malt extracts, correlating with higher TFAAs content in native malts. *Juwain* millet malt had the highest extract yield. Glucose content significantly differed among malt extracts. Viscosity varied, with *Juwain* malt extract exhibiting the highest viscosity.

Evaluation of wort chemical characteristics of malts from different millet varieties

Wort is a sweet liquid that is drained from mash made from crushed malt or grain meal and that is fermented to make beer or whiskey. Karki (2013) also conducted a detailed analysis of the chemical attributes of worts from *Dalle*, *Kabre*, and J*uwain* millet malts covering TSS, extract, TFAAs, FAN, pH, and total reducing sugar. Worts from *Juwain* malt demonstrated superior TSS, extract, TFAAs, and FAN contents, exhibiting statistical significance ($p<0.05$) compared to *Dalle* and *Kabre* malts. Conversely, *Dalle* and *Kabre* malts showed no significant variance in these parameters. Wort pH ranged narrowly from 5.44 to 5.66, averaging at 5.53. *Kabre* malt wort displayed the highest total reducing sugar content at 10.45 g maltose/100 mL, while *Dalle* malt wort exhibited the lowest at 7.64 g maltose/100 mL.

Through meticulous malt analyses, Karki (2013) concluded that *Kabre kodo* finger millet emerged as the optimal choice among studied varieties for malting, particularly in lager beer production or possible malted whiskey production, which remained unexplored. *Kabre* malt's pronounced superiority in TSS, extract, TFAAs, and FAN underscores its potential for enhancing the quality and brewing characteristics of the resultant wort.

Effect of gibberellic acid (GA_3) treatment on enzymatic activity and chemical properties of finger millet malts

In the pursuit of optimizing malt extract quality, Karki (2013) also examined the impact of Gibberellic Acid (GA_3), a plant hormone and a tetracyclic di-terpenoid compound stimulating plant growth and development, treatment on *Kabre kodo* and GPU 0025 millet malts. The investigation focused on elucidating the chemical nuances of malt extracts after spraying 5 ppm of GA_3 solution in water onto the bed of finger millet twice a day and germinated at different times, emphasizing TSS, total reducing sugars, FAN, and colorimetric attributes derived from 56 hours germinated millets. The study revealed parity in TSS and total reducing sugar between *Kabre* and GPU 0025 malts. FAN content in *Kabre* extract surpassed GPU 0025, showcasing a discernible disparity. GA_3 treatment significantly elevated TSS and Total Reducing Sugar in both millet varieties. *Kabre* malt, with or without GA_3 treatment, exhibited higher FAN and color values compared to GPU 0025 malt extracts. GA_3-treated *Kabre* malt extract demonstrated a twofold increase in FAN compared to the untreated counterpart, emphasizing the efficacy of GA_3.

The results suggested that GA_3 treatment enhances amylase activities (**Figure 13** A) and FAN contents in finger millet malts. *Kabre* millet exhibits a more pronounced response to GA_3, not only in terms of amylase production during germination but also in overall malt extract properties. Alpha-amylase activity increased significantly with prolonged germination, notably in *Kabre* malt. Beta-amylase activities mirrored this trend, with *Kabre* and GPU 0025 millets showing robust responses to GA3 treatment (**Figure 13** B). This underscores GA_3's potential as a modulator of malt quality, with *Kabre* millet particularly responsive to its effects. FAN contents, influenced by germination time and millet varieties in response to GA_3 treatment, varied across millet varieties. *Kabre* millet exhibited the highest FAN content at 56 h of germination. Comparative analysis revealed a substantial FAN increase in GA_3-treated millet varieties, further emphasizing GA_3's role in enhancing amylase activities and FAN production during germination. Further exploration of GA_3 treatment interactions with varietal characteristics and malting parameters will advance the understanding in malt quality enhancement.

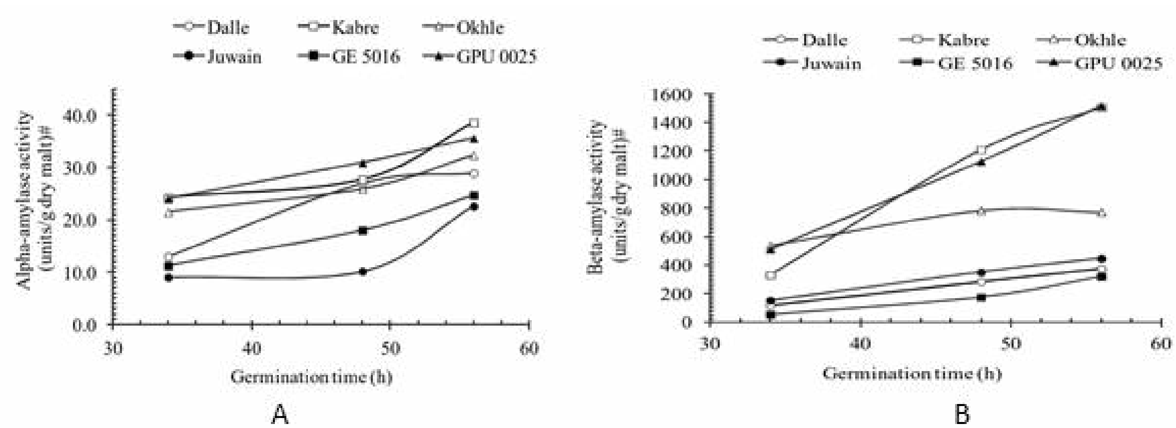

Figure 13. Differences in the alpha-amylase (A) and beta-amylase (B) activities in gibberellic acid-treated finger millet malts. Values are the means of three determinations. One unit of alpha-amylase activity was defined as a one-unit decrease in optical density at 620 nm per minute under the assay conditions. Whereas, one unit of beta-amylase activity was defined as the production of 1 mg of maltose over 30 minute of incubation period under the assay conditions.

Comparison of the complex volatile and quality attributes of millet and barley beers

Karki (2013) further explored the intricate realm of volatile constituents and physical properties of millet and barley beers, presenting a comprehensive analysis of their alcohol content, fusel oil composition, methanol levels, ester content, total aldehydes, vicinal diketones, turbidity, viscosity, color, and starch presence. The investigation unveiled the distinctive profiles, offering insights into the nuanced intricacies that contribute to the unique characteristics of these beverages. Understanding the volatile constituents and physical properties of beers is pivotal in elucidating their flavor complexity and quality. Alcohol content, a critical parameter in beer, exhibited subtle differences among millet (miilet beer 1 (MB_1): the green malt was dried at 50 ± 2 ^{0}C for 24 h; millet beer 2 (MB_2): the green malt was kilned at successively increasing temperature from 50 to 80 ^{0}C as per Matz (1991) and barley variants, with values of 5.12%, 5.60%, and 5.64% (v/v), respectively. Fusel oil content, a vital contributor to beer aroma, varied significantly, ranging from 228.85 g/100 L alc in barley beer to a noteworthy 809.41 g/100 L alc in MB_1. Methanol content, associated with safety considerations, demonstrated a range from 213.75 g/100 L alc in MB_1 to 249.71 g/100 L alc in barley beer. Ester content, specifically as ethyl acetate, showcased intriguing differences, with MB_1 presenting lower values compared to barley and MB_2.

Total aldehyde content, a crucial determinant of beer aroma, exhibited a significant difference, with barley beer surpassing millet beers. Vicinal diketones (VDK) varied significantly, with barley beer recording higher levels (0.44 mg/L) compared to MB_1(0.33 mg/L) and MB_2(0.27 mg/L). Turbidity, indicative of suspended particles, displayed remarkable divergence, with MB_1 registering the highest value (119.67 FTU) and barley beer recording the lowest (16.33 FTU). Viscosity variations were observed, and millet beers exhibited higher values, possibly attributed to elevated dextrin and unconverted starch levels. Color values reflected distinctive hues, with MB_1 presenting lower values than MB_2 and barley beer. Starch-iodine tests revealed a positive outcome for both millet beers, indicating residual starch, while barley beer exhibited a negative test, denoting its starch-free composition.

Karki (2013) also meticulously investigated the sensory quality and fermentation dynamics of millet and barley beers, shedding light on their intricate attributes. Utilizing a panel of ten experienced sensory evaluators, a diverse range of parameters, including taste, smell, color, flavor, body, and overall acceptance, were rigorously evaluated. The sensory panelists discerned subtle differences among the beers, attributing distinct preferences to each attribute. Notably, MB_1 exhibited unique characteristics, as detailed in the hedonic sensory scores on a 5 − point scale (1 = poor, 2 = fair, 3 = satisfactory, 4 = good, and 5 = excellent). The mean scores for taste and smell, both pivotal elements in beer appreciation, displayed nuanced variations. While taste preferences ranged from 3.5 to 4.0, the values did not exhibit statistical differences. Similarly, smell preferences among the beers showed a range of 3.5 to 4.0, with no statistically significant differences observed. Color preferences revealed distinctive inclinations, with MB_1 receiving a lower score (2.9) compared to MB_2(4.1) and barley beer (4.3). Body preferences were comparable between millet beers but were superior to barley beer. Overall acceptance highlighted the distinct inclinations, with MB_1 exhibiting lower preference, while MB_2 and barley beer were closely aligned. The findings suggest that employing millet malt kilned by the standard barley kilning method can yield a beer akin to barley beer in terms of sensory attributes.

Significance of Millet-Based Alcoholic Beverages on Cultural and Socio-Economic Landscape

Nepalese ethnic alcoholic beverages, deeply entrenched in traditional fermentation practices, transcend mere libations, embodying a profound cultural legacy intricately woven into Nepal's social fabric and diverse ethnic groups. Beyond the confines of the laboratory, this exploration delves into the vibrant landscapes where these practices flourish. It embarks on a journey into the heart of Nepalese communities, illuminating age-old rituals that define their identity. Traditional fermentation, meticulously examined, emerges as a repository of cultural nuances, reflecting the stories, beliefs, and values of the engaged ethnic groups.

The economic dimension of these practices is equally compelling. As Nepal grapples with contemporary challenges, the economic empowerment embedded in these traditional practices becomes a beacon of hope. The review envisions future trajectories that not only safeguard cultural identities but also pave the way for sustainable development. It contemplates how these practices, coupled with contemporary insights and technological innovations, can contribute significantly to the economic well-being of local communities. In the ever-evolving global landscape, where cultural homogenization looms, this review stands as a testament to the resilience of Nepalese cultural identity. It underscores the imperative to preserve traditional practices not solely for nostalgic reasons but as dynamic elements capable of adapting to changing times, fostering a harmonious coexistence between tradition and progress.

Conclusion

In this comprehensive review, the intricate dynamics and cultural significance deeply embedded in traditional fermentation practices of Nepalese ethnic alcoholic beverages have been meticulously unveiled. The exploration commenced with a detailed examination of *mana, manpu*, and especially *murcha* crafting methodologies offering a glimpse into the fusion of tradition and scientific intricacies. The subsequent synthesis of physico-chemical and microbiological aspects, drawing from the works of different authors, revealed disparities among alcoholic beverages *and* fermentation starters. This comparative analysis, extending to microbial dynamics in murcha, *manapu*, and *mana*, illuminated the pivotal roles played by specific microbial species, shaping the sensory profiles of these ethnic beverages. The review further explored quality considerations in finger millet fermentation, providing valuable insights into the impact of fermentation containers and cereal types on chemical and sensory attributes.

As the chapters unfolded, the exploration expanded beyond the laboratory, transcending into the vibrant landscapes where these traditions thrive. Nepalese ethnic alcoholic beverages, more than mere chemical concoctions, emerged as emblematic of a rich cultural heritage intricately woven into the social fabric of Nepal and its diverse ethnic groups. This cultural exegesis surpassed the chemical composition of the beverages, portraying them as repositories of cultural nuances, reflecting the stories, beliefs, and values of the ethnic communities involved.

In contemplating the economic dimension, this review envisioned future trajectories that not only safeguard cultural identities but also offer pathways to sustainable development. The economic empowerment inherently embedded in these traditional practices became a beacon of hope for Nepal, navigating the challenges of the modern world. By harmonizing tradition with contemporary insights and technological innovations, these practices stood poised to contribute significantly to the economic well-being of local communities.

In the ever-evolving global landscape, where the specter of cultural homogenization looms, this review serves as a testament to the resilience of Nepalese cultural identity. It underscores the imperative to preserve traditional practices not solely for nostalgic reasons but as dynamic elements capable of adapting to changing times, fostering a harmonious coexistence between tradition and progress. As the final curtain descends on this exploration, the symphony of Nepalese alcoholic traditions reverberates, echoing a harmonious tapestry of cultural richness, economic promise, and a steadfast connection to the roots that define a nation.

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Revalorizing Millet: A Case of Foxtail Millet Rescue and Promotion in Kaski, Nepal

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Abstract

Foxtail Millet (*Setaria italica* (L.) P. Beauv) is traditionally grown in Nepal, especially in western high hill regions, and considered as an indigenous crop. The crop has a short crop cycle (85 to 90 days), making it well adapted to the mountain farming system, commonly grown in dry sloping lands with minimal external inputs. The foxtail millet is listed among neglected and underutilized crops despite its distinctive agronomic characteristics and nutritional value. Some of the factors contributing to its decline include dominance of rice-based food culture; labor intensive intercultural practice; difficult post-harvest operation and limited awareness on its nutritional value amongst consumers. In order to revalorize the foxtail millet, a series of key interventions along the value chains were carried out applying conservation through utilization approach in Kaski district of Nepal, where farmers were supplied with seeds of preferred local landrace, Seto Kaguno; mini-tiller was supported on cost-sharing basis; introduced advanced processing machine; added value through proper packaging and marketing through a private sector partnership; diversified food recipes and its promotion such as 'Kaguno Kheer' pudding through linking with hoteliers and food fair and, producers and their groups were awarded to recognize their contribution in conservation efforts. These interventions have paid off. The average cost of production was reduced by 22% and average milling recovery enhanced by 15%, thereby making cultivation of foxtail millet attractive, reflected in cultivation area increase from 0.025 ha to 4.7 ha with corresponding production increment from 0.006 ton to 4.1 tons in 2023 as compared to 2013. Interest in foxtail millet is gradually increasing amongst producers and consumers. Persistent push-pull efforts have resulted in a positive outcome for crop restoration and establishing a private sector-led value chain which can be a learning for a similar farming system.

Keywords: Foxtail millet, market promotion, conservation through utilization

Introduction

Millets comprise a diverse variety of small-seeded grasses grown for food, feed, or forage (Lata et al 2013, Lata 2015). These resilient grains are celebrated for their ability to thrive in varied and difficult agroecology, serving as a crucial resource in areas with poor soil quality and scarce resources. In contrast to predominant cereals, millets have high nutritional value and yet *coracana* L. Gaertn.), foxtail millet (*Setaria italica* L.P. Beauv), proso millet (*Panicum miliaceum* L.) and sorghum (*Sorghum bicolor* L. Moench) are the most commonly cultivated species in Nepal.

Among millets, foxtail millet is considered as the oldest crop. It is locally known as *Kaguno* in Nepali, is the third most commonly cultivated species among a group of millets in Nepal. It is used as a food grain and is majorly cultivated in high hills and mid hills, mainly of Karnali and Gandaki provinces. Major foxtail millet growing districts in Nepal are Mugu, Kalikot, Humla, Jumla, Bajhang, Bajura, Dolpa, Lamjung, Gorkha, Ramechhap, Kavre, etc, where this crop is grown sole as well as intercropped with finger millet (*Eleusine coracana* Gaertn.), proso millet (*Panicum miliaceum* L.), beans (*Phaseolus vulgaris*), amaranths (*Amaranthus hypochondriacus*), maize (*Zea mays* L.), etc (Ghimire et al 2018). Foxtail millet is valued for its nutritional content and health promoting properties as it is gluten-free, rich in calcium, dietary fiber, polyphenols and protein, ability to grow under low external input conditions and tolerance to multiple abiotic stress particularly towards drought and hailstorm (Ghimire et al 2017). Additionally, the crop has a low infestation of pests and diseases and the grain can be stored for years. These traits of the crops collectively contribute towards sustainable farming as it relies less on external chemical inputs.

Foxtail millet has healthy carbohydrates that balance blood sugar and is also rich in zinc and iron (Chandel et al 2020). The other remarkable feature of foxtail millet as food is their low glycemic index (GI) polysaccharide, gluten free in nature and higher amounts of polyphenols and antioxidant contents. Foxtail millet is associated with traditional food culture of mid-hills and high hills of Nepal. It is used as a regular staple diet *Bhat* (steamed rice) and *Khir* (pudding) while *Dhido* (porridge), *Laddu* (Nepali sweet), and *Puwa* (a kind of pancake) are prepared from its flour. It is also used in fermented form as *Chhyang* and *Chhyangkhol* (local liquors) by different ethnic groups of the Karnali region (Ghimire et al 2018). However, in recent years the cultivation and use of foxtail millet is decreasing rapidly due to change in food culture, introduction of modern crop varieties, labor shortage due to rural-urban and abroad migration, land use change, lack of quality seeds, tedious post-harvest processing, limited market opportunities and income, inadequate research and extension programs (Ghimire et al 2018).

Given the escalating repercussions of climate change, with the persistent challenges of food and nutritional insecurity in remote and climate vulnerable regions, foxtail millet can undoubtedly be a traditional climate resilient crop with immense potential for the future. Being a short duration and hardy crop, foxtail millet has the ability to cope with climate change induced stress. It is also recently acknowledged because of health and medicinal benefits such as reducing blood glucose levels and cholesterol control in normal as well as diabetic patients (Ghimire et al 2018). The paper presents a case example of foxtail millet conservation and promotion in Kaski district of Nepal. The crop once commonly cultivated was on the verge of extension in Kaksi in 2013. Market led approach was promoted to revive the foxtail millet cultivation along with private sector engagement for value addition and marketing.

About the Project Site

The Lake Cluster of Pokhara valley (LCPV) of Kaski district, located at the central section of Lower Himalaya, includes basins of nine lakes (Phewa, Kamalpokhari, Gunde, Khaste, Neureni, Dipang, Maidi, Begnas, and Rupa). The altitude of the lake cluster ranges from 622 to 2403 masl, with an annual precipitation of over 4300 mm. The upland catchment area of the lake cluster is rich in agricultural biodiversity consisting of 876 varieties of food crops and horticultural species (Rijal et al 1998).

Although the upland area of the lake cluster is suitable for foxtail millet cultivation, the cultivation was limited to Pokhara Metropolitan city-28, Kafalghari and Rupa rural municipality-7, Kahure villages. At present, the site of the foxtail millet has expanded to Nirmalpokhari, Puranchaur, Okhle village of Pokhara Metropolitan city and Mahadevbesi and Thumke villages of Rupa rural municipality.

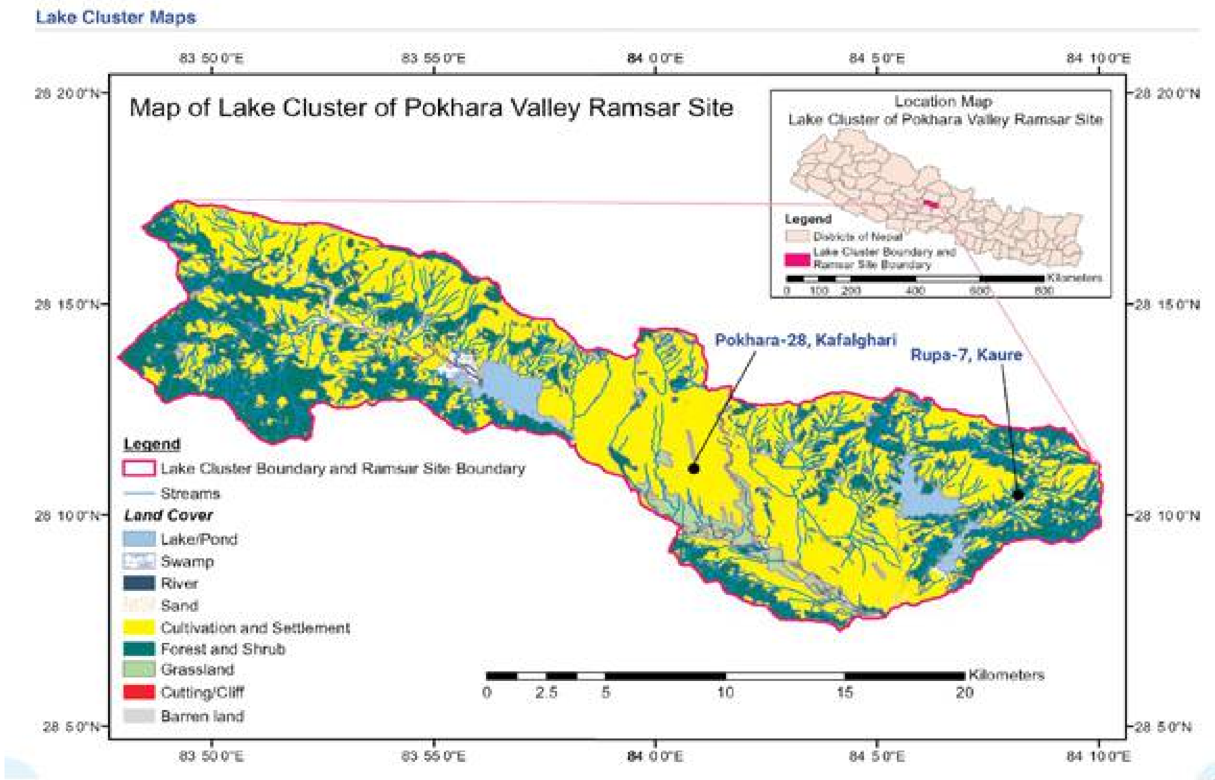

Figure 1. Map of Lake Cluster of Pokhara Valley Ramsar Site

Initiatives and Interventions for Foxtail Millet Conservation and Promotion

Diversity assessment

A single variety of foxtail millet, *Seto Kaguno* was recorded in a diversity fair organized in 2013 in the LCPV area. After that, a focused group discussion involving representatives from 17 farmer groups of the LCPV area was organized to understand the status of foxtail millet in the region. Remarkably, the dialogue revealed that sole cultivation of foxtail millet (Seto Kaguno) was reported by a single farmer from the Barathok women's group of then Rupakot VDC. During the same discussion one more variety of foxtail millet, *Rato Kaguno* was identified which was cultivated in a small area for its medicinal value by some farmers. This revelation served as a pivotal moment prompting the representatives of the farmer groups to recognize the diminishing presence of foxtail millet within their agricultural practices. For identifying better performing variety, the seeds of *Rato Kaguno* and *Seto Kaguno* were distributed among the farmers as a demonstration block. The farmers preferred *Seto Kaguno* over *Rato Kaguno* for its higher productivity and better taste. Hence, *Seto Kaguno* was selected for promotion in Kaski district.

Additionally, to provide varietal options to the farmers, a field trial was conducted in 2020 to assess the performance of 9 different foxtail millet landraces collected from different locations of Nepal at Kaure. The yield of Seto Kaguno was 90.76 kg/ropani and NGRC 06659 was 90.58 kg/ropani (**Figure 2**). There was not much difference in average yield of Seto Kaguno and NGRC 06659. Hence, NGRC 06659 can be another varietal option of foxtail millet for this region.

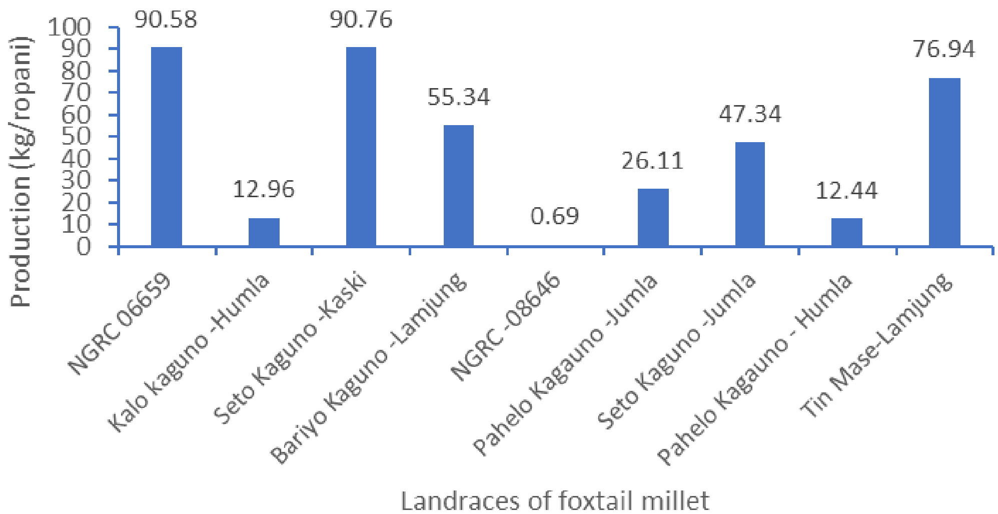

Figure 2. Yield of different landraces of foxtail millet

Awareness raising and sensitization about the food, nutrition and environmental benefits

With the explicit aim of raising awareness regarding the significance and untapped potential of foxtail millet, diverse interventions focused on awareness raising and sensitizing stakeholders were executed. Four diversity fairs, conducted in collaboration with the Bio-resource Conservation Movement, a CBO of the project area across diverse locations of LCPV areas, were instrumental in raising awareness among stakeholders about the available agrobiodiversity, notably highlighting the status of foxtail millet within their respective communities. Approximately, the information was disseminated to more than 1000 individuals participating in the diversity fairs. The grains of foxtail millet were also demonstrated in various local/national food and agriculture fairs elucidating their nutritional composition and health benefits. This concerted effort facilitated the gradual recognition of foxtail millet among urban consumers.

Extensive mass awareness initiatives were further undertaken through various local and regional FM channels, disseminating comprehensive information on the significance, nutritional richness, and diverse food products derived from foxtail millet. Furthermore, LI-BIRD strategically utilized institutional social media platforms and seasonal greetings to disseminate information regarding the manifold benefits of foxtail millets. These concerted efforts effectively reached diverse audiences, amplifying awareness about the nutritional benefits and importance of incorporating foxtail millet into dietary practices.

Seed System analysis and addressing gaps

Unavailability of quality seeds of foxtail millet was among the few hindrances identified for the promotion of foxtail millet in the region. It was found that the farmers accessed the seeds of foxtail millet through an informal seed system. Around 97% of the farmers used their own seeds while 3% of them asked from their neighbors. The farmers did not follow proper seed production and selection methods, which resulted in diminishing seed quality and the overall production of foxtail millet. To address this issue, farmers were supported with the quality seeds of foxtail millet and few resource farmers were developed for quality seed production. The positive selection, a scientific approach to promote the spread of beneficial alleles, was employed to select true to type panicles (Zhang 2008). At first, the experts and technicians were involved in the selection procedure, later the farmers were capacitated to conduct a positive selection procedure through training.

Furthermore, a continuous and comprehensive technical support system was established, aimed at assisting seed-producing farmers in maintaining the requisite standards for seed quality. Around 15 farmers were trained and capacitated in quality seed production, producing 500 kg of quality seed in 2022. To further ensure the preservation of seed quality and enhance its post-harvest shelf life, these trained farmers were provided with hermetic bags, a specialized storage solution designed to maintain optimal seed quality.

Understanding and addressing production, processing and marketing constraints

Compared to other major cereals, the cultivation of foxtail millet demands considerable labor input across various stages, including tillage, sowing, weeding, harvesting, and post-harvest processing. Increasing labor charges and scarcity of labor, and intercultural operations have increased the workload of farmers especially of women. While discussing with the farmers group, tillage, weeding and dehulling of the foxtail millet contributed to inflated cost of production of foxtail millet making the crop unprofitable for growers. In response to the prevalent land preparation issue, the introduction of a mini tiller was implemented within two groups of the study area as a proposed solution to alleviate this concern. Comparative cost analysis between animal drawn vs. mini tiller indicated that cost of ploughing is reduced from NPR 3,150 to 580 for 1,200 m^2 area (82% reduction) when mini tiller is used, directly contributing to reduction in overall cost of production by 18%.

Traditionally, foxtail millets were sun dried and dehulled in “Dhiki” which is very tedious and time consuming and is generally done by women farmers. To cope with this challenge, initially dehulling of the foxtail millet was tested in the rice dehuller. The foxtail millet was passed through the polishing chamber of the rice dehuller. The milling recovery rate was around 65% on rice dehuller. Later on, a small millet table top impact huller -SMF V3 designed and manufactured by Small Millet Foundation, India was piloted and tested in 2020. The milling recovery was 80% which is 15% higher than the rice dehuller (**Table 1**). The utilization of the SMF V3 huller exhibited promising advancements in the dehulling efficiency of foxtail millet, significantly improving the milling recovery rate and potentially offering a more efficient alternative for smallholder farmers. Additionally, these interventions have helped in reducing foxtail millet production cost and thus making it more attractive for farmers.

Table 1. Milling recovery of foxtail millet from rice huller and small millet dehusker

Number of millings	Amount (kg)	Milling recovery of rice huller (kg)	Percentage	Milling recovery of small millet dehusker (kg)	Percentage
First	28	18.1	65	22.1	79
Second	28	18.0	64	22.5	80
Third	28	18.5	66	22.6	81
Average	28	18.2	65	22.4	80

Food recipe development, dissemination and integration in tourism sector

Although foxtail millet is packed with different nutritional values and has high health benefits, the wider dissemination was restricted by limited consumption options as it was only consumed traditionally as “bhat '' in the region. Recognizing the need to diversify the recipe options and expand the scope of its consumption, a collaborative effort was undertaken with Annapaat Agro Pvt. Ltd. to develop and document recipes outlining the preparation methods for Foxtail Millet Porridge, Pudding, and Mixed Fruit Salad. The recipes were disseminated through official websites and social media platforms of LI-BIRD and Annapat.

Furthering the initiative, LI-BIRD in collaboration with the Hotel Association of Nepal (HAN), Pokhara organized an interactive workshop among the chefs of 20 different hotels of Lakeside, focusing on the preparation of various foxtail millet recipes like Kaguno Porridge, Pudding and mixed fruit salad. The participants appreciated the concept and potential of incorporating local nutritious foods into the hotel menu. Presently, Foxtail millet recipe is included in the food menu of four hotels namely Landmark, Queenspark, Mount Kailash and Aatithi in Lakeside of Pokhara city. In addition, a video documentary demonstrating the cooking procedure of foxtail millet pudding was prepared and disseminated across the official social media platforms of LI-BIRD, aiming to amplify awareness and encourage the incorporation of foxtail millet into diverse culinary practices.

Mr. Chhabi Lal Pandey, Purchase Executive at Hotel Landmark, revealed that the hotel's administration has successfully incorporated Kaguno pudding as a prominent dessert option on their menu. This addition has garnered positive feedback from guests and has consistently remained a popular dessert choice over an extended period.

Ms. Pratikchya Thapa, Manager of Bio Resource Conservation Movement, Sundaridanda "The information center managed by BRCM has been selling 0.5 to 0.8 ton of foxtail millet (grains) to its visitors coming to the information center on annual basis."

Kaguno Kheer

Kaguno Porridge

Mixed Salad

Market development through private sector partnership

The *Rupa* and *Begnas* lake watershed areas are the major tourist destinations along with major foxtail millet producing areas of LCPV region. Utilizing this opportunity, a strategy to link foxtail millet with tourism was initiated by Biodiversity Information Center and View Tower managed by Bio Resource Conservation

Movement, *Sundaridada* where the local foxtail millet (seed/cereal) was made available to visitors along with the information on nutritional and health benefits of foxtail millet.

This approach was further enhanced in collaboration with Annapat Agro Pvt. Ltd., a company involved in marketing of local crops. Realizing the importance of quality and attractive products, LI-BIRD supported Annapaat with the processing, grading and packaging machinery.

Key Impacts of the Interventions

Expansion of production area and growing households under foxtail millet

Krishna Prasad Subedi aged 63, a farmer of Rupa Rural Municipality Ward No. 7, Kaure "The crop was cultivated by our grandfather and father; however, it was lost in the due course. LI-BIRD reintroduced foxtail millet in 2014, and we have been cultivating foxtail millet since then. The crop is hardy, full of nutrition, does well in marginal land and requires less water. Additionally, foxtail millet is less damaged by the monkeys in comparison to the maize hence, it has minimized human wildlife conflict.

Back in 2013, area under cultivation of foxtail millet in the LCPV was only 0.5 ropani by a single farmer. After the implementation of various interventions, in 2023 the area of cultivation has increased to 94 ropani (4.7 ha) with more than 100 farmers involved in its production. This successful model has been replicated by LI-BIRD in Sindhupalchok district where the quality seeds of foxtail millet were distributed among 100 HHs, along with capacity building training on its cultivation practices and seed management. The crop is getting popular among the farmers of Sindhupalchok due to its ability to withstand climatic adversities and less damage by monkeys. Hence, reducing human wildlife conflicts.

Increase in consumption, market demand and sale as a result of interventions

Over the course of the decade, there has been a remarkable upsurge in the production of foxtail millet. In 2013, the total production was a mere 6 kilograms. In 2023, the production of foxtail millet has escalated impressively to a substantial 4112 kilograms (**Figure 2**). This exponential growth in production signifies a significant expansion and increased adoption of foxtail millet cultivation practices in the region.

Similarly, the utilization of foxtail millet has also increased among the farming communities. Until recent years, the predominant focus among the farmers was on cultivating foxtail millet primarily for seed production and expanding cultivation areas. However, with increased seed availability and the advent of new recipe developments, there has been a noticeable shift. Farmers have begun to increase the consumption of foxtail millet at the household level, diversifying its usage. Notably, dishes like Kaguno "Kheer" have gained popularity. Foxtail millet *"Kheer"* was also integrated in the day meal of 7 public schools of Sindhupalchok. Mahendrodaya Secondary School of Sunkoshi 6, Sindhupalchok has continued integrating foxtail millet in their school day meal.

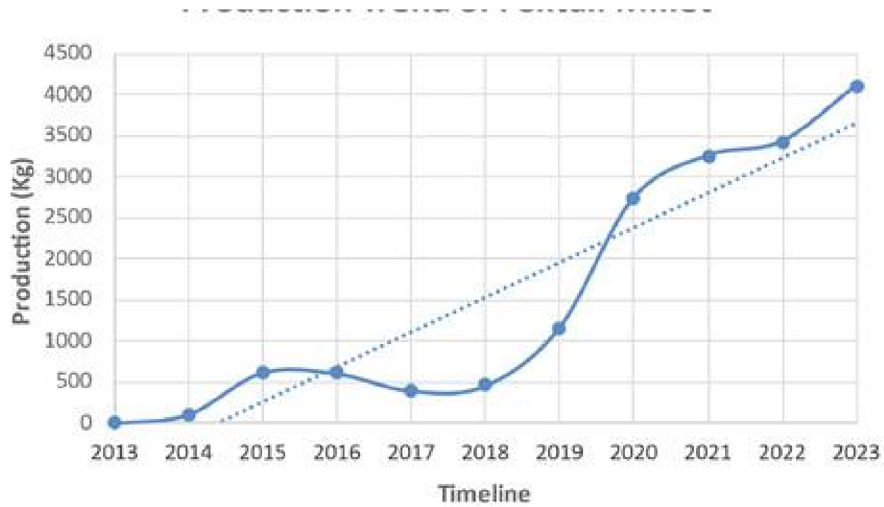

Figure 2. Production trend of foxtail millet

The figure 3 depicts that the sale of foxtail millet was minimal (112 kg) during 2014 which has consistently increased with time and in 2023, the farmers in the project site sold 3620 kg of Foxtail millet. The steady increase in the sale record of foxtail millet implies that the demand is increasing and farmers are able to produce the foxtail millet to meet the market demand. Majority of the foxtail millet produced in the region is sold to Annapat, and then they are supplied to supermarkets in Pokhara such as Sulav department store, Binayak fresh house, Pokhara grocery store, Smile mart, Central department store saleways (Pokhara and kathmandu) and other local grocery stores.

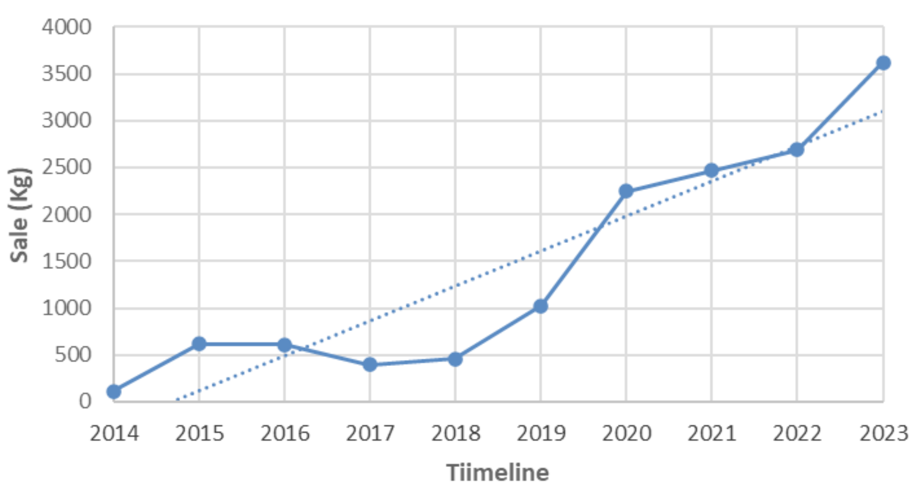

Figure 3. Sale record of foxtail millet

Influence and Integration into Provincial and Local Government's Policies and Programs that Support Local Crops including Foxtail Millet

> Ambika Bhandari, aged 50 and a resident farmer of Pokhara Metropolitan Ward No. 28, Kafalghari, shared her experience: "Previously, I cultivated foxtail millet in a plot of 0.5 ropani solely for household consumption, particularly as 'Bhat'. However, upon securing a guaranteed market for my produce, I expanded the cultivation area to 4.5 ropani. In 2023, approximately 2.2 tons of Kaguno was successfully sold to Annapat by our group, the Kafalghari Samudayik Bikash Amma Samuha."

The Ministry of Agriculture and Land Management (MoALM), has formulated and endorsed Agrobiodiversity and Organic Farming Strategy and action plan of the Gandaki province which has prioritized site-specific local and traditional crops production. Agriculture Development Directorate of Gandaki Province is supporting the transportation, branding and packaging of local crops including foxtail millet. Agriculture Knowledge Center of Kaski and Pokhara Mahanagar has initiated seed distribution of foxtail millet in Kaski to further expand the area of production of foxtail millet. Additionally, to promote foxtail, Pokhara Mahanagar has set a minimum support price (MSP) of NPR 120 per Kg of foxtail millet for the year FY2022/23. Pokhara Mahanagar organized agrobiodiversity and food fair where millet diversity including foxtail is demonstrated and food recipe "Kaguno ko kheer" was promoted.

Conclusion, Lesson Learnt and Way Forward

Foxtail millet, not only being a nutrient dense crop, has great potential to cope with changing climate, address location-specific food insecurity, reduce human-wildlife conflicts and positively contribute toward natural resource degradation and longer-term environmental sustainability of the agroecosystem of the hills and mountain agroecosystems of Nepal. In truth, no approbation would be high enough to illustrate how the foxtail millet possesses global importance, unique pools of nutrition, drought resistance, and pest tolerance. These attributes are significant for the food and nutrition security of growing populations. Hence, there's an urgent need to recognize and capitalize foxtail millet's high adaptability and suitability for marginal lands, harsh climatic conditions and addressing climate crisis thereby sustaining and improving food and nutrition security not only of smallholders and vulnerable communities but also of urban dwellers through developing coordinated value chains. Despite unique adaptive traits and qualities, most of the traditional crops including foxtail millet have been neglected or underutilized by the national agricultural research and extension systems and there is no system to access and supply seeds of such crops.

The challenges of growing and promoting foxtail millet are multiple despite its significance for present and future food and nutrition security and income opportunities. Addressing these challenges requires coordinated efforts from researchers, academia, policy makers, extensionist and private sectors in order to incentivize smallholder producers by generating technologies and innovate context specific market-based solutions as a pull-push approach for scaling production and connecting with local, regional and national markets. Increased awareness on the nutritional and health benefits and availability of food recipes will attract youth and city people to consume foxtail millet thereby creating demand in the commercial market. Additionally, use of foxtail millets in commercial food items such as breads, biscuits will diversify and open new opportunities for farmers to expand production in rural marginal areas with a great pull effect for the private sector to engage in such businesses.

Linking production to improved processing with the use of women-friendly machinery and adding value through diversifying products and food recipes will contribute significantly to better valuing traditional crops, increasing utilization and creating demand which has been demonstrated in the case of foxtail millet. Introduction of small millet dehusker has been instrumental in reducing human labor, drudgery of women and improving the quality of the processed products thereby motivating producers and increasing profit margins of the private entrepreneurs. However, the policies should facilitate private sectors for the local fabrication, customization and multiplication of such processing machinery for easy access and affordability.

Availability of varietal options and high-quality seeds are the most common challenges faced by Nepalese farmers engaged in growing local and traditional crops. Despite the large opportunity to develop site/ region specific native varieties utilizing elite landraces for commercial cultivation, there is only a foxtail millet variety *Bariyo Kaguno* so far registered as a local selection from Lamjung district. This is because of the lack of priority and R&D investment on indigenous crops including millets, limiting the opportunity to utilize Nepal's rich crop genetic resources of millets across hills and mountains that will diversify the agriculture to cope with climate crises and unveil future economic opportunities of such smart crops and nutritious foods through value addition and market development. Hence, it is necessary to devise a policy, systems and mechanisms to identify and provide farmers with location specific varietal options and develop locally managed seed systems that cater to their needs and demands. For this purpose, community seed banks have been proved an effective community-based approach for conserving and utilizing traditional crop varieties (Bhandari et al 2018).

In Nepal, there is dominance of an Ad-hoc promotion and commercialization of exotic technologies and practices (Joshi and Gauchan 2022). The current agricultural policies and programmes are geared towards production and commercialization of a handful of staple crops and their modern varieties as a blanket top down approach neglecting the location-specific opportunities and potentiality of utilizing NUS crops. In the context increased uncertainty and vulnerability of the food systems due to climate change, loss of biodiversity and highly unpredictable market systems, it is almost impossible end hunger, improve food and nutrition security and achieve agricultural growth and sustainability goals of the country without utilizing our rich agrobiodiversity and developing site specific agriculture growth strategies (Joshi et al 2019). It demands a concentrated and coordinated effort and push-pull strategy of policy makers, researchers, academia and extensionists (push factor) as well as private sectors, CSOs and development agencies (pull factor).

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Assessment of Attitude, Awareness, and Consumption Patterns of Students regarding Millets in Agriculture and Forestry University, Chitwan

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Abstract

The study aims to study the status of knowledge, awareness, and consumption pattern of college students on millet and. It was conducted in Agriculture and Forestry University, Rampur, Chitwan from July to August 2023. A total of 180 students, 30 from each batch of undergraduate and postgraduate programs were selected randomly, data was collected through Google Forms and analyzed using Ms-Excel. The majority of students liked the taste of millet of which 25% rated it as very tasty and 53.9% rated it as tasty. *Roti* (87.2%) and *Dhido* (68.3%) were the most tried dishes while other tried recipes *included momo, kholey,* cake, *haluwa*, porridge, *saatu, selroti,* and *bhaat.* However, only 13.3% mentioned that they want to consume millets regularly. 76.1% of the students do not consume millets at their colleges at all. The availability issues (88.9%), followed by limited varieties of millets recipes (7.8%) were the main reasons for their irregular consumption of millet. The majority of the students said they wanted to consume millet for nutrition (45.6%) and change of taste (22.2%). Only 17.2% responded its deliciousness was a factor for consumption. 67.2% knew only 1-3 types of millets and only 7.2% knew about more than 5 types. Only 38.9% knew that 2023 is the International Year of Millets. Availability of different millet dishes around college areas and celebrating a day in a week as “Millet Day” can promote the regular consumption of millet in young people.

Keywords: Attitude, awareness, consumption, millet, students

Introduction

Millets, also called Nutri-Cereals, is a collective term used to include small-grained annual grasses that are cultivated in dry areas of tropical, subtropical, and temperate regions (COAG, 2018). It includes diverse varietals such as sorghum, pearl millet, fonio, proso millet, foxtail millet, and other small species. As believed to be among the earliest domesticated plants, millets contain high protein, fat, iron, and calcium in comparison to rice and wheat (Jena et al 2023). Further, they are a good source of vitamins, antioxidants, and zinc.

There are altogether 21 species of millet in Nepal including 9 wild relative species (Joshi et al 2023). The most common millets include finger (*kodo),* foxtail (*kaguno*), proso (*chino*) and sorghum (*junelo*). Nepal was ranked 13th across the globe in millet production in 2020 (Annapurna Express 2023). The production has increased from 320,953 tons to 326,443 tons while the area decreased from 262,547 ha to 265,401 ha (FAO 2022). The import value of millets has increased to Rs. 732 million (about USD 5 million) in 2022 (*Call to promote millet farming*, 2023). A large portion of the imported millet is used for the preparation of liquor while only a small amount accounts for the consumption as feed and food (Katel et al 2023).

A case study of Kailali district revealed that younger generations have preferences for advanced cereals than neglected and underutilized food crops (Osei et al 2010). There have been numerous researches related to the diversity, utilization, and conservation status of millet genetic resources in Nepal. However, the perceptions and opinions of the younger generation regarding millets consumption have rarely been studied. In India, a study was conducted to understand the knowledge and practices of millet consumption in urban areas (Kane-Potaka et al 2021).

The United Nations General Assembly at its 75th session in March 2021 declared 2023 the International Year of Millets (IYM2023 2022). It aims to highlight the health and nutritional benefits of millets and their climate resiliency further promoting the sustainable market of millets for producers and consumers. This has revived the interest in millets among the public. An understanding of the attitudes and awareness of youths on millet consumption can further promote the campaign. Therefore, this study aims to assess attitude, awareness and consumption pattern of millet in university students of Nepal.

Methods

A random sample survey was conducted to collect primary data on attitudes, awareness, and opinions on millet consumption behavior of the targeted university students in Nepal. Millets in this survey includes finger millet, foxtail millet, and proso millet. Agriculture and Forestry University is located in Rampur, Chitwan, Nepal and the country's first technical university and aims to produce skilled human resources in agriculture. Food choice behavior can be evaluated using surveys on reasons and beliefs in purchase and consumption (Kane-Potaka et al 2021, Roche et al 2012).

Survey Participants

Stratified random sampling was used where 30 students from each batch of undergraduates and postgraduates were randomly selected. A total of 180 students were selected as respondents. Google Forms were sent to them through emails informing the participants about the study's purpose and obtaining their consent before collecting the data.

Questionnaire and data analysis

A structured questionnaire with open-ended and close-ended questions was prepared about millet regarding the attitudes, consumption patterns, awareness, and the reasons for their consumption behavior. The questionnaire was pretested with five subjects and further improvised to address the objectives of the study. The collected data were analyzed using Ms-Excel 2017 using descriptive statistics.

Results and Discussion

Gender and Age

Among the 180 students, 56.1% were female and 43.3% were male. Only 0.6% identified themselves from the LGBTQIA+ community. The average age of the participants was 22 years. The minimum age observed was 17 and the maximum was 31.

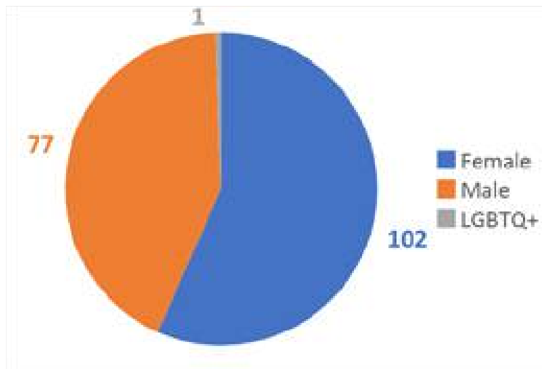

Figure 1. Distribution of gender among respondents

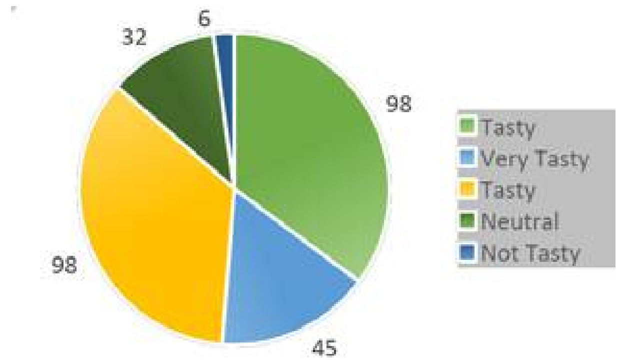

Figure 2. Perception on taste of millets

Perception on taste of Millets

When asked about the taste of millets, 53.9% of the participants perceived millets as tasty, 25% responded to very tasty and only 3.3% labelled it as not tasty. 17.8% found the taste of millet to be neutral.

Cuisines of Millets

Participants were asked about the different food products of millets that they had consumed. *Roti* (87.2%), *Dhido* (68.3%), and cookies (6.1%) were among the most tried products by the students. Other products of millets mentioned by the participants were alcohol*, momo, kodokhole, powa, haluwa, selroti, satu, chino bhaat,* porridge, cake and millet shake.

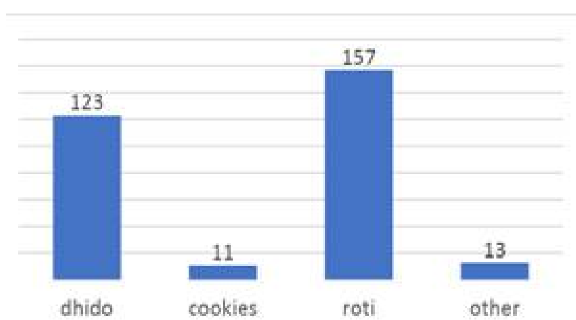

Figure 3. Cuisines of millets

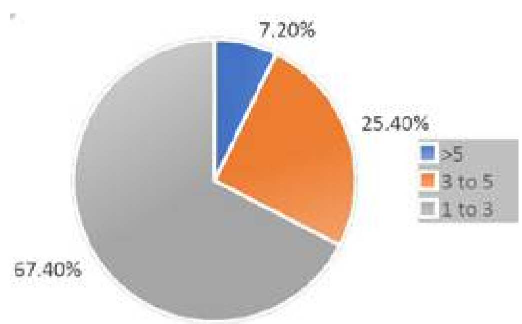

Figure 4. Awareness of different types of millets

Awareness of Different Types of Millets

In Nepal, the list of different millet species includes 12 species (Joshi et al 2023). The study found that only 7.2% of the students were familiar with more than 5 species of millets. 67.2% of the participants had heard of only 1-3 species. The students who knew 3-5 species of millet were 25.6%.

Awareness of International Year of Millets

Surprisingly, majority of the students (61.1%) interviewed were unaware that 2023 is the International Year of Millets and only 38.9% knew about this declaration. Government has been actively promoting millet production, branding and marketing for the Millets Year (*Call to promote millet farming*, 2023). However, lack of student-targeted millet campaigns by the governmental organizations and absence of sufficient millet promoting programs by the University may be the reasons for high number unawareness of International Year of Millets among students. 14.4% affirmed to have plans to celebrate the year of millets.

They mentioned activities such as arranging food festival, sharing knowledge of its cultivation practice and nutrition content, conducting campaign to inform people the importance of millet consumption in diet, developing a unique food product, cultivating millet in their own field, tasting different species of millet and conducting research on millet to celebrate the year of millets.

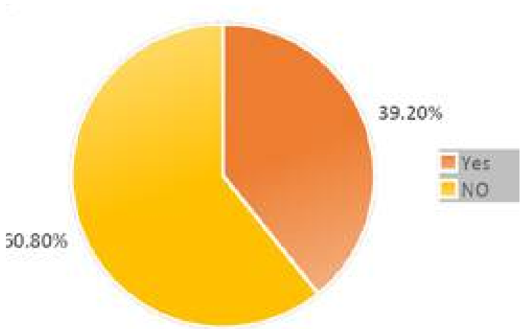

Figure 5. Awareness of International Year of Millets

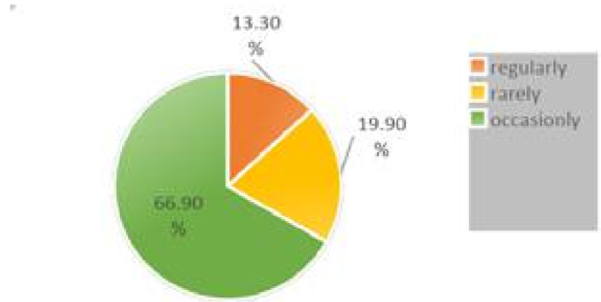

Figure 6. Preference for Regular Consumption of Millet

Preference to Regular Consumption of Millet

It was found that the majority of students (66.7%) would prefer to consume millets occasionally, followed by rarely (20%) and regularly (13.3%). Occasionally, rarely and regularly indicates to at least once a month, once a year and once a week respectively.

Serving of Millet at home

Home is the place where a person learns his eating habits. So, the frequency of millet servings at home can give a picture of the eating habits of a person. More than half of the students (56.7%) responded that millet was rarely cooked and served at their home. 20% of the students responded that millet was served monthly, followed by fortnightly (11.1%), weekly (10%), and daily (2.2%). Millets are consumed mostly for dinner (40.6%), breakfast (32.2%), and lunch (27.2%) at their home. *Dhido* is usually cooked for dinner, *Roti* for breakfast, and *khole, momo*, cookies, *haluwa, Sel roti*, etc, for lunch. The frequency and way of servings of millets at the household level is largely determined by the socio-cultural beliefs and geographic background of the students. Dhido is consumed as a staple food in least developed districts like Humla, Dolpa, Bajura, etc (Ghimire et al 2017). Finger millet is known as the first food for babies in hilly districts (Gyawali 2021).

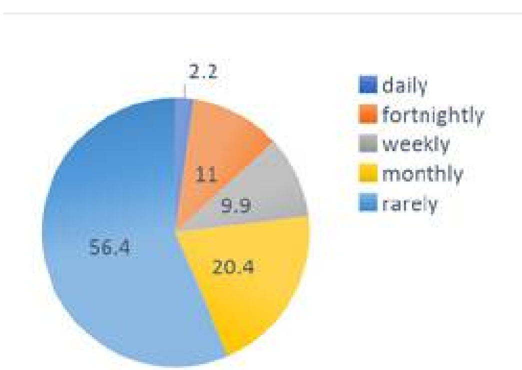

Figure 7. Frequency of Millet Serving at Home

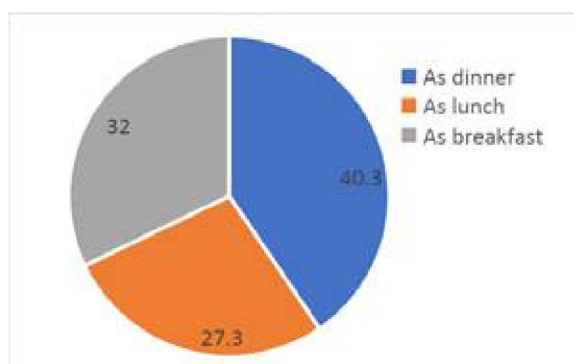

Figure 8. Preference of Millets at Different meals

Consumption of Millet at college

Most students at college eat meals at cafeterias and hotels during their college years. It is important to know how regular their consumption of millet is during their college time. However, the majority of the students (76.1%) responded that they never consumed millet at college. Only 16.1% consumed millet once in 6 months, 3.3% consumed it once a month, and 2.2% consumed it twice a week and twice of month. A shift from traditional food to ready-to-cook and ready-to-eat food, and lifestyle changes are the contributing factors for these findings (Padmalini et al 2023)after many decades of being ignored and considered as food fit for cattle, now millet is back and is considered one of the humble superfoods of the Indian diet. The hectic lifestyle of urban Indians has a direct influence on food choices. A balanced nutritional diet and regular exercise are recommended by World Health Organization (WHO. Consequently, the consumption of millet among the younger generation is low (Khadka, et al 2016). Also, the meals consumed are predominantly of rice and wheat.

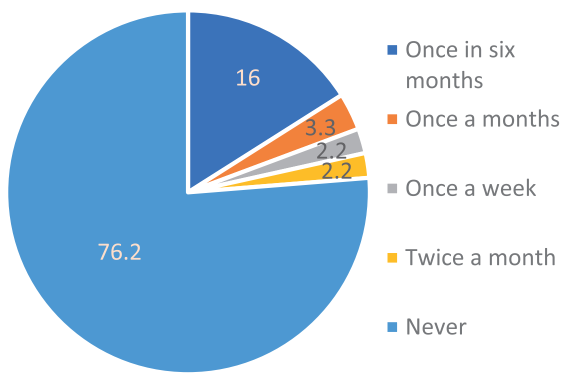

Figure 9. Consumption of Millet at college

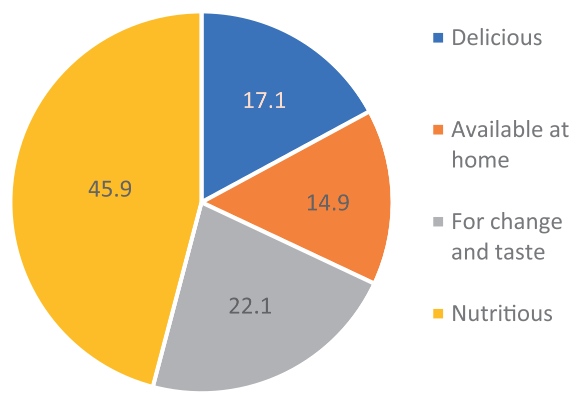

Figure 10. Reasons for Consuming Millet

Reasons for Consuming Millet

It was found that nutritional benefits are the reason for the majority of the students (45.6%). 22.2% consumed it for a change of taste, 17.2% for its delicious taste and 15% stated that it is served at home. In Ahmedabad and Delhi, the majority of urban consumers consumed millet for health and fitness (Kane-Potaka et al 2021). Shah et al (2024) found that millets are introduced to parents with lifestyle diseases by regular consumers. Taste preference, weight loss, longer feeling of fullness, cheap, feeling healthy and served at health among others are other reasons people consume millets in urban places of India (Kane-Potaka et al 2021).

Reasons for not Consuming Millets Regularly

The survey further investigated why students did not consume millet regularly. The unavailability of millet products around the college area was major the reason for 88.9% of students. Limited varieties of millet recipes were cited as the key reason by 7.8%. The remaining 3.3% stated that they did not like the taste of millets. Kane-Potaka (2021) also found that the reasons for not consuming more millets were dislike for the taste, family custom of not eating millets, long cooking time, high price and limited availability.

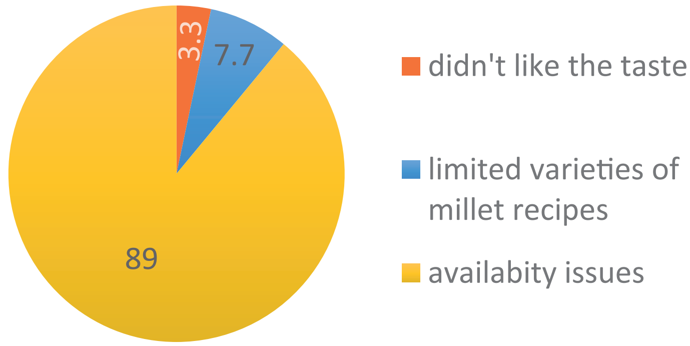

Figure 11. Reasons for not Consuming Millet Regularly

Discussion and Policy Implications

Agriculture and Forestry University is a hub of future agriculture experts. It is disappointing to observe that more than half of the students are not aware of the International Year of Millets and do not plan to contribute to it. The little knowledge of individual students on types of millets indicates that millets are still not a core concern to the students. The higher credit hours given to the major cereals (rice, maize, and wheat) and students prioritizing them for their research activities might have contributed to these findings. The lack of initiatives to promote the millets within the University also adds to the scenario.

About 79% of the students liked the taste of millets which means that millet consumption in the country can be increased if we can cater millets to university students. The cafeterias and hotels around campus where the students consume their meals do not offer millets regularly. In addition to it, students prefer cheaper meals to accommodate their budgets but millets are expensive (*Karnali Emerges in New Avatar as Exporter of Cereals*, n.d.). The regular consumption of millet can be promoted if the university and local area offer different cuisines of millets at an affordable price. Since most students reside in hostels and do not have time for cooking, ready-to-eat food products, no-cook recipes, and servings of millet at the local cafeteria menu are the ways to encourage students for the regularly consumption of millet.

Singh and Raghuvanshi (2012) did a study on knowledge, perceptions, and practices by diabetic patients. They found that the habit of consuming millet from childhood was the reason for the 55% of the participants for consuming millet. Another study by Kane-Potaka et al (2021) on public knowledge and practices of consuming millet in urban areas reported that 39.2% of participants didn't eat millet because they had no cultural habit of consuming millet at home. This strongly suggests that the introduction of millet as a common food for children at home is to develop a habit of consumption of millet in young adults. The current study shows a significant percentage of students (56.7%) come from homes where millet is rarely cooked and served and only a small percentage (15%) said that serving at home was a reason for their consumption of millet.

A major reason for the consumption of millet after the nutritional benefits was the change of taste. This indicates that the students are more likely to prefer millet when they want to have a break from regular meals. This shows a market for millet consumption.

The findings of this study will be useful for policymakers, food companies, and researchers who want to encourage the consumption of millet. Students at the university are potential customers for ready-to-eat and ready-to-cook millet products. They are also the future of Nepal and the inclusion of millet in their food habit can drive a shift in nation's dietary diversity. This information can be helpful to design behavioral change programs in nutrition and in particular celebrating the UN International Year of Millets in Nepal.

There are many universities in Nepal where students spend their 4-6 years away from home. Further studies should be carried out in these universities to obtain similar data on the consumption and attitudes of students in rural and urban areas. Repeated studies can record all the changes and shifts in the behavior pattern.

Conclusion

The government of Nepal has focused its attention on the production and conservation of different species of millet. Consumption of millets as food has also been promoted vigorously in recent years. However, a shift to millet consumption from the regular rice-eating habit of Nepalese is possible if we identify the hidden attitude and consumption pattern of millet. Students are ready to accept millets in their food habits if varieties of millet recipes are available in university areas at affordable prices. There is a need to actively introduce various ways of cooking millets to Nepali kitchens if we aim for its regular consumption among the younger generations.

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B. Statistics, Economics and Marketing

ख. तथ्यांक, अर्थशास्त्र र बजारीकरण

Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Scenario of Domestic and Foreign Trade of Millets in Nepal

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Abstract

Millets are important food crops for ensuring the food and nutrition security of smallholder farmers and marginalized communities in the hills and mountains of Nepal. This paper aims to present the status and scenario of domestic and foreign trade in millets in Nepal. The study uses a combination of data from farm households, market surveys and time series to assess domestic and foreign trade scenarios. The foreign trade data comprised of imports and exports, for the last 14 years (2009-2022) is being used from the official source. We used the compound growth rate, coefficient of variation, instability index, and trade specialization index to assess growth in imports, exports as well as the overall dynamics of millets trade in Nepal. The results showed that most of the millets are locally exchanged and traded informally in rural areas to ensure local food security and income generation. Assessment of the foreign trade growth rate showed that the import value increased at a rate of 17.65 % per annum, while the growth rate for exports is declining and non-significant. There is high variability in the export and import value of millets, with a high coefficient of variation and instability index. The trade specialization index was -0.994, which indicates that millets is in the initial phase. The study implies that there is a need to increase production, productivity, and foreign trade to reduce imports and make the country self-reliant on millets production. Recommendations are made for increasing investment to facilitate domestic and foreign trade of millets and strengthen millets value chain through creating enabling trade policy and trade facilitation.

Keywords: Domestic trade, export, foreign trade, import, millets, nutrition security

Introduction

Millets are important food crops for ensuring the food and nutrition security of smallholder farmers and marginalized communities in the hills and mountains of Nepal. A total of 12 species of millets are reported and cultivated in Nepal (Joshi et al 2023). Among them, four species namely, finger millet, proso millet, foxtail millet, and sorghum, are commonly cultivated in different parts of Nepal, particularly in rainfed marginal lands. Among different species of millet, finger millet is most widely cultivated and ranks as the fourth most important food crop after rice, maize, and wheat in Nepal. The national statistics showed that finger millet is the number one crop in the hill (middle mountain), with 76% area, followed by 20% in the high mountain and 4% in the Tarai (MoALD 2023). Presently, the crop is cultivated on 265 thousand hectares in 70 districts (except Manang, Mustang, and Kailali) in Nepal. They are highly tolerant to drought and heat stress and are often cultivated in *de facto* organic conditions with no use of external inputs (chemical fertilizers and pesticides) (Gauchan et al 2020). Considering their high nutrient dense and climate resilient traits, millets are often considered as "super grains" or "future smart crop." (Li and Siddique 2018, Joshi et al 2019).

Despite the importance of millets for food and nutrition security and the livelihoods of smallholder farmers and marginalized communities, they are neglected and underutilized crops from the perspective of research, development, and policy (Padulosi et al 2015, Joshi et al 2019, Gauchan et al 2020). Hence, the production, consumers' preference, and market demand for millets are low due to a shift towards higher-yielding and profitable crops, resulting in declining area and cultivation in recent years. Weber and Fuller (2008) reported that the low preference for millets can be due to deep-rooted social perceptions about millets as low-status food, a lack of awareness amongst producers and consumers about their nutritional components, and a lack of policy orientation and market arrangement for promoting millets. Moreover, information related to domestic and foreign market demand and preferences for millets is limited in Nepal. This paper, therefore, aims to analyze the status of domestic marketing and foreign trade of millets, which can provide market demand, consumer preferences, utilization, and future directions for its promotion as the super grains for ensuring food and nutrition security in Nepal.

Research Methods, Data Collection and Analysis

This study uses a combination of qualitative and quantitative survey methods for collecting and analyzing domestic and foreign trade data for millets. For domestic trade and marketing information, we used farm households and market survey data for 2020, supplemented with secondary sources of information. A total of 120 sample farm household surveys from the selected six districts of Suddurpachim Province (Doti, Dadeldhura, Darchula, Baitadi, Kailali, and Kanchanpur) and 60 separate sample market surveys of the same six districts of Suddurpacchim Province, along with an additional two districts of Bagmati Province (Kathmandu and Lalitpur), were carried out simultaneously in 2020 (Gauchan 2020). The farm surveys were mainly carried out with individual farmers and cooperatives that are involved in the production, marketing, and local exchange of millet grains and processed products. The market survey focused specifically on market channels, market prices, market margins and uses in food culture in rural local market centers of the target survey districts. For foreign trade information, we used available time series data from the last 14 years (2009-2022) from the Department of Customs and Trade Export Promotion Centre (TEPC), Nepal (TEPC 2023). The data and information are also supplemented with exploratory and qualitative methods of information collection wherever possible. The data also used source destinations for the imports and exports of millets during the period. We used compound growth rate, coefficient of variation (CV), instability index (IIN), and trade specialization index to assess growth in imports and exports as well as the overall dynamics of millets trade in Nepal. The analysis was supplemented with relevant market information and supporting literature (Gairhe et al 2020). The analysis of the results from the survey and secondary data is presented in both tabular and graphic forms. The paper first presents about domestic trade and then foreign trade of millets and millet products in Nepal.

Domestic Trade of Millets and Millet based Products

The status of domestic trade of millets with market participants and their sales volume of millets products is presented in **Table 1**. The analysis of the sample data from the market survey of 2020 showed that only three millet species, namely, finger millet, proso millet, and foxtail millet are mainly domestically traded in formal and informal channels in the rural and urban areas of the study sites in Sudur Paschim Province and in Kathmandu and Lalitpur districts of Nepal. Sorghum was not normally traded in the domestic markets. Most market actors (72% from western and 87% from central mountains) mainly engage in the marketing of finger millet. A fairly good number of market participants were engaged in the sale of proso millet and foxtail millet in the Sudur Pacchim Province. The final selling price of the product was highest in foxtail millet, followed by proso millet, and the lowest price per kg was observed in finger millet. The average volume of sales by retail shops and market participants ranges from a very low amount of 17 kg per month for foxtail in Sudur Pachhim Province to 130 kg per month in Bagmati Province in Kathmandu.

Table 1. Status of Market Participants and Sales Volume of Millet Products

Crops Name	% Market Participants		Sales Volume (Kg/month)		NPR /Kg
	Sudur Pacchim Province (N=36)	Bagmati Province (N=24)	Sudur Pacchim Province (N=36)	Bagmati Province (N=24)	Final Selling Price in Final Market (N=24) Kathmandu
Finger millet	72	87	51	65	134 (1.3)
Proso millet	66	44	NA	104	320 (3.1)
Foxtail millet	59	35	17	130	323 (3.2)

Note: Data in parenthesis indicate value in USD. Exchange rate 1 USD = NPR 117 in 2020.
NA= Not available as producers are not willing to share the information: Source: Field Survey (2020)
Source: Gauchan (2020)

Millet product from the far-western region, mainly from Sudur Pachhim Province, were not available in the final market and were not available to consumers in the major market centers of Kathmandu and major urban centres, as they are mainly marketed locally and in major regional markets such as Dhangadhi and Mahendranagar. The price of the millet products was lower than in Kathmandu due to fragmented value chains. Most of the millets that are sold in major market centers in Kathmandu and Lalitpur are sourced from mountain regions of Karnali Province (eg Jumla, Mugu, Kalikot, and Dailekh), and rural mountains of Bagmati Province, such as Dolakha, Ramechhap, Sindhuplanchowk, Nuwakot, and Kavre districts. Millets are sold as a local (*Raithane*) organic product along with various other consumer goods and food products in major urban centres, such as Kathmandu and Pokhara. Finger millet is being marketed as millet flour after processing the grains, while proso millet and foxtail millet are sold directly as grains. Flour is mainly used as flat bread and *Dhindu* (a sort of thick porridge). Recently, demand for flour among the few segments of consumers has increased. Almost all products are sold with organic self-labeling on packaging, even though they are not formally certified with the details of retail price, source of origin, and branding. The demand for millet products is high in the winter because traditional millet products are tastier in the winter and considered nutritious with the ability to protect from common cold and chilled winter temperature.

Domestic Market Price and Sales Margins of Millet Products

Table 2 presents the purchase and final sale prices of millet products in major destination market, such as Kathmandu (Gauchan 2020). Among the millets, the purchase and final selling price of finger millet is the lowest, while that of proso millet and foxtail millet is the highest. The gross marketing margin, which is a proxy for gross benefits for the products, ranges from 23-77%, with the highest for the foxtail millet. The analysis of gross market margin[1] is the highest for foxtail millet (77%), followed by proso millet (55%), and finger millet (54%).

Table 2. Purchase and Sell prices and Market Margins of Millet Products

Name of crops	Purchase Price in Rural Areas of Bagmati Province (NPR/Kg)	Final Selling Price in final Market (Kathmandu) NPR/Kg	Gross Market Margin (%)
Finger millet	87	134	54
Proso millet	206	320	55
Foxtail millet	183	323	77

Source: Gauchan (2020)

1 Market Margin = (Sell price- Purchase price)/Purchase Price expressed in percent

Some studies indicate the increasing domestic trade of finger millet in Nepal. For instance, Adhikari (2021) carried out a study on supply chain analysis of foxtail millet by taking the case of the Jumla district of Nepal. The study reported that the margins at the marketing stage range from 28 to 82 (NRs/Kg) for grain and from 71 to 108 (NRs/Kg) for flour, depending on the different channels. The major buyers of foxtail millet were farmers or local traders (51%), followed by retailers (27%) and cooperatives (22%). Similarly, Rawat (2020) reported that about 65% of the total proso millet grain produced in the Jumla district was sold to Kathmandu, followed by Surkhet and Nepalgunj (15%), Chitwan and Pokhara (10%), Dang and Butwal (5%) and Jumla (5%). The total amount brought to Kathmandu from the study area was further processed, labeled and packed then redistributed in many of the east-to-west urban areas of Nepal. In Jumla, about 42% of the farmers fixed the price based on last year's price, 34% set the price according to the quality of the produce, and the remaining 24% set the price depending on market demand (Adhikari 2021). The study also revealed that consumers were willing to pay a higher price of about NRs 9.75 per kg for grains and NRs 11.5 per kg for the flour of proso millet if they got the product after value addition. They were willing to pay higher price for flour compared to grain (Rawat 2020).

Domestic Marketing of Millets for Beverage Making

Millets are also domestically traded and exchanged locally for beverage making, mainly for fermented semiliquid beverages (*Jhand* and *Tomba*) and distilled beverages (*Rakshi*). Estimates show that a large proportion of millets are used for beverage production. A previous study carried out about 3 decades ago reported that about 65-70% of the finger millet produced in the eastern hills was used for beverage making, while in the central hill, it was about 50%, but a very negligible amount of it was used in the far western hill and mountain for beverage making (Upreti et al 1991). Similarly, a past study carried out in Kaski district of western Nepal nearly two decades ago showed that about 14% of millet was used for wine making (Adhikari 2006). A recent study by Adhikari et al (forthcoming) from the survey of 452 households in five major millet-growing districts of Bagmati and Gandaki Provinces in 2022, comprising Sindhupalchowk, Makwanpur, Kaski, Dolakha and Baglung reported that about 36% of the finger millet was being used for beverage making. Moreover, the study reported that a major portion of the marketable finger millet was found to be marketed directly from producers to consumers for both food and beverage making. Recently, key informant interviews also indicated that most of the current imports of millets in Nepal are also mainly for beverage making as imported millets are cheaper and easily available in required quantity.

Constraints and Issues in the Domestic Marketing of Millets

A weak, fragmented, and underdeveloped value chain is a key constraint in the domestic marketing of millets. There is poor horizontal and vertical coordination and information asymmetry among producers, value-adders, traders, and consumers. As a result, producers in rural, remote mountains are not able to sell their produce, while consumers are not able to get and purchase millets in the timely and desired form (Gauchan et al 2020). Traders and value adders are not able to get products in sufficient scale and volume for processing and value addition. Recent evidence also indicates weak horizontal coordination, a lack of good and low-cost packaging materials, and a lack of a good and reliable transport system (Adhikari 2021). Horizontal coordination was only marginally present, but vertical coordination was totally absent in the marketing of millets in Jumla (Adhikari 2021, Rawat 2020).

Foreign Trade in Millets

Regular official foreign trade data related to the import and export of millets in Nepal are available only after 2009 (TEPC 2023). Among different species of millet, only finger millet and sorghum are traded with regular import but with an irregular small quantity of export (**Table 3**).

Table 3. Foreign Trade (Import & Export) of sorghum and finger millet, Nepal (2009-2022)

	Import quantity (mt)			Export quantity (mt)		
Year	Sorghum	Finger Millet	Total	Sorghum	Finger Millet	Total
2009	1.4	9812.9	9814.3	0.0	0.0	0.0
2010	0.8	13055.1	13055.9	0.0	0.0	0.0
2011	4.5	17740.3	17744.8	0.0	0.0	0.0
2012	3.7	20511.4	20515.1	0.0	11.1	0.0
2013	94.5	15350.5	15445.0	0.0	42.9	11.1
2014	93.0	15738.8	15831.8	0.0	56.4	42.9
2015	35.6	14398.6	14434.3	21.0	30.6	56.4
2016	5.7	17338.6	17344.3	2674.7	31.7	51.6
2017	13.7	11988.9	12002.6	166.0	6.7	2706.4
2018	1.9	15548.9	15550.8	0.0	21.2	172.7
2019	3.8	17126.6	17130.4	0.3	31.5	21.2
2020	1.7	21074.1	21075.8	3.6	3.8	31.8
2021	5.8	22226.3	22232.1	0.0	3.0	7.4
2022	0.9	20299.4	20300.4	0.0	13.5	3.0

Source: TEPC (2023)

Finger millet is imported and exported as both millet seed and millet grain, while sorghum is imported and exported only as grain. Imports of millet started in 2009, while exports started only after 2012 and are being exported in smaller quantities regularly. Sorghum was being exported in very small quantities in 2015-2017, was absent in 2018, and was again exported in smaller quantities in 2019-2020. The share of exports of both sorghum and finger millet is exceedingly small as compared to the total quantity of imports. However, exports of sorghum in 2016 were high, even higher than finger millet. The data also indicated that the foreign trade of finger millet occurs in diverse countries, covering dozens of countries, while the foreign trade of sorghum is limited to only India and China. Finger millet is imported from India, China, Thailand, Indonesia, and Nambia, while it is exported to about 11 countries in different years, ranging from India, China, Hong Kong, UK, Japan, Canada, the USA, Australia, South Korea and Belgium. Sorghum is both imported and exported in these two countries, while the share of import and export is higher in India (TEPC 2023). However, specific reasons and information about exporting finger millet and sorghum in different countries are not known.

The trend of the quantity and value of imports of millet[2] is presented in **Figure 1**. Import of millet quantity showed sharp increasing trend up to 2012, while value showed an increase up to 2014 and thereafter ups and downs up to 2017, and then increasing trends onwards until 2021. In 2022, the imports slightly declined as compared to 2021. A high level of variability was observed in the import of millet in quantity and value terms after 2014, which was also observed in the past study (Gairhe et al 2020). The import of millet is mainly for liquor purposes without any linkage to the domestic value chain (Gauchan et al 2019).

2 This mainly includes finger millet, as other millets such as proso millet and foxtail millets are not traded. The data for sorghum import and export are also not combined here since there are no significant changes in the trend of traded quantity and volume as the quantity imported and exported is also very small and irregular.

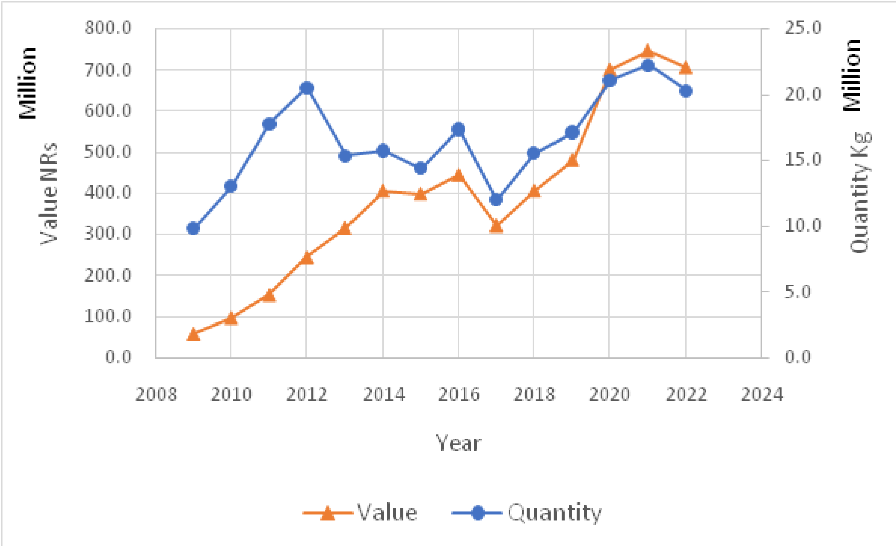

Figure 1. Import of millet in Nepal

The millet export quantity and value are shown in **Figure 2**. A high level of variability of exports in both quantity and value terms was observed in the last 14 years. There was a sharp increasing trend up to 2014, and followed by a declining trend up to 2017, and then again, an increasing trend up to 2019. In 2020 and 2021, both value and quantity showed declining trends and in 2022, both showed an increasing trend.

Figure 2. Export of millet from Nepal

Growth Rate of Millet Import and Export

Table 4 presents the analysis of the compound annual growth rate (CAGR) of millet, in terms of both quantity and value terms. The analysis revealed that the annual growth rate of millet, both in terms of value and quantity of imports is significant. Comparatively, the annual compound growth rate for millet imports in value terms is quite high (17.65) as compared to only 3% growth rate for the millet quantity per annum for the last 14 year (2009-2022). However, the growth rate in both the export quantity and value of millet are negative and non-significant.

Table 4. Compound growth rate of Millet import & export quantity and value 2009-2022

Particulars	Intercept	CGR	R2	P-value
Import Quantity (Kg)	16.35	3.36*	0.35	0.02
Import Value (NRS)	18.36	17.65**	0.82	0.00
Export Quantity (Kg)+	10.67	-15.14	0.30	0.08
Export Value (NRS) +	14.03	-0.18	0.00	0.98

Note: * and ** denotes significance at 5 and 1 percent level of significance respectively. + indicates data from 2012 to 2022.

Coefficient of Variation and Instability Index

The Coefficient of Variation (CV) and Instability Index (IIN) of finger millet from the 2008-2022 period are illustrated in **Table 5**. The analysis showed that the highest CV and IIN were observed in export value, followed by export quantity, import value, and the lowest for import quantity. This indicates that year-to-year variability is very high for export value and quantity as compared to import quantity and value. The main reasons for this year-to-year variability could be due to a combination of production and price variability including changes in import and export demand and supply situations.

Table 5. CV and instability index of import and export of millets 2009 to 2022

Particulars	CV	IIN
Import Quantity (Kg)	21.86	17.56
Import Value (NRS)	55.74	23.63
Export Quantity (Kg)+	75.26	62.77
Export Value (NRS) +	76.76	76.76

Note: “+” indicates data from 2012 to 2022 only for finger millet.

Trade Specialization Index

The Trade Specialization Index (TSI) of millet in Nepal from 2012 to 2022 is shown in **Table 6**. The average value of TSI was found to be -0.994, which indicates the strong negative value of the index between the range from 0 to -1. This implies that the millet has very weak competitiveness with higher import incitement. TSI can also be used to identify the competitive position of a commodity in trade. Since the index value lies between -1 and -0.50, millet is in the introduction phase. There are still high prospects for increasing efforts to promote the trade of millet by increasing production and productivity for its commercialization and increase awareness of its nutrition and health value of the products.

Table 6. Trade Specialization Index of millet from 2012 to 2022

Year	TSI Value
2012	-0.999
2013	-0.998
2014	-0.997
2015	-0.996
2016	-0.995
2017	-0.994
2018	-0.993
2019	-0.992
2020	-0.991
2021	-0.990
2022	-0.989
Total	-10.935
Average	-0.994

Source: Authors estimation

Conclusion and Ways Forward

Millets are important future smart crops that have potential for reducing malnutrition and improving the livelihoods of marginalized communities under changing climate conditions in Nepal. Among the 12 different species of cultivated millets in Nepal, only three species namely, finger millet, foxtail millet, and proso millet, are traded domestically, while sorghum is traded in small quantities in foreign markets. Recently, the trade of millets, particularly finger millet and sorghum, has increased both in domestic and foreign markets. The share of exports of finger millet and sorghum is very small and irregular as compared to the large share of imports. Despite a small share of the export of millets, the specific reasons and information of exporting of millets from Nepal to overseas are limited. The demand for millets is increased in the country, both for food and beverages, resulting in increased imports. Despite the recent increasing trend of market demands and sales of these products, the actual volume of market transactions is very low due to poor market linkage and fragmented value chains. The share of foreign trade in millet is small, particularly the exports, with high variation over the years. The annual growth rate of import value is increasing rapidly, with a growth of 17.65% per annum in the last 14 years. This indicates that current production has not been able to meet the increasing demand for millet products in the country. Presently, the country has a higher coefficient of variation and instability index for export and import values of millets, indicating a high fluctuation in the imports and exports of millets in the country. The trade specialization index is -0.994, which indicates that the millet is in the introduction phase. This indicates that there is still a high prospect of promoting the trade of millets by increasing production and productivity along with creating awareness about their nutrition and health value. Similarly, market and value chain development, building the capacity of both producers and market actors in value addition, product diversification, and innovative marketing are equally important. Legalization of millet beverages can have a potential impact on income generation and substituting imports of foreign beverages, thus saving scarce foreign currency reserves, however, it demands strong quality control mechanisms. This will also help in the utilization of fallow and marginalized lands and reduce the outmigration of youth from rural hills and mountains. Therefore, increased investment is needed in research, value chain development, and trading market surplus in the domestic markets through enabling trade policy and trade facilitation. Further study of the foreign trade of millets specifically the reasons and information about the export of millets in different countries is essential.

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Factors Affecting Consumption of Underutilized Cereals in Kathmandu Valley, Nepal

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Abstract

Nepal possesses enormous opportunity and potentiality for growing and exporting variety of crops, due to the favorable climatic condition and wide range of tropical variations. Despite geographical and nutritive advantages, health benefits of underutilized crops like millets, enough priority has not been given by the government of Nepal. This study was conducted in Kathmandu valley to analyze the status of consumption of underutilized crops for their promotion in Nepal. Primary data were collected using pre-tested interview. Result showed that intermediate education, rare consumption, and mix use were significantly and positively affecting finger millet consumption. In case of barley consumption increased availability were negatively and significantly affecting consumption while intermediate education, household with children, rare consumption, uses for nutrition and mix use were significantly and positively affecting barley consumption. Similarly, results showed that undergraduate education, rare consumption, uses for nutrition, mix use were positively and significantly affecting buckwheat consumption. On contrast, increased availability negatively and significantly affects the buckwheat consumption.

Keywords: Consumption, factor, finger millet, socio economics

Introduction

Adumbrated by slow economic growth, escalating endemic poverty, and wide-scale deprivations from substantial economic growth, Nepal falls under the category of a developing nation with an average economic growth rate of the last decade being 4.6%. Nepal scores 0.579 on the Human Development Index (HDI) obtaining 149th rank out of 189 nations according to the 2019 report of the United Nations Development Program (UNDP). Despite the nation's long-term vision of the Fifteenth Plan which has targeted to drop the population living below the poverty line to 5% by 2030 and below 0% by 2043 by reducing income inequality, the population below the poverty line is still in vulnerable condition with 18.7% of the total population falling below the poverty line (MoF 2019). Indicators of the quality of life of the nation are still unsatisfactory in comparison to the world's scenario with a literacy rate of 67.9% in 2018 and 71.17 years of life expectancy in 2021 (MoF 2022). Recent earthquake of 2015 and the outbreak of pandemic named COVID-19 have impacted its economy significantly.

Agriculture emboldens as a foundation in any aspects of poverty elevation and employment generation. According to the Economic Survey report for the fiscal year 2020-2021, the contribution of the agricultural sector to the GDP has been declining over the years, it is still the largest contributor of national economy. The enhancement of economic growth, employment rate, and livelihood of the population are only possible through the commercialization of agriculture. Search for appropriate crops and cropping patterns to make agriculture more remunerating and beneficial and more attractive to the younger population has always gained priority, with new era studies focusing mainly on diversity in the agricultural system. Agricultural biodiversity is the result of the meticulous interaction between humans and natural ecosystems and the species that they contain, often leading to major modifications or transformations, leading to the resultant agro-ecosystems that vary not just by the physical elements of the environment and biological resources but also according to the cultural and management systems to which they are subjected (Heywood et al 2013). Agricultural biodiversity thus includes a series of social, cultural, ethical, and spiritual variables that are determined at the local community level and these factors played a crucial role in the process of selection of local crops which may be of high nutritive value and signify their importance in economic growth (Heywood 2013, MoFSC 2014). Therefore, proper analysis on underutilized crops (UUC) consumption with the development of niche markets for high-value produce creates new opportunities for developing producers and exporters that can meet the required standards (Ravani and Joshi 2014). By the term "Underutilized crops” or UUC, we refer to those species which possess the potential to improve people's livelihoods, as well as food security and sovereignty, but their worth is not being fully realized or they are not being adequately utilized because of their limited competitiveness with commodity crops in mainstream agriculture

Methodology

Selection of the study area

Kathmandu valley of Nepal was selected to assess the status and factors affecting the consumption of underutilized crops in the major city of Nepal. Kathmandu is the capital of Nepal and forms the core of the nation’s most populous urban region which comprises the two contiguous and closely interlinked administrative entities, Kathmandu Metropolitan City and Lalitpur Sub-Metropolitan City.

Sources of information

Both the primary and secondary data were used. The pre-tested systematic questionnaire was used to obtain the primary data from the respondents of Kathmandu valley. Required data was obtained through respondents’ face-to-face interviews. The secondary information was obtained through reviewing different publications. The various stalls available for the sales of underutilized crops in Kathmandu valley were used to identify the consumers of underutilized crops and three stalls from three different locations at Satdobato, Kalimati and Ratnapark respectively were targeted based on the visit of people there who were interviewed on the status of consumption of underutilized crops.

Field survey

After the finalization of the interview schedule, the schedule of the field visit was prepared to collect information by systematic samplings. Every third person visiting the stalls were interviewed and altogether 99 respondents were surveyed from the three different stalls at Kathmandu valley. 33 respondents were surveyed from each stall. Out of the total sample surveyed, 61 respondents were consumers of any of the studied crops (ie finger millet, barley and buckwheat) under this study. The field survey was conducted in the month of November and December 2021.

Methods and techniques of data analysis

The information of producers collected from the field was entered in the spreadsheet through Kobo tool box. Data import, management, and analysis were done by using computer software packages like Stata and Microsoft Excel. Both descriptive and analytical methods were used to analyze the data.

Socio-economic factors affecting UUC consumption

To estimate or analyze socioeconomic factors affecting UUC consumption, logistic regression was used. Logistic regression was used to describe data and to explain the relationship between one dependent binary variable and one or more nominal, ordinal, interval, or ratio-level independent variables. The underutilized crops decision was taken as the dependent variable and several socioeconomic factors such as education, gender, occupation, participation in cooperatives and training, etc were used as the independent variable to estimate their effect on UUC consumption.

The binary Logit regression model can be expressed as; $Y_i = f(\beta_i x_i) = f$ (Age, Gender, Education of respondents, Income, Household with children, Household with elderly, UUC availability, Consumption frequency, UUC for nutrition, mix use, and crops of hilly regions). Description of the variables is given in **Table 1**.

Table 1. Description of the variables used in the Logistic model

Variables	Description	Value
Age of HH	Age of household head	Number of Years
Gender of HH	Gender of household head	Female=0, Male=1
Education	Education of respondents	Dummy variables
Income	Monthly Family Income	Dummy variables
Household with children	Household with children	No=0, Yes=1
Household with elderly	Household with elderly	No=0, Yes=1
UUC availability	Availability of underutilized crops	No=0, Yes=1
Consumption frequency	Frequency of consumption	Dummy Variables
UUC for nutrition	Uses for nutrition	No=0, Yes=1
Mix use	Mix use of UUC	No=0, Yes=1

Findings and Discussion

Socio-economic characteristics of the respondents

The socio-economic characteristics of the respondents include population and gender distribution, family size, economically active population, occupation, income. Of the total respondents surveyed for accessing consumption, 53% were male and only 47% were female. Educational status was categorized into four categories. The majority of the respondents were well educated with 42.42% undergraduates and 33.33% postgraduates. While respondents with SLC or educational status below 10, were 4.04%. The percentage of high school attendees was 20.2%.

The employment status of the respondents influences the decision-making approach for the consumption of underutilized crops. Employment status of respondents in Kathmandu valley was categorized into three categories ie government employee, private sector and unemployed. The majority of the respondents are unemployed comprising 68.69% of the total sampled households. Government employees were found to be the second major type of employment, comprising 16.16% of the total respondents. About 15.15% of respondents were involved in the private sector.

Analyzing the monthly family income of the respondents for consumption analysis, 26.26% of the respondents had an income less than Rs. 20,000 and 39.39% had an income between Rs. 20,000 to Rs. 50,000. While talking about the rest of the income groups, 28.28% of the respondents had a family income between Rs. 50,000 to Rs. 1 lakh while 6.06% of the respondents had a family income of more than Rs. 1 lakh.

The average age of the respondent was 35.47 years. Among the total number of respondents, the frequency of the members below 15 years of age was 0.68, the members from 15-59 years of age were 4.58, the members greater than 59 years of age were 0.63 and the dependent population was 1.28. So, the majority of the respondents belonged to the young and independent group with enthusiastic vision and ideas regarding the questionnaire.

Consumption of UUC

Underutilized crops (UUC) being the pivot concern of our research, we asked them several questions regarding the consumption of UUC and noticed that 35.35% were non-consumer while the majority ie 64.64% were the consumer of UUC. And thus, UUCs are still prioritized food in Kathmandu.

Frequency of consumption of finger millet, barley and buckwheat

From the frequency analysis of finger millet, barley and buckwheat consumption in the household of the respondents, it was found that buckwheat is preferred more on daily basis while finger millet and barley possess the same frequency of consumption on daily basis. While analyzing on weekly basis, it was found that finger millet was preferred. Considering monthly data, the frequency of finger millet consumption was the highest but the frequency of the monthly consumption of barley was the lowest. From the analysis of consumption of the crops less than once a month it was observed that barley consumption tops the chart followed by buckwheat, but it can be observed that the trend of consumption of finger millet is comparatively lower. In simple random survey, there were non-consumers of the crops too. The frequency of respondents who didn't consume buckwheat was found to be higher, while the non-consumer of finger millet was the lowest. Apart from this, a few periodic analyses of crops consumption were also analyzed such as 4-5 days a week or 2-3 days a week per 1 day a week or 1 day in every 2 weeks which clearly shows that the frequency of consumption of finger millet was somewhat higher in comparison to the frequency of consumption of barley and buckwheat and the frequency of consumption of buckwheat was comparatively lower than the other two crops.

Table 2. Frequency of consumption of finger millet, barley and buckwheat

Frequency	Millet	Barley	Buckwheat
Daily	2 (3.13)	2 (3.13)	4 (6.25)
4-5 days a week	0	1 (1.56)	1 (1.56)
2-3 days a week	12 (18.75)	8 (12.50)	5 (7.81)
1 day a week	8 (12.50)	3 (4.69)	3 (4.69)
1 day every 2 weeks	5 (7.81)	9 (14.06)	7 (10.94)
Once a month	17 (26.56)	8 (12.50)	11 (17.19)
Less than once a month	17 (26.56)	26 (40.63)	23 (35.94)
Never	3 (4.69)	7 (10.94)	10 (15.63)

Note: Figures in parentheses indicate percentage

Purpose(s) of use of finger millet, barley and buckwheat

The purpose behind the consumption of finger millet, barley and buckwheat were surveyed and it was found that for nutritional purpose, the frequency of the consumption of finger millet was maximum followed by buckwheat, while the barley consumption for nutritional purpose remaining comparatively low. Analyzing another significant purpose of consumption ie medicinal purpose, it was observed that both finger millet and buckwheat stand equivalent whereas barely was used for medicinal purpose in comparatively low frequency. Endeavoring about religious significance, barley topped the chart followed by finger millet and it was observed that the utilization of buckwheat for ritual purposes was comparatively lower. And for other purposes, the frequency of utilization of finger millet was highest followed by buckwheat and last but not least, the utilization of barley for other specific purposes was comparatively lower. Hence, from the analysis, it is clear that the frequency of utilization of these UUCs was the highest for nutritional purposes compared to other purposes.

Table 3. Purpose of use of finger millet, barley, and buckwheat

Purposes	Finger millet	Barley	Buckwheat
Nutrition	51 (79.69)	37 (57.81)	42 (65.63)
Medicinal	13 (20.31)	6 (9.38)	13 (20.31)
Ritual	16 (25.00)	33 (51.56)	12 (18.75)
Others	16 (25.00)	14 (21.88)	15 (23.44)

Note: Figures in parentheses indicate percentage

Information on sources to access finger millet, barley, and/or buckwheat for consumption

In the survey conducted among 64 consumers of UUC, it was observed that the places from where they usually bought finger millet, barley, and/or buckwheat were different based on their accessibility. For finger millet, it was observed that the frequency of buying finger millet was highest in directly purchasing from followed by friends and/or relatives further followed by purchasing finger millet from the rural market. Buying finger millet from the urban grocery store was also observed to be more frequent than purchasing from the rural grocery. Buying finger millet from the urban market and obtaining finger millet as a gift, both were observed to be frequent too. Apart from this, only 7.81% of the overall finger millet was purchased from the urban supermarket while 17.19% of the purchasing was done through other ways/areas (apart from the above-mentioned options). So, for buying finger millet, it can be analyzed that the maximum purchasing was done through farmers and minimum through the urban supermarkets. Similarly, for barley too, the maximum purchasing was done from farmers and the lowest purchasing of barley was done through the urban supermarket. Buying of barley from the rural market was frequent too. Urban grocery stores and friends and/or relatives withstand equivalent position in purchasing option of barley. Buying of barley through the urban market was comparatively lower followed by buying barley from the rural grocery store. Regarding the buckwheat purchase, the maximum purchasing was done from farmers. Buying of buckwheat from the rural market was frequent too followed by buckwheat purchasing from friends and/or relatives, further followed by purchasing buckwheat from the urban grocery store. It can be observed that buying buckwheat from the urban market and rural grocery shops withstood the same position in the list of purchasing options. At the same time, the tendency of obtaining buckwheat as a gift or through other purposes also occupied the same position in the purchasing option list. Thus, it was observed that purchasing of UUC directly from farmers topped the chart while purchasing UUC from urban supermarkets occupied a down-bottom position in the UUC purchasing list, with other options remaining as an average arena in the market of purchase of UUC.

Table 4. Information on places to buy finger millet, barley, and/or buckwheat in Kathmandu valley

Markets	Finger millet	Barley	Buckwheat
Urban Supermarket	5 (7.81)	4 (6.25)	6 (9.38)
Urban grocery store	14 (21.88)	15 (23.44)	12 (18.75)
Urban market	10 (15.63)	11 (17.19)	10 (15.63)
Rural grocery store	12 (18.75)	9 (14.06)	10 (15.63)
Rural market	17 (26.56)	18 (28.13)	15 (23.44)
Farmers	25 (39.06)	24 (37.50)	21 (32.81)
Friends and/or relatives	19 (29.69)	15 (23.44)	13 (20.31)
Gift	10 (15.63)	6 (9.38)	7 (10.94)
Others	11 (17.19)	8 (12.50)	7 (10.94)

Note: Figures in parentheses indicate percentage

Edible form of finger millet, barley, and buckwheat

When the survey was conducted among the consumer of UUC to find out in which form finger millet, barley and buckwheat were consumed, the result of the survey obtained was vivacious among each other. It was found that the frequency of consuming finger millet as a homemade snack was the highest, while the frequency of consuming finger millet as an ingredient in a store-bought snack was the lowest. It was also observed that the consumption of finger millet in as major ingredients in homemade meal and store-bought meals were comparatively higher than buckwheat and barley. Analyzing the barley consumption pattern, it was observed that the frequency of consuming barley as a homemade snack was the highest while the frequency of consuming barley as an ingredient in a store-bought snack was the lowest. It was least used as ingredients in the homemade meals while most used as a minor ingredient in store bought meals among the three crops. Discussing the buckwheat consumption pattern, it held average use position among the three crops. But it was also observed that it was used the most as a major ingredient in the store-bought meals. Thus, from the overall analysis of the consumption format of finger millet, barley and buckwheat, it was observed that the frequency was comparatively high for consuming these crops as homemade snacks and the frequency is comparatively low for consuming these crops as a beverage as shown in **Table 5**.

Table 5. Edible forms of finger millet, barley, and buckwheat in Kathmandu valley

Formats	Finger millet	Barley	Buckwheat
A major ingredient in a homemade meal	16 (25.00)	8 (12.50)	13 (20.31)
A minor ingredient in a homemade meal	25 (39.06)	19 (29.69)	21 (32.81)
A major ingredient in a store-bought meal	5 (7.81)	4 (6.25)	7 (10.94)
A minor ingredient in a store-bought meal	4 (6.25)	8 (12.50)	2 (3.13)
Ingredient in a homemade snack	25 (39.06)	23 (35.94)	20 (31.25)
Ingredient in a store-bought snack	2 (3.13)	1 (1.56)	1 (1.56)
Beverage	6 (9.38)	2 (3.13)	2 (3.13)
Others	7 (10.94)	11 (17.19)	8 (12.50)

Note: Figures in parentheses indicate percentage

Factors affecting consumption of underutilized crops

Logistic regression was used to see the effect of different variables on the consumption of underutilized crops in Kathmandu valley. The result **Table 6** showed that gender positively and significantly affects finger millet and buckwheat consumption. In contrast, gender negatively and significantly affects barley consumption. The result implies that while shifting from female to male the more will be the chances of consumption of finger millet and buckwheat. Similarly, on shifting from female to male, the consumption of barley decreases significantly. The level of education was significantly affecting the consumption of underutilized crops. Intermediate education has a positive and significant effect on consumption of finger millet and barley while Undergraduate education has a positive and significant effect on consumption of buckwheat. The result implies that while shifting from post-graduate to the lower level of education, the consumption of underutilized crops goes on increasing. A household with children has a positive and significant effect on the consumption of barley. Barley and Buckwheat being used for nutritious purposes positively and significantly affect their consumption. The result implies that the consumption of barley and buckwheat increases while shifting from other purposes of use toward the nutritional purpose. The frequency of consumption positively and significantly affected the consumption of all studied underutilized crops. The result further implies that while shifting from frequent consumption (ie greater than 4 times a week) to rare consumption (ie less than 4 times a week), the consumption of all studied underutilized crops increase. The formats in which underutilized crops are used also positively and significantly affect the UUC consumption. This implies that while shifting from using underutilized crops as a sole ingredient toward using them as a mixed ingredient in food, the consumption of studied underutilized crops increase.

Table 6. Logistic regression – log-odds scale (ie, log (P/1-P) to determine factor affecting consumption

Variables	Finger millet			Barley			Buckwheat		
	Odds Ratio	SE	p-value	Odds Ratio	SE	p-value	Odds Ratio	SE	p-value
Age	0.07	0.07	0.30	0.03	0.04	0.47	-0.01	0.04	0.83
Intermediate education	2.55**	1.27	0.05	2.47**	1.13	0.03	1.69	1.08	0.12
Undergraduate education	0.89	1.05	0.40	0.62	1.08	0.57	2.48**	1.03	0.02
Low income	0.37	1.43	0.79	0.14	0.95	0.88	-0.29	0.89	0.75
Medium income	1.53	1.14	0.18	-0.19	1.09	0.86	0.19	0.78	0.81
Household with children	1.19	1.12	0.29	1.56**	0.77	0.04	0.76	0.89	0.39
Household with elderly	0.98	0.90	0.27	0.20	0.86	0.81	0.57	0.80	0.48
UUC available	-0.46	0.60	0.44	-1.40	1.40	0.32	0.52	1.15	0.65
Rare consumption	2.47*	1.42	0.08	3.09***	0.83	0.00	2.28***	0.71	0.00
Used for nutrition	0.42	2.02	0.84	5.27***	2.04	0.01	6.01***	1.47	0.00
Mix use	7.72***	2.88	0.01	4.85***	1.37	0.00	5.06***	1.94	0.01
Constant	-6.85	5.32	0.20	-1.85	1.98	0.35	-4.23	2.04	0.04
Log pseudo likelihood	-14.39			-25.68			26.13		
Wald $chi^2(14)$	66.87			52.47			41.00		
Prob > chi^2	<0.001			<0.001			<0.001		
Pseudo R^2	0.78			0.62			0.62		
Number of observations	99			99			99		

Note: ***, ** and * indicate 1%, 5% and 10% levels of significance, respectively.

For the level of education, keeping other variables constant the odd of consumption of finger millet and barley increases by around 155% and 147% when the respondent shift from postgraduate to intermediate level of education. In the case of buckwheat, the odd of consumption increases by 148 % when the respondents shift from postgraduate to undergraduate education. Singh (2021) reported that UUCs are included in the traditional subsistence farming systems particularly in marginal areas and in many cases, these crops and commodities are life-savers for millions of resource-poor illiterate people in the region where food and nutritional security are significant problems.

Keeping other variables constant, the odd of consumption of barley increases by around 56% when the respondents have children in their family. In 2019, 43 percent of children under 5 years old suffered from malnutrition in Nepal (UNICEF 2020). The impact of malnutrition is greater among children, leading to negative effects on immune functioning, cognitive development, child growth, reproductive performance and work productivity. In the Hindu-Kush Himalayan (HKH) region, a substantial proportion of the population is facing malnutrition due to imbalances in dietary intake and the incidence of diseases related to the lack of one or more nutrients (eg, protein, iodine, vitamins, calcium or iron) (Adhikari et al 2017)but their role in achieving nutrition security is not adequately understood, and they do not feature in food and nutrition policies and programs of the countries of the Hindu-Kush Himalayan (HKH. Barley being rich in micronutrients is widely used in children's foods and thus families with children prefer barley consumption more than other crops.

Furthermore, keeping other variables constant, the odd of consumption of finger millet, barley and buckwheat increases by around 147%, 209% and 128% when these crops are used rarely (less than 4 times a week) as compared to frequent consumption (ie greater than 4 times a week). Law of diminishing marginal utility best fit to describe the obtained result

In the case of barley and buckwheat, keeping other variables constant the odd of consumption of these crops increases by 427% and 501% respectively when these crops are used for nutrition. The result implies that the consumption of barley and buckwheat increases while shifting from other purposes of use toward the nutritional purpose. Adhikari et al (2017) stated that to achieve nutrition security for present and future generations, food patterns with a high diversity and a variety of items with an advanced range of micro- and macro-nutrients are important. Furthermore, Sharma et al (2012) reported that barley and buckwheat seeds are of high nutritive values with high concentration of proteins, fibers, lipids, minerals and vitamins; their flours are richer in protein than rice, wheat, sorghum or maize; lysine level is higher in these crops and all amino acids are represented equally. Furthermore, buckwheat is also rich in arginine which is an amino acid that is known as growth hormone releaser, an immune stimulant and a wound-healing agent; because of the presence of protease inhibitors and tannins, the high quality protein in buckwheat is counterbalanced by their low digestibility; buckwheat flour is richer in soluble fibers in comparison to wheat and oats; buckwheat seeds contain mainly short chain lipids (palmitic acid, oleic acids, linoleic acid) and long chain lipids in higher concentration in comparison to other cereals; buckwheat is richer in Zn, Cu and Mn minerals than other cereals and the seeds are also rich in Selenium (Se), an oligo element frequently deficient in human nutrition. Vitamins include B1, B2, B3, B6 and C; the absence of gluten in buckwheat flour constitutes a nutritional advantage; sprouts of buckwheat can be consumed in salads and young plantlets can be harvested to make juice.

Keeping other variables constant, the odd of consumption of finger millet, barley and buckwheat increase by around 672%, 385% and 406% when these crops are used in mixed form as compared to a sole ingredient in the food. Gairhe et al 2021 stated that being rich in micro-nutrients, rare amino acids, dietary fibres, vitamins, calcium and higher proteins, underutilized crops procure valuable stance in food values in

Nepalese and Indian culture, where these crops are pulverized and the resultant flour is utilized as a mixed ingredient for the preparation of traditional food such as roti (flat breads), kanji (thin porridge) and papads (rolled and dried preserved products), flat chhappati roti as well as various modern food recipes such as pancakes, cakes, biscuits, selroti and multigrain breads, and at the same time used as good feeds for livestock. Adhikari (2017) further stated that in modern food culture, it is used as a nutritious multigrain bread, cakes, cookies, *nimkin, momo* etc. showing the increasing use of this crop in the daily life of the Nepalese people.

Conclusion

Consumption of underutilized crop is highly influenced by the socioeconomic characteristics of consumers and their family. The level of education of children in the family, frequency of consumption, purpose of use, format of use in a mix form was significantly affecting the consumption of underutilized crops. Intermediate education has a positive and significant effect on consumption of millet and barley while Undergraduate education has a positive and significant effect on consumption of buckwheat. A household with children has a positive and significant effect on the consumption of barley. Barley and Buckwheat being used for nutritious purposes positively and significantly affect their consumption. The frequency of consumption positively and significantly affected the consumption of all studied underutilized crops. The formats in which underutilized crops are used also positively and significantly affect the UUC consumption in Kathmandu valley Thus, for expansion of commercial UUCs efficient marketing structure and channel must be developed, ensuring higher producers' share to retail price. All the concerned actors should cooperate and work together to enhance and harvest commercial potential of underutilized crops as an enterprise.

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Revival of Future Smart Foods for Sustainable Food Systems in Nepal: A case of Millets

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Abstract

Millets are one of the Future Smart Foods (FSFs), indigenous to Nepal. Millets are rich in micronutrients, more resilient to water and heat stresses and can be cultivated in marginal lands and at different altitudes ranging from plain terai to high hills. They can contribute to the overall sustainability of food systems through their potential contribution to nutrition security, rural income, and resilience to climate change. Beyond their immediate agricultural significance, millets offer potential in advancing agro-/eco-tourism and culinary science. This research paper, rooted in rigorous peer review and a SWOT analysis of the current millet landscape, develops an operational framework. This framework, exemplified through the case of millets, outlines a sustainable, long-term approach for the revival of traditional crops, thereby ensuring the sustainability of food systems in Nepal. In addition to this, the paper provides recommendations that span multiple fronts, including behavioral, technological, market, and policy aspects, to facilitate the revival of millets within the food system. By adopting a holistic approach that considers behavioral changes, technological innovations, market dynamics, and policy measures, we can create an enabling environment for the sustainable revitalization of millets and other FSFs. This comprehensive strategic way will not only contribute to the restoration of agrobiodiversity and dietary diversity but also enhance the resilience of Nepal's food systems in the face of climate change and other challenges.

Keywords: Millets, future smart food crop, revival, agricultural policy, indigenous crop

Introduction

Indigenous crops have been an integral part of the food systems in the Hindu-Kush Himalaya (HKH) for centuries. However, due to several socioeconomic and climatic factors, these crops are gradually declining in the food systems. Due to a decline and underutilization of these crops, these are also called as ‘neglected and underutilized species. In 2017, the FAO relabeled these crops as ‘future smart foods’ in view of their importance for climate change resilience, agrobiodiversity, agriculture sustainability, and food and nutrition security (Hussain and Qamar 2020). Millets are also part of the indigenous crops in Nepal and HKH region and are deeply intertwined with the nation's culture and history. However, along with traditional perception associating millet with lower socio-economic groups and other factors such as evolving dietary preferences due to globalization, limited awareness of their nutritional benefits, restricted market access and a shift toward modern agricultural practices favoring different crops have collectively contributed to a decline in millet consumption (Mal et al 2010) relegating it to the category of neglected and underutilized crops. Recognizing its exceptional nutritional potential, climate resilience, economic viability, and local adaptability, the United Nations Food and Agriculture Organization designated millet as a Future Smart

Food crop in 2018. Furthermore, in 2023, the International Year of Millet is being celebrated with the theme 'Millet Crops for Food Nutrition, Security, Environment, and Rural Transformation.'

In the context of Nepal, Future Smart Food (FSF) crops, including millets, can play a pivotal role in addressing food security, enhancing climate resilience, and transforming the rural economy. They have the potential to bridge the growing production and nutrition gaps in our food system (Li and Siddique 2018). Millets, in particular, can serve as a compelling entry point for advocating the revival and mainstreaming of FSFs in Nepalese agriculture. However, it is essential to recognize that these efforts should not be limited solely to millets. A comprehensive, long-term plan is needed to integrate a wide range of FSFs into our agricultural practices. This paper aims to develop an operational framework, using millets as an example, to guide the long-term revival of traditional crops and ensure the sustainability of our food systems in Nepal.

Methodology

This study is secondary research conducted based on the existing scientific literature and government reports to analyze the status of millet in current food system. Literature is mainly searched from ResearchGate, Nepalese agriculture research journals and Google Scholar based on relevant keywords search including neglected and underutilized species, millets, seed system, mechanization, market, and ethnobotany. Following the literature review, SWOT analysis is conducted focusing on both production and consumption side of the millet food system and finally recommendations are drawn for revival and mainstreaming. In this process will also develop an operational framework with an example of millets for long term revival of traditional crops for sustainability of food systems in Nepal.

FSFs and Food System

For centuries, people across Nepal have utilized a diverse array of nourishing foods. They held a profound understanding of edible food sources within their ecosystem, ranging from wild edibles and medicinal plants to domestically cultivated cash crops (Joshi 2022). Regrettably, due to the forces of increasing globalization, agricultural intensification, and demographic shifts, newer generations are gradually distancing themselves from many of these traditional foods (De Bruin et al 2021). This trend has led to an interruption in the transfer of valuable knowledge, resulting in a rise in food monotony. This shift poses potential issues such as an increased risk of micronutrient deficiency, diminished resilience within the food system, compromised food sovereignty and loss in agrobiodiversity.

In Nepal, demographic and health survey of 2022 states that 69% of children aged 6–23 months consumed unhealthy foods. And throughout the country 30% of children under five-year age are stunted, and 22.3 % children are underweight, of which mountain kids are the most suffering from stunting. Future Smart Food, as defined by the FAO, encompasses Neglected and Underutilized Species (NUS) that are rich in nutrition, resilient to climate variations, economically viable, and locally available or adaptable. These crops are now being considered essential entry points for transforming nutritional and agricultural challenges into opportunities in rural settings (Adhikari et al 2017, Li et al 2019).

Millets are Future Smart Foods, indigenous to Nepal. Compared to popular cereal crops, millets are resilient. Their ability to thrive in marginal lands, resist pests, excel in intercropping setting, coupled with their nutrient-dense composition, makes them a compelling choice for enhancing food and nutritional security and ecological sustainability (Kumar et al 2018). Furthermore, millets demonstrate adaptability across varying altitudes, rendering them suitable for diverse geographical contexts (Khadka et al 2016). Importantly, millets are deeply ingrained in the social fabric of Nepal's food culture, enhancing their acceptance and integration within local diets and contribute to local economy.

Food, nutrition, and tradition are societal concerns associated with millets, which are closely intertwined with economic and environmental aspects through fields like ethno-botany and household economics respectively. The potential for income generation from millets also intersects with environmental considerations due to their relatively superior agroecosystem services, including reduced resource pressure, when compared to other major cereal crops (UNRIC 2023). Based on these functions of millet, which addresses all aspects (social, economic, and environmental) of sustainability in Nepalese food system, a framework is presented in **Figure 1**.

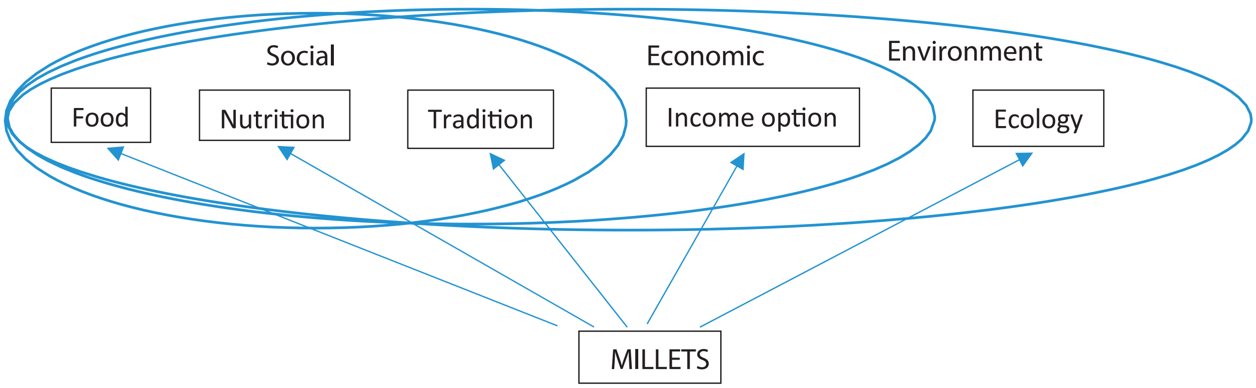

Figure 1. The impacts of Millet in food systems (based on the sustainability framework and authors analysis from on literature review)

In Nepalese food system, millets are used as cereal crop, animal fodder, and for making brewery items. Even though use of millet is engraved in our food system, there is some resistance making it underutilized crop. The resistance to consuming millets in Nepal is often rooted in its socio-cultural perception as 'poor man's food.' Grains like rice and wheat, cultivated in more fertile areas with greater resource requirements, have historically been regarded as more desirable and prestigious. In contrast, millets, grown in less fertile regions, have become associated with lower socioeconomic groups. This ignorance towards millet was also observed in policy level as very less attention was given to agricultural research and development (Shrestha et al 2020a) until recently as scientific evidence increasingly underscores millets' nutritional importance and their resilience in the face of climatic events and pest incidence, the integration of these nutrient-rich traditional foods into the broader food system has become more critical than ever. Beyond their immediate agricultural significance, millets also offer potential in promoting agro- eco-tourism and advancing culinary science.

The Situation of Millets Production and Consumption in Nepalese Food System

Traditional dishes made from millets, such as *dhindo*[1], *kodoko roti*[2], *kagunoko khir*[3], *chinoko bhat*[4], and *Kodoko khole*[5] were once typical local food just a generation ago. However, as discussed earlier, people's preferences have now become limited to food options based on rice, wheat, and maize.

The Annual Household Survey data showing sharp decline in urban consumption and slight decline rural urban consumption of millet in from 2015/16 to 2016/17 suggests a notable change in consumer preferences with only 3.5% household in the nation consuming millet as food option. Similarly, another study examining dietary patterns between 1993 and 2011 revealed that Nepalese consumers gradually

1 Dhindo is made by gradually adding finger millet flour to boiling water while stirring.
2 Kodoko roti is a pancake type flat bread made from thick batter (finger millet) with water and salt or sugar.
3 Kaguno ko kheer is pudding made from proso millet, milk, sugar and dry fruits.
4 Chinoko bhat is rice like food made from proso millet
5 Kodoko khole is soup made from finger millet flour.

shifted from low-cost, calorie-rich foods to more expensive, calorie-dense items. This dietary diversification was made possible due to increased income, changing lifestyles, and other factors (Thapa et al 2019). Another study conducted in a Nepalese village indicated that over the last decade, cash crops like mustard and cardamom replaced traditional food crops, limiting calorie consumption from traditional crop to a mere 7% (Adhikari et al 2019).

Table 1. Consumption of millet in rural and urban populations

Year	Share of millets in average per capita food consumption (%)		
	Urban population	Rural Population	Overall population
2015/16	4.1%	5.7%	5.1%
2016/17	1.8%	4.7%	3.5%

Source: Annual household surveys (CBS 2016, 2017)

Over the 32-year (1990/91 to 2021/22) dataset from Statistical Information on Nepalese agriculture by government of Nepal shows that the area under millet cultivation remained relatively consistent despite decrease in agricultural household percentages over the years. While the total millet production has showed an overall upward (**Figure 2**) trend but in a bigger picture looking at the production of other cereal crops, this is far from status for Nepal being independent on own cereal production. This rise, however, remains insufficient to attain increasing food and nutrition demand. Nepal's imports of millet alone have been substantial, reaching around 22,226 tonnes in the fiscal year 2021, marking an increase from 11,945 tonnes in 2017 (FAO 2023). Despite of an increase in production and import of millets, per capita consumption of millets is decreasing (**Table 1**). This scenario might be result of growing population, use of millets for livestock feed and brewery and changing consumers' dietary habits and social stigma attached with indigenous crops. Similarly, forecasts for 2030 suggest that the gap between domestic rice production and households' direct demand may range from 19% to 80%. This deficit in rice production is likely to persist despite efforts like increased irrigation and fertilizer supply (Prasad et al 2011). These estimates, however, do not account for climate extremes. Given this context, it becomes crucial for Nepal to diversify its cereal options, considering those that exhibit climate resilience and are well-suited to the geographical and socio-economic conditions. Future Smart Food crops like millets are a strong contender in this regard.

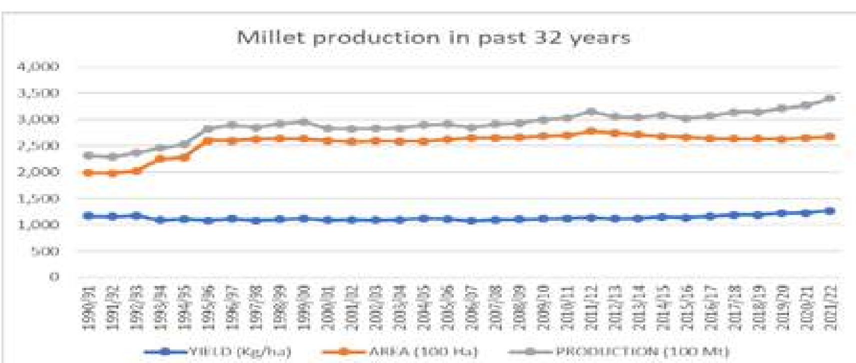

Figure 2. Millet production in past 32 years
MoAD 2015; MoALD 2023

Despite such significant importance of the crop, inadequate efforts are made to mainstream marginalized types of millets such as foxtail millet, proso millet and pearl millet in the food systems. Only data of a couple of types of millets such as finger millet is captured in national data, other millet varieties remain obscured.

Millets are typically found in cropping pattern of rainfed system (Paudel 2016) intercropped with other crop such as maize and legumes (Gauchan et al 2020), and compared to mono cropping the with traditionally practiced intercropping farmers are better off (Paudel 2016) However research on cropping practices of millets is very limited to finger millet with very few evidence agronomic practice of other millets.

Major Constraints and Challenges to Millets and Other FSFs

It is clear that, millets in agri food system has been facing challenges. In this section we will discuss in detail the constraints that FSF such as millets has been facing in the contemporary condition. As, we are also exploring solutions and opportunity, we will later perform SWOT analysis based on the existing literature review of millet production and consumption in Nepal. The major constrains and challenges of millets in food system are as follow:

Policy constraints: Nepal's policies promoting millets utilization are well-intentioned yet face challenges hindering their effective implementation. The National Agriculture Policy (2061 BS) aims to enhance millet and minor cereal productivity via research, extension, and marketing. The policy underscores the importance of the millet's role in food security and marginalized farmers' livelihoods. Likewise, the Agriculture Development Strategy (2015-2035) designates millets as a priority crop for food security, nutrition, and climate resilience. This strategy envisions a 25% increase in millet cultivation area, 50% in production, and 20% in productivity by 2035. It emphasizes improved varieties, value addition, processing, and market linkages. Similarly, the National Nutrition Policy (2072 BS) seeks better nutritional status through diversified and nutritious food availability. The policy promotes millet and nutrient-rich crops in balanced diets and backs millet flour fortification with micronutrients. However, despite these well-defined policies, effective implementation has encountered challenges stemming from various factors:

- Inadequate coordination and collaboration among diverse stakeholders, including government bodies, research institutions, farmer groups, private sector entities, NGOs, and donors, have hindered progress. This lack of synergy can result in redundant efforts, conflicting strategies, and operational inefficiencies (Gyawali 2021).
- Rice and wheat are also more widely available and subsidized by the government in some countries, making them cheaper and more accessible than millet (WFP 2022).
- Insufficient resources, encompassing financial allocations, human capital, infrastructure, and technological capabilities, have constrained the efficacy and scope of policy implementation and monitoring efforts (Joshi and Joshi 2021).
- Political commitment and stability gaps have posed obstacles, impacting the sustainability and continuity of policy initiatives. Interference and corruption within political realms have further eroded transparency and accountability within the policy framework (Joshi and Joshi 2021)
- The absence of evidence-based research and rigorous analysis has led to suboptimal policy design and evaluation. Policy outcomes may suffer when decisions are based on assumptions, opinions, or personal interests rather than concrete data and information (Khadka et al 2016)
- The involvement and awareness of target groups, such as millet farmers and consumers, must be improved. It may diminish the acceptance and endorsement of policies and their potential outcomes. Sociocultural factors also play a role in shaping the preferences and behaviors of these target groups (Gyawali 2021)

Market Constraints: Millets farmers are grappling with challenges that hinder their ability to tap into markets and capitalize on value-addition opportunities effectively. One prominent issue is the need for access to markets and processing facilities, which directly impacts their ability to sell their produce at reasonable prices. Unfortunately, Millets are often sold at lower prices or relegated to uses like home consumption or animal feed.

The lack of established standards, certifications, branding strategies, proper packaging, unambiguous labelling, efficient distribution networks, and promotional efforts all contribute to Millet's struggles in the market (Dos-Santos, 2020). Another crucial missing link is the scarcity of comprehensive market information and connections between various stakeholders in the millet supply chain. The disconnection between millet producers, processors, traders, and consumers exacerbates the challenges all parties involved face. Similarly, in market failures are also observed that has limit consumers from obtaining reliable information regarding traditional variety characteristics (Pallante et al 2016).

From the consumer's perspective, millets are often considered a poor people's crop or a famine food and has low social status compared to rice, wheat, and maize. Millet consumption is also declining due to changing food habits and urbanization (de Bruin et al 2021). There is a need for more awareness and promotion of millet as a healthy and nutritious food that can contribute to food security and malnutrition reduction. A recent study shows that the preference of tourists towards "*Dhido,*" a traditional dish made from millet flour, has increased its demand in recent years (Gyawali 2021).

Technological constraints: Millets are labor-intensive and drudgery-prone crop, requiring manual harvesting, threshing, dehulling, milling, and processing (Naik et al 2022). These operations are time-consuming and tedious, often resulting in low yields and quality losses. Manual processing exposes millet to contamination and spoilage by insects, rodents, fungi, and bacteria (Datta Mazumdar et al 2022). There is a lack of improved seed varieties, innovation, and land management practices to enhance millet productivity and quality. Millet is often grown in marginal lands with poor soil fertility, erratic rainfall, high temperatures, and pest and disease infestation. Millet farmers have limited access to quality seeds, fertilizers, pesticides, irrigation, mechanization, and extension services (Gyawali 2021). There is also a lack of appropriate technologies and equipment to reduce the labor and drudgery involved in millet processing and improve millet products' efficiency and hygiene (Shrestha et al 2020). Most of the existing millet processing technologies are based on traditional methods or adapted from wheat and rice milling technologies. These technologies are unsuitable for the small size, hard texture, and diverse shapes of millet grains. They often result in high energy consumption, low milling recovery, poor product quality, and high wastage (Joshi et al 2023).

A case study by Shrestha et al (2020) in Nepal examined the gender roles and drudgery of millet production and processing in the mid-hills. They found that women farmers were involved in almost all stages of millet production, such as land preparation, sowing, weeding, harvesting, threshing, dehulling, and milling. They also found that women farmers spent more time and energy than men farmers in these activities, especially in the post-harvest processing of millets. They reported that women farmers faced various challenges and drudgery in millet production and processing, such as physical fatigue, health problems, low productivity, low income, and lack of access to improved technologies and services. They suggested that empowering women farmers with improved technologies and skills could enhance their livelihoods and food security.

Behavioral constraints: Millet has a negative perception among many people as a crop only for festivals, rituals, or poor people (Kane-Potaka et al 2021). This is because marginalized communities traditionally consumed millet during famine or scarcity. Millets are also associated with specific religious or ethnic groups with lower social status in some societies (Prasad et. al 2010). Millet is often considered inferior to rice or wheat, which are seen as more modern, refined, and prestigious (Kane-Potaka et al 2021).

There is a lack of awareness and appreciation of the nutritional and health benefits of millets among consumers. Millets are rich in protein, fiber, minerals, antioxidants, and phytochemicals that can prevent or manage chronic diseases such as diabetes, obesity, cardiovascular problems, and cancer (Anitha et al 2021, Anitha et al 2021).

Another pressing challenge is disappearance of local culinary recipes and traditions that use millet as an ingredient. Due to urbanization, globalization, and changing lifestyles, many people have lost their connection with their ancestral food culture and heritage (Adhikari and Dangol 2013). Millet is often replaced by other cereals or processed foods that are more convenient, fast, and appealing (Hawkes et al 2017).

In following subsection, we perform a SWOT analysis based on the existing literature review on contemporary context of millet production and consumption in Nepal. (S: Strength, W: Weakness, O: Opportunities and T: Threats)

		Production/supply side	Consumption/demand side
Socio-cultural	S	• Socially acceptable in several ethnic communities of Nepal • Traditional knowledge to cultivate in Nepal • Linked with indigenous and local customs and norms	• Know how to consume in Nepalese rural households • Millet has many benefits, such as being rich in protein, iron, calcium, zinc, and antioxidants, as well as being gluten-free, drought-tolerant, and adaptable to different soils and altitudes (Saxena et al 2018) (Kumar et al 2021) • Linked with heritage of several ethnic and indigenous groups (Khanal 2022)
	W	• Requiring high labour input mainly during transplanting, weeding, harvesting, threshing, and grinding (Khadka et al 2016). • Millets are more challenging to process initially compared to rice and wheat, with the most demanding processing required for minor millets • (Joshi and Shrestha 2019, Pandey and Bolia 2023)	• Consider socio culturally inferior (Joshi and Shrestha 2019). • Less palatable in traditional culinary practice (Pandey and Bolia 2023) • Disappearance of local cuisine (Adhikari and Dangol 2013)
	O		• Gluten free (Kumar et al 2021), • Population growth (Li and Siddique 2018) • Changing costumer attitude with rise in income and literacy (Thapa et al 2019)
	T	• Decreasing agricultural land (FRTC 2022)	• Compete with cheaper junk food option • Consumer ignorance of nutritional value
Economic	S	• Low volume production in scattered area	• Relatively cheaper and healthier option of food

		Production/supply side	Consumption/demand side
	W	• Lack of knowledge and investment for processing technology (Joshi et al 2020) • High prices of hybrid varieties and poor economic conditions of small and marginal farmers is preventing them from using improved varieties. • Lack of financial facilities (credit and insurance support) (Pandey 2022)	• Low economic evaluation of crops compared to its agroecosystem service. • Farmers are not getting good prices for their products. • Informal value chain • Poor shelf life of millet flour (especially pearl millet) (Pandey and Bolia 2023b) • Grain colour and astringent flavour (Pandey and Bolia 2023b) • Technological interventions are required to handle some of the limitations of small millets like possibility of rancidity during storage (Pandey and Bolia 2023a) • and presence of antinutrients like phytic acid [AP] • Millet based enterprise lack proper linkages • Market failures (Pallante et al 2016)
	O	• Low investment required for water and inputs as majorly grown in rainfed condition (Pandey and Bolia 2023) • Rice and maize yield very susceptible to decline in climate change scenario (Nelson et al 2009). However millets are tolerant to stresses and require less investment in adaptation measures.	• Baby food ingredient • Certification (mountain food, gluten free, vegan, organic) • Use modern culinary science to make it more palatable and attract urban consumer • UN international year of millets • National Policy initiatives (NAP 2016, ADS 2072, NNP 2072) • Public procurement • Growing middleclass costumers • Innovation in machineries (Pandey and Bolia 2023a)
	T	• Hybrid varieties of other cereal crops • Farmers have limited access to quality seeds, fertilizers, pesticides, irrigation, mechanization, and extension services (Gyawali 2021) • Lack of research in agronomic practices (Joshi and Shrestha 2019, Khadka et al 2016, MFSC 2014)	• Cheaper import from neighboring country
Environmental	S	• Fit easily into integrated practice (mix cropping) • Intercropping system is profitable (Paudel 2016) • Ability to tolerate and withstand stress. Less pressure to resources (ie, water) • Low input requirement	• Local produce, low carbon footprint
	W	• -	• -
	O	• Agroecological agronomic package of practices	• Contributes to Agrobiodiversity conservation
	T	• -	• -

Towards a Framework for Sustainable Food Systems; Case of Millets

Based on the earlier section of SWOT analysis of consumption and production aspects of Millet, transformative initiatives are recommended

Behavioral

Linking habit, heritage, and health: At the Himalayan Policy forum in May 2023, an example was shared regarding Natto, a fermented Japanese dish made from soybeans. It was explained how, despite its unpleasant taste, the Japanese actively seek it out for consumption no matter where they are in the world. It was emphasized that, similar to Natto, millets should be linked with habits established from early childhood, health and nutrition benefits, and the cultural heritage of the Nepalese. Such an approach will have a sustainable impact.

Millets can be linked with habit and health by encouraging their consumption among children through child health workers during health advice sessions to new parents, integrating it in school midday meal program and organizing dedicated campaigns. Millets could be further associated with heritage by acknowledging indigenous community for their contribution in preserving the traditional knowledge and considering traditional millet dishes as Nepalese delicacies in international platform.

Technological

Seed system and varietal development: Seed system of all the millets are highly informal in Nepal (Baniya et al 1970; Gurung et al 2020) In a study on genotypes of finger millet, high level of diversity among the genotypes was observed for grain yield indicating their superior trait value suggesting for further research for breed improvement (Dhami et al 2018). Gurung et al (2020) suggest that to address limited knowledge and skill of farming communities in seed selection, processing and storage, strengthening of local seed system could be carried by our research and development work on the traditional mountain crops focusing on community seed banks and other community-based approaches to promote linkage with formal seed system. Similarly, to improve seed genotypes, Ghimire et al 2018 suggest that research institutes can employ an innovative method of using participatory diversity kits to promote farmer selection for immediate benefits.

Agroecological farming approach: As millets are neglected crops, they receive limited attention in research overall. To establish resilient millet farming system in Nepal, it is suggested to research in agroecological agronomic package of practices of millet farming and make technologies available throughout the nation.

Agriculture mechanization: One of the challenges in the millets value chain is post-harvest handling. Proper research is needed to develop suitable machinery that is compatible to local setting and can reduce drudgery associated with millet processing. Potential machinery includes the multi feed dehuller build by Tamil Nadu Agricultural University and Central Institute of Agricultural Engineering (Pandey and Bolia, 2023a), Finger Millet Harvesting Machine developed by Department of Automobile and Mechanical Engineering, Tribhuvan University Institute of Engineering, pedal millet thresher developed by Nepal Agricultural Research Council.

Research in culinary science: The limited consumption of millets in urban contexts often stems from a lack of recipes. Addressing this issue can involve research in culinary science, including the collection of traditional recipes and the study of fusion cuisine in gastronomy. Examples like the *Raithanee*[6] restaurant (Thomas Heaton 2019) demonstrate how this approach can be successful.

6 Raithaane is an urban restaurant situated in Kupondol, which serves food, derived from diverse ethnic groups of Nepal.

Market

Rebranding: Millets have long been associated with lower socio-economic status, perpetuating a stigma around their consumption. To counter this, rebranding millets is recommended. Millets are gluten-free and vegan food options, and when grown using agroecological practices, they can be labelled as organic, fairtrade, and mountain products in Nepalese context. Leveraging these certifications and labels can help change the perception of millets among consumers.

Business incubators for millet base enterprise: Millets based products such as based baby food, lunch item, brewery, and other food item often rely on traditional knowledge for production and marketing. Incentives such like business fellowships for small and medium enterprises can enhance production quality and marketing capabilities, enabling these enterprises to reach a wider audience.

Policy

Financial investment: Government should invest in research on varietal improvements, post-harvest processing technologies, appropriate machinery development, and market structure and infrastructure development of millet to create enabling environment for millet producers.

Awareness raising campaign: Public awareness campaigns to educate consumers, farmers, and food businesses about the economic, nutritional, and environmental advantages of millets. This will also contribute to counter market failures.

Incentives: Through government programs, incentives such as support price, subsidies, public procurement, and insurance should be provided to the millet producer to encourage production. Local government can play crucial role in this regard.

Mainstreaming all the millets: The Nepal Agriculture Research Council have identified 11 millet domesticated millet crops. However, there has been limited research on these millets concerning their traditional agronomic practices, varietal development, post-harvest handling, and food technology. Additionally, disaggregated data on production and yield for different types of millet is also lacking. To mainstream millets, relevant agencies must address these gaps.

Concluding Remark for Solution

As a result of this research, several recommendations emerge to facilitate this transformation. Firstly, it is crucial to establish a strong connection between millets and elements of habit, heritage, and health to encourage behavioral shifts toward millets consumption. Moreover, technological advancements are important in enhancement of seed systems, varietal development, the adoption of agroecological farming practices, mechanization in agriculture, and increased research in culinary science should be prioritized.

In terms of market perspective, it is essential to embark on transformative initiatives such as rebranding millets through ethical and environmental certification and fostering business incubators for millets-based enterprises. Lastly and most importantly, policy intervention plays a critical role in addressing challenges costumer behavior, technology, market failures. It can create enabling environment for revival with approaches such as financial investments, awareness-raising campaigns, the provision of various incentives, and the mainstreaming of all types of millets.

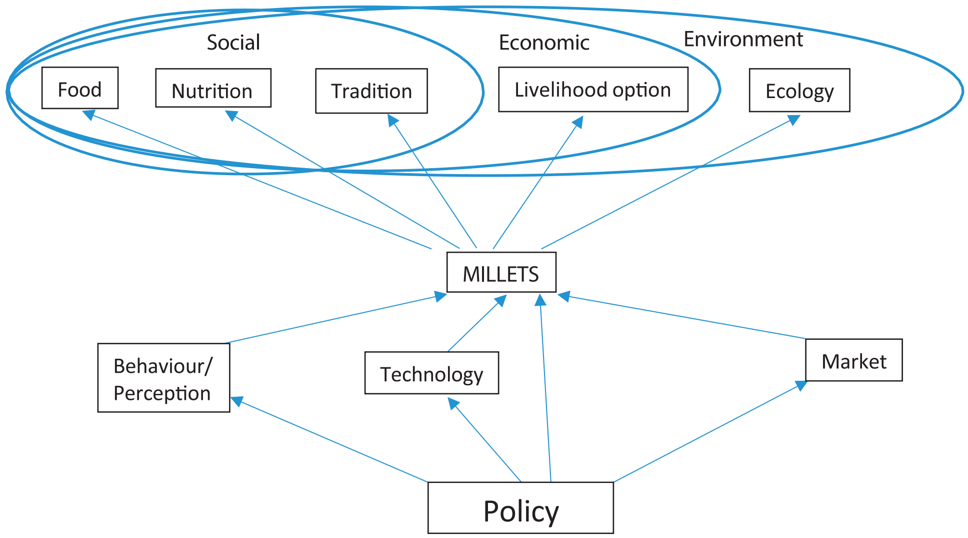

Figure 3: Factors influencing the integration of Millets into the food system and the impacts of Millet- based food systems.

By implementing these multifaceted recommendations drawn via comprehensive strategic way, we can pave the way for a more sustainable and inclusive food system that harnesses the potential of millets and other FSF to address pressing societal, economic, and environmental challenges.

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An Economic Analysis on Production of Underutilized Cereal Crops in Kalikot, Nepal

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Abstract

Despite geographical and nutritive advantages, health benefits, and capacity to enhance the socio-economic condition of local people along with uplifting their livelihoods, underutilized crops are not given much priority in government programs. This study was conducted to analyze the status of production of underutilized crops their promotion in Nepal. The study on production was conducted in Kalikot district by selecting 62 producers as respondents from Kalikot district. Primary data were collected using pre-tested interview schedule and focal group discussion. Comparative study among different underutilized crops was done. Result showed that average cost of finger millet cultivation per hectare was NRs 58315 and per kg cost at farm level was NRs 50. Average productivity of finger millet was 1.16 mt/ha. Average B:C ratio was 1.24 with average return and profit per hectare were NRs. 70860 and NRs 12545 respectively. For Barley, average cost of cultivation per hectare was NRs 42544 and per kg cost at farm level was NRs 33. Average productivity of barley was 1.29 mt/ha. Average B:C ratio was 1.42 with average return and profit per hectare were NRs 60593 and NRs. 18049 respectively. While accessing the economics of buckwheat the average cost of cultivation per hectare was found to be NRs 34723 and per kg cost at farm level was NRs. 31. Average productivity of buckwheat was 1.11 mt/ha. Average B:C ratio was 1.36 with average return and profit per hectare were NRs 44492 and NRs 9770, respectively.

Keywords: Cost of production, finger millet, Kallikot, productivity, economics

Introduction

Nepal is a developing country and with its enthralling richness in biodiversity, Nepal is ranked 25th position in Global biodiversity richness and at 11th position in Asian biodiversity richness (MoFE 2018). Nepal occupies about 0.1 % of the global area, but harbors 3.2 % and 1.1 % of the world's known flora and fauna, respectively, along with 118 types of ecosystem, out of which, agricultural ecosystems accompany the major types (MOFSC 2014). Due to the increasing use of technology and professionalism in agriculture and the expansion of the service sector, the involvement of the population in the agricultural sector is gradually declining.

Nepal possesses enormous opportunity and potentiality for growing and exporting variety of crops, due to the favorable climatic condition and wide range of tropical variations. Despite geographical and nutritive advantages, health benefits, and capacity to enhance the socio-economic condition of local people along with uplifting their livelihoods, underutilized crops are not given much priority in the government progrmas, while local valuable crops are losing their essence due to several constraints such as lack of awareness, prioritization, information, and value addition.

Underutilized crops (UUC) are domesticated plant species that have been used for centuries or even millennia for their food, fiber, fodder, oil or medicinal properties, but have been reduced in importance over time owing to particular supply and use constraints. These can include, inter alia, poor shelf life, unrecognized nutritional value, poor consumer awareness and reputational problems (famine food or "poor people's food"). Along with that, modernization of agricultural practices many of these crops have become neglected and genetic erosion of their gene pools has become so severe that they are often regarded as lost crops (Dahanayake 2015). Underutilized crops fall within the broad basket of “minor crops”. In fact, these crops are those grown primarily in their center of origin/diversity by traditional farmers and are still important for the subsistence of the local communities. Underutilized crops are often used to describe the sorts of plant species that are grown, eaten or used very little, or very locally, but have great promise. These crops are also often called as neglected; orphan; minor; promising; niche and traditional one or underutilized. A widely accepted definition of these crops is “species with underexploited potential for contributing to food security, nutrition, health, income generation, and environmental services” (Singh 2021).

The demand for underutilized crops is increasing in the present era on the global scale. The number of scientific research on the nutritive importance of such crops has been carried out and people had known about the value of such crops. Fair profitability as well as ensuring proper productivity are the only way to attract farmers to UUC cultivation. For improving the livelihood of farmers at a satisfactory level with sustainable production of UUC, efficient cost structure and its appropriate market-investment analysis must be understood (Adhikari et al 2017, Dahanayake 2015)but their role in achieving nutrition security is not adequately understood, and they do not feature in food and nutrition policies and programs of the countries of the Hindu-Kush Himalayan (HKH).

Materials and Methods

Selection of the study area

The study on producers was conducted in the Kalikot district of Nepal, which lies in the Karnali province. Most of the area is covered by temperate (39.4%) and subalpine (37.3%) climatic zone. Dharali, Rautbada, Badalbada, Bhadpani, Dalitbad, and Rakalbada of Tilagupha urban municipality were selected as the study area.

Selection of farmers

From all the six wards of underutilized crop growing areas, a total of 62 farmers were selected as a sample. All the farmers included from each village were selected randomly as possible.

Sources of information

Both the primary and secondary data were used. The pre-tested systematic questionnaire was used to obtain the primary data from the randomly selected UUC producers. Required data was obtained through household face-to-face interviews, focus group discussions (FGD), and key informant interviews (KII). The secondary information was obtained through reviewing different publications.

Field survey

The field survey was conducted in the month of October and November 2021. Respondents were interviewed by visiting their homes. The interview timing was fixed as per the farmer's convenience. Regular checking and validation of the information were done immediately after filling out the interview schedule. Focus group discussions, informal discussions, and key informants' interviews were also done during the field survey.

Methods and techniques of data analysis

The information of producers collected from the field was entered in the spreadsheet through Kobo tool box. Data import, management, and analysis were done by using computer software packages like Stata and Microsoft Excel. Both descriptive and analytical methods were used to analyze the data.

Cost of production

All the major factors involved in the production process were included in the estimation of production cost, namely labor costs, seed cost, and manure.

Total Cost = Cost of (Seed + Manures + Labor)

Benefit-cost analysis

For benefit-cost analysis, the total cost of production of various underutilized crops and total return from produce was used. For calculating total return, the value obtained from produce sales was accounted. So, the B/C ratio was calculated using the following formula:

$$\text{B/C ratio} = \frac{\text{Total Return}}{\text{Total Cost}}$$

Decision rule,

a. If the B:C ratio is <1, then the enterprise is considered to be a failure and undesirable.
b. If the B: C ratio is > 1, then the enterprise is considered to be profitable and desirable.
c. If the B: C ratio is = 1, then the enterprise is in a state of neither profit nor loss.

Results and Discussion

The socio-economic characteristics of the respondents include population and gender distribution, family size, economically active population, occupation, land holding, and farming experience are presented below.

Population distribution and family size

The total population of the sampled household was estimated to be 446, of which 46.64% were male and 53.36% were female. The average family size was 6.86, with the average male and female sizes of 3.20 and 3.66, respectively. Of the total household, 83% of households were male-headed and only 17% of households were female-headed.

Economically active population

The government of Nepal considers the population belonging to the age group of 15-59 years as an economically active population. The total population of sampled households was categorized into three age groups ie <15 years, 15-59 years and >59 years. It was found that 64.35% of the population was economically active.

Educational status of the household head in the study area

Educational status was categorized into four categories. The majority of the household heads seem to be illiterate with the appearing percentage of 50.77. While literacy percentage, on the other hand, seems to be 40. The percentage of high school attendees reaches 4.62 which is the same obtained percentage of College/University level attendees.

Major occupation of the family

The major occupation of the family influences the decision-making approach and process of the household head and family. It provides information about different sources of household income, which can be help develop and implement programs for farming families. The family occupation was categorized into five categories ie agriculture, service, business, off-farm wages and remittance. The majority of the sampled households are involved in agriculture comprising 83.08% of total sampled households. The business was found to be the second most important major source of income, comprising 7.69% of the total sampled household. About 4.62% of households are involved in services while 3.08% of the households are involved in off-farm wages as their family occupation. A very minute number of families are involved in remittance with 1.54% households.

Farming experiences

Farmer's experience greatly affects the quality and quantity of production, adoption of new technology and technology transfer rate. So, farming experience is also an important variable in determining the commercialization and successful cultivation of the crop. Farmer's UUC cultivation experience was categorized into three categories. Most of the UUC farmers were found to have UUC farming experience of 18-41 years with the share of 72.31% of the total sampled household, while farmers with less than 18 years of experience and farmers with more than 41 years of experience comprise 16.92% and 10.77% respectively. Framers expressed that it has always been part of their culture and cultivation system, for many generations. And, many of them also expressed that one of the big reasons behind their involvement in UUC cultivation is their relation with it.

Cost of Production

Human labor was an important and largely used input in the production of underutilized crops. It was required for different operations such as land preparation, seed sowing, weeding, organic manures application, harvesting, threshing and cleaning etc. It was computed in terms of man day and converted to monetary terms evaluating at prevailing wage rate. The costs of human labor in finger millet, barley and buckwheat production per hectare were estimated at NRs 30518.57, NRs 12687.21, and NRs 11629.63. Labor costs accounted for about 52.33%, 29.82%, and 33.49% of the total variable cost in finger millet, barley, and buckwheat production respectively. Per hectare costs of the bullock were about NRs 13807.74, NRs 11161.11, and NRs 7778.15 which accounted for about 23.67%, 26.23 %, and 22.40 % of the total variable cost of finger millet, barley and buckwheat production respectively. Per hectare costs of organic manures were about NRs 12907.77, NRs 14878.34, NRs 13572.36 which constituted 22.13%, 34.97%, and 39.08% of the total variable cost of finger millet, barley and buckwheat production. As regards the production of finger millet, barley, and buckwheat per hectare costs on seed accounted NRs. 1080.67, NRs 3817.83, and NRs 1742.38 which constituted about 1.85%, 8.97%, and 5.02% of total variable cost of production (**Table 1**).

Table 1. Average cost of production of selected UUCs (NRs /ha)

Items of cost	Finger millet (n=37)	Barley (n=62)	Buckwheat (n=26)
A. Inputs			
Seed	1080.67 (13.90)	3817.83 (107.05)	3342.38 (932.93)
FYM	16707.77 (2834.12)	14878.34 (1763.80)	13572.36 (3711.09)
Bullock	10007.74 (362.56)	11161.11 (1771.5)	7778.15 (4911.75)
B. Labor			
Land Preparation and plantation	7141.74 (3281.18)	5613.11 (489.62)	2454.68 (1595.51)
Weeding, fertilization and earthing up	15777.24 (6916.21)	0	0
Harvesting, Cleaning, Grading and Storage	7599.60 (1075.21)	7074.09 (1316.66)	7574.95 (1634.76)
Total Production labor	30518.57 (10456.57)	12687.21 (1368.70)	10029.63 (2486.73)
Grand total cost	58314.75 (10490.86)	42544.48 (2904.23)	34722.51 (6532.54)

Note: Figures in parentheses indicate standard deviation

Farmers in the study area were growing finger millet, barley, and buckwheat on an average at 0.06, 0.12, and 0.04 hectares of land with average productivity of 1.16 mt/ha, 1.29 mt/ha, 1.11 mt/ha and 2.60 mt/ha (**Table 2**). Per hectare gross return was calculated by multiplying the total amount of yield by their respective per unit farm gate price of underutilized crops. Per hectare, gross returns were estimated as NRs 70859.68, NRs 60593.26, and NRs 44492.31 for finger millet, barley, and buckwheat production respectively. Cost and gross margin were also estimated on a per kilogram basis. The average cost of finger millet cultivation per hectare was NRs. 58314.75 and per Kg cost at farm level was NRs 50.37. Average B:C ratio was 1.24 with average return and profit per hectare being NRs 70859.68 and NRs 12544.93, respectively.

Table 2. Economic analysis of UUC production in the study area

Measuring criteria	Finger millet (n=37)	Barley (n=62)	Buckwheat (n=26)
Area (ha)	0.06 (0.02)	0.12 (0.07)	0.04 (0.02)
Productivity (mt/ha)	1.16 (0.04)	1.29 (0.06)	1.11 (0.05)
Gross return (NRs/ha)	70859.68 (2136.64)	60593.26 (6678.27)	44492.31 (2168.30)
Total variable cost (NRs/ha)	58314.75 (10490.86)	42544.48 (2904.23)	34722.51 (6532.54)
Gross margin (NRs/ha)	12544.93 (10479.21)	18048.77 (6518.79)	9769.79 (7967.16)
Average variable cost (NRs/kg)	50.37 (9.00)	33.09 (2.87)	31.26 (5.89)
Benefit cost ratio	1.24 (0.20)	1.42 (0.16)	1.36 (0.46)

Note: Figures in parentheses indicate standard deviation

Production problems

After discussion with the representative of Agriculture Development Office (ADO), Kalikot and FGD with farmers and KII, five major production problems were identified. Then, farmers were asked to rank those problems based on their experience. Unavailability of farm inputs, lack of scientific cultivation knowledge, lack of farm labor, lack of subsidy and lack of irrigation were recognized as the major five problems of UUC cultivation. Among those five problems, lack of irrigation was recognized by farmers as the most important problem with an index score of 0.70. Lack of irrigation was followed by unavailability of farm inputs, and lack of scientific cultivation knowledge, with the index score of 0.68 and 0.66, respectively. Details of production problems of UUC cultivation are presented in **Table 3**.

Table 3. Major production problems of UUC cultivation faced by farmers

Description	Index score	Rank
Lack of Irrigation	0.70	I
Unavailability of farm inputs	0.68	II
Lack of scientific cultivation knowledge	0.66	III
Lack of Subsidy	0.48	IV
Lack of farm labor	0.47	V

Farmers' perception on drivers for commercialization

After discussion with the representative of ADO Kalikot and FGD with farmers, KII and some literature review, five major expectations of farmers from the governmental and non-governmental organizations for commercialization and strengthening of underutilized crops farming were identified. Among them, market creation was recognized as the most important condition with a total score of 4. Market creation was followed by processing facility and timely availability inputs with a total score of 3 and 2. The details of farmers' perceptions on necessary conditions for commercialization and strengthening of underutilized crops farming are presented in **Table 4**.

Table 4. Farmers' perception of conditions for better commercialization of UUC using pairwise ranking matrix

	Market creation	Timely availability of inputs	Training on technology	Processing facility	Provision of subsidy	Total Score	Rank
Market creation		Market creation	Market creation	Market creation	Market creation	4	I
Timely availability of inputs			Timely availability of inputs	Processing facility	Timely availability of inputs	2	III
Training on technology				Processing facility	Training on technology	1	IV
Processing facility					Processing facility	3	II
Provision of subsidy						0	V

Conclusion

The study analyzed economic aspect of production of UUCs, along with production problems. The average cost of finger millet cultivation per hectare was estimated to be NRs. 58314.75. The average cost of human labor was the highest contributor to the total cost of cultivation with a share of 52.33% of the total cost. After the cost of labor, the cost of FYM and the cost of bullock were the highest contributors to finger millet production cost, with the share of 28.65% and 17.16%, respectively. The cost of seed was the lowest contributor to total cost with a share of 1.85% of the total cost. The average return from the finger millet cultivation per hectare was found to be NRs. 70859.68 and the average profit per hectare was estimated to be NRs 12544.93 and average B:C ratio was estimated to be 1.24. The average cost of barley cultivation per hectare was estimated to be NRs 42544.48. After the cost of FYM, the cost of labor and the cost of bullock were the highest contributors to barley production cost, with the share of 29.82% and 26.23%, respectively. The average B:C ratio was estimated to be 1.42 over the variable cost. Similarly, the average cost of buckwheat cultivation per hectare was estimated to be NRs 34722.51. The cost of organic manures was the highest contributor to the total cost of cultivation with a share of 39.08% of the total cost. The average return from the buckwheat cultivation per hectare was found to be NRs. 44492.31 and the average B:C ratio was estimated to be 1.36 over the variable cost.

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Millets and their Products in the Nepalese Markets

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Abstract

Millets, which include various cereal crops like pearl millet, finger millet, proso millet, sorghum, barnyard millet, little millet, and foxtail millet, have gained increasing attention on the global stage owing to their exceptional nutritional profile, gluten-free attributes, and adaptability to various environmental conditions. In Nepal, the prominence of finger millet as a staple crop, particularly in challenging terrains, underscores its pivotal role in addressing food security concerns. The paper explores the multifaceted applications of millets, spanning from their traditional utilization in staple Nepali foods to their incorporation into contemporary culinary delights. Furthermore, it highlights millets' promising prospects as drought-resistant crops, displaying resilience to adverse conditions and contributing significantly to global food security amidst climatic variations. Moreover, market trends depict a rising demand for gluten-free and nutrient-rich alternatives worldwide, albeit facing challenges such as limited product shelf life and insufficient governmental recognition. Strategies proposed to harness the potential of millets include promoting domestic production, enhancing traditional millet-based beverages, and advocating for awareness campaigns and research initiatives. Emphasizing the collaborative efforts required, the paper underscores the importance of leveraging millets' potential to address agricultural, nutritional, and economic challenges on both the global stage and within the Nepali context. Through an examination of global trends and local implications, this review underscores the significance of millets in addressing contemporary challenges, positioning them as a valuable asset in achieving agricultural resilience, nutritional enhancement, and economic advancement.

Keywords: Millet products, millet market, product price, nutritional resilience

Introduction

The global and Nepali millet markets have recently gained significant attention due to the growing awareness of the numerous benefits offered by these small-seeded, highly versatile grasses. Millets, which encompass a diverse group of cereal crops such as pearl millet, finger millet, proso millet, sorghum, barnyard millet, little millet and foxtail millet, have been cultivated for centuries and are known for their high nutritive value. These crops have been a staple in many regions around the world, including Nepal, where finger millet holds a prominent position as the fourth most important crop in terms of both production and cultivation area (Pallante et al 2016, MOALD 2023).

The global millet market is experiencing a significant resurgence, driven by the recognition of millets as a promising alternative to traditional grains. Millets are gaining popularity due to their appealing characteristics: they are highly nutritious, gluten-free, and have a low glycemic index, making them an ideal choice for health-conscious consumers, especially those dealing with conditions like celiac disease, diabetes, and high blood sugar. This renewed interest is underscored by a substantial increase in millet production, with countries such as India, Nigeria, and China leading the way (FAO 2023).

In the context of Nepal, millets play a vital role in ensuring food and nutrition security, particularly in the mid-hill and mountain regions. These small-seeded grains serve not only as a source of nutrition for both humans and animals but also as a resilient solution for filling specific agricultural niches and addressing the challenges posed by marginal lands and stressful growing conditions (Koirala 2020). This dual significance of millets in both global and local contexts highlights their potential to address critical challenges in the ever-evolving landscape of agriculture and nutrition.

As we analyze the dynamics of the millet market, both globally and within Nepal, it becomes evident that the potential for these small-seeded grasses is far-reaching. Millets offer a sustainable and nutritious food source, contribute to local agrifood systems' efficiency and resilience, create livelihood opportunities for small-scale farmers, and bring diversity to the global food system (FAO 2023). This paper explores the multifaceted aspects of millets in the market, shedding light on their promising prospects and their potential to address critical global and local challenges. In doing so, it will draw on the rich heritage and resilience of these crops, which are deeply rooted in ancestral traditions and have long survived harsh growing conditions.

Utilization of Millets

Millets have long been recognized for their diverse and valuable uses, both globally and within the unique context of Nepal. Their utilization extends across a wide spectrum of applications, ranging from traditional staple foods to modern culinary innovations. As we explore the multifaceted landscape of millet utilization, it becomes evident that these small-seeded grains play a pivotal role in food culture, nutrition, and livelihoods.

Globally, millets are gaining resurgence as a versatile source of nutrition and sustainability. They are used in a wide array of products, such as bakery and confectionery goods, protein and nutritional bars, breakfast cereals, functional beverages, dairy substitutes, frozen desserts, dietary supplements, sports nutrition, and infant nutrition, among other items (FAO 2023). This resurgence is marked by the emergence of millet-based products in the consumer market, catering to the preferences of various populations, including vegetarians and vegans who seek the high protein content of millets (APEDA 2023). The global millet market is also witnessing the rise of millet-based infant foods, bakery products, and traditional beverages like millet beer.

In the context of Nepal, millets hold a special place as they fulfill the basic nutritional needs of many, especially in remote and marginalized areas. Finger millet dhindo (**Figure 1**), a beloved Nepali staple, prominently featured on menus across local hotels and restaurants, reflects the cultural significance and widespread appreciation of this traditional dish, Other traditional food items made of millets include porridge (khole), bread (roti, see **Figure 2**), rice (bhaat) and various improved modern food items like pancakes, cakes, cookies, noodles, and super flour (Koirala 2020). Additionally, millet is used in making fermented beverages like raksi, which contributes significantly to the local economy. The nutritional composition of millets, including their high fiber content, makes them an ideal choice for people who rely on these grains for sustained energy during hard work.

Furthermore, millets are renowned for their exceptional nutritional value, offering fiber, calcium, iron, and other essential nutrients (Koirala 2020). These grains are well-suited for individuals with gluten intolerance and are recognized for their easy digestibility. Despite their nutritional benefits, the consumption of millets has faced challenges due to changing food habits and the preference for refined grains.

Figure 1. Finger millet dhindo being popularly offered by Nepali hotels and restaurants

Figure 2: Finger millet bread, a popular breakfast or snack choice in Nepal

Millets in Nepal serve multiple purposes beyond just being food. The straw from finger millet is as important as food for animals all year round, helping them stay healthy and supporting farmers' incomes. Besides being used in traditional meals like dhindo and roti, millets are also used in modern foods like multigrain bread, cakes, cookies, nimkin, and momo (Gairhe et al 2021). People in villages also use millet straw to make pillows. Additionally, the straw is also used for cooking fuel. All these different uses show how millets are important for Nepal's agriculture and the lives of its people.

Promises of Millets from Cultivation Perspective

As the global agricultural landscape faces increasing challenges posed by climate change, millets emerge as a promising solution for a sustainable future. Millet, a drought-tolerant crop, offers a ray of hope for farmers in regions with unpredictable weather conditions. In comparison to many other crops, millets possess distinct advantages, including resistance to drought and pests, making them resilient even in the harshest growing conditions and less fertile soils (GlobeNewswire 2023).

The unsustainable nature of rice and wheat production, primarily due to their intensive water requirements, is a pressing concern as freshwater resources deplete worldwide. With agriculture accounting for a substantial 70% of total water consumption, especially in Asia and Africa, the need for alternative crops with lower water demands becomes evident. Millets, thriving in dry climates with minimal water requirements, offer a sustainable solution as a new staple food. They present an opportunity to ensure food security for a rapidly growing global population, mitigating the impending challenges of water scarcity (APEDA 2023).

Moreover, as the world grapples with the adverse impacts of climate change, the resilience of millets shines through. Millets are photo-insensitive and capable of withstanding climatic fluctuations, making them a hardy and reliable crop. With a low carbon and water footprint, these grains can endure high temperatures and flourish in poor soils with minimal external inputs, a crucial characteristic in adapting to changing climates (APEDA 2023). The situation is no different in Nepal, where climate-smart crops like millets have earned their place. Millets are well adapted to diverse environments, serving as a superfood with a unique capacity to buffer against various stresses, both abiotic and biotic. These grains not only contribute to nurturing soils and ecosystems but also enhance biodiversity, aligning with their C4 plant classification. In times of crisis, millets can act as emergency crops, providing stability and sustenance. Easy to grow and store for extended periods, they are deeply rooted in the country's ancient cultures and traditions (Joshi et al 2023).

In light of these remarkable qualities, the promises of millets from a growing perspective are manifold. From offering resilience in the face of climate change to ensuring sustainable water use and promoting biodiversity, millets emerge as a beacon of hope for global agriculture and food security. These qualities resonate deeply in Nepal, where the adaptability and hardiness of millets make them a valuable asset in the country's quest for sustainable agriculture and resilience in the face of a changing climate.

Promises of Millets from Market Perspective

Millet has gained substantial attention in both developed and developing regions, primarily due to its numerous advantages from a market perspective. The growing demand for gluten-free and nutritionally dense food products has led to an increased consumption of millets in areas like Asia and Africa. Their nutritional superiority over traditional grains such as wheat and rice, combined with diverse color variations, including white, red, grey, and pale yellow, have contributed to their growing popularity (GlobeNewswire 2023). This transition toward millets is further accelerated by the rising public awareness regarding their beneficial impacts on human health and the environment.

A pivotal aspect of millet's market potential is its resilience in the face of climate change, which is increasingly affecting agriculture worldwide. With freshwater resources depleting, water-intensive crops like rice and wheat are being viewed as unsustainable (FAO 2023). In contrast, millets can be grown in arid conditions, require minimal water, and exhibit resistance to high temperatures. As a result, they have emerged as a sustainable alternative and key staple food, addressing issues related to food security for a substantial portion of the global population. Additionally, the market for millets is driven by the rising demand for gluten-free and nutritious food products worldwide. These grains are not only rich in protein but also serve as ideal options for vegetarians and vegans, contributing to the growth of this market segment (GlobeNewswire 2023). Furthermore, the growing trend of adopting healthier dietary choices and low-calorie alternatives is expected to drive the market share of millets even higher.

Incorporating millets into various food and beverage products is increasing, and the expansion of this industry is further facilitated by government support and initiatives aimed at addressing malnutrition (APEDA 2023). This superfood is not only a rich source of essential nutrients but also a versatile ingredient in various food categories. Gluten-free millet-based beers serve to consumers focused on reducing gluten intake, including those with celiac disease or gluten intolerance.

Nonetheless, the millet market faces challenges, including limited shelf life of millet products (APEDA 2023). Government agencies' insufficient recognition of millet products, especially in treating chronic diseases, may also hinder the expansion of this industry. Therefore, continued efforts to raise awareness about the nutritional benefits of millets and their potential to address emerging health and environmental issues will be crucial in driving their sustained growth.

Key Drivers of Millets Market

The market for millets has witnessed substantial growth driven by various influential factors, ranging from health and nutrition considerations to business profitability and evolving consumer preferences (**Figure 3**). In the Asia Pacific region, a visible shift towards healthier dietary choices among urban populations has contributed significantly to the rising consumption of millets (APEDA 2023). This trend reflects a broader global inclination towards well-being and nutrition.

Among the primary drivers is the exceptional health and nutritional value of millets, surpassing commonly consumed cereals like rice and wheat. Rich in essential nutrients such as calcium, iron, and dietary fibers, millets play a pivotal role in fortifying essential nutrients for healthy child growth (APEDA 2023). These attributes have led to an increased usage of millets in nutrition products, encouraging manufacturers to expand their business operations.

Moreover, the rise in lifestyle-related health issues like diabetes, obesity, and cardiovascular problems has boosted the demand for millets. These small-seeded cereals, high in protein and essential minerals like calcium and iron, are viewed as effective in preventing and managing such diseases (APEDA 2023). As dietary habits change and urban lifestyles evolve, the nutritional content of millets is increasingly seen as a means to combat health issues, driving their adoption.

The gluten-free property of millets presents lucrative opportunities for producing gluten-free and low glycemic index (GI) food products. Alongside grains like buckwheat and quinoa, millets find extensive use in preparing popular dishes such as waffles, pasta, pizza, and sandwiches (APEDA 2023). Changing consumer preferences towards low-cholesterol and fat-free alternatives, coupled with increased awareness of healthy diets, contributes to the increasing demand for gluten-free food products, motivating manufacturers to incorporate natural and gluten-free ingredients into their products.

Beyond health and nutrition, several additional drivers significantly contribute to the growth of the millet market. Business profitability stands out as a significant motivator, urging producers to explore millet's potential due to consumer demand for diversified food products. Mechanization in food preparation has simplified the inclusion of millets in various culinary offerings, aligning with market demands. Increasing awareness campaigns, promotional actions advocating millet benefits, dedicated marketplaces, and fairs have stimulated consumer interest and acceptance, fostering wider integration into diverse diets. The rising trend of fast-food culture and appealing packaging have propelled millets into quick, convenient meal options, catering to modern consumer lifestyles.

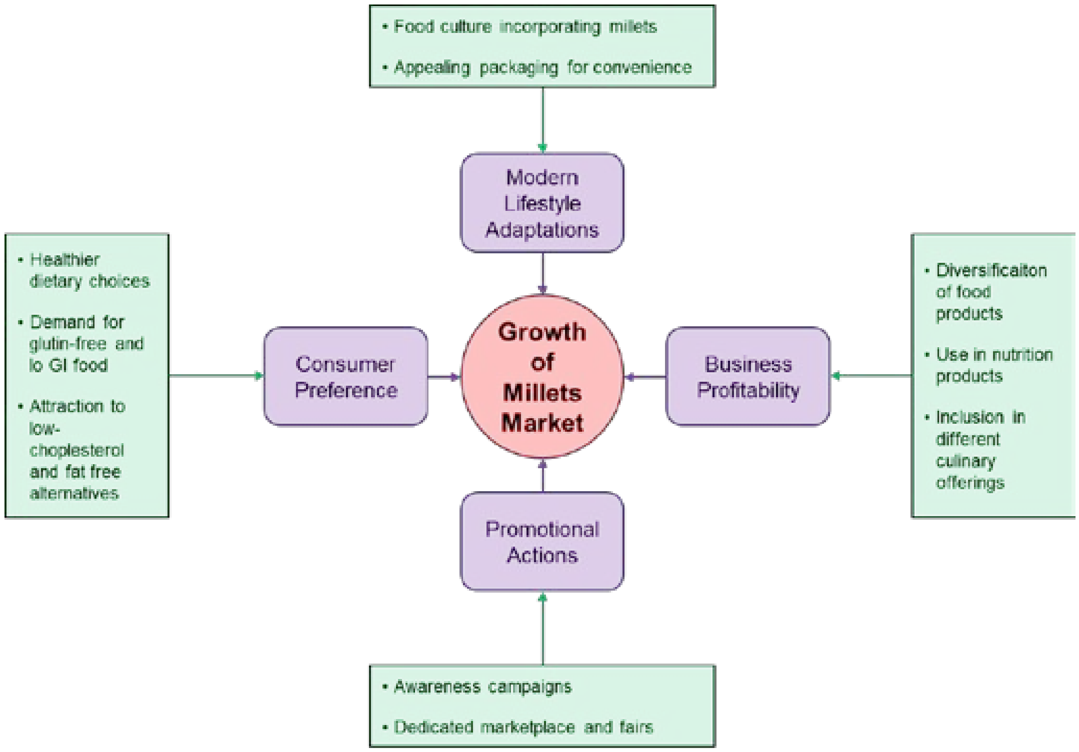

Figure 3. Key drivers of millets market growth

Global Millet Market Trends

The global millet market is projected to experience substantial growth, with data indicating a promising future. By 2033, the millet market is expected to reach a valuation of USD 44.1 billion, a significant increase from the anticipated value of USD 12.5 billion in 2023 (GlobeNewswire 2023). This remarkable expansion foresees a Compound Annual Growth Rate (CAGR) of 13.4% over the forecast period, highlighting the dynamic nature of the millet market (GlobeNewswire 2023).

A significant shift in consumer preferences towards healthier dietary choices has become a driving force behind the surging demand for millets. These small-seeded grains have gained immense popularity due to their gluten-free nature, catering to individuals with gluten intolerance and those committed to reducing their gluten intake (FAO 2023). This growing trend aligns with the global wave of health-conscious consumers actively seeking nutritious, gluten-free food products.

The growing awareness of millets' health benefits has played a pivotal role in expanding the market. Millets are nutrient powerhouses, boasting high levels of essential elements such as calcium, iron, fiber, and proteins. These attributes have transformed millets into an appealing choice for health-conscious consumers, contributing substantially to the upward trajectory of the millet market (APEDA 2023). Urban populations, particularly in the Asia Pacific region, have embraced millets as part of their dietary shift away from traditional staples like rice and wheat. The rise of urbanization has prompted a transformation in dietary habits, with consumers recognizing millets for their nutritional value and health benefits (APEDA 2023).

Millet trade trends reveal a blend of major consumers and producers in several countries, predominantly across Africa and Asia. Africa leads in both millet production and consumption, with over 55% of the world's output originating from this region (GlobeNewswire 2023). The demand for millets is robust in developing nations, notably in India and parts of Africa, driven by concerns related to food and nutritional security within challenging environmental conditions (APEDA 2023).

The millet market extends beyond regional boundaries, with significant consumption patterns evident across the globe. In Africa, millets serve as a dietary staple in drier regions, particularly the Sahel. India and various parts of Asia exhibit substantial millet consumption, though variations exist among countries. These regional dynamics underscore the diversity of millet consumption and production trends. The millet market landscape is evolving dynamically as both new entrants and established companies diversify their product offerings (GlobeNewswire 2023). Manufacturers are innovating to meet consumers' demands for gluten-free and healthy food products, leading to an array of millet-based food items like waffles and pasta (APEDA 2023). The market anticipates a wealth of lucrative opportunities, fueled by factors such as changing dietary habits, the rising popularity of low-calorie alternatives, and growing awareness of the health benefits linked to millet consumption.

The global millet market is on an upward trajectory, characterized by a shift towards healthier eating, growing consumer awareness, and evolving dietary preferences. Supported by robust market projection data, millets are poised to remain a significant component of the global food landscape, catering to the needs of health-conscious consumers while offering sustainable and nutritious dietary alternatives. As international recognition and consumer demand continue to rise, the global millet market's robust growth trend is poised for sustained expansion.

Nepal's Growing Millet Market and International Recognition

The Nepali millet market exhibits intriguing dynamics, as seen in the import and consumption patterns, as well as its trade relationships with neighboring countries, particularly India. Import data for millets in Nepal reveals an interesting pattern. While the data indicates some fluctuations, an overarching trend is the significant increase in import value. In 2019, Nepal spent NRs 180.10 million to import millets, highlighting the country's growing demand for this nutritious grain (Gautam and Subedi 2022). The data showcases the robust demand for millet products in the Nepali market. India is a primary source of millet imports for Nepal. The majority of millet imports from India are directed towards liquor production within Nepal, without significant integration into the domestic value chain (Gautam and Subedi 2022). This underscores the importance of establishing a more sustainable value chain and enhancing domestic millet production to meet the growing demand.

Nepal is not an isolated case in recognizing the value of millets. The demand for underutilized crops, including millets, is on the rise due to their multiple uses and the health benefits they offer. The UN has declared 2023 as the International Year of Millets, with the objective of increasing public awareness of the health benefits of millets and their suitability for cultivation under challenging climate conditions. The Nepali market's demand for millets aligns with this global initiative.

Millet Products in the Market

The global market for millet products is experiencing a substantial surge in popularity, driven by various factors that have contributed to the versatile application of millets in culinary and dietary contexts. Consumers worldwide are embracing millet-based products as they become increasingly health-conscious and seek gluten-free alternatives. Here, we explore the diverse range of millet products and the market trends that have propelled their growth.

Millet-Based Baked Goods

One of the most noticeable trends in the millet market is the growing availability of millet-based baked goods, including bread, waffles, pasta, and more (APEDA 2023). These products cater to the increasing demand for gluten-free and nutritious alternatives to traditional wheat-based baked items. Gluten-free millet flours and blends have become essential ingredients for bakers and manufacturers, giving rise to a variety of millet-infused products that offer the same taste and texture as their wheat-based counterparts.

Millet Flours and Grains

Millet flours and whole grains have gained popularity in the market as staple ingredients in both traditional and modern cuisines. The versatile nature of millet flours makes them suitable for baking, thickening, and as a base for gluten-free recipes (GlobeNewswire 2023). The grains themselves can be cooked as a side dish or used in salads, soups, and stews. Their mild flavor allows them to complement various dishes, making millet an attractive option for health-conscious consumers looking to diversify their diets.

Millets in Snack Foods

The increasing emphasis on healthier snacking has opened up avenues for millets in the snack food sector. Millet-based snacks are gaining popularity for their nutritional value and gluten-free appeal. Manufacturers are creating an array of millet snacks, from puffed millet bars to gluten-free crackers, to cater to consumers looking for convenient, on-the-go options that are not only tasty but also health-conscious.

Millet Breakfast Foods

Breakfast foods enriched with millets are becoming increasingly popular, contributing significantly to the overall revenue generation in the millet market (APEDA 2023). Millet cereals and granolas cater to consumers seeking nutritious and fiber-rich morning options. These products offer a gluten-free alternative to traditional breakfast cereals, meeting the demands of consumers who prioritize health-conscious dietary choices.

Table 1 provides an overview of various millet products available across different markets, encompassing both physical and online stores in Nepal, as well as online outlets in India and the USA. In Nepal, physical markets such as Bhatbhateni, Salesberry, Muna Krishi Bazar, and Big Mart offer a selection of millet products. Finger millet emerges as the most prevalent variety among the available millets. The range of millet products available is diverse, encompassing grains, flour, rava or sooji, daliya, noodles, and more. Each product category caters to distinct consumer preferences and culinary uses.

Interestingly, Flipkart, an online platform, offers a wider array of millet products compared to Nepali online markets and physical stores. Flipkart stocks all species of millets, whereas Nepali online and physical markets typically offer a more limited selection, comprising finger millet, foxtail millet, proso millet, and sorghum. Further, an interesting trend is observed wherein Nepali online markets tend to present a broader collection of millet products compared to their physical counterparts. The pricing range varies greatly across these products, primarily influenced by factors such as product differentiation, organic versus non-organic classifications, and varying quality standards.

Table 1. Millet products in various online and physical markets

Common Name	Product	Product price (NPR)*				Local Name
		Nepali Super Markets	Online Markets			
			Daraz	Amazon	Flipkart	
Finger millet	Grain	130	90	2660	96-576	Kodo, Ragi
	Flour	115-150	85-144	1596-5320	86-733	
	Rava				413	
	Flakes				528-560	
	Sprouted grain flour				576	
	Daliya				360	
	Pancake		557			
	Muesli (13% millet)	1149	1050-1100			
Foxtail millet	Grain	400	480-990	3129-11837	275-768	Kaguno
	Flour				352-858	
	Vermicelli		3222			
	Noodles		3021			
	Rava				218-440	
Pearl millet	Grain				349-1760	Bajra
	Flour				328	
	Dalilya				382	
	Rava				354	
Proso millet	Grain	380-400	380		288-509	Chino
	Flour				357-568	
Sorghum	Grain		429		286-432	Junelo, Jowar
	Flour		200		338-544	
	Rava		200		240-517	
Barnyard millet	Grain			6916	304-494	Sama
	Flour				357-563	
	Rice				480	
Little millet	Grain				638	Suji Kodo
	Flour				432	
	Rava				240-512	

Millet-Based Non-Alcoholic Beverages

Millet-based beverages, including millet milk and millet-based smoothies, are gaining traction as an alternative to traditional dairy products. These beverages offer a lactose-free, plant-based option that aligns with the growing trend of plant-based diets (GlobeNewswire 2023). Moreover, the nutritional advantages of millets, including calcium and protein content, position them as suitable ingredients for beverages targeted at health-conscious consumers.

* The prices on Flipkart have been converted to Nepalese Rupees (NPR) at a rate of 1 INR equals 160 NPR. Meanwhile, on Amazon, the conversion has been calculated at a rate of 1 USD equals 133 NPR.

Millet-based products are at the forefront of the evolving food industry, responding to the increasing demand for gluten-free and nutritious options. As the global population becomes more health-conscious, millets have emerged as a versatile ingredient, inspiring a wide range of product innovations. These millet-based offerings cater to a broad spectrum of dietary preferences and dietary requirements, making them a valuable component of the global food market. As the demand for healthier and gluten-free food options continues to rise, millet-based products are poised to play a significant role in shaping the future of the food industry.

Millet-Based Alcoholic Beverages in Nepal: A Promising Untapped Market

Nepal hosts rich cultural traditions, notably including the craft of producing indigenous grain-based alcoholic drinks. Chyang (**Figure 4**), made of finger millet is one of such drinks, which symbolizes Himalayan cultural heritage. This ancient practice not only preserves cultural identity but also holds promise for Nepal's economy by reducing reliance on imported alcohol. Its mild yet distinct taste has attracted both younger generations, appreciating its mildness similar to juice, and older generations, valuing its potency. Its affordability, due to simple production methods, has firmly established Chyang as a popular Nepalese beverage.

Figure 4. Chyang, a finger millet – based alcoholic beverage
Source: Rauniyar 2020

Figure 5. Brewing finger millet-based local alcohol in a rural Nepali village
Source: Baral 2023

In addition to Chyang, Nepal offers an assortment of traditional alcoholic drinks, including Raksi (**Figure 5**). This distilled alcohol, made from millet or rice, gained global recognition by being featured among CNN's esteemed selection of delightful beverages (Baral 2023). The alcohol content in traditional Nepalese alcoholic beverages varies considerably. For instance, Chyang, crafted from finger millet, typically contains a moderate alcohol concentration, making it a preferred choice for various age groups due to its milder strength. Conversely, Raksi, a distilled beverage made from millet or rice, often carries a more potent alcohol content compared to Chyang. The exact alcohol concentration in these drinks can fluctuate widely based on production methods, fermentation duration, and regional variations, with some homemade brews showing alcohol concentrations that surpass factory-produced beer.

Tongba is another revered traditional drink in Nepal which holds significant cultural importance and is known for its distinct preparation and taste (**Figure 6**). Crafted from fermented millet, this Himalayan beverage goes through a brewing process, fermenting in bamboo vessels for several weeks or months, resulting in a comforting drink ideal for the cold Himalayan climate. Beyond its taste, Tongba signifies unity and warmth, bringing people together to share in its essence. It represents not just a beverage but a cultural symbol, reflecting the resilience and communal values deeply embedded in Nepali heritage.

Despite their intrinsic cultural significance, the local alcoholic drinks of Nepal encounter a series of challenges that impede their wider recognition and market potential. Regulatory hurdles present a notable obstacle, with the requirement for licenses hindering home-brewing practices and restricting the wider production and distribution of these beverages. Moreover, the limited scientific documentation and understanding surrounding these drinks pose a challenge in terms of branding and establishing quality standards, potentially affecting their market viability and recognition. Additionally, the lack of concerted efforts to reform federal laws to support and promote these traditional beverages restricts their progress (Baral 2023).

Figure 6. Tongba, a finger-millet based alcoholic beverage of Nepal
Source: Fatima 2021

Several initiatives aim to overcome these obstacles and foster the recognition and sustainability of Nepali local alcoholic drinks. Academic institutions like Gandaki University have embarked on branding efforts, particularly with millet-based raksi, signifying a step towards acknowledging and preserving these age-old traditions (Baral 2023). Moreover, research endeavors, albeit limited, endeavor to understand the qualitative aspects of these beverages, aiding in establishing quality benchmarks and supporting branding initiatives. Some regions, such as Bhirkot Municipality in Syangja, have taken proactive steps in production and branding, setting an example for others (Baral 2023). However, the lack of comprehensive reform at the federal level remains a critical challenge, demanding collective efforts to navigate these regulatory complexities and support the growth of Nepal's indigenous alcoholic beverages.

Conclusion

The small-seeded millet grains, including pearl millet, finger millet, proso millet, and foxtail millet, have gained recognition for their nutritional value and adaptability. In Nepal, finger millet, in particular, plays a crucial role in enhancing food and nutrition security, especially in the challenging terrain of the mid-hill and mountain regions. The global millet market is witnessing substantial growth, driven by the increasing awareness of the gluten-free and highly nutritious qualities of millets. A diverse range of millet-based products, from baked goods, flours, and grains to snacks, breakfast foods, and non-alcoholic beverages, caters to the preferences of health-conscious consumers globally. In Nepal, the millet market is expanding, marked by a significant increase in imports, primarily from neighboring India. Considering the insights drawn from this review, it is imperative to adopt the following proactive stance to leverage the potential of millets in both global and local contexts:

Promote Domestic Millet Production: Encourage and support local farmers in cultivating millets, providing them with training and resources to enhance domestic production and reduce the country's dependence on imports.

Value Addition and Diversification: Local food industries should invest in value-added millet products that resonate with evolving consumer dietary preferences, such as gluten and lectin free baked goods, snacks, and breakfast items.

Enhance Traditional Millet Beverages: Modernize and promote Nepal's traditional millet-based alcoholic beverages, tapping into their cultural significance, and reducing the need for importing alcohol.

Educate and Raise Awareness: Implement educational programs and awareness campaigns to inform the public about the nutritional benefits and climate resilience of millets.

Collaboration with International Initiatives: Align efforts with international initiatives, such as the United Nations' declaration of 2023 as the International Year of Millets, to foster global awareness of millet's nutritional and environmental advantages.

Government Support and Policy Development: Advocate for government support and policy development to promote millet production, processing, and marketing. This may include offering incentives for millet farmers and food producers.

Research and Development: Invest in research and development to enhance millet varieties, increase yield, and improve product shelf life, thereby addressing the growing demand for millets and their derivatives.

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C. Case Studies

ग. ठाउँ बिशेष अध्ययन

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मकवानपुरगढी गाउँपालिकामा कोदोजन्य बाली प्रवर्द्धनका लागि गरिएका केही प्रयासहरू

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साराशं

मकवानपूरगढी गाउँपालिकामा विगतमा कोदोजन्य बालीको खेती व्यापक मात्रामा हुने गरेको भएता पनि विभिन्न कारणहरूले गर्दा कोदोजन्य बालीहरूको उत्पादन र उपभोग घट्दै गइरहेको सन्दर्भमा आ. व. २०७७/७८ देखि संघीय सशर्त वित्तिय हस्तान्तरण मार्फत "रैथाने बाली प्रवर्द्धन कार्यक्रम" को कार्यान्वयन शुरु भए पश्चात कोदो र अन्य कोदोजन्य रैथाने बालीको उत्पादन वृद्धि, परिकार विविधिरकण, मूल्य अभिवृद्धि र बजारिकरण एवं जातीय संरक्षण लगायतका क्षेत्रमा विभिन्न कृयाकलापहरू सञ्चालन हुँदै आएका छन्। गाउँपालिकाले सञ्चालन गरेका कोदोजन्य रैथाने बाली प्रवर्द्धनका विभिन्न प्रयासहरूको फलस्वरुप स्थानीय स्तरमा कोदोजन्य बालीको उत्पादन तथा उपभोग पुनः बढ्न थालेको पाइएको छ। यसबाट स्थानीय विद्यार्थी तथा सर्वसाधारण जनताको पोषण अवस्थामा सकरात्मक सुधार हुनाको साथै स्थानीय कृषकको आय वृद्धि हुने अपेक्षा गर्न सकिन्छ।

पृष्ठभूमी

मकवानपुरगढी गाउँपालिका बागमती प्रदेश अन्तर्गत मकवानपुर जिल्लामा अवस्थित चुरे र पहाडी विशेषता बोकेको गाउँपालिका हो। समुन्द्री सतहको १३०४ मिटर सम्मको उचाईमा रहेको मकवाानपुरगढी गाउँपालिका मकवानपुर जिल्लाको सदरमुकाम एवं बागमती प्रदेशको राजधानी हेटौडासँग सिमाना जोडिएर पूर्व तथा उत्तर भागमा रहेको छ। यस गाउँपालिकाको पूर्वमा बकैया गाउँपालिका, पश्चिममा हेटौडा उपमहानगरपालिका र भीमफेदी गाउँपालिका उत्तरमा भीमफेदी गाउँपालिका र दक्षिणमा हेटौडा उपमहानगरपालिका र बकैया गाउँपालिका सँग सिमाना जोडिएको छ। जिल्लाको कूल क्षेत्रफलको ६.५२ प्रतिशत भूभाग ओगट्ने यस गाउँपालिकाको क्षेत्रफल १४८.७३ वर्ग किमी रहेको छ। जसमा ५८५६ हेक्टर धान खेत र ३०८६ हेक्टर पाखोबारी गरी जम्मा ८९४२ हेक्टर खेतीयोग्य जग्गा रहेको देखिन्छ। (केन्द्रिय तथ्यांक विभाग २०६८)

कोदो बाली मकवानपुरगढी गाउँपालिकामा खेती गरिने खाद्यान्न बालीहरू मध्ये क्षेत्रफल र उत्पादनको हिसाबले मकै र धान पछिको तेश्रो प्रमुख खाद्यान्न बाली हो। यस गाउँपालिकाको वडा नं. १ देखि वडा नं. ८ सम्म सवै वडामा खेती गरिने कोदोबालीले हाल करिव ३०० हेक्टर क्षेत्रफल ढाकेको छ। जसमा वडा नं. १, २, ४ र ७ मा बढी कोदो खेती भईरहेको देखिन्छ। अन्य कोदोजन्य बालीहरूमा धानकोदो १० हेक्टर र जुनेलो ५ हेक्टर खेती गरीरहेको पाईन्छ।

कृषकहरूले खेती गरिने बालीहरूमध्ये अरु बालीको तुलनामा उत्पादन र आम्दानीको हिसाबले कोदो खेतीबाट कम आम्दानी हुने भएकोले क्रमशः कोदो खेतीको क्षेत्रफल घट्दै गईरहेको सन्दर्भमा आ.व.०७७/७८ देखि कृषि विभाग अन्तर्गतको बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र श्रीमहल, पुल्चोक ललितपूरबाट ''रैथाने बाली प्रवर्द्धन कार्यक्रम'' सञ्चालनको लागि संघीय सशर्त बित्तिय हस्तान्तरण मार्फत बजेट प्राप्त भइ रैथाने बाली प्रवर्द्धनका विभिन्न कृयाकलापहरू सञ्चालन आरम्भ भएको थियो। उक्त कार्यक्रम कार्यान्वयनको लागि उक्त कार्यालयबाट हालसम्म निरन्तर रुपमा संघीय सशर्त अनुदान प्राप्त हुँदै आएको छ।

कोदोजन्य बाली प्रवर्द्धनका लागि सञ्चालित गतिविधि र उपलब्धीहरू

१) कोदो बालीको क्षेत्रफल विस्तार

रैथानेबाली प्रवर्द्धन कार्यक्रम संचालन हुनु भन्दा पहिला सरकारी स्तरबाट कोदोबाली प्रवर्द्धनका लागि कार्यक्रमहरू सञ्चालन हुन नसकेको अवस्थामा कृषकहरूले खेती गर्दै आएको कोदो बाली अन्य बालीहरूको तुलनामा उत्पादन र आम्दानीको हिसावले कम हुने हुँदा कोदो खेतीको क्षेत्रफल घट्दो अवस्थामा रहेको थियो।

तस्विर १. कोदो बालीको क्षेत्र विस्तार अन्तर्गत रोपिएको कोदो

तस्विर २. कोदो बालीको क्षेत्र विस्तार अन्तर्गत प्रवर्द्धन गरिएको काट्न तयार हुँदै गरेको कोदो

आ.व.०७७/७८ देखि रैथाने बाली प्रवर्द्धन कार्यक्रम अन्तर्गत कोदो खेतीको क्षेत्र विस्तार, प्राविधिक सहयोग, कोदो संकलन, परिकार विविधिकरण र बजारीकरण लगायतका कार्यहरूमा गाउँपालिकाबाट सहयोग उपलब्ध हुन थालेपछि गाउँपालिका भित्र २५० हेक्टर क्षेत्रफलमा कोदो खेती हुँदै आईरहेकोमा ५० हेक्टर क्षेत्रफल विस्तार भई हाल ३०० हेक्टर क्षेत्रफलमा कोदो खेती भईरहेको छ।

२) कोदो खरिद तथा विक्रीमा नगद प्रोत्साहन अनुदान

मकवानपुरगढी गाउँपालिकाले आ.व.०७७/७८ देखि नै कोदो बाली प्रवर्द्धनको लागि कृषकहरूले उत्पादन गरेको कोदो बिक्रीको सुनिश्चितता गर्न न्यूनतम समर्थन मूल्य निर्धारण गरी स्थानीय सहकारी संस्था मार्फत खरिद बिक्रीको व्यवस्था मिलाउँदै आएको छ। यसरी निर्धारित मूल्यमा कोदो बिक्री गर्ने कृषकहरूलाई बिक्री परिमाणको आधारमा र सहकारी संस्थालाई खरिद गरी भण्डारण, व्यवस्थापन गरेवापत प्रति क्वीन्टल रु २००/२०० का दरले जम्मा रु ४००। – नगद प्रोत्साहन अनुदान गाउँपालिकाले उपलब्ध गराउँदै आईरहेको छ।

तस्विर ३. न्यूनतम समर्थन मूल्यमा स्थानीय कृषि सहकारी मार्फत कोदो खरिद

तस्विर ४. न्यूनतम समर्थन मूल्यमा स्थानीय कृषि सहकारी मार्फत कोदो खरिद

कोदो संकलनको कार्य मकवानपुरगढी गाउँपालिका वडा नं. ४ कालीखोलामा अवस्थित श्री अपाङ तथा विपन्न कृषि सहकारी संस्था लि. ले गर्दै आईरहेको छ। विभिन्न आर्थिक वर्षहरूमा भएको कोदोको खरिद/विक्री सम्बन्धी विवरण **तालिका १** मा दिइएको छ।

तालिका १. न्यूनतम समर्थन मूल्यमा कोदो खरिद/बिक्री सम्बन्धी विवरण

आ. व.	कायम गरिएको न्यूनतम मूल्य (प्रति क्विन्टल) रु	खरिद/बिक्री परिमाण (टन)
०७७/७८	४२००। –	३.०९
०७८/७९	४८००। –	११.२९
०७९/८०	४५००। –	१०.८०

यसरी कृषकहरूले आफ्नै गाउँमा सजिलैसँग कोदो बिक्री गर्न पाएपछि वडा नं. ४ कालिंखोलाका कृषकहरू कोदो खेतीतर्फ आकर्षित भएको पाइन्छ।

३) विद्यालय दिवाखाजामा कोदोजन्य बालीको परिकार समावेश

मकवानपुरगढी गाउँपालिकामा ३७ वटा सामुदायिक विद्यालयहरू रहेका छन्। जसमा बाल विकास देखि कक्षा १२ सम्म गरी जम्मा ५६०० विद्यार्थीहरू अध्ययनरत रहेका छन्। सामुदायिक विद्यालयहरूमा अध्ययनरत विद्यार्थीहरूको दिवा खाजा कार्यक्रम वापत कक्षा ५ सम्मका लागि संघीय सरकारबाट वजेट प्राप्त भईरहेको छ भने बाँकी कक्षा ६ देखि कक्षा १२ सम्मको विद्यार्थीहरूको लागि स्थानीय तहबाट वजेट विनियोन गरी विद्यालय दिवा खाजा कार्यक्रम संचालन भइरहेको देखिन्छ। यस गाउँपालिका भित्र रहेको सामुदायिक विद्यालयहरूलाई लक्षित गरी गाउँ कार्यपालिकाको मिति २०७९ पौष २९ गते वसेको बैठकले हरेक विद्यालयमा हप्ताको एक दिन विहिवारका दिन अनिवार्य रुपमा स्थानीय एवम् रैथानेबालीको परिकार समावेश गर्ने निर्णय गरे अनुसार कोदोबालीबाट बनेका विभिन्न परिकारहरू (कोदोको सेल, कोदोको हलुवा, कोदो/फापरको फुलौरा) विद्यालय दिवा खाजामा उपलब्ध भईरहेका छन।

तस्विर ५. स्थानीय विद्यालयको दिवा खाजामा कोदोजन्य बालीको परिकार समावेश १

तस्विर ६. स्थानीय विद्यालयको दिवा खाजामा कोदोजन्य बालीको परिकार समावेश २

यसले गर्दा विद्यार्थीहरूले पौष्टिक खाजा खान पाउने हुँदा कुपोषण कम गर्न मद्दत पुग्नुको साथै स्वास्थ्यलाई समेत राम्रो गर्ने र विद्यार्थीको भोक मेटिइ शिक्षण सिकाई प्रभावकारी बन्न सहयोग पुग्ने देखिन्छ। अर्कोतर्फ यस कार्यक्रमले गर्दा स्थानीय स्तरमा कोदोबालीको खपत र उपभोगमा समेत वृद्धि भएको देखिन्छ।

तस्विर ७. स्थानीय विद्यालयको दिवा खाजामा कोदोजन्य बालीको परिकार समावेश ३

कोदोबाट बनेका परिकारहरू खाजाको रुपमा उपभोग वृद्धि गर्ने उदेश्यले विद्यालयमा अध्ययनरत विद्यार्थीहरूलाई कोदोको पौष्टिक महत्त्व वारे अभिमुखीकरण कार्यक्रमहरू समेत संचालन गरिएको छ।

४) कोदो संकलन, भण्डारण, प्रशोधन, प्याकेजिङ र बजारीकरण

कोदोबालीको उत्पादन गरेर मात्र कोदो खेतीमा कृषकहरूलाई टिकाउन सकिँदैन। यसलाई बजारसँग जोडेर कृषकहरूको आयस्तरमा वृद्धि गर्न सकियो भने मात्र कृषकहरूलाई कोदो खेतीमा लागिरहन प्रेरित गर्न सकिन्छ भन्ने अभिप्रायले कोदोबालीको मूल्य श्रृंखला विकासको अवधारणा अनुरुप आ.व. ०७८/७९ मा मकवानपुरगढी गाउँपालिकाको आर्थिक सहयोगमा मकवानपुरगढी गाउँपालिका वडा नं. ४ कालीखोलामा रहेको श्री अपाङ तथा विपन्न कृषि सहकारी संस्थासँगको लागत साझेदारीमा कोदो संकलन तथा भण्डारण भवनको निर्माण सम्पन्न गरिएको थियो।

तस्विर ८. न्यूनतम समर्थन मूल्यमा स्थानीय कृषि सहकारी मार्फत खरिद गरी बजार पठाउन तयारी कोदो

तस्विर ९. न्यूनतम समर्थन मूल्यमा खरिद गरिएको कोदो पिस्दै मिल प्राविधिक

तस्विर १०. कालीखोला ब्राण्डको कोदो प्रदर्शनी तथा बिक्री गर्दैं

कोदो संकलन तथा भण्डारण भवन सँगै कोदो प्रशोधन गर्ने मेशिनहरू कोदो फल्ने मेशिन, कोदो पिस्ने मिल, कोदो पिस्ने विद्युतीय घट्टको स्थापना कार्य समेत भएको छ। यसरी पूर्वाधारहरूको तयारी पश्चात आ.व.०७९/८० मा कोदोको ब्रान्डिङ र प्याकेजिङका प्रक्रियाहरू अगाडि बढ्यो। अन्ततः खाद्य प्रविधि तथा गुण नियन्त्रण कार्यालय, हेटौडा मकवानपुरबाट अनुज्ञा पत्र प्राप्त गरीसकेपछि कालीखोला ब्रान्डको नाममा एक केजीको प्याकेटमा कालीखोला कोदो पिठो बजारमा उपलब्ध भईरहेका छन्। जसको बजारीकरण अपाङ तथा विपन्न कृषि सहकारी संस्था लि.ले गरीरहेको छ।

५) कोदोजन्य बालीको वीउ संकलन तथा संरक्षण, सम्वर्द्धन

मानिसहरूको खानपान, रहनसहन सँगै कोदोजन्य बालीहरू दिनानुदिन लोपोन्मुख हुँदै गईरहेको अवस्थामा यसको संरक्षण र सम्वर्द्धन गर्न अपरिहार्य रहेको देखिन्छ। यसै सन्दर्भमा यस मकवानपुरगढी गाउँपालिकाका कृषकहरूले परापूर्वकाल देखि खेती गर्दै आएका कोदोजन्य बालीहरू साथै जिल्ला बाहिरका अन्य ठाउँहरूबाट समेत कोदोजन्य बालीहरूको वीउ संकलन र संरक्षण गरी राखिएको छ।

तस्विर ११. संकलन गरी राखिएको कोदोजन्य बालीका रैथाने जातका बीउहरू

तस्विर १२. संकलन गरी राखिएको कोदोजन्य बालीका रैथाने जातका बीउहरू

जसमा यस गाउँपालिकामा खेती गरिने कोदोहरूमा मुड्के कोदो, चरीनङग्रे कोदो, स्थानीय बर्बन्दी कालो कोदो, पहेंले कोदो, सेतो कोदो रहेका छन्। यसैगरी अन्य कोदोजन्य बालीहरूमा धानकोदो, जुनेलो र स्थानीय हरियो लट्टेका वीउहरू र अन्यत्र ठाउँहरूबाट काब्रे कोदो १, डल्ले कोदो १, चिनो, कागुनो (कालो र सेता), लट्टेको वीउहरू संकलन गरी राखिएको छ। संकलन गरिएका वीउहरू कृषकहरूले माग गरेको खण्डमा नमूनाको रुपमा उपलब्ध गराउने र उत्पादन पश्चात पुनः वीउ फिर्ता लिने कार्य गरिएको छ। यसरी कोदोजन्य बालीको वीउहरू संकलन, संरक्षण र सम्वर्द्धनका कार्यहरू सञ्चालन गरिएको छ।

निष्कर्ष

खाद्य सुरक्षा, पोषण, ग्रामिण जनताको आय तथा रोजगारी, जलवायु परिवर्तन अनुकूलन लगायतका दृष्टिले कोदोजन्य रैथाने बालीको महत्त्व दिनानुदिन बढ्दै गइरहेको सन्दर्भमा मकवानपूरगढी गाउँपालिकाले कार्यान्वयन गर्दै आएको रैथाने बाली प्रवर्द्धन कार्यक्रमको स्थानीय कोदोजन्य बालीको खेती विस्तार, उत्पादन, मूल्य अभिवृद्धि तथा संरक्षण कार्यको अलावा स्थानीय कृषक तथा व्यवसायीहरूको आयमा समेत सकरात्मक प्रभाव देखिएको छ। प्राप्त उपलव्धी र सिकाईको आधारमा कार्यक्रमलाई थप परिस्कृत तथा विस्तार गर्न सकेमा यसले स्थानीय खाद्य सुरक्षा तथा पोषणको अवस्थामा सुधारको अलावा स्थानीय जनताको जिविकोपार्जनमा समेत महत्त्वपूर्ण योगदान पुर्याउन सक्ने देखिन्छ।

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक) । २०८० । राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ ।

कोदोजन्य र अन्य रैथाने बालीको संरक्षण, उत्पादन तथा प्रवर्द्धनमा गौमुल गाउँपालिका र बडीमालिका नगरपालिका, बाजुराको प्रयास

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सारांश

सुदुरपश्चिम प्रदेश अन्तर्गतको बाजुरा जिल्लाबाट कोदोजन्य रैथाने बालीको प्रवर्द्धनको लागि सरकारी तवरबाट संस्थागत रुपमा अभियानको शुरुआत भएको पाइन्छ। बाजुरा जिल्लाको बडीमालिका नगरपालिका र गौमूल गाउँपालिकाहरूमा रैथाने बाली प्रवर्द्धनको लागि आर्थिक बर्ष २०७७/०७८ देखि संघीय सशर्त अनुदान प्राप्त हुँदै आएको छ। कार्यक्रम अन्तर्गत यी दुई पालिकाहरूमा संघीय सशर्त अनुदान प्राप्त हुँदै आएको छ। उक्त संघीय सशर्त अनुदान मार्फत यी पालिकाहरूले रैथाने बालीको उत्पादन वृद्धि, मूल्य श्रंखला विकास र बजारिकरणको अलवा तिनको संरक्षणमा विभिन्न कार्यहरू गर्दै आएका छन् । खासगरी परिकार विविधिकरणमा यी पालिकाहरूमा भएको उपलव्धीहरू देशका अन्य पालिकाहरूको लागि समेत अनुकरणीययोग्य रहेको छ।

परिचय

बाजुरा जिल्ला नेपालको दुर्गम पहाडी जिल्लाहरू मध्ये एक हो । जिल्लाका विभिन्न वस्तीहरूले विगत देखि नै खाद्यान्न अभाव तथा खाद्य असुरक्षाको अवस्था झेलिरहेका छन् । त्यसै गरी जिल्लामा कुपोषणको अवस्था पनि खराव रहेको पाइन्छ। पछिल्लो समय समाजमा भात खाने प्रचलन बढ्दै जाँदा देशको अन्य भागमा जस्तै बाजुरामा पनि कोदोजन्य र अन्य रैथाने बालीहरूको उत्पादन र उपभोग घट्दै गएको पाइन्छ भने खेतीयोग्य जमिन बाँसो राखि बजारबाट खाद्यान्न किनेर खाने प्रचलन बढ्दै गएको देखिन्छ । यसले एका तर्फ आयातित खाद्यान्न माथिको परनिर्भरता बढ्दे गएको छ भने कुपोषणलाई समेत बढावा दिइरहेको अवस्था विद्यमान छ । जिल्ला सदरमुकाम रहेको बडीमालिका नगरपालिका र सँगै जोडिएको गौमुल गाउँपालिका पनि न्यून खाद्यान्न उत्पादन हुने क्षेत्रमा पर्छन् । धान खेती कम हुने र प्रायः पाखो बारीको बाहुल्यता रहेका यी दुई पालिकाहरूमा विगतमा कोदो, कागुनो, चिनो, जुनेलो लगायतका कोदोजन्य र जौ, उवा, फापर, लट्टे (स्थानीय रुपमा मार्से भनिने) जस्ता अन्य रैथाने बालीहरूको प्रसस्त मात्रामा खेती हुने गरेकोमा वर्तमान ति बालीहरूको खेती गर्ने क्रम घट्दै गइरहेको पाइन्छ।

यसै क्रममा ग्रामिण भेगमा सहजै उत्पादन हुने कोदोजन्य र अन्य रैथाने बालीलाई संरक्षण र प्रोत्साहन गरी स्थानीय खाद्य सुरक्षामा टेवा पुर्याउनुको साथै त्यस्ता उत्पादनको बिक्री मार्फत स्थानीय समुदायको आयआर्जनमा वृद्धि गर्ने उद्देश्य सहित नेपाल सरकार कृषि तथा पशुपन्छी विकास मन्त्रालय, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र मार्फत कार्यान्वयनमा आएको 'रैथाने बाली प्रवर्द्धन कार्यक्रम' अन्तर्गत आर्थिक बर्ष २०७७/०७८ देखि यी दुई पालिकाहरूमा संघीय सशर्त अनुदान प्राप्त हुँदै आएको छ। उक्त संघीय सशर्त अनुदान मार्फत यी पालिकाहरूमा रैथाने बालीको उत्पादन वृद्धि, मूल्य श्रंखला विकास र बजारिकरणको अलवा तिनको संरक्षणमा विभिन्न कार्यहरू गर्दै आएका छन् ।

गौमुल गाउँपालिकाद्वारा सञ्चालित गतिविधिहरू एवं हासिल उपलव्धिहरू

- गौमुल गाउँपालिका वडा नं. १ देखि ६ वडा सम्मका ६ आधारभुत तहका विद्यालयहरूमा विद्यार्थी संख्याको अनुपातमा दिवा खाजा व्यवस्थापनको लागि प्रति विद्यार्थी रु १५ का दरले ४५० जना विद्यार्थीहरूलाई स्थानीय बालीको पोषणको महत्त्व र स्थानीय स्तरमै उत्पादन भएका खाद्य बस्तुको उपयोग गर्न अभिप्रेरित गर्न दिवा खाजामा कोदोको हलुवा, लट्टे र जौ को सातु र फापरको रोटीको परिकार तयार गरी विद्यार्थीहरूलाई खुवाईएको छ ।

रैथाने बालीको परिकार दिवाखाजामा उपभोग गराउदै जिवनज्योती आधारभूत विद्यालय गौमुल गाउँपालिका, बाजुरा

बडीमालिका नगरपालिका वडा नं.६ कोर्धमा मार्से (लट्टे) खेती

गौमुल गाउँपालिका वडा नं. १ फापर खेती

- स्थानीय बाली उत्पादन गरी प्रयोग गर्दा स्थानीय किसानहरूले फापर, जौ, उवा, चिनो, कागुनो, कोदो जस्ता बालीहरूको उत्पादन वृद्धि गर्न प्रोत्साहित भइ ति बालीहरूको उत्पादन वृद्धि गरेका छन।
- रैथाने बाली प्रवर्धन कार्यक्रमबाट पुराना लोप हुन लागेका बाली जौ, कोदो, चिनो, कागुनो जस्ता बाली जातीय संरक्षण, उत्पादन वृद्धि र थप क्षेत्र विस्तारका लागि विभिन्न स्थानीय मिडियाहरूमा प्रचार प्रसार, तालिम, गोष्ठि, खाद्य मेला परिकार, प्रदर्शनी आदी कार्य गरिएको।
- जौबाट बन्ने परिकार विविधिकरण गरी राष्ट्रिय स्तरसम्म बजार पहुँच बढाउन कृषि ज्ञान केन्द्र, बडीमालिका नगरपाललिका र गौमुल गाउँपालिकाको आर्थिक सहयोगमा गौमुल २ स्थित नौमुल बहुउद्धेश्यीय सहकारी संस्था मार्फत जौबाट बनेका सातु, चामल र च्याख्लाको बजारीकरण गरिएको।
- पालिका वा वडा स्तरमा संचालन हुने तालिम गोष्ठिहरूमा प्रायः गरेर रैथाने बालीका परिकारहरूको खाजा खुवाउने गरिएको।
- वडा स्तरमा संचालन हुने हरेक क्रियाकलापहरूमा सहभागीलाई खाजा नास्ता स्वरुप प्रायशः रैथाने बालीका परिकार निर्माण गरी उपलब्ध गराउने गरिएको।
- गौमुल गाउँपालिकाका ६ वटै वडाहरूमा सार्वजनिक समारोह, तालिम, गोष्ठी आदिमा रैथाने बालीका परिकारहरूको खाजा नास्ता खुवाउने गरेका।
- पालिका स्तरिय खाद्य मेलाको आयोजना गरी रैथाने बालीबाट बन्ने परिकारहरूको प्रदर्शन गरी प्रदर्शनमा सहभागि भएका समुदायलाई रैथाने बालीको महत्त्व सम्वन्धमा अन्तरक्रिया मार्फत जानकारी गराइएको।

- रैथाने बालीको उपज बिक्री वितरणको लागि जिल्लाको सदरमुकाममा सहकारी मार्फत कोशेली घर स्थापनामा सहयोग गरिएको।
- रैथाने बालीको उत्पादन गर्न र त्यसको पौष्टिक महत्त्वको विषयमा सवै उपभोक्ताहरूलाई उपभोग गर्न समुदायलाई जातृत गर्न पालिका स्तरका विभिन्न निकायका सामाजिक परिचालक, महिला स्वयम सेविका, ईसिडी सहजकर्ता, पोषण शिक्षक आदिलाई रैथाने बालीको महत्त्व र प्रवर्धन सम्बन्धी अभिमुखिकरण गरिएको।
- कम्तिमा ३ देखि ५ रोपनी जग्गामा रैथाने बालीको एकल खेती गर्ने किसानलाई विशेष अनुदानको व्यवस्था गरिएको छ।
- जिल्लाका अन्य स्थानीय तह तथा बैतडि र बझाङ्ग लगायतका जिल्लाहरूलाई रैथाने बालीको करिव १३ क्विन्टल बीउ बिक्री गरिएको।

बडीमालिका नगरपालिकाद्वारा सञ्चालित गतिविधिहरू एवं हासिल उपलब्धिहरू

- रैथाने बालीको महत्त्व बारे विभिन्न संचार माध्यम मार्फत प्रचार प्रसार गरिएको।
- पालिका स्तरमा संचालन हुने हरेक गोष्ठि सेमिनारहरूमा रैथाने बालीका परिकारहरूको खाजा व्यवस्था गर्ने गरिएको।
- बडीमालिका नगरपालिका वडा नं. ५ र ६ लाई रैथाने बालीको उत्पादन प्रदर्शनी क्षेत्र र उत्पादन क्षेत्रको रुपमा स्थापित गरिएको।

भावी योजना

- जौ बालीको क्षेत्र विस्तारको लागि बडीमालिका नगरपालिका वडा नं. ३, ५ र ६ का २/२ हेक्टरमा यसको खेतीको लागि कृषकसँग छलफल गरिएको।
- बडीमालिका नगरपालिका भरिका २५ वटा सामुदायिक विद्यालयहरूका २९०० विद्यार्थीहरूको लागि २०८० मंसिरबाट दिवाखाजामा हप्तामा एक दिन कोदोको परिकार समावेश गराउने योजना रहेको।
- कोदो लगायत अन्य रैथाने बालीहरूको प्रशोधन र कुकिज् लगायतका प्रशोधित खाद्य पदार्थ उत्पादन गरी बजारिकरण गर्न सुदुरपश्चिम प्रदेश सरकार समेतको सहयोगमा एक प्रशोधन प्लान्ट स्थापना गरिने।

निष्कर्ष

कोदोजन्य र अन्य रैथाने बाली प्रवर्द्धन कार्यमा बाजुरा जिल्ला र यहाँका स्थानीय तहहरूको अग्रणी भूमिका रहेको छ। यस्ता बालीहरूको प्रवर्द्धनको लागि संस्थागत रुपमा सरकारी प्रयास बाजुराबाट नै भएको मानिन्छ। हाल आएर जिल्लाका गौमुल र बडीमालिका लगायतका स्थानीय तहहरूले कोदोजन्य र अन्य रैथाने बालीको उत्पादन, मूल्य श्रंखला विकास तथा बजारिकरणको साथै संरक्षणमा उल्लेखनिय भूमिका खेल्दै आएका छन्। अन्तमा, बाजुरा जिल्लाका अन्य स्थानीय तहहरूले बडीमालिका नगरपालिका र गौमुल गाउँपालिकाले रैथाने बालीमा गरेको प्रयासहरूको अनुसरण गरी स्थानीय स्तरमा सजिलै उत्पादन हुने कोदोजन्य रैथाने बाली उत्पादन र उपभोग वृद्धि गर्न सकेमा जिल्लामा खाद्य सुरक्षा र पोषणको अवस्थामा सुधार गर्न सकिनुको साथै स्थानीय रुपमा रोजगारी एवं आयआर्जनको अवसर समेत बढ्न जाने छ।

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक)। २०८०। राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ।

नारायण नगरपालिका दैलेखमा कोदोजन्य रैथाने बालीको प्रवर्द्धनको लागि भएका प्रयासहरू

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सारांश

देशका अन्य भू भागमा जस्तै दैलेख जिल्लाको नारायण नगरपालिकामा पनि कोदोजन्य बालीको उत्पादन र उपभोग क्रमिक रुपमा घट्दै गइरहेको छ। यसै विच संघीय सशर्त वित्तिय हस्तान्तरण मार्फत आ.व. २०७८/७९ देखि "रैथाने बाली प्रबर्दन कार्यक्रम" कार्यान्वयनमा आए पछि यस पालिकामा कोदोजन्य बालीको महत्त्वको बारेमा सचेतना बढि ति बालीहरूको उत्पादन र परिकार विविधिकरण गरी उपभोग पनि बढ्दै गइरहेको पाइन्छ। यस लेखमा हालसम्म उक्त कार्यक्रम कार्यान्वयनको अवस्था र हासिल उपलव्धीहरूको बारेमा चर्चा गरिएको छ।

परिचय

कर्णाली प्रदेश दैलेख जिल्लाको सदरमुकाम रहेको नारायण नगरपालिका जिल्लाका सात गाउँपालिका र चार नगरपालिका मध्ये एक स्थानीय तह हो। जिल्लाको जेठो नगर यस नगरपालिकाको कूल क्षेत्रफल ११००० हेक्टर मध्ये खेती योग्य जमिन ३६३७ हेक्टर, खेती गरेको २८०० हेक्टर र बाँसो जमिन ८०० हेक्टर रहेको छ। यस पालिकामा धान, मकै, गहुँ, विभिन्न तरकारी बालीहरू मुख्य बालीको रुपमा लगाइन्छ। पाखो बारी तथा भिरालो जमिनमा जौ, कोदो, फापर लट्टे, सखरखण्ड, पिँडालु, फापर, सिमी जस्ता रैथाने बालीहरू लगाउने गरेको पाइन्छ। रैथाने बालीहरू मध्ये कोदो प्रमुख बाली हो। त्यसै गरी पिँडालु, सिमी र फापर तरकारीको प्रयोजनका लागि लगाउने गरेको पाईन्छ । अन्य रैथाने बालीहरू सामान्य चलन चल्ती र चाड पर्वमा आवश्यक पर्ने भएको कारण पनि लगाउने गरेको पाईन्छ।

रैथाने बाली प्रवर्द्धन कार्यक्रम अन्तर्गत कोदोजन्य बालीको प्रवर्द्धनका लागि सञ्चालित गतिविधिहरू र उपलब्धिहरू

यस नगरपालिका क्षेत्र भित्र कोदोजन्य र अन्य रैथाने बालीको खेती विगतको तुलनामा वढ्दै गएको पाइन्छ। खासगरी कृषि विभाग अन्तर्गतको बाली बिकास तथा कृषि जैबिक विविधता संरक्षण केन्द्र मार्फत संघीय सशर्त वित्तिय हस्तान्तरण अन्तर्गत "रैथाने बाली प्रबर्दन कार्यक्रम" संचालन भए पश्चात यस्ता बालीहरूको महत्त्व बारे प्रचार प्रसार बढ्न गइ आम कृषक र उपभोगक्ताहरू क्रमशः ति बालीहरूको उत्पादन र उपभोगमा फर्कन थालेको पाइएको छ। साथै कोदोजन्य र अन्य रैथाने बालीहरूको प्रवर्द्धनको लागि नगर कार्यपालिकाको नीति तथा कार्यक्रममा समाबेश समेत गरिएको छ। "रैथाने बाली प्रबर्दन कार्यक्रम" कार्यान्वयनको लागि यस पालिकामा आ.व. २०७८/७९ मा रु १३,००,०००। र आ.व. २०७९/८० मा रु १०,००,०००। संघीय सशर्त अनुदान प्राप्त भएको थियो। चालु आ.व. २०८०/८१ मा भने रु ५,००,०००। प्राप्त भएको छ।

क) प्रचार प्रसार र सचेतना

स्थानीय एफ एम रेडियो र होडीङ्ग बोर्ड मार्फत रैथाने बालीको महत्त्ववारे सचेतना प्रचार प्रसार गरिएको छ। यसै गरी स्थानीय विद्यालयका शिक्षक शिक्षिका तथा महिला स्वास्थ्य स्वंयम सेविका गरी ४१ जनालाई रैथाने बालीको महत्त्व सम्वन्धी तालिम प्रदान गरिएको छ।

तस्विर १. कोदोजन्य रैथाने बालीको पोषण महत्त्व बारे महिला स्वास्थ्य स्वयंसेविकालाई अभिमुखिकरण गर्दै

तस्विर २. कोदोजन्य रैथाने बालीको महत्त्व बारे जानकारीमूलक होर्डिङ्ग बोर्ड

तालिम प्राप्त शिक्षक शिक्षिका तथा महिला स्वास्थ्य स्वयं सेविकाहरूले क्रमशः विद्यालयका विद्यार्थी र स्थानीय महिला तथा पुरुपहरूलाई रैथाने बालीको महत्त्वको बारेमा प्रचार प्रसार गरेका छन्।

ख) परिकार विविधिकरण

स्थानीय होटल व्यवसायी र रेष्टुरेन्ट सञ्चालकहरू, स्थानीय सहकारीका प्रतिनिधि समेत गरी १५ जना लाई रैथाने बाली परिकार बनाउने तालीम दिइएको छ। नारायण नगरपालिका प्राङ्गडमा परिकार प्रर्दशनी गरी २ पटकमा करिव ६०० जनालाई रैथाने बालीको महत्त्व बुझाइ कोदोको सेल, कोदोको म.म., कोदोको जेरी, कागुनोको खीर मिश्रित अचार बनाई खाजा खुवाइएको थियो।

तस्विर ३. कोदोजन्य रैथाने बालीका विभिन्न परिकारहरू तयारी तालिम पश्चात प्रदर्शनीमा राखिएका परिकारहरू

हाल तालिम प्राप्त स्थानीय होटल तथा रेष्टुरेन्टहरूले स्थानीय सरकारी तथा गैर सरकारी निकाय र अन्य उपभोक्ताहरूको मागको आधारमा त्यस्ता परिकारहरू बनाई बिक्री गर्ने गरेका छन्।

ग) विद्यालयमा दिवा खाजा कार्यक्रम

स्थानीय दुई माध्यमिक विद्यालयहरूमा रैथाने बाली परिकार तयारी तथा प्रर्दशनी गरिएको छ। यस क्रममा शुरुमा शिक्षक, विद्यार्थी र व्यवस्थापन समितिका पदाधिकारीहरू एवं जनप्रतिनिधिहरू लाई कोदोजन्य र अन्य रैथाने बालीको महत्त्व बारे जानकारी गराइएको थियो। परिकार बनाई देखाउनको लागि अघिल्लो वर्ष तालिम दिइएका स्थानीय होटल व्यवसायीहरूलाई उपयोग गरिएको थियो।

तस्विर ४. विद्यालय दिवा खाजामा कोदोजन्य रैथाने बालीको परिकार समावेश गर्नुको फाइदा एवं महत्त्व बारे प्रकाश पार्दै

तस्विर ५. रैथाने बालीको पोषण महत्त्व बारे महिला स्वास्थ्य स्वयंसेविकालाई अभिमुखिकरण कार्यक्रम

विद्यार्थी र शिक्षक तथा व्यवस्थापन समितिका पदाधिकारीहरू एवं वडाका जनप्रतिनिधिहरू समेत गरी करिव ६०० जनालाई दिवा खाजा खुवाइएको थियो। यसबाट सहभागी विद्यार्थीहरूले रैथाने बालीका परम्परागत र आधुनिक परिकारहरूको महत्त्व र बनाउन सकिने परिकारहरूको बारेमा आ आफ्नो घरमा सन्देश पुर्याउने र यसबाट उत्पादन एवं उपभोगमा सकरात्मक प्रभाव पर्ने अपेक्षा गरिएको छ। त्यसै गरी शिक्षक तथा व्यवस्थापन समितिका पदाधिकारीहरूलाई विद्यालयको दिवा खाजामा विद्यार्थीहरूलाई कोदोजन्य रैथाने बालीको परिकार खुवाउने बारेमा सचेतना र उत्प्रेरणा बढेको पाइएको छ।

घ) रैथाने बाली क्षेत्र विस्तार

स्थानीय चार वटा कृषि एवं बहुउद्देश्यीय सहकारी, एक कृषक समूह र एक कृषि तथा पशुपन्छी फर्म मार्फत आफनो वा लिजमा लिएको जमीन खनजोत गरी ३८० रोपनी क्षेत्रफलमा कोदो, कागुनो, स्थानीय सिमी, फापर, लट्टे, भटमास, कालोगुडे धान लगायतको खेती विस्तार गर्न सहयोग गरिएको छ। यस क्रममा बीउ विजन, माटो सुधार, भकारो सुधार, साना मेशिनरी तथा औजार आदि सहयोग गरिएको थियो। उत्पादन भए पछि बजारिकरणमा पनि सहयोग पुर्याइएको छ।

तस्विर ६. क्षेत्रविस्तार सहयोग अन्तर्गत स्थानीय सहकारीद्वारा गरिएको कोदो खेती

तस्विर ७. क्षेत्रविस्तार सहयोग अन्तर्गत स्थानीय सहकारीद्वारा उत्पादित कोदो

ङ) रैथाने जातको संरक्षण

कोदोजन्य र अन्य रैथाने बालीहरूको रैथाने जातको महत्त्व र संरक्षण बारे सम्बन्धीत सरोकारवालाहरूलाई सचेत बनाउन रैथाने जातका बीउहरू संकलन गरी नगर कार्यपालिकाको कार्यालयमा र्याक सहितको बीउ कक्ष स्थापना गरी प्रदर्शन गरिएको छ।

तस्विर ८. रैथाने जात संकलन र बीउ कक्षमा प्रदर्शनी

यसबाट जनप्रतिनिधि एवं कार्यालयमा सेवा लिन आउने सेवाग्राहीहरूले अवलोकन गरी थप जानकारी लिन सक्ने र त्यसले रैथाने जात संरक्षणमा टेवा पुग्ने अपेक्षा गरिएको छ।

कार्यक्रमबाट परेको प्रभाव

रैथाने बाली प्रबर्द्धनका लागि माथि उल्लेखित बिभिन्न क्रियाकलापहरू संचालन गरिए पछि स्थानीय स्तरमा कोदोजन्य र अन्य रैथाने बालीहरूको पोषण र स्वास्थ्य सम्बन्धी र अन्य विविध महत्त्व बारे प्रचार प्रसार भइ स्थानीयहरूमा कोदोजन्य बाली र अन्य रैथाने बालीको बारेमा सचेतना बढि ति बालीहरूको उत्पादन र उपभोग बढ्न थालेको पाइएको छ। त्यसै गरी शिक्षक शिक्षिका तथा स्वास्थ्य स्वयं सेबिकाहरूलाई तालिम दिनाले एवं सार्बजनिक स्थल तथा बिधालयमा रैथाने बालीका विभिन्न परिकार प्रर्दशन गर्दा र खाजा खुवाउँदा जनस्तरमा सकरात्मक छाप परेको देखिन्छ। कार्यक्रमको प्रभावले गर्दा नै कोदोजन्य बालीको बजार र मूल्यमा सकरात्मक प्रभाव परेको पाइएको छ। उदाहरणको लागि विगतमा पालिका भित्र कोदो उत्पादन भए पनि बजारमा बिक्री नहुने समस्या थियो तर अहिले बजारमा कोदोको अभाव भइ उपभोक्ताले किन्न नपाउने समस्या हुने गरेको छ। त्यसै गरी कोदोको पिठोको मूल्यमा पनि निकै बढोत्तरी भएको छ। पहिले प्रति किलो रु ८०। मा किनबेच हुने गरेकोमा अहिले बजारमा प्रति किलो रु २००। सम्म पनि पर्ने गरेको छ।

निष्कर्ष तथा भावी योजना

अन्तमा आ.ब. २०७७/०७८ देखी २०८०/०८१ सम्म रैथाने बाली प्रबर्द्धनका बिभिन्न क्रियाकलापहरू संचालन गर्दा नेपाल सरकारको कोदोजन्य रैथाने बाली प्रवर्द्धनको राष्ट्रिय अभियानलाई सहयोग पुग्ने गरी नगरपालिकामा क्षेत्र बिस्तार, प्रचार प्रसार, उर्बराशक्ति सुधारका कार्यक्रम संचालन गर्दा कृषकहरू उत्साहित भएको तथा यी बालीका उत्पादनहरूको बजारमा माग बढिरहेको देखिन्छ। यसको अलावा नगरकार्यपालिका तथा नगर सभामा रैथाने बाली प्रवर्द्धन बारे छलफल हुने गरेको छ भने कृषि बिकास कार्यालय, दैलेख र नेपाल कृषि अनुसन्धान परिषद अन्तर्गतको स्थानीय कृषि अनुसन्धान केन्द्र सँगको समन्वयमा रैथाने बाली प्रवर्द्धनको लागि विभिन्न कार्यक्रम संचालन हुने गरेको छ। त्यसै गरी विद्यालयको दिवा खाजामा रैथाने बाली समाबेशको लागी नगर शिक्षा समितिमा सवाल उठान भएको छ भने बिद्यालयका प्रधानाध्यापकहरूको बैठकमा दिवा खाजामा रैथाने बालीको परिकार समाबेश गर्नको लागि छलफल भएको छ। यी सवै नविनतम् पहल एवं प्रयासहरूमा पालिकाको अहं भूमिका रहेको छ। साथै भावी दिनमा पालिकाको पहलमा रैथाने बालीको क्षेत्र बिस्तारको साथै नमुना बिधालय तथा पालिकाको खाजा घरमा दिवा खाजामा रैथाने बालीका परिकार समाबेशलाई नितिगत रुपमा नै सम्वोधन गरी अघि बढ्ने पालिकाको सोच रहेको छ।

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक) । २०८० । राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ ।

बारपाक, गोरखामा कोदोको परम्परा र संस्कृति

दयाराम सापकोटा

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सारांश

गोरखा जिल्लाको बारपाक गाउँपालिका कोदोजन्य बालीको परम्परागत उत्पादन पकेट मध्ये एक रहेको छ। मध्यपहाडका धेरै बस्तिहरूमा जमिन बाँसो हुने समस्या रहेको भएता पनि बारपाकमा भने अहिले पनि खासगरी कोदोखेती निरन्तर रुपमा भैरहेको पाइन्छ। गुरुङ्ग र घले जातिको बाहुल्यता रहेको यस पालिकामा ति जातिहरूले कोदोसँग सम्बन्धीत धैरै जसो परम्परा र संस्कृतिको जगेर्ना र अवलम्वन गरी आएको पाइन्छ। यस लेखमा बारपाकमा कोदोसँग सम्बन्धीत इतिहास तथा परम्परा एवं स्थानीयहरूको खाद्य संस्कृतिको साथै स्थानीयहरूले प्रयोग गर्ने कोदोसँग सम्बन्धीत औजार तथा उपकरणहरूबारे जानकारी समावेश गरिएको छ।

बारपाकमा कोदो खेतीको इतिहास र परम्परा

बारपाकका स्थानीयहरूको अनुसार सदियौं देखि नै बारपाकमा कोदो खेती हुँदै आएको पाइन्छ। विशेषगरी कात्तिके र मङ्गसिरे गरी दुई स्थानीय जातहरूको कोदो मात्र खेती गरिने गरिन्छ। यदाकदा रातो कोदो, सेतो कोदो पनि खेती गरिने गरिएता पनि ति एकदमै नगन्य रुपमा रहेको पाइन्छ। आज भन्दा करिब २०० वर्ष अघि बारपाकमा कोदोको ब्याड राखेर कोदो छर्ने चलन थिएन। असार महिनामा छरुवा विधिबाट मात्र कोदो छरेर गोरुले दादे हालेर बारी जोत्ने र छोड्ने चलन थियो। तर हालको धार्चे गाँउपालिका कोरुजाको मुखिया बारपाक आएर बारपाकका मुखिया (प्रल्हाद घले) लाई नर्सरीब्याडमा कोदोको बीउ राखि तयार पारिएको बेर्ना रोप्दा कोदो धेरै फल्छ भनेर सिकाए पछि बारपाकमा कोदो रोपेर खेती गर्न शुरु गरिएकोले यसको श्रेय उनै कोरुजाको मुखियालाई जान्छ भनेर हाल बारपाक गाँउपालिका वडा नं २ बस्ने ७१ वर्षे धनीलाल घले भन्नुहुन्छ।

पहिला पहिला कोदो खेती गर्ने समयमा प्रत्येक घरबाट प्रल्हाद मुखियाकोमा पाँच दिन कोदो लगाउन जानु पर्ने चलन रहेको, पछि पञ्चायती व्यवस्था शुरु भए पछि तिन दिन मात्र जानु पर्ने नियम बनाईएको कुरा आफुले आफ्नो बाबु बाजेबाट थाहा पाएको धनीलाल घले भन्नुहुन्छ। यसरी मुखियाकोमा काम गर्न जाँदा स्थानीयले दिउँसो खाजा र बेलुका जौ र कोदोको पिठो पाउने चलन रहेछ। प्राय गरेर एक वर्ष कोदो लगाएको जग्गामा अर्को वर्ष कोदो नलगाउने चलन रहेको र हाल सम्म पनि निरन्तरता दिँदै आएको कुरा थाहा पाउन सकिन्छ।

बारपाकबासीहरूको लागि कोदोको बहुआयामिक महत्त्व

कोदोको पौष्टिक महत्त्व

कोदोमा शरीरको लागि आवश्यक पर्ने प्रोटीन, कार्बोहाइड्रेट र सुक्ष्म पोषक तत्वहरू प्रसस्त रुपमा पाइने भएता पनि सुत्केरी भएको बेला कोदोको परिकार खुवाउँदा पच्न गाहो हुने हुँदा सुत्केरी महिलालाई यसको परिकार खुवाउने चलन नभएको पाइन्छ।

सामाजिक प्रतिष्ठा र खाद्य सुरक्षामा महत्त्व

बिहे गरे पछि छोरीले भौके बस्नु पर्ने अवस्था नआओस भन्ने कुराको सुनिश्चितता गर्न पहिले पहिले जसको घरमा धेरै वर्ष पुरानो धेरै कोदो छ उसैकोमा छोरी दिने चलन पनि रहि आएको बारपाकका स्थानीयहरू बताउँछन्। विक्रम सम्वत २०१५ सालमा असिना पानीको कारण जौ उत्पादन नभएको, खानको लागि मकै पनि नभएको अवस्थामा गाउँमा नै भोकमारी लाग्ने अवस्थाबाट बचाउन कोदोले महत्त्वपूर्ण भूमिका निर्वाह गरेको अनुभव बारपाकका बुढापाकाबाट सुन्न पाइन्छ। त्यतिबेला जसको घरमा कोदो भएपनि बाँडीचुडी खाएको अनुभव पनि उनिहरू बताउँछन।

कोदोको धार्मिक महत्त्व

कोदो बालीलाई धार्मिक हिसाबले पनि देवकार्य तथा पिर्तकार्यमा पनि महत्त्वपूर्ण बालीको रुपमा लिने गरिन्छ। विशेषगरी गुरुङ्ग समुदायमा मान्छेको देहवसान भएर घाटमा लैजाने बेलामा धान, मकै, तिल, पैसासँग आनिवार्य रुपमा कोदो पनि मिसाएरबाटोमा छर्दै हिड्ने प्रचलन पनि रहि आएको पाइन्छ। विशेषगरी लामा र झाँक्री समुदायमा कोदोको पिठोबाट तोर्मो (बाहुन क्षेत्री समुदायमा मान्छे वितेको १० औं दिनमा बनाईने डिकुरो) बनाउने चलन रहेको छ।

बारपाकमा पाइने कोदोको परिकार र उपभोग गर्ने तरिका

आधुनिकतासँगै कोदोको रैथाने परिकार उपभोग गर्ने क्रम घट्दै गएको भएता पनि अझै पनि कतिपय खाद्य परिकारहरू एवं पेय पदार्थहरू बारपाकबासीहरू विच प्रचलित छन्। बारपाकमा कोदोबाट बनाईने विभिन्न परम्परागत परिकारहरू सम्बन्धी विवरण **तालिका १** मा दिइएको छ।

तालिका १. कोदोका विभिन्न परम्परागत परिकारहरू

क्र.स	परिकारको नाम	उपभोग गर्ने तरिका
१.	आलुम (डल्लो)	बिहान तथा दिउँसो खाजाको रुपमा खाने चलन रहि आएको छ।
२.	कोदोको ढिँडों	आडिलो र तागतिलो हुने भएकोले, बिहान र बेलुका खानाको रुपमा प्रयोग गरिने।
३.	कोदोको सेलरोटी	मेलापातमा खेतालालाई खाजाको रुपमा दिइने। पुजाआजा र धार्मिक कार्यमा भगवानलाई चढाउनको लागि प्रयोग हुने। कोशेलीको रुपमा दिने लाने चलन पनि रहि आएको छ।
४.	कोदोको खोले (सुप)	पुस, माघको बढी चिसोमा कोदोको खोले खादाँ शरीरलाई न्यानो हुने, चिसोबाट बच्न सजिलो हुनेहुँदा यसको प्रयोग गरिने।
५.	कोदोको रोटी (प्यान केक)	बिहान, बेलुकाको खाना र दिउसोको खाजामा आडिलो र तागत दिने भएको हुनाले प्रयोग गरिने।
६.	कोदोको रक्सी	घले र गुरुङ्ग समुदायमा मान्छेको जिवनको विभिन्न महत्त्वपूर्ण अवसर जस्तै बिहे, व्रतबन्ध र मरणको बेला कोदोको रक्सी उपभोग गर्नु अनिवार्य मानिन्छ। केटी माग्न जादाँ पनि पोङमा (रक्सी राख्ने भाडोँ) रक्सी राखेर लैजानु पर्ने चलन रहि आएको छ।
७.	कोदोको पुवा	घरायसी काम गर्दा खाजाको रुपमा खाने गरेको।

कोदोको रक्सीको साँस्कृतिक पक्ष

गुरुङ्ग शास्त्र अनुसार सृष्टिको शुरुवात तिर कोदो बालीलाई घरमा नै बनाईने मदिरा (रक्सी) बनाउने अन्नको रुपमा लिइन्थ्यो। कोदोलाई पुरुषले टिपेर ल्याउने र महिलाले निफन्ने गर्दथे। भुस र कोदो छुट्टाएपछि त्यसलाई पकाएर मर्चा हालेर मान्द्रोमा फैलाईन्थ्यो। एक रातमा अलि अलि रस आउन थाल्थ्यो। दोश्रो रातमा अलि बढी रस आउँथ्यो र तेश्रो रातमा जाँड (क्हुइ पा) तयार हुन्थ्यो। नेपालका अन्य केहि रक्सी उपभोग गर्ने समुदाय झैं गुरुङ्गहरूलाई जन्म देखि मृत्यु सम्म नै जाँड, रक्सी चाहिन्छ। गुरुङ्ग समुदायमा चाड पर्व बाहेक अरु बेला पनि कोही पाहुना आए कोदोको जाडँ, रक्सी दिएर स्वागत गर्ने चलन रहेको पाइन्छ। कतै कतै मलामी जानेहरूलाई पनि कोदोको रक्सी दिने चलन छ। मृत्युको कार्य गर्दा गुरुङ्ग समुदायलाई जाडँको छोक्रा चाहिन्छ, जन्मिदा जस्तै थाँसो फाल्ने भनेर कोदोको छोक्रा र कोदोको ढिँडोको स–साना भगवान बनाएर त्यसलाई फालेर शुद्ध गर्ने चलन रहेको पाइन्छ। पहिला पहिला सबै भन्दा ठूलो इज्जत नै कोदोको रक्सीमा हुने बताउने गुरुङ्ग समुदायका मानिसहरू अरुको घरमा पाहुना जाँदा पनि कोदोको रक्सी लिएर जाने चलन रहेको बताँउछन्। तर अहिले आएर बिस्तारै अन्य पेय प्रदार्थले रक्सीलाई विस्थापित गर्दै गरेको अनुभव पनि सुन्न पाइन्छ।

कोदो खेती, प्रशोधन, भण्डारण र परिकार उपभोगको लागि प्रयोग हुने औजार र सामग्रीहरू

बारपाकमा कोदोको खेती गर्दा अलावा बाली कटानी, चुटानीको साथै भण्डारण र कुटानी एवं पिसानी लगायतका कार्यहरूमा प्रायः परम्परागत औजार तथा उपकरणहरू नै प्रयोग गरिन्छ। त्यस्ता केहि प्रमुख औजार तथ उपकरण र तिनको प्रयोग बारेको जानकारी **तालिका २** मा दिइएको छ।

तालिका २. कोदो बालीसँग सम्बन्धीत औजार, उपकरण एवं सामग्रीहरू

क्र.स.	औजार/उपकारणको नाम	प्रयोग
१.	चाल्नु (सिजी)	कोदो चुटेपछि दाना चाल्ने
२.	मदुस (भकारी)	कोदो भण्डारण गर्ने काठको बाकस, प्राय यत्तिकै मदुसमा कोदो राख्ने गरिएता पनि यदाकदा मदुसलाई खरानीले लिपेर पनि कोदो भण्डारण गर्ने चलन रहेको पाइन्छ। यो एक किसिमको काठको बाक्स हो।
३.	थुम्से (मास्य)	कोदो टिपेर राख्ने

क्र.स.	औजार/उपकारणको नाम	प्रयोग
४.	माना (मन)	कोदो नापतौल गर्ने
५.	पाथी डाली (टोलो)	कोदो तथा अन्न बाली भर्ने
६.	छोम	कोदोको बीउ फल्ने (कोदो पिन्नु अगाडि, बाहिरी बाक्रा फाल्ने)
७.	पोङ	कोदोको रक्सी राख्ने भाडाँ (यो कटहरको रुख वा दार भन्ने रुखबाट बनाउँदा बलियो हुन्छ भन्ने मान्यता छ।)
८.	त्रिपाल (पाल)	कोदो सुकाउनको लागि प्रयोग हुने
९.	गुम (स्यागुम)	कोदो रोप्दा पानी पर्दा ओढ्ने
१०.	हँसिया (कोरे)	कोदो टिप्ने/नल काट्ने
११.	चिरकिली (लौरो)	कोदोको बाला चुट्ने
१२.	कराई	कोदो भुट्ने भाडाँ
१३.	जाँतो	कोदो पिन्ने (जाँतोको तल्लो भागः रन्ता म (आमा) र जाँतोको माथिल्लो भागः रन्ता पो (बा))
१४.	फुक्चे	रक्सी खाने भाँडो
१५.	दाबिलो (पुय)	कोदोको ढिँडो ओढाल्नको लागि प्रयोग हुने
१६.	नाङ्गलो	कोदो निफन्नको लागि प्रयोग हुने
१७.	हलो	कोदो खेती गर्दा खेतबारी जोत्नको लागि प्रयोग हुने
१८.	छोरमा	कोदोको जाँड बनाउदा छान्न प्रयोग हुने

कोदोजन्य बालीसँग सम्बन्धीत केहि प्रमुख औजार तथा उपकरणहरूको चित्र

चाल्नु (सिजी)

पोङ

दाबिलो (पुय)

मदुस (भकारी)

थुम्से

गुम (स्यागुम)

जाँतो

छोम

छोरमा

डोको

हँसिया (कोरे)

पाथी डाली (टोलो)

हलो

चिरकिली (लौरो)– कृषकले समातेको

***

नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक) । २०८० । राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौं ।

समिभञ्ज्याङ, लमजुङमा सामा, बाजरा (घोंगे), काउनो, धानकोदो, कोदो र जुनेलो बालीहरूको इतिहास र वर्तमान

बाल कृष्ण जोशी[१], बाल कुमार जोशी[२] र ओम बिर गुरुङ[२]

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सारांश

पश्चिम लमजुङको समिभञ्ज्याङमा कोदे (कोदोजन्य) बालीहरू जस्तै: कोदो, सामा, बाजरा (घोंगे), काउनो (कागुनो), धानकोदो र जुनेलो खेती गर्ने निक्कै पुरानो चलन थियो । यी बाहेक सामा घाँस, बन्सो, कनिके कागुनो, कोदे झार, र भिर्कौलो (जोगी माला) खेत-बारी वरपर प्रशस्त रुपमा पाइन्थ्यो । कोदो बाहेक अन्य बालीहरू २०१४ सालतिरबाट नै लोप हुँदै गएर हाल आएर कोदो र कतै कतै जुनेलो खेती गरेको पाइन्छ। जातीय विविधता कोदोमा बढी भएपनि हाल आएर ति जातहरू धेरैजस्तो हराईसकेको उक्त गाउँका किसानहरू बताउने गर्छन् । यी बालीहरूबाट विविध परिकार बनाएर खाने र बस्तुभाउहरूलाई पनि हुने भएपनि अहिलेको पुस्तालाई केही थाहा छैन ।

परिचय

गण्डकी प्रदेश, लमजुङ जिल्ला अन्तर्गत हालको मध्यनेपाल नगरपालिका वडा नं. ५, समिभञ्ज्याङको खर्क, आमडाँडा, पराजुली बेंसी, पुरानो हटिया र अन्य ठाउँमा कोदे बालीहरू (कोदोजन्य बालीहरू) जस्तै: कोदो, सामा, बाजरा (घोंगे), काउनो (कागुनो), धानकोदो र जुनेलो खेती गर्ने निक्कै पुरानो चलन थियो। ति बाहेक सामा घाँस, बन्सो, कनिके कागुनो, कोदे झार, र भिर्कौलो (जोगी माला) खेत-बारी वरपर प्रशस्त रुपमा पाइन्थ्यो। यी जंगली कोदे बालीहरू मुख्य गरेर पशु (भैंसी, गाइ र बाख्रा) लाई खुवाउने चलन थियो। खर्क र पराजुली बेंसी प्राय: जसो सुख्खा र रुखो जमिन भएकोले कोदे बालीहरूको खेतीबाट राम्रो उत्पादन लिने गरेको पाइन्थ्यो। खाद्य, पोषण र स्वस्थ हुनको लागि यी बालीहरूको राम्रो योगदान रहेको पुरानो किसानहरूले बताउने गर्नु हुन्छ। बिरामी हुँदा जस्तै: पेट दुख्दा, यी बालीहरूको परिकार खाने चलन पनि थियो। यी बालीहरूको भुस, तथा नल पशुहरूलाई खुवाउने चलन थियो साथै भुसबाट सिरानी बनाउने चलन रहेको थियो। कोदो अन्तरगत धेरै रैथाने जातहरू जस्तै: पाउँदुरे, पुषे, कातिके, मंसिरे, मुड्के, लाफ्रे, आदि भए पनि अन्य कोदे बालीहरू, जस्तै: सामा, बाजरा, काउनो र जुनेलोमा जातीय विविधता निक्कै कम भएको अग्रज किसानहरू बताउँछन्। कोदे बालीलाई मिसिनी बाली पनि भन्ने गर्छन्। कोदोलाई कुअन्न भने पनि अन्य कोदे बालीहरूलाई कु-अन्न भन्ने चलन थिएन।

समिभञ्ज्याङका ८५ वर्षिय (२०८० सालमा) किसान मिन बहादुर शाही सानैदेखि उक्त बालीहरू खाने, लगाउने गर्दै आएकोमा हाल कोदोबाहेक अन्य कोदोजन्य बालीहरू हराइसकेको भन्नुहुन्छ। यी बालीहरू सयौं बर्ष पुराना भए पनि कोदो बाहेक अन्य बालीहरू २०१४ सालतिरबाट नै लोप हुन थालेको कुरा शाही बताउनु हुन्छ। बुवा बाजेहरूले खेती गर्दै आउनु भएकोले उक्त बालीहरूको ज्ञान आफ्नै परिवारबाट प्राप्त भएको कुरा उहाँ उल्लेख गर्नु हुन्छ।

सोही गाउँकी ८४ वर्षिया आमा श्रीमाया थापा मगर (चित्र १) सँग पनि कोदोजन्य बालीहरू मुख्यत: कोदो, जुनेलो र सामाको बारे छलफल गरी परम्परागत ज्ञान संकलन गरिएको छ। यो लेख कोदोजन्य बालीहरू (चित्र २) सँग सम्बन्धीत उनै किसानहरू लगायत पदम थापा मगर र टक्सारको मनु गिरिको ज्ञान र अनुभवमा आधारित छ र धेरै जसो अभ्यासहरू धेरै बर्ष अगाढीको हो। किसानहरूको भनाइमा मल भए जे पनि एकदम राम्रो हुने र धेरै उत्पादन लिन सकिन्छ। रासायनिक मल र बिषादी बिना खेती गरिने एकदम पुराना यी बालीहरूको बीउ किसान आफैंले राख्दै आएका छन्।

चित्र १. ८५ बर्ष उमेरका किसान (बायाँ: मिन बहादुर शाही) र ८४ वर्षिया (दायाँ: श्रीमाया थापा मगर, मुंग्रोले कोदो छुट्दै) हरू (कोदोजन्य बालीहरूको सँगतबाट निरोगी, बलियो, हट्टाकट्टा, स्वस्थ भएको अनुभव)

सामा

घैया (पाखो बारीमा हुने छरुवा धान) र मकै लगाउने समय, चैत्र वैशाखमा नै घैया छरेको जस्तै गरी सामा छर्ने गरिन्छ। घैयालाई जस्तै मल राखी घैया गोडे जस्तै गोडमेल गर्ने गरिन्छ। सामा गँजाउँछ र रोग किरा कम लाग्ने हुन्छ। श्रावण-भाद्रमा काट्न तयार हुन्छ र उत्पादन घैयाको भन्दा कम हुने गर्छ। पाकेपछि लठ्ठीले चुटेर कोदो जस्तै गरी दाना निकाल्ने गरिन्छ। घाममा सुकाएर दानालाई भुँड्का (सानो मुख भएको माटोको भाँडो) मा राखेर भण्डार गरिन्छ। सामालाई ढिकीमा फलेर भात जस्तै गरी पकाएर खाने गरिन्छ। सामाको खिर पकाएर खाँदा राम्रो र पोषिलो हुने किसानहरू बताउँछन्। सामाको दाना मसिनो हुने र खिर मिठो हुन्छ र बुढा बुढीले बढी मन पराउने गर्छ। काउनो दुख पाउने र सामा सुख पाउने कहानी किसानहरू बताउँछन्। भुस धेरै फाल्नु पर्ने हुन्छ र पशुलाई नल र भुस खुवाउने गरिन्छ।

बाजरा

यसलाई बाजुरे, घोगे, भय-काउनो पनि भनिछ र यसको घोगा न्याउरी मुसा जस्तो देखिने हुन्छ। घैया, मकै लगाउने समय चैत्र वैशाखमा नै घैया छरेको जस्तै गरी छर्ने चलन छ। घैयालाई जस्तै मल राख्ने, घैया गोडे जस्तै गोडमेल गर्ने गरिन्छ। बाजरा कम मात्रामा गँजाउने गर्छ र रोग किरा कम लाग्ने हुन्छ। श्रावण-भाद्रमा काट्न तयार हुन्छ। उत्पादन घैयाको भन्दा कम हुने गर्छ। चुट्न गारो तथा ठटाउने कठिन हुने हुँदा पाके पछि लठ्ठीले चुटेर वा हिर्काएर वा हँसियाले खुर्केर गेडा झार्ने गरिन्छ। मलिलो ठाउँमा निक्कै ठुलो हुने गर्छ र यसको झुसले चिलाउने हुन्छ। दानालाई भुँड्कामा राखेर भण्डार गरिन्छ। ढिकीमा कुटेर फल्ने र भात खाने गरिन्छ। पिठो बनाएर रोटी खानुको साथै जाँड बनाएर रक्सि बनाउने पनि गरिन्छ। कोदोको भन्दा यसको रक्सि बढी पर्ने र माग बढी भएको देखिन्छ। ढाड दुख्दा, अंग भाचियो भने यसको भात खुवाउने चलन छ र भैंसीलाई पात र टुप्पा खुवाउने गरिन्छ।

काउनो

काउनोलाई चैत्र-बैशाखमा लगाएर श्रावणमा बाली लिने गरिन्छ। छरेर लगाउने गरिन्छ र हल्का गोडमेल गर्ने गरिन्छ। झुलेको बाली राम्रो देखिने हुन्छ। बाला टिपेर कोदोको जस्तै चुटेर दाना झार्ने र घाममा सुकाएर भण्डार गर्ने गरिन्छ। यसलाई ढिकीमा फलेर भातको रुपमा खाने अथवा खिर

बनाउने चलन रहेको छ। काट्ने बित्तिक्कै खानको लागि काउनोलाई बफाएर केही समय सुकाउने र कुटेर चामल निकाल्ने चलन पनि रहेको छ। यसलाई अनिकाल टार्ने अन्नको रुपमा लिइन्छ। यो छिटो पाक्ने, खुट्टाले माढेर घाममा सुकाए पछि ढिकीमा कुट्ने चलन छ। घनपोखरा मा हराइसकेको बरिय कागुनोलाई केहि छनौट गरी अहिले उक्त ठाउँमा धेरै किसानहरूले उक्त कागुनो लगाउछन् र बर्षमा करिव ३० मुरी उत्पादन गर्छन जुन प्रति केजी २५० रुपिया मा बिक्रि भईरहेको छ।

सामा

कागुनो

धानकोदो

घोगे

जुनेलो

कोदो

चित्र २. बिभिन्न कोदोजन्य (कोदे) बालीहरू

धानकोदो

आमडाँडा, टक्सार, जित्तामा धानकोदोको खेती हुने र धेरै जसो डाँडाबारीतिर लगाउने चलन थियो। यसलाई कोदो लगाउने समय (श्रावण-भाद्र) मा नै लगाउने र सोही अनुसार कार्तिक-मंसिरमा काट्ने गरिन्छ। यसलाई छरेर लगाइन्छ र गोड्ने बेलामा पातलो भाको ठाउँमा बेर्ना सार्ने पनि गरिन्छ। यो छुट्टै एकल बालीको रुपमा साथै कोदो भएको फिल्डमा नै मिसिएको पाइन्थ्यो। बढी गँजाउने र एकदम मसिनो दाना हुन्छ। धान जस्तै देखिने यसको गाँजमा बाला एकदम लरक्क परेको अति राम्रो हरियो बोट देखिन्छ। कोदोको फिल्डमा भएको धानकोदो, कोदोसँगै काट्ने, चुट्ने, र खाने गरिन्छ। यसबाट भात, रोटी, ढिँडो बनाएर खाने गरिन्छ र रोटी मिठो हुने किसानहरू बताउँछन्।

कोदो

लगाउने समयको आधारमा कोदो दुई थरीको हुन्छ। पहिलो रैथाने जात जुन चैत्रमा रोपिन्छ र श्रावणमा टिपिन्छ। यस्तो कोदोको जात पाउँदुरे कोदो हो। यो ब्याड राखेर वा छरेर पनि लगाउन सकिने हुन्छ। ब्याड राखेपछि एक कुरेतको बेर्ना भए पछि रोप्नुपर्छ र छरुवा गरी लगाएको कोदो हो भने एक कुरेत भए पछि बाँसो जग्गा जोतेजस्तै जोत्ने गरिन्छ। जोतेको १०-१५ दिनपछि गोड्ने गरिन्छ। यो जातको मूल बाला पाकेर टिपेपछि फेरि हाँगाबाट अन्य बाला निस्कन्छ र पुन: २-३ पटकसम्म बाला लिन सकिन्छ।

अर्को थरी जातहरू श्रावण-भाद्रमा छर्ने वा रोप्ने र कार्तिक मङ्सिरमा काट्ने गरिन्छ। जातहरू धेरै थरिका छन् जस्तै: कातिके, मंसिरे, लाफ्रा, सेतो कोदो (ज्वाई कोदो), कुकुर काने कोदो, पहेंले कोदो, केउरयंगे, आदि। सेतो कोदो रोटीको लागि राम्रो मानिन्छ, तर यो ढिला पाक्ने र कम फल्ने हुन्छ र केउरयंगे कोदोको दाना ठुलो हुने तर झार्न कठिन हुन्छ। तर हाल आएर धेरै जातहरू हराएको पाइन्छ। केही जातहरू जेष्ठ-असारमा ब्याड राखेर एक कुरेतको भएपछि रोपिन्छ। लेकतिर कोदोलाई मकै बारीभित्र रोप्ने गरिन्छ। मकै काटेपछि कोदो रोप्ने गरिन्छ र कोदोभित्र गहत, मास लगाउने गरिन्छ। कोदोको ब्याड राखेर बेर्ना रोप्ने चलन बढी छ र एक एक वटा बेर्ना रोप्ने गरिन्छ। बेर्ना नजिक नजिक रोप्ने चलन छ। बेर्नामा गाँठा देखिए पछि (गाँठा परेको भनिन्छ) रोपेमा एक दम साना बाला (सिन्काजस्तो बाला) हुन्छ र यो अवस्थाको रोप्दा बेर्ना भाँचिने बढी हुन्छ जसले गर्दा कोदोको उत्पादन अति न्यून हुन्छ।

गोडमेल खासै गर्नु नपर्ने भएपनि झार बढी आएमा गोड्ने गर्नुपर्छ। रोग किरा खासै न लाग्ने तर २०७४ सालमा हरियो पात खाने लार्भाले गाउँको पुरै कोदो सखाप पार्न खोजेको थियो। बाला टिपेपछि भकारीमा १०-१५ दिन गुम्साएर राख्ने चलन छ। यसरी गुम्स्याउँदा भित्र दानालाई केही असर नहुने तर बाहिरको खोस्टा गलेर चुट्न वा झार्न सजिलो हुने हुन्छ। झार्नको लागि लट्ठी, मुंग्रोले ठटाएर झार्ने गरिन्छ। धेरै कोदो भएमा खला बनाएर दाइँ हाल्ने (गोरुलाई मियोमा बाँधेर कोदोमाथि हिनाउने) चलन छ। टिपेपछि उतिखेरै खुट्टाले माडेर वा लट्ठीले चुटेर कोदोको दाना छुट्याउने पनि गरिन्छ। कोदोको पिठोबाट रोटी र ढिँडो बनाएर खाने गरिन्छ। कोदोको दाना र मर्चाबाट रक्सि, जाँड, छयांग, बनाउने गरिन्छ। रातो तथा कालो कोदोको रक्सि बढी आउने गर्छ। यसरी रक्सि वा जाँड बनाएपछि आउने कट सुँगुर, तथा अन्य वस्तुभाउलाई दिने चलन छ। कोदोको भुसबाट सिरानी बनाउने चलन छ तर भुस गाइवस्तुले त्यतिसारो मन पराउँदैनन्। कोदोको नल मान्छे तथा बादर ले गुलियो हुने भाकोले चुस्ने चलन पनि छ।

कोदोको रोचक प्रसँग पनि छ। कति ठाउँहरूमा नेवारलाई कोदे पनि भन्ने चलन छ। धेरै पहिला नेवारहरूले घर-बुना कपडा आफैं उत्पादन गरेर बेच बिखन गर्थे। उक्त कपडा तयार गर्दा चाहिने धागोलाई बलियो र राम्रो बनाउन उक्त धागोको डल्लालाई कोदोको पिठो र पानी पकाएर बनाएको माढा दल्ने चलन थियो र उक्त कार्य गर्दा कोदोको पिठो धेरै प्रयोग हुने हुँदा नेवारलाई कोदे भन्ने चलन भएको कुरा पुराना पाकाहरूले बताउने गर्छन।

जुनेलो

जुनेलो चैत्र-बैशाखमा लगाएर भाद्र-कातिकमा बाली लिने गरिन्छ र य्स यसलाई जुनेलो मकै पनि भनिन्छ। यसलाई घैयाजस्तै छरेर वा मकैजस्तै रोपेर खेती गर्ने गरिन्छ र धेरैजसो किसानहरूले खेतबारीको डिलहरूमा थोरै बोटहरू लगाउने गर्छन्। डिल, पखेरा, छेउछाउमा लगाउँदा राम्रो हुने हुन्छ र केही मात्रामा अहिले पनि खेती भईरहेको पाइन्छ। नवलपुरको मह-डाँडामा यसको खेती धेरै मात्रामा हुन्थ्यो। जुनेलोका मुख्य दुई जात, रातो र सेतो जुनेलो पाइन्छ। यसलाई मल धेरै हाल्नु पर्दैन, मल धेरै भएमा हौसिन्छ र ढल्छ। यसको गोडमेल घैया गोडेजस्तै गरी गोडमेल गर्ने र झारपात हटाउने चलन छ। यसमा रोग किरा कम लाग्छ र उत्पादन मकैजत्तिकै हुन आउँछ। यसलाई भातको रुपमा खाने, भुटेर खाने, पिठोबाट आटा बनाएर खाने र रक्सि बनाउने पनि गरिन्छ। यसको लड्डु राम्रो मानिन्छ। मकैको जस्तै पात र टुप्पा गाईभैंसीलाई खुवाउने गरिन्छ।

कोदे बालीहरू लोप हुनुको कारण

कोदे बालीहरूमा कोदो र जुनेलो बाहेक अन्य प्रजातिहरू र तिनका जङ्गली नातेदार प्रजातिहरू सबै समिभञ्ज्याङबाट लोप भैसकेका छन्। ती बालीहरू किसानहरूले आफैँ नै लगाउन छोडेको कुरा किसानहरू बताउँछन्। तर यसरी हराउनुमा मुख्यत: उन्नत प्रविधिको विकास नहुनु, धेरै खेताला लाग्ने, धानको भात खाने बानी परेको, विकासे जातप्रति बढी उन्मुख भएको र धेरैजसो किसानहरूले कृषि पेशालाई छोड्ने क्रम हुनु हो।

सन्दर्भ-सामग्री

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राष्ट्रिय योजना आयोग र विश्व संरक्षण संघ। २०५०। स्थानीय वाताबरण योजना, समिभञ्ज्याङ गाउँ विकास समिति, लमजुङ्ग।

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International Year of Millets 2023 : Global Perspective

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Summary

The International Year of Millets 2023 aims to create greater awareness of millet production, contribute to food security, nutrition, support to the livelihood and income of farmers, poverty eradication and the achievement of the Sustainable Development Goals. This chapter aims to provide overview of millets and its economic, cultural, social and environmental values for better production, better nutrition, a better environment and a better life. ‘Further, it provides policy recommendations for sustainable millets value chain development.

Keywords: Economic, environment, international year of millets, millets, social, value chain

Introduction

In the seventy-fifth session of the United Nations General Assembly (UNGA), Bangladesh, Keyna, Nepal, Nigeria, the Russian Federation, Senegal, and India submitted the draft resolution A/75/L.63, entitled “International Year of Millets, 2023” believing to create greater awareness of millet production, contribute to food security, nutrition, support to the livelihoods and income of farmers, poverty eradication and the achievement of the Sustainable Development Goals (SDGs), which was sponsored by more than 60[1] delegations (UN 2021a). The session decided to declare 2023 the International Year of Millets, which is linked to previous declarations including the United Nations Decade of Action on Nutrition (2016-2025), and the United Nations Decade of Family Farming (2019-2028) and invited the Food and Agriculture Organization of the United Nations to facilitate the implementation of the International Years (UN 2021b).

The UNGA has acknowledged the significance of millets in supporting the nutritional needs, means of subsistence, and earnings of family farmers, particularly those operating on a small scale. As such, millets can be a vital factor in promoting food security, eliminating poverty, and ultimately aiding in the attainment of the SDGs. The millet farming is crucial for sustainable farming and production practices to the livelihoods of millions of rural farm families and small family farmers around the globe. Encouraging the market to recognize millets' advantages and fostering effective value chains are essential.

1 Afghanistan, Algeria, Argentina, Armenia, Azerbaijan, Belarus, the Plurinational State of Bolivia, Brazil, Cameroon, the Central African Republic, Chile, China, Colombia, Cuba, Egypt, Eswatini, Ethiopia, Georgia, Guatemala, Guinea, Indonesia, the Islamic Republic of Iran, Israel, Japan, Jordan, Kazakhstan, the Lao People’s Democratic Republic, Lebanon, Lesotho, Malaysia, the Maldives, Mali, Mauritius, Mongolia, Nicaragua, the Niger, Papua New Guinea, Paraguay, the Philippines, Qatar, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Singapore, South Africa, Sri Lanka, Tajikistan, Togo, Turkey, Turkmenistan, Uzbekistan, the Bolivarian Republic of Venezuela and Zambia.

Population is growing, climate change is posing challenges to the agrifood system, food and nutrition insecurity is deepening, and cost of healthy food is rising. In such scenario, millets, a climate resilient crop, provide an affordable and nutritious option (FAO 2022). In the last 70 years, agricultural productivity has increased significantly (FAO 2023), however, millets including other indigenous nutrient-dense, and climate smart crops are neglected.

Prevalence of undernourishment is continuously rising since 2015 (**Figure 1**). During 2000-2002 there were 12.9% people undernourished in the world, which dropped to 7.8% in 2013-2015. Unfortunately, the figure increased to 9.2% in 2020-2022.

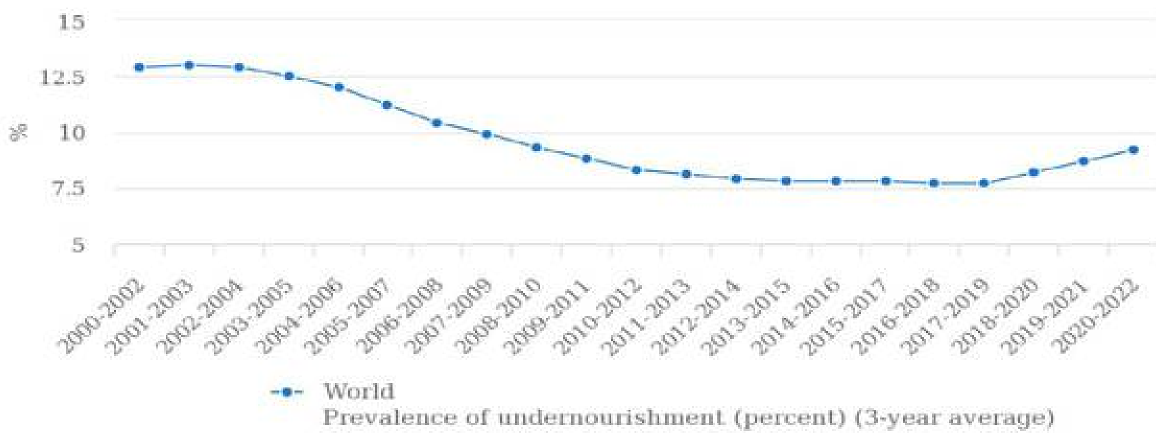


Figure 1. Prevalence of undernourishment (3-year average)
Source: FAOSTAT 2023

Millets

Encyclopedic Dictionary of Archaeology (2021) has defined millet as "any of various grasses used as forage or cereals, probably first cultivated in Asia or Africa about 4,000 years ago. Four cereals are grouped under this name. *Panicum miliaceum* was the most important, first recorded at Jemdet Nasr in Mesopotamia. It was widely grown in Neolithic Europe and was the staple crop in early China. *Setaria italica* was possibly developed in Southern Europe, and even there was never as common as *Panicum*. Grains of the *Setaria* genus were an important item of diet in parts of Mexico as early as 6500 BC. *Eleusine* and *Pennisetum* are of more recent origin, largely confined to tropical Africa, and introduced thence to India. Millets are an important food staple in much of Asia, Russia, and western Africa. In the United States and western Europe, they are used chiefly for pasture or to produce hay, although they were major grain in Europe during the Middle Ages."

The word "millet" has originated from the French word "Mile", which means thousand implies a handful of millets contain thousands of grains (Paschapur et al 2021). Millets were described in ancient texts. Foxtail millet (priyangava), proso millet (aanava), and Barnyard millet (shyaamaka) were mentioned in the Yajurveda and millets are mentioned in Sushruta Samita (600-500 BC), Charaka Samhita (100 – 200 AD), Vishnu Puran (450 AD), Abhijana Shakuntalam (400-500 AD) and Ramadhanya Charithre (1600AD) (Paschapur et al 2021).

Millets were domesticated more than 10,000 years ago (Paschapur et al 2021). It is assumed that common millet and foxtail millet are originated in East Asia and landraces of foxtail millet was found around Europe, Afghanistan, Nepal, India, Myanmar, Thailand, Korea, China, Japan, Taiwan, Philippines, and Indonesia (Sakamoto 1987).

Finger millet, pearl millet, foxtail millet, barnyard millet, proso millet, kodo millet and little millet are seven important millets globally (Paschapur et al 2021). Finger millets are main grown in Africa (Uganda, Kenya, Tanzania, Ethiopia, Rwanda, Malawi, Sudan, Zambia, and Zimbabwe) and Southern Asia (India and Nepal) (Dida and Devos 2006). Foxtail millet is mostly grown in China for human consumption and for forage for livestock, which was traditional grown as a summer crop until the 17th century before replacing by maize (Panaud 2006). Pearl millet can be grown in too dry and too infertile regions of Africa and southern Asia, where other major cereal face challenges to flourish (Devos et al 2006). Northen Namibia is greatly dependent on pearl millet for food (Devos et al 2006).

Finger millet is adapted in a wide range of ecosystems, ranging from sea level to up to the Himalyas in Nepal (Dida and Devos 2006) of the altitude of more than 3500 m. Its global production is estimated to be around 4.5 million tons of grain (Dida and Devos 2006).

Distribution of Millets

Millets are mainly distributed around Africa and Asia. **Table 1** presents the detail distribution of millets around the world.

Table 1. Distribution of millets

SN	Millet	Distribution (Region/Countries)
1	**Pearl millet** (*Pennisetum glaucum, P. typhoides, P. tyhpideum, P. americanum*)	Western Africa, Central, Eastern and Southern Africa, Asia (India, Pakistan, and Southern coast of the Arabian Peninsula.
2	**Finger millet** (*Eleusine coracana*)	Eastern Africa and in Asia (India, Nepal)
3	**Foxtail millet** (*Setaria italica*)	China, Korean peninsula, some part of southern Europe
4	**Teff** (*Eragrostis tef*)	Ethiopian highlands
5	**White fonio** (*Digitaria exilis*)	sub-Sahelian Western Africa (except Liberia)
6	**Black fonio** (*Digitaria iburua*)	isolated pockets in the Jos-Bauchi plateau of Nigeria and the northern parts of Togo and Benin
7	**Guinea millet** (*Brachiaria deflexa*)	Fouta-Djallon plateau of Guinea and Sierra Leone
8	**Barnyard millet** (*Echinochloa crusgalli, E. colona*)	the tropics and subtropics of India
9	**Little millet** (*Panicum sumatrense*)	India, Nepal, Pakistan, Sri Lanka, eastern Indonesia and western Myanmar
10	**Kodo millet** (*Paspalum scrobiculatum*)	Western Africa and India
11	**Job's tears** (*Coix lachryma-jobi*)	Southeast Asia

Source: FAO and ICRISAT (1996)

Classification

Millet species can be divided into two broad categories: pearl millet and "small" millet and they consist of Peral millet (Pennisetum glaucum, P. typhoides, P. tyhpideum, P. americanum), Finger miller (*Eleusine coracana*), Proso or Common millet (Panicum miliaceum), Foxtail millet (Setaria italica), Teff (Eragrostis tef), White fonio (Digitaria exilis), Black fonio (Digitaria iburua), Guinea millet (Brachiaria deflexa), Barnyard millet (Echinochloa crusgalli, E. colona), Little millet (Panicum sumatrense), Kodo millet (Paspalum scrobiculatum) and Job's tears (Coix lachryma-jobi) (FAO and ICRISAT 1996).

Millets are divided into major and minor depending on the size of the millet seed (Orsat, Murugesan and Ghosh 2022).

- Major: Finger millet, Proso millet, Pearl millet (Bajra) and Foxtail millet (Italina millet)
- Minor: Job's tears (Adlay millet), Fonio (Polish millet), Barnyard millet, little millet, Kodo millet and Brown top millet.

Values

Millets are valuable from the perspective of food, feed, fodder, and ecological services. Although millets contribute only two percent of the global cereal utilization, it is important staple food in the majority of the semi-arid tropics where precipitation and soils are poor. It is estimated that about 80% of world millets is used as food, followed by feed (7%) and other uses, including seed, beer, and waste. Whereas in Asia and Africa, it is 95% of millets are consumed as food (FAO and ICRISAT 1996).

Millets can be promoted for food security, nutrition security, safety from diseases and economic security (Kumar et al 2018). Millets can grow in harsh conditions where other traditional cereals cannot be grown to its potential. Further, they are also resistant to various climatic stresses and disease pest infestations. These qualities of millets help to ensure food and security in various parts of the world where food security is still a significant issue. It is generally utilized as food, animal feed, commercial brewing and opaque beer.

Millets are rich in micronutrients, including calcium, iron, zinc, iodine, and other bioactive compounds. Further, it has better amino acids profile. Therefore, promotion of millet consumption will support to ensure nutrition security- especially for pregnant and lactating women, and children.

Millets are gluten free, low glycemic index including other beneficial substances, which are beneficial for cardiovascular diseases, diabetic persons, celiac diseases, anemia and calcium deficiency, etc. Diet-targeted intervention is curial to curb increasing diet-related non communicable diseases (Sing and Vemireddy 2023).

The recent report of The State of Food Security and Nutrition in the World suggested that prevalence of anemia in women (15-49 years) is still high in various part of the world (Finkelstein et al 2015, Finkelstein et al 2017) irrespective of the development status. Still 14.4% women of that age group are suffering from anemia in high income countries, which is 39.4% in the low-income countries with the global average of 29.9% (FAO et al 2023). Millets, having a high iron content (Finger millets: 3.3-14.89 g/100g) (Zahra Mohammed Hassan et al 2021), can contribute to increase iron status, hemoglobin level and reduce iron deficiency anemia (Anitha et al 2021, ICRISAT 2013, Cercamondi et al 2013, Tako et al 2015, Finkelstein et al 2015, Datir et al 2018).

Prevalence of undernourishment in the total is also a global challenge. Still 27.9% of population in the low-income countries and 9.2% globally are undernourished (FAO et al 2023). The cost of healthy diet has increased significantly in the recent years[2]. The cost of animal source foods (26.3%) and the cost of vegetables (23.9%) are the highest cost for a healthy diet. However, millets, having diverse range of abundant nutrients could be a cheap source of healthy diet.

Due to climate change, crop failure is increasing (Kim and Mendelsohn 2023) in various part of the world (Henrique et al 2021, Mendelsohn, 2007, Challinor et al 2010, Caparas et al 2021). Such crop failure not only creating income loss for the farmers, but also causing food and nutrition insecurity. However, millets, being a climate-resilient crop and having capacity to grow in infertile soil and water scare scarcity, can be a reliable source of income and can act as the insurance crop as well.

2 https://www.fao.org/faostat/en/#data/CAHD/visualize

Millets can be stored for a longer period with little loss and damage. Such attribute of millets can be utilized to make a buffer food stock, which would be helpful in case of natural disasters.

Area and Production

Millets are grown in more than 76 countries, however, 90% of area has been confined within 14 countries as presented in the **Table 1** (FAO 2022).

Table 1. Millet area harvest (ha) in 2021

SN	Area	Area (ha)	Global Share	Cumulative%
1	India	9,764,817	30.7%	30.7%
2	Niger	6,145,774	19.3%	50.0%
3	Sudan	2,800,000	8.8%	58.8%
4	Mali	2,079,082	6.5%	65.3%
5	Nigeria	2,000,000	6.3%	71.6%
6	Chad	1,117,818	3.5%	75.1%
7	Senegal	968,218	3.0%	78.1%
8	China	900,311	2.8%	81.0%
9	China, mainland	900,000	2.8%	83.8%
10	Burkina Faso	850,247	2.7%	86.5%
11	Ethiopia	450,000	1.4%	87.9%
12	Namibia	314,353	1.0%	88.9%
13	United Republic of Tanzania	300,000	0.9%	89.8%
14	Russian Federation	270,015	0.8%	90.7%
15	United States of America	267,900	0.8%	91.5%
16	Nepal	265,401	0.8%	92.3%
17	Myanmar	240,000	0.8%	93.1%
18	Pakistan	226,614	0.7%	93.8%
19	Ghana	170,000	0.5%	94.3%
20	Guinea	168,542	0.5%	94.9%

Source: FAOSTAT

Despite smaller share of the world grain production, millets are extremely important in sub-humid and the semi-arid zones as they are the major source of energy and protein for millions of people in Africa and Asia (Obilana and Eric 2002, Panaud 2002). However, at the global level, area under millets is continuously decreasing (see **Figure 2**). Interestingly, millets area harvested in Africa shows higher volatility. Cultivated area increased up to 1973 from 1961 and started declining till 1982. However, it started to boost again till 2000 and then it is demonstrating ups and downs.

In America, there is also higher level of volatility and after sharp decline in area harvested from 1979 to the deep in 1989, it slightly increased with annual fluctuations. However, in 2021, cultivated area under millets surged significantly.

In Asia, there is a clear year-on-year declination of millets harvested area with some fluctuations. However, after 2013, it is somehow stabilized. Contrary to Asia, in Europe, there was a sharp fall in area harvested under millets after 1991 and now it is less than 500,000 hectares since 2017. Europe's record high area harvested under millets was in 1962, which was almost 4,500,000 hectares. However, in Oceania, area harvested under millets has somehow stable, despite some fluctuation each year. Since 2006, it is almost covering around 35,000 hectares.

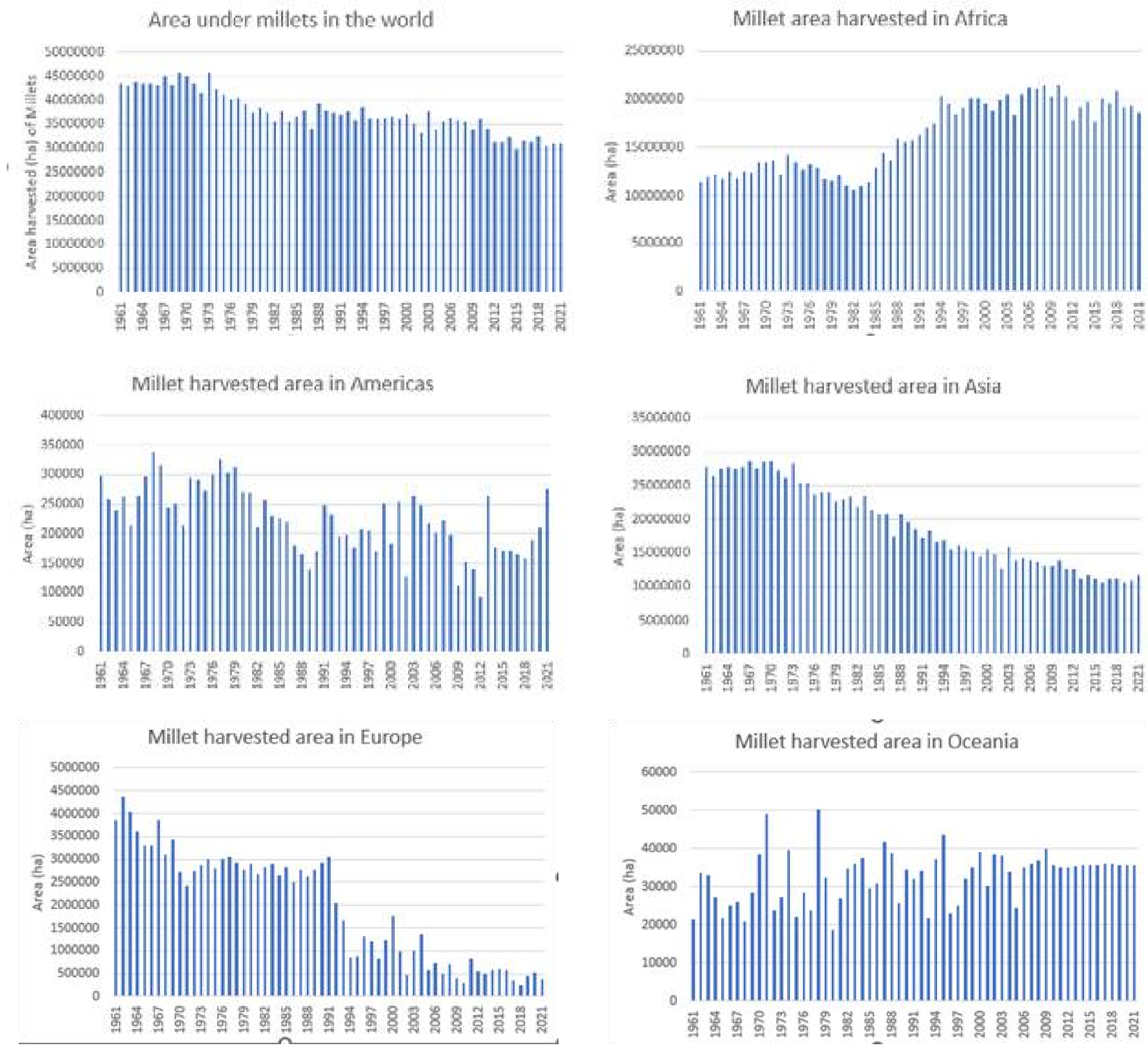


Figure 2: Area under millet production (1961 to 2021)

Yield

Although area has been significantly declined over the period, at the global level, yield of millets has been constantly increasing (**Figure 3**). Nonetheless, as compared to the major cereals, like rice, wheat and maize, the yield of millets is significantly lower. At the global level, yield of millets reached just one ton per hector. The highest yield of millets was observed in Americas followed by Europe, Oceania, and Asia. Africa has the lowest yield of millets.

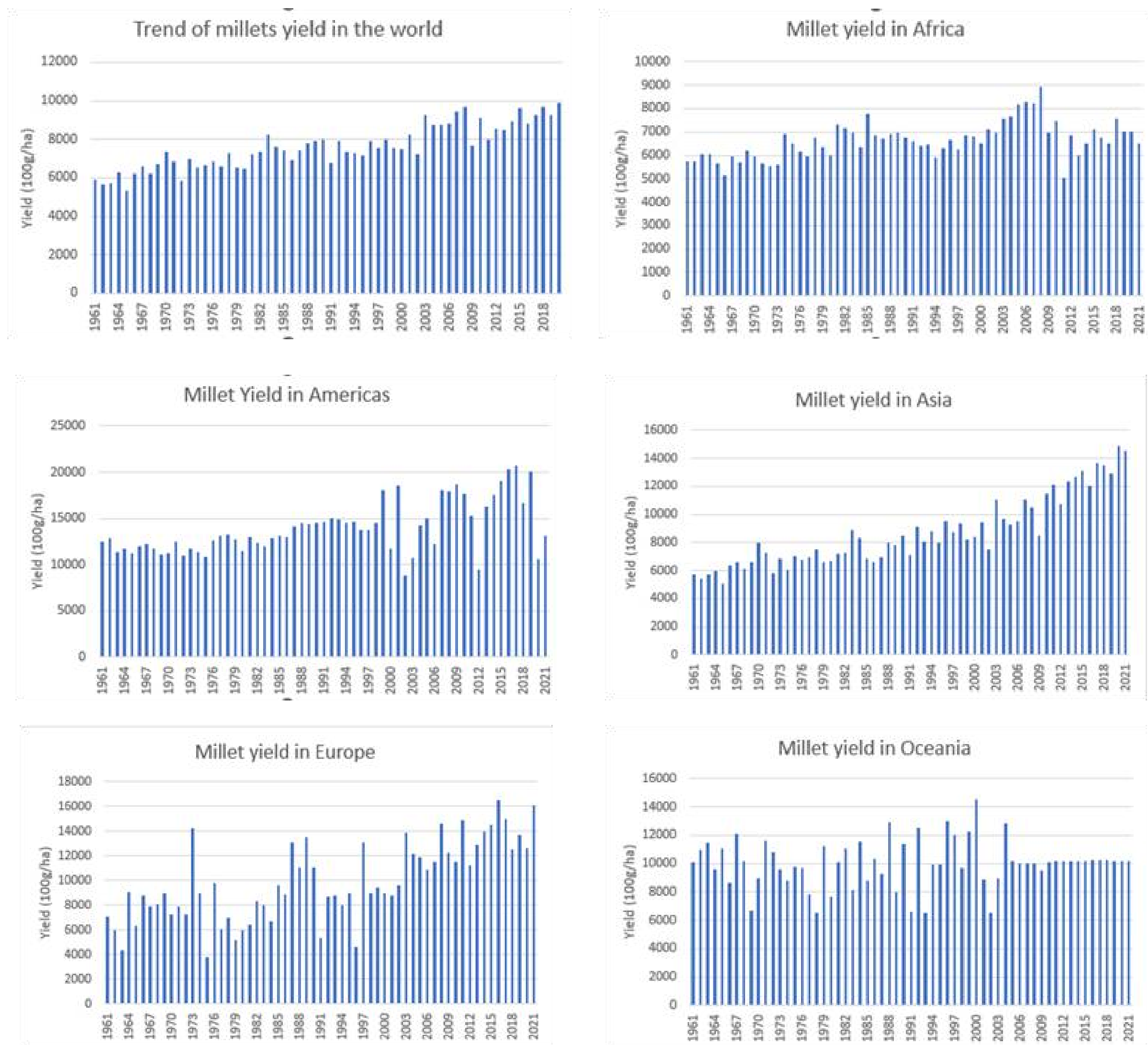


Figure 3: Millet production trend (1961 to 2021)

Millet Products

One of the contributing factors on underutilization of millets is the lower level of product diversification. In most of the regions, millets are consumed as a traditional food. However, recently, there are a lot of product diversification can be observed. At this moment, India is aggressively promoting millets diversification.

FAO has recently published the Millets Recipe Book, which documented various millets dishes3 – starters, main dishes, snacks and desserts. Besides these there are various ready-to-eat and ready-to-cook food items has been developed in the various part of the world.

3 Starters: Millet with purple yam and avocado emulsion, Millet appe with fresh coconut chutney, Millet tamal with spicy cherries and wild oregano, Navratri bruschetta, Fonio salad, Millet salad with grilled glazed aubergine, Cold millet salad, Blue crab and carrot millet chawanmushi
Main Dishes: Monique's caldou with fonio and sorrel-okra relish, Roman-style millet and walnut gnocch, Millet tortillas with mushroom stuffing, Pearl millet crêpe with avocado and pickle, Minced free-range chicken and millets with peas, beans and roasted onion cream, Kodo millet risotto with barnyard millet crisp, Millet with vegetables and curry, Millet with mussels, peppers and chickpeas
Snacks: Sweet and savoury ragi churma, Plantain banana bread, Millet pastel (duo of prawns and tuna), Finger millet smoothie
Desserts: Chocolate mousse with millets, Sorghum, orange and ginger cake, Pistachio and millet bliss balls

Millets and 4 Betters

FAO is guiding by a Strategic Framework since 2010 and currently FAO Strategic Framework 2022-2031 has been formulated in placed to contribute the 2030 Agenda through agrifood transformation to more efficient, inclusive, resilient and sustainable for better production, better nutrition, a better environment, and a better life, leaving no one behind (FAO 2021). Benefits of millets exactly fits with these four betters (FAO 2023b). Good yield potential even in low inputs and under unfavorable growing conditions, their short crop cycle, higher resilience to disease pests, including other signifies its better production. Similarly, low external inputs (chemical fertilizers and pesticides) requirements, low water requirements, growing in arid areas to contribute soil restoration and reduce degradation, including others indicates its better environment attributes. Likewise, millets are rich in dietary fiber, vitamin, antioxidant, proteins, and minerals. They are proven to be beneficial for bowel function, blood sugar and lipids. These features millets for better nutrition. Finally, being able to be thriving in the tough soil and climatic condition to provide food and nutrition to people, its health benefits, its cultural, and traditional linkages, diverse culinary practices, strong connection with indigenous community, including other make it a vehicle for better life.

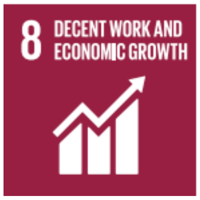
SDG and Millets

IYM 2023 aims to contribute to the UN 2030 Agenda for Sustainable Development, particularly SDG 2 (Zero Hunger), SDG 3 (Good health and well-being), SDG 8 (Decent work and economic growth), SDG 12 (Responsible consumption and production), SDG 13 (Climate action) and SDG 15 (Life on land) (FAO, 2023a).

According to the recent report, in 2022, around 9.2% population was facing chronic hunger, which is 122 million more than 2019. Similarly, 45 million children under the age of five suffered from wasting, 148 million had stunted growth and 37 million overweight. Furthermore, prevalence of undernourishment and production zone of millets highly overlapped. Additionally, cost of healthy diet is increasing, and millets can be a good cheap source of nutrients.

Adding millets as the staple for nutritionally challenging children is crucial as a solution to malnutrition (Anitha et all 2022). Anitha et al (2022) found that 28.2% more height of the children under intervention group. Similarly, 25% higher in the weight, 37% higher in the chest circumference of the intervention group as compared to regular rice-base diet pattern. It clearly indicates that sustainable production and promotion of millets consumption will greatly contribute to achieving the zero-hunger goal of the SDGs.

Good health and wellbeing are the goal three of the SDGs. Millets can significantly contribute to achieve this goal. Mainly, being a nutrition-dense crop, and full of other health benefits, including low glycemic index, higher mineral content, no gluten and higher iron content, it has significant linkage to fight against non-communicable disease, especially cardiovascular diseases, anemia, including others. Singh and Vemireddy (2023) reported that pre-empting health conditions, health consciousness, influence of social media and social network increases the likelihood of adopting millets-based food consumption. The green revolution created overdependency on the major cereals and current lifestyle is becoming more sedentary. These two factors are believed to be the major contributor for current health-related disorders like diabetes, coronary heart diseases, obesity, gastrointestinal disorders and risk of colon, breast, and esophageal cancer (Paschapur et al 2021).



A decent job and economic growth is another goal of the SDGs which is linked to millets value chain. Multiple crises have serious implications on the global economy. In such case, mindful and coordinated effort for the millets value chain development can greatly support to the revitalization of the rural economy. Millets can be grown in marginal land with low-level of inputs. Consequently, it can be a good source of income for the marginal land holdings. Furthermore, there is huge scope for innovation and investment in millets post-production. Product diversification and intelligent marketing can significantly contribute to rural farm and off-farm income growth.

One third of the global food production is either wasted or lost. It has huge environmental and economic consequences. Most of the food are lost, mainly due to perishability in nature. Millets, however, can be stored for several years with minimal losses (Dida and Devos 2006). More importantly, being a nutrient-dense crop, quantity needs to be consumed will be much lower as compared to rice and wheat. It will also directly contribute to reduce food waste. Furthermore, millets being a climate-resilience and low-input requiring crops, its environmental and climate footprints will be significantly less than rice and wheat.

Agriculture is one of the major contributors to the greenhouse gas (GHG) emissions, which has direct link to the climate change, and the most affected economic sectors from climate change. On the one hand, to feed ever growing population, we need to produce more. However, there is very limited luxury to expand area for more production. Consequently, we need to intensify the production so that we can produce more from less land. In doing so, we need to apply more inputs to produce food which has direct impact on climate change and environmental degradation. On the other hand, increasing climate-related hazards are impacting agricultural productions. Millets are C4 plants, which are superior photosynthetic efficiency, short duration, higher dry matter, and a high degree of tolerance to heat and drought. These attributes are making millets a climate-resilient crops (Paschapur et al 2021). In this context, millets being a climate-resilient crops and can be grown with low-inputs, can be a good solution toward achieving the climate action related goals.

Terrestrial ecosystems are crucial for sustaining human life and encompassing diverse cultural, spiritual, and economic values. However, the world is facing a triple crisis of pollution, climate change and biodiversity loss. Millets not only serve for food and nutrition, rather it has ecological services, and it is linked with culture and biodiversity as well.

Way Forward

A comprehensive and integrated approach is imperative for the sustainable promotion of millets. Despite being ancient crops, millets have been overlooked for an extensive period. In this connection, understanding the factors contributing to the underutilization of millets is crucial. The current context, characterized by of environmental degradation from agriculture and non-agricultural economic activities, persisting malnutrition, stagnant rural farm income, various lifestyle-related health issues and alarming impact of the climate change, underscores the global promotion of millets.

To ensure the sustainable promotion of millets, a systematic and multidimensional approach is required. Firstly, extensive efforts on awareness raising and behavioral changing activities are required to create demand for millets consumption. To be incorporated in the regular diet for consumers, millets demand several innovation and product diversification. Secondly, varietal development is another critical aspect that should be supported by a robust knowledge and skill generation and transfer system. Thirdly, policy support for the millets production and consumption. Several enabling policies might need to promote millet production and conservation, investment in the millet value chain, rigorous research and innovation, reliable and efficient marketing system and promotion for consumption. Incorporation of millets in the school meal and other government sponsored programme are important example for demand creation. Fourthly, digitalization of all stages of value chain and promotion of appropriate mechanization is required for sustainable millet value chain.

Moreover, linking millets with culture and traditional is essential. In summary, promotion for production and consumption, increased investment, innovation, collaboration among various stakeholders and Incentivization is required to promote millets which will be a vehicle for the sustainable agrifood system transformation for better production, better nutrition, a better environment and a better life leaving no one behind.

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Chapter 4. Policy Landscape

अध्याय ४. नीतिगत परिदृश्य

Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Government Policies and Programs on Millets Promotion

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Summary

Despite possessing multiple benefits, production and consumption of millets in Nepal have been on constant decline owing to several reasons, domination of rice in both the meals of common Nepalese households as well as in society and in government agricultural policies being the main reason behind. However, with the growing realization of importance of millets for food security and nutrition as well in dealing with climate change impact in agriculture, among others, these small seeded nutrient dense crops have been gaining renewed interests globally as well as domestically in recent years. Accordingly, a number of policy initiatives and programmatic interventions have been taken from the government of Nepal. This paper highlights government policies and programs and recent initiatives for revamping millets and fostering their value chain development.

Keywords: Policy, program, initiatives, collaboration, value chain

Introduction

Millets are a group of small seeded cereals and nutrient dense crops. According to Joshi et al (2023) there are 12 types of domesticated millets in Nepal. Finger millet is by far the most widely grown millet. Other major millets are foxtail millet, proso millet and sorghum millet. Once served as the foundation of food and nutrition security for the majority of Nepalese households, production and consumption of millets have been declining over the years owing to a number of reasons, change in dietary pattern with the proliferation of modern life style and foods culture being one of the main reasons. However, with the growing realization of their health benefits and climate resilient properties, there has been a renewed interest in millets globally as well as domestically.

Policy Frameworks for the Conservation and Promotion of Millets

Government of Nepal has been supporting the production and value chain development of millets in various ways in a bid to ensure food security and enhancing nutrition in the country. However, only a few policy frameworks have been exclusively dedicated to millets although millets have been covered indirectly in a number of government policies and programs.

Multi-Sector Nutrition Plan (MSNP), (2018-2022) explicitly mentioned about indigenous crops including millets. It had a number of provisions of promoting nutrient dense minor crops for food security and nutrition. One of such provisions was improving the availability, access to and consumption of indigenous local foods (GoN 2018). As per the climate change policy, 2019, crops suitable for dry areas will be identified.

Likewise, the policy mentions about crop diversification, agrobiodiverisy conservation and organic farming to be promoted (GoN 2019).

National Agriculture Policy (NAP) 2004 has provisioned in-situ and ex-situ conservation of agrobiodiversity (2004). Agriculture Development Strategy (ADS) has mentioned about the possibility of scaling of indigenous crop promotion program by converting them into core or flagship program on the basis of level of success of this program (GoN 2016). Likewise, Seed Act 1988 (Amendment 2008) has provisioned ownership rights to local varieties which are applicable to millets landraces too. Similarly, National Seed Policy 1999 has made a provision of conserving local crop varieties including millets and protecting the rights of the local community on them. Further, agro-biodiversity Policy 2007 (1st amendment 2014) has emphasized in-situ and ex-situ conservation crop landraces and incentives for the conservation of local germplasm which covers millets as well.

Roadmap of agricultural transformation of the Ministry of Agriculture and Livestock Development (MoALD), 2075 B. S. (2018/19) for the first time categorically mentioned government support for the promotion of millets such as finger millet, proso millet, foxtail millet and other minor crops including buckwheat, amaranth and barley. Under 'Food Security and Nutrition' chapter of 15th plan, policy of conservation and promotion of crop and livestock landraces in order to improve nutritional status of local community has been mentioned.

Other Recent Initiatives Taken for Millets Promotion

Conservation and promotion of millets and other indigenous crops for food security and nutrition, and climate resilience has been one of the top agendas of discussion in various national and provincial dialogues conducted in lead up to UN Food System Summit (UNFSS) 2021. As a result, this agenda has been documented in country's food system transformation pathways and associated actions (NPC 2022). 'Millets and other indigenous crops production and promotion program should be given top priority also on the eve of International Year of Millets, 2023' in planning and budgeting of annual program' was mentioned in National Planning Council (NPC) directives to the ministries and agencies for the program planning and budgeting for the fiscal year 2080/81. Millets and other indigenous crops have been continuously featured in GoN annual 'Policy and Program' and 'Budget Speech' presented before the parliament in the last four years as shown in **Table 1**.

Table 1. Millets in GoN annual policy and programs and budget speech in the last four years

SN	Fiscal year	Policy and program/ budget speech	Description
1	2077/78	Policy and program	Study will be carried out for registration, productivity and multiple use of local and native cereals, fruits, vegetables, livestock and fisheries and such crops will be promoted based on the study findings
2	2078/79	Budget speech	Bullet number 108: Nepal will be made self-sufficient …..in wheat, maize and finger millet in three years, and in buckwheat in five years.
			Bullet number 113:….Partnership will be done with the university for the conservation of seeds of landraces and indigenous breeds
3	2079/80	Budget speech	**Bullet number 42:** …………Nepali calendar year 2079 will be observed as 'National Agrobiodiversity Year'
4	2080/81	Policy and program	**Bullet number 32: ………….**Conservation of millets and other indigenous crops….

SN	Fiscal year	Policy and program/ budget speech	Description
5	2080/81	Budget speech	**Bullet number 88:** seed conservation and cropped area expansion of traditional and nutritious millets and other indigenous crops will be carried out under the slogan **'Take pride in indigenous crop'.**
			Bullet number 202: Nutritious meal made from the ingredients of millets and other local and indigenous crops will be served to the students under 'Mid-day meal' program **Bullet number 349:** Lift irrigation facilities developed which help in conserving millets and other indigenous crops as well in Karnali. Finger millet, foxtail millet, buckwheat, amaranth, barley, local beans and indigenous cold tolerant rice (*Marshi*) produced by the local farmers will be purchased through Food Management and Trading Company (FMTC), a GoN undertaking.

Major Programmatic Interventions and Initiatives

A number of programmatic interventions and initiatives have been taken in recent years for millets promotion. For example, then District Agriculture Development Office (DADO), Bajura started implementing a five-component model of millets and other indigenous crop promotion in Nepali FY 2072/73. The current federal program of indigenous crop promotion *(Raithane Bali Prabardhan Karyakram)* being implemented in collaboration with provinces and local levels is basically based on that particular five-component model. **Table 2** summarizes major government sponsored programs aimed at millets promotion in recent years.

Table 2. Some major millets promotion program of government of Nepal

SN	Millets focused program	Status	Implementing government/agency	Remarks
1	Finger millet production campaign (Abhiyanmukhi kodo utpadan karyakram)	Implemented in FY 2070/71 B.S. (2013/14)	Then Crop Development Directorate (CDD) under the Department of Agriculture (DoA)	
2	Millets and other indigenous crop promotion	Started in FY 2072/73. (2015/16).	Then District Agriculture Development Office (DADO), Bajura	
3	Organic agriculture promotion mission	Started in FY 2075/76 (2018/19) in Bagmati and Gandaki provinces	DoA	Handed over to provinces next year. Now being implemented by provinces
4	Millets and indigenous crops promotion and conservation program (Raithane bali prabardhan tatha samrakshan karyakram)	Implemented in FY 2075/76 (2018/19)	Then CCD	Implemented in Bajura, Humla and Lamjung districts
5	Millets and indigenous crops promotion program (Raithane bali prabardhan karyakram)	Implemented in FY 2077/78 (2020/21)	Centre for Crop Development and Agrobiodiversity Conservation (CCDABC)	Covered all the seven provinces. In FY 2080/81, 133 local levels have been covered but programs in provinces have been discontinued

Millets and indigenous crops promotion program (Raithane bali prabardhan karyakram)

This centrally sponsored program was started from the FY 2077/78 (2020/21). Centre for Crop Development and Agrobiodiversity Conservation (CCDABC) under DoA has been implementing the program. This is a nationwide program covering all the seven provinces and selected local levels. In FY 2080/81, 133 local levels have been covered but programs in provinces have been discontinued. The program is based on the five-component model of millets promotion. Those five components include; i. awareness and sensitization, ii. production and technology support, iii. Product diversification and value addition, iv. Entrepreneurship development and marketing support, and v. conservation of millets landraces. Thus, the activities are carried out covering entire value chain. Operational guidelines were prepared and sent to provinces and local levels for the activities to be implemented by them. **Table 3** provides information on the provinces and local levels covered under this program with the fiscal conditional grant budget provided to the provinces and local levels.

Table 3. Millets and indigenous crop promotion program (Raithane bali prabardhan karyakram)

Nepalese fiscal year	Number of local levels involved	Provinces under the program	Conditional grant (in million rupees)
2077/78	30	Gandaki, Bagmati, Karnali and Sudurpachhim	45.00
2078/79	100	-	42.05
2079/80	106	Koshi, Gandaki, Bagmati, Lumbini, Karnali and Sudurpachhim	221.67
2080/81	133	-	68.95

International Year of Millets, 2023

The International Year of Millets, 2023 (IYM, 2023), is probably the biggest ever global initiatives for the promotion of millets. The resolution to that effect was initiated by India and was adopted by the 75th session of General Assembly of the UN in March 2021. In Nepal, various activities are being carried out by all the three tiers of government as well as non-government sectors to observe the Year.

A proposal of observing IYM, 2023 in Nepal was developed by Centre for Crop Development and Agro-biodiversity Conservation (CCDABC)/Department of Agriculture (DoA) with the inputs from the national genebank, NARC and other stakeholders and put forwarded to the MoALD through DoA. Activities are being carried out based on the proposal. Some of the major activities carried out and initiatives taken are listed below.

IYM 2023 related posters, pamphlet, brochure, sticker, standee, and so on IEC materials were produced and distributed across the country. The IYM, 2023 kick off program was organized at DoA on the first of January 2023 in the presence of relevant stakeholders. Likewise, millets related PSA jingles and other educational contents are being aired from FM radio networks covering the most parts of the country. Similarly, provincial governments and local levels have been officially requested to observe the year. Non-government sectors and relevant stakeholders as well have been officially requested for the same.

As the country observed 2079 of Nepalese calendar year as the National Agrobiodiversity Year as per the decision of the government, millets were featured in the Year celebration wherever possible. For example, millets related food recipes, seeds and plants of millet landraces, various millets food products and drinks, and millets related tradition and culture were showcased in ABD fairs and exhibitions organized in National

Agrobiodiversity Day (1st of the month of the Nepalese calendar month Magh which falls on the mid of January) and 'Agrobiodiversity Week' (Magh 1-7). Likewise, policy dialogues and interactions among the stakeholders for the conservation and promotion of millets were also organized.

Collaboration has been done with National Farmers Group Federation (NFGF), Local Initiatives for Biodiversity Research and Development (LI-BIRD), Federation of Nepalese Cottage and Small Industries (FNCSI), Food Management and Trading Company (FMTC) and some other institutions for observing IYM, 2023 celebration and in other millets related events and initiatives.

Collaboration with FAO

DoA/CCDABC and FAO collaborated on observing the IYM, 2023 by jointly planning and implementing the various activities:

- International millets conference slated for January in Kathmandu which is expected to be participated by foreign and national delegates. In the conference status paper on global, regional and national millets related developments, achievements, issues and opportunities were presented and discussed.
- Millets' food fair will also be organized on the sideline of the conference. A number of other side events were also organized.
- Millets' podcast produced and circulated across the local levels to raise awareness among the students in schools and on other occasions of gathering of students.
- School millets campaign was organized in more than 120 schools across the country. In the campaign students were oriented on the importance of millets and benefits of consuming millets. The millets podcast on the importance of millets were played during the school assembly in those schools.
- Twelve-episode radio program on various aspects of millets aired through one of the community radios having countrywide network.
- Millets' fair was organized in Barpak Gorkha which is the project location of Food and Nutrition Security Enhancement Project (FANSEP), in which FAO is providing technical support.
- Interaction with millets growers of Indrawati, Sindhupalchowk and Barpak, Gorkha on millets tradition and culture, and other various aspects of millets.
- Millets and IYM, 2023 related standee, poster and other display materials produced and displayed in various public places, and PSA jingle and other educational contents aired through various online platforms and mass media
- On the eve of the IYM, 2023, 'Millets: Traditions, Science and Technology (Millets Compendium)' has been published in collaboration of FAO, DoA/CCDABC and national genebank. The compendium included over 80 millets based research papers and review articles as well as collection of information on history, tradition, culture and so on about millets.
- A high-level delegation including the higher officials one each from MoALD, MoF, NPC, Gandaki province and five-member FAO team has visited International Crop Research Institute for Semi-Arid and Tropics (ICRISAT) and Indian Institute of Millets Research (IIMR) under ICAR to observe and acquire first-hand information on recent developments in millets research and development and value chain development in India. During the visit, an understanding has been reached between ICRISAT and FAO for the collaboration in millets research and value chain development.

Other activities and initiatives on the eve of IYM, 2023

A Policy Brief on Millets has been published in English as well as Nepali language under the auspices of ICIMOD, Himalayan University Consortium (HUC) and FAO in collaboration with DoA/CCDABC and national NARC/genebank. The Policy Brief was unveiled amid a function organized by ICIMOD in Kathmandu on 6th of December. Likewise, status of millets in Nepal and proposed activities for observing the IYM, 2023 was shared through a presentation in a program mediated by Agriculture and Processed Food Development Authority (APEDA) India and hosted by Indian Embassy in Kathmandu on December 15, 2022 to share the ongoing preparations of both Nepal and India for observing the IYM, 2023. Similarly, possible collaboration between Nepal and India in millets technology transfer and exchange, and millets trade was discussed in a virtual meeting jointly organized by APEDA and FNCSI.

Major Achievements of 'Millets and Other Indigenous Food Crops Promotion Program' and Other Initiatives

Approximately 2754 ha millets area has been increased and an additional production of 4026 tons has been achieved under 'millets and other indigenous food crops promotion program' implemented by local levels through the federal conditional grant in the last three years as per CCDABC (CCDBAC 2023).

Proso millet dehuller (*Chino Kutak*) was provided to proso millets producing 16 local levels of Karnali province and Far Western provinces piloted for proso millet dehulling. It has helped the locals in dehulling proso millets which is otherwise a tedious and labour intensive work and has traditionally been increasing women drudgery in those regions. The adoption of this technology has now been increased after the success of the piloting. In another intervention, forty-two hoteliers, restaurant owners and homestay owners have been provided 'master trainer' training on making 32 different traditional as well as modern millets based recipes. Those master trainers have been involved in training others in their respective places. Some of them have started making and selling millets based recipes *albeit* in most of cases on demand.

Marketing of the millets has been facilitated by assisting in linking the millets producers with the traders in Kathmandu and other cities. Likewise, various support and promotional activities aimed at boosting millets production, and facilitating marketing and value chain development have been carried out in collaboration with NGOs and private sectors including homestay association, gastronomy tourism association and private firms.

A number of initiatives have been taken for the conservation of landrace of millets and other indigenous food crops. Three custodian farmers involved in conservation of millets and food crop landraces have been rewarded and felicitated in the last two years. Likewise, a museum has been established at CCDABC which has maintained, among other things, the seeds of millets landraces and cultivars for display purpose. Similarly, Community Seed Bank Association of Nepal has been supported and collaborated in conserving and utilizing millets landraces in the country.

Various efforts have been made in popularizing the millets recipes as a snack in official meeting and public gathering by linking millets snack making restaurants to GOs and NGOs. Many such institutions now regularly order millets based snacks. Such snacks have even been served in the Office of the Prime Minister and Council of Ministers (OPMCM). In similar vein, continuous efforts have been made to popularize the millets across the country utilizing various mass media and social network platforms. Millets are being continuously discussed through various means including TV talk show, radio program, interviews, publishing opinion articles, and many more. Further, an official request has been made from DoA/CCDABC to all the local levels to facilitate the inclusion of millets recipes in 'mid-day meal' program in schools. Likewise, another request has been made from the same institutions to Provinces as well as Rural Municipalities (RM) and Municipalities regarding serving the millets based snacks in official meetings and public gatherings. Some RM and Municipalities have been learnt to have followed the request and started serving the millets snacks in official meetings and other public gatherings.

Attempts have been made to incentivize the producer to continue or switch to millets production. Direct cash incentive of Rs. 18000/- for farmers for cultivating millets in the block (at least 1 ha) and by utilizing fallow land as provisioned in 'millets and other indigenous food crops promotion program' being implemented in RM and Municipalities (133 in FY 2080/81) has attracted rural farmers to switch to or expand millets cultivation. Likewise, direct cash support of Rs. 10/- to the growers of millets for per kilo millets produced and sold to local cooperatives or markets as decided by the concerned local levels has also been found to have motivated the growers for millets production.

Besides federal government, lower level governments have also been involved in millets promotion. Besides implementing the federal program on millet promotion, some provincial governments and local levels have also been implementing millets promotion program. Such initiatives have been found to be focused more on supporting farmers for the millets production. They usually do not cater the need of the entire millets value chain development. Likewise, provinces and local levels not having implemented the federal programs on millets promotion also have been promoting and supporting the production of millets.

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Millets Promotion in Nepal: A Gateway to Rural Transformation

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Summary

Millets in Nepal are important for food security and nutrition, climate change adaptation and curbing ballooning cereal import among others. Millets can also create a number of economic opportunities through value chain development. Besides, millets also provide ecological benefits as they provide a number of ecosystem services. Despite their multiple benefits, millets farming and consumption have been declining over years. The government of Nepal has been striving for the conservation and promotion of millets in the country with a number of policy and programmatic interventions. However, still there are a number of issues around millets production and value chain development. This paper explores some of the major issues in millets value chain development and suggest roadmap for the millets promotion in the country. The successful implementation of the roadmap can prove as the gateway to the transformation of rural Nepal.

Keywords: Conservation, millets products, policy, product diversification, value addition

Introduction

Millets served as a foundation of food security and nutrition of common Nepalese people until a few decades ago. Finger millet is by far the most important millet in terms of area and production. Other major millets grown in Nepal include proso millet, foxtail millet and sorghum millet. There has been a declining trend of millets cultivation and consumption in the country primarily due to the change in food habits, which preferred rice over millets, increased purchasing power of the people and other number of factors. Decline in production and consumption of millets is rather a global trend. It has been estimated that around 25.71% area under millets cultivation has declined from 1961 to 2018 across the continents. However, global millet productivity has increased by 36% from 1961 (575 kg/ha) to 2018 (900 kg/ha). The data of the last 58 years indicated that millets production declined in most parts of the world, except Africa (Rajendra et al 2021).

With the growing realization of health and nutritional benefits as well as climate resilient properties of millets, a renewed interest in millets has been seen in recent years. Millets are crucial in curbing malnutrition and growing incidence of non-communicable diseases besides their importance in ensuring food security of millions of people from marginal groups.

Climate change has emerged as the biggest threats to sustainable food production globally. Given the fact that Nepal is among the most vulnerable countries and its inherently poor coping capacity, the impact is even more serious for Nepal. As millets are hardy crops, they can better withstand the vagaries of weather prompted by climate change compared to other major cereals and many other crops. With the growing realization of the importance of millets, the government of Nepal has been promoting millets and minor cereals for last couple of decades. The federal government has been implementing a national program on the promotion of millets and other minor cereals in collaboration with provincial and local governments for the last five years.

Notably, many millet species have remained neglected and underutilized, causing decline in cultivation of such species among farmers, who have shifted towards rice and wheat in the last 50 years or so. As per the call of the UN, Nepal observed the 'International Year of Millets (IYM), 2023' with a number of awareness as well as promotional activities. It has given us an opportunity in popularizing and promoting millets in the country. As was also learnt during the IYM, 2023, there are a number of issues across the millets value chains which need to be addressed in order to realize the full potential of millets.

Issues and Challenges of Millets Value Chain Development

Low productivity and profitability

Productivity of millets is quite low in our condition. As per the official statistics of Ministry of Agriculture and Livestock Development, current productivity of finger millet is 1.27 ton/ha (GoN 2023). Data on other millets are not available. Although the productivity is more than global average of 0.9 ton/ha in 2018 (Rajendra et al 2021), it is one of the reasons for farmers quitting millets farming and switching to other cereals and cash crops. Another major reason for declining trend of millets farming is low profitability of such crops. Millets are usually grown in relatively less fertile and marginal lands which tend to give low production. The production and postharvest operations are labour intensive. On the whole, millets production for small scale subsistence farmers is not profitable or it gives much less profit than other competitive cereals. Therefore, farmers, in general, are less attracted to millets farming.

Low level of awareness and social taboos

Although awareness on the importance of millets has grown in recent times especially among health-conscious people and city dwellers, still large section of the society is still ignorant about the benefits of millets. Likewise, in many cases, prevailing social, religious, and cultural aspects undermine and neglect millets. In many parts of the country millets are still considered as the food of poor people and hence the persons or families consuming millets are considered as poor and they are sometimes even humiliated. Similarly, in many rural areas, some social taboos are attached to millets consumption even today. In some places, lactating mothers are not allowed to consume some millets recipes due to erroneous belief of potential harm to the former.

Poor value chain development

Millets value chain has always been poor, fragmented and disintegrated in Nepal. Small and scattered production always finds it hard to access market and fetch reasonable price. Collection of production locally; doing primary processing at the production sites and supplying to distant markets is very inefficient and cumbersome. This has caused high transaction cost and poor return to the producer. Outside traders generally exploit this situation and offers low price to the local producers in the production site while himself/herself making a good profit.

Poor value addition and product development

One of the reasons for the declining trend of millets consumption is only a few food recipe and value added product options available because of poor poor value addition and product development. Variety of modern food recipes and processed food products that could attract children and youngsters are not readily available at home or in market.

Poor millets entrepreneurship development

Poor value addition and product diversification is one of the main reasons for poor millets entrepreneurship development. System and mechanism of business incubation services are virtually non-existent. Access to finance, technology and market is also poor which keeps prospective entrepreneurs from embarking on millets businesses. Also, there has been a poor provision of technical as well as logistic supports to millets based micro, small and medium enterprises (MSMEs).

Labor intensive and cumbersome production and post-harvest operations

High cost of production aside, millets production and primary processing are labor-intensive and cumbersome demanding more time of women as most of the able-bodied men have migrated mainly to abroad as unskilled laborer. This is one of the reasons for farmers quitting millets farming and opting to reduce number of crops to one, such as maize, in a year or leave land fallow.

Millets tradition and culture

With the trends of millets cultivation and consumption declining over years, traditional knowledge and wisdom pertinent to millets has been forgotten; being eroded or not being transferred to the next generation. Millets tradition and culture across different social groups have not been properly promoted as well as documented. Likewise, sufficient attempts have not been made to preserve millets culture and traditions including millets based traditional food recipe, tools and implements used in millets production and post production related operations. Likewise, information on millets based traditional food is missing from the current national food composition database.

Research and conservation

Research on millets in Nepal, initiated in 1971, has encountered a number of challenges, resulting in limited progress. The predominant reliance on conventional breeding methods, with a focus only on finger millet, has hindered the exploration of diverse millet species. The influence of external factors, such as funding constraints and market dynamics, has further complicated research endeavors.

Conservation issues surrounding millets in Nepal are becoming increasingly critical, marked by the alarming loss of more than 50% of landraces for these species. Many millet varieties are now classified under the red list across the country, signifying their vulnerability and the urgent need for adopting conservation measures. The current approach to conservation, primarily static in nature, has proven insufficient in stemming the decline of native landraces. Dynamic conservation, which involves the active management and sustainable use of genetic resources, has not received the due attention that is required to address the ongoing threats. The utilization of foreign germplasm in breeding practices is exacerbating the issue by inadvertently promoting the replacement of native landraces. While the introduction of foreign genetic material can potentially enhance certain traits, the unintended consequence is often the displacement of locally adapted varieties. This poses a significant threat to the biodiversity and resilience of millet crops in Nepal. Moreover, the current provisions are not sufficient to incentive the custodian farmers for maintaining the genetic diversity of millets.

Poor millets database

Database on millets is very poor in Nepal. Genetic and spatial diversities of millets have been poorly documented. Likewise, area and production related database of different millets is not available. The official statistics cover only area, production and yield of finger millet only (GoN 2023). Mapping of millets production regions and zoning of the millets production and value chain development is urgently needed.

Policy and legal issues

Bringing millets landraces into formal breeding program within the national agricultural research system has been poor. Likewise, proper utilization of such landraces has also been hampered due to the lack of provision of entering into the formal seed system. As per the prevailing Seed Act of the country, any crop variety or landrace has to be registered at National Seed Board (NSB) for it to be able to be marketed. Moreover, budget and other supports and subsidies of the government are highly inclined towards the major cereals and commercial crops thus giving less priority to the conservation and promotion of millets and other minor crops.

Way forward

Strengthening millets research and conservation of genetic resources

A multifaceted strategy should be envisioned to address the pressing challenges for millet research and conservation in Nepal. The establishment of demonstration blocks and diversity blocks, complemented by diversity and food fairs, will serve as platforms for showcasing the diverse array of millet varieties, fostering awareness among local communities. Concurrently, targeted awareness programs will engage farmers, communities, and policymakers, emphasizing the significance of millet genetic resources and the urgent need for conservation efforts. Systematic documentation of traditional knowledge and capacity-building initiatives within indigenous communities should be planned to strengthen local involvement in millets conservation. Collection, characterization, evaluation, and conservation of millet germplasms should also be prioritized through ex-situ, on-farm and in-situ methods along with conservation breeding.

Local levels should be sensitized and capacitated for in-situ and ex-situ conservation. Likewise, custodian farmers to be rewarded and incentivized. Similarly, community seed bank/local community should be supported and incentivized for the conservation. Budget increment should also be planned for sustainable millet genetic resource management. Initiatives such as an agro gene sanctuary, the conservation and utilization of wild millet relatives, and rigorous impact assessments before mega-project implementation might be the very important future actions to preserving millet biodiversity and ensuring a resilient future for these crucial crops.

There is a good potential of increasing the productivity and thus helping the farmers realize more return per unit of land. Various strategies including site-specific varietal development, landrace registration, and exploration of geographical indications to safeguard unique varieties are necessary. The millets research should also focus on technological advancements, incorporating fast-track breeding, molecular breeding, and omics science to accelerate progress. Use of millets landraces in crop improvement program should be given priority by NARC. Nutrient and health related quality aspects of millets should be analysed and published. The establishment of a National Millet Research Center for the enhanced and more effective research and conservation of millets, and capacity building of scientists in millets research are equally important. Likewise, millets profile and database at national, province and local levels should be developed and updated regularly.

Awareness and sensitization

Awareness raising of general consumers on various benefits of millets should be the first step of millets promotion endeavors. Countrywide awareness campaign is necessary to popularize millets. Local mass media including FM radio, newspaper and magazine can be utilized. Likewise, display board, wall painting can also be used (Shrestha, RK. 2023). Similarly, school assembly can also be utilized to disseminate the message about the benefits of millets among the students besides incorporating the learning sessions in higher classes. Moreover, frontline extension workers, teachers, NGO workers and Female Community Health Volunteers (FCHV) can be trained on the importance of millets and mobilized in making local people, men and women and children, aware of the importance of millets and give up social taboos associated with millets consumption. Celebrity personnel can also be mobilized as a goodwill ambassador in popularizing millets and millets-based cuisine. Likewise, social media and public gatherings such as fair and exhibition can also be utilized.

Sensitizing policy makers and other stakeholders is equally important. Workshops, seminars and policy dialogues can be organized to sensitize them on the issues of millets promotion and finding ways to resolve those. Similarly, youths and volunteers can also be mobilized in millets popularizing campaign. Moreover, IEC materials need to be designed in different languages and circulated widely to influence the behavior change.

Reducing cost of production

Seeds of improved varieties of millets should be made readily available in order to boost the current level of millets productivity. Millets cultivation package of practice (PoP) should be developed based on available technology of best management practice (BMP) and massive training of trainers to agricultural technicians and progressive farmers should be given. The trainers will in turn train the farmers in respective production pockets. Seeds of millets landraces should also be circulated and promoted. Various technical and other supports for improving soil fertility and overall soil health should also get priority. Such supports and interventions may include soil testing, compost and farm yard manure production, green manuring, introducing legumes and other cover crops. Small machinery supports for tilling and other farm operations should also be introduced preferably on cost sharing basis.

For millets farmers to become more competitive, they need to be provided output based direct cash support. Cash support can be provided on the basis of area under millets cultivation as well as on the basis of volume of millets production. Similarly, farmers who till fallow land for millets cultivation can also be provided cash supports and other required technical supports. Minikit demonstration and large plot demonstration should also be conducted to popularize the new varieties of millets and newly registered millets landraces. Also, wherever possible small irrigation supports can serve as an important aid for the yield gain. Appropriate for smallholders and women friendly small machineries could play an important role in reducing the cost of production in millets farming. Tilling, sowing or transplanting, weeding and harvesting machines suitable for small and narrow terraces could be very helpful to help stay farmers in millets farming besides reducing the cost of production.

Processing and value addition

Improved post-harvest equipment and machineries such as thresher, dehuller and dehusker at individual farmers' level as well as community level could play a crucial role in cost saving and reducing the women drudgery which may ultimately help in attracting farmers in millets farming. For bigger scale processing, primary processing facilities can be set up nearby the millets production pockets. Local cooperatives and producers' group can set up such facilities. Such facilities will help minimize the cost of production of value-added products by reducing the transportation and other associated costs of unprocessed primary production. Local government can provide financial and other necessary supports for small machineries as well as in setting up of primary processing facilities.

Secondary processing and value-added products development facilities should be established in urban areas and cities. Major value-added products may include millets flour, ready to cook mixed flour, semolina, vermicelli, flakes, puffed items, energy bars, bread, cookies, biscuits, pizza base, and so on. Producer cooperatives and companies, and private business firms can develop such facilities with or without government support. A strong support and incentive mechanisms should also be developed to encourage innovation and startups in millets production, processing and value addition.

Product diversification and value addition has been found the most critical factor in millets promotion or value chain development endeavors. Product diversification and value addition help in creating forward and backward linkage in millets value chain. Increased demand for millets products gives impetus to millets cultivation and production. This also helps in opening up of millets-based startups and businesses.

Based on the market survey and consumer preferences, various millets-based cuisines and value-added products can be produced and marketed. For this, hoteliers, restaurant owners, homestay owners, and so on can be trained on traditional as well as modern millets cuisines. Likewise, standardizing protocols is necessary for traditional millet-based beverages and globalizing them through collective trademarking or geographical indications to promote these products globally.

Agripreneurial and marketing support

Value added product development endeavors should go hand in hand with the entrepreneurial and marketing supports to startups and businesses. Local governments should provide handholding and other supports to local youths, women and their groups for establishing souvenir shop or retail outlet of millets value added products (*Kosheli ghar*). Likewise, local restaurants and homestays specialized in millets cuisines should also be promoted and supported. They could be given product development training followed by some capital supports for necessary machineries and equipment, among others. In urban centers and cities, startups firms and companies producing modern millets value added products should be provided various product development and marketing supports mainly by provincial government. Supports should also be provided for branding of local millets products and their market access to distant markets.

Preserving and popularizing millets tradition and culture

Millets food fair can be organized at the local level to popularize millets and related tradition and culture. In such fair and exhibitions, besides the display of plants and seeds of millets cultivars and landraces along with artefacts pertinent to millets based tradition and culture, traditional food recipes and tools and implements, among others, can also be showcased. In such local food fairs, cooking lessons can be provided to the interested visitors with the live food tasting sessions. Women farmers and indigenous people can be mobilized in promoting such foods.

School millets campaign

Students can be very helpful in popularizing millets. Diversity block and school gardening can be maintained in school premises. Likewise, inclusion of healthy dietary pattern and food preparation and conservation related sessions in school curricula will also be helpful. More importantly, home-grown millets-based foods should be made mandatory in the school mid-day meal program. For this cook of the school can be trained on preparing millets based recipe in mid-day meal. Millets conservation, production and value addition can be included in school curricula in higher classes. The provision of local curricula could be handy to this end.

Conservation of millet landraces

landrace conservation should be an integral part of millets promotion. A number of good practices of agrobiodiversity conservation can be adopted at various levels. First of all, local communities should be made aware of the importance of millets and the conservation of their landraces and encourage them to strive for conserving such landraces. For this, they will need a grassroots institution or platform called community seed bank (CSB). Agriculture unit of Municipality and Rural Municipality can organize diversity fair in collaboration of such CSBs. In such fairs, local residents should be encouraged to bring and display the different types of millets and other products and materials related to millets. In such fairs, also taking help from the elderly people, endangered millet species should be identified and characterized. Such species then should be maintained in diversity block to be maintained by the CSBs or the agri. section of local level. Such landraces are evaluated for yield and other beneficial features. Based on the evaluation in diversity block, seeds of landraces can be distributed among the community members for further testing and seed production. Likewise, seeds of such endangered species can be sent to national gene bank Khumaltar, Lalitpur after filling the passport data for the long-term ex-situ conservation. Moreover, custodian farmers can be publicly felicitated for their contribution in the conservation of agrobiodiversity.

Other policy supports

Various policy supports and initiatives are necessary to bolster the millets promotion campaign across the country. The government of Nepal announced the program of procuring millets and other minor cereal grains from farmers through Food Management and Trading Company (FMTC), a public enterprise of the Government of Nepal in the budget of the government of Nepal for the fiscal year 2080/81 which should be continued in days to come as well. Moreover, the procured grains should be included in public distribution system (PDS) of the government. Likewise, mandatory provision of millets-based cuisines as snack in public gathering and in official meetings would enormously help in popularizing millets and in their value chain development. Further a special support and incentive packages can be implemented for helping farmers produce millets organically or employing regenerative principles.

Only a few millets landraces have been registered in National Seed Board (NSB) so far. As per the prevailing seed law, crop varieties or landraces need to be registered at NSB for the commercial production and marketing of seeds. Due to this reason, conservation and utilization of millets landraces has been hampered. A special legal provision should be in place in order to recognize the informal seed systems and facilitate the seed multiplication of millets landraces and selling in the market.

To discourage the consumption of high calorie highly processed food, nutrient-based mandatory labelling system should be introduced. Likewise, there should be restriction on the inflated advertisement of low grade packaged foods high in salt, sugar and trans-fat. Moreover, each local level should have millets landrace conservation strategy and plan based on the status report of existing situation.

On the whole, to implement all the above-mentioned interventions, a special national millets mission, to be implemented in the involvement of three tiers of government, is urgently needed. A national pride project could be designed and implemented in the upcoming sixteenth periodic plan of the country.

Box 1: Role of different governments in promoting millets

Role of federal government	Local level
• National framework for millets promotion • Crop zoning and national millets database • Millets research and technology development • Millets nutrient profiling • Managing national millets resource center and center of excellence • Federal conditional and other grants • National value chain development and trade promotion • National millets fair and exhibition • Inter-province coordination • Capacity building of lower-level governments • Registration of millets landraces • Export of millets value added products • International collaboration **Role of provincial government** • Millets popularizing campaign including fair and exhibition • Provincial millets value chain development • Product development and branding support • Support to millets startups and businesses • Conditional and other grants to local levels for millets promotion • Capacity building of local level • Development of provincial millets resource centers • Provincial millets database • Networking of millets value chain actors	• Awareness raising • Production and technology support • Processing and value addition support • Establishing and managing community seed bank for millets landrace conservation • Promoting and conserving millets based traditional cuisines. • Cash support and other incentives for millets farming and production • Support to seed production of millets varieties and landraces • Support to start millets based restaurants and homestays • Branding and marketing supports to local entrepreneurs • Support for market access • Millets database • Enforcing the mandatory provision of millets based snacks in official meetings and gatherings • Local level millets fair and exhibition • Implementing school millets campaign • Felicitating millets custodian farmers • Millets seed production • Support the community in millets landrace registration at NSB • Support the community for in-situ and ex-situ conservation of millets landraces

Conclusion

Role of millets is critical for overall food and nutrition security and livelihood improvement in Nepal as well as for potential export earnings. The on-going millet promotion initiatives of the Government of Nepal has contributed in drawing renewed interest of different groups of the society towards millets. More policy supports and robust incentive mechanisms for the conservation and utilization of millets are necessary. Product diversification and value addition is the key for creating backward and forward linkages. More support and handholding are necessary to the local communities and businesses. Better coordination between three tiers of government and capacity building of the local government is the key. A national mission for millets promotion is urgently needed. The successful implementation of such mission could be a 'gateway to the transformation of rural Nepal'.

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Chapter 5. Status and Issues
अध्याय ५. अवस्था र मुद्दाहरू

Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Status and Prospects of Millets in Nepal

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Summary

In the early 1990s, Nepal boasted a rich tapestry of diverse millet crops, reflecting the country's agricultural heritage. However, over the years, a disconcerting trend has emerged with both genetic diversity and production of millets experiencing a drastic decline. This decline has been accompanied by the disappearance of traditional knowledge associated with millet cultivation, posing challenges to the preservation of agricultural heritage. Millets, known for their adaptability, were traditionally grown across all districts and agroecozones in Nepal. Despite research initiatives dating back to 1971, the impact on production has been limited. The ecological roles of millets, such as promoting beneficial insects and microbes and contributing to soil improvement, remain poorly understood. Efforts like the Millet Mission and dedicated research stations have struggled to make a substantial impact on farmers. While millets offer great value and versatility in preparing various food items, comparable to those made from rice, wheat, and maize, their potential has not been fully realized. Nonetheless, there is a silver lining as millet consumption is on the rise. Despite their nutritional density and climate resilience, challenges persist in both farming and post-harvest systems. Recognition of millets as a major commodity is imperative for ensuring nutritional sufficiency and fostering a healthy environment. Millets stand as a promising solution to address food security and nutrition challenges in Nepal. Their cultivation can be a transformative force, contributing to both ecological sustainability and the well-being of the population, marking a crucial step towards a resilient and self-sufficient food system.

Keywords: Millet species, distribution, production, research, values, technology

Nepal and Millets

Nepal's agricultural landscape is characterized by a diverse range of production environments, from the fertile plains of the Tarai to the challenging terrains of the Mid Hill and High Hill regions. In this context, millets stand out as resilient and versatile crops. They exhibit a remarkable ability to adapt to various agroecosystems and climates, making them suitable for both lowland and high-altitude cultivation. Their adaptability ensures that millets can be grown across the country. Most common species are finger millet and goose grass which are found across the country.

Nepal faces challenges related to the scarcity of agricultural inputs, including modern equipment and chemical fertilizers. The reliance on manual labor and traditional farming practices characterizes the country's agriculture. In such conditions, millets offer a compelling solution. They are inherently low-input crops, demanding minimal external resources. Moreover, millets are hardy and can withstand biotic and abiotic stresses, making them a dependable choice for Nepal's fragile agriculture. Their low care requirements and resilience make them a valuable asset for small-scale farmers, providing a buffer against external uncertainties.

Many parts of Nepal feature barren and marginalized lands that are often overlooked for agricultural purposes. Millets thrive in such environments and can be a catalyst for transforming these lands into productive assets. Beyond their adaptability and resource-efficiency, millets offer a multitude of benefits. They are a source of nutritious food, contributing to improved health, and can serve as the basis for local businesses. Moreover, the cultivation of millets aligns with environmental sustainability, as these crops have grains belonging to either a positive or neutral group. Positive grain millets like foxtail, browntop, little, kodo and barnyard millets are instrumental in enhancing health, while neutral grain millets such as finger millet, sorghum, pearl millet and proso millet play a vital role in maintaining health. In Nepal, millets are more than just crops; they are a multifaceted solution addressing food security, health, livelihoods, and environmental conservation.

Agroecosystem and Millet Species

In Nepal, millet cultivation extends across three major agroecozones - Tarai, Mid Hill, and High Hill. All major millet species, including finger millet, proso millet, and foxtail millet, are grown in these agroecozones. In the Tarai region, specific landraces adapted to heat and drought tolerance are cultivated. The Mid Hill agroecosystem, with its diverse microclimates, is suitable for all major millet species and have maintained specific landraces. In the High Hill region, where temperatures are cooler and growing seasons shorter, these millets (with specific landraces) also find a place. Beyond these major agroecozones, Nepal boasts various agroecosystems, each with its unique conditions, allowing for the cultivation of major millet species and agroecosystem-specific landraces. The adaptability of these millet varieties to different agroecosystems enhances food security, supports local communities, and preserves agricultural biodiversity.

Millets, as a group of cereal crops, exhibit a general intolerance to waterlogged conditions due to their preference for well-drained soils. Typically, millets are regarded as summer crops, best suited for cultivation during the warm and dry seasons when the conditions are favorable for their growth. However, it's worth noting that finger millet, one of the major millet species, stands as an exception to this rule. This resilient crop demonstrates the versatility to be cultivated in the spring season in specific regions of Nepal.

Species and Cultivars Richness

In Nepal, millets showcase a remarkable diversity in terms of both species and cultivars. Among the 22 millet species found in the country, 10 are predominantly cultivated for grain production, serving as a vital source of nutrition for the local population. On the other hand, the remaining 11 millet species are primarily utilized for forage, playing a crucial role in livestock feeding and other agricultural activities. Additionally, Nepal is home to 12 domesticated millet species and 9 wild relatives. In the quest for agricultural advancement, Nepal boasts a total of 8 officially registered millet varieties, meticulously developed through breeding programs. Furthermore, the country is enriched with a staggering 1,100 landraces of 12 domesticated millet species, reflecting the rich tapestry of locally adapted, traditional cultivars that have been nurtured and maintained by generations of local farmers.

In Nepal, genetic erosion of millet crops is a significant concern, with over 50% of millet diversity lost due to the neglect of these crops and a shift toward rice, maize, and wheat. Many regions have witnessed the near-complete disappearance of millet varieties, except for finger millet. This erosion is driven by the exclusive focus on a few modern varieties, emphasizing yield and uniformity. The loss of millet diversity hampers agricultural resilience and limits the ability to address challenges like climate change. Urgent measures are needed to promote the cultivation and conservation of diverse millet varieties for sustainable agriculture and food security.

Distribution

Millet crops exhibit a widespread distribution across Nepal, growing in all 77 districts of the country. Their cultivation spans a remarkable altitude range, from as low as 60 meters above sea level (masl) to the lofty heights of 3650 masl. Among the diverse millet varieties, finger millet takes precedence as the most commonly cultivated, followed by sorghum, foxtail, and proso millet. The prevalence of various millet crops in each district are detailed in **Table 1**, providing valuable insights into the geographical diversity of millet farming practices across Nepal. This comprehensive distribution signifies the adaptability of millet crops to varied agro-climatic conditions, making them a versatile and resilient component of Nepal's agricultural landscape.

Table 1. Millets growing districts in Nepal

Crop	Districts
Finger millet	All 77 districts
Sorghum	All districts except Manang and Mustang (ie 75 districts)
Foxtail millet	Achham, Baglung, Baitadi, Bajhang, Bajura, Dadeldhura, Dailekh, Dang, Darchula, Dhading, Dolakha, Dolpa, Doti, East Rukum, Gorkha, Humla, Jajarkot, Jumla, Kailali, Kalikot, Kaski, Kavreplanchok, Khotang, Lalitpur, Lamjung, Makwanpur, Manang, Mugu, Myagdi, Okhaldunga, Parbat, Ramechhap, Salyan, Sindhuli, Sindhupalchowk, Syangja, Tanahun, Udhaypur, West Rukum
Proso millet	Bajhang, Bajura, Dhading, Dolpa, Humla, Jajarkot, Jumla, Kalikot, Lalitpur, Lamjung, Mugu, Ramechhap, Udayapur
Little millet	Chitwan, Dang, Dhading, Gorkha, Lalitpur, Lamjung, Makawanpur, Okhaldhunga, Tanahun
Barnyard millet	Chitwan, Dang, Dhading, Gorkha, Gorkha, Lalitpur, Lamjung, Makawanpur, Rautahat, Tanahun
Kodo millet	Dang, Dhanusha, Kapilvastu, Lalitpur, Rasuwa
Pearl millet	Chitwan, Lalitpur, Lamjung, Nuwakot, Sindhupalchowk

Area and Production

In Nepal, comprehensive data on the geographical distribution of various millet species is notably lacking. The available records primarily focus on finger millet, offering insight solely into the cultivation areas of this specific millet crop. Unfortunately, information regarding the distribution of other millet species remains conspicuously absent from the documented records. Moreover, there has been a substantial reduction in the overall cultivation areas of millets throughout the country over the past few decades.

Despite the limited scope of available data, the Karnali province in Nepal emerges as a notable exception. This region stands out for its cultivation of a diverse array of millet crops. The province has become a hub for the growth of various millet landraces, contributing to the agricultural diversity in the area. However, the precise extent of this cultivation and the specific types of millets involved are not explicitly detailed in the available records.

In Nepal, the cultivation of millet crops is primarily characterized by a seasonal pattern, with all millet species categorized as summer crops. This generalization holds true for the majority of millets, implying that they are traditionally grown during the summer months. However, finger millet stands out as an exception to this rule, displaying a versatile growing capability in both summer and spring seasons.

The adaptability of all millet species, including finger millet, to various agro ecozones across Nepal further underscores their resilience. These crops exhibit the flexibility to thrive in all three agro ecozones, emphasizing their suitability for diverse ecological conditions. For precise agricultural planning and execution, **Table 2** offers valuable insights into the specific seeding and harvesting months for millet crops. This information assists growers in aligning their cultivation practices with the seasonal dynamics, ensuring optimal growth and yield. The nuanced understanding of the growing seasons for millet crops in Nepal, with the unique characteristic of finger millet thriving in both summer and spring, highlights the strategic considerations that farmers must undertake to harness the full potential of these resilient and adaptable crops.

Table 2. Millet crops calendar in three agroecozones

SN	Species	Tarai		Mid Hill		High Hill	
		Seeding month	Harvesting month	Seeding month	Harvesting month	Seeding month	Harvesting month
1	Bristly foxtail millet	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir	Falgun-Baisakh	Asoj- Mangsir
2	Browntop millet	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir	Falgun-Baisakh	Asoj- Mangsir
3	Finger millet	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir	Falgun-Baisakh	Asoj- Mangsir
4	Foxtail millet	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir	Falgun-Baisakh	Asoj- Mangsir
5	Japanese barnyard millet	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir	Falgun-Baisakh	Asoj- Mangsir
6	Job's tear millet	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir	Falgun-Baisakh	Asoj- Mangsir
7	Kodo millet	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir	Falgun-Baisakh	Asoj- Mangsir
8	Little millet	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir		
9	Nepalese barnyard millet	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir	Falgun-Baisakh	Asoj- Mangsir
10	Pearl millet	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir		
11	Proso millet	Falgun-Srawan	Jestha- Kartik	Baisakh- Asar	Badhra -Kartik	Falgun-Baisakh	Asoj- Kartik
12	Sorghum	Falgun-Srawan	Asar- Mangsir	Baisakh- Asar	Badhra -Mangsir	Falgun-Baisakh	Asoj- Mangsir

In Nepal, the documentation of millet crop production is primarily centered around finger millet, with a notable scarcity of official data on other millet varieties, including both landraces and modern varieties.

The available chapters in the book have shed light on the productivity and production of different millet crops, but the focus remains largely on finger millet. The reported average productivity of millet crops in Nepal is approximately 1 kilogram per hectare, signaling a relatively low yield. This modest productivity raises concerns, particularly considering that the total production is deemed insufficient to meet the demands within the country. The disparity between demand and production is a significant challenge in the context of millet agriculture in Nepal.

Furthermore, it is noteworthy that a substantial portion of the finger millet production is dedicated to the production of beverages. This allocation suggests a specific utilization pattern for the crop, potentially impacting its availability for other purposes, such as food consumption or animal feed. A contemporary challenge emerges in the growing demand for millets, which is on the rise. Despite this increasing demand, the current production levels are not keeping pace. This disjunction underscores a pressing need for strategic interventions in agricultural practices, research, and policy to bridge the gap between the burgeoning demand for millets and the available production resources in Nepal.

Millets Based Research in Nepal

Millets are the major cereal crops in fighting hunger and malnutrition in Nepal. These crops are comparatively better than other cereals in terms of drought resistance, insect pest tolerance, soil and climatic adaptability, and management factors (Gyawali 2021). The research in agriculture was initiated in Nepal back in 1950 and in major cereals (paddy, wheat and maize) from 1972 with the establishment of major commodity research programs (Joshi et al 2019). There are only 84 crops included in the national list where any of the domesticated crops can be included in the formal seed system (SQCC 2023). Many studies were done to assess the potentialities of millets, their conservation and increasing production which are presented below.

Diversity of millets

Most of the studies in millets in Nepal are focused in the exploring the diversity and their conservation. Altogether, 8 varieties have been notified by the national seed system. Five varieties of finger millets have been released (**Table 1**) in the country whereas single variety each of finger millet (Rato kodo), Proso millet (Dudhe chino) and foxtail millet (Bariyo kaguno) have been registered in 2021 (SQCC 2023).

Table 1. Released varieties of finger millet in Nepal.

Variety	Origin	Release year	Plant height (cm)	Maturity (days)	Yield (t ha-1)	Finger type	Recommended domain
Okhle-1*	Nepal	1980	80	154 – 194	3.3	Compact	Mid to high hills
Dalle-1	India	1980	110	125 – 151	3.3	Compact	Inner terai to mid hill
Kabre kodo-1**	Nepal	1990	82	147	2.3	Erect	Mid hill (900-1900m)
Kabre kodo-2	Nepal	2015	91	153	2.5	Open	Mid hill
Shailung kodo-1	Nepal	2015	100	155	2.5	Compact	High hill

* Local landraces from Okhaldhunga. ** Local landraces from Surkhet.

Source: Joshi et al (2017) and Ghimire (2015)

National catalogue of economically valuable landraces has listed several landraces of finger millets in three different ecosites (Bara, Kaski and Jumla) with their conservation status (Joshi et al 2005). Proso millet, foxtail millet and sorghum have been reported as neglected and underutilized crop species (NUCS). Eight different crops including buckwheat, foxtail millet and proso millet are identified as Himalayan super food.

Proso millet has one of the lowest moisture requirements among cereals and can be grown up to 3500m above sea level. Foxtail millet, proso millet, tartary buckwheat, amaranth was identified among 25 future smart foods considering their nutritional quality, economical value, climate resilient and social acceptance. The nutrient composition of some native crop landraces has been listed. A native staple crop for a particular site can be selected as a staple crop (Joshi et al 2019).

The pictorial description of all 12 millet species grown in Nepal with additional 9 wild relative species of millets have been reported. Actual collection of germplasm of small millets started from 1950 and actual characterization started from 1972 (Baniya et al 2002). Then Agri-Botany Division of NARC started this work and after the establishment of Hill Crops Research Program in 1986, the millet research is undergoing by this program. There are 1100 millets landraces found in Nepal and the millets are grown in all 77 districts. National Agriculture Genetic Resources Centre (NAGRC) has conserved more than 1280 millet genetic resources in medium and long-term while 1107 Nepalese millets accessions have been conserved in foreign genebanks. (Joshi et al 2023). Genetic diversity among different landraces of finger millets were assessed by using different markers by Joshi et al (2020). Characterization of millet genetic resources at NAGRC showed high diversity among accessions of finger millet and foxtail millet while low diversity among proso millet.

Millets have their own characteristics. Proso millet is a crop growing in a short period of 60-90 days cycle. Pearl millet is the most drought tolerant crop among millets and other cereals. Nepal is one of the centres of diversity of foxtail millet (Nakayama, 1999) and has high genetic diversity of this crop (MoFSC, 2002). However, very little research has been conducted and its status is still unexplored. Poor utilization of local genetic resources conserved in genebank for foxtail millet improvement and development program is evident due to i) absence of public and private sector plant breeding, and ii) unavailability of characterization and evaluation information for wider use (Ghimire et al 2017).

Diversity of millets is higher in high hills and Karnali province in particular. The existence of diversity is at the levels of species, landrace, genotype and allele. Fifty percent of millets diversity have been lost (Joshi et al 2023). Some millets and their wild relatives are used only for forage purpose. These crops are conserved at national and international Genebanks. Millets have been grouped on the basis of various characteristics such as grain size (large or major millets and small or minor millets), husk (naked and husked), area and production (major and minor), national list (farmer's varieties, registered native landraces, released native varieties and released exotic varieties), health benefit (positive and neutral), conservation status (common and rare, endangered) and domestication (domesticated and wild) (Joshi et al 2023).

Utilization of genetic diversity

Many local landraces of finger millets have been reported such as *Mudke, Jhyape, Chulthe, Chyalthe, Raato kodo, Seto kodo, Kaalo kodo, Sano kodo, Thulo kodo, Okhle kodo, Tauke koto, Bhaisi kodo* and *Ashoje kodo.* Many landraces have been identified and named by their shape, size, time of maturity, colour of grains, etc. Many of these species have special attributes such as early maturity, lodging resistant, tolerant to diseases pests, heat tolerant, flouring quality, better yield and better taste. These traits are important not only for the present but also for the future generation (Ghimire 2015).

Less utilization of local genetic resources conserved in genebank for crop improvement program is evident due to lack of information about the desirable accessions in the genebank resulting from the poor characterization and evaluation data. Great intra-specific diversity has been observed in finger millet. Proso millet has two popular types of landraces: Dudhe and Hade. Nepali genebank holds 51 accessions of proso millet, 55 accessions of foxtail millet, 15 accessions of sorghum, 2 accessions of barn yard millet, 1 accession of pearl millet and 3 accessions of kodo millet (Ghimire et al 2017). Foxtail millet has higher intra-specific diversity than proso millet as studied by national genebank. Proso millet is grown mainly in Karnali region but cultivation of foxtail millet is found across mid hills and high hill of the country. However, sorghum, barn yard millet and pearl millet are grown in small areas and have less economic contribution to the country. (Ghimire et al 2017).

Production practices of finger millets

Finger millets is cultivated either broadcasted or transplanted. Broadcasting can be done during Baisakh which is harvested in Bhadra whereas transplanting is done during Jestha to Shravan according to the location. The appropriate time for cultivation of finger millets in terai, inner terai and basin region is first to second week of Ashar, third to fourth week of Jestha for mid hills and mid Baisakh to mid Jestha for high hills. If planted late, the availability of moisture can be limited which hinders the flowering of millets adversely affecting the production. Soil with adequate moisture, well-drained and fertile loamy is desirable. 400-500g finger millets per ropani of land with more than 85% germination rate is required. A raised bed of 20cm height is taken and seeds are planted at 2-3cm depth. Moisture of 12-13% is desirable for long term storage for seed purpose (Ghimire 2015). Finger millets are also cultivated as a relay crop with maize in the hills of Nepal. The prospects and constraints of maize-millet relay cropping has been reviewed and analysed (Parajulee and Panta 2021) which showed its potentiality to have multiple benefits like reduced weed infestation, increasing the yield, reduced the risk of complete crop failure and finally increased profit.

Paudel et al 2023 has evaluated different transplanting methods of finger millet. System of finger millet intensification resulted in higher number of fingers per head, finger length, number of seeds per head, head weight, and straw yield than direct seeding and conventional transplanting methods in Dalle-1, Okhale-1 and Pangdure cultivar. The research suggests that SFI influences some major yield attributes in finger-millet and contribute to better yield attributes with low inputs. Transplanting in spring season (March to early April) in puddled field like rice transplanting, irrigation by flooding method and very good yields that farmers are getting (2.4 to 3.0 t/ha) in a very short crop period (less than 75 days after transplanting) Mukhiyapatti, Dhanusha (Dhital and Acharya, 2023). This is a unique farmers practice with local cultivar, none of the introduced varieties from the hills performed better.

The access of improved seeds to the farmers is very limited and more than 90% of farmers uses farm saved seeds of the local varieties for the production of millets (Devkota et al 2015). However, decreasing interest in farming, migration to urban areas and scarcity of labour etc contributed to decreasing on-farm conservation of agrobiodiversity and food security in the community level. Empowerment of farmers in the local seed system is the most for contributing to seed sovereignty in the country. A study about millets production determinants in Nepal found a significant positive relationship of fertilizer, rural total population, and cultivated area on millet production. This shows that the millets have been contributing to the livelihood of rural farmers (Joshi et al 2023). However, the growth rate analysis of finger millet showed that the area is declining but the import value, production, and yield is increasing. Similarly, trade specialization index indicated that millet is in the introduction phase (Gairhe et al 2021). The fertilizer, cultivated area, and rural population have a significant impact on millet production howver, the temperature has a negative and insignificant impact on millet production (Joshi et al 2023). It means climate change had no significant impact on millet production.

Mechanization of millets

The use of mini-tillers are quite common in land preparation of the millet field in recent days. Threshing and dehulling finger millets is a tedious, labor intensive and time-consuming job. Agri-engineering Division of NARC has developed the Pedal millet thresher (Shrestha 2022) which was tested by LI-BIRD in the hills of Nepal. The results showed that use of pedal thresher saved 30 percent of farmers' time in threshing finger millet. They found pedal thresher good for easy grain separation, grain cleaning, and husk removal, when the grain is free of dust and other inert materials. The result showed that the thresher also helped increase the participation of male members in threshing by 17 percent. Bhandari et al 2020 designed and piloted the proso-millet thresher (Chino Kutter) which showed good results for simplification of processing of Dudhe chino variety. The machine has provided a potential opportunity to save time, reduce drudgery of women and cost of processing and thereby promoting conservation, production and improving the value chain of proso millet.

Extension Activities in Millets Before Federalization

The extension activities of millets were initiated as early as 1980 after the improved variety Okhle-1 and Dalle-1 of finger millet were released. Kabre Kodo-1 variety of finger millet was released in 1990. (Ghimire et al 2017). Crop Development Directorate under the Department of Agriculture initiated the campaign program on millets production in 24 hilly districts of Nepal in the fiscal year 2013. Improved seed production and their distribution, seed-kit demonstration, production remonstrations of improved variety, trainings to the farmers, insect-pests management services were the part of agriculture extension services in the District Agriculture Development Offices (DADOs) for long time.

Extension activities after federalization at the national level

Centre for Crop Development and Agro-Biodiversity Conservation (CCDABC) under Department of Agriculture (DoA) is the focal organization for the promotion of millets after the restructuring of the state at federal level. The Ministry of Agriculture and Livestock Development (MoALD) included the indigenous crops including millets in its roadmap for agriculture transformation, 2018. Millets were included in the Organic agriculture promotion mission program which is now a part of provincial agricultural development programs from 2018. United Nations Food Systems Summit dialogues during 2021 and different discussions in Nepal at national and sub-national level has prioritized the conservation and utilization of indigenous crops including millets. Indigenous crops promotion program has been in implementation in local level with the financial and technical support of the federal level organizations including their production and promotion for marketing and consumption since 2019. The number of local levels implementing such programs is increasing every year and reached to 133 in the Nepali FY 2080/81 with the budget allocation of 68 million rupees. The government has also announced to buy the indigenous crops-based products and to include the indigenous crops in the school day-meal program for the students (MoF, 2023). All sub-national governments were requested to include indigenous crops including millets in the day-meal school programme and many of them has been following. The National Planning Commission (NPC) prioritized the indigenous crops for the budgeting purpose. The government has prioritized the indigenous crops in the policy and programs as well as budget of the Nepali FY 2080/81 and has urged "Let's be proud of indigeneity".

Many promotional activities like supporting the milling machineries, training programs on the products diversification and recipes preparation of millets for the hotels, restaurants, schools and homestays, capital subsidies for the facilitation of millets-based business such as establishment of gift shops, management of homestays, establishment of bakeries, packaging, labelling and branding, extension-communication technical materials dissemination etc have been implemented and thus contributing for the positive impacts. National Government has been collaborating with the sub-national government agencies, co-operatives, private sectors, associations and non-governmental organizations for the promotion of indigenous crops including millets. The CCDABC has established a museum by collecting the seeds of millets and other indigenous crops from throughout the country and co-ordinated with the national gene bank under NARC. It has been collaborating with the community-based seed banks (CBSB) and associations of CBSB. The 17 CBSBs have conserved 113 cultivars of finger millet, foxtail millet, proso millet, sorghum and bajra and utilizing them for the extension of these cultivars (Shrestha et al 2023, this book) .The centre has also been implementing the government scheme of providing NRs 900 per ropani of barren land brought under the cultivation of millets and other indigenous crops at the local level. It also provides the subsidy of NRs 10 per Kg of millets for the producer farmers and collector farmer's group or co-operatives at the local level. A museum of indigenous crops and the related tools is established by the CCDABC, Shreemahal, Lalitpur for the study and conservation of such ancient wisdoms.

Activities on National Agro-biodiversity year 2079BS and International Year of Millets (IYM) 2023

Different works has been initiated by the Government of Nepal for the development of indigenous crops of Nepal including millets. On the occasion of National Agro-biodiversity year 2079 BS and the International Year of Millets 2023, the government announced various activities through the annual budget programs. Millets has been an important component of the government initiatives for the conservation of the indigenous crops in the country. Conservation program was conducted on the occasion of *Baalaa Chaturdashi*, a celebration where many (hundred) kinds of seeds are mixed and sown in the forest as a ritual of giving back to the mother nature. This is an ancestral celebration for the country like Nepal (CCDABC and NAGRC 2023).

On the occasion of the International Year of Millets (IYM) 2023, the information regarding the cultivation to consumption has been broadcasted through FM networks. Similarly, informative posters, flex, stickers have been extended across the country. The provincial and local governments and non-government parties have been requested to celebrate the IYM 2023 (CCDABC 2023) with different activities. The draft of Millets policy brief is being prepared by the multidimensional team including CCDABC, the International Centre for Integrated Mountain Development (ICIMOD), the Himalayan University Consortium and the FAO. With the support of FAO, CCDABC has been implementing School millets campaign in more than 120 schools of all the provinces. Varietal and fertilizer demonstration activities were conducted in Gorkha, Dhading, Sindhupalchowk and Dolakha districts with the support of Food and Nutrition Sector Project (FANSEP) of the government. Visits to the International Crop Research Institute for Semi-Arid and Tropics (ICRISAT) and Indian Institute of Millets Research (IIMR) were done (CCDABC 2023).

Different programs were conducted for a week-long celebration of the National Agro-biodiversity Day and Week in the year 2079 BS that included a national message from the honourable Prime Minister, Agriculture Minister, exhibitions of indigenous food recipes including that of millets, discussion programs, dramas, workshops, publications, communication materials, radio jingles, advertisements, etc. With the co-ordination of Homestay federation, indigenous foods were integrated into the menu of homestays as an integral component of offered food items. Such promotional and awareness programs were prioritized by the government. The federal government provides conditional grants to the provincial and local level government for the promotion of millets. (CCDABC and NAGRC 2023).

Provincial and Local level programs

Different works has been initiated by the local levels. Many local governments have been involved in the promotion of millets. Significant work has been done by the Makwanpurgadhi rural municipality, Makwanpur; Hariban municipality, Sarlahi; Konjyosom rural municipality, Lalitpur, Gaumul rural municipality and Badimalika municipality of Bajura, Narayan municipality, Dailekh and Pokhara Metropolitan city, Kaski. Similarly, programs were conducted by the provincial agricultural ministry of Karnali province in co-ordination with the non-governmental organizations (NGOs) such as LI-BIRD, *Bhakari Pariyojana* and CEAPRED (CCDABC and NAGRC 2023). Karnali and Sudurpaschim provinces have focussed program on indigenous crops mainly on finger millets and proso millets.

Makwanpurgadhi rural municipality has promoted the area expansion work with the help of conditional grant from the Government of Nepal since the fiscal year 2077 BS. It has fixed the minimum support price (MSP) for the millets which is bought through the co-operatives (**Table 2**). In addition, subsidy of NRs 200 per quintal is provided to the farmers on the basis of their marketed surplus and NRs 200 per quintal is provided to the co-operative on the basis of their quantity bought for the storage and management. The Municipality has decided to include indigenous crops every Thursday in school day meal program which has helped for the utilization of millets which creates the demand and also added the nutritional requirements of the students. The local level has facilitated the construction of collection and storage centre for millets. They also supported the installation of machineries such as millets dehulling machine, millets grinding mills and electric millets traditional mills (*ghatta*). From the fiscal year 2079 BS, it has supported the branding and packaging of millets. The local government supported in getting the license from the Department of Food Technology and Quality Control for selling the millets flour in their local brand. The rural municipality has also supported in the collection, conservation and maintenance of local millets landraces through local seed distribution management system (Chaudhary 2023).

Table 2. Minimum support price for finger millet in Makwanpurgadhi rural municipality, Makwanpur

Year	MSP (NRs Per quintal) of finger millet	Quantity brought by co-operatives (mt)
2077/78 BS	4200	3.09
2078/79 BS	4800	11.29
2079/80 BS	4500	10.80

Source: Chaudhary 2023

Values

Millet crops in Nepal are not just agricultural commodities; they embody cultural, religious, and economic values. Serving both as food and fodder, millets contribute to food security, nutrition, and overall health. Beyond sustenance, they create economic opportunities through the sale of processed products. Millets also hold ecological significance, promoting beneficial insects, enhancing soil health, and contributing to environmental sustainability. A noteworthy cultural product derived from millets is "rakshi," a traditional alcoholic beverage with deep cultural and social importance. In essence, millets in Nepal are integral to diverse aspects of life, reflecting their multifaceted importance in the country's heritage and livelihoods.

Consumption pattern

The consumption of millets in Nepal has declined significantly over the years, with people favoring rice, wheat, and maize. While millets were once considered staples associated with strength and health, the younger generation is less inclined towards them, and some may not even be familiar with these crops. However, millet products still appeal to older individuals and those seeking nutritional benefits during illness. Recent trends show a resurgence in millet consumption, with some restaurants and shops now offering millet-based foods, reflecting a renewed interest in traditional crops within modern diets.

Problems and Prospects

Despite of the importance of millets in human and animal nutrition and climate resilient nature, millet crops are still neglected in Nepalese agriculture. Its importance is well documented, however, due to migration to urban areas from rural areas, change in food habit to rice and many technical issues etc, its production has not been increased and consumption is also reduced. The main underlying problems of millet value chains are lack of awareness among producers and consumers, low productivity of these crops, lack of product diversification, marketing promotions, inadequate institutional arrangement, inadequate research and technology development, inadequate government support programs, less mechanization facility, poor co-ordination among stakeholders etc. Low productivity has been attributed by the low yielding varieties, poor nutrient management, inadequate technical service delivery etc. Thus, the dedicated institutions on millets research, and promotion should be established; the awareness of the quality of millets on nutrition and health benefits should be increased through different promotional programs, processing and marketing facility development, research and technology development and their extension on different aspects of millets value chain should be strengthened, and the potentiality of its marketing and trade should be promoted for the benefit of farmers, other value chain actors and consumers for the benefit of the country.

Way Forward

Advancing the promotion and sustainability of millets in Nepal requires a multifaceted approach encompassing awareness, conservation, utilization, and support mechanisms. Here are some key ways forward:

- **Awareness Campaigns**: Launch comprehensive awareness campaigns targeted at farmers, consumers, and young people to educate them about the nutritional benefits and ecological advantages of millets. This can be done through workshops, seminars, and social media outreach.
- **Diversity Assessment**: Conduct a nationwide assessment of millet diversity to better understand the distribution and characteristics of different species and landraces. This data will inform conservation and breeding efforts.
- **Conservation Strategies**: Implement diverse conservation strategies, including on-farm conservation by involving farmers in preserving traditional varieties, in-situ conservation by protecting millet-rich ecosystems, and ex-situ conservation through seed banks and gene banks.
- **Breeding**: Utilize the assessed diversity to breed site-specific millet varieties that are adapted to different agroecological zones, ensuring optimal yields and resilience.
- **Mechanization and Product Diversification**: Invest in the complete mechanization and automation of millet cultivation and processing, making it more efficient. Encourage value addition by promoting diverse millet-based products such as snacks, beverages, and processed foods.
- **Traditional Knowledge Preservation**: Foster the transmission and enhancement of traditional millet cultivation and processing skills, acknowledging the valuable knowledge held by local communities.
- **Market Guarantee**: Ensure a steady and profitable market for all types of millet products, incentivizing both producers and consumers. Government-backed guarantees can provide stability.
- **Incentives to Farmers**: Provide incentives to farmers who cultivate millets, including financial incentives, subsidies, and access to credit for millet farming.
- **National Millet Research Center**: Establish a dedicated national millet research center to centralize research, breeding, and conservation efforts. This institution can act as a hub for knowledge dissemination and innovation.

By pursuing these strategies, Nepal can strengthen its millet sector, enhance food, nutrition, business, health and environment security, and contribute to the conservation of these valuable crops. Additionally, these measures will support rural communities, empower small-scale farmers, and promote sustainable agriculture in the country.

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Trend in Area, Production and Productivity of Finger Millet in Nepal

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Abstract

A study was carried out to assess the trend of area, production, and productivity of finger millet in Nepal. The time-series data (2008 to 2019) were collected from the "Statistical Information on Nepalese Agriculture" published yearly by the Ministry of Agriculture and Livestock Development, Nepal. Mann-Kendall test (M-K) and Sen's slope method were used for trend analysis. The production and productivity of finger millet had an increasing trend during the study period as indicated by the positive value of Kendall's tau (τ) but the area had a decreasing trend. Findings from this study could be used to suggest necessary policy guidelines for future production and marketing strategies of millet crops in Nepal.

Keywords: Finger millet, Area, Production and Productivity, Trend Analysis

Introduction

Serving as the crucial staple crop to millions of economically disadvantaged people in the Asian and African nations, finger millet is one of the important small-seeded cereal crops. Finger millet phenotypically possess dark brown or brick red colored seed coat with the thin membranous pericarp, and are either processed by malting or fermentation, resulting flour as the end product extensively used in weaning, geriatric food, beverages as well as therapeutic products (Udeh et al 2017). Finger millet is a veritable food crop among cereals which is richest in calcium, iron, fiber and amino acids making it important for bone health, anemia prevention, gastro intestinal tract health, and muscle repair (Wyss 2016). Finger millet is rich in minerals. Its iron content is twice as that for rice and a special attribute of finger millet is that it can be stored for more than ten years with little deterioration in quality, securing its status as a crop critical for long term global food security. It is ranked as the fourth important cereal crop after rice, maize and wheat in terms of production (339,462 metric tons) and area of cultivation (267,071 hectare) in Nepal (MoALD 2022).

Historically, the crop was domesticated in western Uganda and the Ethiopian highlands at least 5,000 years ago before introduction to Asia approximately 3,000 years ago. Presently, the crop is cultivated in more than twenty-five countries, mainly in Africa and Asian nations like India, Nepal, Malaysia, China, Japan, Iran, Afghanistan and Sri Lanka. Annual world production of finger millet is at least 4.5 million metric tons of grain, of which Africa produces 2 million tons while India being a major producer of finger millet in Asia with a production of 120 lakh tons (FAOSTAT 2022). Three species of finger millet ie *Eleusine coracana*, *E. indica* and *E. aegyptiaca* are found in Nepal, out of the fifteen species reported in the world (Kandel et al 2019). Apparently, there exists high diversity of finger millet in the mid hills of Nepal and its major production area outstretches to Khotang, Sindhupalchowk, Baglung, Syangja, Kaski, Gorkha and Sindhuli (Gairhe et al 2021). The production of finger millet increased over the time (MoALD 2079). In terms of productivity of finger millet, Udaypur tops the chart with 1.97t/ha productivity followed by Panchthar and Okhaldhunga with almost the same productivity rate. In terms of province, the highest productivity of finger millet is in Koshi Province (1.35 t/ha), whereas Baglung district of Gandaki Province possesses the largest area and production of finger millet in Nepal (Gairhe et al 2021). As per the five years food import data of Nepal, it can be observed that the import value raised from NPRs 44.43 billion (333 million USD) in 2009/2010 to NPRs. 127.51 billion (957 million USD) in 2013/14, and Nepal has spent NPRs. 180.10 (1.35 million USD) million to import millet in 2019, despite the increased millet productivity (Gairhe et al 2021).

Methodology

The time series data on production of finger millet area, production and productivity in Nepal from 2008 to 2019 was collected from Statistical Information on Nepalese Agriculture published by MoALD from 2008 to 2019. The data was analyzed using MS Excel and XLSTAT. Simple descriptive statistics like minimum, maximum, mean, standard deviation was computed. Mann-Kendall test was used to determine the monotonic trend in a given time series data and Sen's slope method was used to quantify the trend. Mann- Kendall test (MK test) is a non-parametric test which was developed by Mann (1945) and Kendall (1975) and it analyzes the sign of the difference between later measurements with earlier measurement. The null hypothesis (H0) for this test is, "there is no monotonic trend in time series" and the alternative hypothesis (HA) for this test is, "there is monotonic trend in time series".

Findings and Discussion

Trend of productive area and production of finger millet

The descriptive statistics for area, production and productivity is tabulated in **Table 1**. The maximum area, production and productivity of finger millet during this period was 278,030 ha, 320,953 t and 1.22 t/ha respectively. The average annual productivity of finger millet for 12 years period from 2008 to 2019 was 1.10 t/ha. The productivity was below this annual average (1.22 t/ha) as per the report from Agriculture Diary published by Agriculture Information and Training Center in 2022.

Table 1. Descriptive statistics for area, productive area, production, and productivity of finger millet

Parameters	Minimum	Maximum	Mean	SD
Area (ha)	26,2547.00	278030.00	267957.88	4789.58
Production (t)	292,683.00	320953.00	307200.87	7825.35
Productivity (t/ha)	1.10	1.22	1.15	0.04

It is evident from **Table 2** that the production and productivity of finger millet had an increasing trend during the period of 2008 to 2019 as indicated by the positive value of Kendall's tau (τ) but the area had a decreasing trend. The trends of all parameters were statistically significant at a 95% confidence level as indicated by p-values (0.05). Sen's slope method quantified that the area of finger millet decreased at the rate of 813.99 ha per year, production increased at the rate of 1,772.81 ton per year and productivity increased at the rate of 0.01 t/ha during the study period.

Table 2. Mann-Kendall test and Sen's Slope estimators for overall area, productive area, production and productivity of finger millet

Parameters	p-value	Kendall's tau (τ)	Sen's slope	Trend	Significance
Area (ha)	0.011*	-0.576	-813.993	Decreasing	Significant
Production (t)	0.007**	0.606	1772.813	Increasing	Significant
Productivity (t/ha)	0.000**	0.818	0.010	Increasing	Significant

**denotes significant at a 1% level of significance

According to the national agriculture census, there is declining area of finger millet production in the last decades due to certain social taboo in its consumption by the elite groups still prevalent in the rural and urban areas. In Nepal, although there are numerous advantages of its cultivation at smallholder farmer level, finger millet is commonly seen as "poor people's food" – both by the authorities and by consumers themselves ie finger millets, for example, are known as '*kuanna*' in Nepal, literally meaning 'bad cereal' (Wyss 2016). To majority of people, the commercial importance and market value is still unknown leading to devaluation and degradation of cereal as low grade food item in Nepal due to the wrong and narrow perception of the people (Adhikari 2012) which result in declining area for its cultivation as shown in **Figure 1**.

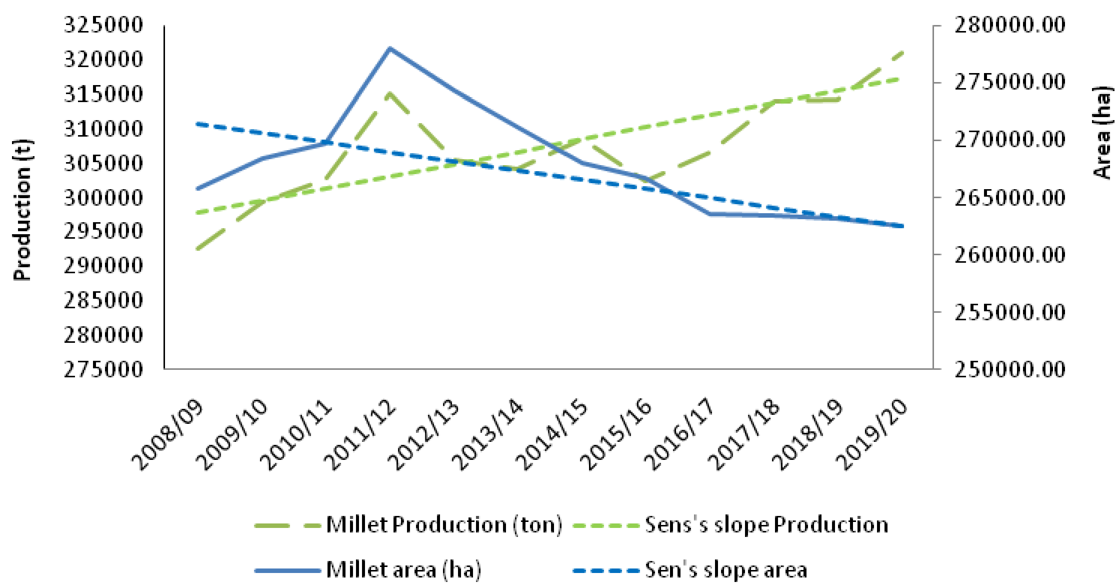

Figure 1. Trend of area and production of finger millet

Finger millet of Nepal anchors unique gene pools, which is crucial for nutritional security of smallholder farmers and marginalized mountainous communities facing the extensive impacts of climate change presently, and farmers of such areas prefers participatory method of crop production while promoting an agronomic package of practice as well as creating market incentives to enhance domestic production to uplift its productivity in Nepal (Gairhe et al 2021)production, productivity, and trade for the year 2009-2019. The study used a combination of exploratory survey and secondary data for assessing the production system, compound growth rate, coefficient of variation (CV, which is clearly indicated in **Figure 2**. In modern food culture, it is used as a nutritious multigrain bread, cakes, cookies etc showing the increasing use of this crop in the daily life of the Nepalese people (Gairhe et al 2021, Adhikari 2012).

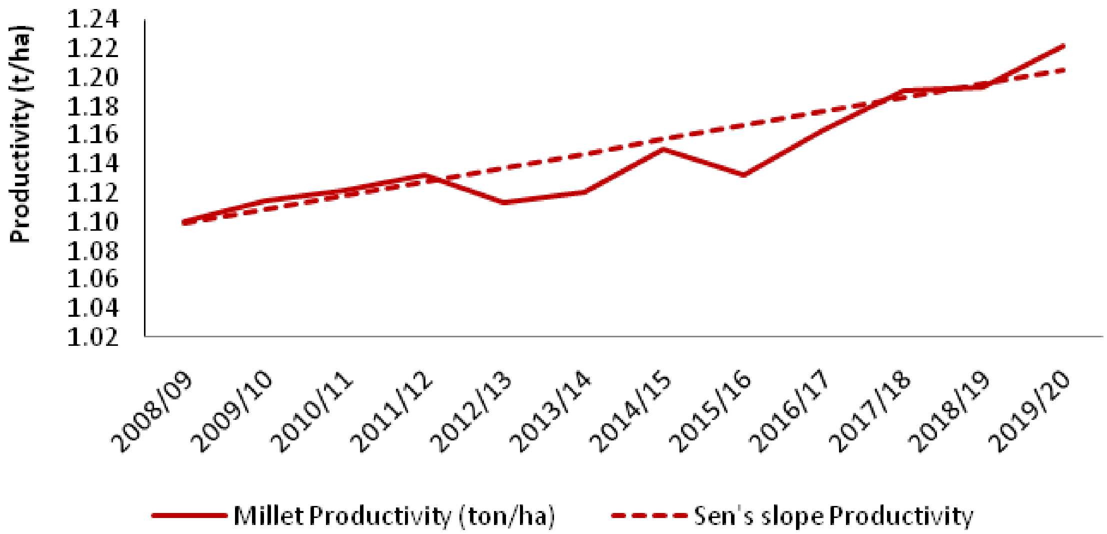

Figure 2. Trend of productivity of finger millet

At present scenario, because of its nutritional and health benefits awareness, it can be observed that more attention is grabbed towards its research by plant breeders nowadays, causing the change in the status of finger millet from neglected and underutilized to future smart crop which ultimately contribute in its increased productivity through development of improved agronomic package of practices.

Conclusion

The area of finger millet was decreasing at the rate of 813.99 ha per year, production was increasing at the rate of 1772.81 t per year and productivity was increasing at the rate of 0.01 t/ha during the study period. To explore the potential of finger millet to increase agricultural production, crop diversification and a better nutritional environment, research and improvement efforts are needed along with the improvements in market development. Possessing climate resiliency, finger millet crops are drought and stresses resistant with high potentiality of improving health security of ever-expanding urban and global population in terms of changing climate and environmental condition

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक) । २०८० । राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ ।

कोशी प्रदेशमा कोदोजन्य बाली

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सारांश

सयुक्त राष्ट्रसंघको बिश्व खाद्य तथा कृषि सँगठनले यस बर्षलाई अन्तर्राष्ट्रिय कोदोजन्य बाली वर्ष, २०२३ घोषणा गरेकोले संसारभर बिभिन्न कार्यक्रम गरी मनाइएको छ । यस अन्तर्राष्ट्रिय कोदोजन्य बाली वर्ष २०२३ को माध्यमबाट कोदोजन्य बालीको पौष्टिक महत्त्व र मानव स्वास्थ्य विचको अन्तरसम्बन्धलाई दर्शाउन तथा चेतना दिन खोजिएको छ । घाँस परिवार अन्तर्गत पर्ने यी बालीहरूको खेती ७-१० हजार वर्ष अघि भएको भनिन्छ । कोदोजन्य बाली मध्यम सुख्खा भएको एसिया तथा अफ्रिकाको भागमा मुख्य खाद्यान्न बालीको रुपमा खेती गरेको पाइन्छ । त्यसैगरी कोदोजन्य बाली रैथानेबालीको रुपमा विश्वभरका विभिन्न देशमा खेती गर्ने गरिन्छ । नेपालको कृषि प्रणालीमा कोदो, कागुनो, चिनो, जुनेलो, सामा, बाजरा, कुट्की सामा र कोदी गरी जम्मा ८ प्रजातिका कोदोजन्य बालीहरू पाइन्छ । जसमध्ये उपयुक्त हावापानी तथा प्रयोग प्रचलनका आधारमा मुख्यरुपमा कोदो, चिनो, कागुनो र जुनेलोको खेती गर्ने गरिन्छ भने बाँकी प्रजातिहरू विस्तारै लोपोन्मुख अवस्थामा रहेको छन् । नेपालमा कृषकस्तरको पहलबाट कोदोजन्य बालीको उत्पादन बढाउन तथा प्रचारप्रसार गर्नको निम्ति आ. व. २०७८ सालदेखि कोदो दिवस बनाउन थालिएको छ । पहिलो पटक कोदो दिवस आ. व. २०७८ काठमाण्डौमा, दोस्रो पटक आ. व. २०७९ मकवानपुरमा र तेस्रो पटक आ. व. २०८० काभ्रेपलान्चोकमा मनाइएको थियो । नेपालमा कोदोजन्य बाली सम्बन्धी विभिन्न कार्यक्रम, अनुसन्धान तथा प्रचारप्रसारको कार्य नेपाल सरकारको कृषि तथा पशुपन्छी विकास मन्त्रालय, नेपाल कृषि अनुसन्धान परिषद्, लि-वर्ड तथा इसिमोड आदिले गर्दै आएका छन्। नेपालको मध्य तथा उच्च पहाडी क्षेत्रहरूमा खाद्य तथा पोषण सुरक्षा कायम गर्नको लागि रैथाने कोदोजन्य बालीको महत्त्वपूर्ण स्थान रहेको पाइन्छ ।

कोशी प्रदेशमा कोदोजन्य बालीको हालको अवस्था

नेपालमा कोदो बाहेक अन्य कोदोजन्य बालीहरूको आधिकारिक तथ्यांक पाइँदैन । कोशी प्रदेशका बिभिन्न जिल्लामा कोदो बालीको अवस्था तालिकामा प्रस्तुत गरिएको छ । हाल सोलुखुम्बु जिल्लाको परिवेशलाई हेर्ने हो भने आज भन्दा २०/२५ बर्ष अघिको खेती गर्ने प्रकिया र हालको खेती गर्ने प्रक्रिया तथा प्रविधिमा खासै फरक नभएको पाइएको छ । विशेषगरी जेष्ठ २५ देखि असार अन्तिमसम्म कोदो रोप्ने चलन छ । प्राय: यहाँ पराम्परागत जातहरू जस्तै - डल्ले, नङसे, कालो कोदो आदि रोप्ने चलन छ । थोरै कृषकहरूले मात्र कोदोलाई मलिलो तथा खेत/पाखो जग्गामा लगाउँछन् भने धैरैले मकैसँग मिश्रित बालीको रुपमा लगाउने गर्दछन् । मकैसँग कोदो लगाउँदा बाली सघनता धैरै हुने तथा एकै पटकमा दुई बालीको उत्पादन लिन सकिने हुँदा बढी फाइदा हुने गर्दछ । धैरै मलिलो माटोमा कोदो मात्र लगाउँदा कोदो छिटो बढ्ने र पछि ढल्ने समस्या हुने गर्दछ । यी दुवै तरिकाले खेती गर्दा कोदो पाक्ने समयमा भने केही फरक नभएको किसानको अनुभव पाइयो ।

प्राय: कार्तिक-मंसिरमा कोदो भित्र्याउने कार्य गर्ने गरिन्छ ।बाटो, बजार तथा सिंचित खेतको अभावले गर्दा धान खेती नहुने साथै चामल सजिलै उपलब्ध नहुने भएकोले बाध्यात्मक कारणले गर्दा पनि कोदो खेती गरी रोटी, ढिंडो तथा रक्सि/तोम्बाको लागि यो कोदो बाली लगाउने प्रचलन रहेछ । पहिलादेखि नै प्राय: कोदोलाई रक्सि र तोम्बाको लागि प्रयोग गरिने रहेछ । अन्यबाली भन्दा धैरै मिहिनेत गर्नु पर्ने तर उत्पादन भने सारै कम हुने यो बाली सदियौंदेखि लगाइंदै आउनुका कारणहरूमा पौष्टिक तत्व बारेको चेतना, खाद्य सुरक्षा, बजारमा कोदोको दाना नै लगेर बिक्री गर्दा पनि सजिलै नगद प्राप्त गर्न सकिने, कोदोको परम्परागत परिकारहरू खाने बानी परेको र बुढाबुढी लगायत बच्चाबच्चीको लागि सातु लिटोको रुपमा खुवाउनु पर्ने, आदि रहेछन् । कोदो खेती प्रविधि परम्परागत शैली नै अपनाएको पाइयो । यतिका वर्षमा कोदो खेती प्रविधिमा, बीउविजन तथा मलको प्रयोगमा खासै फरक नभएको भनाइ कृषकहरूको छ भने कोदो चुट्ने मेसिन कतिपय कृषकहरूसँग रहेको जानकारी पाइयो । कोदोबालीमा पहिलादेखि नै खुम्रे तथा माटोको नजिकबाट डाँठमा प्वाल पारी कोदो नष्ट गर्ने स्टेम बोरर किरा लाग्ने गर्दछ । हालको विद्यमान तथा जल्दोबल्दो समस्या भनेको कृषकले खेती गर्न छाडेर सुविधा सम्पन्न बजारतिर सर्ने तथा विदेशिने प्रक्रियाले गर्दा कोदो लगायत कृषि गर्ने जनसंख्या नै पलायन भएको पाइन्छ । कृषकको भनाइ अनुसार कोदो खेती गर्न धैरै मिहेनत परेतापनि बजारमा सजिलै विक्री गरी नगद रकम प्राप्त गर्न सकिने तर उत्पादन भने सारै कम हुने भन्ने छ । हालसम्म पनि कोदो खेतीमा कुनै प्रकारको नयाँ प्रविधिको अवलम्बन नभएको हुँदा कोदोबालीको उत्पादन पूर्णरुपमा प्राङगारिक खेती रहेको छ ।

कोशी प्रदेशका बिभिन्न जिल्लाहरूमा कोदो बालीको अवस्था

क्र.सं.	जिल्लाहरू	कोदो ७६/७७			कोदो ७७/७८			कोदो ७८/७९			कोदो ७९/८०		
		क्षेत्रफल (हे)	उत्पादन (मे ट)	उत्पादकत्व (मे ट)	क्षेत्रफल (हे)	उत्पादन (मे ट)	उत्पादकत्व (मे ट)	क्षेत्रफल (हे)	उत्पादन (मे ट)	उत्पादकत्व (मे ट)	क्षेत्रफल (हे)	उत्पादन (मे ट)	उत्पादकत्व (मे ट)
१	ताप्लेजुंग	२९८६	४१८२	१.४०	२९८७	४२४२	१.४२	२९८५	४२६९	१.४३	२९६६	४२७०	१.४४
२	संखुवासभा	६६६४	८३२९	१.२५	६६६४	८६६४	१.३०	६६६४	८६६४	१.३०	६६६६	८६६६	१.३०
३	सोलुखुम्बु	२१०५	२८४२	१.३५	२१०५	२८३०	१.३४	२१०५	२८००	१.३३	२१०५	२८००	१.३३
४	पांचथर	३२३८	६१५२	१.९०	३२३८	६२१७	१.९२	३२३७	६२१५	१.९२	३२०८	६४१६	२.२२
५	ईलाम	१५९५	१८८२	१.१८	१६००	१९२५	१.२०	१६१०	१९७०	१.२२	१५९७	१९१६	१.२०
६	तेह्रथुम	२५०५	१८८०	१.१५	२५०५	२८५६	१.१४	२५०५	२८५४	१.१४	२१२३	२५४८	१.२०
७	धनकुटा	७२३०	८६०८	१.१९	७२३०	८४५९	१.१७	७२३०	८२१४	१.१४	७२२८	८२४०	१.१४
८	भोजपुर	५२७२	६५६८	१.२५	५२८४	६६५७	१.२६	५२०५	७८०७	१.५०	५०४८	७०६७	१.१४
९	खोटांग	२१३१५	२४९३२	१.१७	२१३१५	२७३०८	१.२८	२१३१५	३७७२८	१.७७	२१३१५	३८३६७	१.८०
१०	ओखलढुंगा	७७५१	१५५०२	२.००	७७५१	१९३७८	२.५०	७७५१	१६२७७	२.१०	७७५१	१९३७६	२.५०
११	उदयपुर	२७६८	५५३६	२.२२	२७६८	५६४७	२.०४	२७६८	५४५३	१.९७	२७६८	५२५३	१.९७
१२	झापा	१०१२	१३१६	१.३०	१०००	१३००	१.३०	९९५	१२९४	१.३०	८५०	११०५	१.३०
१३	मोरंग	१२१७	१४९७	१.२३	११९०	१४६३	१.२३	११३०	१३९१	१.२३	१२९०	१५८७	१.२३
१४	सुनसरी	४९०	५९३	१.२१	४८१	५९१	१.२३	४५७	५६२	१.२३	४५७	५६२	१.२३
प्रदेश- १		**६६१४९**	**९०८२६**		**६६११८**	**९७५३६**	**१.४८**	**६५९५७**	**१०५५२२**	**१.६०**	**६६५३७२**	**१०८३७५**	**१.६६**

कोदोबालीमा हुनुपर्ने व्यवस्था

बिगतका बर्षहरूमा नेपालको कृषि क्षेत्रमा उल्लेखनीय परिवर्तन भएता पनि कोदोबालीमा भने खासै परिवर्तन भएन। हाल **खान नपाएर भन्दा खान नजानेर** दिन प्रतिदिन बिभिन्न रोगहरूको शिकार हुनुपरेको विद्यमान परिवेशमा कोदोबालीको परिकारहरूको उपभोग गर्न अति नै आवश्यक रहेको छ। कोदोबाली आफैँमा एक रैथानेबाली भएको हुँदा यस बालीमा खासै अध्ययन अनुसन्धान नभएकोले भावी दिनमा यस बालीमा धेरै उत्पादन दिने, छिटो फल्ने, रोगकिरा प्रतिरोधात्मक जातको विकास गरी किसानहरूको पहुँचमा पुर्याउनु आवश्यक हुन आउँछ। नेपाल सरकारको नीति तथा कार्यक्रम अनुसार प्रति रोपनी रैथाने बाली लगाउने कृषकलाई दुई हजारका दरले प्रोत्साहन अनुदान, ७५ प्रतिशत अनुदानमा कृषि यान्त्रिकरण दिने व्यवस्था, शत प्रतिशत अनुदानमा बीउविजन उपलब्ध गराइने रहेको छ तर वास्तविक कृषक समक्ष नपुगेको र पुगेका स्थानमा पनि सही सदुपयोग नरहेको अवस्था छ। कोदोमा बाली बीमाको व्यवस्था गरीनु पर्ने र रोग तथा किरा व्यवस्थापनमा प्रविधिक सहयोगको खाँचो रहेको हुँदा यस विषयलाई ध्यान दिई विभिन्न तहका सरकारले कृषकको समस्यालाई सम्बोधन गर्ने प्रकारका कार्यक्रममा जोड दिनु पर्दछ। त्यसैगरी उन्नत प्रकारका बीउविजन, मल तथा विषादि वितरण गरी उत्पादन तथा उत्पादकत्व वृद्धि गर्नु पर्दछ। विशेषरुपमा कोदोखेती हुने क्षेत्रमा बजारीकरणको लागि ढुवानीको सुनिश्चितता सरकारको तर्फबाट हुने कार्यक्रमको कार्यान्वयन गर्नु पर्दछ। कतिपय कृषकको भनाइ अनुसार चामल आयातमा रोक लगाउनु पर्ने, एक क्लष्टरमा एक बजारको व्यवस्था गरीनु पर्ने तथा हरेक घरधुरीले कोदो अनिवार्यरुपमा लगाउनु पर्ने जस्ता सुझाव आएको छ।

कोदोबाट बन्ने परिकारहरूलाई विशेष स्थान दिई औद्योगिकीकरण गरेमा कोदोबालीको माग बढ्ने र कृषकले उत्पादनको सही मूल्य प्राप्त गर्न सक्ने विचार व्यक्त गरेका छन्। त्यसैगरी कोदोबाट बन्ने रक्सिको गुणस्तर मापन गरी कानुनी मान्यता दिन सकिएमा कोदोको बजार माग बढ्ने र कोदो लगाउने कृषकको संख्या पनि बढ्ने साथै वैदेशिक रोजगारीमा जाने जनसंख्या कम हुन सक्ने आंकलन रहेको छ। स्थानीय स्तरमै कोदोबालीको उत्पादन प्रर्वद्धन तथा उपयोगमा जोड दिई सुरक्षित खानपान र पौष्टिक तत्वका स्रोत तथा उपयोगबारे सचेतनात्मक कार्यक्रम संचालन गर्नु पर्दछ। खाद्य सुरक्षाको दृष्टिकोणले कोदोको परिकारहरू विद्यालयस्तरमा बालबालीकालाई खाजाको रुपमा खुवाउनु पर्दछ। कृषि तथा पशुपंक्षी मन्त्रालय मार्फत् बन्न लागेको कृषि ऐनमा पनि कोदोबाली तथा रैथानेबालीलाई विशेष प्राथमिकता दिनुपर्दछ। तसर्थ कृषिको अन्य क्षेत्रमा भैरहेको सकारात्मक परिवर्तन जस्तै कोदोजन्य बालीहरूको क्षेत्रफल,उत्पादन र उत्पादकत्वमा वृद्धि गर्न र कृषकको उत्पादनले सहजरुपमा बजार माग अनुरुप नगद प्राप्त गर्न तीन तहको सरकारले कोदोबालीको माग र जनताको आवश्यकता अनुसारको नीति, कार्यक्रम तथा बजेट मार्फत् कोदोबालीमा आधुनिकीकरण तथा व्यवसायिकरणमा जोड दिनुपर्ने देखिन्छ।

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Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Status and Prospects of Millets in Madhesh Province

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Abstract

Madhesh Province possesses an enormous opportunity and potential for growing millets due to favorable climatic condition and other production environments. There has been a number of socio-cultural and economic significances of millets in Madhesh Province. Finger millet is by far the most widely grown millets in the Province and other millets are confined to only a small area. Despite their health benefits, climate change resilience properties and capacity to uplifting the livelihoods of the local people, area and production of millets have been continuously declining in the Province like other parts of the country owing to several reasons. Basically, with the proliferation of modern life style and food habit favouring rice and high calorie fast foods, consumption of millets based recipes has been virtually on the verge of extinction. Besides, there are a number of other constraints too. Millets have been given a less priority by the government of Nepal and Provincial governments and local farmers alike as they are focused more on major cereals such as rice, wheat and maize. Farmers, governments and other stakeholders are required to increase policy and investment priority to millets research and development, and value chain development in order to reap the potential benefits of such crops.

Keywords: Millets, Madhesh, prospects, recipe, significance

Introduction

Situated in the extensive lap of panoramic Himalayas of Nepal, Madhesh Province is epitomized by its unity in diversity concept. With its enthralling richness in biodiversity and increasing use of technology and professionalism in agriculture and the expansion of the service sector, the involvement of the population in the agricultural sector is gradually declining. Adumbrated by slow economic growth, escalating endemic poverty, and wide-scale deprivations from substantial economic growth, Madhesh Province faces a challenge in reducing poverty and overall socio-economic development.

Agriculture serves as a foundation for the poverty alleviation and employment generation in Madesh Province like in other Provinces. Search for appropriate crops and cropping patterns to make agriculture more remunerating, beneficial and more attractive to youths has always gained priority in this Province.

By the term "Underutilized crops" or UUC, we refer to those species which possess the potential to improve people's livelihoods, as well as food security and sovereignty, but their worth is not being fully realized or they are not being adequately utilized because of their limited competitiveness with commodity crops in mainstream agriculture. From the perspective of Madhesh Province, underutilized crops are those indigenous crop species that have food, nutritional and cultural values but are given less attention by researchers, extension and development organizations, policy, and decision-makers. Among the UUC species, millets hold the top position in this Province in terms of scale of production and associated benefits. Despite their importance in improving food and nutrition security and livelihood of the local people, such crops have been poorly explored, documented and studied in Madhesh Province.

Status of Millets in Madhesh Province

The most significant millet crop in Madhesh Province in terms of area and production is finger millet followed by proso millet and foxtail millet. Sorghum, barnyard millet, pearl millet, little millet, and kodo millet are other millets that are grown in various parts of the Province in a very small area (Ghimire et al 2017). Besides finger millet, other millets are cultivated in a small area in the Province and data on area, production and yield of millets of the latter are not available (MoALD 2023). In Madhesh Province, finger millet covers 1655 ha area with the production of around 1669 tons and yield of 1.008 t/ha (**Table 1**).

Table 1. Area, production and yield of finger millet by districts in 2021/22

SN	District	Area (ha)	Production (t)	Yield (t/ha)
1	Saptari	183	231	1.26
2	Siraha	440	458	1.04
3	Dhanusha	176	180	1.02
4	Mahottari	-	-	-
5	Sarlahi	709	638	0.90
6	Bara	76	88	1.16
7	Rautahat	71	74	1.04
8	Parsa		-	-

Source: MoALD 2023

Distribution of millets in Madhesh Province

Eight different types of millets have been reported from Madhesh Province (**Table 2**). All the millets, except foxtail millet and proso millet, are commonly grown across the Province. Foxtail millet and proso millet are reported only from Sarlahi district. However, disaggregated data on area, production and yield of different millets are not available as of now.

Table 2. Cultivated species of millets grown in Madhesh Province

SN	Crop	Nepali Name	Distribution
1	Finger millet	कोदो (Kodo)	All districts
2	Foxtail millet	कागुनो/काउन (Ka guno)	Sarlahi
3	Proso millet	चिनो/चिनु (Chino)	Sarlahi
4	Sorghum	जुनेलो/ज्वार/जनेरमकै (Junelo)	All districts
5	Barn yard millet	सामा/साँवा (Sama)	All districts
6	Pearl millet	बाजरा/घोगे (Bajra)	All districts
7	Little millet	कुट्की सामा (Kutkisama)	All districts
8	Kodo millet	धानकोदो/कोदी (Kodi)	All districts

Finger millet

Like in other parts of the country, the trend of production and consumption of finger millet has been continuously declining in Madesh Province. Saptari contributes the highest production (231 tons) among the eight districts of the Province although Sarlahi tops the list in area covered (709 ha). Finger millet is used to make *roti* (flat breads) and *Khichri* (cooked food of finger millet flour and legume and pulses). It is also used for feeding domestic animals and birds. Mukhiyapatti Musharniya near Janakpur in Dhanusha district is reported to be the lowest point (59.8 msl) among the finger millet producing locations in Nepal. Likewise, in terms of productivity, Udaypur district of this Province tops the chart with 1.97t/ha. Sixteen different improved varieties as well as landraces have been reported in Madhesh Province (Gairhe et al 2021). In **Table 3**, the diverse use of finger millet varieties with farmers preferred traits and major usages have been given.

Table 3. Finger millet varieties, preferred traits and usage in food culture

SN	Important Varieties	Farmer Preferred Traits	Usage in food culture
1	Jhype	High yield	*Dhindo* (thick porridge)
2	Mudke	Early maturity	*Chhapati*/ flat *roti*
3	Chulthe	Disease tolerance	*Haluwa*, sweets
4	Dalle	Pest tolerant	Millet Soup (*Khole*)
5	Lampate	Drought tolerance	Home-made Liquor (*Jhand*, *Tomba*, *Rakshi*)
6	Lurke	Ease in processing	Modern food dishes (multigrain bread, pancake, biscuits, *namkin*, *momo*, cakes, *selroti*)
7	Chhatre	Cooking quality	Straw as livestock feed
8	Batule	Stay green nature of straw	
9	Rato kodo, Seto kodo, Dudhe, Lopre, Nangre, Tauke, Tinmase, Paudere		

Source: Gairhe et al 2021production, productivity, and trade for the year 2009-2019. The study used a combination of exploratory survey and secondary data for assessing the production system, compound growth rate, coefficient of variation (CV)

Surplus production of finger millet is sold in the market. Major portion of the marketable surplus of finger millet is marketed directly from producers to the consumers in Madhesh Province. The local buyers of the finger millet are the consumers as well as local wine makers, and very little amount of finger millet is marketed through the middle men. In Madhesh Province, finger millet has the potential to improve resource management and serve as a staple food, weaning food and a cash crop which contributes to household income.

Proso millet

Proso millet, locally known as Chino holds significant importance in Madhesh Province as the second most important crop within the millet group offering a wide range of applications. This versatile grain is commonly used for preparing traditional dishes such as *bhat*, *kheer* and *raksi* (homemade liquor). Its flour and grass can be used as a feed for domestic animal.

Foxtail millet

In Madhesh Province, foxtail millet is considered as a traditional, climate-resilient, and nutritionally dense crop. It is consumed as *bhat* (similar to rice), *kheer* (resembling rice pudding) in Madhesh.

Sorghum

Sorghum is a relatively low priority crop among millets in Madhesh Province and is cultivated in not much area. Sorghum is cultivated mostly in Siraha district. The crop is locally called as *janer* and is used as *khichdi*, *roti* (flat bread, *bhat*, *laddu* (a small round ball made from roasted flour mixed with jaggery) in Maghe Sakranti (one of the Hindu festivals that falls on mid-February). It is also used as a feed for domestic lactating cattle and buffalo to enhance milk production.

Barnyard millet

Barnyard millet is cultivated in a few locations Madhesh Province. Its cultivation specially occur in Saptari, Siraha and Sarlahi districts. In Madhesh Province, it is used as indigenous food and animal feed. It is also used in a number of local religious as well as cultural occasions.

Pearl millet

Pearl millet cultivation is confined in a limited area in Madhesh Province. Besides its role as a dietary staple like as b*hat*, *roti* (flat breads), *bagiya* (made from boiling the dough in various shapes), farmers also use this crop as animal fodder, livestock feed, and for the production of fermented beverages.

Kodo millet

Kodo millet is cultivated across the Madhesh Province *albeit* in small area. It is famously used for making *roti* (flat breads). Roti made from kodo millet is consumed by Madhesi woman specially in local festival called *Jitiya* at the time *Paran* (first bite to break the fast) in a few districts of Madhesh Province. Livestock feed and locally brewed wine can also be made from it.

Usage of Finger Millet in Food Culture

Being rich in micro-nutrients, rare amino acids, dietary fibers, vitamins, calcium and higher proteins, finger millet procures valuable stance in food values in Nepalese culture, where this crop is pulverized and the resultant flour is utilized for the preparation of traditional food such as *roti* (flat breads), *kazhi* (finger millet balls), *kanji* (thin porridge) and *papad* (rolled and dried preserved product) in Nepal, it is utilized as main meals in high altitudinal ranges and traditional societies as *Dhindo*, *chhappati roti* (flat breads), *selroti* (traditional deep fried circular shaped millet recipe) as well as various modern food recipes such as pancakes, cakes, biscuits and multigrain breads, and at the same time used as good feeds for livestock (Gairhe et al 2021)production, productivity, and trade for the year 2009-2019. The study used a combination of exploratory survey and secondary data for assessing the production system, compound growth rate, coefficient of variation (CV. The straw is used as an important livestock feed in Madhesh Province during dry lean season.

Social, Cultural and Economic Significance of Millets in Madesh Province

Millets farming and its associated traditions are an important part of the cultural heritage of many indigenous communities in Madhesh Province. In Madhesh Province, millets are often used in various religious and ritual ceremonies. They are offered to god and goddess during festivals and religious events such as in Jitiya festival. The harvest of millets is celebrated with great enthusiasm in the Province. Millets are not only a cultural staple but also serves as an important economic crop for many small-scale farmers in the Province. In some parts of the Province, millets are considered as a resilient crop as it can grow in adverse environmental conditions including areas with poor soil and limited water resources. Overall, millets are not only a source of sustenance but also a symbol of tradition and cultural heritage in Madhesh Province.

Prospect of Millets Production in Madesh Province

The soil of the districts in Madhesh Province are best suited for the production of millets. Moreover, the agro climatic conditions are also favorable for their production. As a tradition, majority of cultivated land in Madesh Province is being used for rice cultivation which requires huge amount of water but due to climate change and other conditions rainfall is insufficient to support rice cultivation and in such a situation millet production is one of best options. But majority of economically active population of Madesh Province are abroad rendering a severe scarcity of labor for rice cultivation. Therefore, previously rice cultivating farmers are seeking either a perfect non-labor intensive technology for rice cultivation or any other non-labor intensive commodity. As non-labor intensive technology for rice cultivation is very rare to exist or if it does exist, the machineries and their accessories are very unlikely to be applicable in Nepalese context because of fragmented and marginal land. Thus, Millets production becomes one of the best options as it is relatively less labor intensive farming which requires nursery preparation, transplantation and harvesting. Millet cultivation does not require frequent irrigation as in the case of rice cultivation. Due to favorable climatic condition, growth of millets suppresses the weed infestation and in most of the cases, weeding is not required. Since, insect and pests of millets in Madesh Province mostly resides below economic injury level, pesticide spraying is not necessary. Millets have potential benefits in terms of nutrients and can replace other agronomic crops, the farmers of Madhesh Province can reap the economic and other benefits out of its production and can improve their livelihood.

Constraints in Finger Millet Expansion in Madhesh

In Madhesh Province, although there are numerous advantages of its cultivation at smallholder farmer level, finger millet is commonly seen as "poor people's food" – both by the authorities and by consumers themselves ie finger millets, for example, are known as '*ku anna*' in Nepal, literally meaning 'bad cereal' (Wyss 2016). To majority of people, the commercial importance and market value is still unknown leading to devaluation and degradation of the cereal as low grade food item in the Province due to the wrong and narrow perception of the people (Adhikari et al 2012)female labor and fertilizer costs were positively significant to total revenue at Kalabang while only fertilizer and female labor costs were positively significant at Begnas. Direct marketing of finger millet from producers to the consumers was most frequent in rural areas while involvement of middlemen was common in the urban areas. Attack of rat to standing crop and damage by disease especially, blight were the major production problems.

As income of the people have increased and there has been a shift in dietary preferences towards rice and wheat. Millets have often been linked to poverty and rural living. This perception has led to a decreased interest in consuming and cultivating millet among population in Madhesh Province. The market demand for millets products has declined as people are increasingly demanding processed and refined foods.

Modern farming techniques and technologies have largely been developed for high-yield crops like rice and wheat. Farmers have shifted towards these crops, which often offer higher yields and can be more easily mechanized. Government policies and subsidies in the Province have often favored rice and wheat production over millet. This has discouraged farmers from cultivating millets. Changes in weather patterns and increasing climate variability can affect millet cultivation. There is a lack of awareness among consumers and farmers about the nutritional benefits of millets. With increasing exposure to global food trends and a desire to mimic Western dietary patterns, there has been a cultural shift away from traditional foods like millets. Land use patterns in Nepal have changed with urbanization and infrastructure development leading to the reduced arable land for traditional crops like millets. The research and development efforts directed towards improving millet varieties and farming practices have been limited. Only a few researches have been done in finger millet, despite its importance for local food security and nutrition, making it a neglected and underutilized species of crop from a research and development perspective.

Conclusion

Millets are renowned for their exceptional capacity to thrive in a variety of challenging agro-ecological conditions. These crops are nutritious and thrive well under the conditions of low fertility and low input management. Therefore, millets are essential sources of plant genetic resources that are readily accessible at the field level as a food source for rural poor farming communities living in arid, infertile, and marginal lands as well as a means of addressing and coping with unpredictable climate conditions, the process of desertification, and socioeconomic marginalization. Millets are the crops of the future in the context of climate change, with significant potential to deal with food insecurity in the country as whole. Due to certain social taboos associated with the consumption of millets in some societies there has been a declining trend in area and production in the last three decades (1991-2021) according to the national census of agriculture in Nepal. Moreover, import of millets has also been growing in recent years amid

To fully explore the potential of millets to improving food and nutrition security and wellbeing of the people focus on millets research and development and value chain development is highly desirable. The provincial government has a main role to play to this end.

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक) । २०८० । राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ ।

बागमती प्रदेशमा कोदोजन्य बालीको उत्पादन स्थिती, अवसर, चुनौती र भावी कार्यदिशा

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सारांश

कोदोजन्य बालीमा कोदोका अतिरिक्त चिनो, कागुनो, जुनेलो, बाजरा र साँवा लगायतका अन्नबालीहरू पर्दछन् । तर बागमती प्रदेशमा चिनो, कागुनो, जुनेलो, बाजरा र साँवा जस्ता कोदोजन्यबालीको नगन्यरुपमा खेती गरिने गरेको पाइएको छ । बागमती प्रदेशका १३ वटै जिल्लामा कोदोको खेती गरिन्छ । बागमती प्रदेश सरकारले आफ्नो स्थापनाकालदेखि नै अन्यबालीका साथै कोदो तथा कोदोजन्यबालीको प्रबर्द्धनका लागि बिभिन्न प्रयासहरू गरेको देखिन्छ ।

पृष्ठभूमि

संयुक्त राष्ट्रसङ्घले भारत लगायत अन्य मुलुकहरूको प्रस्तावमा सन् २०२३ लाई अन्तर्राष्ट्रिय कोदोजन्य बाली वर्ष मनाउने घोषणा गरेको छ (भुसाल २०८०) । सोही अनुरुप नेपालले पनि 'अन्तर्राष्ट्रिय कोदोजन्य बाली वर्ष २०२३' लाई विभिन्न क्रियाकलापहरू मार्फत मनाइरहेको छ । यसबाट कोदो तथा कोदोजन्यबालीको उत्पादन प्रबर्द्धन हुने, यी बालीहरूमा भएका उच्च पोषणयुक्त तत्वको महत्त्व जानकारी हुने, उपभोगमा बृद्धि हुनुका साथै खाद्य तथा पोषण सुरक्षामा सहयोग पुग्ने र खाद्यान्न आयात प्रतिस्थापनमा समेत टेवा पुग्ने देखिन्छ ।

परिचय

कोदोजन्य बालीमा कोदोका अतिरिक्त चिनो, कागुनो, जुनेलो, बाजरा र साँवा लगायतका अन्नबालीहरू पर्दछन् । तर बागमती प्रदेशमा चिनो, कागुनो, जुनेलो, बाजरा र साँवा जस्ता कोदोजन्यबालीको नगन्यरुपमा खेती गरिने गरेको पाइएको छ । यसले गर्दा तथ्याङ्कीय हिसाबले यी बालीहरूको बिस्तृतरुपमा प्रस्तुत गर्न कठीनाई हुने देखिन्छ । कोदोजन्यबालीमा बागमती प्रदेशमा मुख्यतया कोदो नै भएकाले यहाँ कोदोकोबारेमा उल्लेख गरिएको छ । खेती गर्न सजिलो र पौष्टिकताले भरिएको मुख्य रैथाने बालीका रुपमा समेत कोदोलाई लिइँदै आएको छ ।

कोदोजन्य बालीको इतिहास

कोदोजन्यबालीहरूको उत्पत्ति तथा फैलावटका ऐतिहासिक तथ्यहरूमा एकरुपता पाईदैन । यी बालीहरूको उत्पत्ति र फैलावटको सन्दर्भमा फरक फरक विवरणहरू पाइने गरेको छ । बागमती प्रदेशमा कोदोजन्य बालीहरूमा कोदो प्रमुख बालीको रुपमा लिइन्छ । कोदो (*Eleusine coracana Gaertn.*) आजभन्दा करिब ७,००० वर्ष पहिले अफ्रिकी महादेशको पूर्वि भागमा उत्पत्ति भै करिब ४,००० बर्ष अघि भारतीय द्वीप हुँदै नेपालमा भित्रिएको अनुमान छ ।

कोदोजन्य बालीहरूमध्ये कागुनो एक हो । यो बालीलाई हरियो कागुनो (Green foxtail: *Setaria viridis* L.)बाट क्रमबिकास भएको मानिन्छ । करिब ८,००० बर्ष अघि यो बालीको उत्पत्ति चीनमा भएको भन्ने भनाई छ । नेपालको विशेषगरी पश्चिमी पहाडी जिल्लाहरूमा कागुनोको खेती गरिने भएता पनि बागमती प्रदेशको रामेछाप जिल्लामा नगण्य रुपमा खेती गरेको पाइएको छ भने चितवन लगायत अन्य जिल्लाहरूमा यसको खेतीको गरिएको छ ।

कोदोजन्य बालीमध्ये अर्को महत्त्वपूर्ण बाली चिनो हो । यसको उत्पत्ति र फैलावटको ऐतिहासिक तथ्य फेलापार्न नसकिएता पनि नेपालको ३,५०० मी. सम्म उचाई भएको पश्चिमी क्षेत्रमा यसको खेती गरेको पाइन्छ । तर बागमती प्रदेशमा भने कति ठाउँमा खेती गरिन्छ भन्ने एकिन तथ्याङ्क छैन ।

कोदोजन्यबालीको प्रकार तथा जातहरू

कोदोजन्यबालीमा कोदो सहित कागुनो, चिनो, जुनेलो आदि पर्ने भएता पनि बागमती प्रदेशमा कागुनो, चिनो, जुनेलोका जातहरू स्पष्ट र आधिकारीक रुपमा कतै उल्लेख गरिएको पाईदैन। तर कोदोको हकमा भने नेपालको बिभिन्न जिल्लाबाट ८५० भन्दा बढी स्थानीय जातहरू संकलन गरी खुमलटार स्थित राष्ट्रिय जीन बैंकमा संरक्षण गरिएको छ। नेपालमा हालसम्म सिफारिश पाँच वटा र एक वटा पंजिकरण गरी छ वटा जातहरू प्रचलनमा छन्। ती जातहरूमा डल्ले-१, ओख्ले-१, काब्रे कोदो-१, काब्रे कोदो-२, शैलुंग कोदो-१ र जुम्ली रातो कोदो (बराल २०८०)। तर उपरोक्त जातहरूले बागमती प्रदेशमा कति क्षेत्रफल ओगटेको छ भन्ने कुरा आधिकारीक तथ्याङ्क भेटिदैन।

उत्पादन स्थिती

बागमती प्रदेशका १३ वटै जिल्लामा कोदोको खेती गरिन्छ। यस प्रदेशको भित्री मधेश र बेंसी क्षेत्रहरूमा धान, मकै तथा पहाडी र हिमाली क्षेत्रमा मकै, कोदो, जौ र आलु बढी उत्पादन हुने गर्दछ (पहिलो आवधिक योजना, बागमती प्रदेश २०७६-२०८०)।

पछिल्लो तथ्याङ्क आ.व. २०७८/ ७९ का अनुसार नेपालको कोदो खेती हुने कुल क्षेत्रफल २६७,०७१ हेक्टर मध्ये बागमतीको २२.३७ प्रतिशत हिस्सा रहेको छ। बागमती प्रदेश कोदो उत्पादन गर्ने क्षेत्रफलको हिसाबले नेपालको तेश्रो स्थानमा छ भने उत्पादन र उत्पादकत्वको हिसाबमा क्रमश: तेश्रो र छैठौं स्थानमा छ (कृषि तथा पशुपंक्षी बिकास मन्त्रालय २०२३)।

बिगत पाँच बर्षमा बागमती प्रदेशमा कोदोको उत्पादन तथा क्षेत्रफलको स्थिति हेर्दा आ.व. २०७४/७५ देखि २०७७/७८ सम्म सामान्य हिसाबले क्षेत्रफल र उत्पादन बढेको देखिन्छ। तर आ.व. २०७८/७९ मा बढ्ने क्रम रोकिएको देखिन्छ। यो बर्ष आ.व. २०७७/७८ को तुलनामा क्षेत्रफलमा २४९ हेक्टरले कमि आएको छ भने उत्पादनमा ३,२३९ मे.ट.ले कमि भएको देखिन्छ। यसले कोदोको उत्पादकत्वमा समेत ह्रास हुँदै आएको देखाउँछ।

बिगत पाँच बर्षको तथ्याङ्क अध्ययन गर्दा जिल्लागत हिसाबले बागमती प्रदेशमा क्षेत्रफल र उत्पादनको हिसाबले सबभन्दा बढी सिन्धुपाल्चोक जिल्ला त्यसपछि सिन्धुली, धादिङ्ग अनि रामेछाप जिल्लाले क्रमश: दोश्रो, तेश्रो र चौथो स्थान ओगटेको पाईन्छ। बिस्तृत विवरण तलको तालिकामा दिइएको छ।

तालिक १. गत बर्षहरूमा कोदोको उत्पादन स्थिति

क्र.सं.	जिल्ला	आ.व. ७४/७५		आ.व. ७५/७६		आ.व. ७६/७७		आ.व. ७७/७८		आ.व. ७८/७९	
		क्षे.फ. हे.	उत्पादन मे.ट.	क्षे.फ. हे.	उत्पादन मे.ट.	क्षे.फ. हे.	उत्पादन मे.ट.	क्षे.फ. हे.	उत्पादन मे.ट.	क्षे.फ हे.	उत्पादन मे.ट.
१	दोलखा	३,६०५	४,७९९	३,५५६	४,७५९	३,६३५	५,१३३	३,६७५	५,२२१	३,६५९	४,८५४
२	सिन्धुपाल्चोक	१६,५७०	२१,७३८	१६,६५९	२१,८५३	१६,९५२	२२,०७९	१७,१३९	२२,४५७	१७,३५०	१८,५००
३	रसुवा	८९६	९३६	८३१	८९०	८२८	८१४	८३८	८२८	८९८	१,०३२
४	रामेछाप	४,९९९	५,६८३	४,९३३	५,७०१	४,८३१	५,३९९	४,८८४	५,४९२	४,९८९	५,६९०
५	सिन्धुली	११,६५२	१२,७८८	११,८०१	१२,९५४	११,९३४	१२,१६३	१२,०६५	१२,३७१	११,७००	११,०८९
६	काभ्रे	३,५५५	४,१८४	३,५९५	४,१७६	३,४४४	३,४९०	३,४८२	३,५५०	३,५०५	४,५३०
७	भक्तपुर	११०	१३५	११२	१३९	११५	१५५	११६	१५८	११०	११७
८	ललितपुर	५६१	५७४	५६०	५७६	५७२	६४६	५७८	६५७	६००	८०४
९	काठमाण्डौ	६५६	६७२	६०८	६३८	६१३	७४२	६२०	७५४	७७०	१,३००
१०	नुवाकोट	५,१३३	६,२९६	५,१५८	६,३८२	५,२४५	६,९२६	५,३०३	७,०४४	५,११०	७,२३४
११	धादिङ्ग	६,९४०	६,४२३	६,९३३	६,४०८	६,९४०	७,१७५	७,०१७	७,२९८	६,९४०	७,४४५
१२	मकवानपुर	२,६६९	३,३३४	२,७७४	३,४६७	२,७७३	३,३०८	२,८०३	३,३६५	२,६५०	३,३४०
१३	चितवन	१,४९२	१,५२८	१,४८३	१,५२२	१,४७३	१,६४५	१,४८९	१,६७३	१,४७८	१,६९३
	जम्मा	५८,८३९	६९,०८८	५९,००३	६९,४६६	५९,३५५	६९,६७६	६०,००८	७०,८६७	५९,७५९	६७,६२८

श्रोत: कृषि तथा पशुपंक्षी बिकास मन्त्रालय, सिंहदरबार काठमाण्डौं

बागमती प्रदेश सरकारबाट गरिएका नीतिगत प्रयासहरू

बागमती प्रदेश सरकारले आफ्नो स्थापनाकालदेखि नै अन्यबालीका साथै कोदो तथा कोदोजन्यबालीको प्रबर्द्धनका लागि बिभिन्न प्रयासहरू गरेको देखिन्छ। बागमती प्रदेशको पहिलो आवधिक योजना (बि.स. २०७६-२०८०) मा “ प्रदेशको भित्री मधेश र बेंशी क्षेत्रहरूमा धान मकै र गहुँ तथा पहाडी र हिमाली क्षेत्रमा मकै कोदो जौ र आलु बढी उत्पादन हुने गर्दछ” भनेर कोदोलाई बढी उत्पादन हुने बाली मध्ये एक मानिएको छ।

यसै गरी प्रत्येक वर्ष घोषणा गरिने सरकारको नीति तथा कार्यक्रममा कोदो तथा रैथानेबालीमा बागमती प्रदेश सरकारले देहाय बमोजिमका बिभिन्न कार्यक्रम संचालन गर्ने प्रतिबद्धता जनाएको देखिन्छ।

- प्रदेशमा खेती भै रहेका रैथाने जातका बालीको पहिचान, प्रयोग, संरक्षण र प्रबर्धन गर्दै उत्पादन, उपभोग तथा बजारीकरणलाई प्रोत्साहन गर्ने नीति लिइनेछ (आ.व. ८०/८१ को नीति तथा कार्यक्रम)।
- "प्रदेशको शान, मौलिक कृषि हाम्रो पहिचान" अभियानका साथ रैथाने बाली तथा पशुपंक्षीहरूको पहिचान, संरक्षण, सम्बर्द्धन र बिस्तार गर्दै ब्यबसायीक बनाउन विशेष परियोजना लागू गरिनेछ (आ.व. ७९/८० को नीति तथा कार्यक्रम)।
- प्रमुख खाद्यान्न बालीको गुणस्तरीय उन्नत बीउ बृद्धि गर्नुका साथै स्थानीय रैथाने जातिका बीउहरूको संरक्षण तथा प्रबर्द्धन गरिने छ (आ.व. ७८/७९ को नीति तथा कार्यक्रम)।
- धान, मकै, गहुँ, कोदो र आलुको उत्पादन र उत्पादकत्व बृद्धि गर्न प्रतिफलका आधारमा कृषकहरूलाई बीउबिजन, प्राङ्गारीक मल तथा कृषि बिद्युत महसुलमा विषेश छुट एवं अनुदानको ब्यबस्था मिलाईनेछ (आ.व. ७७/७८ को नीति तथा कार्यक्रम)।

उत्पादन प्रविधि

कोदोको उत्पादन गर्ने तरीका बागमती प्रदेशमा ठाउँअनुसार फरक फरक भएको पाईन्छ। कुनै ठाउँमा ब्याडमा बेर्ना तयार गरी मकैबाली भित्र बेर्ना सार्ने गरिन्छ भने कतिपय स्थानमा खाली जमीनमा खनजोत पछि एकलबालीको रुपमा रोप्ने प्रचलन छ। केही स्थानमा भने बीउ नै छरेर छरुवा बिधिबाट उत्पादन लिने चलन छ। यहाँ सिन्धुपाल्चोक, दोलखा, मकवानपुर,सिन्धुली, धादिङ्ग लगायतका वागमती प्रदेशभित्र अपनाइने सामान्य तरीकाको बारेमा छोटकरीमा प्रस्तुत गरिएको छ।

जमीनको तयारी

सामान्यतया मकैमा घुसुवा बालीका रुपमा कोदो लगाइने स्थानमा मकैबाली भित्र र खाली जमीनमा कोदालोले माटो पल्टाएर वा ट्र्याक्टर वा हलोले जोतेर माटो खुकुलो बनाउने, झारपात हटाउने र माटो मसिनो बनाईन्छ। कोदो रोप्न माटो धेरै मिहिन भने बनाउनु पर्दैन तर छरुवा खेतीका लागि मसिनो बनाएकै राम्रो हुन्छ। कोदोको खेती गरिने ठाउँमा पानी निकासको प्रबन्ध राम्रो हुनु उपयूक्त हुन्छ।

मलखाद

प्राङ्गारीक मलका रुपमा गोठेमल वा कम्पोष्ट मल प्रयोग गर्न सकिन्छ। तर कोदोखेतीका लागि मात्र भनेर मल प्रयोग नगन्यरुपमा गरेको पाईन्छ। मकैभित्र घुसुवाबालीको रुपमा खेती गर्ने कोदो बालीमा त झन् मल प्रयोग गर्ने गरेको पाईदैन। कम्पोष्ट तथा रासायनिक मलले उत्पादन बढाउने भएता पनि माटोको उर्बराशक्तिको बिष्लेषण गरी मल प्रयोग गर्नु उपयुक्त हुन्छ। सामान्यतया कोदो खेतीका लागि ५ टन/हेक्टर का दरले गोठेमल/कम्पोष्टमल र ६०: ३०: ३० के.जी. नाईट्रोजन: फस्फोरस: पोटास प्रति हेक्टरका दरले सिफारिश गरिएको छ (बराल २०८०)।

सिंचाई तथा झारपात ब्यबस्थापन

कोदो सुख्खा सहन सक्ने र बर्षे बाली पनि भएकाले सिंचाईको खासै जरुरत पर्दैन। तर लामो खडेरी परेको तथा फूल फूल्ने अवस्था भएको भए सिंचाईको प्रबन्ध गर्नु राम्रो हुन्छ।

एकल वा मिश्रीत बालीको रुपमा कोदो खेती गर्दा शुरुमै झारपात नियन्त्रण गर्नु राम्रो हुन्छ। झारपात नियन्त्रण गर्ने सबैभन्दा उपयूक्त बिधि गोडमेल नै हो।

रोगकिरा ब्यबस्थापन

सामान्यतया किसानहरूले कोदोबालीका रोगकिरा बारे गम्भिरता अपनाएको पाईदैन। अरु बालीमा जस्तै यो बालीमा पनि रोगकिराको प्रकोप हुने गर्दछ। बेलैमा रोगकिरा पहिचान गरी उपयूक्त ब्यबस्थापन गरेको खण्डमा उत्पादन राम्रो लिन सकिन्छ। कोदोबालीका मुख्य रोगहरूमा मरुवा रोग, थोप्ले रोग, पाते फेद डढुवा रोग देखा पर्दछ भने किराहरूमा गबारो र खुम्रे मुख्य रुपमा देखा पर्दछ।

बाली कटानी, चुट्ने तथा भित्र्याउने

सामान्यतया रोपेको ४-५ महिनामा बाली भित्र्याउन तयार हुन्छ। कोदोको बालाका औंलाहरू खुम्रिएर खैरो भएपछि काट्ने बेला भएको जान्न सकिन्छ। स्थानीय हिसाबले प्राय बाला काट्ने चलन छ। बाला काटेर ४-५ दिन गुम्स्याए पछि लठ्ठीले चुटेर कोदो झारिन्छ। चुटेको कोदोलाई सफा गरेर राम्ररी सुकाई भण्डारण गर्ने हो भने 8-१0 बर्षसम्म भण्डारण गर्न सकिन्छ (Ghimire 20१9)।

कोदोको उपयोगिता

खाद्यान्नको रुपमा

प्राचीनकाल देखि नै नेपालमा कोदोलाई खाद्यान्नको रुपमा प्रयोग गरिएको पाईन्छ। यसका परम्परागत परिकारहरूमा ढिंडो, रोटी, पुवा र खोले मुख्य हुन्। आजकल कोदोबाट केक, पाउरोटी, बिस्कुट, कुकिज, नमकिन, पफ आदि बनाई खाद्य पदार्थको रुपमा उपयोग हुन थालेको छ।

पेय पदार्थको रुपमा

कोदोबाट स्थानीयस्तरमा उच्च गुणस्तरको घरेलु मदिरा पनि बनाईन्छ।

पशु आहारको रुपमा

पशुपालक कृषकका लागि पशु आहारा आपूर्ति गर्ने कुरा महत्त्वपूर्ण हुन्छ। हरियो घाँस हिउँदमा पर्याप्त उपलबध नहुने भएकाले कोदोको नल ज्यादै महत्त्वपूर्ण पशु आहारा बन्न सक्दछ। यसमा प्रोटीन, खनिज, कार्बोहाईड्रेट लगायत पशुलाई चाहिने तत्वहरू प्रशस्त पाईन्छ। जसले गाईभैंसीको स्वास्थ्य र दुध उत्पादनमा प्रभावकारी भूमिका खेल्दछ भने अन्य खशि, बोका, भेडा बाख्रालाई खुवाएर मासु उत्पादनमा बृद्धि ल्याउन सकिन्छ (पौडेल, २०८०)।

चुनौती , अवसर र सम्भावनाहरू

मुख्य चुनौतीहरू

- कोदोबालीले ढाकेको क्षेत्रफल घट्दै गएको देखिन्छ। हुन त समग्र सिजनल/अस्थायी बालीले ढाकेको क्षेत्रफल बि.सं २०६८ को कृषि गणनाको तुलनामा २०७८ को कृषि गणनामा ३ लाख ९२ हजार हेक्टर क्षेत्रफल घटेको पाईन्छ। त्यसभित्र कोदोबालीको क्षेत्रफल २०६८ मा २ लाख ९ सय हेक्टरबाट २०७८ मा १ लाख २२ हजार १ सय हेक्टर कायम भएको छ (कृषि गणना, २०७८)। यसबाट के देखिन्छ भने कोदोबाली खेती ह्रासोन्मुख छ। यसको हिस्सा बागमती प्रदेश पनि भएकाले बागमती प्रदेश सहित हामी सबैका लागि ठूलो चुनौती हो।
- अर्को मुख्य चुनौती भनेको युवा कृषक पलायन हुनु हो। बि.स. २०६८ को कृषि गणनाको तुलनामा २०७८ मा २४-३४ बर्ष उमेर समूहका मुख्य कृषक १६.१ प्रतिशतबाट घटेर १४.९ प्रतिशतमा, ३५-४४ बर्ष उमेर समूहका २६.७ प्रतिशतबाट घटेर २५.७ प्रतिशतमा र 54-45 बर्ष उमेर समूहका २५.१ प्रतिशतबाट घटेर २४.८ प्रतिशत छ (कृषि गणना, २०७८)। यो समुहका युवा कृषकहरूको अधिक हिस्सा वागमती प्रदेश पनि भएकाले ठुलो चिन्ताको बिषय भएको छ।

अवसरहरू

उपभोक्ताहरूको खानेबानीमा परिवर्तन हुँदै गएको वर्तमान सन्दर्भमा कोदो र कोदोजन्यबालीको देहाय अनुसारको केही नयाँ अवसर छ।

- हिजोआज गाउँघरमा भन्दा कोदोको खपत शहरमा बढी हुन थालेको छ। शारिरीक श्रम कम गर्ने, उच्च रक्तचाप तथा कोलेस्ट्रोलका कारण पनि शहरी जनसंख्यामा कोदोप्रति रुचि बढी देखिन्छ।
- नेपालको कोदो प्रांङ्गारीक भएकाले पनि स्वास्थ्य प्रति सचेत नागरीक एवं तारे होटेलका पाहुनाहरूले समेत कोदोको ढिंडो तथा अन्य परिकारहरू खोज्न थालेका छन्।
- कोदोबालीको अनुसन्धान गर्ने नेपाल कृषि अनुसन्धान परिषद् अन्तर्गतको पहाडीबाली अनुसन्धान कार्यक्रम, काब्रे , दोलखा वागमती प्रदेशभित्र अवस्थित छ।

सम्भावनाहरू

- कोदोको उन्नत जात प्रयोग गरी हालको उत्पादकत्व १.१8 मे.ट./हे.बाट बृद्धि गरी उत्पादन बढाउन सकिन्छ भने बाँसो तथा खाली जमीन प्रयोग गरी क्षेत्रफल बिस्तार गर्ने प्रचुर सम्भावना छ।
- वागमती प्रदेशका उच्च पहाडी जिल्लाहरू रसुवा, दोलखा सहित प्राय सबै जिल्लामा कोदोखेतीका लागि उपयूक्त हावापानी पाईनुका साथै परम्परागतरुपमा समेत खेती गरीदै आएको छ। यसले थप क्षेत्र बिस्तार तथा उत्पादन बृद्धि हुने सम्भावना देखिन्छ।

आगामी कार्यदिशा

- तीनै तहका सरकारले कोदोजन्यबालीको प्रबर्धन गर्न प्राथमिकता दिने। वागमती प्रदेशका ११९ पालिका मध्ये खासगरी चितवन जिल्लाका ६ वटा पालिका, काठमाण्डौ र ललितपुर महानगरपालिका बाहेक बाँकी सबै पालिकाले प्राथमिकता दिने।
- नेपाली सेना, नेपाल प्रहरी, सशस्त्र प्रहरी, वनरक्षकको खाद्य समाग्रीमा अनिवार्यरुपमा कम्तिमा एउटा आइटम कोदोजन्य बालीबाट उत्पादित खाद्यबस्तु समावेश गर्न संघिय सरकारले पहल गर्ने। साथै निजामती लगायत शिक्षक र सरकारी कर्मचारीहरूले समेत अनिवार्य कोदोजन्य बालीबाट उत्पादित खाद्यबस्तु समावेश गर्ने वातावरण मिलाउने।
- बिद्यालयमा बिद्यार्थीलाई खाजा खुवाउने ब्यबस्था भएका बिद्यालयहरूमा अनिवार्यरुपमा कम्तिमा एउटा आइटम कोदोजन्य बालीबाट उत्पादित खाद्यबस्तु समावेश गर्ने प्रबन्ध मिलाउने।
- कोदोजन्यबालीको पौष्टिक महत्त्व बुझाउन प्रचार प्रसार लगायतका अभियान चलाउने।
- कोदोजन्यबालीको उत्पादन प्रबर्धन तथा बजारीकरणमा संलग्न सबैलाई प्रोत्साहनका कार्यक्रम संचालन गर्ने।

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गण्डकी प्रदेशमा कोदोजन्य बालीको अवस्था

कुल प्रसाद तिवारी

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सारांश

गण्डकी प्रदेश कोदे-बालीहरूको उत्पादन र क्षेत्रफलका हिसाबले एक महत्त्वपूर्ण प्रदेश मानिन्छ। यस प्रदेशमा कुल ७८,७४८ हेक्टर क्षेत्रफलमा कोदोजन्य बालीको खेती भई ९२,७९४ मेट्रिक टन उत्पादन हुन्छ। गण्डकी प्रदेशमा कोदोजन्य बालीहरू प्रया गरेर पाँखो, असिंचित, कम मलिलो र भिरालो जमिनहरू लगाउने प्रचलन कायम रहेको छ। कोदोजन्य बालीहरूको खेती पद्धतिमा उन्नत प्रविधिहरूको खासै प्रयोग भएको पाईदैन। त्यसैले, यस बालीको खेती गर्न बढी झन्झटिलो र उत्पादकत्व पनि निकै न्यून रहेको छ। कोदोजन्य बालीहरूको परिकारमा विविधिकरण भएको पाईदैन। प्रया गरेर रोटी, ढिडो, सेल रोटी, रक्सी जस्ता परिकार मात्र बनाएर खाने प्रचलन रहेको पाईयो। गण्डकी प्रदेशमा कोदोजन्य बालीको क्षेत्र विस्तार र व्यवसायिकरणको प्रवल संभावना रहेको छ। यस प्रदेशमा प्रया गरेर कोदोजन्य बालीको खेती गरीब कृषकहरूले आफ्नो जीविकोपार्जनका लागि मात्र नै गरेको पाईयो। कोदोजन्य बालीहरूमा पाईने पौष्टिक तत्वहरूको बारेमा यस क्षेत्रका युवा तथा शिक्षित वर्गलाई त्यति जानकारी नभएको पाईयो। अब उन्नत प्रविधिहरूको प्रयोग गरी व्यवसायिकरण र क्षेत्र विस्तारमा जोड दिनु पर्ने आवश्यक छ। कोदोजन्य बाली उत्पादन गर्ने कृषकहरूलाई प्रतिफलको आधारमा सहयोग उपलब्ध गराई व्यवसायिक उत्पादनमा युवा वर्गलाई संलग्न गराउँनु पर्ने देखिन्छ। उपभोक्ताहरूको माग र चाहना अनुसार परिकार विविधिकरणमा जोड दिनु पर्ने र कोदोजन्य बालीका उत्पादनलाई प्रदेश सरकारले ब्राण्डिङ्ग गरी बिक्री वितरण गर्ने नीति निर्माणमा जोड दिन सकेमा गण्डकी प्रदेशले कोदोजन्य बालीबाट निकै फाईदा लिन सक्ने अबस्था देखिन्छ।

पृष्ठभूमि

गण्डकी प्रदेश कोदोजन्य बाली (कोदे-बाली) उत्पादनका हिसाबले एक महत्त्वपूर्ण प्रदेश मानिन्छ। यसको प्रमुख कारण भनेको यस प्रदेशका प्राय: सबै जिल्लाहरूमा कोदोजन्य बालीहरूको खेती भईरहेको र क्षेत्र विस्तारको प्रवल संभावना रहेको छ। यस प्रदेशमा कोदोजन्य बालीको क्षेत्रफल र उत्पादनका हिसाबले धान र मकैपछि तेस्रो स्थानमा रहेको छ।

गण्डकी प्रदेशमा तीन प्रकारका कोदे-बालीहरू जस्तैः कोदो (Finger millet), कागुनो (Foxtail millet) र जुनेलो (Sorghum) मात्र खेती गरेको पाईन्छ। तर पनि गण्डकी प्रदेशको तथ्यांक हेर्ने हो भने कोदो (Finger millet) र कागुनो (Foxtail millet) लाई मात्र तथ्यांकमा समावेश गरेको पाईन्छ। केही जिल्लाहरूमा जुनेलोको खेती भएको भएतापनि तथ्यांकमा समावेश गरेको पाईदैन। गण्डकी प्रदेश लगायत देशैभरि कोदोजन्य बालीलाई सांस्कृतिकरूपमा पनि 'कुअन्न' भनेर परिभाषितगरीनु र यसलाई न्यून आए भएको व्यक्तिहरूको खाना'को रुपमा चित्रण गरिएका कारणले पनि यसको उत्पादन, प्रशोधन, परिकार विविधिकरण र बजारीकरणमा जोड दिन नसकेको देखिन्छ।

हाल आएर गण्डकी प्रदेशका विभिन्न होमस्टे र होटल रेष्टुरेण्टहरूमा यहाँ ढिडो खान पाईन्छ भनेर लेखिएका बोर्डहरू टाँसिएका र ती स्थानहरूमा मानिसहरूको बाक्लै उपस्थिति देखिनुले पनि यसको महत्त्व बढ्नै गएको आभास हुन्छ। कोदोजन्य बालीमा भएको खाद्यतत्व प्रतिको जनचेतनाको कारण हिजोआज कोदोको परिकारलाई 'सुपर फुड' र 'स्मार्ट फुड' भन्न पनि थालिएको छ। साथै यसको परिकार सेवन गरेमा मानव स्वास्थ्यमा प्रत्यक्ष फाइदा हुने कुरा विभिन्न अध्ययनले देखाएका छन्।

गण्डकी प्रदेशका प्राय: सबै जिल्लाहरूमा कोदोजन्य बालीको खेती भईरहेको पाईन्छ। तर विडम्बनाको कुरो के भने कोदोजन्य बालीको खेती पहाडका सुक्खा र असिंचित क्षेत्रहरूमा मात्र गर्ने गरेको देखिन्छ र न्यून आय भएका र विशेषगरी जनजातिहरू कोदोजन्य बालीको खेतीमा संलग्न भएको पाईन्छ। ज्ञबाली (२०२१) ले पनि संसारभरका गरीब देशका लाखौ जनताको प्रमुख खाद्यान्न बालीको रुपमा कोदोजन्य बालीको खेती न्यून आय भएका मानिसहरूले गर्ने गरेको कुरा उल्लेख गरेका छन्।

गण्डकी प्रदेशमा कोदोको क्षेत्रफल र उत्पादन

गण्डकी प्रदेश कोदोजन्य बाली उत्पादनका हिसाबले एक महत्त्वपूर्ण प्रदेश मानिन्छ। किनकी यस प्रदेशका प्राय: सबै जिल्लाहरूमा कोदोजन्य बालीहरूको खेती भईरहेको कुरा तलको तालिकाले देखाउँछ।

तालिका १. गण्डकी प्रदेशमा कोदोजन्य बालीले ओगटेको क्षेत्रफल र उत्पादन

जिल्ला	कोदो (Finger Millet)		कागुनो (Foxtail Millet)		जम्मा	
	क्षेत्रफल (हे.)	उत्पादन (मे.ट)	क्षेत्रफल (हे.)	उत्पादन (मे.ट)	क्षेत्रफल (हे.)	उत्पादन (मे.ट)
तनहुँ	६३२०	५८३०			६३२०	५८३०
कास्की	१३२६३	२१८८३	३	२	१३२६६	२१८८५
पर्वत	८३५०	८३२०			८३५०	८३२०
स्याङ्गजा	१४७६६	१६२४२			१४७६६	१६२४२
म्याग्दी	२९९०	२९८०			२९९०	२९८०
वाग्लुङ्ग	१८०५०	२२८५०			१८०५०	२२८५०
मुस्ताङ्ग						
मनाङ्ग						
गोरखा	१२१८०	१४८२०			१२१८०	१४८२०
लम्जुङ्ग	७२०८	६४८०	११	८	७२१९	६८८८
नवलपुर	२६२	२८५			२८२	२८४
जम्मा	८३३८९	९९६९०	१४	१०	८३४२३	१०००९९

स्रोतः Agriculture Development Directorate, Gandaki Provincial Government 2023.

गण्डकी प्रदेशमा सालाखाला ८३,४२३ हेक्टर क्षेत्रफलमा कोदोजन्य बालीको खेती भईरहेको छ भने १०००९९ मेट्रिक टन उत्पादन हुने गरेको कृषि विकास निर्देशनालय, पोखराको तथ्यांकले देखाउँछ। गण्डकी प्रदेशका जिल्लाहरू मध्ये वाग्लुङ्गमा सबैभन्दा धेरै १८,०५० हेक्टरमा कोदोजन्य बालीको खेती हुन्छ भने २२,८५० मेट्रिक टन उत्पादन हुने कुरा तथ्यांकले देखाउँछ। गण्डकी प्रदेशका हिमालपारिका जिल्ला भनेर चिनिने मनाङ्ग र मुस्ताङ्गमा भने कोदोजन्य बाली निकै कम क्षेत्रफलमा लगाई भएकाले तथ्यांकमा समाबेश गरेको पाईदैन। गण्डकी प्रदेशमा जुनलो चाहिँ लगभग लोप नै हुने अवस्था रहेको देखिन्छ। विभिन्न जिल्लाका कृषि प्राविधिक र कृषकहरूलाई सोद्धा जुनेलो विरलै देख्न पाईने कुरा बताउँछन्। कतै कतै पाखो वारीका डिलहरूमा एक-दुई वटा बोटहरू देख्न पाईन्छ।

खेती प्रविधि

कोदोजन्य बालीलाई सुक्खा सहन सक्ने, रोगकीराको प्रकोप कम देखिने, मलजलको प्रयोग निकै कम हुने, लामो समयसम्म भण्डार गरेर राख्न सकिने भएकाले नेपाल लगायत संसारका गरीब देशका लाखौं जनताको प्रमुख खाद्यान्नकोरुपमा रहेको छ।

गण्डकी प्रदेशमा कोदोजन्य बालीको खेती गर्ने पद्धति परम्परगत् नै भएको पाईयो। कोदोजन्य बालीको खेती पद्धतिमा आधुनिकिकरण निकै कम भएको छ। धान, मकै र गहुँ जस्ता अन्नबालीहरूको खेती पद्धतिमा विभिन्न प्रकारका मेशिनहरूको प्रयोग गर्ने गरिएता पनि कोदोमा वर्षौंदेखि उही परम्परागत विधि प्रयोग हुँदै आएको छ। जातको प्रयोग, बाली लगाउने, गोड्ने, काटने र झार्ने तरीकामा कुनै आधुनिकीकरण हुन सकेको छैन। केही स्थानहरूमा कोदो झार्ने मेशिनको प्रयोग भएको पाईयो तर अन्य कामका लागि मेशिनहरूको प्रयोग नगण्यरुपमा भएको छ।

जग्गाको छनोट

गण्डकी प्रदेशमा अधिकांश कोदोजन्य बालीहरू पाँखो, असिंचित, कम मलिलो र भिरालो जमिनहरू लगाउने प्रचलन कायम रहेको छ। कोदोजन्य बाली कम मलिलो माटो, सुक्खा र अन्य बालीका लागि अनुकुल नहुने जग्गामा पनि खेती गर्न सकिन्छ भन्ने मानसिकता किसानहरूको रहेको पाईन्छ। गण्डकी प्रदेशका अधिकांस क्षेत्रहरूमा सिंचित खेतहरूमा कोदोजन्य बालीहरू लगाएको विरलै देख्न पाईन्छ। यसले के देखाउँछ भने कोदोजन्य बाली कृषकहरूको प्रथामिकता परेको छैन भन्ने देखाउँछ।

कोदोजन्य बाली मध्येको जुनेलो बाली त अझ धेरै जसो कृषकहरूले वारीको ढिल र कान्लामा लगाउने प्रचलन रहेको कुरा थाह हुन आयो। गह्रामा मकै वा घैया धान वा अन्य बाली लगाउने र डिलमा जुनेलो लगाउने चलनचल्ती रहेको थियो।

जातको प्रयोग

कोदोहरू बिसौँ वर्षदेखि खेती गरीदै आएका जातहरूकै नै प्रयोग भईरहेको अवस्था छ। तनहुँका कृषक डोलराज गुरुङ्गका अनुसार भिमाद ९ भानुमतीमा कृषकहरूले कुकुर काने, पहेंले, मुडके, चम्प्रे, गोरखाली, डल्ले र डाँडे जातका कोदो लगाउने कुरा बताउनु भयो। त्यस्तै वाग्लुङ्ग जैमिनी न.पा १, शेरा अम्टारीका त्रिविक्रम आचार्यका अनुसार झाते, भच्चुवा र मुङ्गसिरे जातका कोदो लगाउने कुरा बताउनु भयो। धम्पुस, कास्कीका भानु भण्डारीका अनुसार तहाँ कृषकहरूले डल्ले, घ्याम्पे जातका कोदो लगाउने कुरा बताउनु भयो। लम्जुङ्ग, क्व्होलासोँथर, घाम्राङ्गका गम बहादुर गुरुङ्गका अनुसार त्यस क्षेत्रमा मुठ्ठी कोदो, दूधे कोदो, नङ्ग्रे कोदो र कालो कोदो कृषकहरूले लगाउँदा रहेछन्।

कृषकहरूका कुराबाट के बुझिन्छ भने उनीहरूले लगाउने कोदोलाई आफ्नै तरीकाले नामाकरण गरेका छन। २०-२५ वर्ष पहिला ल्याईएको उन्नत जातहरूलाई अहिले स्थानीयकरण, जातीयकरण गरेको वा भएको पाईयो। नेपाल कृषि अनुसन्धान परिषदले सिफारिस गरेका जातहरूको अस्तित्व नै नभएको देखियो। गण्डकी प्रदेशमा कोदोको तुलनामा कागुनो र जुनेलोको खेती निकै कम रहेको पाईयो। यो कुरा माथिको तथ्यांकले पनि देखाउँछ। कागुनोको जातको सन्दर्भमा कृषकहरूले उनीहरूले लगाउने कागुनोको जात नै थाहा नभएको पाईयो।

तथापि रीता गुरुङ्ग (२०१६) ले कास्कीको घनपोखरामा बरियो, रातो, कालो, सेतो गरी ४ प्रकारको कागुनो खेती कृषकहरूले गर्ने कुरा उहाँको लेखमा उल्लेख गर्नु भएको छ।

फोटो १. बारियो कागुनो (माथि देब्रे) कालो कागुनो (माथि बीचमा) सेटो कागुनो (दाहिने र रातो कागुनो (फेदमा)। यो गोरखा पत्रमा भेटिएको कागुनोको चार वटा जातहरू। चित्रहरू रीता गुरुङ्‌/ लिवर्ड

बाली लगाउने र भित्र्याउने

कृषकहरूको भनाई अनुसार कोदो लगाउने गह्रा स-सानो र अग्लो भएकाले हाल बजारमा उपलब्ध मेशिन प्रयोग हुने संभावना छैन। त्यसैले कोदोको बेर्ना सार्दा कोदालोले खनेर चप्परी पल्टाएर त्यसमाथि रोप्ने प्रचलन रहेको पाईयो। जुन तरीका एकदमै कष्टप्रद र खर्चिलो पनि छ। आजका युवाहरू यसरी कोदो लगाउने पक्षमा देखिदैनन्।

कागुनो लगाउँदा बारीलाई राराम्रोसँग जोतेर माटोलाई बुर्बराउँदो बनाएर अनि कागुनो छर्ने र हल्का तरीकाले जोत्ने प्रचलन रहेको छ। कोदोको तुलनामा कागुनो लागउन अलि सजिलो हुने कृषकहरूले बताए। कृषकहरूले बर्षौंदेखिको गर्दै आएको तरीकामा कुनै आधुनिकीकरण वा परिवर्तन हुन नसकेको देखिन्छ। युवाहरू गाउँमा नहुनु र मेशिनको प्रयोग नहुनु पनि कोदोजन्य बालीको क्षेत्रफल घट्नु एउटा प्रमुख कारण हो भन्ने कुरा कृषकहरूको भनाईबाट थाहा हुन आउँछ।

कोदोजन्य बालीको जातहरू लगाउने समय पनि फरक रहेको पाईयो। लम्जुङ्ग, क्व्होलासोँथर, घाम्राङ्गका गम बहादुर गुरुङ्गका अनुसार मुठ्ठी कोदोलाई असार मसान्तमा लगाउने मंसिरमा टिप्ने प्रचलन रहेछ भने नङ्ग्रे कोदो चाहिं जेष्ठमा वीउ छर्ने, असारको अन्तिममा सार्ने र कार्तिकमा काट्ने प्रचलन रहेछ। दूधे कोदोलाई बैशाखमा वीउ छर्ने र भदौ-असोजमा काट्ने गरिन्छ।

कागुनोको चाहि माघ-फागुणमा वीउ छर्ने, चैत्र-बैशाखमा गोडने र जेष्ठ-असारमा बाली काट्ने चलन छ। कागुनो प्राय: असार महिनामा काट्नु पर्ने भएकाले आकाशको पानीले निकै नोक्सान पुर्याउँछ र सुकाउन पनि गाह्रो हुने कुरा कृषकहरू भनाई रहेको पाईयो। जुनेलोको हकमा फाल्गुण-चैत्रमा लगाउने र कार्तिक-मंसिरमा बाली काट्ने गर्दछन्।

कोदोजन्य बाली लगाउन गाह्रो र गोडमेल गर्न अलि बढी खर्चिलो हुने कुरा कृषकहरूमार्फत जानकारी प्राप्त भयो। कोदोलाई बाँदरले नोक्सान नगरेता पनि कागुनोलाई चराले निकै नोक्सान गर्ने र जुनेलोलाई बाँदरले नोक्सान गर्ने कुरा कृषकहरूले बताउनु भयो।

गण्डकी प्रदेशमा कोदोजन्य बाली झर्न मेशिन वा थ्रेसरको प्रयोग गरेको पाईदैन। एक मुरी वा ५० केजी कोदो झार्नलाई एक जना ज्यामी वा ८ सयदेखि १ हजार रुपैया खर्च हुन्छ। एक मुरी धान झार्न भन्दा १ मुरी कोदो झार्न ३ गुणा महङ्गो हुने कुरा कृषकहरूको छलफलबाट थाहा हुन आयो।

कोदोजन्य बालीमा कृषकहरूले प्रया रासायनिक मल, शूक्ष्म खाद्यतत्व र विषादी प्रयोग गर्दैनन्। बाली लगाउनेदेखि बाली झार्नेसम्मका कार्यमा नगन्यरुपमा मेशिनको प्रयोग भएको पाईन्छ। उत्पादन सरदर ९ क्विण्टल प्रति हेक्टर भएको पाईन्छ। त्यसैले, कोदोजन्य बाली लगाउँदा आम्दानी भन्दा खर्च बढी लाग्ने कुरा कास्की, घ्रम्राङ्गका कृषक गम बहादुर बताउनु हुन्छ। हिजोआज शहरका मात्रै हैन गाउँघरका कृषकहरू कोदो रक्सी बनाउन पनि भारतीय कोदो प्रयोग गर्न थालेको कुरा गम गुरुङ्ग बताउनु हुन्छ।

फोटो ३. कि कुमारी गुरुङ्ग कागुनोको लामो बाला लिएर उभिनु भएको छ। फोटो श्रीराम सुबेदी लिवर्ड

कोदोको परिकारहरू

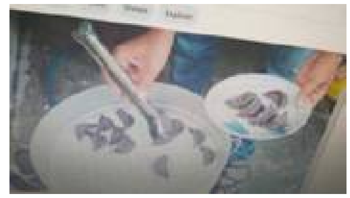
गण्डकी प्रदेशमा कोदोजन्य उत्पादनबाट त्यति धेरै परिकार विविधिकरण हुन सकेको देखिंदैन। कृषकहरूले आफ्नो घरमा ढिंडो, खोले, रोटी, जाँड र रक्सी बनाएर आफू खाने वा पाउनाहरूलाई खुवाउने चलन रहेको छ। ढिंडो, खोले र रोटी प्राय: गरेर जाडो मौसममा तथा रक्सी र जाँडचाहिँ अरु महिनामा पनि खाने परम्परा रहेको छ।

कागुनो चाहि कृषकहरूले आफ्नो गाउँघरमा भात र खीर बनाएर खाने चलन रहेछ। कागुनोको भातलाई चामलको भातको विकल्पको रुपमा पनि कृषकहरूले प्रयोग गर्ने गरेको थाह हुन आयो। कागुनो लगाउने ठाउँमा खीर निकै प्रख्यात रहेको छ। आचार्य (२०७९) का अनुसार जुनेलो हिउँदको खाजा र धार्मिक कार्यमा प्रसाद बनाउन पनि प्रयोग गरिन्छ। यो सुगर भएका मान्छेहरूले खोजी खोजी खाने प्रचलन रहेको पाईयो। गण्डकी प्रदेशका गाउँघरमा अधिकांश (८० प्रतिशत) भन्दा धेरै कोदो रक्सी पार्न वा घरेलु मदिरा उत्पादन गर्नका लागि प्रयोग हुने कुरा कास्की, घाम्राङ्गका गम बहदुर गुरुङ्गले बताउनु भयो। युवावर्गले गहुँको परिकार त्यति मन नपराउने भएकाले रोटी, ढिंडो, पीठो बनाएर खाने चलन हराउँदै गएको अवस्था देखिन्छ।

प्रदेशका शहरी क्षेत्रका होटल र गाउँका घरबासहरूमा चाहिँ आन्तरिक र केही वाह्य पर्यटकका लागि कोदोका परिकार आकर्षक खाद्य परिकारको रुपमा प्रस्तुत भएको देखिन्छ। होटेलमा आउने पाहुनाले चामल भन्दा गाउँमा उत्पादित प्राङ्गारिक कोदोको परिकार खोज्ने र मूल्य पनि बढी तिर्ने गरेका कुरा म्याग्दी जिल्ला बेनी बजारकी होटल यतिकी सञ्चालिका विमला गौचनले जानकारी दिनु भयो। बागलुङको काठेखोला गाउँपालिका–३ धम्जा ओखलेस्थित सामुदायिक घरबास, बेलढुङ्गा सामुदायिक घरबास, जैमिनीको मारुनी घरबास र भकुण्डेको अतिथि सत्कार घरबासमा कोदोको सेल रोटी बनाउने कुरा उक्त घरबासका सञ्चालक इन्द्रकुमारी थापाले बताउनुभयो।

गण्डकी प्रदेशका वाग्लुङ्ग, तनहुँ, स्याङ्गजा, गोरखा, कास्की र म्याग्दीका घरबासहरूमा पाहुनाहरूलाई बेलुका ढिडो, खोले र रक्सी तथा विहान पानी रोटी वा सेल रोटी खुवाउने चलन रहेको छ। तर ती घरबासहरूमा कोदोजन्य बालीका अरु परिकारहरू बनाउने गरेको पाईएन। घरबास संचालकहरूले कोदोजन्य बालीका अन्य परिकारका वारे जानकरी भए पनि कतैबाट तालिम पनि नपाएको थाह हुन आयो। यसबारे तालिम दिन सके उनीहरूले पनि विभिन्न परिकार बनाउने कुरा बताए।

पोखराका केही होटल वा रेष्टुरेण्टहरूमा कोदोजन्य बालीको परिकारहरू बनाउन थालिएको पाईयो । जस्तैः उदाहरणको लागि पोखरा लेकसाईडमा रहेको महादव अर्गानिक बेकरी र कफी सप (Mahadab Bakery and Coffee Shop, Pokhara) ले कोदो र फापरको पिठो मिसाएर ब्राउन पाउरोटी, मुफिन, नमकिन, हलुवा, मालपुवा, केक, सेलरोटी बनाएर बिक्री वितरण गर्ने गरेको पाईयो । जाडोको समयमा विशेषगरी मंसिरदेखि फागुणसम्म नियामितरुपमा ब्राउन ब्रेड, मुफिन केक र सेलरोटी बनाउने गर्दछन् । अरु परिकारहरू चाहिँ मागको आधारमा बनाउने कुरा बेकरीका प्रोपाइटर माधब केसीले बताउनु भयो। उहाँलाई शुरुमा लि-वर्ड नामक गैर सरकारी संस्थाले सहयोग गरेको कुरा केसीले जानकारी दिनु भयो। तर पोखरामा अरु त्यस्ता कोदोको परिकार बनाउने होटल/रेष्टुरेण्ट नभएको थहा हुन आयो ।



तनहुँ जिल्लाको दमौली बजारमा बाबुराम सापकोटाले ***गाउँले कोदोको मःम*** नामक रेष्टुरेण्ट खोलेर २०७९ साल भदौतिरबाट कोदोको मःम र परौठा बनाउनु शुरु गर्नु भएको थियो । सापकोटाको भनाई अनुसार मःम र परौठा उपभोक्ताले निकै मन पराउनु भयो । उहाँको अनुसार कोदोको परिकार बनाउन निकै गाह्रो हुने किनकी कोदोको पिठो स्टिकी नहुने भएकाले मःम बनाउँदा खाली फुट्ने र एक दिनमा १०-१५ प्लेट भन्दा बढी बनाउन नसकिने र अलि बढी खर्चिलो हुने कुरा उल्लेख गर्नु भयो । तर प्रति प्लेट रु २००। –मा बेच्ने हो भने नाफा नै हुने कुरा बताउनु भयो । हाल उहाँको घरयासी समस्या भएकाले पसल बन्द गर्नु भएको छ ।

सन २०१८ डिसेम्बर २२ मा कास्कीको अन्नपूर्ण गाउँपालिकाको भदौरे (पञ्चासे) मा युवा क्लब र आमा समूहले तमु ल्होसार तथा कोदो महोत्सव संचालन गरी कोदोका २२ परिकार तयार गरी प्रदर्शनमा राखिएको थियो । पाँच दिनसम्म संचालन भएको महोत्सवमा कोदोको ढिँडो, सेल रोटी, डोनट, स्याफली, मःम, जेरी, खोले, केक, शंखे मिठाई, दाम्ले मिठाई, परौठा, पकौडा, गिलो रोटी, बनाना पेन केक, एप्पल पेनकेक, सुक्खा रोटी, तोङ्बा, नमकिन, पुरी लगायत परिकार प्रदर्शनीमा राखिएका थिए (कृषि गुरु, २०१८) ।

अन्नपूर्ण गाउँपालिका क्षेत्र पदयात्रा पर्यटनको उत्कृष्ट गन्तव्य मानिन्छ । अन्नपूर्ण क्षेत्रमा कोदोको उत्पादनमा अभिप्रेरित गर्ने कार्यक्रमका साथै यहाँका प्रत्येक होटेलका मेनुमा कोदोको परिकार राख्नुपर्ने अनिवार्य व्यवस्था गरिएको उक्त पालिकाका प्रमुख प्रशासकिय अधिकृतले जानकारी दिनुभयो । त्यसैले, गण्डकी प्रदेशमा कोदोजन्य बालीको परिकार विविधकरण कार्यले संस्थागत रुप लिएको अवस्था छैन । यसो कहिले काहीँ बनाएर देखाउने र खुवाउनेमा मात्र सिमित रहेको अवस्था छ । तालिम, प्रचार प्रसार र नियमितताको खाँचो देखिन्छ।

गण्डकी प्रदेशमा कोदोजन्य बालीको अवस्थाको विश्लेषण

सवल पक्ष

- गण्डकी प्रदेशका अधिकांश कोदो लगाउने दुर्गम र पहाडी क्षेत्रमा यातायात र बिजुलीको सुविधा पुगेको छ । कोदो लगाउने कार्य गर्न, उत्पादन सामग्री तथा उत्पादित कोदो ढुवानी गर्न निकै सहज छ ।
- कोदोजन्य बालीको व्यवसायिकरणका लागि उपयुक्त जग्गाहरू प्रशस्त मात्रामा उपलब्ध छन् र व्यवसायिकरण र क्षेत्र विस्तारको प्रवल संभावना छ ।
- कोदोजन्य बालीका स्थानीय जातहरू अझै पनि कृषक तथा जैविक विविधता संरक्षण समितिहरू तनहुँको, पुर्कोट र नवलपरासीको कावासोती, मराम्चे, घन पोखरा, राईनास र साथै राष्ट्रिय जोन बैक खुमलटारमा पनि संरक्षण गरेर राखेकाले जैविक विविधता अझै कायम रहेको छ ।
- लि-वर्ड नामक गैर सरकारी संस्थाले कोदोजन्य बालीका विस्तृत तथ्यांक, जातीय विवरण, उपयुक्त प्रविधि र संभावित परिकार सम्बन्धी जानकारीहरू संरक्षण गरी राखेको र ती तथ्यांक र विवरणहरूलाई उपयोग गरी सरकारीस्तरबाट नयाँ कार्यक्रम र आयोजनाहरू संचालन गर्न सकिने अवस्था रहेको देखिन्छ ।

कमजोरी

- गण्डकी प्रदेशमा कोदोजन्य बाली न्यून आय भएका कृषकहरूले जीविकोपार्जनमा आधारित उत्पादन प्रयासहरूमा मात्र संचालन भएको अवस्था। व्यवसायिकरण लक्षित वा आम्दानी बढाउने प्रणाली वा विधिमा आधारित प्रयासहरू तथा कार्यक्रमहरू संचालन नभएको अवस्था।
- प्रदेशमा विभिन्न जिल्लाका कोदोजन्य उत्पादनलाई संकलन, प्रशोधन, परिकार विविधिकरण, ब्राण्डिङ्ग र बजारीकरण जस्ता कार्यहरूसँग नजोडिएको। उदाहरणको लागि कोदोजन्य उत्पादनमा संलग्न कृषक, कृषक समूह र कृषि सहकारी कोदोजन्य उत्पादनका प्रशोधनकर्ता, परिकार विविधिकरणमा संलग्न होम स्टे र होटल रेष्टुरण्ट संचालक र कोदोजन्य उत्पादन विक्री वितरण गर्ने कोशेली घर, मिनीमार्ट संचालक, विक्री वितरणमा संलग्न सहकारीहरूका वीचमा सोझै सम्पर्क र समन्वय नभएको अबस्था।
- प्रदेश सरकार र स्थानीय सरकारको कोदोजन्य बाली लगायत अन्य रैथाने बालीहरूको जातीय संरक्षण, व्यवसायिक उत्पादन प्रवर्द्धन, प्रशोधन, परिकार विविधिकरण र बजारीकरणलगायतका कार्यहरूका लागि निकै कम बजेट विनियोजन गरेको अवस्था रहेको। स्थानीय तहहरूले त खाली संघीय बजेटमा मात्रै भर पर्ने गरेको।
- धान मकै लगायतका अन्य बालीहरूमा जस्तो कोदोजन्य बालीको उत्पादन प्रक्रियामा मेशिनको प्रयोग हुनु नसक्नुले उत्पादन लागत बढी भएकाले •कृषकहरूको कोदोजन्य बाली प्रति आकर्षण कम हुँदै गएको।
- कृषकहरूले कोदो लगाउँदा लामो सयमदेखि आफ्नै घरमा राखेको बीउ नै प्रयोग गर्ने गरेकाले उत्पादकत्व निकै न्यून हुनु पनि एउटा कमजोरीको रुपमा देखा परेको छ।

अवसर

- कोदोजन्य बालीहरू विशेषगरी कोदो र कागुनोलाई बाँदर त्यति धेरै नोक्सान नगर्ने भएकाले गण्डकी प्रदेशका बाँदरको समस्या बढी भएका स्थानहरूमा व्यवसायिक उत्पादन गर्न सकिने राम्रो अवसर रहेको छ।
- गण्डकी प्रदेशमा बढ्दै गएको २०% असिंचित बाँसो जमिनलाई स्थानीय तहले न्यून आय भएका व्यक्तिहरूलाई समूहमा आबद्ध गरी व्यवसायिकरुपमा कोदोजन्य बालीको उत्पादन प्रवर्द्धन सक्ने राम्रो अवसर रहेको छ।
- कोदोजन्य बालीमा भएको पौष्टिक महत्त्व र स्वास्थ्यवर्द्धकताको प्रसार प्रचार गरी गण्डकी प्रदेशका अन्तरिक पर्यटकीय स्थलहरू जस्तैः पोखरा, घलेगाउँ, भुझुङ्ग, साराङ्ककोट, सिक्लेस जस्ता ठाउँहरूमा परिकार विविधिकरण गरी होमस्टे र स्थानीय होटल रेष्टुरेण्टमार्फत कोदोजन्य परिकारको व्यापार गर्न सक्ने राम्रो संभावना छ।
- गण्डकी प्रदेशमा कोदोजन्य बालीलाई रासायनिक मल प्रयोग नगर्ने प्रचलन रहेकाले प्राङ्गारिक उत्पादनका रुपमा ब्राण्डिङ्ग गरी विक्री वितरण गर्ने सक्ने निकै ठूलो संभावना रहेको छ।

चुनौतीहरू

- आन्तरिक बसाई सराईले गर्दा ग्रामीण क्षेत्रका कोदो लगाउने गाउँ खाली हुँदै गएको।
- कोदो लगाउने सयममा गाउँघरमा आवश्यक जनशक्तिको अभाव हुने गएकाले कृषकहरूले विस्तारै कोदो लगाउन छोडने अवस्था रहेको।
- अन्य बालीहरूको तुलनामा कोदो खेती गर्न अलि बढी झन्झटिलो र कष्टप्रद हुनु।
- कोदो रोप्न, गोड्न, काँट्न र झार्न मेशिन प्रयोगमा नआएकाले उत्पादन लागत बढी हुनु,
- विगत २० औ वर्षहरूदेखि खेती गरीदै आईएका कोदोका स्थानीयजातहरू विस्तारै लोप हुँदै जानु।
- गण्डकी प्रदेशका प्रमुख बजारमा स्थानीय कोदो भन्दा वाहिरबाट आयात भएको कोदो सस्तो मूल्यमा प्राप्त हुनु र उपभोक्ताले पनि गुणस्तरीय भन्दा सस्तो कोदो खरिद गर्ने ईच्छा देखाउनु।
- उच्च उत्पादकत्व भएका कोदोको नयाँ जातहरू र अन्य खेती प्रविधि सम्बन्धी अध्ययन गर्ने अनुसन्धान केन्द्र गण्डकी प्रदेशमा नहुनु।
- स्थानीय कोदोजन्य बाली संरक्षण र व्यवसायिक उत्पादन, परिकार विविधिकरण र बजारीकरणमा सरकारी तथा गैर सरकारी क्षेत्रबाट प्रभावकारीरुपमा कार्यहरू संचालन नहुनु।
- गाउँघरमा कोदोको विभिन्न परिकार बनाएर त्यसको प्रचार प्रसार गर्नु भन्दा पनि रक्सी मात्र बनाउने र विक्री विरतण गर्ने प्रचलन हावी हुनु।
- गण्डकी प्रदेशमा कोदो बालीले ओगटेको क्षेत्रफल र उत्पादन हरेक वर्ष घटदै जानु एउटा प्रमुख चुनौती हो।
- जलवायु परिवर्तनका कारणले कोदोजन्य बालको उत्पादनमा निकै ह्रास आउन थालेको पनि अर्को चुनौतीको रुपमा देखिएको छ।

सुधारका लागि सुझाबहरू

- उत्पादनमा जोडः हाल गण्डकी प्रदेशमा कोदोजन्य बालीहरूको उत्पादन घटिरहेको सन्दर्भमा प्रदेश तथा स्थानीय सरकारहरूले कोदोजन्य बालीहरू उत्पादन हुने क्षेत्रहरूमा कोदोजन्यबालीमा युवा लक्षित बिशेष आयोजनाहरू संचालन गर्नु पर्ने देखिन्छ। उक्त आयोजनामा उन्नत बीउ, उन्नत खेती प्रविधि, आधुनिक मेशिनेरी प्रयोगमा जोड, प्रतिफलको आधारमा अनुदानको व्यवस्था र न्यूनतम समर्थन मूल्य तोक्न सकेमा गाउँ छोडेका र बैदेशिक रोजगारीबाट फर्केका युवाहरूलाई आर्कषण गर्न सकिन्छ।
- कोदोजन्य बालीको पौष्टिक महत्त्ववारे प्रचार प्रसारः कोदोजन्य बालीको पौष्टिक महत्त्व र यसको सेवनबाट मानिसलाई प्राप्त हुने फाईदाका बारेमा शिक्षित, युवावर्ग र अन्य आम जनमानसलाई त्यति जानकारी छैन। त्यसैले, प्रदेश सरकार र स्थानीय तहमा कार्यरत कृषि प्राविधिकहरूले तथा जनप्रतिनिधिहरूले यसको स्वास्थ्यवर्द्धक महत्त्ववारे आमसंचारका माध्यमबाट (सामाजिक सञ्जाल, पत्रपत्रिका, रेडियो टेलिभिजन, होर्डिङ्ग बोर्ड) जानकारी दिने, प्रचार प्रसार गर्ने र बुझाउने कार्य गरी ती बालीहरूको उपभोग बढाउन बिशेष पहल हुन आवश्यक छ।
- गैर सरकारी संस्थासँग समन्वयः गण्डकी प्रदेशमा कोदोजन्य बालीमा राम्रो दखल भएको गैर सरकारी संस्था लि-वर्ड र जैविक विविधता संरक्षण समितिहरूसँग सहकार्य गरी कोदोजन्य बालीहरूको जातीय पहिचान, रैथाने तथा जंगली प्रजातिहरूको पहिचान र संरक्षण तथा लोपोन्मुख रैथाने जातहरूको संरक्षण र दर्ता गर्ने कार्यहरू यथाशिघ्र गर्नु पर्ने र कोदोजन्य बालीको पोषण र व्यवसायिक प्रवर्द्धनका कार्यक्रम संचालन गर्नु पर्ने देखिन्छ।
- परिकार विविधिकरण तथा उपभोगः गण्डकी प्रदेशमा हालसम्म कोदोजन्य बालीहरूको परिकार विविधिकरणमा केही शुरुआत भएतापनि प्रभावकारी काम हुन नसक्दा कोदोजन्यबालीका खाद्य परिकारप्रति युवा, शिक्षित र धनी वर्गका मानिसहरूको त्यति आकर्षण देखिदैन। गण्डकी प्रदेशका आन्तरिक र बाह्य पर्यटक बढी आवतजावत गर्ने स्थानका रेष्टुरेण्ट, होटल, घरवास /होमस्टे संचालकहरूलाई कोदोजन्य बालीका विभिन्न परिकार बनाउने विशेष तालिम र औजार/उपकरण उपलब्ध गराउने कार्यक्रमहरू संचालन गरी युवा र शिक्षित वर्गले मन पराउने स्वाद तथा आकारमा कोदोजन्य बालीका परिकारहरू बनाई उपभोग बढाउन सहयोगी कार्यक्रम संचालन गर्नु पर्ने आवश्कयता छ।
- कोदोजन्य उत्पादनको ब्रान्डिङः कोदोजन्य बालीबाट बन्ने रक्सी ब्राण्डिङ्ग गर्ने र पिठोलाई गुणस्तर परीक्षण र गण्डकी प्रदेशका ग्रामीण क्षेत्रको प्राङ्गारिक कोदोजन्य उत्पादनको रुपमा संकेत समावेश गरी पोखरा, दमौली, स्याङ्गजा, बेशीशहर जस्तै आन्तरिक बाह्य पर्यटन हिडडुल गर्ने क्षेत्रका बजारहरूमा स्थानीय कृषि उपज विक्री स्टल र सुपरमार्केट मार्फत् विक्री वितरण गरेमा ती उत्पादनको प्रचार र उपभोगमा बृद्धि आउने सक्ने भएकाले त्यस्ता कार्यमा गण्डकी प्रदेश सरकारले बिशेष जोड दिनु आवश्यक छ।
- गण्डकी प्रदेशका अन्तरिक पर्यटक बढी आबतजावत गर्ने राजमार्ग वरिपरि रहेका विभिन्नहोटल तथा रिसोर्टहरूमा स्थानीय वा रैथाने खानाको रुपमा कोदोको ढिंडो, रोटी, अर्गानिक ब्रेड र अन्य परिकारहरूले यात्रु तथा पर्यटकलाई स्वागत गर्न सकेमा उपभोक्ताहरू सन्तुष्ट हुने, पर्यटन व्यापार फस्टाउने, कृषकको आम्दानी वृद्धि हुने तथा रोजगारीको अवसर पनि सृजना हुने देखिन्छ। स्थानीय सरकारहरूले यसमा विशेष ध्यान दिनु पर्ने देखिन्छ।
- गण्डकी प्रदेश वा स्थानीय सरकारले आफ्नै बजेटबाट कोदोजन्य बालीको पकेट, ब्लक, जोन स्थापना गरी संचालन गरेमा उत्पादन र उपभोग दुबै बढ्न सक्ने देखिन्छ।

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Ambition of Finger Millet Promotion: Perspectives from Lumbini Province

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Abstract

Out of millet crops, finger millet is an important food crop with respect to area and production in Lumbini province. Despite of its high nutritive and economic value, the crop was neglected. The area and production of finger millet was almost stagnant over last five years. Provincial government attempted to promote the finger millet in collaboration with federal as well as local governments. Indigenous crop promotion and marketing program, finger millet smart agriculture village program, indigenous crop processing program, seed production, storage and marketing program, and farmers' capacity building programs for finger millet were foremost programs launched in the province. Roti and dhindo were the common food recipes from finger millet chiefly consumed in the province. Special finger millet promotional program is further obligatory to make the province self-reliant in finger millet.

Keywords: Finger millet, indigenous, local variety, Lumbini province, seed production

Introduction

Finger millet (*Elusine coracona* L.) is an indigenous crop and has been grown since ancient time in Nepal. Different assumptions are appeared about the history of finger millet in Nepal. Shobana et al (2013) ascertained that it had been cultivated since 2300 BC in India and later dispersed in the subcontinent. Since then it was cultivated in Nepal. Finger millet is called as "*Kodo*" in Nepali language and different assertions are there about the name *Kodo*. One of the close assertion argued by Blench (2016) is that the word *'Kodo*' seems to have been borrowed from Chepang '*kədəw*' a Tibeto-Burman language and used widely. In Nepal, it has been cultivated between 96 to 2300 m above mean sea level (Luitel et al 2020) in terai, hill and mountain regions however, mostly in mid-hill terraces. Finger millet is an important crop specifically for the smallholders in rural Nepal (Sherchan 1989) because it is resilient to diverse agro-climatic and soil adversities having wide geographical and ecological adaptability as well as high nutritional value.

Previously, finger millet was staple food in mid-hills and mountains for those who had to do hard work. Later, it was neglected although it was important food crop in rural areas. Neither farmers picked it as profitable crop nor did extension worker put it on priority crop for promotion. It was also neglected for research and development (Upadhyaya 2007). Production of crop having higher nutritive value is important to combat with food and nutrition security in the context of climate change (Dhami et al 2018). In such adverse situation of climate change, finger millet is a nature gifted crop of millets group and has high significance. It can play a vital role in food and nutrition security of rural marginalized farming communities because it is the rich source of micro-nutrients such as magnesium, iron, calcium, phosphorus (Kandel et al 2019). Moreover, it has average protein contents of 9.8%, crude fiber contents ranges from 3.2-4.7%, calcium contents 0.24%, phytic acid contents 0.50-0.70% and oxalate contents 21-29 mg/100 gram dry weight (Ravindran 1991). Equally, it is important crop for cattle as its straw and byproduct is used as feed. Consequently, Lumbini province government has put it as priority crop and carried out different promotional activities because of its diverse benefits.

Finger millet in Lumbini province

Nonetheless, millets group consists of many crop species, finger millet (*Elusine coracana* L.) is the main crop in terms of area and production in Lumbini province. Farmers grow other millet crops like foxtail millet (*Setaria italic*), proso millet (*Panicum miliaceum*), sorghum millet (*Sorghum bicolor*), and amaranth millet (*Amaranthus* sp.) sporadically in confined area of the region. Finger millet is fourth important food crop and occupied almost 1.92 percent of total cultivated area. It has been grown in almost 10373 hectares of land and harvested approximately 13500 metric tons annually (**Figure 1**). The productivity of finger millet was 1.1 metric tons^{-1}hectare in 2018/19 that grew slightly to 1.3 metric tons^{-1}hectare in 2022/23. The provincial productivity of finger millet was slightly higher than national average (1.27 metric tons^{-1}hectare). The area, production and productivity of finger millet was slightly in increasing trend during last five year of period. The cropped area was about 9977 hectares in 2018/19 and increased to 10373 in 2022/23. During five years period, the area was increased only by 3.96 percent. Similarly, the production and productivity were increased by 24.14 and 18.18% respectively.

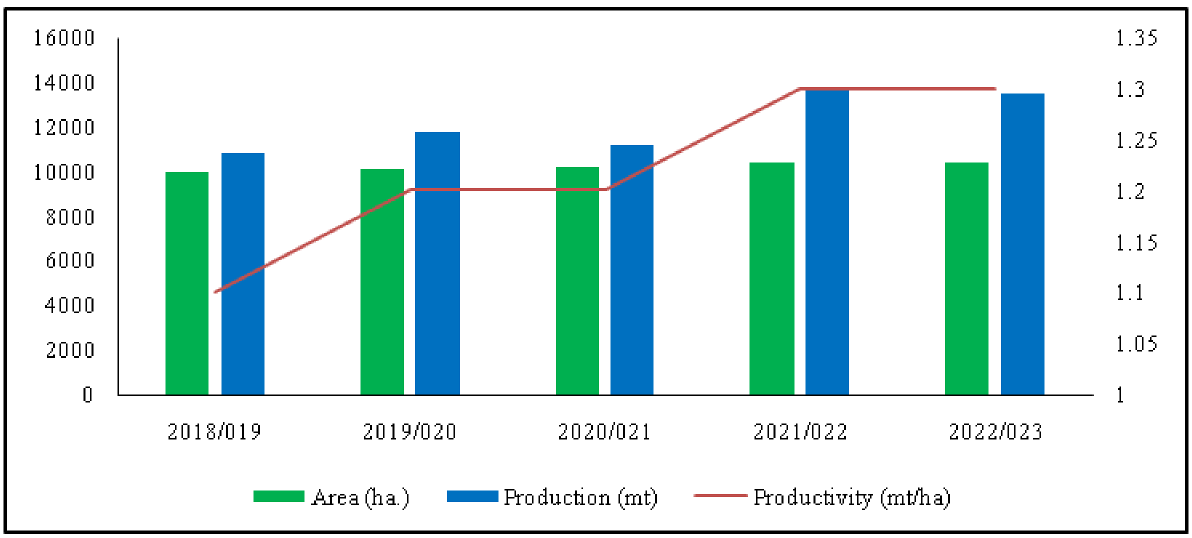

Figure 1. Area, production and productivity trend of finger millet in Lumbini province
Source: Annual progress and statistical book, 2022/023. DoAD, Lumbini Province

In Lumbini province, mid hill districts are the major millet growing districts and almost 92 percent millet is produced there. Gulmi, Palpa, Pyuthan and Rolpa were the major millet growing districts with cultivated area of 2921, 2680, 2195, and 1235 hectares and the annual production was 3826, 3561, 2929, and 1535 metric tons respectively in 2022/023 (**Table 1**). Similarly, in Rukum East, Arghakhanchi, Nawalparasi (Barghat Susta West), Rupandehi and Dang districts the finger millet was grown in 576 hectares, 505 hectares, 208 hectares, 38 hectares and 15 hectares respectively. Out of 12 districts Banke, Bardia and Kapilvastu districts were finger millet free districts in the province. Highest productivity of finger millet was observed in Dang district (1.4 metric tons/hectares) and lowest was in Nawalparasi district (1.04 metric tons/hectares).

Table 1. Area, production and productivity of finger millet in different districts of Lumbini province

District	FY2020/21			FY 2021/22			FY 2022/23		
	Area (Ha.)	Production (Mt.)	Productivity (Mt./ha.)	Area (Ha.)	Production (Mt.)	Productivity (Mt./ha.)	Area (Ha.)	Production (Mt.)	Productivity (Mt./ha.)
Nawalparasi	228	238	1.04	228	238	1.04	208	217	1.04
Rupandehi	46	53	1.15	46	53	1.15	38	44	1.16
Kapilvastu	0	0		0	0		0	0	
Palpa	2684	3162	1.18	2684	3762	1.40	2680	3561	1.33
Gulmi	2927	3317	1.13	2927	3817	1.30	2921	3827	1.31
Arghakhanchi	511	577	1.13	511	577	1.13	505	620	1.23
Rolpa	1126.4	1298	1.15	1126	1498	1.33	1235	1535	1.24
Dang	14	15	1.07	14	15	1.07	15	21	1.40
Banke	0	0		0	0		0	0	
Pyuthan	2205	2718	1.23	2205	2918	1.32	2195	2920	1.33
Rukum	473.2	607	1.28	640.89	833	1.30	576	755.6	1.31
Bardia	0	0		0	0		0	0	
Total	10215	11985	1.17	10382	13711	1.32	10373	13500	1.30

Data source: Annual progress and statistical book, 2022/023. DoAD, Lumbini Province

Despite of more than half dozen improved varieties released and recommended for cultivation in the country, majority of the farmers grow local varieties. *Dalle*, *Jhapri*, *Dale*, and *Mudke* are the most popular local varieties in the province. Farmers harvest the yield from these local varieties ranges from 1.0 to 2.3 metric tons per hectare depending on input use and management practices applied. Few farmers also grew recently released modern varieties who had the access to improved seed. Majority of farmers cultivated finger millet in relay system with maize. Weed management and removing of maize leaves during transplanting is critical for good yield. In maize-millet relay cropping defoliation of maize leaves below ear improve the millet yield due to easy penetration of sun light on millet (Subedi 1996) and farmers were aware about it. It is also grown as intercropping with legumes such as soybean and black gram. Cropping system approach either sequential or intercropping with legume found beneficial for productivity (Maitra et al 2020). Farmers grew the crop raising nursery bed and transplanting seedlings in well prepared field as sole cropping or relay cropping with maize or intercropping with legumes. Few experienced farmers maintain their local varieties by selecting and harvesting the panicle (*Kapani*) separately for seed purpose but majority use the seed taken from the whole bulk.

Programs and activities initiated in the province

Indigenous crop promotion and marketing program

Provincial government focused for the conservation and promotion of indigenous crops to check biodiversity loss. Under this common basket program, finger millet was a main crop and different activities related to millet farming such as seed kit distribution (local varieties), area expansion, plant protection services, training etc were carried out. Farmers were assisted in technology adoption of improved cultivation practices using local seed and marketing of the product.

Finger millet smart agriculture village program

The program was initiated with high ambition of achieving the goal of commercialization, profit maximization and market led production of finger millet in Khungri rural municipality of Rolpa district. Support services of improved production packages and improved varieties for growers was still insufficient. It was found that majority of farmers prefer high yielding and early maturing varieties (Gebreyohannes et al 2021) nonetheless, availability of such varieties was in short supply in the province. Province started the smart agricultural village program for commercialization of economically important crops since 2018. The smart program was focused to climate smart, irrigation smart, nutrient smart, technology smart and market smart activities. Climate smart signified the adoption of site specific climate resilient technologies and practices related to finger millet. Irrigation smart advocated about the efficient use of irrigation water, rain water harvest technology, solar pump etc. Nutrient smart emphasized about the adoption of integrated crop and nutrient management, carbon fixation, soil productivity improvement etc. Technology smart guided the adoption of improved technology, sustainable farming, sustainable agricultural mechanization, land management etc. Finally, market smart emphasized the sustainable market promotion.

Indigenous crop processing program

The main objective of the program was to increase the consumption and marketing of indigenous crops including finger millet by assisting the farmers to establish small processing plant particularly the mill at the production sites.

Publications on finger millet

Dissemination and adoption of technology is critical for enhancing agricultural productivity. Farmers' awareness and interest is critical for technology adoption. Different publications on indigenous crops including finger millet were published and distributed to the farmers for promotion.

Seed production, storage and distribution program

Seed is the vital input and the quality seed can increase yield substantially. Seed production program of indigenous crops including finger millet were carried out in the province. Easy access of quality seed was helpful in increasing the finger millet production. Climate change impact resulted almost constant production of finger millet over the five years creating food deficit problem in the region. Due to excessive food deficit farmers were forced to consume the stored seed grains. In such situation the program highlighted to establish community seed bank because seed production program combined with community seed bank concepts are playing a vital role to save valuable seed (Mal et al 2010).

Farmers' capacity building activities to finger millet farming

Different training programs and workshops for indigenous crops especially focused to finger millet were conducted in the millet producing districts. Such programs were essentially helpful for the improvement of local landraces of millets and other indigenous crops.

Success cases

Case 1. Distinct practice of finger millet transplanting

Gir Bahadur Lamtari Magar (75) is an elder farmer. He is a inhabitant of Rainadevi Chhahara rural municipality 7, Jogdamar Palpa. He managed his almost 0.75 hectares of field and cultivated different crops required for home consumption and also to sell surplus product in local market. He cultivated finger millet in almost 0.5 hectares of land and harvested about 1 metric tons last year. He started to cultivate finger millet when he migrated to Jogdamar in 1975 AD and continuing it to date. He shared the distinct transplanting method of finger millet seedlings. First, he raised seedlings in nursery bed and then he threw 3-4 well grown seedlings in the well tilled field for transplanting. If rainfall occurred that day the seedlings would survived and grew otherwise failed. Sometimes he had thrown seedlings behind the bullock plough for transplanting. Mostly he performed a weeding during the crop cycle and no need of insect pest management. However, he experienced the infestation of armyworm last year with minor loss. He sold his product at 75 rupees per kg in local market.

In group discussion, farmers of Jogdamar, shared their experiences about finger millet farming. They usually grew three local varieties *Jhapri, Landape & Mudke* which were more popular in the locality. These varieties had good performance with higher productivity. The total cultivated area of Jogdamar was almost 25 hectares and out of that about 60% area was occupied by finger millet. The productivity of finger millet was around 2.0 metric ton per hectare and that was higher than provincial average. They were not aware about the nutritional value of finger millet but heard that it gives more power. They usually consumed finger millet recipes as *roti and dhindo* which are common Nepalese traditional food. Farmers also used finger millet to make local alcohol which is precious drink in their every festival.

Case 2. No negative impact of climate change on finger millet farming

Local variety: Mudke. Photo: Ram

Tilak Khadka (Right) is a young farmer who is involved in farming since childhood. He is the inhabitant of Lungri rural municipality 4, Thulo Namja, Rolpa and secretary of "finger millet smart agriculture village program" a special program implemented by government of Lumbini province at Thulo Namja, Rolpa. They chose finger millet and vegetable in their smart agricultural program. Finger millet was a major food crop which was grown in almost 33 hectares by 350 households and produced more than 80 metric tons annually. The production was utilized locally as well as sold the surplus in niche market. Almost all farmers in the community, grew finger millet in their field ranges from 0.1 hectare to 1.0 hectare. They harvested the yield approximately 2.5 metric tons per hectare. Finger millet is a traditional crop in the village. Farmers raised the seedbed during pre-monsoon and transplanted the seedlings during monsoon so that the plant can withstands vigorously.

Economic return from millet is increasing because of both increased productivity and price of the millet. Few years earlier the price of the millet was low but because of high demand the price increased substantially and reached up to Rs. 70 per Kg. Insect pest damage was not serious problem. However, occurrence of blast disease and infestation of stem borer were noticed with minor loss. In group discussion farmers shared their different experience about the impact of climate change to finger millet farming. In Thulo Namja, farmers grew paddy as well as finger millet in rainy season. Because of irregular pattern of rainfall, the area of paddy decreased and that area was used for finger millet farming eventually finger millet area increased. This positive impact of climate change in finger millet farming was distinct from others. In Thulo Namja, farmers grew chiefly two local varieties Mudke (95%) and Dale (5%) which were more popular in the village.

Farmers were less aware about the nutritional and economic value of finger millet. After smart program launched, farmers understood the significance of finger millet and started to commercialize it. Chief recipes of finger millet were roti and dhindo in the village. Finger millet also used to make local alcohol which is precious drink in rituals and festivals of the village people.

Use of Finger Millet in the Province

Finger millet is the traditional crop and commonly used as traditional food. The most common food items of finger millet in the province are *Roti* (pancake) and *Dhindo* (thick porridge). Similarly, the most popular and precious liquor in countryside is millet liquor and largest portion of production is used for millet liquor processing. It is also a necessary item in the rituals and festivals of various ethnic group.

The straw and byproduct of the finger millet is used as fodder and feed for the cattle. The rural farmers in the province operate integrated type of farming keeping few cattle, goats, poultry, and cultivating cereals and vegetables. Manure from the livestock is utilized in farming and straw and bye-product of the crops is used for cattle, sheep and goat feed. So, it fulfills the fodder requirement for lean period.

Opportunities for Finger Millet Promotion

Because of high nutritive value of finger millet, wider adaptability and resilient to climate change impacts its importance is increasing. Increasing awareness about nutritive value of millet, increases the farmers' desire of growing it. This could be helpful for food and nutrition security of people. Consequently, three tier of governments has been fixed the priority for finger millet cultivation and that attracted the concern of all people significantly. There is potentiality of niche market development as the urban population are attracted to finger millet recipes and willing to pay premium price (Pallante et al 2016). In addition to this, finger millet can be stored for longer period of time and that longer storage opportunity provides food security to poor people (Thilakarathna and Raizada 2015) in the region.

It is equally important for food diversification. The food recipes of finger millet is narrow in our context however, noodles, pasta, sweet mixes, papads, soups, and bakery products are emerging recipes (Shobana et al 2013) that can help in food diversification. Because of its high nutritive value, it serves the balance diet for the smallholders. Furthermore, it has pharmacological significance. Kalsi et al (2023) suggested that phenolic of finger millet seed coat exhibits excellent anti-diabetic, anti-oxidant, antimicrobial, anti-osteoporosis, wound healing, anti-lithiatic and enzyme properties that may serve pharmacological purposes without paying additional cost for marginalized people.

Climate change has produced negative impact for growing various crops. Contrary, farmers shared their experience of positive impact in finger millet farming. In some districts, paddy farming area shifted to millet because of low and irregular rainfall pattern. Additionally, it was found positive to finger millet yield. Luitel et al (2019) claimed the yield increment of 36.9 kg/ha. in upper tropical to sub-tropical climate region.

Challenges for Finger Millet Promotion

In rural areas of the province, farming is feminized due to male out migration. In such areas, women are suffered with increased workload of farming besides household work and care of their children. Increasing workload of farming to women is a vital challenge of finger millet promotion. However, it can be minimized by the use of improved farm practices combined with use of farm machineries particularly mini tiller and millet threshers. Farm mechanization reduces the work load of women if they are given an opportunity to improved practices (Devkota et al 2016).

Yield and net profit from the millet farming is another challenge. Pragmatically, farmers are harvesting lower yield and getting minimum net benefit from the finger millet. Raj (2012) established that the benefit cost ratio of finger millet farming is only 1.05 in rural areas of Nepal that is very low as compared to other profitable crops. However, surplus household labor force can be employed in millet farming.

Conclusion

Finger millet is an important food crop after rice, maize and wheat in the province. It is important for food and nutrition security of small holders particularly to subsistence farming system (Joshi and Joshi 2002). The area under millet cultivation is almost stagnant over a period of five years with negligible increase in yield. The demand for finger millet is increasing and the national production is insufficient to meet the growing demand. There is continuous need to increase production and productivity for import substitution and to make the country self-reliant in millet (Gairhe et al 2021). In this context, government of Lumbini province launched the different finger millet promotion programs such as indigenous crop promotion and marketing program, finger millet smart agriculture village program, indigenous crop processing program, seed production, storage and marketing program, and farmers' capacity building programs in collaboration with federal and local governments. Continuous efforts jointly or independently from three tier of governments is again obligatory for achieving the intended goal of import substitution and self-reliant in finger millet in the province.

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक)। २०८०। राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ।

कर्णाली प्रदेशमा कोदोजन्य बालीहरू

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सारांश

कर्णाली प्रदेशमा धेरै थरीको कोदोजन्य बालीहरू परापूर्वकालदेखि नै खेती गर्दै आइरहेको पाइन्छ। मुख्य गरेर कोदो, कागुनो, चिनो, र जुनेलो धेरैजसो जिल्लाहरूमा खेती गरिन्छ र सबै बालीहरूमा विविधता पाइन्छ। कतिपय जिल्लाहरूमा यी बालीहरू नै प्रमूख खाद्यान्न बाली हुन्। कृषकहरूसँग यी बालीहरूको बारेमा धेरै क्षेत्र समेटिएको ज्ञान छ। यी बालीहरूको संरक्षण र प्रबर्द्धन गर्न बिभिन्न कार्यहरू पनि भैरहेको छ। यहाँका कृषि उपजहरू पञ्चगुणले भरिपूर्ण मानिन्छन् र उक्त बालीहरूवाट विभिन्न रैथाने तथा आधुनिक परिकारहरू बनाउने चलन बढ्दो छ। यी बालीहरूको उत्पादकत्व बढाई राष्ट्रिय तथा अन्तराष्ट्रिय स्तरमा बजारीकरण गर्नुपर्ने देखिन्छ।

परिचय

पहाडी १० जिल्ला रहेको कर्णाली प्रदेश भौगोलिक विविधतायुक्त छ। कुल ७९ वटा स्थानीय तह रहेको यस प्रदेशमा देशको २७,९८४ वर्ग कि.मी. भूभाग अवस्थित छ। प्रदेशको कूल ग्राहस्थ उत्पादनको ४५.६ प्रतिशत कृषि क्षेत्रले ओगटेको छ अत: कृषि क्षेत्र यस प्रदेशको जिविकोपार्जनको आधार रहनुका साथै आर्थिक विकासको लागि प्राथमिकता प्राप्त क्षेत्र हो। यो प्रदेश भौगोलिक विविधता र पुर्वाधार विकासको दृष्टीकोणवाट समेत कृषि विकास मार्फत् समृद्धिका लागि प्रचुर सम्भावना बोकेको क्षेत्र हो। यहाँ धेरै थरीको कोदोजन्य बालीहरू परापूर्वकालदेखि नै खेती गर्दै आइरहेको पाइन्छ। यहाँको कृषि उपजहरू पञ्चगुणले भरिपूर्ण छन् जसको कारण राष्ट्रिय तथा अन्तराष्ट्रिय स्तरमा बजारीकरण गर्न सकिने राम्रो सम्भावना देखिन्छ।

बालीहरूको क्षेत्रफल र उत्पादन

जिल्लागत रुपमा कोदो, कागुनो, चिनो र जुनेलो बालीको क्षेत्रफ़ल र उत्पादन **तालिका १** मा उल्लेख गरिएको छ। यी सबै बाली रैथाने तथा भुमि-जात भएकोले उत्पादकत्व कम हुन्छ र यिनीहरूको उत्पादकत्व बढाउने कार्य गर्नु अति आवश्यक देखिन्छ।

तालिका १. कर्णालीमा कोदोजन्य बालीहरूको क्षेत्रफल र उत्पादन विवरण

जिल्ला	विवरण	कोदो	कागुनो	चिनो	जुनेलो	जम्मा
रुकुम	क्षेत्रफल (हे)	६८९	३	५	१	६९८
	उत्पादन (मे.ट.)	१२३०	५	६	३	१२४५
सल्यान	क्षेत्रफल (हे)	७५०	०	०	०	७५०
	उत्पादन (मे.ट.)	८६०	०	०	०	८६०
सुर्खेत	क्षेत्रफल (हे)	२९९५	-	-	-	२९९५
	उत्पादन (मे.ट.)	२०९७	-	-	-	२०९७
दैलेख	क्षेत्रफल (हे)	२७४५	३	२	१	२७५१
	उत्पादन (मे.ट.)	३७६७	५	३	२	३७७७
जाजरकोट	क्षेत्रफल (हे)	११००	२०	०	०	११२०
	उत्पादन (मे.ट.)	१८५०	१०	०	०	१८६०

जिल्ला	विवरण	कोदो	कागुनो	चिनो	जुनेलो	जम्मा
डोल्पा	क्षेत्रफल (हे)	३००	३००	५००	०	११००
	उत्पादन (मे.ट.)	२३१	२८०	४८०	०	९९१
जुम्ला	क्षेत्रफल (हे)	३७००	१५	२००	०	३९१५
	उत्पादन (मे.ट.)	३८५०	१५	२४०	०	४१०५
कालीकोट	क्षेत्रफल (हे)	१२४०	७७	६८	०	१३८५
	उत्पादन (मे.ट.)	२०९५	५४	५४	०	२२०३
मुगु	क्षेत्रफल (हे)	४२७५	६३५	७०९	०	५६१९
	उत्पादन (मे.ट.)	४१२९	४३२	७००	०	५२६१
हुम्ला	क्षेत्रफल (हे)	१३५०	१०८	३४६	०	१८०४
	उत्पादन (मे.ट.)	१५४०	१२०	२६०	०	१९२०
जम्मा	क्षेत्रफल (हे)	१९१४४	११६१	१८३०	२	२२१३७
	उत्पादन (मे.ट.)	२१६४९	९२१	१७४३	५	२४३१९

कोदोजन्य बालीहरूको खेती प्रविधि

तीन प्रमूख कोदोजन्य बालीहरू: चिनो, कागुनो र कोदोको (चित्र १) चिनारी सहित खेती प्रविधि **तालिका २** मा उल्लेख गरिएको छ। यी सबै बालीहरू गर्मी समयमा लगाइन्छ र भदौ-असोजमा काटिन्छ। जुनेलो प्राय जसो थोरै बोटहरू घर तथा बारी वरिपरी लगाउने चलन छ। कर्णाली प्रदेश प्राय जसो बालीहरू मिसाएर लगाउने चलन छ। यस प्रदेशमा पाइने रैथाने जात (भुमि-जात) हरू **तालिका २** र ३ मा उल्लेख गरिएको छ।

तालिका २. कर्णाली प्रदेशमा कोदोजन्य बालीहरूको खेती प्रविधिको संक्षिप्त बिवरण

बाली	सामान्य चिनारी	हावापानी	उपलब्ध पौष्टिक तत्व	उपयुक्त माटो	जातहरू	उत्पादन
चिनो	चिनो उत्तरी चाइनाबाट उत्पत्ति भएको मानिन्छ। नेपाल लगायत अफगानिस्तान, पाकिस्तान, भुटान, चाइना, इन्डियाको उच्च पहाडी क्षेत्रमा चिनोको खेती वर्षौ पहिले देखि हुँदै आएको छ।	उचाइः २००० मिटर देखि ३५०० मिटरसम्म रोप्ने समयः जेठ १५ देखि असार २५ सम्म तापक्रमः १० देखि १५ डिग्री सेल्सियस	१०० ग्राम चिनोमा कार्बोहाइड्रेड ७३.९%, प्रोटीन ९.७६%, खरानी ४.५%, रेशा ११.९%, चिल्लो पदार्थ ६.२%, क्याल्सियम ५५ मिलिग्राम, फस्फोरस १९.४ मिलिग्राम र फलाम ५५ मिलिग्राम पाइन्छ।	दोमट, बलौटे दोमट र प्रशस्त प्राङ्गारिक मल भएको माटो उपयुक्त, पिएचः ४.४ देखि १०	रातो चिनो, दुधे चिनो, हाडे चिनो,, भरभरे चिनो, कालो चिनो, सनवा चिनो, समाई चिनो, भूमारो चिनो, आदि नेपालमा स्थानिय रुपमा खेती गरिएको पाईन्छ।	उत्पादनः ५०० देखि १२०० के.जी. प्रति हेक्टर।
कागुनो	कागुनो वा काउनो सबैभन्दा पुराना अन्न बालीहरू मध्य एक हो। यो बाली पुर्वी एसीयाली देशहरूमा विशेषगरी चीनमा प्राचिन कालदेखि खेती गरींदै आएको देखिन्छ।	उचाइः २००० मिटर भन्दा माथिको उचाईसम्म लगाउने समयः जेठमा रोपेर भदौमा काट्ने बीउ दरः ५०० ग्राम/रोपनी	कागुनोको दानामा सरदर प्रोटीन १२.३५%, चिल्लो पदार्थ ४.३५%, कार्बोहाइड्रेट ६०.९५%, रेसा ८.०% तथा भस्म ३.३% पाइन्छ।		स्थानीय जातहरू कालो कागुनो, सेतो कागुनो, रातो कागुनो, पहेँलो कागुनो, खैरो कागुनो, सानो कागुनो, ठुलो कागुनो आदि।	उत्पादन १५०० देखि २००० के.जी. प्रति हेक्टर

बाली	सामान्य चिनारी	हावापानी	उपलब्ध पौष्टिक तत्व	उपयुक्त माटो	जातहरू	उत्पादन
कोदो	नेपालको पहाडी तथा हिमाली क्षेत्रका बासिन्दाको खाद्य सुरक्षाका लागि धान, गहुँ, र मकै पछाडिको मुख्य बाली नै कोदो हो। यसको उत्पत्ति अफ्रिकी महादेशको ईथोपियामा भएको पाइन्छ।	उचाइः ३१०० मि. सम्म। लगाउने समयः चैत्र-बैशाखमा लगाएर भदौ-असोज महिनामा काट्ने गरिन्छ। बीउ दरः छरुवा खेतीको लागि प्रति रोपनी ५००-९०० ग्राम र ब्याड राख्दा २००-४०० ग्राम आवश्यक पर्दछ।	यसमा औसतमा ९.२५% प्रोटीन, १.३५% चिल्लो पदार्थ, ६.१५% खनिज पदार्थ, ७६.३२५% कार्बोहाइड्रेट आदि तत्वहरू मूख्य रुपमा पाइन्छ।	बलौटे दोमट माटो यसका लागि उपयुक्त मानिन्छ र पि एच ४.५-१० सम्म राम्रो	स्थानीय जातहरूः भदौरे कोदो, चरिकोटे कोदो, चुल्ठे कोदो, च्याल्से कोदो, डल्ले कोदो, डल्ले सेतो कोदो, डुँडे कोदो, झुप्पे कोदो, कालो बुंगे कोदो, कालो कोदो, कात्तिके कोदो, कात्तिके डल्ले, किर्ने कोदो आदि। बिकसित जातः ओख्ले–१, डल्ले–१, काब्रे कोदो–१, काब्रे कोदो-२, शैलुङ कोदो-१ र रातो कोदो।	सामान्यता नेपालमा कोदोको औसत उत्पादन १.१ टन प्रति हेक्टर। उन्नत जातको कोदोको उत्पादन क्षमता ४-५ टन प्रति हेक्टरसम्म हुन्छ।


कोदो र लट्टे


कागुनो र कोदो


चिनो


चिनो र लट्टे

कागुनो र चिनो

कोदो

चित्र १. कोदोजन्य बालीहरू

रैथाने जात र स्थानीय स्तरमा बनाईने परिकारहरू

परम्परागत रुपमा यी बालीहरूको भात, रोटी, रक्सी र खीर खाने चलन छ (**तालिका ३**)। दाना र पिठोबाट धेरै किसिमको परिकार बनाउन सकिने हुँदा हिजोआज आएर विविध परिकार बनाउने क्रम बढ्दो छ। यसको ताजा हरियो नल तथा सुकाएर पराल पशुलाई दिइन्छ।

तालिका ३. रैथाने जात र स्थानीय स्तरमा बनाईने परिकारहरू

बालीको नाम	उपलब्ध स्थानीय जातहरू	स्थानीय स्तरमा बनाईने परिकारहरू
कोदो	कालो, रातो, डल्ले र झरुवा कोदो। सल्यान जिल्लामा झाप्रे, टाउके, कात्रे कोदोको रुपमा विविधता भएको। हुम्लामा स्थानिय अवले, तेमासे कोदो हुने गरेको	• रोटी, पखाला लागेमा पुवा बनाएर खाने चलन • मध्य पहाड विशेषत सल्यान, रुकुम तिर रक्सी बनाउन प्रयोग गरिने। • रुकुममा शुद्धि कार्यमा प्रयोग गरिने गरेको। • कोदोलाई रोटी, तुम्वा, ढिंडो, रक्सीको रुपमा प्रयोग गर्ने गरेको। • आजकल कोदोको विस्कुट, पाउरोटी, मःमः, चाउमिन र थुक्पा पनि बनाउन थालिएको।
कागुनो	रातो, कालो	• प्रसादको रुपमा खीर बनाएर खाने
चिनो	दुधे, हाडे	• प्रसादको रुपमा खीर बनाएर खाने। भातको रुपमा प्रयोग हुने। • अनिकाल टार्ने अन्नको रुपमा हुम्लामा परिचित।
जुनेलो		• माघे सङक्रातीमा लड्डु बनाउन प्रयोग गरिने

चित्र २. कोदोजन्य बालीहरूको परिकारहरू

कोदोजन्य बालीहरूको बिक्रेता तथा कोशेली घर

यो प्रदेशको कृषि उपजहरूको माग बढी भएकोले तथा बिक्रीवितरण सहज हुने हिसाबले जिल्लाहरूमा स्थापित प्राङ्गारिक तथा रैथाने कृषि उपज बिक्रेता, सङ्कलनकर्ता, फर्म तथा कोशेली घरहरूको नाम **तालिका ४** मा दिईएको छ। त्यसै गरी काठमाडौँमा कर्णाली प्रदेशको कृषि उपज पाइने स्थानहरूको विवरण **तालिका ५** मा उल्लेख गरिएको छ।

तालिका ४. प्राङ्गारिक तथा रैथाने कृषि उपज बिक्रेता तथा कोशेली घरको जिल्लागत विवरण

प्राङ्गारिक तथा रैथाने कृषि उपज बिक्रेता, सङ्कलिनकर्ता, फर्म तथा कोशेली घरको नाम	प्रोपाईटरको नाम	ठेगाना	सम्पर्क नम्बर
डोल्पा			
डोल्पा कोशेली घर	अन्जु महतारा	ठुलिभेरी-३	९८६१०९४०२७
फोक्सुन्ड़ो कोशेली घर	निमा बैजी	से-फोक्सुन्ड़ो-८	९८५१०३४०१८
माझफाल कोशेली घर		ठुलिभेरी-५	
मूगु			
सन्तोस मल्ल	सन्तोस मल्ल	छायाँनाथ रारा-२	९८४८३०८३२४
मस्टा सहकारी स. लि	लिक्ष्मी मल्ल	सोरु-१०	९८६९८७०८५०
छायानाथ कोसेली घर	चेतना मल्ल शाहि	छायाँनाथ रारा-२	९८४९३०८३८३
रारा कोसेली होमस्टे	मणि चन्द्र भाम	छायाँनाथ रारा-४	९८४८३०८५५५
हुम्ला			
सुबर्ण सिमकोट खाद्य उद्योग	मुकुन्द रोकाया	सिमकोट-६	९८५८३२११४१
पञ्चमुख दुधेदह कृषि सहकारी सस्था	पार्वति शाही	सिमकोट-४	९८६८२४३९०२
हुम्ला एग्रो प्रा. लि.	सडुप दोर्जे लामा	सिमकोट-३	९८५११००४९४
एस. के. कृषि तथा पशुपालन फर्म	सागर शाही	सिमकोट-३	९८६९९६९२९५
हिमालय रेष्टुरेण्ट	पाङ्गेन लामा	सिमकोट-५	९८४८३६४६३६
श्री हिमालयन एग्रो फार्म	बिनोद लामा	सिमकोट-४	९८४९३८६६२५

प्राङ्गारिक तथा रैथाने कृषि उपज बिक्रेता, सङ्कलिनकर्ता, फर्म तथा कोशेली घरको नाम	प्रोपाईटरको नाम	ठेगाना	सम्पर्क नम्बर
जुम्ला			
रारालिही अर्गानिक पसल	अर्जुन बुढा	चन्दननाथ-४	९८६९८७८१८२
धिताल कोसेली घर	टिकाराम धिताल	चन्दननाथ-५	९८४८१५९१४१
महिला श्रीजनशील कृ.स.स. एन्ड कोसेली घर	सहकारी	चन्दननाथ-१	९८६८३८५६३१
प्रेरणा र प्रकृती अर्गानिक कोसेली घर	कमला खत्री	चन्दननाथ-५	९८४८३०६८२३
रचना जनरल स्टोर एन्ड कोसेली घर	हिरा कुमारी खत्री	चन्दननाथ-५	९८४८३००७००
प्रवेश किराना पसल एन्ड कोसेली घर	लक्ष्मी थापा	चन्दननाथ-५	८७५२३०११
तिला अर्गानिक पसल	तिला बिस्ट	चन्दननाथ-५	९८६८३०९५६२
आर.बि. कोसेली घर	राम माया भण्डारी	चन्दननाथ-६	९८४८३४४७११
न्यु कोसेली घर	दिपराज रावत	चन्दननाथ-६	९८६८३५४२३९
अर्गानिक कोसेली घर	अग्र शाही	हिमा-६	९८६६०८२१३१
हिमाली खाद्य तथा कोसेली घर	मान बहादुर शाही	हिमा-४	९८४८३३५२०६
गायत्री उद्योग	गिबराज शाही	हिमा-१	९८४८३६२५९०
रारा टप सोभा होटेल एन्ड कोसेली घर	भक्त बहादुर बुढा	कनकासुन्दरी-५	९८४८३१२१४८
सिंजा भ्याली भ्यु प्रा. लि. कोसेली घर	प्रकाश आचार्य	सिंजा-१	९८५१२२२६४१
लाईन मालिका जनरल स्टोर एन्ड कोसेली घर	सेर बहादुर बुढा	सिंजा-३	९८६७७०७४१२
राना जनरल स्टोर	मन्जिते राना	सिंजा-३	९८६७०६२४४२
रोकाया जनरल स्टोर	गीबी रोकाया	सिंजा-३	९८६६१६०५१०
हमाल जनरल स्टोर	प्रेम हमाल	सिंजा-३	९८६७७०७९१५
SSB कोसेली घर तथा मार्फा संकलन केन्द्र	सङ्खबहादुर रोकाया	सिंजा.गा.१	९८४८००८४८५
तातोपानी अर्गानिक (TOH) कोसेली घर	नमराज बुढा	तातोपानी-२	९८६६७८१३४२
कृषि उपज संकलन केन्द्र	कृष्ण कठायत	तातोपानी -२	९८४८३३३९७७
लिक्षाल खेती पैकेला सहकारी संस्था	कालीबहादुर रावत	तातोपानी -७	९७४८९३१५५१
पंचेश्वर बहु उद्देश्यीय सहकारी संस्था	मुन बहादुर रावत	तातोपानी -५	९८३८३१२५२०
पाँचताल सहकारी संस्था	बिष्णु रावल	तातोपानी -२	९८६३२१५९०४
दैलेख			
दैलेख सौगात गृह	झविराज खत्रि	नारायण-१	९८५८०५०३२५/ ०८९-४२०४०७
सुर्खेत			
दुर्गा सप्लायर्स	मोहन सुबेदि	वीरेन्द्रनगर, सुर्खेत	९८५८०५१९६८
सुर्खेत कोसेली गृह	तुल्सि बि सि	वीरेन्द्रनगर, सुर्खेत	९८४८२७९६६१
ज्वालागढी मसला उद्योग	कविराज खत्रि	वीरेन्द्रनगर, सुर्खेत	९८५८०५०३२५
कर्णाली एग्रो मार्ट	इन्द्रजित सुनार	वीरेन्द्रनगर, सुर्खेत	९८५१२११६७७
चन्दननाथ सहकारी संस्था	विश्वराज खत्री	वीरेन्द्रनगर, सुर्खेत	९८४९६३८८५५
कञ्चन कृषि फर्म	डायमण्ड ज्योति शर्मा	वीरेन्द्रनगर, सुर्खेत	९८५८०६१७३८
रारा कर्णाली अर्गानिक पसल	कन्न बहादुर बुढा	वीरेन्द्रनगर, सुर्खेत	९८६७९६५९५१
नेपाल आर्गानिक पसल	हिमाल भण्डारी	खजुरा रोड, सुर्खेत	९८४८३००४२८
अर्गानिक पसल	धनिराम अधिकारी	औद्योगिक क्षेत्र चोक पुल	९८४८२१०२७०
धिताल अर्गानिक फलफुल तथा तरकारी पसल	बिशेस धिताल	कृषि हाटबजार, सुर्खेत	९८४८३९६६४१
युवराज प्रकृति अर्गानिक खाद्य तथा फलफुल कोसेली अर्डर यण्ड सप्लायर्स	कमल नेपाल	वीरेन्द्रनगर-४, सुर्खेत	९८४८००८८१४, ९८६८३४९५४६
अर्गानिक पसल	प्रेम नेपाल		९८४४७०७०३५
कर्णाली अर्गानिक कृषि एण्ड सुपरफुड	हिक्मत चन्द	आचार्य चोक	९८४८००५०००
सामेल एग्रिकल्चर प्रा लि	कर्ण बहादुर बुढा	वीरेन्द्रनगर-१०	९८५८०७१९०२

प्राङ्गारिक तथा रैथाने कृषि उपज बिक्रेता, सङ्कलिनकर्ता, फर्म तथा कोशेली घरको नाम	प्रोपाईटरको नाम	ठेगाना	सम्पर्क नम्बर
रुकुम पश्चिम			
मोहबिर खड्का	मोहबिर खड्का	त्रिबेणी-२	९७४८५२५४७९
टेक बहादुर ओली	टेकबहादुर ओली	त्रिबेणी-३	९८०९५४१७४०
धनराज खड्का	धनराज खड्का	त्रिबेणी-१०	९८५७८२२८४७
बलजित खड्का	बलजित खड्का	त्रिबेणी-२	९७४८१६६००४
प्रविन पाण्डे	प्रविन पाण्डे	मुसिकोट-७	९८४७९९९७७३
मिलन कृषि तथा पशु बिकास फार्म	केसर के.सी.	त्रिबेणी-६	९८१५५७२४२१
राम बहादुर खड्का	राम बहादुर खड्का	त्रिबेणी -७	९८१०९९१०८९
रमेश खत्री	रमेश खत्री	आठबिसकोट-७	९८६४३६४२२५
जाजरकोट			
प्रदिप जनरल स्टोर	नर ब. थापा	छेडागाड-१	
सपना जनरल स्टोर	राजकुमार खत्री	नालिगाड-५	९८४५६७६४४५
सल्यान			
कुपिन्डेदह टिमुर उद्योग प्रा.ली.	पूर्ण बहादुर बुढा	बनगाड कुपिन्डे-९	९८४००५९९०८
भुवनेश्वरी अचार उद्योग	सुनहरी राइ श्रेष्ठ	शारदा-२	९८४४९७९२७५
हाम्रो पहाडी खाजा घर	सीता बोहोरा	बनगाड कुपिन्डे-६	९८६६१७०३५१

तालिका ५. काठमाडौँमा कर्णाली प्रदेशको कोदोजन्य बालीहरूको बिक्रेताहरूको विवरण

प्रांगारिक तथा रैथाने कृषि उपज संकलनकर्ता/ बिक्रेता/ फर्म/ कोशेली घरको नाम	प्रोपाइटरको नाम	ठेगाना	सम्पर्क नम्बर
जुम्ला घर अर्गानिक्स एण्ड सुपर फुड्स	राजबहादुर शाहि	काठमाडौ	९८५१०५२२७३
द लोकल्स	सुधिरप्रसाद चापागाई	कुमारीपाटी	९८४३५५०९८५
सिजन अर्गानिक्स	शिव गौतम	खुमलटार	९८५१२४०९९३
ताजा एग्रो	पदम राज अबस्थि	काठमाडौ	९८६५५३८२९८
यलिस अर्गानिक	रिन्चेन छोदेन लामा	जोरपाटी	९८४१०१६११७
काठमाडौ अर्गानिक्स	भुवन के.सी	काठमाडौ	९८५१२२०६४२
पैंचो पसल प्रा.लि.	केशवराज न्यौपाने	बुटवल	९८५७०७६०८०
रारा कर्णाली अर्गानिक प्रोडक्ट		कीर्तिपुर, काठमाण्डौं	९८४०३५७२२७
लिङखु एग्रिकल्चर डिर्पान्मेन्ट स्टोर	अरुण पाण्डे	गठ्ठाघर, भक्तपुर	९८४६८४७३६०
अर्गानिक माउन्टेन फ्लेवर / दि अर्गानीक भ्याली प्रा.ली.	समिर नेवा	भेरीगंगा-५, सुर्खेत	९८५१०३८१६१
सात्विक कृषि घर	विवेक पण्डित	कलङ्की	९८५१३१९०८५

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक)। २०८०। राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ।

सुदूरपश्चिम प्रदेशमा कोदोजन्य बालीको वर्तमान अवस्था, अवसर तथा सम्भावना र चुनौतीहरू

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पृष्ठभूमी

विश्वभर चामल, मकै र गहुँको उपभोग व्यापक रुपमा बढि रहेको अवस्थामा हाम्रो शरिरका लागि आवश्यक पर्ने धेरै जसो पोषक तत्वहरू पाईने, सजिलै उत्पादन गर्न सकिने, कमसल जमिनमा पनि उत्पादन हुने, अन्य बालीको तुलनामा उत्पादन लागत पनि कम लाग्ने रोग तथा किराको प्रकोप कम हुने, सुख्खा खडेरी बढि सहन सक्ने लगायत जलवायु परिवर्तनको अन्य असर बढि सहन सक्ने विशेषताहरू भएको र शहरबजारका उपभोक्ताको माग बढ्दै गईरहेको सन्दर्भमा कोदोजन्य बालीको महत्त्व दिनानुदिन बढ्दै गईरहेको पाइन्छ। रैथाने बाली अन्तरगतका बहुसँख्यक बालीहरू कोदोजन्य बाली अन्तरगत पर्ने गर्दछन्। विज्ञ तथा अनुसन्धाता र विभिन्न सन्दर्भ स्रोतहरूको आधारमा नेपालमा कोदो, कागुनो, चिनो, जुनेलो, सामा, बाजरा, कुट्की सामा र धान कोदो (कोदी) गरी जम्मा ८ प्रजातिका कोदोहरू पाइन्छन्। जसमध्ये मुख्य रुपमा कोदो, चिनो, कागुनो र जुनेलोको खेती गरिन्छ भने बाँकी प्रजातिहरू लोपोन्मुख अवस्थामा रहेका छन्।

विगतमा आधुनिक खेती प्रणालीको विस्तार लगायत विभिन्न कारणले यी बालीहरू ओझेलमा परेका भएता पनि पछिल्ला केहि वर्षहरूमा विश्वव्यापी रुपमा कोदोजन्य बालीहरूको खाद्य पोषण सुरक्षा र जलवायु परिवर्तन अनुकूलन लगायतका महत्त्वहरूको कारण तिनको उत्पादन तथा उपभोग वृद्धि गर्न विभिन्न पहलहरू हुँदै आएका छन्। यसै सन्दर्भमा संयुक्त राष्ट्रसंघ साधारणसभाको पचहत्तरौं सत्रले पारित गरे बमोजिम सन् २०२३ लाई अन्तर्राष्ट्रिय कोदोजन्य बाली वर्षको रूपमा मनाइँदैछ। यो अवसरमा कोदो तथा कोदोजन्य बालीहरूको फाइदा एवं महत्त्वको बारेमा व्यापक प्रचार प्रसार भइ यी बालीहरूको उत्पादन तथा उपभोग बृद्धिका साथै बजारीकरण प्रवर्द्धनमा महत्त्वपूर्ण सहयोग पुग्ने अपेक्षा गरिएको छ।

कोदोजन्य बालीको इतिहास र वर्तमान अवस्था

सुदूरपश्चिममा कोदोजन्य बालीको खेती कहिलेदेखि शुरु भयो भन्ने कुराको एकिन तथ्य उपलव्ध नभए पनि यी बालीहरूको परम्परागत रुपमा स्थानीय कृषकहरूले खेती गर्दै आएकाले यस क्षेत्रमा मानव बसोबास र कृषि पेशाको शुरुवातसँगै कोदो तथा कोदोजन्य बालीको खेती शुरु भएको मान्न सकिन्छ। यी बालीहरूलाई रैथाने बालीको नामले पनि चिनिनुको साथै यिनका विभिन्न रैथाने तथा स्थानीय जातहरू खासगरी पहाडी क्षेत्रमा बढि खेती गर्ने गरिएको पाईन्छ। कैलाली, कञ्चनपुर जस्तो तराई क्षेत्रको तुलनामा डडेल्धुरा, वैतडी, डोटी र अछाम जिल्लाहरू जस्ता पहाडी क्षेत्रहरू यी बालीहरूको खेती बढी हुने गरेको छ। त्यसैगरी मध्य पहाडी क्षेत्र भन्दा उच्च पहाडी तथा हिमाली क्षेत्रका बझाङ्, दार्चुला तथा बाजुरा जिल्लाहरूमा रैथाने बालीअन्तरगत कोदोजन्य बालीको खेती बढी हुने गरेको पाईन्छ। बर्षे मौसममा खेती गरिने भएकोले प्राय सिंचाईको आवश्यकता नपर्ने, जस्तो सुकै माटोमा पनि फल्ने, रोग तथा किरा कम लाग्ने, छोटो समयमा तयार हुने, अन्तरबाली तथा घुसुवा बालीको रुपमा पनि खेती गर्न सकिने र अन्य बालीको तुलनामा खेती गर्न सजिलो भएका कारण पनि यी बालीहरू यस प्रदेशमा वढि खेती हुने गरेको पाईन्छ।

सुदूरपश्चिम प्रदेशको कुल खेतीयोग्य जमिन ३६९,६९७ हेक्टर मध्ये ३१८,५२६ हेक्टरमा खेती गरिन्छ। खेती गरिएको जमिन मध्ये सबै भन्दा बढी क्षेत्रफल खाद्यान्न बालीले ओगटेको पाईन्छ। यस प्रदेशमा कुल १७,७७१ हेक्टरमा कोदोजन्य बालीको खेती गरिन्छ जुन कुल खेती गरिएको क्षेत्रफलको ५.५८ प्रतिशत हुन आँउछ। कोदोजन्य बाली मध्ये क्षेत्रफल र उत्पादनका दृष्टिले कोदो अग्र स्थानमा रहेको छ।

सुदूरपश्चिम प्रदेशको कुल खेती गरिएको जमिनको ५६ प्रतिशत जमिनमा मात्रै सिंचाई सुविधा रहेको छ भने त्यस मध्ये करिव ३१ प्रतिशतमा मात्रै वर्षैभरी सिंचाई हुने क्षेत्र रहेको छ। करिब आधा क्षेत्रफल असिंचित जमिन भएबाट पनि हिउँदे भन्दा वर्षे बालीको खेती गर्नुपर्ने अवस्था छ। कोदोजन्य बालीहरूको खेती पनि वर्षे मौसममा नै गरिने भएकोले धान बाहेकको अधिकाँश क्षेत्रफलमा कोदोजन्य बालीहरूको खेती गर्ने गरिएको पाइन्छ।

कोदोजन्य बाली लगाइने क्षेत्रफल, उत्पादन तथा उत्पादकत्व र यान्त्रिकरणको अवस्था

सुदूरपश्चिम प्रदेशको कोदो तथा कोदोजन्य बालीको उपलव्ध तथ्याङ्क **तालिका १** मा दिइएको छ। यस प्रदेशमा सबै जिल्लामा कोदोजन्य बालीको खेती गरिएको पाईन्छ। क्षेत्रफलका हिसाबले सवै भन्दा बढी बाजुरा जिल्लामा कोदोजन्य बालीको खेती हुने गरेको पाइन्छ। त्यसपछि क्रमशः डोटी, अछाम, वझाङ्ग, दार्चुला, डडेल्धुरा, वैतडी र कैलाली जिल्लाहरू रहेका छन्। कञ्चनपुर जिल्लाको अभिलेख अनुसार कुनै पनि कोदोजन्य बालीको तथ्याङ्क राखिएको छैन तथापि नगण्य रुपमा कोदो र हरियो साग खानका लागि लट्टेको खेती गर्ने गरिएको पाईन्छ।

यसरी यस प्रदेशमा कोदोजन्य बालीको कूल क्षेत्रफल मध्ये वाजुरा जिल्लामा सवै भन्दा बढि ३१.२८ प्रतिशत र सबै भन्दा कम कैलाली जिल्लामा ०.५९ प्रतिशत क्षेत्र कोदोजन्य बालीले ढाकेको पाइन्छ। विभिन्न रैथाने एवं कोदोजन्य बालीहरूको क्षेत्रफल र उत्पादनको दृष्टिले कोदो प्रमुख बाली रहेकोछ भने त्यसपछि क्रमशः फापर, कागुनो, लट्टे, जुनेलो र चिनो रहेका छन। कोदोले मात्रै कुल कोदोजन्य बालीको ९६ प्रतिशत क्षेत्रफल ओगटेको पाईन्छ भने अन्य कोदोजन्य बालीहरूले ४ प्रतिशत क्षेत्रफल ओगटेको पाईन्छ।

कोदोजन्य बालीको उत्पादकत्वका हिसावले सवै भन्दा बढी चिनोको उत्पादकत्व १.३ मे टन/हे रहेको छ भने त्यसपछि क्रमशः कोदो, लट्टे, कागुनो, जुनेलो र फापरको उत्पादकत्व रहेको छ। अन्य कोदोजन्य बालीको उत्पादकत्व औसतमा १ मे टनको हाराहारी रहेको देखिन्छ।

कोदोजन्य रैथाने बालीको खेती गर्ने क्रम घट्दै जानुको एक प्रमुख कारण र फल्न समय पनि बढि लाग्ने र यस्ता बालीहरूको प्राथमिक प्रशोधन कार्य झन्झटिलो हुनु हो। उदाहरणको लागि चिनोको वाहिरको बोक्रा सारै चिप्लो हुने भएकोले यसलाई ओखलमा फल्न तथा कुट्न निकै नै झण्झटिलो हुन्छ। पछिल्लो समयमा भएको चिनो कुट्ने मेसिनको बजारमा सहज उपलब्धता र प्रयोगले अहिले चिनोको खेती विस्तारै बढ्न थालेको पाइन्छ। त्यसै गरी कोदोजन्य बाली लगाइने पाखोबारी जोत्नको लागि हाते ट्र्याक्टरको प्रयोग पनि यस प्रदेशमा बढ्दै गएको देखिन्छ। अझै पनि उत्पादन र प्रशोधन कार्यमा यान्त्रिकरणको उपयोगको अवस्था भने कमजोर नै रहेको छ।

तालिका १. सुदूरपश्चिम प्रदेशमा जिल्लागत आधारमा कोदोजन्य बालीको तथ्याङ्क विवरण (आ. व. ०७९/०८०)

जिल्ला	बाली	कोदो	कागुनो	जुनेलो	चिनो	फापर	लट्टे	जम्मा
बाजुरा	क्षेत्रफल हे	५२५०	७५	८	१५	२००	१०	५५५८
	उत्पादन मे टन	६३००	६०	७.५	२०	१४०	८	६५३५.५
	उत्पादकत्व मे टन/हे	१.२	०.८	०.९	१.३	०.७	०.८	१.१८
वझाङ	क्षेत्रफल हे	२२००	३	०	०	८	५	२२१६
	उत्पादन मे टन	२४०४	३	०	०	८	४	२४१९
	उत्पादकत्व मे टन/हे	१.१	१.०	०.०	०.०	१.०	०.८	१.०९
अछाम	क्षेत्रफल हे	३४०२	६	०	२	६	२.५	३४१८.५
	उत्पादन मे टन	३१३०	४.२६	०	२.७६	५.५८	१.८२	३१४४.४२
	उत्पादकत्व मे टन/हे	०.९	०.०	०.०	१.४	०.९	०.७	०.९२
दार्चुला	क्षेत्रफल हे	११९५	६०	२०	०	१०२	०	१३६७
	उत्पादन मे टन	११८५	५०	१८	०	८६.७	०	१३३९.७
	उत्पादकत्व मे टन/हे	१.०	०.८	०.९	०.०	०.९	०.०	०.९८
बैतडी	क्षेत्रफल हे	३००	१७	०	०	१२.५	२१	३५०.५
	उत्पादन मे टन	४८०	१७	०	०	८.७५	२५.२	५३०.९५
	उत्पादकत्व मे टन/हे	१.६	१.०	०.०	०.०	०.७	१.२	१.५१

जिल्ला	बाली	कोदो	कागुनो	जुनेलो	चिनो	फापर	लट्टे	जम्मा
डडेल्धुरा	क्षेत्रफल हे	३३४	७	०	०	०	१०	३५१
	उत्पादन मे टन	५६७	१२	०	०	०	९	५८८
	उत्पादकत्व मे टन/हे	१.७	१.७	०.०	०.०	०.०	०.९	१.६८
डोटी	क्षेत्रफल हे	४३५०	७	०	०	८	४०	४४०५
	उत्पादन मे टन	५२७१	६.५	०	०	६	४१	५३२४.५
	उत्पादकत्व मे टन/हे	१.२	०.९	०.०	०.०	०.८	१.०३	१.२१
कञ्चनपुर	क्षेत्रफल हे	०	०	०	०	०	०	०
	उत्पादन मे टन	०	०	०	०	०	०	०
	उत्पादकत्व मे टन/हे	०.०	०.०	०.०	०.०	०.०	०.०	०.००
कैलाली	क्षेत्रफल हे	१०५	०	०	०	०	०	१०५
	उत्पादन मे टन	१२५	०	०	०	०	०	१२५
	उत्पादकत्व मे टन/हे	१.२	०.०	०.०	०.०	०.०	०.०	१.१९
जम्मा	क्षेत्रफल हे	१७१२६	१७५	२८	१७	३३७	८९	१७७७१
	उत्पादन मे टन	१९४६२	१५३	२६	२३	२५५	८९	२०००७.१
	उत्पादकत्व मे टन/हे	१.१	०.९	०.९	१.३	०.८	१.०	१.१३

स्रोतः प्रदेश कृषि डायरी, २०८० तथा प्रदेशस्थित कृषि ज्ञान केन्द्रहरूबाट लिइएको तथ्याङ्क एवं विवरणको आधारमा तयार पारिएको।

कोदोजन्य बाली र यसबाट बन्ने परम्परागत खाद्य परिकारहरू र तिनको धार्मिक तथा साँस्कृतिक महत्त्व

पोषणका हिसाबले हाम्रो शरिरका लागि चाहिने धैरै जसो पोषक तत्व उपलब्ध हुने र प्रसस्त मात्रामा फाईवर पाइने भएकोले कोदोजन्य बाली स्वास्थ्यका लागि राम्रो मानिएको छ। यसको उपभोगको हिसाबले हेर्दा सुदूरपश्चिममा अहिले पनि कोदोको पिठोको हलुवा बनाएर सुत्केरीलाई खुवाउने प्रचलन रहेको छ। यसले सुत्केरीको शरीरलाई तातो गर्ने, जीउ कसिलो बनाउने, शरिरमा रगतको मात्रा बढाउने मान्यता रहिआएको हुँदा सकेसम्म गाईको शुद्ध घिउमा हलुवा बनाएर अनिवार्य रुपमा खुवाउने गरिन्छ। त्यसका अलावा कोदोको ढिडो तथा रोटी बनाएर पनि खाने गरिएको छ। त्यसै गरी हिउँदको समयमा लामो सम्म रुघाखोकी लागेर ठीक भएन भने पनि कागुनोको खिर बनाएर तातो खिरको वाफ लिनका लागि खिर पकाएको भाँडो नजिक मुख राखी माथिवाट बाक्लो सिरकले ओढाउने र वेस्सरी पसिना निकाल्ने र वाफ लिने प्राकृतिक उपचार पद्धति पनि निकै नै लोकप्रिय छ। लट्टे (स्थानीय स्तरमा मार्से भनिन्छ) लाई भुटेर सातु बनाउने, भेली वा महमा मोलेर लड्डु वनाउने, कहिलेकाँहि भुटेर सिधै खाने वा रोटी बनाएर खाने पनि गरिन्छ। चिनोको खिर निकै नै मिठो हुने गर्छ भने यसलाई भातकोरुपमा पनि पकाएर खाने गरिन्छ। जुनेलोलाई मकै जस्तै भुटेर पनि खाने गरिन्छ भने यसको पनि लड्डु बनाएर खाने गरिन्छ। त्यसै गरी कागुनो जस्तै वाला सिधा माथि आकाशतिर फर्केको स्थानीय स्तरमा झुमरो भनिने कोदोजन्य बाली पनि केहि स्थानमा पाईन्छ। यसलाई विभिन्न धार्मिक पुजापाठ तथा कार्यक्रममा प्रसादको रुपमा यसको सुजि जस्तै हलुवा वनाएर खाने, घरमा खिर वा भात पकाएर पनि खाने गरिन्छ।

कोदोजन्य बालीको उत्पादन र मूल्य श्रृंखला विकासको अवसर र सम्भावना

विगतमा खाद्य सुरक्षा तथा पोषणको महत्त्वपूर्ण आधारको रूपमा रहेको भएतापनि आधुनिक जीवनशैली र सोसँगै खाने बानीमा आएको परिवर्तन लगायतका कारण कोदोजन्य बालीहरूको उत्पादन तथा उपभोग घट्दै गइरहेको तथ्याङ्कले देखाउँछ। विभिन्न धार्मिक तथा सामाजिक र स्वास्थ्यका हिसाबले परम्परादेखि नै यी बालीहरूको लोकप्रियता भए पनि गरीवी र अभावको बेला अन्य केही विकल्प भएन भने वाध्यात्मक अवस्थामा मात्रै खाइने रैथाने बालीको पुरानो पहिचान समयक्रम सँगै स्वास्थ्य प्रतिको सजगताका साथै अर्गानिक उत्पादन प्रतिको आकर्षणले गर्दा वदलिएको छ। हिजोआज सचेत उपभोक्ताहरू र शहर बजारका उपभोक्ताहरूले खोजेर खाने भएसँगै यसको उपभोगमा बृद्धि हुँदै गईरहेको पाइन्छ। विभिन्न रैथाने बाली प्रवर्द्धन सम्बन्धी कार्यक्रम, यी बालीको बजारीकरण र स्वास्थ्य तथा पोषण प्रतिको सचेतनाका कारण पछिल्लो समय कोदोजन्य बालीप्रति नेपाल तथा विश्वव्यापी रूपमा नै आम चासो बढ्दै गएको पाइन्छ। कोदोजन्य बालीहरूमा विद्यमान खाद्य सुरक्षा, स्वास्थ्य तथा पोषण एवं जलवायु परिवर्तन न्यूनीकरण तथा अनुकूलन सम्बन्धी गुणलगायतका कारणले गर्दा पनि यी बालीहरू प्रतिको चासो र आकर्षण बढ्दै गएको पाइन्छ।

सुदूरपश्चिम प्रदेशको अधिकांश खेतीयोग्य जमिन एवं जलवायु कोदोजन्य बालीको खेतीको लागि प्रायः उपयुक्त नै देखिन्छ। धान तथा गहुँ जस्ता बालीहरूको तुलनामा प्रायः छोटो अवधिमा नै तयार हुने भएकाले ती बालीहरूको खेती विस्तारमार्फत उत्पादन बढाई चामलमाथिको अत्यधिक निर्भरता कम गरी खाद्य सुरक्षा र आत्मनिर्भरतामा प्रत्यक्ष टेवा पुर्‍याउन सम्भव छ। कोदोजन्य उत्पादन प्रोटीन, फाइवर, भिटामिन, आइरन, क्याल्सियम, म्याग्नेसियम लगायतको राम्रो स्रोत भएकाले शरीरको लागि आवश्यक पोषणको आपूर्ति गर्नमा महत्त्वपूर्ण भूमिका निर्वाह गर्ने भएकोले सुदुरपश्चिम प्रदेशमा व्याप्त खाद्य असुरक्षा र कुपोषणको समस्या सम्वोधन गर्नमा कोदोजन्य रैथाने बालीको अहं भूमिका हुने देखिन्छ। ।

जलवायु परिवर्तनको दृष्टिकोणबाट पनि अन्य बालीहरूको तुलनामा कोदोजन्य बालीहरू बढी उपयुक्त छन्। यस्ता बालीहरू रासायनिक मलखाद र विषादिको प्रयोग नगरी वा कम गरेर पनि औसत उत्पादन लिन सकिने प्रकारमा हुने हुँदा हानिकारक हरित ग्याँस उत्सर्जन कम गर्नमा सघाउ पुर्‍याई जलवायु परिवर्तन न्यूनीकरणमा समेत सहयोगी छन्। त्यसैगरी अन्य बालीहरूको तुलनामा यी बालीहरूमा कम सिंचाइ भएमा पनि खेती गर्न सकिने र सुक्खा, खडेरी तथा उच्च तापक्रम बढी सहन सक्ने गुणहरू विद्यमान भएकोले जलवायु परिवर्तन अनुकूलनको दृष्टिले पनि उपयुक्त छन्। सुदुरपश्चिम प्रदेशको खास गरी पहाडी र हिमाली क्षेत्र कम वर्षा हुने क्षेत्र भएको र जलवायु परिवर्तनको दृष्टिले जोखिमयुक्त क्षेत्र भएको कारण यी बालीहरूको खेती विस्तारबाट स्थानीय जनताको खाद्य सुरक्षा र जलवायु परिवर्तन उत्थानशिलता (Resilience) बढाउनमा सघाउ पुर्याउन सकिने सम्भावना देखिन्छ।

कोदोजन्य बालीको मूल्य श्रृंखला विकास र बजारीकरणमा भएका प्रयासहरू

सुदूरपश्चिम प्रदेशमा कोदोजन्य बालीहरूको महत्त्वबारे प्रचारप्रसार गरी तिनको उत्पादन र उपभोग बढाउन विभिन्न प्रयासहरू भै रहेका छन्। उत्पादक कृषक, उपभोक्ता र अन्य सरोकारवालाहरूलाई प्रेरित गर्न तथा वजारीकरण प्रवर्द्धन गर्न विभिन्न जिल्लामा कोसेली घरको स्थापना, धनगढी तथा महेन्द्रनगर जस्ता ठुला शहरमा बिक्री केन्द्रको स्थापना, धनगढीमा एग्रो मार्ट स्थापना गरी रैथाने बालीको बिक्री लगायत विभिन्न परिकारहरू सहितको रेष्टुरेन्टहरू संचालन आदि रहेका छन् । यसै गरी खाद्य तथा व्यापार कम्पनि लिमिटेड मार्फत कोदोजन्य र अन्य रैथाने बालीको उत्पादन खरिद गर्ने कार्यको अलावा स्थानीय तहहरू मार्फत पनि वजारीकरणका लागि विभिन्न प्रयासहरू भईरहेका छन्। यस दिशामा संघीय सरकारको रैथाने बाली प्रवर्द्धन कार्यक्रम जस्तो अभियानमूलक कार्यक्रमले यस प्रदेशमा कोदोजन्य रैथाने बाली प्रवर्द्धनमा उल्लेखनीय योगदान गरेको पाइन्छ। रैथाने बाली प्रवर्द्धन कार्यक्रम कार्यान्वयनको लागि विगत पाँच वर्ष देखि संघीय सरकारले संघीय सशर्त अनुदान प्रदेश र स्थानीय तहहरूमा उपलव्ध गराउँदै आएको छ। यस्ता प्रयासहरू मार्फत कोदोजन्य बालीको क्षेत्र विस्तार, उत्पादन तथा उत्पादकत्व वृद्धि तथा वजारीकरणमा सकरात्मक प्रभाव परेको अवस्था छ।

समग्र सुदूरपश्चिम प्रदेशमा बाजुरा जिल्लाबाट रैथाने बालीप्रवर्द्धनको विशेष अभियान थालनी भएको पाइन्छ। रैथाने बाली प्रवर्द्धनका लागि सरकारी र गैर सरकारी क्षेत्रबाट विगतदेखि नै केहि न केहि प्रयासहरू भएका भएता पनि अभियानका रुपमा आर्थिक वर्ष २०७२/७३ देखि रैथाने बाली प्रवर्द्धन अभियान शुरु भएको पाईन्छ। यस जिल्लामा विभिन्न कोदोजन्य र अन्य रैथाने बालीहरूबाट बनाईने परिकारहरू जस्तै फापरको मफिन वा केक, चिनो तथा कागुनोको खिर, कोदोको हलुवा, लट्टेको लड्डु, स्थानीय सिमि र आलुको झोल तरकारी र चट्नी समावेश गरी एक पूर्ण स्वस्थवर्धक एवं पोषणयुक्त खानाको सेट प्रचलनमा ल्याइएको छ जस्लाई बाजुरा रैथाने तथा अर्गानिक थाली नामाकरण गरिएको छ जुन केहि स्थानीय होटल तथा रेष्टुरेन्टहरूमा मागको आधारमा सर्भ गर्ने गरिन्छ। पछिल्लो समय उक्त रैथाने खाजा सेट स्थानीय बजारको अलावा जिल्लाका अन्य बजार क्षेत्रहरूमा र बाहिरी जिल्लाहरूमा पनि लोकप्रिय बन्दै गइरहेको पाइन्छ।

त्यसै गरी कृषि ज्ञानकेन्द्र बाजुरा लगायतका केहि सरकारी कार्यालयहरू र प्रदेश अन्तर्गतका केहि स्थानीय तहहरूले बैठक, तालिम, गोष्ठी लगायतका औपचारिक कार्यक्रमहरू कोदोजन्य र अन्य रैथाने बालीबाट तयार पारिएका खाद्य परिकार खाजाको रुपमा उपभोग गर्ने क्रम विगत केहि समय देखि जारी रहेको छ। यी र यस्ता प्रयासहरूको कारण स्थानीय कृषकहरूलाई पहिलेको जस्तो यस्ता रैथाने उत्पादनहरू कहाँ बेच्ने होला भन्ने अवस्था अब छैन।

कोदोजन्य रैथाने बालीको उत्पादन एवं मूल्य श्रृंखला विकासमा रहेका समस्या एवं चुनौतिहरू

सुदुरपश्चिम क्षेत्रको खाद्य पोषण सुरक्षा तथा सामाजिक आर्थिक रुपान्तरणमा कोदोजन्य रैथाने बालीको बहुआयामिक महत्त्व रहेको भएता पनि यी बालीहरूको बालीको क्षेत्र विस्तार, उत्पादन तथा उत्पादकत्व वृद्धि र मूल्य श्रृंखला विकासमा उत्तिकै चुनौतिहरू पनि रहेका छन्। बढ्दो उत्पादन लागत र कम प्रतिफलको कारण फाइदाजनक नहुने हुँदा कृषकहरू यस्ता कोदोजन्य रैथाने बालीहरूको खेती प्रति कम आकर्षित हुने गरेका छन्। यसको साथै पहिले अन्य विकल्प नहुँदा वाध्यतावश खेती गरीँदै आएको भए पनि पछिल्लो समयमा चामलको सहज उपलव्धता र सडक संजालका कारण रैथाने बालीप्रतिको निर्भरता घट्दा खेती गर्ने क्रम पनि क्रमशः घट्दै जानु, अधिकाँश स्थानीय जातहरू धेरै पुराना भएका कारण उत्पादत्व न्यून

हुनु, परम्परागत खेती प्रणालीको बाहुल्यता रहनु, व्यवसायीक रुपमा नभई एउटा परम्परा निर्वाहको लागि स सानो जमिनमा मात्रै खेती गरीनु र कतिपय स्थानमा पुराना बालीहरूको वीउ समेत लोप भई सकेको अवस्थामा खेती गर्न चाहेर पनि वीउको सहज उपलव्धता नहुनु जस्ता कारणले गर्दा पनि आशातित रुपमा उत्पादन बढ्न सकेको पाइँदैन। त्यसै गरी परिकार विविधिकरणको कमि र अन्य कोदोजन्य रैथाने बालीका तयारी खाद्य पदार्थको उत्पादनको कमजोर अवस्था, कोदोजन्य बालीको प्राथमिक उत्पादन, कच्चा पदार्थ र प्रशोधित तयारी खाद्य पदार्थको लागि भरपर्दो वजारको सुनिश्चितताको अभाव रहेको कारण पनि कोदोजन्य बालीको प्रवर्द्धनमा सोचेजस्तो सफलता प्राप्त गर्न सकिएको छैन।

निष्कर्ष

सुदुरपश्चिम प्रदेशको खासगरी पहाडी क्षेत्रहरूमा परम्परागत रुपमा कोदो तथा कोदो जन्य बालीहरूको खेती हुँदै आएकोमा सडक सञ्जालको विस्तार र बजार केन्द्रको विकास सँगै आधुनिकता र खाद्य संस्कृतिमा आएको परिवर्तन लगायतका कारण यी बालीहरूको खेती गर्ने क्रम र उपभोग घट्दै गएको पाइन्छ। तथापी, पछिल्लो समय कोदोजन्य रैथाने बालीका फाइदा एवं गुणहरूको बारेमा सचेतना बढ्दै जाँदा खासगरी शहर बजार र सचेत उपभोक्ताको माग बढ्दै गएको पाइन्छ। बढ्दो माग पुरा गर्न उत्पादन बढाउन सकिने प्रयाप्त अवसर र सम्भावना विद्यमान भएता पनि त्यस दिशामा विभिन्न समस्या तथा चुनौतिहरू रहेका छन्। खासगरी उत्पादन लागत कम गरी र उत्पादित उपजको बजार सुनिश्चितता गरी कृषकलाई ति बालीहरूको उत्पादन तर्फ आकर्षित गर्नु र परिकार विविधिकरण तथा मूल्य श्रंखला विकास गरी जंकफूड तथा फास्टफूडमा अभ्यस्त युवापुस्तालाई कोदोजन्य परिकार तथा प्रशोधित खाद्य पदार्थ प्रति आकर्षित गर्नु प्रमुख चुनौतिको रुपमा रहेको छ। त्यसै गरी दुर्गमता र भौगोलिक विकटताको कारण सानो परिमाण र छरिएर रहेको उत्पादन बजार मुल्य श्रृंखलासँग स्थायी रुपमा जोडिन पनि अप्ठ्यारो छ।

यी केहि समस्याहरूको सम्वोधन गर्न सकिएमा कोदोजन्य बालीको उत्पादन वृद्धिवाट खासगरी पहाडी क्षेत्रमा रहेको वाँझो तथा कमसल जमिनको अधिकतम सदुपयोग गर्न सकिनुकोसाथै उत्पादनको बिक्रीवाट स्थानीय कृषकले राम्रो आम्दानी लिन सक्ने देखिन्छ। यसवाट समग्र पहाडी तथा ग्रामिण क्षेत्रको आर्थिक गतिविधिमा वढोत्तरी हुन गई रोजगारी सृजना र आय वृद्धिमा महत्त्वपूर्ण योगदान पुग्न जाने छ। यसको अतिरिक्त कोदोजन्य उत्पादनको नियमित सेवनवाट आयातित चामल माथिको परिनर्भता घट्न जानुको साथै स्थानीय खाद्य तथा पोषण सुरक्षामा समेत टेवा पुग्ने देखिन्छ।

अतः कोदोजन्य रैथाने बालीको उत्पादन वृद्धि र मूल्य श्रृंखला विकास मार्फत समग्र सुदुरपश्चिम प्रदेशको खाद्य सुरक्षा र पोषणको स्थितिमा सुधार र ग्रामिण रोजगारी तथा आय आर्जनको अवसरको विस्तार गरी ग्रामिण रुपान्तरणको ढोका खोल्न सम्भव हुने देखिएकोले यस दिशामा स्थानीय कृषक र सवै सरोकारवालाहरूको ठोस र योजनावद्ध प्रयासको आवश्यकता देखिन्छ।

सन्दर्भ स्रोतहरू

बार्षिक कृषि विकास कार्यक्रम तथा प्रगति पुस्तिका, आ.व. २०७२/७३, जिल्ला कृषि विकास कार्यालय, बाजुरा

रामकृष्ण श्रेष्ठ २०७३, बाजुराका स्थानिय तथा रैथाने खाद्यान्न बालीहरू र तिनको प्रवर्द्धनका लागि भएका प्रयासहरू पुस्तिका

प्रदेश कृषि विकास डायरी २०८०, कृषि विकास निर्देशनालय, दिपायल, डोटी

बार्षिक कार्यक्रम तथा उपलव्धि पुस्तिका आ.ब.२०७८/०७९, कृषि विकास निर्देशनालय, दिपायल, डोटी

रामकृष्ण श्रेष्ठ, बढ्दो खाद्य असुरक्षा र अन्तर्राष्ट्रिय कोदोजन्य बाली वर्ष २०२३, २०७९ पुष १७ गते अनलाईनखवरमा प्रकाशित लेख

मीनप्रसाद जैशी २०७७, रैथाने बालीहरूको खेती प्रविधि तथा परिकार तयारी पुस्तिका, कृषि ज्ञान केन्द्र बाजुरा

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Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

Potentiality of Finger Millet in Eastern Mountain Landscape of Nepal

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Abstract

Finger millet (*Eleusine coracana*) is an important crop in Nepal, which is widely grown in mountain landscape. It is farmer's choice due to its high drought tolerance, and the long storage time span of the grains. Among different species of millet in Nepal, finger millet (Kodo) is the most important crop in terms of area of production and yield. In this study we have explored the potentiality of finger millet in terms of trade value, use patterns, and ecological potential in the mountain settlements of Sankhuwasbha district in eastern Nepal. Among them, we have further analyzed the ecological potential of finger millet. Local farmers mentioned that this crop could be instrumental as an early succession crop in the barren mountain terrain, in utilizing the fallow land in mountains, as it can be easily grown in dry, slopy terraces with low harvesting cost depending on monsoon rainfed. We could initiate a concept of no more barren land in mountains, and by utilizing fallow land that help us improving our food security and promoting land stability as well as controlling weed invasion in mountain landscapes.

Keywords: Drought, ecological potential, fallow land, finger millet, mountain landscape, slopy terraces

Introduction

Finger millet (*Eleusine coracana*) is a grass family (Poaceae) plant and is widely cultivated in Africa and Asia. It is considered as the oldest domesticated tropical African cereal, believed to have been originated about 5000 years ago in the beginning of Iron Age in the highlands of Eastern Africa (western Uganda to Ethiopia). Finger millet (FM) is a self-pollinating crop developed by genome multiplication while domesticating wild millet variety *Eleusine africana*, and is cultivated at altitudes over 2000 m above sea level. It is farmer's choice due to its high drought tolerance, and the long storage time span of the grains. Over 15 different species of finger millet are reported in the world, and three of them namely *Elusine coracana, E. indica* and *E. aegyptica* are only found in Nepal (Kandel *et al* 2019a). Different species of millet are under cultivation in Nepal such as proso millet, foxtail millet, barnyard millet, pearl millet, little millet and kodo millet (Ghimire et al 2017). Among them FM (Kodo) is the most important crop in Nepal in terms of area and production. In Nepal FM is the fourth major crop after rice, maize and wheat, representing major component of Nepalese agriculture, especially in mountainous terrain at which paddy plantation is not possible. It is often considered a poor person's crop despite being rich in high quality nutrients including minerals.

FM is mainly grown in more than 70 districts in Nepal, with the higher diversity in mid hills (MoALD 2022). It could be highly potential crop in hilly areas of Nepal, where the environment is getting harsher due to rapidly warming temperatures and higher uncertainties of rainfall trend in the recent decades. FM can be easily grown in mountain terraces with low investment and there is high potential of this crop in the context of rapidly changing climate in mountains due to its adaptability and suitability for low, marginal lands even for harsh weather conditions (Gull et al 2014, Kandel et al 2019b). FM is one of the easy crops in terms of harvesting procedure, which is providing multiple livelihood options such as food, nutrients, fodder and provision of ecological balance of hill agroecosystem in Nepal. It is also considered Himalayan Superfoods because it is glutton-free, nutrient rich, rich in dietary fibers, consists of rare amino acids, vitamins and protein. Although its production in Nepal could be easily raised, Nepal is importing huge quantity of millet in the recent years even though its productivity has increased over a period.

FM is the main crop in eastern Nepal (Province 1), which is the region of highest productivity of millet in Nepal. Although people in many parts of the nation are consuming less amount of millet as their food, the use of FM is increasing for making alcohol and related products is taking its toll. At least millet is being happily harvested in the mid hills of eastern Nepal including Sankhuwasabha district, where three major alcohol products: *Jand*, *Tongba* and *Raksi* are quite popular. Now it has been high time to educate people about the health benefits of millet and promote this Himalayan Superfoods in our daily food menu rather than the exploitation of millet in alcoholic beverages only. The happiness of reviving the neglected crop as seen in Sankhuwasabha district will proliferate if we could be independent in millet production in our homeland and could fight against malnutrition of children living in mountain areas of Nepal by its maximum consumption as staple food.

Due to topographic variation formed by altitude and regional climate pattern, Nepal harbors varieties of FM grown by smallholder farmers across different altitudes, farming systems, and locations, hence Nepal could also contribute as secondary center of FM diversification. It is cultivated as high as 3100 m altitude from sea level in Humla district of western Nepal, and it is reported as the highest altitude of finger millet harvest in the world (Baniya et al 1992, Ghimire et al 2017, Ghimire et al 2020). Millet crop could be one of the best options in warmer and drier world (IPCC, 2014) as being a C4 plan with high photosynthetic efficiency, rich nutrients, and climate resilient crop particularly with high adaptation to drought and other environmental stresses (Ghimire et al 2020, Gauchan et al 2019).

Harvesting FM is one of the oldest farming systems in Nepal, and millet is harvested in diverse climatic conditions exposed to different habitat conditions. Hence it is believed that the millet of Nepal constitutes globally important unique gene pools associated with great nutritive value, cold, drought, and pest tolerance that are highly important for food and nutrition security of the smallholder farmers and mountain communities in context of rapidly changing climate in Nepal (Ghimire et al 2018, Gauchan et al 2019). In mountain regions of Nepal, FM is grown under natural organic conditions, which is providing multiple securities for food, fodder, low-cost nutrition, and ecological functions and stability for smallholder mountain farmers. This crop stands out as a gluten-free and nutrient-rich option, boasting an abundance of micronutrients, dietary fibers, rare amino acids, vitamins, and notably higher levels of protein, calcium, and iron when compared to major food staples like rice, wheat, and potatoes (Gauchan 2019). It has earned recognition as a "Future Smart Food" due to its exceptional nutritional value, adaptability to local conditions, resilience in the face of climate challenges, and its potential for diversifying agricultural risk (Ghimire et al 2018, Joshi et al 2019, Gauchan et al 2019).

With overall increase in gross domestic production MoALD (2022), and significant rise in import value over a five-year period, soaring from NRs. 44.43 billion in 2009-10 to NRs. 127.51 billion in 2013-14 (Gairhe et al 2018), the consumption of FM is ever increasing in Nepal. Despite the increased productivity of millet in recent years, Nepal still invested NRs 180.10 million in millet imports in 2019 (TEPC 2019). This clearly indicates that FM is still a high potential crop for the mountain landscape in Nepal. This study therefore is aimed at analyzing the production trend, use patterns and ecological role of FM harvesting in mountain settlements of Sankhuwasabha district of eastern Nepal, where growing FM is one of the oldest agricultural practices, as the locals have very low availability of land to grow paddy.

Materials and Methods

This study was carried out in mountain settlements of Sankhusabha district in eastern Nepal, that included Rukuma, Chepuwa, Lingam, Chyamtang, Chumsur, Ridak villages at Bhotkhola Rural municipality (**Figure 1**). A total of 12 key informants were selected as local farmers and were consulted regarding the potential of finger millet as an agricultural component. Secondary data compiled from faostat and MoALD (2022) were analyzed.

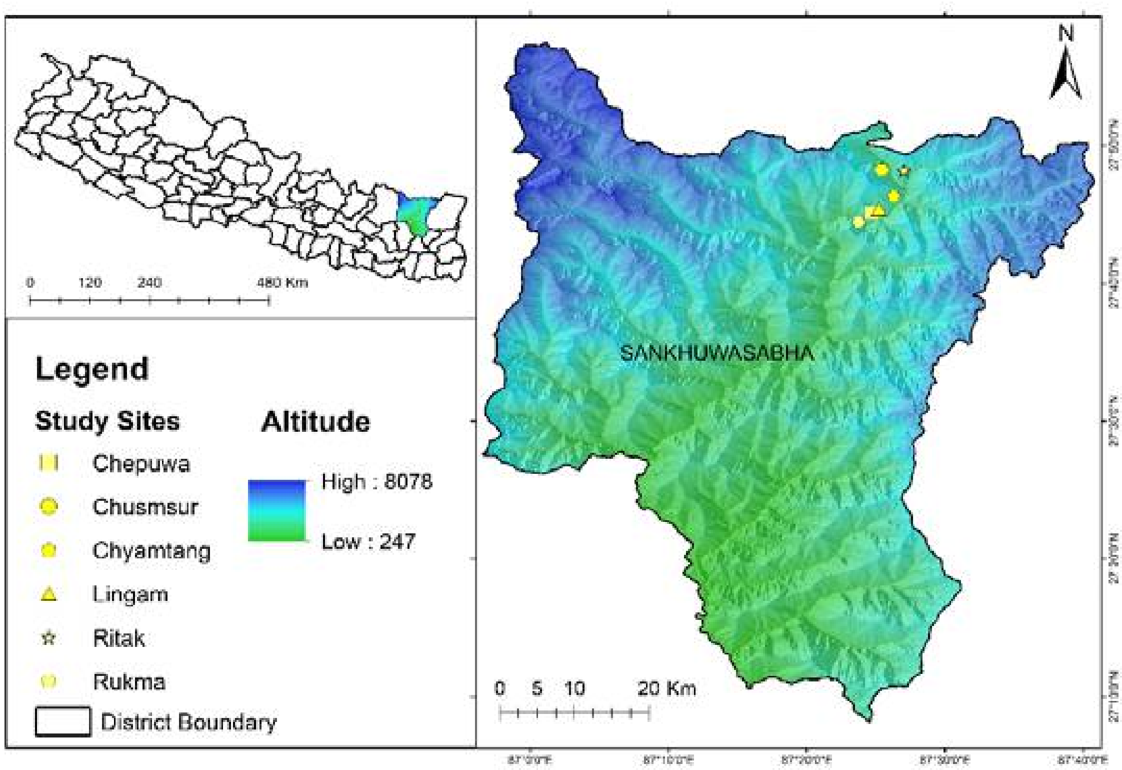

Figure 1. Map of study area in Sankhuwasabha district of Eastern nepal

Results and Discussion

Finger millet production status

The results showed that there has been a significant increase in total production of FM as well as the crop yield in recent decades (**Figure 2**) in Nepal. However, there has been no increase in the harvested land for FM in recent decades. This clearly indicates that the increased production is either attributed to the use of chemical fertilizers or due to climate suitability in the region.

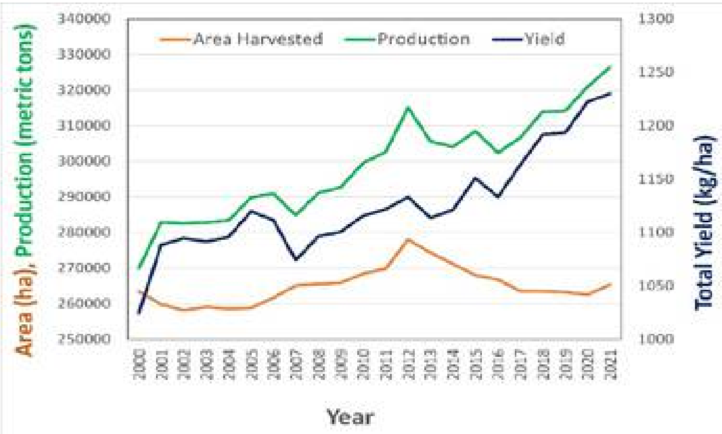

Figure 2. Annual production (metric tons), harvested area (ha) and total yield of finger millet in Nepal (kg/ha) (www.fao.org/faostat)

When the production rate was analysed for the last five fiscal years in Sankhusabha district, the trend is quite different. There was no trend for the harvested area and total production however, there has been significant rise in total yield of FM per unit area of harvested land (**Figure 3**). The increasing pattern of total yield in Sankhuwasabha showed the similar trend for whole Nepal. thus there is a huge potentiality of increasing the production of FM in Sankhuwasabha district by increasing the harvetable areas in the district.

There are only five varieties of FM released by the government of Nepal (SQCC 2019) with their productivity rangeing from 2.4 to 3.3 t/ha. However average productivity in Nepal is far below the potential productivity. Hence, more is yet to be done to increase the productivity of FM in Nepal. Studies already predicted that there will be a significant shrinkage of existing suitable FM growing areas with an increase in temperatures, increasing erratic pattern of rainfall and increasing drought stress in the warmer future in Nepal (Zomer et al 2014, Luitel et al 2020). Further, the declining trend in FM farming in mountain settlements in Nepal is also due to labour shortage and processing difficulty for the farmers (Devkota et al 2016, Ghimire et al 2017, Gauchan 2019).

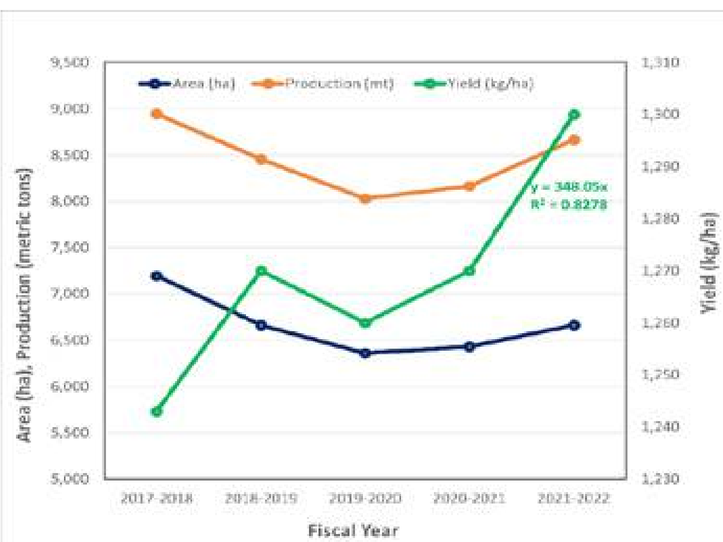

Figure 3. Annual production, area and yield of finger millet in Sankhuwasabha district Nepal

Use patterns of finger millet

FM is a multipurpose crop used in different forms. We have identified five different common uses of finger millet from the villages in Shankhuwasabha district. They are *Raksi*, *Jand* (*Tongba*), *Dhindo* (thick porridge), *Roti* (Bread), *Khole* (thick soup of millet flour). The maximum use of this crop is making alcoholic products (*Raksi* and *Jand*) followed by *Dhindo*, whereas the minimum use in the form of *Khole* in the study areas. The substantial use of finger millet in alcohol and alcoholic products could be an important strategy of minimizing the trade of branded alcoholic products, although the quality control issues, and government rules and regulations have always been critical. During the interview most of the respondents mentioned that the use of FM as staple food (mainly in the form of Dhindo) is declining in recent years as rice is easily available in the local market due to ease in transportation. Some local villagers think that eating dhindo is a symbol of poverty, and many prefer rice even selling their FM stock. There is an urgent need to make local people aware of the health benefits of FM which is mainly related to high amount of calorie and easily available minerals in the millet.

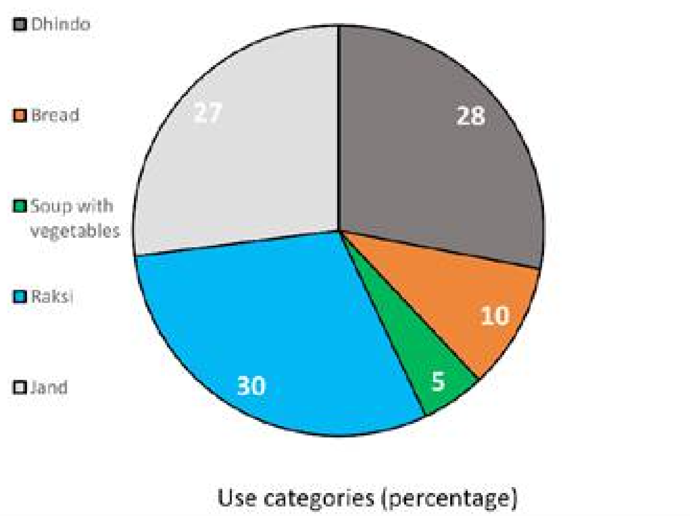

Figure 4. Use patterns of finger millet as approximate estimation in percentage (average of KII quantity)

The limited consumption of FM as a food in this area, as well as throughout Nepal, can be attributed primarily to the limited food recipes known by the local people. In Nepal, the predominant food processing techniques include milling, cooking, and fermentation. However, FM offers a wide range of food processing options, including soaking, malting, puffing, roasting, extrusion, and radiation as practiced in India (Chandra et al 2018). These various techniques have significantly contributed to the promotion of FM as a staple crop and have added value to its use.

In light of the increasing concerns regarding obesity and diabetes, FM could serve as an essential choice for providing gluten-free, non-acid-forming (Muthamilarasan et al 2016), easily digestible, and low glycemic index foods (Manjula and Visvanathan 2014). Its low glycemic index makes it particularly suitable for individuals with conditions like celiac disease (caused by the consumption of gluten-containing cereal proteins) and diabetes, as it helps regulate blood glucose levels (Jideani and Jideani 2011). FM grains are also rich in vital nutrients such as dietary fiber, carbohydrates, iron, and calcium, with concentrations surpassing those found in other cereal grains (Sood et al 2016). Furthermore, FM grains contain significant amounts of magnesium and phosphorus, and the absorption and utilization of these nutrients in the human body contribute to the reduction of chronic diseases, including high blood pressure, ischemic strokes, cardiovascular diseases, cancers, obesity, and type II diabetes (Kaur et al 2014, Ramashia 2018).

Ecological and Economic benefit

The ecological and economic benefit of FM in terms their sustainable harvesting in the region were collected. Local communities are well-acquainted with the complementary properties of FM for intercropping and cross-cropping, which constitute integral aspects of integrated agricultural practices in mountainous landscapes. Over 60% of farmers engage in the practice of intercropping FM with maize, a crucial approach for preserving soil nutrient levels, weed control, and ensuring food sustainability. The relay intercropping of maize and finger millet is a well-established tradition in Nepal, particularly prevalent in hill agriculture. FM is typically cultivated on the residual fertility of maize crops, with farmers applying approximately 10-25 tons per hectare per annum of manure to maize (Sthapit and Subedi 1990). In the higher altitudes, the overlap period between maize and millet cropping becomes longer (Subedi 2001), and FM flourishes with minimal competition after maize is harvested. The efficient utilization of available moisture following maize removal is pivotal to enhancing this farming system (Bishwokarma et al 2001). Furthermore, intercropping presents a promising opportunity to enhance profitability while keeping fixed land costs low, as it allows for the cultivation of a second crop in the same field (Thobatsi 2009).

The local people realize that consuming FM is far more healthier than rice although the new generation is hesitant to eat FM as a part of their meal. FM in the study area is still the first choice for making alcohol and alcoholic products, and in some places it is only used to make alcohol and related products despite the fact that local alcohol and alcholic products are not legalized and there are some legal consequences on it. FM crop is an imortant part of traditional agricultural system where livestock and millet go side by side, mainly the animal derived manures have been highly effetive to improve millet yield. The fodder both fresh and dry are widely used for livestock, the dry fodder in winter is highly beneficial for cattles as the fodder contain relatively high amount of carbohydate (Kaithwas et al 2020).

The local people also shared important ecological benefit of millet in mountain settlements. Millet can be easily grown in slopy terraces where any crop can not be grown apparently. In such slopy terrain millet can be grown to maintain slope stability and control soil erosion basically in the monsoon season when there is high rate of rainfall. One is successfully able to grow millet, the same terrain can be used to grow maize and other vegetables. Millet can promote soil nutrient quality and perpetuates soil quality as a result the soil is ready to support other agricultural products. Invasive alien plant species (IAPS) have been recognized as one of the emerging threats to biodiversity and habitat degradation (Shrestha 2019), and it is mentioned that there are 27 species of IAPS in Nepal (Shrestha and Shrestha 2021). The number of IAPS and their climatically suitable areas in Nepal has increased over time with the future potential to increase owing to increasing agricultural abandonment and fallow land in Nepal (Shrestha and Shrestha 2019). Large amount of investments are used to contend the spread of IAPS globally. In this context growing finger millet in barren area is highly cost effective method of controlling the invasion of IAPS, which could also improve food security as well as biodiversity conservation.

Harvesting FM has also been shown to bring about a range of environmental benefits. It contributes to the enhancement of microclimates and water tables, promotes agricultural biodiversity, mitigates soil erosion, enhances soil biota and overall soil health, and facilitates the renewal of nitrogen and carbon in the soil (Praveen et al 1997). Additionally, FM efficiently manages water and nutrient availability during periods of scarcity (Bright 2017, Ceperley et al 2012, Singh 2003). FM provides a variety of ecosystem services that benefit the environment. Some farmers also adhere to traditional practices of cultivating millets under tree canopy due to the high nutritional value of millets, their drought tolerance, ease of cultivation, and their ability to rejuvenate semi-arid or resource-poor land (Bose 2015, Pardo and Van Buren 2021).

The traditional FM harvesting methods primarily rely on renewable resources, making them a suitable approach to boost productivity while minimizing the risk of crop failure. A study in the West African Sahel (WAS) demonstrated that FM, specifically *P. reticulatum*, doesn't compete with millets for limited water resources, as shrubs in this region utilize water from the previous rainy season for growth in the following year (Bright 2017). The millet-based agroforestry (MbAF) system is not only cost-effective but also compatible with low-input farming systems. It plays a crucial role in ensuring the sustainable management of soil, land resources, and ecosystem services (Bado et al 2021).

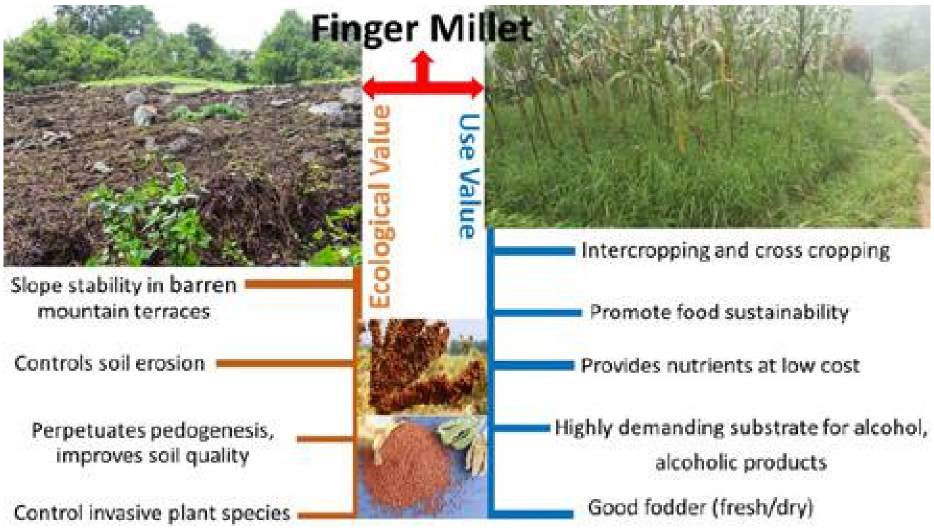

Figure 5. Ecological and economic benefit of finger millet as revealed by Key Informant Interview in Sankhuwasabha district.

Native crops and their local varieties including local rice, buckwheat, finger millet, corn, foxtail millet and many vegetables are on the verge of extinction in most part of Nepal due to ever increasing exploitation of so-called improved variety hybrid crops and vegetables. It is estimated that the practice of growing indigenous crops has been reduced to as below as 10 per cent, as most of the farmers in Nepal have switched to exotic crops, thus putting local crops at the risk of complete disappearance. The introduction of hybrid seeds every year has been the regular practice, which is not only costly but also attenuating our native gene pool. Further, there has been huge uncertainties about the efficacy of the easily available seeds in the local market of Nepal. The seeds of native crops like buckwheat and finger millets are already difficult to find although these crops are healthier than other crops. However, nutritious crops have been the choice of health-conscious people of urban areas of Nepal in recent times. Agriculture has been no more of interest of Nepali youth; and they are increasingly turning away from agriculture, and they are very unaware of health benefits of local crops. Nepal must work sincerely to improve our agriculture to restrain the roaring import of goods including cereals and vegetables. There has been huge potential to improve agriculture and horticultural production in Nepal as the nation harbors the diverse climate and physiography. Hence, FM could effectively contribute as a resilient cereal that can provide an affordable and nutritious option and help guarantee food security while securing sustainability of agroecosystem in mountain landscape.

Conclusion

Finger millet is a vital crop in Nepal's mountainous landscapes, especially in areas without irrigation. The consumption of FM in Nepal is steadily increasing, as evidenced by rising local production and import rates. However, there has been no corresponding increase in the cultivated area of finger millet, making it imperative to focus on enhancing FM harvesting. This requires the of novel processing techniques and recipes for FM so as to make it more popular, along with efforts to promote it as a cost-effective, nutrient-rich cereal in Nepal. Moreover, additional studies are needed to assess farmers' acceptance of specific finger millet varieties and the factors influencing their adoption. Beyond the economic benefits of FM, integrating it into our agricultural system can also contribute to the ecological health of mountain agroforestry. However, unlocking the potential of underutilized crops like finger millet for climate resilience, food security, and nutrition necessitates addressing various economic and social constraints. This study underscores the substantial potential of FM, particularly concerning the national economy, food security, and sustainable agricultural practices in Nepal's mountainous landscape.

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The Science of Millets in Agriculture Curricula

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Abstract

Literature shows that millets are the oldest food known to humans as well as future food, but course contents and weightage of millets contents in curricula of agriculture courses at Agriculture Academic Institutions (AAI) of Nepal are placed as under-rated crops. More than 30 AAIs of six universities are making their efforts to design, modify and upgrade their academic curricula to address the country's emerging needs and priorities in agriculture academic sectors. In most of the faculties and institutions of universities a minimum attempt has been made over the past four decades to revitalize the curriculum, it has remained more or less static. The curriculum shows that Millets are considered a minor crop and fewer contents are included. Though there have been production-relevant advances of millet crops in the context of crop production, plant breeding, physiology, mechanization, new advances, varietal development and techniques, innovation, and research methods, the inclusion of millet in the agronomy curriculum is limited. Consequently, agriculture graduates put less priority on innovative community exposures to agronomical competencies of millet which results in a decline in the production and productivity of millet. In this connection, a study was conducted to review and prepare a synopsis of the status of millet from the science of millet integration in the curricula. A review of the course curriculum of millets from four universities: AFU, TU, PU, FWU, was performed to assess the content distribution of millets. The review aims to address the academic perspective of the ways to encourage and engage millet producers to fetch attractive financial returns as other crops. The article assumes that academic excellence is the fundamental to developing the scope of millet.

Keywords: Agriculture academic institutions, extension, food security

Background

Millets being cultivated in more than 130 countries have been considered an integral part of the diet of over 50 lakhs of people across Asia and Africa for centuries. Millet ranks fourth in terms of area of cultivation and production after rice, maize and wheat. Millet is cultivated in 3,39,462 ha of land with a total production of 21,44,568 MT (MoALD 2023). Finger millet, Foxtail millet, Proso millet, Sorghum, Barnyard millet, Pearl millet, Little millet and Kodo millet are cultivated in various parts of Nepal, however, the cultivation is limited to certain geographical regions. There has been almost 50% loss in the diversity of millet in Nepal while on the other hand the market scope of millet is increasing in terms of current changing consumption pattern. While millet provides good scope in terms of food security, employment and livelihood, it is equally important in terms of biodiversity because it is C4 plants and have numerous features to adapt to diverse environments, hardy crops with buffering capacity, abiotic and biotic resistance easy to grow with long storability uses as emergency crops (Joshi et al 2022).

Nepal along with other countries proposed Year 2023 as the International Year of Millets (IYM) in the 75th session of the UN General Assembly. Thus, the Food and Agriculture Organization and UN recognized 2023 as International Year of Millets 2023. The government of Nepal is also celebrating IYoM 2023 to promote sustainable millet production, raise awareness, direct policy attention and create domestic demands. This declaration is not sufficient until the stakeholders put sufficient efforts into the production, processing and marketing of millet which in turn needs skilled technical manpower for technology development in terms of production, processing and marketing of millet. So the integration of the science of millets in the university curriculum offer a sustainable solution to fortify nutrition, food security and safeguarding bio-diversity. Specific structure and curriculum can vary between universities and countries, reflecting local agricultural practices, research priorities, and the university's resources. However, millet as a future crop has to be highly prioritized in Nepal by the Agriculture Academic Institutions (AAI) because of its manifold reasons such as:

- Millets are climate-smart, hardy crops, rooted in ancient cultures and food traditions.
- Millets are produced organically without pesticides and with zero or low inputs.
- Millets are important for changing industry needs and scientific advancement
- Barren land is ever growing especially in the mid hills. So efforts to be concentrated on using these much barren land to engage ever-increasing youth migration tendency,
- Millets provides diversified food items with high nutrition and higher adaptability.
- Millets can be used for food, feed, nutrition, health, business and environment
- Millets like pearl millets can be used to prevent soil erosion as they have extensive root systems.
- Millets’ promotion helps to empower farming to control of food system and thus achieve food sovereignty.
- Dependency on imports for food can also be reduced.

The curriculum may evolve to keep up with changing industry trends and scientific advancements in agriculture. It is pertinent time to revitalize the content related to the millet in academic curricula at various levels of education. The significance of this study lies in the transformative power of academia and to drive socioeconomic transformation. For example, the inclusion of millet will help to develop technology for increased production and productivity of millet and develop it as a sustainable food source by identifying its climate-resilient farming practices. Its nutritional and health benefits can be unfolded through additional studies. It is important to equip agriculture students and graduates with accurate and up-to-date awareness-knowledge-attitude-skills continuum about millet and allied science to empower them to become change-makers in promoting millet cultivation, processing, value-adding, trading and consumption. Millet can be added to the courses of food science to develop diverse recipes to promote wider global cuisines. In the subsequent section of this paper, we have delved into the current state of millet content in agronomy, deficit, gaps and discrepancies. A possible approach of AAI-community engagement so that the millet could be learnt in the farming communities has been highlighted and the strategies for millet learning have been proposed.

Methodology

This article is primarily based on the review of literature. A review of course curricula of millets of four universities: Agriculture and Forestry University (AFU), Tribhuvan University (TU), Purbanchal University (PU), Far Western University (FWU) and Council for Technical Education and Vocational Training *(*CTEVT) was done to assess the distribution of contents of millets in the courses of respective universities. Departmental faculties and stakeholders from the research and extension agencies were also consulted to recapture their views from the curriculum perspectives. The purpose of this consultation is to triangulate the information that has been stated and transferred to learners through the teaching-learning process. The postgraduate students of the departments were also consulted to capture their perception of the distribution and their learning of the millets and allied crops in respective AAI of Nepal.

Results and Discussion

The current state of teaching-learning in agronomy of millets

Formal lectures and one way of delivery are the primary methods of teaching-learning in almost all of AAIs in Nepal. An innovative way of teaching-learning is limited by resource constraints in almost all of the AAIs are running under the faculties deficit situation (Khanal 2022). Further, there is no separate course specifically related to millet. Since the millets are neglected crops in terms of support for production and promotion as compared to other crops (CIFSRF 2014). They are included as a small part within the different courses of agronomy such as cereals crop production. This crop production is backed by other basic agricultural courses like pathology, entomology, plant breeding, soil, and so on (Striegel 2021). Other technical and human skill requirements are also transferred through different social science disciplines such as extension, and agribusiness. **Table 1** shows various courses and credit hours that are included in courses of different AAIs of Nepal. The credit hours indicate the number of classes per week where the theory class incudes one hour and the practical class for two hours.

Table 1. Name of course and credit hours related to millet in different AAIs of Nepal.

Faculty and institution	Name of the course	Credit Hours (theory and practical)
Institute of Agriculture and Animal Science (IAAS), Tribhuvan University	Agronomy of cereal crops	2+1
Faculty of Agriculture (FoA), Agriculture and Forestry University	Cereal crops	2+1
FoA, Far-Western University	Field Crop Production Advance agronomy, Biodiversity Conservation and NUS	2+1 2+1
Purbhanchal University	Cereal crop production I	2+1
CTEVT	Cereal crop production	2+2
TVE, MoE	Food crop production	2+2

Source: Authors compilation

Existing curricula include very less content related to millet in both theory as well as practical aspects. Although millet is specified in the course, the content is not sufficient to address the production and processing technologies. The teaching-learning methodologies are not mentioned. In current practice particular faculties prepare their own micro syllabus and instruction techniques according to the chapter and content of the course.

Current course contents are not updated enough to support the development of competencies for external field professionals. Also, the content needs amendment to provide basic knowledge in research and managerial competencies. Therefore, the current course content, credit hours and subject need to be revitalized. The revisions of the course content should be based on the recommendations and requirements as suggested by the academician, private sector, development expert, government organizations and field workers. The last curriculum updates in IAAS were performed in 2020 while the courses in AFU were developed in 2010 and PU in 2016. Marginal changes to the existing curricula are still unable to bring about the necessary changes in the millets sector.

On reviewing the course syllabus of IAAS/TU, AFU, FWU, PU, CTEVT and TVE, MoE teaching of millets was found in different courses of agronomy. The IAAS/TU syllabus included millets in the Agronomy of Cereal Crops course which included 13.33% theory lectures whereas the practical portion included 20% of work (**Table 2**). Similarly, other universities/institutions like AFU, and FWU also included specific millets lectures which included 10% (Cereal Crops) and 6.67% (Field crop production and Advance agronomy, Biodiversity Conservation and NUS) respectively (**Table 2**). Similarly, PU, CTEVT and TVE, MoE included millets along with other major cereal crops in their syllabus. Apart from IAAS/TU no other universities/institutions have practical work related to millets in respective courses.

Table 2. Lecture weightage on millets course of agriculture intermediate and undergraduate level of AAI.

University	Total theory lectures (hours)	Total practical lectures (hours)	Grand Total	Percentage in theory	Percentage in Practical	Percentage in total course (theory and practical)	Agronomy Theory courses (hours) offered	Agronomy Practical (hours) offered	Total Agronomy lectures (hours)	Percentage in total agronomy courses
TU/ IAAS	4	3	7	13.33	20	15.56	195	105	300	2.33
AFU	3	0	2	10	0	6.67	135	90	225	0.89
FWU	4	0	4	6.67	0	4.44	210	90	300	1.33
PU	9	0	9	30	0	20.00	120	60	180	5
CTEVT	6	0	6	20	0	13.33	210	150	360	1.67
TVE, MoE	24	0	24	37.5	0	18.75	192	192	384	6.25

Source: Authors compilation

Also, research extension and academic sectors are not uniformly interlinked. Strengthening of linkage and integration among agriculture research, extension and education agencies through functional linkage systems among these institutions is pivotal. So, discussion and networking among these institutions may be the beginning point to create collaborations for research extension and millet science-knowledge sharing. To make the faculties and institutions more responsive towards the millet as science 'Curriculum revitalization' and 'sensitization workshop' with the participation of Agriculture Research, Extension and Education (AREE) stakeholders is important to link and integrate (AREE) institutions for long-term and short-term sustainable promotion of millet crops.

Table 3. Agronomy department-wise credit hour related to crop production and seed technology

Faculty and institution	Theory lectures (Hours)*	Practical lectures (Hours)	Total lectures (Hours)	Percentage to total credit [12]
IAAS, Tribuvan University	13x15=195	7x15=105	300	300/2505=8.35
FoA, Agriculture and Forestry University	9x15=135	6x15=90	225	225/2475=9.09
FoA, Far-Western University	12x15=180	6x15=90	270	270/2475=10.90
Purwanchal University	11x15=165	6x15=90	255	255/3225=7.9
CTEVT (Credit)	90	60	150	8\150 =5.3
TVE, MoE (Credit)	192	192	384	128/384= 33.33

*1 credit hour equivalent to 15 lectures hours

Source: Authors compilation

Table 2 outlines the credit hours and lecture distribution related to crop production and technology in various agronomy departments across different universities and institutions in Nepal. It appears to show the theoretical and practical lecture hours alongside their totals and the percentage contribution to the overall credit requirements. The curriculum also lacks focus on action research, the problems-based solution to identify low-cost, low-barrier easily adjustable farming practice solutions and deployment strategies that are expected to lead to increased yields, decreased pest and disease damage, and reduction of post-harvest loss, value addition and millet-based agribusiness concept. Course weightages are given below.

- **IAAS, Tribhuvan University:** This institution designates 195 hours to theory lectures and 105 hours to practical lectures, a total of 300 lecture hours. These hours represent 8.35% of the total credit.
- **FoA, Agriculture and Forestry University:** Allocates 135 hours for theory lectures and 90 hours for practical lectures, summing up to 225 lecture hours. This contribution accounts for 9.09% of the total credit.
- **FoA, Far-Western University:** Allots 180 hours for theory lectures and 90 hours for practical lectures, amounting to 270 lecture hours. This segment contributes 10.90% to the total credit.
- **Purwanchal University:** Assigns 165 hours for theory lectures and 90 hours for practical lectures, totaling 255 lecture hours. This represents 7.9% of the total credit.
- **CTEVT (Credit):** Specifies 90 hours for theory and 60 hours for practical lectures, making a total of 150 hours, contributing 5.3% to the overall credit.
- **TVE/MoE:** Allots equal weightage (192 hours) to both theory and practical contents. The percentage of agronomy to total credit account 33. 33 percent.

The table specifies that one credit hour equates to 15 lecture hours, and the total lecture hours and their distribution between theory and practical sessions vary across the different institutions. The percentage shown represents the proportion of these lecture hours concerning the total credit requirements for the respective programs. This breakdown gives insight into the emphasis and allocation of educational hours in crop production and technology across these institutions.

Coverage of science of millet in agriculture education curricula

In most of AAI, the contents of the millet are taught under the Department of Agronomy with limited coverage of millet categories such as finger millet, Kaguno, etc. Furthermore, the content covers only introductory and cultivation practices. Most of the millet is native to us. Therefore, for conservation and development, a wider range of millet types has to be incorporated into the syllabus. While studying millet in agronomy, students can explore a wide range of topics and practices related to the cultivation and management of these crops.

Millet is an ancient as well as the future promising crop. Efficient and effective deliberation in millet research and extension in academic institutions may play a significant role in integrating millets in the AREE system. Incorporating millet into agricultural education programs is essential for producing well-rounded and informed agricultural professionals who can address the challenges of modern agriculture, including food security, sustainable farming practices, and climate change adaptation. At the AAI level, following millet science has to be focused because of several reasons (Gupta et al 2017).

- **Diversity of Crops**: Including millet in agricultural education programs exposes students to a wide variety of crops. Millet is a group of small-grained, annual cereals that encompass several species like pearl millet, foxtail millet, finger millet, and more. Studying millet helps students understand the diverse crop options available to farmers and the importance of crop diversification for sustainable agriculture.

- **Resilience and adaptation**: Millet are known for their adaptability to diverse agro-climatic conditions. They can thrive in regions with limited water resources, making them essential for studying sustainable farming practices in arid and semi-arid regions. Agricultural students can learn about the importance of crop selection based on local conditions and climate change resilience.
- **Nutritional value:** Millet are highly nutritious and rich in essential nutrients, making them an important component of food security and nutrition. Agricultural education should include an understanding of crop choices that can enhance food security and improve public health through diversified diets.
- **Crop management and pest control:** Teaching students about millet cultivation provides insights into the specific requirements, growth stages, and pest management strategies associated with these crops. This knowledge can be applied to other crops as well.
- **Crop rotation and soil health:** Millet can be used in crop rotation strategies to improve soil health and reduce the risk of pest and disease buildup. This knowledge is critical for sustainable farming practices and maintaining soil fertility, which is a fundamental aspect of agricultural education.
- **Climate change mitigation:** Millet has lower greenhouse gas emissions compared to some other major crops, and they can contribute to climate change mitigation. Students can learn how choosing the right crops can play a role in addressing environmental challenges.
- **Economic importance:** Millet are often grown by smallholder farmers, and understanding their cultivation and value chains is vital for agricultural students. Learning about millet production, processing, and marketing can help students appreciate the economic aspects of agriculture.
- **Global perspective:** Millet are essential staple foods in many parts of the world, including Africa and Asia. Agricultural education should provide students with a global perspective and an understanding of the importance of different crops in various regions.
- **Research opportunities:** Universities often research millets to improve their yield, nutritional content, and pest resistance. This research not only contributes to academic knowledge but can also lead to innovations that benefit farmers and the broader agricultural industry.
- **Contemporary issues and their solution:** millet products and by-products also may have a connection with the industry. Barring land and youth migration also could be connected with the high commercialization of millets in the nation.
- **Millet classification and varieties**: Introduction to the different millet species and their botanical characteristics. An overview of millet varieties and their adaptability to different agro-climatic regions.
- **Millets in agriculture**: Historical and global significance of millets in agriculture, Comparison of millets with other major cereal crops.
- **Yield improvement:** Techniques for increasing millet yield, including improved seed varieties and agronomic practices.
- **Crop rotation and diversification:** The role of millets in crop rotation and its benefits for soil health and pest management. The importance of diversifying cropping systems for sustainable agriculture.
- **Nutritional value and uses:** Nutritional content of millets and their importance in human and livestock diets, Food and industrial uses of millet grains.
- **Global production and market:** Insights into the global production and consumption trends of millets, Market opportunities and challenges for millet growers and entrepreneurs.
- **Climate-resilient agriculture:** Millets as climate-resilient crops and their role in climate change adaptation, Sustainable practices for reducing the carbon footprint of millet cultivation.
- **Research and innovation:** Current research in millet agronomy and opportunities for innovation, Sustainable and regenerative agricultural practices in millet farming
- **Fieldwork and practical training:** Hands-on experience in millet cultivation, including field visits, soil testing, and pest management.

- **Government policies and support:** Understanding government policies and support systems for millet farmers, including subsidies and incentives.

Millets in the thesis of Undergraduate and Postgraduate

Millets are among the least used crops for research work of undergraduate and graduate students. Major works have been conducted by the Department of Agronomy on spacing, yield, fertilizer response, weed dynamics and management in finger millet. Similarly, some research work has been done in foxtail millet on phenotypic characterization, diversity study and fertilizer trial. Whereas research work on other millets as part of an academic thesis is yet to be done.

Approaches incorporating millet into AAI curricula

Including different models and approaches to teaching about millet can create awareness, perceptual attitudes, knowledge and hands-on skills among the students to integrate the science of ecosystem, climate resilience, nutrition, traders, business and value chains to develop healthier and sustainable communities by integrating research-extension and education in the future career. Many AAI-community engagement approaches (**Table 3**) are being practiced over the globe. This is implacable to the Nepalese AAI too. For example, multi-variety trials could be practiced to strengthen AAI-community partnership activities with the support of undergraduate, and postgraduate researchers and PhD scholars. This is also a model to strengthen the AAI-community engagement program. Some of the approaches have been listed in **Table 3**.

Table 4. AAI-community engagement for undergraduate and postgraduate students

Model	Description of models
Millet based One-time service project	Arrangements for service projects can be made before the semester and included in the syllabus. This model allows faculty and peer interaction because a common service experience is shared. These kinds of arrangements could be used in providing lentil-based advisory services by the graduating UG and PG in mid-hills-based AAI.
Normal course work on millets	A portion of the normal coursework is substituted by the community-based component. For example, a traditional research paper or group project work can be replaced with experiential research.
Millet service project within the course	All students are engaged in millet-based service projects as a requirement of the course. This requirement outcome must be clearly defined at the orientation, on the syllabus, with a clear rationale provided to students as to why the service component is required. This is the sort of approach being used in enterprise learning schemes in the IAAS BSc agriculture program.
Millet based action research	This involves students in research within the community. The results of the research are communicated to the AREE institution so that it can be used to address community needs. Action research and participatory action research take a significant amount of time to build relationships of trust in the community and identify common research agendas.
Disciplinary campaigns	Community engagement is an excellent way to build upon students' cumulative knowledge attitudes, and skills in a specific discipline and to demonstrate the integration of that knowledge with real-life issues.
Multiple course projects	Community engagement projects with one or more partners may span different courses in the same semester or multiple courses over a year or longer. These projects must be broad enough to meet the learning goals of multiple courses over time. This they may have a cumulative impact on both student learning and community development that is robust.

Model	Description of models
Hands-on cooking	Organization of cooking workshops to familiarize students with the taste of a millet-based dish, and sharing recipes in innovative ways encourage them to incorporate millets as an ingredient in their cooking.
Expert lecture and demonstration	Guest speakers with expertise in millet production, research and industry share their experiences and learnings on different aspects of millet. Also, demonstration on cultivation practice, varietal display, processing, and storage and value addition helps students to develop a comprehensive understanding of cultivation and millet value chain.
Thesis work (UG and PG)	Students of undergraduate and postgraduate levels identify a particular research problem (as per discipline) and design a research work as part of their academic degree on millets. The outcomes of research are also helpful; in addressing problems/challenges in millet.
Internship and industry placements	Internships and placement in millet-based industries provide practical exposure to millet production and value chain. Hands-on experience in agronomic practices, plant protection and processing help in escalating the learning process.
Online course and webinar	Encouraging students to attend online talks, webinars and online courses related to millets on different platforms helps in a better understanding of millets. The online platform will be useful for facilitating discussion, sharing case studies and getting engaged with experts around the world.

Source: Jaishi et al 2022

Conclusion and Way Forward

Millets, often overlooked despite their significance, offer a multitude of advantages. By incorporating millet cultivation into the agricultural curriculum, students can gain exposure to diverse crops and understand the importance of agricultural diversification for long-term sustainability. The integration of millet crops within agricultural education stands as a pivotal strategy for ensuring sustainability and bolstering global food security. Teaching about millet emphasizes the critical link between crop selection and local conditions, providing a bedrock for resilient and sustainable farming practices, crucial in the face of climate change and environmental volatility. There are different approaches to connecting students with the real farming situation to understand the farmers and farming from the perspective of innovations. Students' exposure to millet farms is the best way to understand millet which can be the initial point to scale up under-rated, under-utilized multipurpose, highly adaptive, climate resilience and nutritive crops. Academia should be sensitive enough to integrate the science of millet into their courses. Academia has to develop its strategic action on capacity building, research innovation, policy engagement and reaching the community with proper faculty and learner engagement. Millet extension manuals to guide the expansion of millet knowledge, attitudes and skills are urgent to develop.

A comprehensive and strategic educational focus on millet can equip students with comprehensive insights into effective millet crop management strategies that are transferrable to the agriculture innovation system. Introducing students to the significance of these crops creates a wider understanding of the scope and importance of different millet in terms of climate resilience, food security, biodiversity and import substitution. In addition, this integration enriches knowledge about specific agronomic practices of millet for sustainable production systems. Ultimately, this educational integration primes students to become adaptable and informed agricultural professionals, capable of addressing modern agricultural challenges to ensure food security and promote sustainable farming practices globally.

Practices of related guest lectures about the importance of millet in diet to the students of high schools may also create awareness among the children and motivate them to use these traditional crops in their daily diets and hold classes on hands-on millet cultivation. The school should also seek to equip the teachers with information on millets. AAIs can develop and implement short-term online courses to cater for gaps in knowledge and skills to the pools of millet development workers, millet researchers, related educationists, and extension experts on the advanced development of millet. Front-line demonstration sites, seed hubs, millet week, and hands-on cooking workshops in millet have to be developed in the respective AAI.

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Issues and Way Forwards of Millet Value Chains in Nepal

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Summary

Millets are minor cereal crops of Nepal and gaining popularity as nutrient laden foods. These crops have a lot of qualities such as healthy and nutritious food, addressing poverty and malnutrition, capable of growing in an adverse weather and soil condition, low nutritional requirement, appropriate for human food and animal feeds and export potentialities. Millets have been grown and consumed in Nepal since long time. However, due to migration to urban areas from rural areas, low productivity, change in food habit to rice etc its production has not been increased and consumption is also reduced. The main underlying problems of millet value chains are lack of awareness among producers and consumers, lack of product diversification, marketing promotions, inadequate research and technology development, inadequate government support programs etc. In current days, the awareness on this contribution on human and animal health and its potentiality to climate resilience has started to raise significantly. Thus, the dedicated institutions on millets research and promotion should be established, the awareness of the quality of millets on nutrition and health benefits should be increased through different promotional programs, research and technology development and their extension on different aspects of millets value chain should be strengthened, and the potentiality of its marketing and trade should be promoted for the benefit of farmers, other value chain actors and consumers for the benefit of the country.

Keywords: Export, gluten-free, nutri-cereals, promotion, resilient

Introduction

Millets are one of the most important group of cereals cultivated in Nepal since time immemorable. They are considered as nutri-cereals and has played a significant role in promoting food and nutritional security in the country. Millets are very important crops for the feed and fodder security too. These are nutritionally valued underutilized crops and are future smart food (Joshi et al 2019) which are climate resilient and nutrition dense. Particularly, finger millet is widely consumed as important daily food in indigenous communities in mid-hills. Finger millet is fourth major cereal of Nepal which is cultivated in 267,071 hectares producing 339,462 metric tons of grains with the average productivity of 1.27mt/ha (MoALD, 2023). These crops are cultivated as monocrop or as mixed crop with legumes. They are also cultivated as intercrops with fruits such as citrus. These are known for providing energy and the feeling of hunger satiation for longer duration compared to other cereals. Scientific evidences have shown that these crops are high in dietary fibres, are gluten free, highly nutritious with calcium, phosphorus, magnesium, manganese and iron content compared to rice, wheat and maize. They are capable of preventing diabetes, cardiovascular diseases, for treating anaemia, obesity, reduces high blood pressure and good source of antioxidants (APEDA 2023).

In view of its importance in food, feed and nutrition security, the United Nations General Assembly in March 2021 declared 2023 as the International Year of Millets (IYM) under the theme “Rich in heritage, full of potential”. IYM 2023 is set to contribute the goals number 2 (zero hunger), 3 (Good health and well-being), 8 (Decent work and economic growth), 12 (Responsible consumption and production), 13 (climate action) and 15 (Life on land) of the sustainable development goals. IYM has contributed in raising the awareness about the crop and has helped in its product diversification (FAO 2022). Countries like Nepal, India, Nigeria, Japan, Taiwan, Italy, United States, Hungary, France, Zimbabwe have organized different events to celebrate the IYM 2023 which has been listed by the FAO (FAO 2023).

Promotion of millets helps building a resilient economy

Unlike major cereals, millets seeds have been maintained by farmers through selection of healthy heads. These crops have the potentiality of reducing the imports of seeds, chemical fertilizers, soil additives, other cereals for consumption and the processed cereal products. Exploring the potentiality of millets value chain system including the diversity of millets recipe can bring back our economy by reducing the imports. Moreover, the crops can play significant role in reducing agricultural trade loss as lots of import is done for food and feed purpose. Furthermore, low disease pest attack can save millions of rupees for importing pesticides and at the same time reducing the environmental pollution. Due to rich calcium, iron like nutrients and also dietary fibres and antioxidants, being gluten free these crops have higher possibilities of saving millions of rupees allocated for health-related expenditure of the country. Millets are important for animal feed and fodder. There are tonnes of feed import which can be significantly reduced by millets promotion. These nutritious crops can be utilized for the same by exploring their potentiality and creating awareness (Ghimire et al 2017). The crops can play significant role in reducing agricultural trade loss as the country is investing a lot of money to import paddy and maize based products for food and feed purpose.

Millets are referred as climate resilient crops as they are capable of growing on marginal lands with minimal inputs and management, tolerant or resistant to diseases and pests. These are more resilient to climate shocks compared to other cereals. Expanding the millets production can help create sustainable agri-food systems and contribute to better nutrition, environment and a better life (FAO, 2022). Millets are photo-insensitive and are sustainable, as they demand minimal water quantity. They have smaller harvesting period and can grow in dry climate (Ahuja and Bayas 2022). Millets can grow in very poor soils and in dry areas. These crops do not deplete the soil nutrients heavily. They can reduce soil degradation by providing land cover in arid regions. It helps support the biodiversity and sustainable restoration of land (FAO 2022).

Regarding the cultivation of these species of millets and their promotion in Nepal, there are number of issues and problems identified in different regions of Nepal. These issues may be similar and sometimes differs with different species of millets. This paper aims to identify the underlying issues and problems related to the millets value chain and possible ways forward in Nepal.

Issues on Millets Value Chain In Nepal

Millets have played very important role as one of the major cereal crops in combating with hunger and malnutrition in Nepal. Yet, there are various issues and constraints associated with these crops which are discussed hereunder.

Nationally unprioritized Crop

Millets were not given priority in the education, research and extension services for long time because of less awareness of its nutritional importance and its resilience towards climatic extremities. It was cultivated as an indigenous food crop and consumed mainly in rural areas. In recent years, the nutritional and health benefit of the millets are noticed well and thus initiations are being taken from different agencies. Millets are being promoted as indigenous crops by the Government of Nepal though national agriculture extension system. The Hill Crops Research Program is mandated to run research programs on millets and allied crops. FAO as an UN agency and quite few NGOs like LI-BiRD and others are involved in the research and development of this crops. Currently, dedicated institutions neither for millets research nor for the promotion and extension of millets is present in the country. Moreover, the dedicated projects or programs for the millet promotion is also lacking. Promising species of millets were identified as having potentiality for global market such as Dude *kaaguno*, a landrace of foxtail millet and other species of millets (Joshi et al 2019). Yet, their promotion and utilization aspect are not getting attention from governmental and private sector. These crops have not been identified as export-potential crops although the possibilities are high for export in the Europe, America, Africa, Asia and the Arabian countries. The allocation of financial resources for the promotion of millets seems to be around 100 million rupees (DoA 2023). The budget seems very low as compared to the national allocation on the agriculture sector. Moreover, the allocated programmes and budgets are scattered and the impact is limited.

Low productivity and production

The production of millets has been above 0.3 million metric tons in the last ten years and productivity has been in an average 1 mt/ha (MoALD 2023). No much significant achievements have been attained in terms of production and yield so far. Different factors were identified for influencing millet production such as lack of high yielding varieties, marketing facilities, preference towards other cereals, inadequate of subsidy support, poor linkage with tourism industry and farmers poor motivation for millets cultivation (Gyawali 2021). There are number of reasons for the low productivity of millet crops:

- **Lack of high yielding varieties and their quality seed**: As the varietal development research are not getting priority in the millet crops, the high yielding varieties are lacking. Till now, only 5 varieties of fingermillet (Kaabre kodo-1, Okhale-1, Dalle-1, Kaabre kodo-2, Sailung kodo-1) have been released and a single variety (Rato kodo) has been registered mostly for hills and single variety each of foxtail millet (Bariyo kaaguno) and proso millet (Dhudhe chino) have been registered in the national seed system of the country (SQCC, 2023). Except Dalle-1, no any varieties of finger millet and other species of millets for the terai region have been released or registered so far. Moreover, the seed production system of these varieties is also very weak and limited to fewer areas resulting the poor availability of the quality seed to the farmers.
- **Poor nutrient management**: Due to decreasing livestock population and shifting of farmers towards commercial agriculture, manure production is decreasing resulting in the less use of manure in the field. Moreover, chemical fertilizer is either unavailable or poorly practice to use in millets.
- **Poor pest management technologies and services:** Economic insect pests of millets are shoot flies, stem borers, caterpillar, cutworms, grasshoppers, bugs, aphids, spider mites, etc (ICAR 2016). Important diseases of millets are grain mould, sugary disease, smut, downy mildew, blast, anthracnose, rust, blight, spot, etc (Das et al 2016). These crops are not much prone to diseases and pests and the grain can be stored without the attack of pests for years (Ghimire et al 2017). However, the pest damage is quite often noted in many parts of the country. Poor pests and diseases management of millets due to less awareness in farmers and lack of proper management technologies developed and delivered are also the major setbacks in the productivity of millets.
- **Inadequate technical services:** The number of technical manpower available for research or the extension in the country is very less to develop and deliver proper technical services in agriculture. Moreover, the skilled and empowered technical manpower dedicated to the millet sector is scarce

in the country. This has resulted the poor technology development and adoption of the available technology in the field level. The poor co-ordination among the technical institutions of three tiers of government and among the research and extension institutions have led to the poor technology delivery to the farming community.

- **Less mechanization:** Millet cultivation and harvesting is very labour intensive and cumbersome job to the farmers. This is one of the important issues for the repulsion of the farmers in millet production. Mechanization of millets value chain functions such as tillage, transplantation, weeding, harvesting, and post-harvest operations are at primitive stage. Very less research work has been done for the mechanization of the millet cultivation and harvesting. Millet thresher and 'Chino Kutter' has been developed and are available in the market (Shrestha 2022). However, their promotion in the production areas is extremely low as low priority given in the millet promotion.
- **Climate change and Environmental impact:** Nepal is a vulnerable country in terms of environmental impacts such as climate change. Water sources in terai and hilly areas are drying up. Country has been facing climate-based disasters increasingly in recent years. Arid regions are prevalent. Millet crops are said to be resilient crops against climate change impacts than other cereals, however its impact may cause significant reduction in the production and productivity especially due to long draught or continuous heavy rain. They are considered as challenge crops and are can grow well under drought conditions and non-irrigated land too (Karuppasamy 2015). However, many millet varieties are categorized in red list, that are on the verse of extinct (Joshi et al 2005).

Food habits and feeding mind set

People in rural areas used to eat millets-based diets in daily basis and it was common in the country. Now, the scenario has changed. There has been trend to consider it as a 'Poor-man's cereal' and people started to feel humiliated and socially neglected to consume millets. The health and nutritional awareness on the consumption of the millet crops was less understood. Transportation facility developed in the hilly regions and Government itself promoted rice to hills and high hills of the country. Rice-based food culture has developed all over the country. Many people shifted to paddy cultivation and consumption by replacing millets. Now, it has become challenging to change their food habits and feeding mind set to re-start the millet consumption. Millets are important for human food and also for animal feed purpose. These nutritious crops can be utilized by exploring their potentiality and creating awareness (Ghimire et al 2017). This side of the nutri-cereals has been undermined and neglected and thus it has to be imported for it uses mainly in urban areas (MoALD 2023).

Inadequate effort in conservation of the millet landraces

Nepal has been constantly going through the socio-political turmoil and natural shocks vin the past. More than thousand conserved accessions of different millets species were lost to fire during the political conflict period at Hill Crops Research Program (HCRP), Kabre (Ghimire et al 2017). Moreover, many millet species are either lost or pushed to the red list due to the earthquake of 2015 Due to outmigration of the people from the hilly and rural areas to the urban areas for better life has created the abandonment of the agriculture, which has resulted the loss of many farmers conserved landraces. Conservation work in the country in the form of the seedbanks or the genebanks are undergoing but not sufficient to conserve these landraces for future use. Only 1056 accessions of the 7 millet species have been collected from 70 districts are conserved in the National Genebanks (Joshi 2023).

Poor marketing infrastructure and functions

Production of millets should be linked with the markets so that it becomes a profitable business. Proper marketing requires the information about the possible markets for the farmers, the demand of diversified products and proper pricing mechanisms. Market information system and proper marketing strategies are required for selling millets to the market at fair price to the farmers. Better price can be fetched through collectivization of the products and through trading of voluminous quantity. These amarketing infrastructure, channel and the information system all are at primary stage and specific facilities for millets marketing are lacking. Moreover, the export potentiality of millets is very less studied and thus not promoted in the millet growing areas.

Less processing and product diversification

The semi-or full processing of the millets for packaging and marketing purpose is very important for marketing to urban consumers. Marketing in urban areas is now changing towards supermarket culture which demands processed or semi-processed products. Processing invites the use of proper machineries and tools, thus their promotion to the production pockets. Due to less prioritized activities this part is very weak. Millets are mostly used for making traditional dishes like porridges(dhido) or pancakes (roti) or puddings, local alcoholic beverages, across the country and people are little aware of its multi-use in making several recipes Moreover, the traditional food products/dishes are poorly accepted by the youths in the urban restaurants. Proper development of the different recipes and product diversification is utmost importance. Very less work has been done so far in this area.

Weak partnership and co-ordination

Promotion of millets cannot be only the government's job. It requires the co-ordination of non-governmental organizations (NGOs), cooperatives, private firms, farmers and civil societies. All of these sectors should form networks and action groups for ensuring the availability, accessibility and affordability of millets (FAO 2022). Co-ordination among three tiers of the government, co-ordination among education, research and extension agencies are also equally important. However, the co-ordinated efforts of these sectors in the promotion of millets in Nepal has very less realized.

Ways forward

There are plenty of issues and challenges in the promotion of millets as discussed above. Yet, many opportunities are associated with the prioritization of millets in the future. Different significances to be considered for millets sector value chain development are discussed in this section.

Research and technology development is the key to millet value chain development

Nepal Agricultural Research Council has been involved in the research of millets in limited manner as compared to paddy, wheat and maize. National commodity research program for millets research should be established and national and basic research should include all the 21 different species of millets for the research and development. Similarly, the focal organization for millets promotion is also vital for the technology delivery and co-ordination.

Proper research on the conservation and promotion of local land races, development of the high yielding varieties of the millets, mechanization, nutrient management, pest management and product diversification technology development and market research are very important for the promotion of millet value chains. The specific technologies may need to the specific species due to their variation in the cultivation process and market potentiality. The technology developed by countries like India should be verified by our national research system before implementation in the country. Developing and expanding the climate-friendly millets production can help create sustainable agri-food systems and contribute to better nutrition, environment and a better life (FAO, 2022). Conservation of the climate-friendly millets and their promotion is the need of the time.

Specific research like the potentiality of millets for industrial use may also be explored. Proso millet can be an alternative to corn in biofuels production, leading to the green-energy industry (Joshi et al 2019). Thus, there is plenty of opportunity for the technological and food product diversification research in this millet sector in the country.

The technologies developed for millets production, processing, value addition and marketing should be made easily available for the farmers. Technical service delivery should be strengthened with establishment of dedicated institutions, appropriate number of human resources and their capacity development and proper co-ordination among the institutions. Academic courses on millets is also a prime important for human resource development.

Awareness and promotion of the potentiality of millets

Awareness should be raised among the farmers about the importance and economic value of millets and to the consumers about the nutritional and health benefits of millets consumption. Promotion of the millet crops by providing quality seeds, manure and fertilizers, mechanization and marketing facilities can increase the production and productivity of the crops. Government and other organizations should join hands for the promotion and publicity of healthy millets' diet. Campaigns should be initiated for millets promotion by organizing exhibitions, technologies demonstrations, millet talks, high level promotion of millets and competitions. Hotel and homestay associations can come together by including some millets recipes to their menu. Government should lead the campaign by announcing some special advantages to the millets growing farmers and other value chain actors including promoting millets by investing in research and development activities, declaring minimum support price, incubating the millets-based start-ups, establishing millet food parks, millets-based cafes and bazars, supporting farmers producer organizations, raising awareness through high political level and many more activities. Promotion of branding, packaging, labelling and marketing can be made by subsidizing these processes. The Government of Nepal has declared Magh 1st (Maghe Sankranti) of Nepali calendar as the National Agricultural Biodiversity Day from the year 2023. This contributes to raise the awareness on crops like millets.

Local marketing and export promotion

Marketing promotion of millets-based products should be done through appropriate labelling, branding and attractive packaging. Thus, it is crucial to follow the marketing promotion techniques in Nepal that can penetrate the local and internal market as well as explore the export potentiality. There is growing consumer demand of millets in urban areas. Millets have a high export opportunity by targeting the vegetarian and vegan population in different parts of the world including those of developed regions such as Europe, America and Australia (R and M 2023). An estimated 1.2 billion people consume millet in their diet which itself is a huge global market (APEDA 2023). Market studies shows the current market size in 2022 of USD 12.33 billion is expected to grow to USD 16.27 billion in 2028 and USD 44.1 billion by 2033 (FMI 2023 and IMARC 2023). Thus, market exploration and support to the value chain process for the local an export promotion can be the successful strategy to capture the possible niche markets.

Food habit change

Global pandemic has increased the level of awareness and people are switching from junk food to millet-based products (R and M, 2023). Foxtail millet, finger millet and Proso millet have been identified as

Himalayan Super food (Joshi et al 2019). Millets can offer a variety of recipes for breakfast, lunch, snacks and dinner. It is necessary to change the rice-based food habit of Nepalese people and introduce millets in their food system. This can be done by raising awareness about the nutritional and health benefits of millets. This is a positive scenario for millets value chain industry. Production and consumption of proso millet and foxtail millet has increased in Karnali and Gandaki province of the country. Proper facilitation on its consumption by the governmental and non-governmental sector is important for the food habit change.

Product diversification targeting youths and urban consumers

Finger millets can be used to prepare dhido, porridge, bread, cakes, cookies, laddu, pastries, bars, waffles, chocolates, sattu, flours, flakes, fermented products such as gluten-free beer and non-alcoholic drinks. Similar products can be made with sorghum, chino and kaguno. Many food recipes such as waffles, pasta, pizza, sandwiches can be prepared and they are gluten free. This is going to drive up the millets market in the future. Nepalese people are less exposed to these products. Thus, products diversification helps in better marketing of millets and it should be promoted targeting youths and urban consumers.

Incentives and pricing policy to be in place

Conditional grants have been provided by the Government of Nepal to local levels (DoA 2023) and provincial governments for the promotion of indigenous crops including millets. Some local level governments have been playing exemplary role in the promotion of millets. Several local authorities have promoted these crops and declared the minimum support price for these products such as finger millet, buckwheat. Government incentives is required for production and collectivization of products and promotion of farmer groups and co-operatives. Thus, there should be incentives and pricing policy in place from all three tiers of the governments for promotion of millets.

Invest for poverty and malnutrition reduction

Absolute poverty in Nepal is 15.3% and multidimensional poverty is 17.4% (NPC 2023). Malnutrition and stunting in children are severely prevalent. Anemia during pregnancy is 43% of the pregnant women (The World bank, 2023). Children below 5 years of age suffering from stunting is 25%, wasting is 8%, 19% are underweight in Nepal (MoHP 2023). These are all associated with the malnutrition caused by lack of carbohydrates, protein, macro and micronutrients, etc. Millets are rich in protein, carbohydrates, calcium, iron like nutrients and are capable of combating with these nutrition related challenges faced by the country. These crops are grown in all the 77 districts of Nepal (Joshi 2023). This very potentiality should be tapped for food and nutritional security of the country. Investing in the promotion of millets value chain up to consumption helps reduce poverty and malnutrition.

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Chapter 6. Miscellaneous

अध्याय ६. विविध

नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक)। २०८०। राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ।

कविताः कोदो हाम्रो परिवार

भवानी खतिवडा

कृषि विभाग, हरिहरभवन, ललितपुर

हातजस्ता राम्रा बाला बालाभित्र दाना
हामी गुणी कोदोबाली बन्छौँ मीठो खाना
सामा, चिनो कागुनो रे एक हाम्रा जात
क्याल्सियम र फलाम तत्व छन् है हामी साथ।

ढिँडो रोटी खीर पुवा हाम्रो परिकार
पौष्टिकताका खानी हामी हुन्छौँ रेसादार
भात मात्रै होइन अब ढिँडो खाने गर
चामलको अभावलाई पार पर पर।

कोदो भनी नहेप्नू है अन्न नै हौँ हामी
मल पानी नपाए नि फल्नलाई नामी
रूखो माटो पाए पनि मज्जासित फुल्छौँ
चाहिँदैन खेतटारी सुर्कामा नै झुल्छौँ।

नेपालले मनाइदियो कोदो बाली वर्ष
हामीलाई लाग्यो गर्व लाग्यो ज्यादै हर्ष
नेपालको समृद्धिमा जग बन्न सक्छौँ
धानजस्तै मानो रोपे मुरी फल्न सक्छौँ।

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक)। २०८०। राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ।

कोदो

शिव प्रसाद आचार्य

दुप्चेश्वर-७, शिखरबेशी, नुवाकोट; फोन नं. ९८४३५३७६३४

कोदो शक्ति प्रदायिनी रससुधा, हुन् औषधी वाहिनी,
हट्छन् भोकमरी, हटाउँछ कडा, व्याधी अनेकौं पनि।
कोदोमा प्रतिरोध तागत बडा, के रोगले भ्याउला,
कोदोजन्य पदार्थ सेवन गरे, दिर्घायु झन् पाउला।

कोदो पौष्टिक तत्व हो अमृत हो, स्वादिष्ट खाद्यान्न हो,
कोदोको परिकार बन्दछ मिठो, सम्पूर्णको मान्य हो।
कोदोको परिवार ब्यापक सामा, कोदी घोगे कागुनो,
भिर्कौलो घरगाउँको वनभरी, फल्दा जुनेलो चिनो।

आफ्नै देश हराभरा शहरमा, गाउँभरी अन्न छ,
के को संकट राज्यमा कति फल्यो, निर्यात भो भन्नु छ।
आफ्नै पौरख रोजगार सबको, सन्तोषको स्वास छ,
यो हाम्रो अभियान शान गतिलो, उत्साह विश्वास छ।

आफैँमा परिपूर्ण छन् खनिज हुन्, या हुन् स्वयम् ओखती,
धेरै तत्व रहेछ शुद्ध यसमा, भेटे सके जे जति।
यसैको उपकारले कति बने, स्वादिष्ट छन् पुष्ट छन्,
प्राणीको हितमा समाहित हुँदा, सन्तृप्त सन्तुष्ट छन्।

बाँसो खेत हराभरा समयले, नङ्ग्रा खियाएपछि,
के फल्दैन गरा गरा छ पसिना, धारा चुहाएपछि।
आफ्नै पौरखको छ गर्व मनमा, मर्का लुकाएपछि,
के को झुक्नु विरानुको नजरमा, छात्ती फुकाएपछि।

अर्कैको भरमा परेर परको, बीवै मगाएपछि,
जन्मन्छन् वर वर्णशङ्कर सवै, आफ्नो भगाएपछि।
रैथाने नचिनेर स्थानिय गयो, आफ्नो पराई भयो,
गुम्दैछन् पहिचान मान सबको, बाँकी यहाँ के रह्यो।

आस्था जाँगर चेतना मनुजको, बाँकी छ ज्यूँदो स्वर,
भातै मात्र किनेर चामल मिठो, नखा भने हुन्न र ?
कोदो जन्य पदार्थको दिनदिनै, आस्था जगाउँ अब,
कोदो भोजन गर्नुहोस् सुजन हो, कोदो बनोस् उत्सव।

कोदो खाद्य पदार्थ मात्र नहुँदा, यो औषधी तुल्य छ,
कोदो देश विदेशमा चलन होस्, कोदो अहम् मूल्य छ।
नैवेद्य घरको प्रसाद सबको, के हैन के छैन र?
यै हो वैद्य धन्वन्तरी प्रकृतिको, हुन् नर्स हुन् डाक्टर।

माटो चिन्दछ कर्मले सरल छन्, चाहिन्न धेरै मल,
आफैँमा परिपूर्णका तरल छन्, चाहिन्न धेरै जल।
फल्छन् भीर पहाडमा बगरमा, बारी र टारी तिर,
कोदो फल्छ जताततै नगरमा, गाउँ जता जे गर।

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नेपालमा कोदोजन्य बालीहरू : परम्परा, विज्ञान र प्रविधि (बाल कृष्ण जोशी, राम कृष्ण श्रेष्ठ, कृष्ण हरि घिमिरे, हरि बहादुर केसी र अरुण जिसी; सम्पादक) । २०८० । राष्ट्रिय जीन बैंक, बाली विकास तथा कृषि जैविक विविधता संरक्षण केन्द्र र एफ.ए.ओ.; काठमाडौँ ।

कोदो गजल

हरि बहादुर के सी

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दाना साना भए पनि, गुण ठूलो अमृत सरी
नहेप्नु है फेरि अव 'कुअन्न'को नाम गरी ।

१
फलिदिन्छौँ हिमाल, पहाड, तराइ सबैतिर हामी
अब्बल जग्गा होस् वा रुखा सुख्खा पाखो घर बारी।

२
जलवायू परिवर्तन भन्छन् क्यारे सबैतिर
मजासँग पचाइदिन्छु मतलवै छैन सरी ।
३
गुलियो मीठो नल दिन्छु पशुहरू पनि खुशी
किसानहरू पनि खुशी भई बस्छन् माया गरी ।

४
पौष्टिक तत्व भरिपूर्ण छ सबैलाई जाती हुनी
संसारले बुझ्न थाल्यो उत्साहको सन्देश छरी ।

५
मेरै गुणगानको चर्चा गरेका छन् सबै तिर
कोदोबाली बर्ष भनी मनाएर संसार भरी ।
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गजल: अनन्य बाली, कोदोजन्य बाली

कृष्ण हरि घिमिरे

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काउनो, कोदो, चिनो, सामा, घोगे भन्ने बाली;
दाना सानो, गुन ठुलो, कोदोजन्य बाली ।

आजभोलि सहरमा ढिंडो खोज्छन् सबै;
'कुअन्न हुन्' भन्दै हिजो कोही नगन्ने बाली ।
दाना सानो, गुन ठुलो, कोदोजन्य बाली ।

चामल बनाई भात, खीर, पिठो ढिंडो, रोटी;
केक, बिस्कुट, म:म:, चाउचाउ सबै बन्ने बाली ।
दाना सानो, गुन ठुलो कोदोजन्य बाली ।

दाना अनि नल यिनको पशु आहार राम्रो;
जलवायु अनुकुलन गर्ने धन्य बाली ।
दाना सानो, गुन ठुलो, कोदोजन्य बाली ।

सिंचाई अनि विकासे मल नभए नि फल्ने;
डाँडापाखा पखेरामा हुन्नन् अन्य बाली ।
दाना सानो, गुन ठुलो, कोदोजन्य बाली ।

चिसो, तातो, सुख्खा सहने, पौष्टिकताले पूर्ण;
सर्बगुणले सम्पन्न छन् यी अनन्य बाली ।
दाना सानो, गुन ठुलो, कोदोजन्य बाली ।

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Chapter 7. Photo Gallery

अध्याय ७. तस्बिरहरू

Millets and their Wild Relatives in Nepal

Millets and their Wild Relatives in Nepal

कोदे बालीहरु र तिनको जंगली नातेदार प्रजातिहरू

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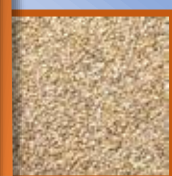
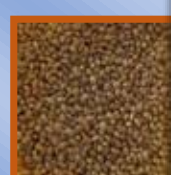


5. Japanese barnyard millet
सेतो सामा
Echinochloa esculenta
(A.Braun) H.Scholz


6. Job's tear millet
भिर्कौलो, जोगी माला
Coix lachryma-jobi L.


7. Kodo millet
कोदी
Paspalum scrobiculatum L.




8. Little millet
धानकोदो, सुजीकोदो, कुट्की
Panicum sumatrense Roth.

9. Nepalese barnyard millet
नेपाली सामा
Echinochloa frumentacea Link

10. Pearl millet
घोगे, बाजरा
Pennisetum glaucum (L.) R.Br.

11. Proso millet
चिनो
Panicum miliaceum L.

12. Sorghum
जुनेलो
Sorghum bicolor (L.) Moench.

Wild relatives of millet crops in Nepal

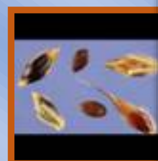
1. Awnless barnyard Grass
बन्सो, सामा घाँस
Echinochloa colona (L.) Link

2. Barnyard grass
टुंडे सामा, सन्वा
Echinochloa crus-galli (L.) P.Beauv.

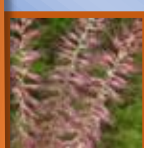
3. Crowfoot grass
काग खुट्टे झार, कोदे झार
Eleusine aegyptiaca (L.) Desf.

4. Goose grass
कोदे झार, दादे झार
Eleusine indica (L.) Gaertn.

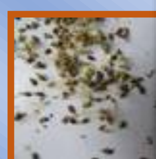
5. African goose grass
अफ्रिकन कोदे झार
Eleusine africana Kenn. O'Byrne



6. Johnson grass
जंगली जुनेलो
Sorghum miliaceum (Roxb.) Snowden



7. Wild pearl millet,
Oriental fountain grass
बन घोगे
Pennisetum orientale Rich.



8. Wild foxtail millet,
Garden bristle-grass
कुकुर बंसो, कनिके कागुनो, जंगली कागुनो
Setaria pallide-fusca (Schumach.)
Stapf & C.E.

9. Wild proso millet, Blue panic grass
जंगली चिनो
Panicum antidotale Retz.

10. Wild red sorghum
जंगली रातो जुनेलो
Sorghum nitidum (Vahl) Pers

Joshi BK, KH Ghimire, RP Mainali, SK Shrestha and M Bhattarai. 2023. Pictorial dictionary of millets and their wild relatives in Nepal. NAGRC, Khumaltar, Kathmandu. https://www.researchgate.net/publication/371984042

Millet Plant Parts and Growth Stages

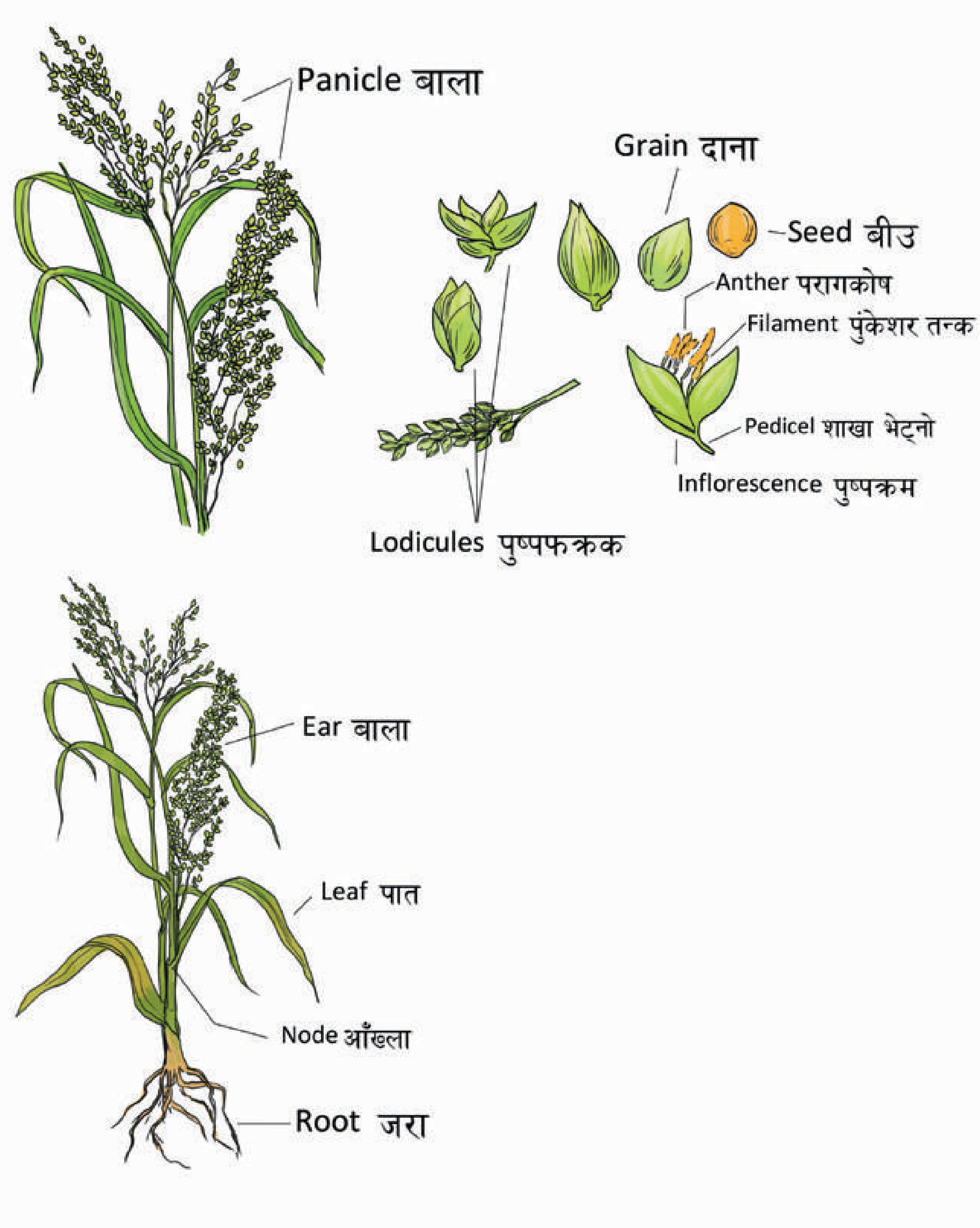
SN	Character, part	Little millet	Finger millet	Foxtail millet	Proso millet	Pearl millet	Sorghum	Barnyard
	Scientific Name	*Panicum sumatrense* Roth.	*Eleusine coracana* Gaertn.	*Setaria italica* (L.) Beauv.	*Panicum miliaceum* L.	*Pennisetum glaucum (L.)* R.Br.	*Sorghum bicolor* (L.) Moench	*Echinochloa frumentacea* Link
1	अंग	धानकोदो	कोदो	कागुनो	चिनो	घोंगे	जुनेलो	सामा
2	Root	जरा	जरा	जरा	जरा	जरा	जरा	जरा
3	Crown root	ताज जरा	ताज जरा	ताज जरा	ताज जरा	ताज जरा	ताज जरा	ताज जरा
4	Lateral root	शाखा जरा	शाखा जरा	शाखा जरा	शाखा जरा	शाखा जरा	शाखा जरा	शाखा जरा
5	Primary root	मूल जरा	मूल जरा	मूल जरा	मूल जरा	मूल जरा	मूल जरा	मूल जरा
6	Stem	काण्ड, डाँठ	काण्ड, डाँठ	काण्ड, डाँठ	काण्ड, डाँठ	काण्ड, डाँठ	काण्ड, डाँठ	काण्ड, डाँठ
7	Node	आँख्ला	आँख्ला	आँख्ला	आँख्ला	आँख्ला	आँख्ला	आँख्ला
8	Internode	नली, अन्तर आँख्ला	नली, अन्तर आँख्ला	नली, अन्तर आँख्ला	नली, अन्तर आँख्ला	नली, अन्तर आँख्ला	नली, अन्तर आँख्ला	नली, अन्तर आँख्ला
9	Branch	शाखा	शाखा	शाखा	शाखा	शाखा	शाखा	शाखा
10	Tiller	सरा	सरा	सरा	सरा	सरा	सरा	सरा
11	Leaf sheath	पर्णच्छद	पर्णच्छद	पर्णच्छद	पर्णच्छद	पर्णच्छद	पर्णच्छद	पर्णच्छद
12	Leaf blade	पर्णफलक	पर्णफलक	पर्णफलक	पर्णफलक	पर्णफलक	पर्णफलक	पर्णफलक
13	Ligule	जीव्हिका	जीव्हिका	जीव्हिका	जीव्हिका	जीव्हिका	जीव्हिका	जीव्हिका
14	Leaf	पात	पात	पात	पात	पात	पात	पात
15	Auricle	कर्ण	कर्ण	कर्ण	कर्ण	कर्ण	कर्ण	कर्ण
16	Flag leaf	झंडे पात	झंडे पात	झंडे पात	झंडे पात	झंडे पात	झंडे पात	झंडे पात
17	Plant height	बोटको उचाई	बोटको उचाई	बोटको उचाई	बोटको उचाई	बोटको उचाई	बोटको उचाई	बोटको उचाई
18	Pedicel	शाखा भेट्नो	शाखा भेट्नो	शाखा भेट्नो	शाखा भेट्नो	शाखा भेट्नो	शाखा भेट्नो	शाखा भेट्नो
19	Peduncle	भेट्नो	भेट्नो	भेट्नो	भेट्नो	भेट्नो	भेट्नो	भेट्नो
20	Culm	नल	नल	नल	नल	ढोड	ढोड	नल
21	Inflorescence	पुष्पक्रम	पुष्पक्रम	पुष्पक्रम	पुष्पक्रम	पुष्पक्रम	पुष्पक्रम	पुष्पक्रम
22	Spikelet	अनुमन्जरी	अनुमन्जरी	अनुमन्जरी	अनुमन्जरी	अनुमन्जरी	अनुमन्जरी	अनुमन्जरी
23	Sterile floret	नपुंसक पुष्पिका	नपुंसक पुष्पिका	नपुंसक पुष्पिका	नपुंसक पुष्पिका	नपुंसक पुष्पिका	नपुंसक पुष्पिका	नपुंसक पुष्पिका
24	Fertile floret	उर्वर पुष्पिका	उर्वर पुष्पिका	उर्वर पुष्पिका	उर्वर पुष्पिका	उर्वर पुष्पिका	उर्वर पुष्पिका	उर्वर पुष्पिका
25	Pericarp	फलावरण	फलावरण	फलावरण	फलावरण	फलावरण	फलावरण	फलावरण
26	Spike	मन्जरी	मन्जरी	मन्जरी	मन्जरी	मन्जरी	मन्जरी	मन्जरी
27	Ear	-	बाला	बाला	-	घोगा	बाला	बाला
28	Finger	-	औंला	औंला	-	-	-	-
29	Glume	बिपत्रक	बिपत्रक	बिपत्रक	बिपत्रक	बिपत्रक	बिपत्रक	बिपत्रक
30	Panicle	बाला	-	-	बाला	-	-	-
31	Awn	टुँडा	टुँडा	टुँडा	टुँडा	टुँडा	टुँडा	टुँडा
32	Anther	परागकोष	परागकोष	परागकोष	परागकोष	परागकोष	परागकोष	परागकोष
33	Outer lemma	बाह्य विपत्रक	बाह्य विपत्रक	बाह्य विपत्रक	बाह्य विपत्रक	बाह्य विपत्रक	बाह्य विपत्रक	बाह्य विपत्रक
34	Inner lemma	भित्री विपत्रक	भित्री विपत्रक	भित्री विपत्रक	भित्री विपत्रक	भित्री विपत्रक	भित्री विपत्रक	भित्री विपत्रक

SN	Character, part	Little millet	Finger millet	Foxtail millet	Proso millet	Pearl millet	Sorghum	Barnyard
35	Outer glume	बाह्य अधशल्क	बाह्य अधशल्क	बाह्य अधशल्क	बाह्य अधशल्क	बाह्य अधशल्क	बाह्य अधशल्क	बाह्य अधशल्क
36	Inner glume	भित्री अधशल्क	भित्री अधशल्क	भित्री अधशल्क	भित्री अधशल्क	भित्री अधशल्क	भित्री अधशल्क	भित्री अधशल्क
37	Filament	पुंकेशर तन्क	पुंकेशर तन्क	पुंकेशर तन्क	पुंकेशर तन्क	पुंकेशर तन्क	पुंकेशर तन्क	पुंकेशर तन्क
38	Palea	अवशल्क	अवशल्क	अवशल्क	अवशल्क	अवशल्क	अवशल्क	अवशल्क
39	Lemma	बिपत्रक	बिपत्रक	बिपत्रक	बिपत्रक	बिपत्रक	बिपत्रक	बिपत्रक
40	Stigma	स्त्रीकेशर	स्त्रीकेशर	स्त्रीकेशर	स्त्रीकेशर	स्त्रीकेशर	स्त्रीकेशर	स्त्रीकेशर
41	Ovary	गर्भाशय	गर्भाशय	गर्भाशय	गर्भाशय	गर्भाशय	गर्भाशय	गर्भाशय
42	Stamen	पुंकेशर	पुंकेशर	पुंकेशर	पुंकेशर	पुंकेशर	पुंकेशर	पुंकेशर
43	Lodicules	पुष्पफक्रक	पुष्पफक्रक	पुष्पफक्रक	पुष्पफक्रक	पुष्पफक्रक	पुष्पफक्रक	पुष्पफक्रक
44	Grain	दाना	दाना	दाना	दाना	दाना	दाना	दाना
45	Seed	बीउ	बीउ	बीउ	बीउ	बीउ	बीउ	बीउ

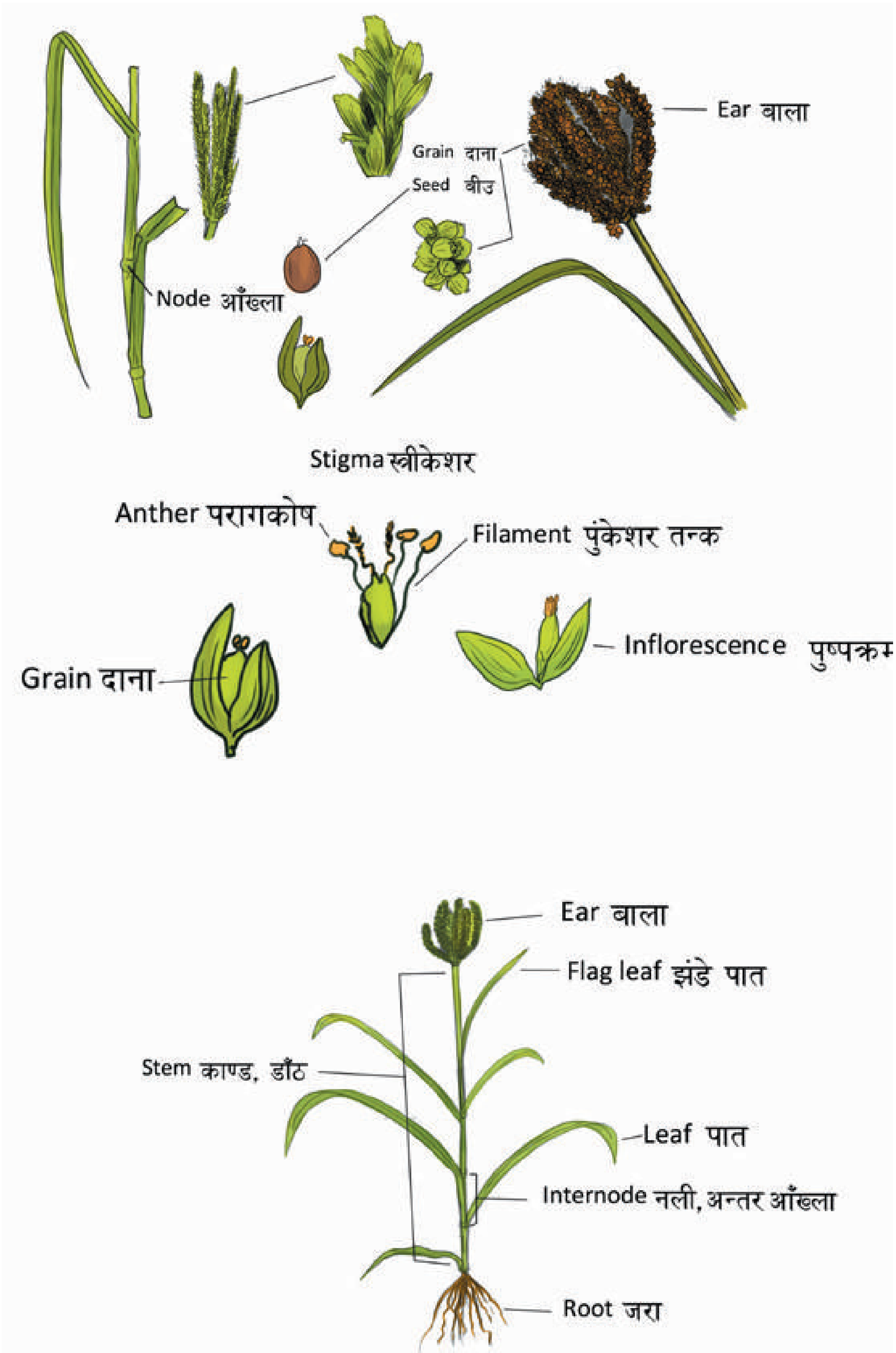
Growth stage

Growth stage	वृद्धि अवस्था/चरण
Dormant stage	सुषुप्त अवस्था/चरण
Seedling stage	वेर्ना अवस्था/चरण
Vegetative stage	वानस्पतिक अवस्था/चरण
Reproductive stage	प्रजनन् अवस्था/चरण
Grain filling stage	दाना भरिने अवस्था/चरण

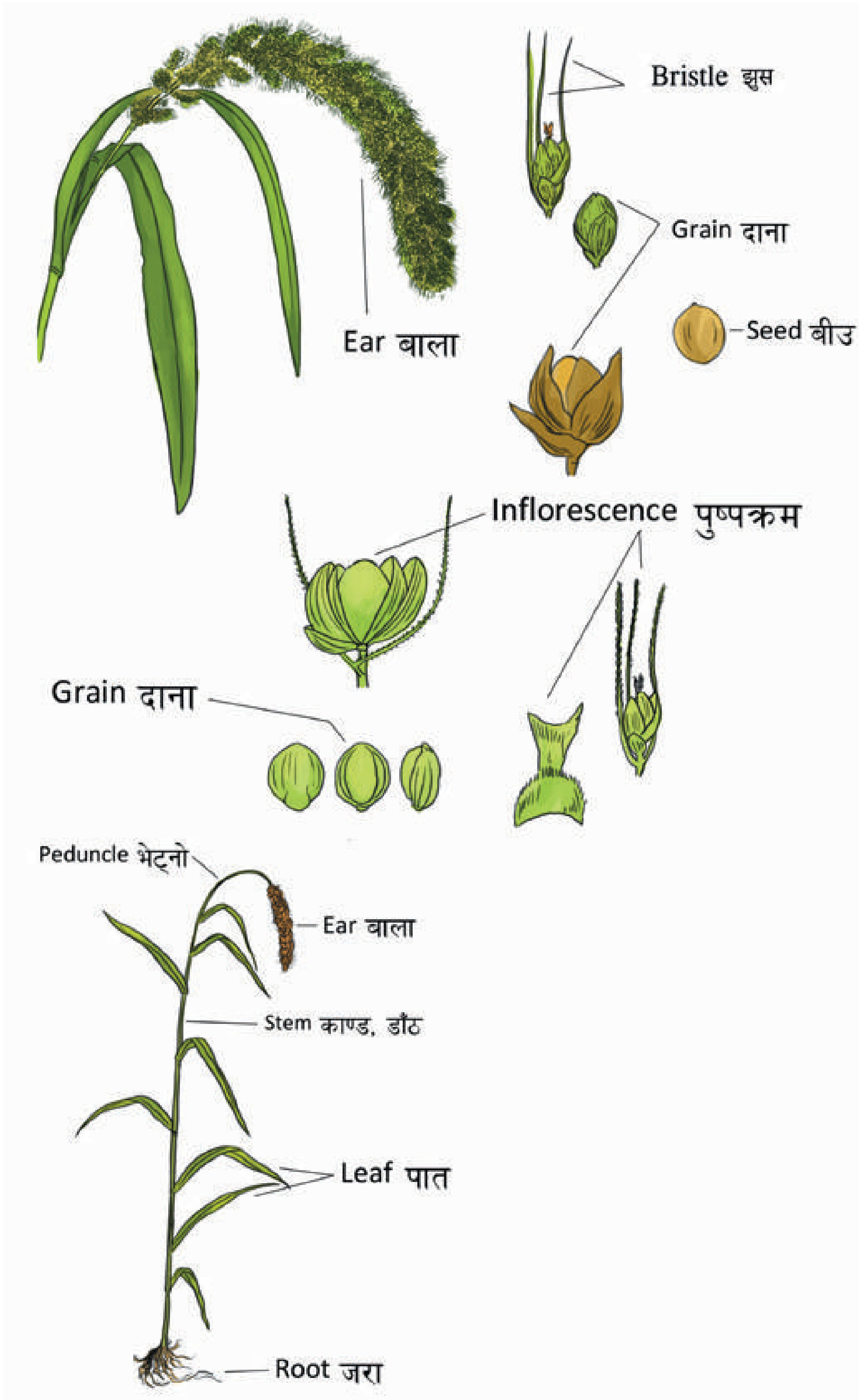
Little Milet, धान कोदो (*Panicum sumatrense* Roth.)



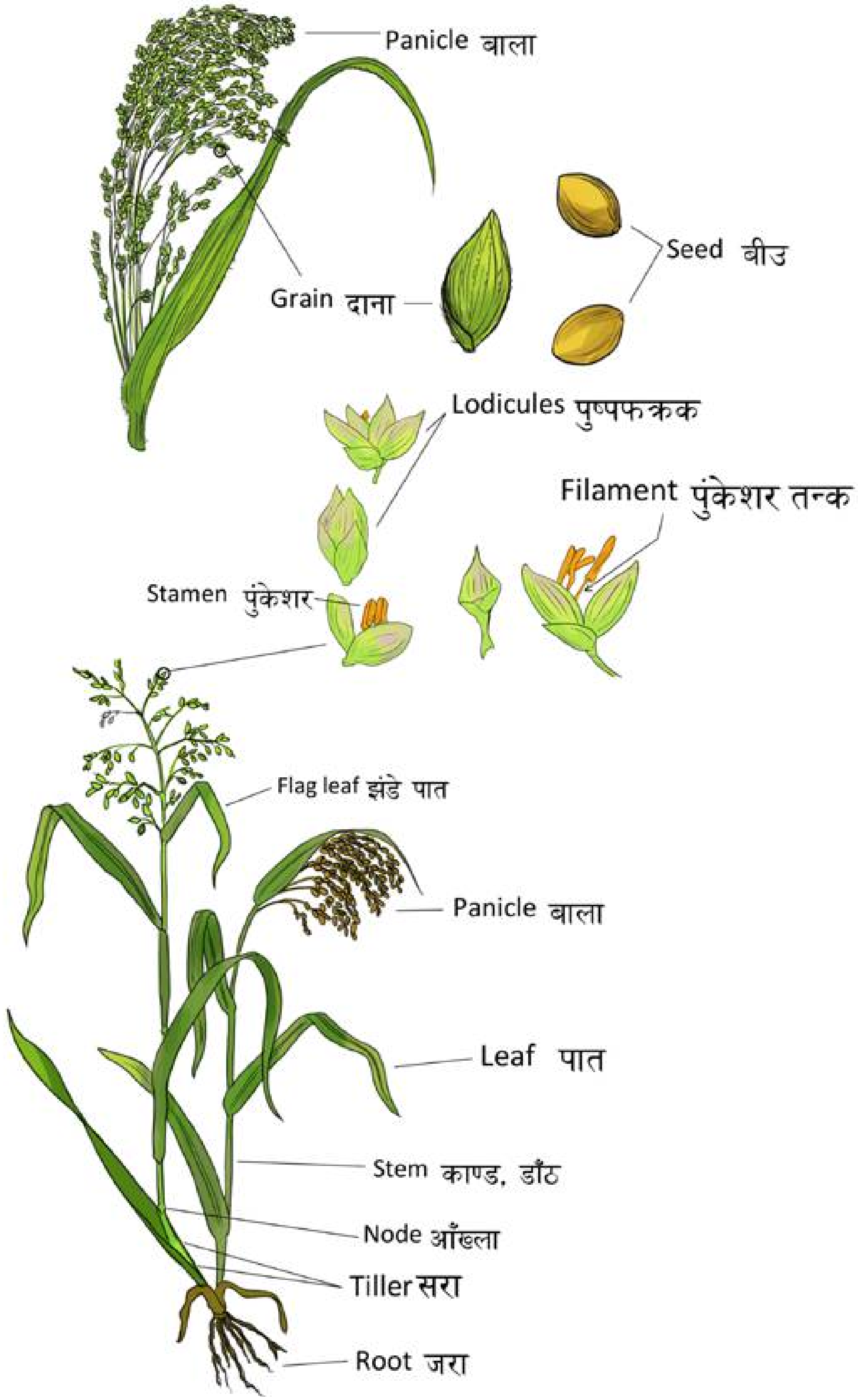
Finger Millet, कोदो (*Eleusine coracana* Gaertn.)



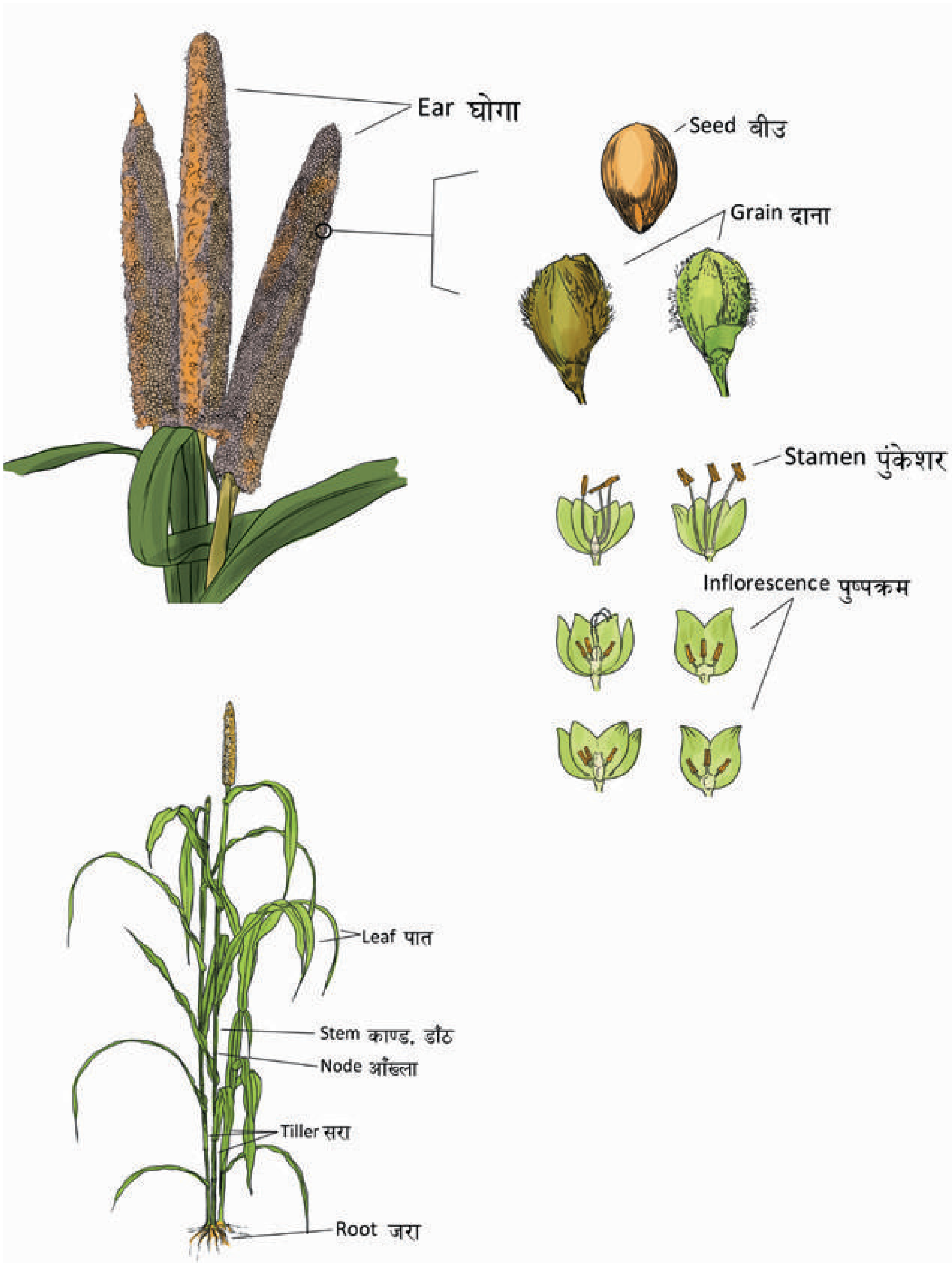
Foxtail Millet, कागुनो (*Setaria italica* (L.) Beauv.)



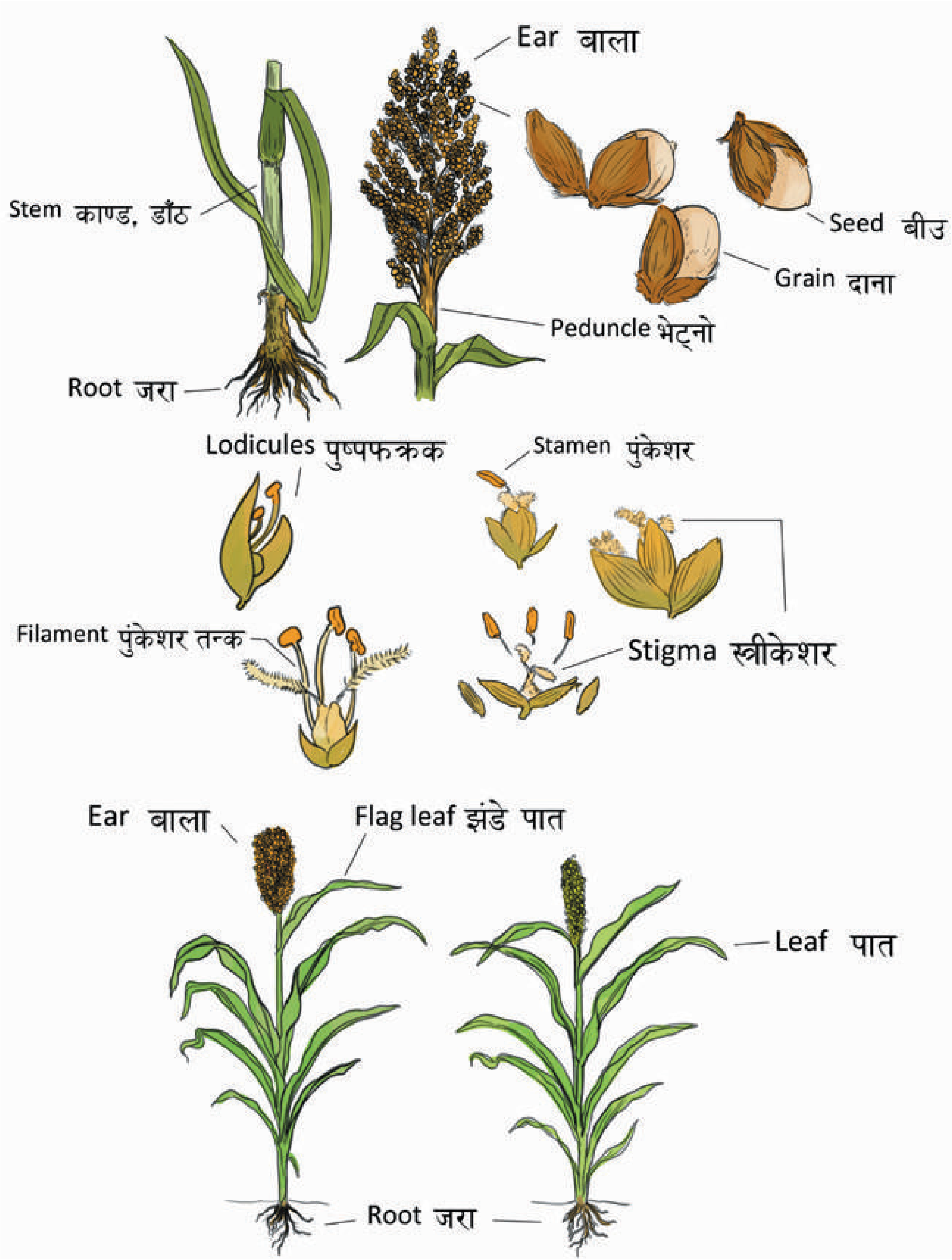
Proso Millet, चिनो (*Panicum miliaceum* L.)



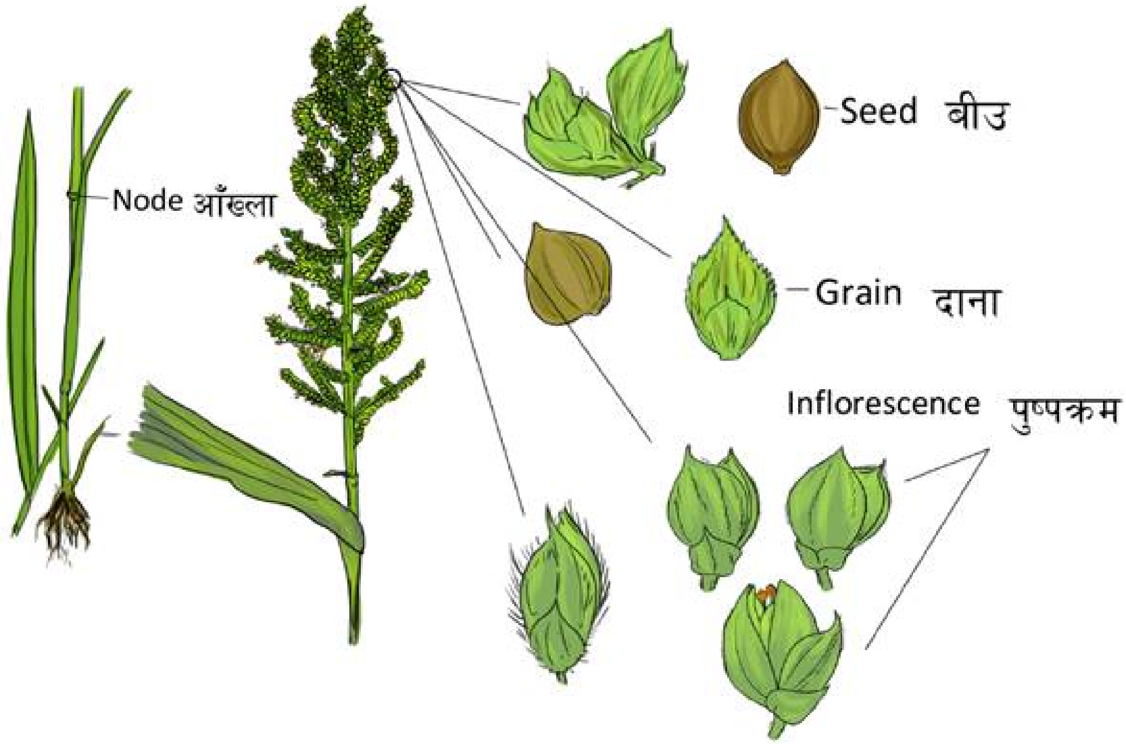
Pearl Millet, घोंगे (*Pennisetum glaucum* (L.) R.BR.)

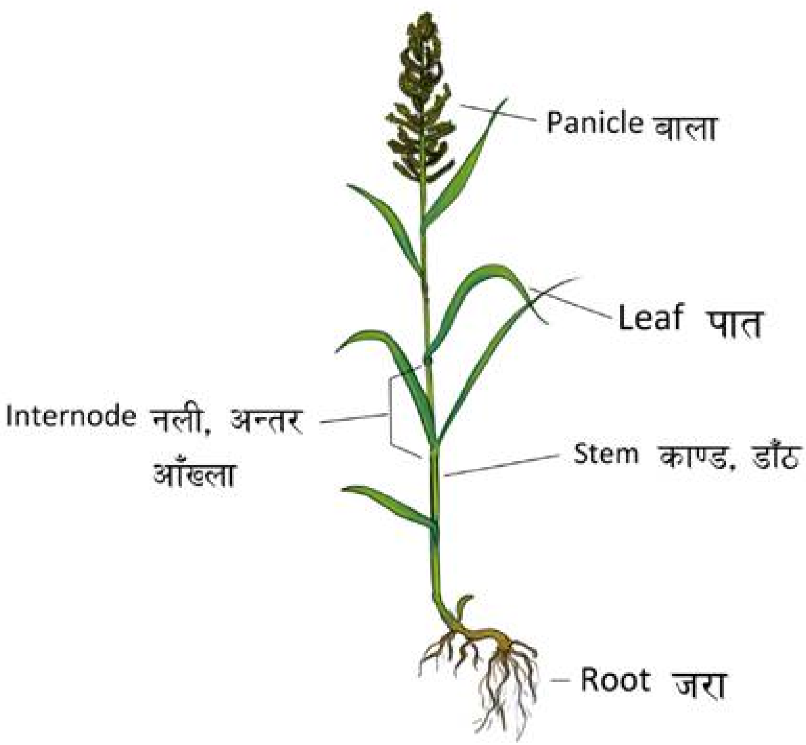


Sorghum, जुनेलो (*Sorghum bicolor* (L.) Moench)



Barnyard, सामा (*Echinochloa frumentacea* Link)





Growth Stage

Little millet

Finger millet

Foxtail millet

Proso millet

Pearl millet

Sorghum millet

Barnyard millet

Plants, Seeds and their Parts

Photo: Bal Krishna Joshi

Little millet

Barnyard grass

Chino chaamal

Nepalese barnyard millet

Finger millet (spreading earhead)

Inflorescence of finger millet

Sorghum

Little millet

Japnese barnyard millet

Proso millet

Seeds of barnyard millet

Damaged sorghum seeds


Sorghum seeds


Foxtail millet


Browntop millet


Weeding finger millet

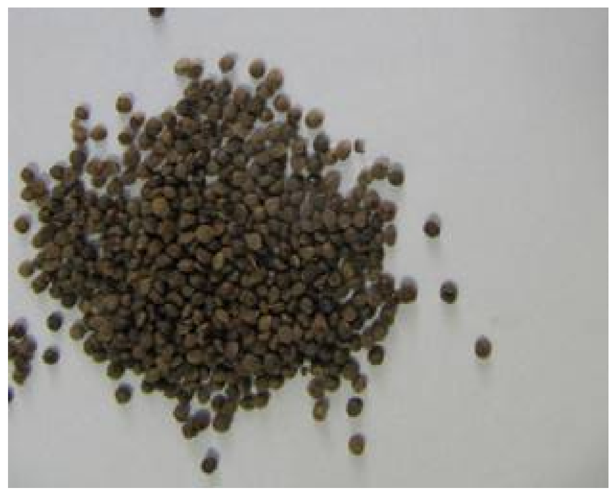

Barnyard millet


Pearl millet


Finger millet field


Foxtail millet


Foxtail millet in glasshouse


Kodo millet


Barnyard millet


Pearl millet

Protecting pearl millet

Foxtail millet

Seeds of different millets and other crops prepared for ***Satbeej***

Seeds of different millets and other crops prepared for ***Satbeej***

Flowers of pearl millet

Foxtail millet

Kodo millet

Farmers in finger millet field

Fields, Processing and Storage

Photo: Bal Krishna Joshi, Nawaraj Pandey, Dhan Bahadur Kathayat

Insect in foxtail millet

Seeds of different millets

Sun drying millet

Barnyard millet

Field protecting birds

Insect in finger millet


Finger millet drying for threshing


Gumsaayeko finger millet


Finger millet


Storing sorghum


Barnyard millet


Barnyard millet


Pearl millet


Pearl millet


Pearl millet


Pearl millet


Pearl millet


Pearl millet

Pearl millet

Saamaa

Harvesting finger millet

Harvesting finger millet

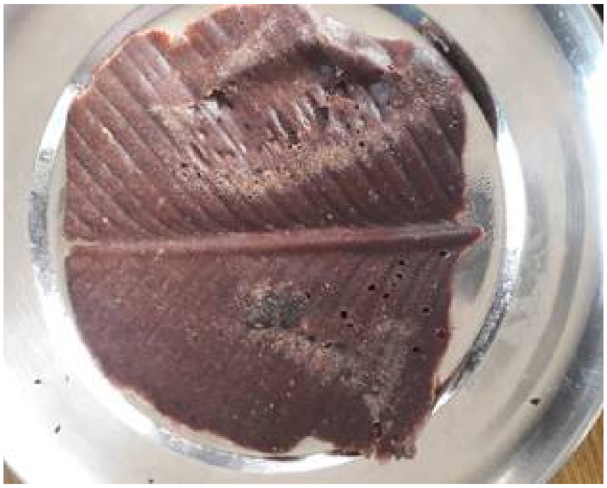
Threshing finger millet

Threshing finger millet

Sund drying millet grains

Food Items

Photo: Bal Krishna Joshi



Kodo roti (kerrako paatmaa pakaako)

Tongbaa (kodo ko)

Kheer (kaaguno)

Khole (kodo ko)

Raksi (kodo ko)

Dhindo pakayeko (kodo ko)

Dhindo (kodo ko)

Sel roti (kodo ko)

Bhaat (chino ko)

Editors eating Dhindo

Biscuit (proso millet)

Cookies (proso millet)

Dhindo paskadai

Kodoko parikaar

Chino-kaaguno paapad

Junelo bhutdai

Bhuteko junelo

Chino ko daanaa

Bhuteko chino

Kodoko pitho

Chaulaani (chino ko)

Bhijayeko chino

Chino ko bhaat

Chino bhijayeko

Kaguno ko bhaat

MoMo (kodo ko)

Khadya melaa-2074

Traditional Tools and Equipment

Photo: Bal Krishna Joshi

Chino Kutak

Halo

Gorule field jotdai

Khal

Storage items (wood)

Storage items (bamboo)


Dhiki and jaato


Raksi banaudai


Khal


Dhindo maskaudai


Jaato


Agenaa


Hasiyaa, Khurpeto


Saah, Ledko


Daalo


Biu mela


Kaatne hatiyaar


Paani ghatta

Bhakaari

Dhiki ra Chahine anne saaman

Jotne ra sammyaune aujaar

Junelo bhutne karaai

Biu bhandarn bhaado

Biu raakhne bhando

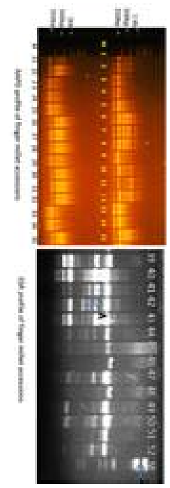
Ghaito

Others

Photo: Bal Krishna Joshi

Seeds in open market

Foxtail millet



DNA band of finger millet

Finger millet

Finger millet

Finger millet

Finger millet


Sorghum stalk


Saamaa


Finger millet mixture


Proso millet seeds


Seeds of foxtail millet


Foxtail millet and rice mixture

Mixture of finger millet

Seeds of proso millet

Finger millet in dry damage pillar

Seeds of nagre kodo

Seeds of seto kodo

Saamaa in rice field

7-brothers millet seeds

Harvesting foxtail millet

Japanese barnyard millet

Wild proso millet

Insect in foxtail millet

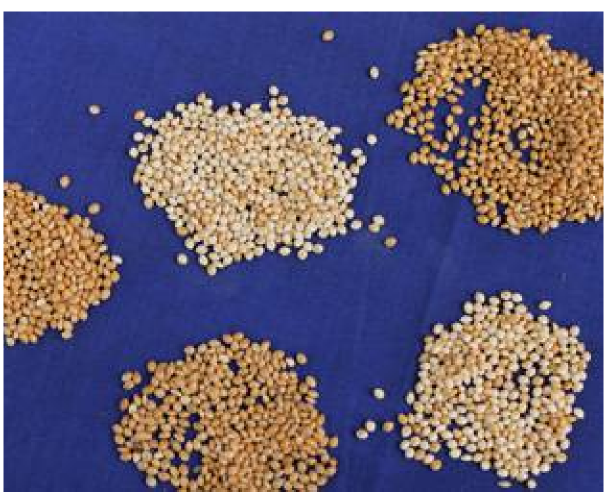
Diversity in foxtail millet

Bird in proso millet field

Proso millet

Diversity in proso millet

Crushed seeds of proso millet



Diversity in seeds of proso millet

Diversity seeds of foxtail millet


Finger millet field


Finger millet field


Finger millet field


Finger millet field


Finger millet field


Sorghum

Sorghum

Millets seeds in Nepal map

Foxtail and little millet

Little millet

Insect in finger millet

Seeds of different millets

Finger millet diversity at Genebank, Khumaltar

Promising finger millet landrace at Khumaltar

Finger millet grain color variation

Finger millet head diversity

Finger millet seed herbria

AFAOR Dr Binod Shah iproviding interview to Ujyaalo Radio

FAOR Ken Shimizu in Chef Nepal to promote millets

Collaborate with ICRISAT for cross learning

FAO Nepal official after the recording a song

Dr. Ram krishna Shrestha, Chief of CCDABC recording the audio message for student

Group pictire after School Millets Campaign

Interaction with the millets producing farmers

Dil Bahadur Yonjan Chair of Apanga tatha Bipanna Krishi Cooperative

Providing token of love to community at Barpark

School Millets Campaign in over 150 schools.

PSA on millets at Tripureshwor

Millet varites from ICRISAT

Eco-fare - relishing millet pancakes on World Environment Day

Mr Ken Shimizu FAOR for Bhutan and Nepal is tasting the Millets Pancake in exhibition

Local farmers with millets flour

Learning Sharing on Millets varities from ICRISAT

Millets displayed by FAO Nepal in FAO HQ Rome during WFF 2023

Serving the new taste of Millets' pancake

Static design of radio program Kura Kodoka

Students displaying the IYM banner after the calss session

Students inspired by the International Year of Millet

Tradition Millets grinding machine

Women farmers are planting millet plants

Millet curry in Nepali style

Millet Dosa

Millet magic baked into a delicious cake

Millet Pulao

Millets Nachos and Cookies for visitors

Steamed perfection-Millet idli

Millets varities in a frame

Keywords Index

Authors Index

Editor's Profile

Bal Krishna Joshi

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Affiliation: National Agriculture Geneteic Resources Center (Genebank), NARC, PO Box 3055, Kathmandu
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Education: PhD (Plant Genetics and Breeding) from the University of Tsukuba, Japan
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Experience: Dr Joshi is working on agrobiodiversity conservation and utilization, and plant breeding since last 25 years and have developed and identified 101 good practices and approaches along with varietal development. Some of the specific working areas of Dr Joshi are banking AGRs, genetic enhancement of landraces, use of biotechnology, geographical information system, climate analog tool, participatory and evolutionary plant breeding, computer aided statistical training, policy formulation, etc. He has published about 620 articles and edited 25 books and proceedings. He had served as an Editor-in-Chief for two journals and had received 12 different awards. Working motto of Dr Joshi is to make site specific agricultural genetic resources competent and dynamic.

Ram Krishna Shrestha

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Experience: Dr. Shrestha has been working in the areas of agricultural extension, agrifood policy, sustainable agriculture, climate change, agro-biodiversity conservation, agroecology and other nature positive farming, mountain farming system, conservation agriculture for more than twenty years. He has been leading the federal program in promoting millets and other indigenous crops across the country for the last five years. Hes is an invited member of Food System National Steering Committee. He has also led and coordinated the Action Track 2 (Shift to sustainable and healthy consumption patterns) of UN Food Systems Summit Nepal Country Dialogue, 2021. He has been involved in drafting a Policy Brief titled 'Revitalising millets for rural transformation in Nepal' as the lead of the drafting team, on the auspices of ICIMOD, Himalayan University Consortium (HUC) and the University of Reading on the eve of 'International Year of Millets, 2023'. He has published more than 20 articles. He has also served as a member of editorial board in half-a-dozen books and proceedings. Mr. Shrestha has received Nepal Civil Service Award from the government of Nepal and dozens of other awards and felicitations.

Krishna Hari Ghimire

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Experience: Mr Ghimire has more than 24 years of experiences on plant breeding and agrobiodiversity research under NARC with contribution in the release and registration of more than 20 crop varieties of major and minor crops in Nepal. He had published more than 200 research and review articles in peer reviewed journals, proceedings and books.

Hari Bahadur KC

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Experience: He has more than 28 years of experience in the civil service in agricultural policy formulation, program planning and implementation. His academic works focused on exploration of the crop pests and natural enemies and their diversity and distribution, IPM and Farmers' Field School. He has published more than twenty scientific articles in national and international peer reviewed journals and workshop proceedings. He has served as the editor of two Journals, has reviewed many Journal articles and proceedings in English and edited more than ten books and booklets in Nepali language. He was awarded 7 different awards and scholarships including Nepal Viddha Bhusan 'Ka' (Nepal Academic Award, First) from the Government of Nepal and TWAS (The Academy of Sciences for the Developing World) Award 2011 in Biology from the Nepal Academy of Science and Technology.

Arun GC

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Experience: With over a decade of comprehensive expertise in public policy, public administration, research, development and education, he brings a wealth of experience to the intersection of these domains. His passion lies in the field of economics, agricultural development, climate change and international trade. He has authored more than twenty-five scientific and research articles, alongside several op-ed articles in prominent publications. He has reviewed numerous articles for the international peer-review journals. Further, he served as a member of various studies and assessments.

Editing Assistants

Himani Oli

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Experience: Ms Oli recently completed her undergraduate studies in Agricultural Science from Purbhanchal University, Nepal. She has begun her first professional career at the Food and Agriculture Organization of the United Nations as a Programme Intern. Her experience, although relatively short, already shaped her both managerial and problem-solving skills at higher level with unparalleled opportunities working with seasoned experts and forward-thinking visionaries. She is exploring how intricate web of global challenges emanated from food insecurity, unsustainable exploitation of agriculture in the face of climate change has impacted at local levels in Nepal.

Surendra Kumar Shrestha

Birth place: Kathmandu
Affiliation: National Agriculture Geneteic Resources Center (Genebank)
Job title: Database officer
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Experience: Mr. Shrestha brings over 23 years of extensive experience in agrobiodiversity conservation, utilization, and policy-related projects, primarily in NAGRC under NARC. Serving as a project staff, he has played a pivotal role in the field of project and database management. His proven track record showcases a comprehensive involvement in various facets of project management and support.

He has excelled in relationship-building efforts to enhance project implementation. He adeptly addresses database-related issues and has independently managed internal and external requests for project-related advice and information. Beyond project management, his contributions extend to publication management, where he skillfully handles tasks such as graphic design and editing. His multifaceted expertise and hands-on experience make him a valuable asset in the successful execution of projects in the realms of agrobiodiversity conservation and policy implementation.

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URL: https://www.fao.org/nepal/en/

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