ICIMOD Manual 2017/9

ICIMOD

FOR MOUNTAINS AND PEOPLE

Package of Practices for Climate Resilient Value Chains Development of Selected Vegetable Crops and Ginger in Barshong, Bhutan

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The International Centre for Integrated Mountain Development, ICIMOD, is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

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ICIMOD gratefully acknowledges the support of its core donors: the Governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Sweden, and Switzerland.

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Package of Practices

for

Climate Resilient Value Chain Development of Selected Vegetable Crops and Ginger in Barshong, Bhutan

Authors

Purushottam P. Khatiwada
Pema Chofil
Surendra Raj Joshi
Sanjeev Bhuchar
Tshering Samdrup

International Centre for Integrated Mountain Development, Kathmandu and

Ministry of Agriculture and Forests (Royal Government of Bhutan)

October 2017

Published by
International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu, Nepal

ISBN 978 92 9115 545 3 (electronic)

LCCN 2017-322013

Production team
Shradha Ghale (Consultant editor)
Christopher Butler (Editor)
Dharma R Maharjan (Layout and design)
Asha Kaji Thaku (Editorial assistant)

Photos: Tshering Samdrup - cover, pp 3, 4; WOCAT - pp3, 4(B), 9 (TR, B); Jitendra Bajracharya - pp 1, 4(T), 5(T), 7, 13, 21, 29, 38, 45; Madhav Dhakal - 6(M); Elishabeth - pp15; Suraj Lepcha - pp6(T), 8, 9(TL), 16, 17(T); Sanjeev Bhuchar - 17(B); Purushottam P. Khatiwada - p11; Whitney Cranshaw, Colorado State Univ., Bugwood.org - 24(T), 33(B), 40; Alton N. Sparks Jr, Univ. of Georgia, Budwood.org - 24(M) 33(T), 49(T); Howard F. Schwartz, Colorado State University, Bugwood.org - pp25, 40(B); Mariusz Sobieski, Bugwood.org - p32; USDA APHIS PPQ - Imported Fire Ant Station , USDA APHIS PPQ, Bugwood.org - 49(B)

Citation: Khatiwada, P.P., Chofil, P., Joshi, S.R., Bhuchar, S., Samdrup, T. (2017) *Package of practices for climate resilient value chains development of selected vegetable crops and ginger in Barshong, Bhutan.* ICIMOD Manual 2017/9. Kathmandu: ICIMOD

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Acknowledgements

The authors would like to extend their sincere thanks to the farmers, extension workers and staff of Geog Administration Office, Barshong, and Dzongkhag office, Tsirang for sharing their knowledge about existing farming practices.

We would also like to thank Erling Valdemar Holmgren, Programme Coordinator for Himalica; Dhrupad Choudhury, Regional Programme Manager for Adapting to Change; and Eklabya Sharma, Director of Programme Operations at ICIMOD, for recognizing the need to document climate-resilient practices in vegetable and ginger farming. Thanks are also due to Sundar Rai, Uma Partap, Madhav Dhakal, Anu Joshi Shrestha and Chanda Gurung of ICIMOD for their valuable feedback on an earlier draft of the report.

We gratefully acknowledge the financial support provided by the European Union for this study.

We would like to thank Christopher Butler for editing, Dharma Ratna Maharjan, and Jitendra Raj Bajracharya for photos for layout design the report, and Gopilal Acharya, Communications Specialist at ICIMOD, for helping with its publication. Finally, we thank Golam Rasul, Livelihoods Theme Leader, for his helpful comments on the report.

Acronyms and Abbreviations

°C	Degree centigrade
cm	centimeter
CRA	Climate Resilient Agriculture
DAT	Days after transplanting
DP	Dusts
F1	Filial 1
FYM	Farm yard Manure
g	gram
GI	Galvanised Iron
ICIMOD	International Centre for Integrated Mountain Development
kg	kilogram
LLDH	Late Large Drum Head
LS	Lump Sum
m^3	cubic meter
masl	meter above sea level
ml	milliliter
mm	millimeter
mt	metric ton
NEPCAT	Nepal Conservation Approaches and Technologies
NSC	National Seed Centre
Nu	Ngultrum (Bhutan's currency)
OM	Organic matter
PVC	Polyvinyl chloride
RH	Relative Humidity
t	ton
WOCAT	World Overview of Conservation Approaches and Technologies
WP	Wettable powder

Message from the Secretary, Ministry of Agriculture and Forests, Royal Government of Bhutan

Bhutan is an agrarian country where more than 58% of the population depends on subsistence agriculture for livelihood. The country's difficult and rugged mountain terrain poses significant challenge to farmers to produce food. The total cultivable land is shrinking fast because of competing uses of land by various development activities. Today, only about three percent of total land is under cultivation.

It's against this backdrop that the Department of Agriculture (DoA) under the Ministry of Agriculture and Forests (MoAF) has been making concerted efforts to increase agriculture productivity through introduction of innovative farming technologies, high yielding crop varieties, and improved irrigation systems. Efforts are also underway to mechanize agriculture and adopt innovative technologies to address farm labour shortage and reduce drudgery. These efforts are aimed to make mountain agriculture climate resilient, sustainable, and cost effective and suitable to achieve food self-sufficiency goals.

EU ICIMOD Himalica pilot project in Tsirang dzongkhag (district) has helped the farmers of Barshong gewog (sub-district) make considerable progress in rural livelihood options and climate change adaptations. The project has introduced a number of improved and innovative farming technologies and practices. I personally witnessed how these technologies and practices were making a difference to lives of Barshong farmers.

We must now find ways and means to up-scale and out-scale successful technologies and practices in Barshong and the rest of the country. In this regard, the "**Package of Practices for Climate Resilient Value Chains Development of Selected Vegetable Crops and Ginger in Barshong, Bhutan**" is an important milestone which documents and disseminates 'best practices' knowledge from the pilot site.

The book outlines climate resilient agriculture practices such as raising of quality seedlings, water harvesting, water application methods, composting, cattle urine collection and use, bio-char preparation, and storage of farm produces. It also covers various cropping requirements of beans, cabbage, ginger, and onion.

I am hopeful that this Package of Practices (PoP) will offer valuable and practical knowledge to our farmers to make farming more scientific, climate resilient, productive, sustainable, and gender friendly.

Finally, I sincerely wish to extend my deep appreciation to all the individuals who worked tirelessly and with determination to bring out this publication.

(Rinzin Dorji)
Secretary, MoAF, Bhutan

Message from the Director General

In the Hindu Kush Himalaya (HKH), the amount of area under niche-based agricultural crops, such as vegetables and fruits, appears to be expanding with corresponding improvement in infrastructure, information services, market networks and favourable policies. Mountain farmers, especially women, are taking up agriculture-based enterprises either individually or in groups enhance their livelihoods and household income.

The increasing trend of commercial vegetable cultivation is contributing positively to the development of resilient mountain communities in the HKH. However, excessive application of chemical fertilisers and pesticides can lead to environmental and human health hazards, such as groundwater contamination. Chemical methods of crop protection also damage useful insects in the production areas.

Gender and social inequity issues may also emerge among all these changes. Therefore, agricultural value chains should integrate practices that are environmentally and socially sustainable and reduce climate and production risks. Only then, can the long-term sustainability of production systems and value chains be ensured.

With the objective to build resilient livelihoods by harnessing emerging opportunities, the EU-funded Support to Rural Livelihoods and Climate Change Adaptation in the Himalayas (Himalica) programme has been promoting vegetable value chains in Barshong Gewog in Bhutan and Udayapur district in Nepal with visible outcomes. I am glad to see that a Package of Practices (POP) for climate-resilient value chain development of selected vegetables and ginger has been developed as part of the Himalica activities. This well-elaborated publication contains simple and sustainable practices for climate resilient vegetable production and will serve as a useful reference for local agriculture officials, farmers and others who are involved in vegetable production. In my view, the POP will be useful for professionals and practitioners across all eight HKH countries and not just Bhutan. I extend my sincere appreciation to all who have contributed to the production of this important publication.

David Molden, PhD
Director General
International Centre for Integrated Mountain Development
Kathmandu, Nepal

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Climate Resilient Agricultural Practices

Basic Concept

Climate Resilient Agriculture (CRA) is an innovative climate-friendly agricultural practice for adaptation, resilience and mitigation of climate change impacts. It integrates the economic, social and environmental aspects of sustainable agriculture to address food security and climate challenges and increase incomes. Land, water and inputs should be utilized effectively to enhance productivity. This can be done through integrated nutrient management, pest and disease control by bio-pesticide, water recharge, harvesting and (re)use, and other climate resilient measures. Further, CRA practices can ensure a high rate of production and technological adaptability. These practices help in reducing greenhouse gas emissions or the amount of required labour or equipment. CRA is geared towards three main objectives: i) sustainably increasing agricultural productivity and incomes, ii) adapting and building resilience to climate change, and iii) reducing greenhouse gas emissions.

The basic pillars of CRA are as follows:

Weather smart: In a broad sense, this approach encompasses seasonal weather forecasts, agro-advisories based on information and communications technology and index-based insurance. It will take a few more years to implement these components in Barsong Geog. At the farm level, the approach includes alteration in production and harvesting time to escape extreme weather (e.g., farmers started planting potatoes 15 days later in the mid-hills of western Nepal to escape frost during the peak growing period), introduction of new varieties (e.g., onion and cabbage varieties suitable for the rainy season are available in regional markets), changes in farming practices (e.g., plastic house technology for rainy season tomato production in the hills), etc. Some of these activities can be carried out/recommended according to recent weather conditions and trends of Barshong area.

Water smart: It includes soil moisture and aquifer recharge, rainwater and snow harvesting, community management of water, and efficient use of water and irrigation based on crop water requirement. Crop varietal selection plays an important role if water is scarce. Some varieties need less water and are more drought tolerant than others. Other sustainable practices include irrigation based on the crop's vegetative phases and watering early in the morning or in the evening. Household level water harvesting and judicious and efficient use of water is also a water-smart approach.

Soil and nutrient smart: It includes maintenance of soil health by retaining organic matters in soil; low and efficient use of chemical fertilizers, such as site specific nutrient management; optimum use of fertilizers (mainly, nitrogen, phosphorus and potash); balanced application of macro and micro nutrients (boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo) and zinc (Zn); green manuring; crop rotation; legume integration, etc. It also includes activities that control soil erosion and enhance carbon sequestration by promoting the agro-forestry system and conservation agriculture, e.g. reduced tillage and other sustainable land use systems.

Energy smart: This approach focuses on minimizing fossil fuel use and maximizing the use of natural energy, such as fuel-efficient engine, use of bio fuels, maximizing plant residue management, and minimum tillage. It includes options like solar power/pumps to lift water for irrigation, energy efficient dryer, productive use of renewable energy for grinding, powdering as well as biogas.

Knowledge smart: It consists of farmer-to-farmer learning, participatory extension, and farmers' networks on adoption technologies, maintaining a community seed storage and exchange system and access to market information. It further encompasses activities like exchange of information on the specific requirements of end markets, resource sharing among value chain actors, collective branding, use of mobile phones for climate and market information, etc.

Along with these, gender smartness will be taken into consideration in order to reduce women's workload and drudgery, easy to perform agricultural practices as well as to build on their knowledge and experience as women play a central role in agriculture.

Basic Elements of CRA

CRA covers activities on the farm and beyond the farm, encompassing agriculture related technologies, policies, institutions and investment. More precisely, different elements that can be integrated in CRA approaches include:

- Management of farms, crops and livestock to better utilize resources and produce more while increasing resilience: Livestock is integral to the hill farming system, particularly to subsistence and semi-commercial farming. By-products from agricultural crops like straw, legumes waste and leaves of vegetables can be used as livestock feed. In return livestock provides animal protein and cash income for the family. They are also a reliable source of manure.
- Adding value to the products, process and functions to meet the requirements of end markets: Value addition is important for raising incomes from horticultural crops, as these crops are primarily grown for markets. Value addition and building links with the end markets is a challenge in the context of hill farming. It is important to make adjustments to the production system to get good prices and keep up with the competition in the market. Exchanging information and risk sharing are effective ways to build relations with value chain actors and service providers both at the horizontal and vertical level.
- Conservation and better management of ecosystem and landscape for resource efficiency and resilience: Landscape and ecosystem management is a chief component of CRA. The amount of carbon emission, production technologies and labour use are determined by the type and size of agricultural land. Farming in the hills is significantly different from farming in the plains in terms of production, resources requirement and cultivation techniques. Crops grown in river basin areas mature earlier than crops grown at higher elevations. Therefore, climate smart practices should be designed according to the landscape and ecosystem in an inclusive way. Landscape management is also important for pollination services.
- Services that enable farmers to implement required changes from village based institutions to the higher level: As farmers are familiar with the production system of their own area, they could play a vital role in designing appropriate climate smart technologies for the area. Services such as teaching farmers about the trends in climate change and global warming and their potential impacts on future agriculture can help them implement climate smart practices at the local level. Targeted efforts to include women are equally important, as women and men have different needs and priorities (Figure 1).

Figure 1: **Sharing knowledge with farmers**

Water Management

Water management is a sub-set of water cycle management, which consists of activities like planning, developing and managing water resources for optimum use. At the community and household level, management of water resources, irrigation and soil moisture has practical implications. Agricultural methods that involve climate smart technologies require the ecosystem approach to conserve water. Crops are grown under different water management regimes but rainfed or partial irrigation farming is the feature of hill agriculture, like in Barshong. Hence water management and irrigation in Barshong are completely dependent on nature, either through natural streams or rainfall. Timely irrigation is very important for crops to stabilize and to increase yield. Irrigation not only increases productivity, it also contributes to land intensification, i.e., it enables farmers to increase the number of crops grown per year. Evidence shows that irrigated crops have twice as much yield as rain-fed crops. Reliable and flexible supply of water is vital for high-value crops like vegetables. Irregular rainfall, drought, water scarcity, temperature rise and other environmental issues are emerging problems faced by the hill farming system. Barshong is not an exception. Water management is crucial for enhancing productivity.

Cropping systems broadly fall into two categories based on their water use and management:

Rainfed cropping system: Irrigation is one of the main constraints of agriculture in Bhutan. The hill cropping system of Barshong is mainly rainfed and productivity of the crops primarily depends on rain. As rain is not a perennial water source, any change in rainfall pattern poses a lot of difficulty for farmers. Productivity in rainfed hills can be improved by growing deep-rooted crops in rotation, adapting crops to develop a deeper rooting habit, increasing soil water storage capacity and minimizing evaporation through organic mulching. These approaches are, however, not enough to bring anticipated yield and income from vegetable crops. Out of the four value chains selected for promotion in Barshong area, three (bean, cabbage and onion) are primarily winter crops and only one (ginger) is the rainy season crop. If rainfall is irregular or absent, it leads to moisture shortage during critical stages of growth, which severely affects the yield. Farming in the hills involves more risks than farming in the plains regardless of the crop or the season in which it is grown. This is because of hilly terrain has low capacity for holding water, resulting in quick drainage of rain water. Serious planning for water management is hence crucial for improving yield in hills areas like Barshong.

Irrigated cropping system: Crops can be irrigated using artificial structures to channel water from ponds, rivers and other water resources. However, this method requires adequate labour and equipment to be effective. Generally subsistence farmers do not use organized irrigation systems because it requires a lot of resources. As subsistence farming is the most common type of farming in Barshong Geog, formal irrigation structures were not observed during the field visit. Provision of irrigation water is necessary if farmers are to opt for the market-oriented production system. Out of three winter vegetable crops, cabbage and onion have shallow roots. Their productivity will be highly dependent on moisture management.

Water harvesting techniques: Water harvesting technique encompasses three basic elements namely, catching area, collection device and using techniques. More precisely, this technology includes collection and storage of water from water sources such as surface water and rain water using simple (such as jars and pots) as well as complex (such as artificial ponds) techniques. The most common technique of irrigation in the hills is making furrows starting from the nearest water sources such as rivers and springs. But surface irrigation by furrow or basin is often less efficient than overhead micro-irrigation such as sprinkle and drip irrigation. As majority of the springs dry up in winter, harvesting rain water during the later stage of the rainy season might be a better option for meeting the demand for water in winter, along with working on reviving the dry springs through hydrogeological approach. The following section briefly describes some simple methods of rainwater harvesting which are appropriate for hill areas like Barshong.

Figure 2: **Plastic lined water harvesting pond**

- Surface runoff harvesting: Water running from the surface (natural springs or runoff) of hills flows downwards due to the slope. The water can be caught by constructing artificial ponds in the lower areas. Low-cost plastic ponds (Figure 2) are more suitable for Barshong as it does not require sophisticated technology or a large amount of resources. This technology is appropriate for growing high-value crops such as bean, cabbage and onion.
- Rooftop rainwater harvesting: In rooftop harvesting, the roof serves as the catchment and the rainwater is collected from the roof of the house (Figure 3). It can either be stored in a tank

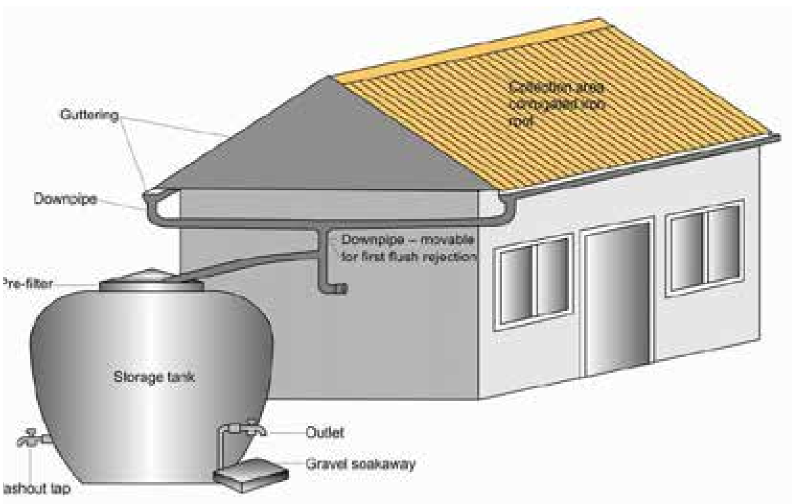


Figure 3: **An illustration of Roof Rain Water Harvesting**

or diverted to a pond. This method is a bit more expensive than plastic pond but effective for growing high-value horticultural crops. The harvested water can also be used for drip irrigation if stored in a plastic tank, low-cost ferro-cement jars, or bamboo plastic jars. Water collected through this method can be used for household purposes such as washing clothes or preparing animal feed, tasks that are mostly performed by women.

Water efficient irrigation techniques:

Wise use of water during crop production period can help to conserve the precious water resource. It is important to choose an irrigation method that consumes less water and supplies water according to the need of the crop. The different systems of irrigation used for vegetable production are: flood system, basin system, furrow system, ring system, and modified furrow system. Following are water-efficient systems widely used for climate smart agriculture. These are also appropriate for the socioeconomic setting of Barshong area.

Sprinkler system: Different types of sprinklers, from programmable automatic to manual, are used in different parts of the world (Figure 4). Manual sprinklers seem suitable for Barshong Geog considering the local socioeconomic situation and the scale of farming in the area. The gravitational flow of water in a hose-pipe is sufficient for running a sprinkler in the hills; there is no need for additional energy. The user simply has to fit the sprinkler into the pipe, fix it in the field with the help of a stick and then check it during watering times. If water runs off the plot, watering time should be split into two sessions to increase the rate of percolation. This system is good for closely spaced vegetables like garlic and onion. As this technique does not demand continuous attendance, it can be considered a gender friendly technique.

Figure 4: **Irrigation with sprinkler**

Drip irrigation: Drip irrigation (Figure 5) is a highly effective method for utilising water as it provides water to individual plants. But it is more suitable in small areas of land because of its high initial cost. Furthermore, it requires more pipes and is thus difficult to install in larger areas on hilly slopes. The advantage of drip irrigation over sprinklers is that there is little water loss due to evaporation and runoff. Among the selected value chains, drip irrigation is more appropriate for vegetables that require wide spacing, e.g., cabbage. Nitrogen uptake efficiency is closely related to irrigation efficiency. It could increase up to 80–90% with the use of drip irrigation. Nitrogen can also be supplied along with irrigation water (fertigation) on a regular basis by adding cattle urine in the drip irrigation tank. It is less labour intensive and easy to operate, and could be categorized as a gender friendly technology.

Figure 5: **Drip irrigation**

Hand watering: The simplest and most common irrigation system is a hose pipe or watering can (Figure 6). The main advantage of hand irrigation is that the person irrigating the field can easily avoid over watering. When water stops being absorbed into the ground, s/he can move to another location. Hand watering and sprinkler is the most beneficial technique of water supply for vegetable crops in the hills.

Figure 6: **Hand irrigation with water can**

Pitcher irrigation: In its simplest form, pitcher irrigation (Figure 7) consists of unglazed baked earthen pitchers that are buried up to their necks in the soil and filled with water. The water gradually seeps through the porous walls into the root zone under hydrostatic pressure and/or suction to maintain plant growth around the pitchers. When the pot is filled with water, the natural pores in the pot's walls allow water to spread laterally in the soil, creating the moist conditions necessary for plant growth. Pitchers are filled as needed, maintaining a continuous supply of water directly to the plant root zone. Hollow bamboo culms can also be used for pitcher irrigation after making fine pores considering crop root zone.

Figure 7: **Pitcher irrigation using unglazed clay pots**

The benefits of the aforementioned techniques can be increased through mulching, which reduces soil evaporation. Hence, always use organic (straw/dried leaves or grasses) mulch to the crop. Mulch further helps to suppress weed, lower soil temperature during warm weather and add-up organic matter in the field.

Soil and its Improvements

Soil health: Healthy soil enables plants to accumulate nutrients efficiently, compete well with weeds, resist pests and suppress erosion through an extensive root system. Soil health in the agricultural sense is a state of soil that sustains crop productivity, good physical and chemical properties and sustainable microbial ecology with their balanced population. More precisely, soil temperature, moisture, organic carbon, structure, microbial population, respiration and soil water availability are the determinants of soil health. Hence, maintenance of soil health is crucial for achieving the anticipated output from high-value crop cultivation.

Maintaining soil health on hilly slopes is a challenging task. The first step for soil health maintenance involves conservation of top soil by checking the mass soil erosion through terracing (Figure 8) and contour farming. Terracing and contour farming is a common practice in Barshong area. Subsequent activities include improvement and management of cropping practices (such as intercropping and mixed cropping), inclusion of legume crops in crop rotation, use of green manure, incorporation of compost manure, improvement of animal management system (shade improvement, urine collection and no tethering), rotational fallowing, minimum tillage practice and agroforestry management (introduction of improved varieties of grasses and legumes). All of these have their own importance and used at different levels in Barshong Geog. In terms of promoting high-value horticultural commodities, promotion of organic manure is particularly significant in the context of climate smart agriculture.

Organic manure (OM) is a common term for farmyard manure (FYM) and compost, but 'organic manure' and 'compost' are also used as synonyms in

Figure 8: **Irrigated terraces**

many places. Farm animal manure and litters are the main materials in farmyard manure whereas compost consists of materials from plant sources. However, composting is a common word, which means biological decomposition (rotting and decaying) of plant residues, farm animal manures and kitchen scraps under controlled conditions. Organic manure is prepared upon complete decomposition. Well-decomposed organic manure looks earthy, dark and crumbly, and is odorless. However, farmers in Barshong primarily use undecomposed organic manure. It is strongly recommended that they use only decomposed organic manure for all crops including bean, cabbage, onion and ginger. The major sources of organic manure, which can be easily promoted in Barshong Geog, are briefly described in the following section.

Farm yard manure improvement

Farmyard manure (Figure 9) is the most commonly used organic manure. It is mostly derived from cattle and buffalo dung, litters and residues from animal husbandry. High organic matter content in the soil has multi-faceted advantages, such as friable soil structure, high rate of cat ion exchange capacity, increase in water holding capacity, high rate of water infiltration and lower susceptibility to pest problems. Use of FYM is an age-old practice in the hill farming system but its quality is very low because of improper management and inappropriate application methods. Field observation and interaction in Barshong Geog revealed the following constraints in FYM management:

Figure 9: **Farm yard manure**

- Difficult to collect dung and urine because the tethering system remains predominant
- Wastage of urine because the importance of urine collection is not considered during shed construction
- Animal sheds are constructed without planning and therefore the FYM pit/heap is exposed to rain, runoff water and direct sun.
- The practice of using undecomposed FYM, which results in a high incidence of pests such as white grubs and poor nutrient release.
- Nutrient loss in the field because of a long gap between field application and incorporation into the soil

Nitrogen level in FYM can easily be doubled by improving the current FYM management practices. Since dung and urine are the primary sources of plant nutrients in the hills, the following points need to be considered for improving FYM:

- Check urine loss by improving the shed.
- Make a furrow for urine collection and collect urine in a small pond or tank.
- Use dry litter to absorb the urine immediately after release if there is no provision of urine collection.
- Make a pit for dung and litters if there are chances of runoff.
- Protect the manure from the sun (to check de-nitrification) and rainwater (to check potash leaching) by provide the shade above the collection pit or heap.
- Check to ensure that runoff water does not enter the collection pit.
- In the case of green litter use, apply easily decomposable and nutritious plant species.
- If possible, add ash or lime to the pit/heap for better results.
- Incorporate FYM into the soil immediately after it is transported to the field. If this is not possible, heap the FYM up in convenient spots and cover it with soil, plant twigs or plastic sheets.

Cattle urine

Nitrogen is the most important and most limiting macronutrient in the hill farming system. Cattle urine is an important source of nitrogen and also has pesticide properties. Of the nitrogen excreted by cattle, 60 percent is found in urine and the remaining 40 percent in dung. But the farmers of Barshong have not internalized this fact, and there is an urgent need to provide them this information. To promote cattle urine use for high-value horticultural crops (as well as other crops), cattle sheds should be designed so that urine gets collected in a pit or a drum (Figure 10). The urine collection pit or drum should be located in the shed or just outside, connected to the drainage channel and protected from direct sun, rainfall and runoff water. Urine is applied with water in the ratio of 1:7–8 in seedlings and 1:4–5 in growing plants. Urine can also be mixed with irrigation water in the case of drip irrigation.


Figure 10: **Improved cattle shed for urine collection**

Compost preparation

Compost can be prepared with any kind of plant materials. Promoting compost in Barshong area is necessary for the following reasons: i) sufficient FYM cannot be prepared because only a small number of livestock is reared in the area ii) abundant availability of plant material for compost preparation, iii) crop growing households without large animals can still produce the required amount of compost, and iv) compost can be prepared in the field itself, so there is no need to spend time and labour on transporting it from the animal shed to the field. Since, carrying of organic manure is considered as a women's job, it reduces the work load to women. Generally composting materials consist of green materials rich in nitrogen (freshly cut grasses, twigs, branches and barks cut into small pieces, kitchen scraps) and brown materials that are rich in carbon (dried leaves, straws, rice husks and other plant residues). A high proportion of carbon rich materials delays the process of decomposition; in contrast, a high proportion of nitrogen rich materials causes quick decomposition. Maintaining a carbon-to-nitrogen (C-N) ratio of 30:1 accelerates decomposition. In addition to the C-N ratio, the moisture content of composting materials is equally important for decomposition. Moisture content should be around 55–60% and watering should be done when large quantities of dry materials are used. Another important step for enhancing the decomposition process involves incorporating suitable materials for a high rate of microbial activities. These materials are commonly known as starters. Compost starters include dung urine slurry, biogas slurry, partially decomposed FYM, forest topsoil, soil from old pits and effective microorganisms. Earlier studies in Bhutan showed that use of effective microorganisms has drastically shortened the process of compost preparation. Application of small amounts of wood ash, mineral fertilizers and lime improves the overall balance of nutrients in the compost. Since decomposition is an aerobic process, air circulation in the composting process is also important. The quality of compost is determined by the composting materials. High-quality compost is made by using legume-based residues, young leaves and twigs and kitchen wastes. Plants with bio-pesticide properties can be grown as hedge species for composting, along with plants high in nutrients, such as Malabar nut tree or *Asuro* (rich in nitrogen) and tree marigold or *Tara Mandal* (rich in phosphorus). Growing composting materials as hedge will save women's time, as they won't have to collect raw materials for compost. Compost can be prepared using the heap, pit, or semi-pit method. The heap method is more appropriate in the rainy season when the moisture content in the composting materials is high. In contrast, the pit method is suitable in dry season when the moisture content in the composting materials is low. The semi-pit method comprises elements of the two methods. The procedures for the heap and pit methods are briefly described below.

Procedure for the heap method: Spread a 20–25 cm-thick layer of brown material on surface soil. The next layer should be of finely chopped green materials and as thick as the first layer (Figure 11). Water it if necessary, but make sure it is only moist, not wet. Top this with a 10 cm-thick layer of starter. Continue piling the materials in the same order until a heap of about one metre in height is formed. The heap should be slightly concave at the top. Cover the heap with a black plastic sheet to increase the temperature inside (Figure 12). After 4–7 weeks, turn the pile using a spade or shovel and make sure the materials are mixed properly. The length of the decomposition process is primarily determined by the outside temperature and the nature and proportion of the mix. Repeat the process after 4–7 weeks. In the high hills, it might be necessary to turn the pile three times. If the moisture content of

Figure 11: **Compost heap under a thatch shade**

Figure 12: **Compost heap covered with black plastic**

the pile is low, add water while turning it.

Alternatively, the biodynamic composting method can be used to produce a large quantity of compost. The process is almost the same as the traditional method, but in the biodynamic method, a rectangular plot, generally of 5x2 m, is marked and logs or PVC pipes are placed along the length in the middle to facilitate air circulation. Crushed slaked lime and rock phosphate are added and watering is done at weekly intervals.

Procedure for the pit method: Ideally a pit is 1 metre deep and 1 metre wide. The length of the pit is determined by the need and availability of composting materials. The site for the compost pit should be free from water logging and partially shaded to prevent moisture loss.

To prepare compost, first chop the composting materials into tiny bits; this will quicken the decomposition process. Make a 20–25 cm-thick layer of chopped and moistened composting materials and add a 10 cm-thick layer of starters such as mixture of dung and urine, forest topsoil and ash bone meal. Repeat the steps until the pile reaches a height of 1 meter from the ground level. Make pile thicker in the middle to create a dome shape. This makes turning the pile easier. Place the plastic pipe or sticks vertically into the pile to allow the air to circulate into the various layers. Cover the pit with soil or the leaves of broad-leaved plants like banana and taro. A black plastic sheet could be used to raise the temperature in winter season. Turn the pile at least twice at 4–6 week intervals. The compost will be ready after 3–4 months.

Well decomposed compost or FYM should have the following characteristics:

- Manure should be soft and black or brown in colour.
- It is almost odorless or has an earthy smell.
- It does not stick to your skin when you hold it in your hand.
- Parent materials completely lose their identity.
- Fungus or earthworms can be seen in the pit.

Vermicompost

It is a simple biotechnological composting process that uses certain species of earthworms to enhance the process. Vermicompost (Figure 13) is basically a mixture of compost and earthworm excreta. Species like *Elsenia foetida* and *Eudrilus eagiva* are found to be the most effective composting agents in hilly areas with similar agro-climatic conditions. These species are popular because of their capacity to convert different types of plant materials into vermicompost. They can successfully be reared in bins (natural habitat is close to the surface). Different kinds of containers

Figure 13: **Vermicompost**

can be used for vermicomposting but it should have good ventilation, more surface than depth and protect from sun and rain.

To prepare vermicompost, layer the base of the container with sand and top it with dried and shredded cow dung. Add a thick layer of waste materials. Add another layer of dried and shredded cow dung and cover it with a thin layer of soil. Put earthworms on it and sprinkle water to make it moist. If you want to prepare vermicompost on a large scale, buy earthworms in small quantity and multiply them on farm. This technology has high potential for high-value crop production in Barshong area because vermicompost has higher macro-nutrient content than other available organic sources.

Biochar

Organic waste can be converted to biochar through the process of thermal decomposition from gasification. When biomass is heated with little to no oxygen, all volatile gases dissipate, leaving the carbon behind. This carbon-rich charcoal is applied in the field in powder form. The reported advantages of biochar are: it requires less fertilizer (it absorbs and slowly releases nutrients to plants); improves water holding capacity and conserves water; makes crop resilient to drought; improves seed germination in seed crops like beans; reduces methane emissions from farmyard manure; increases soil microbes; helps loosen the soil and improves root growth. Biochar has to be applied in large quantities; the recommended amount is 1–8 tonnes per acre. Experience has shown that biochar is very effective for high-value crops and localized application such as in pit planting. Since Barshong has an abundant source of organic carbon, this technology would help make the agricultural system more resilient and sustainable in the long term.

Biochar preparation method:

- Different types of kilns are available or can be fabricated.
- Chop plant materials to accommodate them in the kiln.
- Make the raw materials dry (< 20% moisture).
- Put the raw materials on the kiln, making it as dense as possible.
- Fire from the top.
- Reduce the flames by sprinkling water or putting an extra layer of raw materials.
- When raw materials turn dark brown or black, take them out with the help of a shovel.
- Spread the materials on a mud/concrete floor or an old GI sheet and sprinkle water on it.
- Powder the materials before applying them in the field.

Liquid fertilizer (*Jholmal*)

Jholmal is an extract of organic manure or plant parts. It is non-poisonous, eco-friendly, sustainable and capable of managing various plant nutrients, and thus reduces plant protection problems. There are generally two types of *Jholmal*: FYM based and plant based.

FYM based *Jholmal*: Make a 500 gram-pouch of well-decomposed FYM using muslin cloth. Dip the pouch in 10 litres of water for 24 hrs. The extract is ready for application and it should be applied to the crop within two days.

Plant based *Jholmal*: Plant-based *Jholmal* enhances growth and vigor. It is prepared by fermenting plants, fruits and molasses together. Materials needed to prepare plant-based *Jholmal* include 6 kg of aromatic plants (e.g., African marigold or *Sayapatri*, field mint or *Pudina* (*Mentha arvensis*), mugwort or *Titepati* (*Artemisia vulgaris*), *Gandejhar* (*Ageratum conyzoides*), lantana or *Dhungri Ful* (*Lantana camara*), and wild tomato), 3 kg of ripe fruits (e.g., banana, papaya, mango; sour fruits should not be used), and 10 litres of molasses.

To prepare plant-based *Jholmal*, clean the plant materials and fruits and chop them separately. Place half (3 kg) of the plant materials at the base of a 30-litre plastic drum. Top it with 3 litres of molasses. Put all the chopped fruits (3 kg) on top of the molasses. Add the remaining 3 kg of chopped plant materials to the fruit layer. Finally pour the remaining 4 litres of molasses on the layer of plant materials. Pressure should be exerted on the layers by placing a stone or bricks. Place the drum in the shade area for 10–15 days. Filter the liquid from the drum with the help of wire mesh or muslin cloth. Apply 1% solution (10 ml per liter) at 2–4 week intervals.

Plant-based astringent *Jholmal*:

Astringent *Jholmal* is fertilizer with additional attributes of bio-pesticides. It is prepared from plants with astringent and unpleasant odors and sour, hot, bitter or acrid taste. The common species include crown plant (*Aank*), ageratum (*Gande Jhar*), mugwort (*Titepati*), *Eupatorium* spp. (*Banmara*), castor bean (*Andhir*), chirata, field mint (*Pudina*), spearmint (*Babari*), neem, chinaberry (*Bakainu*), marsh pepper (*Pirejhar*), holi basil (*Tulasi*), prickly ash (*Boke timmur*), Florida soapberry (*Riththo*), stringent nettle (*Sisnu*), Indian privet (*Simali*), tallow tree (*Khirro*), century plant (*Ketuke*), chilli, tobacco, mango leaves, papaya leaves, garlic, onion and ginger.

To prepare this type of *Jholmal*, mix more than five different available species and chop them into small pieces. Put 8 kg of chopped materials in a jute sack and place it in a 30-litre drum. Pour 20 litres of cattle urine into it and cover the drum to make it airtight. Place the drum in the shade. Stir the sack at weekly intervals. Make sure the drum lid is tightly closed after you open it. The *Jholmal* will be ready in 20–30 days depending on the ambient temperature. The *Jholmal* can be applied with water in the 1:8 ratio for young plants and 1:4 ratio for mature plants of bean, cabbage, onion and ginger. It is advisable to spray *Jholmal* during late afternoon so that it can dry up by evening.

Efficient Energy Use

Energy means all forms of energy products such as combustible fuels, heat, renewable energy, and electricity. Energy efficiency means using less energy to get the same service. Agricultural energy is energy consumed in an agricultural production system including for the production of all indirect inputs (e.g., replacing old machinery with new and more efficient machinery). Use of organic manure demands less energy than the use of mineral fertilizers. Energy consumption during postharvest handling is of particular significance in vegetable and spice production. In a market-oriented production system, culled vegetables would not have market value. Such vegetables can be made into dried products. Use of solar energy would be a climate-smart method of drying vegetables.

Use of solar power for postharvest processing: The traditional food drying method involves spreading foodstuff in open air under direct sun. This increases chances of food contamination. Further, this method cannot be used in cloudy, rainy or windy weather. In the improved method, agricultural products are dried in a closed structure using solar energy. The products are dried entirely by hot air. There is no direct impact of solar radiation (sunshine) on the product. Solar energy produces hot air in the solar collectors. Increasing the temperature of a given volume of air decreases the relative air humidity and increases the water absorption capacity of the air. A slow circulating stream of hot air into the drying chamber passing through the product results in continuous and efficient dehydration.

The concept of solar dryer is relatively simple. The basic principles employed in a solar dryer are: converting light to heat (any black surface on the inside of the solar dryer will make this conversion more effective); trapping heat (isolating outside air from the air inside the dryer); and moving the heat around the food product. Different types of dryers are in use in the hilly areas but plastic tunnel dryer could be the best option for Barshong Geog because it is easy to construct and cost effective.

Figure 14: **Solar tunnel dryer**

Solar tunnel dryer: A solar tunnel dryer (Figure 14) can be constructed from indigenous materials like bamboo and wood for frame. Tunnel dryers can be of varying capacities. Silpauline sheet can be used as the covering material. As it has only one door and is completely closed with ventilations on both sides, it protects the product from insects, rain, dust and birds. It consists of a tunnel-like semi-cylindrical drying chamber. Trolleys and trays are provided to hold food items to be dried. On sunny days, it has 60% drying efficiency compared to open sun drying because of the higher inside temperature (about

22–25°C). This type of solar dryer can be used for drying ginger, *grundruk* made out of any type of leafy vegetable including cabbage, *masaura* (balls made of chopped cabbage leaves and black gram paste), *channa* (dried pieces of bean, radish and ash gourd) and bean grains.

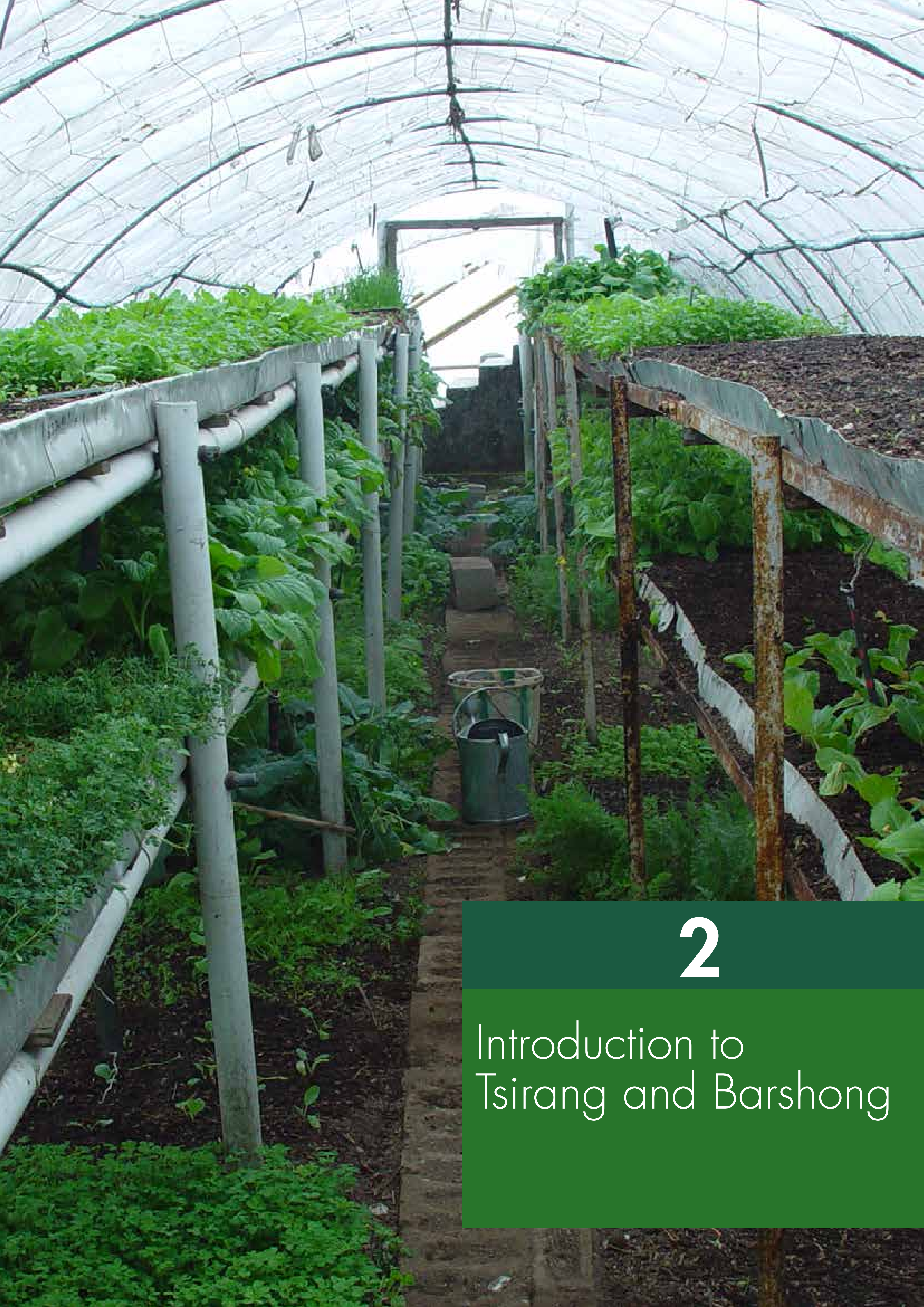
Solar water pump: Solar water pump could be an option if there is a permanent water source nearby (e.g., stream) that is below the field level. Water pump of any capacity can be used depending on the amount of water required in the field. The solar pan should be big enough to meet the power requirement of the water pump.

Summary

Table 1 summarizes the activities that HIMALICA will promote to make vegetable and ginger farming climate resilient.

Table 1: **Interventions for making vegetable and ginger farming climate resilient**

Issue	Existing practices	New climate smart interventions
Water management	Flood irrigation	• Low cost water harvesting pond • Use of sprinkler irrigation • Use of drip irrigation for high-value crops • Mulching
Soil management	Application of low quality farmyard manure Tethering system	• Shade improvement for urine utilization • FYM improvement • Compost preparation in the field • Use of rhizobium • Piloting of biochar
Soil nutrient management	More nutrient mining than replacement	• Cattle urine collection and use • Piloting of vermicomposting • Cattle shed improvement • Localized manure and fertilizer application • Use of Jholmal
Use of solar energy in agriculture	Not in use	• Piloting of low-cost solar dryer • Demonstration of solar water pump
Knowledge on crop management, market and weather	Extension services through District Agriculture Office	• Detailed market assessment, strengthening of farmers' groups/cooperative, use of social media for knowledge exchange on good practices, training on entrepreneurship development, participatory guarantee scheme and branding for better positioning of vegetables, manuals for practitioners and farmers



2

Introduction to Tsirang and Barshong

Tsirang Dzongkhag (Figure 15) is located in the south-central part of the country and has an area of 638.3sq. km. Its altitude ranges from 400 to 2,000 meters above sea level. Approximately 58% of the land is under forest cover comprising mainly of broadleaf and Chir Pine species while 42% is under agricultural cultivation. Its diverse agro-ecological features are favorable for the cultivation of many different types of cereals as well as horticulture crops. Paddy, Maize and Millet are the major cereal crops grown while orange, cardamom and vegetables are the principal cash crops. Mandarin constitutes an important source of cash income for most of the farmers. Livestock rearing is also an important economic activity contributing to both subsistence consumption and income generation although livestock productivity is limited due to the dominance of local livestock population.

The Wangdue-Sarpang highway passing through the Dzongkhag provides access to markets in both Thimphu and Gelephu. It is perhaps due to the access that Tsirang's agricultural and livestock produce are popular and most sought after in both these markets.

Tsirang Dzongkhag is administratively divided into 12 Gewogs and Barshong Gewog is one of them. Barshong geog is located at an altitude of 700-1500 masl with an area of 21.2 km^2. The total population of the Gewog is 2383, with 1239 male and 1144 female under eight villages in 5 different Chiwogs (Barshong Geog data, 2015). The Gewog is connected by farm road and has agricultural, forestry and livestock extension offices as well as lower secondary school and basic health unit (BHU). It has 249.41 acres of dry land and 112.37 acres of wet land in Barshong.

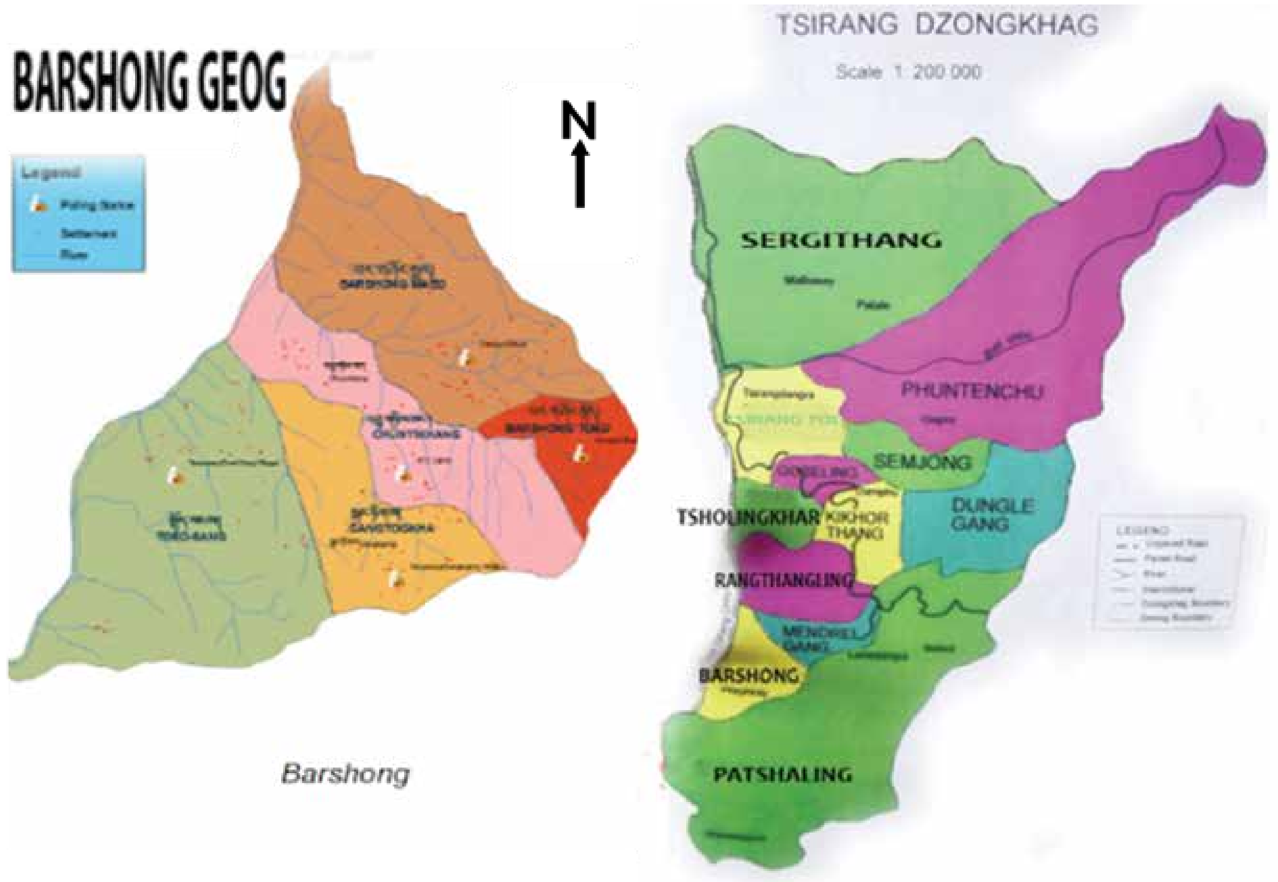
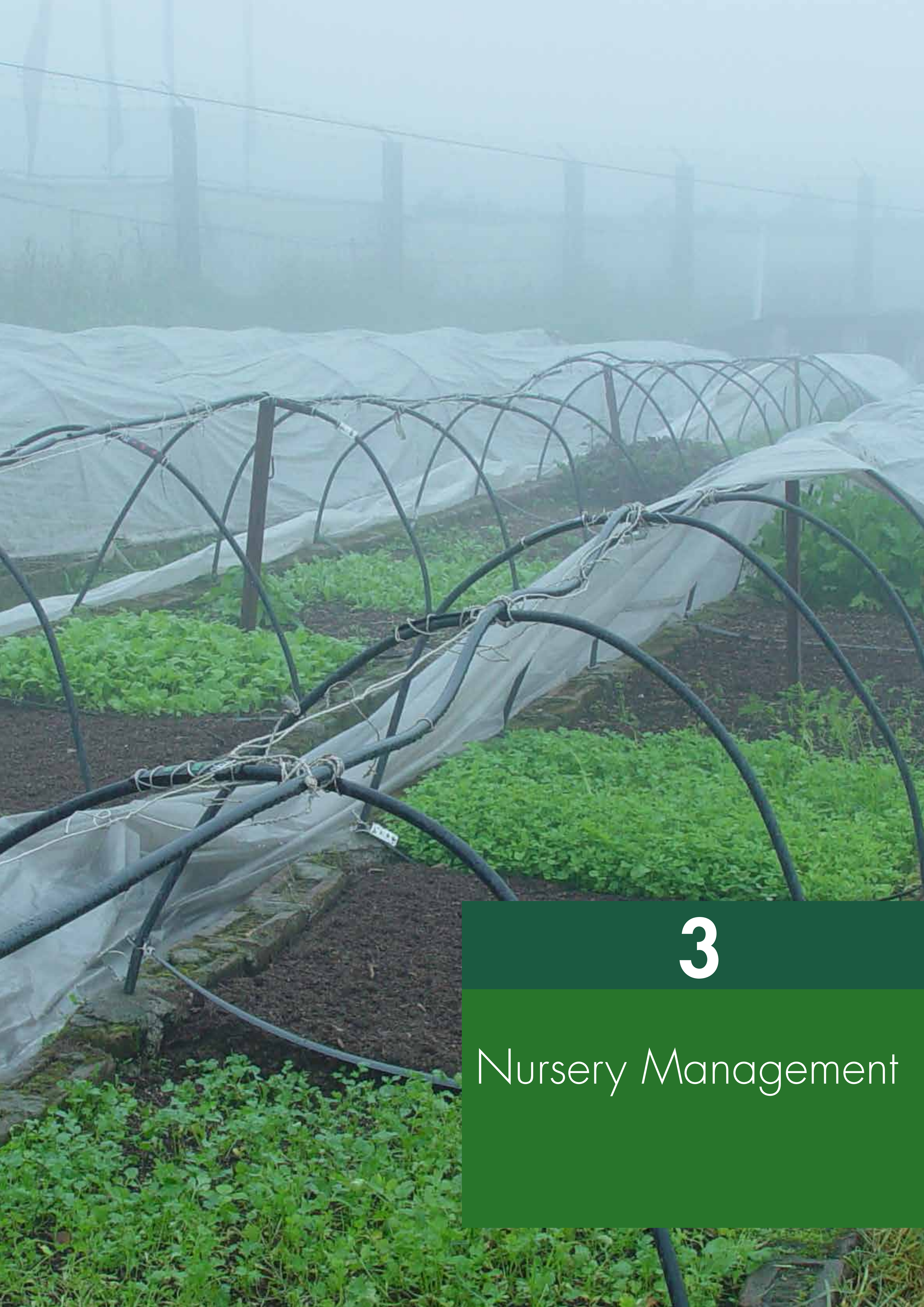


Figure 15: **Location of Tsirang Dzongkhag and Barshong Geog**



3

Nursery Management

Introduction

Nursery management encompasses a range of activities: bed preparation, seed sowing, day-to-day care, fertilization, weeding, watering, uprooting, transplanting and selling the seedlings. Nursery management is not necessary for all kinds of vegetables. Some vegetable crops like bean, cress, carrot, etc. are directly sown in the main field. On the other hand, some species like cabbage, onion, tomato, etc. are first sown in a nursery, and their seedlings are later transplanted in the main field. Good nursery management is important for farming such species successfully. Nursery grown seedlings have many advantages over directly sown seeds. They are:

- As seedlings are grown in a nursery for about one month, it helps increase land-use intensity.
- A small area can be modified to create a favourable microenvironment for growing seedlings during the off-season.
- They have a high rate of germination, which reduces requirement of seed and ultimately increases seed use efficiency.
- It is easy to take care of nursery grown seedlings and protect them from stress at the early plant stage.
- More seedlings can be prepared easily and quickly in a limited area.
- It is easy to produce healthy and stout seedlings in a nursery.

Site Selection

Site selection is an important step in nursery management. The following points should be borne in mind while selecting a site for a nursery. The nursery site should receive sufficient sunlight from morning to evening. Although a nursery does not require a lot of water, the source of water should be relatively close. The nursery site should have good drainage. As a nursery needs constant care, the site should be convenient for day-to-day operations, as well as easy to protect form animals and trespassers. Fertile loamy soil is desirable for a successful nursery. Alternatively, good nursery media can be prepared and used for seedling production.

Nursery Type

Different types of nurseries include shrunken bed, flat bed, raised bed and bed on bench. Shrunken and flat beds are more water efficient than the raised bed and the bench nursery. Bench nursery is more popular in areas infested with red ants, areas with damping off problems, and flood-prone areas. Raised bed is more common because it is suitable for all seasons. Raised nursery bed is 15 cm high from the ground level. A standard size nursery bed is 1 m wide. The length of the nursery varies according to the need of the seedlings and the size of the nursery block.

Nursery Structure, Size and Required Material

Nurseries may vary according to the scale of production and technological capacity. In areas where farmers are moving towards commercial vegetable farming, three types of low-cost nursery structures are recommended.

Plastic tunnel: Plastic tunnel (Figure 16) is suitable for raising seedlings in winter season. For a 1 m- wide nursery bed, 2–2.5 m bamboo splits are used to make a tunnel. The tunnel height should be approximately 0.5 metre at the middle. The bamboo splits should be placed about 75 cm apart. The tunnel should be covered with a white plastic sheet to allow distribution of solar radiation inside the tunnel. The plastic sheet should be 2 m wide and 1 metre longer than the tunnel frame. Commercial farmers can substitute bamboo splits with iron rods as iron can last for many years.

Figure 16: **Plastic tunnel**

High shed: High shed is appropriate for raising seedlings in the rainy season. A raised bed of 1 m width is prepared and poles pegged just outside the bed (Figure 17). One-sided roof of 2 m should be constructed to maximize sun exposure. For intercultural operations, the height should be 125 cm from the ground on the taller side and 75 cm on the shorter side. Straw or grass thatch can be used but while plastic is a better option for allowing enough light to penetrate into the nursery bed.

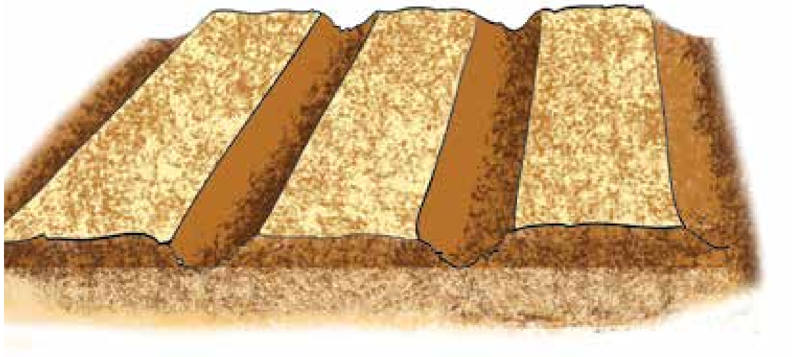


Figure 17: **Raised bed for nursery**

Poly-pit nursery: Poly pit nursery is suitable for raising seedlings in winter season. A pit (1 m deep, 1.5 m wide and of desired length) is dug and then covered with a semi-transparent polythene sheet (Figure 18). The polythene sheet is supported by a bamboo frame. Except on cold and rainy days, the sheet is removed from 11 a.m. to 4 p.m. to allow the pit to get direct sun exposure.

Figure 18: **Polypit**

Plastic or Plug Tray

Plug tray (Figure 19) is very popular among commercial farmers, who mostly use expensive hybrid seed. Seedlings production on a plug tray has many advantages over bed nursery. These include: low risk for soil borne diseases and soil insects; less labour intensive; straight and stout seedlings; there's no root damage when the seedlings are uprooted; and seedlings can be transplanted as per one's convenience. Plug tray, coco peat (processed products made from the coir of young coconut) and well-decomposed organic manure are required to grow seedlings with this technique. Though coco peat is not a local product of the area, it has many advantages over locally available materials. It has high water holding capacity, is rich in plant nutrients (almost equal to farmyard manure) and creates porous spaces around the root zone. The tray should be filled with dry coco peat (150–200 g) and well-decomposed organic manure (1 kg). For media preparation, dry coco peat should be soaked in water for about 20 hours and then squeezed so that it is moist but not dripping wet. The moist coco peat should be mixed properly with organic manure. The media should be filled up to the brim and pressed with another plug tray. Sow the seed at the centre and cover it with the same media. It should be watered every day with a watering can. Seedlings will be ready for transplanting when they reach the 4–5 leaf stage.

Figure 19: **Plug tray for seedlings**

Nursery Bed Preparation

- Dig the land properly, break the clods, make the soil friable and remove gravels and all plant debris.
- A standard size nursery bed is 1 m wide. The length may vary as per the need of seedlings.
- Raised bed in a permanent nursery should be about 15 cm high from the ground. This allows excess water to drain out easily. Placing bamboo splits around the bed helps firm the soil at the edges of the bed.

- Forest topsoil is the best media for a nursery.
- Loamy soil is the most suitable choice. Add well-decomposed organic matter at the rate of 2 kg per m^2.
- If the soil type is very poor, add sand and well-decomposed organic manure. The ratio of soil, sand and organic manure should be 1:1:1 for ordinary soil, 2:1:1 for clay soil and 1:2:2 for sandy soil.

Soil Sterilization

Nursery media sterilization is a common practice in commercial vegetable farming. However, it is not so common in the hilly regions of South Asia. The easiest methods for soil sterilization are soil solarization and use of chemical compounds.

- Solarization: The nursery bed is watered sufficiently so that water infiltrates 10 cm into the soil. The moistened bed is covered airtight with a 300 gauge white plastic sheet for three weeks. Maximum sun exposure will enhance the soil. Seed are sown a week after the plastic sheet is removed.
- Chemicals: Solarization is not a viable option in the rainy season. To sterilize soil with chemicals, drench the nursery bed with a solution of carbandazim (50% WP) at a rate of 2 g per litre of water. The solution should seep 7–8 cm into the soil. The bed should then be covered airtight with a 250 gauge white plastic sheet for three nights.

Seed Sowing

- Perfectly level the nursery bed with the help of a straight stick or bamboo split.
- Make 3 cm deep lines across the length of the bed. The lines should be about 10 cm apart.
- Sow the small seeds closer to the surface and the big seeds deeper into the soil. A rule of thumb is that the depth of sowing should be three times the seed diameter.
- The seed should be covered up to the bed level with forest topsoil, treated soil, sand, ash, or well-decomposed organic manure.
- Provide mulching using straw or dried grass immediately after sowing and then water the bed.

Nursery Care

- Regularly monitor the bed to check the moisture level. While watering, make sure the bed is just moist and not saturated for long.
- Certain crop seeds may begin to sprout after three days. Lift the mulch as soon as the sprouts appear.
- Seedlings should not be wet at night. Therefore the bed should be watered before 3 o'clock in the afternoon.
- In some instances, seeds are sown inside a plastic tunnel in winter season. Once the seeds have germinated, open the tunnel from one side during daytime and cover it again 3–4 hours before sunset. Remove the plastic completely 3-4 days before transplanting.
- Thinning may be necessary in the case of close sowing and very high germination. If seedling population is dense, they will grow up to be lanky.
- Weeds should be removed as soon as they emerge in the nursery
- Spray *Jholmal* a week after the weeds emerge.
- Spray bio-pesticides based on *Beauvaria bassiana* at a rate of 2 g powder formulation or 4 ml liquid formulation per litre of water about two weeks after germination.

Seedling Uprooting

- Irrigate the nursery bed saturating the soil up to the rooting zone 3–4 hours before uprooting.
- Uproot seedlings with the help of a spatula, pushing the root zone up in order to keep soil intact with roots.
- Put the uprooted seedlings gently on trays to carry into the main field.

Seedling Transplanting

- To minimize water loss by transpiration, seedling should be transplanted when solar intensity in minimum. Generally transplanting is done in late afternoon but any time is appropriate on an overcast day.
- Make sure the stem of the transplant is buried in the soil at the same level as in the nursery. To prevent transplant lodging, farmers generally prefer to plant the seedling deeper than the required level.
- Fill the soil around the seedling after planting and press the soil around the seedling to make it compact.
- Mulching is a must after transplanting. Put mulching materials about 5 cm away from the transplant stem. If mulch materials are stiff, apply mulch before transplanting.
- Provide shade to the transplants on the initial 3–4 days to reduce transplant mortality, where applicable. Easily available plant materials like banana bracts or big leaves can be used as protective materials.

Nursery Disease

- Damping off: Damping off is the most destructive disease in a nursery. Its initial symptom includes appearance of soft, water-soaked tissues at the lower part of the stem. The stem at the infection point subsequently gets restricted and then topples over, causing seedling mortality.

Management Practices

- Nursery bed should always be sterilized by soil solarization before seed sowing.
- If solarization is impracticable, nursery bed can be disinfected by burning the bed. Put a 6–7 cm thick layer of paddy husks or sawdust in the nursery bed and burn it out.
- A bench nursery can be made. Soil for the bench nursery should be from a paddy field or a forest (topsoil)
- Mix 2.5 kg *Tricoderma* in 100 kg of well-decomposed organic manure before applying it in the nursery bed.
- Maintain soil moisture in the nursery at an optimum level and do not water the nursery in late afternoon.
- Spray 1:5 decomposed cattle urine and water solution or 1% astringent *Jholmal* if plant growth is not satisfactory.
- Apply mancozeb (45% WP) 2 g per litre of water as soon as disease symptoms appear in the plant and drench the soil as well.

Summary

Table 2 highlights the major activities that could be recommended to the farmers for semi/commercial scale of vegetable farming.

Table 2: **Major activities for semi/commercial scale of vegetable farming**

Issue	Current practice	New intervention
Nursery site	No permanent nursery	A permanent nursery established in appropriate site
Nursery structure	Not in practice	Plastic roofed high shed constructed in each household Use of plastic tunnel during winter season
Nursery bed preparation	Unorganized bed	Raised bed with forest topsoil media will be used for seedling preparation.
Seed sowing	Broadcasting and dense sowing	Line sowing, sparse seeding and mulching will be practised.
Seedling uprooting	High rate of root damage and bare root planting	Watering before uprooting and transplants will have soil ball around the root while uprooting.
Seedling transplanting	High rate of mortality and lodging	Transplanting in evening, maintaining the right depth while planting, pressing soil around stem and application of mulching

4

Bean (*Ghiu Simi*)

Introduction

Common bean (*Phaseolus vulgaris*), also called French bean or simply bean, is one of the important members of leguminosae family. There are diverse varieties of common bean. They differ in their growth habit (runner or bush), pod colour and seed colour, and pod sizes. *Ghiu Simi*, which is very popular in Barshong area, is a pinto type pole bean. Immature pods of the bean are consumed in cooked form or as salad. Dried seeds of beans are used for making soup. Fresh pod bean contains protein, vitamin A, vitamin B, vitamin C, calcium, iron and phosphorus. Bean has special significance in the context of climate-smart farming for nutrient recycling as it fixes atmospheric nitrogen with the help of soil microbes (rhizobia).

Climate

Common bean performs well in warm weather and cannot withstand frost. As long as it is protected from frost and snow, it can be cultivated any time of year in Barshong Geog. The suitable temperature regime is 18–25°C for seed germination and 15–21°C for vegetative growth, flowering and fruiting. Plant growth ceases at a temperature below 12°C. Hot (>32°C) and dry environment causes the flower and young pods to drop. As common bean has some capacity to tolerate partial shading, bean can be intercropped with maize and fruit trees. Intercropping of bean and maize is a resilient system and a common practice in high hill areas.

Soil

Bean can be cultivated in any kind of soil. Sandy loam soil is more appropriate for early (February) planting but clay loam soil is suitable if it's planted from August onwards. Bean performs better in slightly acidic (5.5–6.0) pH range. Low pH hinders phosphorus uptake by the plant, which is more important than nitrogen in the case of nitrogen fixing leguminous crops. Plants respond better to the application of a high rate of organic manure in low pH condition. But lime application is recommended for correcting soil acidity; the rate of lime application is determined by the existing soil pH and soil type.

Planting season

To prevent the crop from severe cold, bean can be planted in two distinct seasons in the mid hills. At an altitude of 800–1,500 masl, bean can be sown during February-April and August-September. In Barshong Geog, bean is sown in August-September. Planting in February-April is also recommended to expand the production season. In warm places (<800 masl), it is better to plant it in August-September to avoid very high temperatures. At an altitude of 1,500–2,100 masl, March-May is the only suitable season for sowing bean seeds.

Variety

Phaseolus bean has diverse horticultural traits like pod colour, pod shape, seed shape, seed colour and growth habit. *Ghiu Simi* literally means 'butter bean'. As its name suggests, it has little or no fibre content in its pods even at the mature stage. Many landraces and cultivars of *Ghiu Simi* are available in areas with similar agro-ecological conditions across the region. The pinto pod type is more popular in Barshong Geog. The local landraces are highly adapted to the area and resilient to the effects of climate change. For this reason, the local variety should not be undervalued. Improved varieties, however, are developed with the clear objectives of quality and higher productivity, so they tend to perform better under good management.

Top Crop: Borlotto type pole bean very popular in Barshong area. It starts flowering in about 50 days of planting and the first harvest can be obtained in around 70 days. The pods have protruded ends. The mature pods are three seeded and are about 7–9 cm long. Under good management, pods can be harvested about 10 times.

Land Preparation

Land preparation for bean depends on the slope of the land. Only 2-3 rounds of land ploughing is suggested in the flat land for bush bean planting. Surface levelling is suggested for dry season cultivation in order to maintain uniform moisture while providing irrigation. Making a raised bed in heavy soil is highly recommended for rainy season cultivation. In the case of pole bean, raised bed is a suitable option for both wet and dry season cultivation. The furrows made in the field serve as irrigation channels in the dry season and as drainage paths in the wet season. In pole type bean cultivation, the rows have to be made far apart from one another. For this reason, pit planting is a better alternative in the hills; it ensures that the nutrients are utilized and helps minimize soil disturbance. A 20–25 cm deep pit can easily accommodate about 0.5 kg of compost. Band making and manure and biochar application in the band is suggested to minimize soil disturbance and increase the efficiency of nutrient and moisture. Minimum tillage can be also tried for reducing soil erosion, conserve moisture and reducing labour requirements.

Soil Fertility Management

Providing additional manure and fertilizers for bean is not a common practice in Barshong Geog. To get the anticipated yield from the crop, it is necessary to provide nutrients to the plant. Bean can fix nitrogen at 16.2–28.3 kg per acre/per crop/per year, but it depends upon the growing environment and activeness of rhizobia. To ensure that higher rates of nitrogen are fixed, there should be a presence of the right type (*Rhizobium phaseoli*) of microbes, good aeration in soil, appropriate soil temperature, right level of nitrogen (not high), appropriate soil pH and available phosphorus in the soil. It is important to observe the nodules to check whether nitrogen fixation is effective or not. If it is not effective, the seed should be treated with rhizobium inoculum (or with fungicide). Rhizobium can be applied directly in the soil for treated seeds.

As bean fixes nitrogen at the later stages, nitrogen fertilization at the time of sowing improves yield. It would be better to apply 8,000–10,000 kg of organic manure, 16 kg each of nitrogen and potash and 24 kg of phosphorus per acre. This could be applied during final land preparation for bush bean planting. For pole bean, it can be applied at the time of mixing with compost and filling the pit. *Jholmal* should be sprayed during the growing and fruiting stages.

Soil field tests can be used for assessing soil physical and chemical characteristics. It is also possible to estimate nutrient deficiency of plants by observing plant's health. For instance, Nitrogen deficiency results in very stunted, spindly yellow plants of yellow leaves, sometime with pink tints (Source: www.rsc.org).

Seed Rate

The seed rate of bean is determined by its variety, cropping practices (sole or intercropping with maize), germination ability of the seed, soil moisture level and the planting method (line sowing or broadcasting). About 16–20 kg of pole type and 32–35 kg of bush type are required for an acre of land. Despite seed supply from the formal system, seed perpetuation by farmers was found to be very common. In such cases, seed should only be selected from healthy and true-to-type plants with marketable attributes (three-seeded pods). Dried pods from the selected plants should be harvested from the very beginning.

Seed Sowing

Line sowing is impractical in the mixed or relay cropping situation. Line sowing has many advantages, such as low seed requirement, easy for intercultural operations, staking and harvesting. For the pole bean, make a bed of 120 cm with 30 cm furrows in between. Maintain a 100 cm gap between the rows and 15 cm gap between the plants for the pole bean. Bush bean can be planted with a 40 cm gap between the rows and 10 cm gap between the plants. Sow 2-3 seeds in each mound at a depth of 5–7 cm. Land should have sufficient moisture at the time of sowing. If not, irrigate the field before sowing. Provide mulching after sowing, leaving open space for emergence.

Intercultural Operations

Thinning and staking: Only one healthy seedling should be maintained per mound, thinning out the weakest seedling at two-true-leaf stage. Staking is necessary for better yield in the case of pole bean and it has to be completed before vine development. It is worth remembering that late staking can damage primary vine and drastically reduce yield. There are different types of staking materials and methods. Bamboo splits or tree twigs are placed along the line, making a cross at the top. For broadcasting, single plant staking is the only alternative.

Weeding: Inadequate weed management drastically reduces bean yield. Two to three rounds of weeding are necessary during the growing season, and more attention should be paid during the early stage. Dense canopy of bean plants suppress the weed in the later stage. Care should be taken while weeding the beans at the later stage, as the crop is sensitive to injury after plants begin to flower.

Irrigation: Bean is sensitive to both water excess and water stress conditions. As with other legumes, 6–7 hours of water stagnation in the field is detrimental to bean plants. It is relatively tolerant to moisture stress in the early stage but susceptible at pre-blooming, flowering and pod-filling stages. Irrigation should be planned taking all these issues into consideration. Surface irrigation should be provided through furrows or with a watering pipe because of dense canopy and to reduce the spread of disease. Knowing when to irrigate will reduce the problems of over- or under-irrigation and help to improve crop yield. The "Look and Feel" method is one of practical and simple way to assess soil moisture and irrigation needs (UC Davis). Mulching is strongly recommended to conserve soil moisture, reduce labour required for irrigation and suppress weed infestations. Mulching would be instrumental in enhancing yield because bean plants have shallow roots and are sensitive to moisture in the flowering and fruiting stages. Water harvesting ponds can be built to collect water for the dry seasons. The collected water should be used efficiently through drip or micro-irrigation systems which are available locally.

Insect Pests and Diseases

AphidAphids are black in colour. These insects suck sap from different parts of the plant and make the plant weak (Figure 20).

Figure 20: **Aphid infestation**

Management practices

- Ladybird beetle, syrphid flies, lace wing and wasp are predators of aphids. Aphids can be controlled if these predators are present in substantial numbers.
- Spray washing soap solution on the dorsal side of the leaves, making it completely wet.
- Spray astringent *Jholmal* on both sides of the leaf, making it completely wet.
- Commercially available bio-pesticides based on *Beauvariabassiana* can be used at a rate of 2 g powder formulation and 4 ml liquid formulation per litre of water.
- Spray Neem based (Azadirachtin) insecticides like Margosom, Nimbicidine at a rate of 2 ml per litre of water.

Borer

Two types of borers damage the bean crop. Fruit borer larva makes holes in the pod and forages on the seeds inside. Larva of the second type makes white silky cocoons on the leaves, pods and flower buds and hides inside these cocoons to feed on these parts (Figure 21).

Figure 21: **Borer infestation**

Management practices

- Commercially available biopesticides based on *Bacillus thuringiensis* can be used at a rate of 2 g per litre of water.
- Spray Neem based (*Azadirachtin*) insecticides like Margosom, Nimbicidine at a rate of 2 ml per litre of water.

Bean rust (Figure 22)

Minute red pustules appear at the early stage and later become distinct, yellowish and circular. The pustules develop on both sides of the leaves and other plant parts including pods. Brown powdery substance can be seen in case of severe infection.

Figure 22: **Bean rust**

Management practices

- Collect all the plant debris and bury them in a deep pit.
- Do not reuse staking materials from the infected field. Spray Bordeaux mixture at 7–10 day intervals.
- Spray mancozeb (45%) at a rate of 2 g per litre of water at weekly intervals before pod setting.

Anthracnose (Figure 23)

Small, dark brown to black lesions appear in any plant parts like leaf, vine and pods. The diseased spots gradually enlarge lengthwise, forming sunken lesions.

Management practices

- Adopt crop rotation avoiding other beans (lima bean, asparagus bean, lablab bean, cowpea, etc.)
- Do not reuse staking materials from the infected field. Disinfection is necessary in the case of reuse.
- Treat seeds with 2 g carbandazim (50% WP) per kg if seeds have been obtained from the informal system.
- Spray carbandazim (50% WP) at a rate of 2 g per litre of water at weekly intervals before pod setting.

Maturity Index

Beans are harvested when they reach a physiologically mature stage. Three distinct stages can be seen based on the pod color. Immature pods are mottled green, mature pods are mottled red, and over-mature pods are mottled light black. Beans should be harvested when they are mature with firm and full size pods (well-developed seed) that are mottled red in colour. However, consumer preferences may vary from location to location and these should also be considered while selecting harvesting stage.

Figure 23: **Anthracnose**

Harvesting

Vegetative and reproductive growths, including fruiting, take place simultaneously in pole bean. Therefore pole beans should be harvested periodically at the appropriate pod stage. It is better not to harvest over-mature pods and mix them with the good ones. Rather, over-mature pods should be left in the plant till they dry and can be used to make soup. As a single inflorescence bears more than three pods, care should be taken not to damage other pods and the vine itself. Using a clipper is more advisable than exerting pressure by hand during harvest. Pole bean should be harvested at weekly intervals at the correct time of day – in the morning and late afternoon, when the plants are dry. After harvest, pods should be placed in the shade during field storage.

Yield

Yield of bean varies considerably according to location, soil fertility status, variety used, growth habit, growing season and management practices. Pole type bean naturally gives more yield than the bush type. With proper management, about 2000 kg of pods can be harvested from an acre of land. The present (2014 statistics) level of productivity in Tsirang is lower (561 kg/acre) than its potential.

Postharvest Care

Grading: Diseased, distorted, broken and inferior pods should be separated from the good ones. As the pods with three seeds have higher market value, these should be sorted separately. Beans can also be graded based on the pod colour if they have been harvested after a long time gap.

Packaging: Bean pods should be packed in a sturdy container. Bamboo baskets can be used for carrying them to a nearby market. Plastic crates, bamboo baskets with sturdy frames, or paper cartons are appropriate for transporting them to distant markets. Line the crate or basket with clean sheets of paper or large leaves of vegetables (e.g., cauliflower) to prevent the bean pods from getting bruised. While packing the beans, leave some space at the top of the crate for air circulation. Good packaging entails two main elements: protection and proper ventilation.

Storage: Beans are highly perishable and it is necessary to cool them immediately after harvest to maintain quality. They should be stored in cool and humid places with good air circulation. Short-term storage (for about three weeks) can be done at 5–70C with 92–95% relative humidity. As temperature control option is not available in Barshong Geog, beans have to be sold as soon as possible after harvest. However, small growers can store fresh vegetables in zero energy cool chambers and different models suitable for the hills are available.

Transportation: Load the beans into a carrying van just before transporting them. Place the packs on stakes to allow a little space between the packs for air circulation, and make sure the packs at the bottom are not squashed. Cover the packs with a waterproof sheet to protect them from wind, sun, rain and dust, maintaining a 20–25 cm gap between the sheet and the top of the stack. Transport the beans during the coldest part of the day, i.e., early morning or at night.

Marketing

Beans can be marketed through different channels. The appropriateness of a particular marketing channel is determined primarily by the scale of production and the distance between the production site and the end market. Small-scale farmers who live near a market can directly sell their produce. In such a case, farmers get a good price and consumers get very fresh produce. Marketing intermediaries become necessary when the production site is located far from the end market. Visits to the markets of Thimphu and Damphu revealed the existence of four marketing channels in Bhutan: i) Producer to consumer, ii) Producer to retailer to consumer, iii) Producer to collector to retailer to consumer, and iv) Producer to collector to wholesaler to retailer to consumer. The involvement of more marketing actors simultaneously increases the product cost because the profit margin increases at each step of the supply chain. Increase in the number of marketing intermediaries also lengthens the time it takes for the produce to reach the market. This leads to postharvest losses and quality deterioration as normal vans are used for vegetable transport. Therefore the shortest possible marketing channel is desirable for vegetable marketing. Since commercial farmers do not have the time to market their produce themselves, one marketing intermediary is highly desirable. A farmers group or cooperative would be the best option.

Market-oriented production and product marketing are two sides of the same coin; one cannot move forward in the absence of the other. A market-oriented production system has to analyse potential markets along with associated risks beforehand to get better returns. To earn higher incomes from market-oriented production, one should consider the following points:

- Farmers should keep a good record of the production costs. This will allow them to accurately estimate the minimum price of the produce. A rough calculation of the production cost of bean is provided in the table below just for reference.
- Farmers should find out how much area is under bean cultivation in the village. This will give them an idea about potential competition or the volume of production required for distant markets.
- Focus on high-quality produce rather than on average quality produce. High-quality produce gives higher returns in high-end markets.
- Analyse existing marketing channels taking given geophysical and social conditions into consideration and identify the most profitable channel.
- Farmers should be prepared even to switch to a new crop if there is demand for that particular crop in the market.
- Vegetable market is highly dependent on trust. Trust should be maintained by all market actors including producers.

Table 3: **Estimated production cost and net profit of *Ghiu Bodi* (Nu/acre)**

Particular	Unit	Quantity	Nu/unit	Total
1. Variable cost				**35,684**
a. Human labour	Day	60	300	18,000
b. Bullock labour	Day	4	650	2600
c. Seed	Kg	17	200	3400
d. Manure	Kg	3000	1	3000
e. Mineral fertilizer	Kg	0	0	0
f. Pesticides	LS		300	300
g. Staking material	No	14,000	0.25	3500
g. Management cost	LS		2500	2500
h. Interest on variable cost	LS	8%		2384
2. Fixed cost				**400**
a. Land tax	LS		300	300
b. Repair and maintenance	LS		100	100
3. Total cost				**36,084**
4. Gross income at farm gate				**35,910**
a. Main product		576		
i. Fresh pod		561	60	33,660
ii. Dried grain		15	150	2250
5. Net profit at farm gate				**-174.00**
6. Production cost per kg				**62.65**

The calculation shows that *Ghiu simi* cultivation is not profitable because of the high cost of staking materials. This is how calculating the cost of cultivation gives a clear picture of the profitability of a commodity.

Summary

Major interventions needed to promote climate-smart bean cultivation are summarized in Table 4.

Table 4: **Interventions for climate-smart bean cultivation**

Issue	Current practice	New intervention
Land preparation	Field ploughing Flatbed planting	• Localized land digging/ploughing for row planting • Planting bed preparation for pole bean
Soil fertility management	Use of poor quality FYM, spreading in field, no use of rhizobium	• Soil testing and application of soil amendments • Specific rhizobium application • Localized organic manure application
Seed sowing	Broadcasting	• Line sowing of bean • Line sowing of maize as well for intercropping
Planting season	Single season (August – September) planting	• Introduction of February-April sowing in mid hills
Mulching	Not in practice	• Made compulsory
Staking stage	As per convenience	• Before growth of primary vine
Crop protection	As per availability of pesticides	• IPM based • More focus on bio-pesticides
Post-harvest operation	Not in consideration	• Harvesting during the cooler part of the day • Adopt sorting and grading • Demonstration of zero energy cool chamber • Packaging in rigid container
Market information	Selling directly to local markets or selling to local collectors	• Encourage farmers to record the cost of cultivation and calculate unit price • Selection of most efficient marketing channel

5

Cabbage

Introduction

Cabbage (*Brassica oleracea* var. *capitata*) is the second most important vegetable crop after cauliflower among the Cole crops. It is rich in vitamin A, B and C and also contains minerals such as phosphorus, potassium, calcium, sodium and iron. The tender leaves of cabbage are consumed as cooked vegetable, as major ingredients of vegetable momo, salad, pickle and *gundruk* (a fermented and dried product).

Climate

Cabbage is a cool season crop and grows well in a cool and moist climate. Development of heat tolerant hybrid varieties has made it possible to grow cabbage all year round in the upper mid hills (>1,600 masl) and high hills. The suitable temperature range is 7–35°C for seed germination, 15–20°C for vegetative growth and 15–25°C for heading. Because of climatic variations in the hills from low to high, the same variety can be grown in different seasons at different elevations. Head formation of cabbage is a process of vegetative growth and needs relatively warmer temperature. Extreme cold or very low temperature during late growing stage leads to bolting.

Soil

Cabbage can be cultivated in all types of soils. However, it does not perform well in sandy soil, clay soil and soils with gravels. Sandy loam soil is more suitable for early varieties and clay loam is suitable for late varieties. In all cases, light fertile soil with high organic matter is the most important prerequisite. Cabbage does not grow well in acidic soil and the best suited pH range is 6.0 to 6.5. Agriculture lime should be applied to raise the soil pH, as soils in the hills are mostly acidic. But it should be done only after soil testing.

Planting Season

Cabbage is primarily a winter season crop in the tropics, but it can be grown all year round in the hills by using heat tolerant hybrid cultivars. In the mid hills, the open pollinated early varieties are planted during July-August, mid varieties in September-October and late varieties in October-November. In the high hills (>2000 masl), the early and mid-varieties are planted during May-June and the late varieties are planted in June-August.

Variety

Open pollinated varieties are more suitable where low mineral fertilizer is applied. The most common open pollinated variety in Tsirang is Golden Acre. Other open pollinated varieties are grown in similar agro-ecological contexts. Some of these varieties are also grown in Tsirang to expand the production season. They include Pride of India, Copenhagen Market and Late Large Drum Head.

Golden Acre: It is an early variety and matures in 65–75 days. The plant is semi erect and has a small round head that weighs 1–1.5 kg. It has yield potential of 7,500 kg per acre under good management.

Copenhagen Market: Copenhagen Market is a mid-duration variety that matures in 75–80 days. The plant is semi erect, stem is short and leaves are light green. It has a compact round head that weighs 2–3 kg. It has yield potential of 9000 kg/acre under good management.

Late Large Drum Head (LLDH): LLDH is a late maturation variety that can be harvested in 100–110 days. Plant has a spreading structure with a flat and solid head that weighs about 4 kg. With good management techniques, 9500 to 11,000 kg of LLDH can be harvested from an acre of land.

Lucky Ball F1: Lucky Ball performs well in hot and humid conditions, and can be harvested 55–60 days after transplanting. With a short core, the slow bursting, ball-shaped, fresh green head weighs 1.3–1.8 kg. It has a good field holding ability and is adapted to long distance shipping.

It is resistant to *Fusarium* and tolerant to black rot.

Green Presto F1: This is a heat resistant variety and matures in 50–55 days. The plant is compact and produces a green, semi-flat head that weights 1–1.5 kg. It is resistant to *Fusarium* and tolerant to black rot.

Land Preparation

Cabbage is a heavy feeder vegetable crop. Crop rotation after legume or other species except *Brassica* is recommended to maintain fertility and reduce disease and pest loads. Land should be ploughed 2–3 times, and ploughing depth should be 30 cm deep. Big clods should be broken and the residue of previous crops should be removed. Well decomposed organic manure should be applied in the pit during planting. Crop can be planted in a raised bed in winter season but ridge planting should be adopted for proper drainage in the post-monsoon and rainy season. No tillage or minimum tillage method can be adopted to minimize soil disturbance; planting pit is thus a preferable option. Organic manure and biochar are applied in the pit rather than spreading them over the field.

Soil Fertility Management

Cabbage requires high amounts of nitrogen and potassium. In general, cabbage takes up 131.2 kg of nitrogen, 45.4 kg of phosphorus and 110.9 kg of potash per acre, though these amounts may vary according to cabbage variety and management practices. Application of 1,500 kg of improved farmyard manure per acre only supplies about 37.5 kg of nitrogen, 12.5 kg of phosphorus and 45 kg of potash. Assuming 12.15 kg of nitrogen, 8.1 kg of phosphorus, 40.5 kg of potash from the inherent source and 14.98 kg nitrogen, 3.1 kg phosphorus and 10.93 kg potash from residual nutrients of organic manure applied for maize, the total availability of N, P and K is going to be 64.6, 23.7 and 96.0 kg per acre respectively. Managing nutrients through an organic approach within a short span of time is thus a daunting task. Hence it is recommended that 40 kg of nitrogen, 24 kg of phosphorus and 20 kg of potash per acre are applied in the beginning. All phosphorus and potash, along with half of the nitrogen, should be applied as basal fertilizer to be mixed with organic manure. The mixture of manure, biochar and fertilizers should be placed in the planting pits in order to utilize the nutrients effectively. The remaining half of the nitrogen should be further divided into two portions and applied as top dressing. The first top dressing should be done after one month of transplanting and the second just before heading. Weeding should be done before top dressing and soil should be moist enough. Apply nitrogen (urea) around the cabbage plant without letting the fertilizer touch any plant parts. An alternative method would be to collect and use cattle urine. Cattle sheds in Barshong must be improved so that cattle urine can be collected properly.

To move towards organic farming, mineral fertilizers should be reduced and application of improved organic manure should be increased. In addition, other methods of improving soil health should be practised. Boron and molybdenum micronutrient deficiencies are common problems in acidic soil, particularly on hill slopes. To correct the molybdenum problem, spray a solution of sodium molybdate (250 ml/litre of water) on the standing crop. If cabbage will be planted in the same field in the next season, apply 810 g of sodium or ammonium molybdate per acre in the soil at the time of land preparation. Boron deficiency in standing crop can be corrected by spraying borex (2 g/litre of water). In the consistently boron deficient field, apply borex at the rate of 4–5.5 kg per acre at the time of land preparation.

Seed Rate

Cabbage seed is sown in raised beds (15 cm high) in rows that are 10 cm apart. Seeds are sown at a depth of 0.5 cm and 3–4 cm apart from each other. There is no need to make a poly-tunnel for early sowing but a tunnel is a recommended option when temperature drops down. About 240 g of seeds of the open pollinated variety and about 150 g of seeds of the hybrid variety have to be sown in the nursery to cover an acre of land. Depending on the plant spacing, 20,500–30,000 seedlings are required for an acre of land.

Transplanting

Depending on the growing temperature, cabbage seedlings are ready for transplanting in 21–30 days. Seedlings uprooted from the nursery should be carefully brought into the main field with minimum disturbance to the root system. Only healthy, stout and 4–5 leaf stage seedlings should be transplanted in well prepared land or planting pits. Long duration variety is planted at 45x45 cm distance and short duration variety can be planted at 45X30 cm either in ridge or bed. After transplanting, roots of the seedlings should be in the same position as it was in the nursery. Care should be taken to maintain the same planting depth as in the nursery. After transplanting, lightly press the soil with your fingers to prevent lodging. Watering should be done immediately after transplanting. Always transplant the seedling in late afternoon to avoid shocks due to heat and sunlight. Gaps in the planting hills should be filled completely within 3–4 days of first transplantation.

Mulching is strongly recommended in the cabbage field soon after transplantation. Rice straw is the best mulching material but any types of dried grasses (care should be taken not to disperse weed seed from the mature grasses) or dried leaves from forest trees can be used. Mulching helps to suppress weed in all seasons. During the dry season, mulching helps conserve and stabilize soil moisture. Furthermore, mulching in the rainy season speeds up seedling establishment by promoting root development in the upper layer of soil.

Intercultural Operations

Irrigation: Cabbage requires constant soil moisture to minimize water stress shocks in all stages of its growth, especially after transplanting and heading. Quick fluctuation in soil moisture often causes abnormal growth and physiological disorders. Frequent but insufficient irrigation should strictly be avoided as it promotes feeder roots in the upper stratum of soil. Sufficient amount of water should be supplied so as to saturate all the cultivated layer of soil. Sprinkler is the most suitable system in the hills as it economizes available water, but furrow irrigation can also be practised on leveled land provided abundant water is available. Care should be taken while providing flood irrigation, as cabbage is sensitive to water logging even for a short period of time. Good drainage system should be planned for irrigation or for draining out excessive rainwater in the rainy season. If farmers can afford, they should use drip irrigation for increasing water use efficiency.

Weed management: Weed management in the early stage is more important than in the later stage. Perform manual weeding followed by earthing-up 30 days after transplanting (DAT) and repeat the process three more times at 20-day intervals for long duration varieties. Proper mulching reduces the frequency of weeds. For short duration varieties, first round of weeding and earthing-up should be done 15 DAT and subsequent rounds at 10-day intervals.

Top-dressing: It is best to spray *Jholmal* immediately after seedling establishment. At early growing and heading stages, top dressing at least twice with cattle urine (1 part cattle urine mixed with 5 part water) solution is recommended. The urine solution should be applied around the plant without touching the plant parts or with drip irrigation. If time and resource permits, top dressing at fortnightly intervals will be beneficial. In case of inorganic fertilizer application, two split top dressings of Urea are suggested at early growing and heading stages. Soil should be sufficiently moistened at the time of top dressing or irrigated immediately afterwards.

Insect Pest and Diseases

Cabbage butterfly

Adult butterflies lay bright yellow eggs in clusters on the dorsal side of the leaves. The hatched larvae (Figure 24) forage the leaves in groups. Two species (dark green larva with hairs and blue green larva with three yellow stripes) are the common pest.

Management practices

- Visit the field regularly and destroy eggs, larvae and pupas as soon as they appear.
- Catch the adult larvae with the help of a nylon net and destroy them.

Figure 24: **Cabbage butterfly**

- Protect the predator wasps (*Apanteles* spp).
- Dilute 1 litre extract of stinging nettle and 50 g of yeast in 10 litres of water and spray it on the crop.
- Spray Neem based (Azadirachtin) insecticides like Margosom, Nimbicidine at a rate of 2 ml per litre of water.

Diamondback moth

The larvae of the insect are green in colour and slightly enlarged at the middle of the body (Figure 25). They appear on the dorsal side of leaves and feed on the surface of young leaves. They only feed the green parts of the mature leaves, leaving the veins.

Figure 25: **Diamondback moth**

Management practices

- Destroy all stubbles after crop harvest (either use them as animal feed or bury them in a pit).
- Spray Neem based (Azadirachtin) insecticides like Margosom, Nimbicidine at a rate of 2 ml per litre of water.
- *Apantelesplutellae* wasp is the most effective natural predator of this type of larva. Other predators are ants, spiders and birds. All predators should be conserved.
- Commercially available biopesticides based on *Bacillus thuringiensis* can be used at a rate of 2 g per litre of water.

Cabbage aphids

Cabbage aphids are of ash colour (Figure 26). The insects suck plant sap from different parts of the plant and make the plant weak. They excrete sweet dew on leaf surface, leading to a type of fungus that makes the surface black.

Figure 26: **Cabbage aphid**

Management practices

- Lady bird beetle, syrphid flies, lace wing and wasp are predators of aphids. Insect problem will be reduced to a minimum if these predators are present in the field.
- Spray washing soap solution on the dorsal side of the leaves, making them completely wet.
- Spray astringent *Jholmal*, making both sides completely wet.
- Commercially available bio-pesticides based on Beauvariabassiana can be used at a rate of 2 g powder formulation or 4 ml liquid formulation per litre of water.
- Spray Neem based (Azadirachtin) insecticides like Margosom, Nimbicidine at a rate of 2 ml per litre of water.

Downy mildew

Yellow areas on the upper side and mildew on the lower side of the leaves appear confined within leaf veins. A feathery white growth can be seen on lesion surfaces. The spots may also appear on stems.

Management practices

- Many resistant varieties have been developed in other parts of the world. Those varieties could be introduced where the problem is severe.

- Destroy crop debris and other perennial weed hosts.
- Adopt crop rotation with non-cruciferous crop.
- Avoid dense planting to reduce relative humidity around the plant. But also bear in mind that wider spacing accommodates fewer plants and simultaneously decreases total yield.
- Application of *Fusarium proliferatum* at a rate of 2 g per litre is also found to be effective.

Maturity Index

Head compactness or firmness is the main indicator of cabbage maturity. A compact head that gets slightly compressed under moderate hand pressure is considered physiologically mature for harvest. Very soft heads are immature and these should not be harvested. Very hard heads may be over-mature and susceptible to cracking during handling. Some varieties are also susceptible to cracking if they are not harvested at the right time. Overall appearance of the plant also gives an idea about the harvesting stage, where wrapper leaves are spread and the head is exposed.

Harvesting

Cabbages should be harvested when the head firmness is optimum for the variety. Only mature cabbages are dense and have good weight relative to its size. As with other crops, cabbage should be harvested at the coolest time of day. However, the plants should be dry at the time of harvest. Care should be taken while harvesting during early morning when the crop is wet with frost or dew. While harvesting, 4–6 wrapper leaves should be left attached to the head. The head is manually harvested by bending it to one side and cutting the stem with a sharp knife. All rotten and damaged outer leaves should be removed at the same time. Field drying is suggested if there is doubt that cabbage heads might contain water. Heads are placed upside down for drying, with no contact with the soil for 2–3 hours. Field surface drying should be done in the shade, preventing direct sun exposure. While transferring the heads after harvest, never throw them around, rather place them gently in a shady area.

Yield

Cabbage yield is determined by the selected variety and management practices. Hybrid varieties can yield as much as 25,000 kg per acre in the hills with the application of recommended dose of mineral fertilizer. In case of open pollinated varieties, about 4,000 kg per acre cabbage yield can be expected with proper management, even in organic farming situation. However, the average productivity of Tsirang in 2014 was 2,790 kg/acre and it indicates potential for productivity enhancement.

Postharvest care

Trimming: Trimming is a process of removing loose leaves to promote air circulation between cabbage heads. The level of trimming depends on the types of packaging containers. If heads are packed in sturdy containers like plastic crates, cartons, bamboo baskets with rigid frames, 2–3 wrapper leaves are sufficient. Cabbages that are to be packed in loose structures like sacks or bags should be lightly trimmed, leaving a maximum (about 6) of wrapper leaves.

Packaging: Well-trimmed heads with 2 or 3 wrapper leaves should be packed in double layers. Crates or cartons would be the ideal packaging options for cabbage. Cabbages can be divided into three grades: large, medium and small. If cabbage heads are being packed in sacks or nets, the size should not be more than 25 kg and they should have a maximum number of wrapper leaves. Strong bamboo baskets are also appropriate in the hills. Bamboo basket of 30 kg capacity is found to be most appropriate in the hills. Packaging 50–60 kg cabbages with 5–6 leaves in sacks saves the cost of packaging materials and labour. But wastage could be as high as 40–50% in such cases.

Storage: Cabbage can be stored for many months in cold storage. Since cold storage is not available in Barshong area, cabbages should be sold as soon as possible after harvest. For short-term storage, appropriate temperature is 2–100C with 92–95% relative humidity. While storing at the road head, cabbages should be stored in cool and humid places with good air circulation. Cabbages are sensitive to ethylene, which causes the yellowing of leaves before they fall. Therefore cabbage should not be stored with large quantities of ethylene producing crops like tomato.

Transportation: Load the cabbages in the carrying van just before transporting them. Put the packs on stakes, taking care not to exert pressure on the cabbages underneath and allowing some space between the packs for air circulation. Cover the cabbages with a waterproof sheet to protect them from wind, sunshine, rain and dust, maintaining a 20–25 cm gap between the sheet and the top of the stack. Like other crops, cabbage should be transported during the coldest part of the day, i.e., early morning or at night.

Marketing

Cabbage is an important vegetable in terms of production and consumption. For hill farmers, an important attribute of cabbage is its relatively long shelf life. This allows cabbage to be transported to distant markets. As production season can be altered at different elevations, farmers can get a better price by escaping the local production season of big cities. Advancements in communications technology has also played a vital role in the distribution of vegetables. The assemblers or collectors contact the wholesalers based in cities and divert the product to where they can get a better price. Farmers' groups can also adopt this approach to fetch better prices. Producers could sell their produce to collectors at the road head or directly deliver it to the wholesalers. Different marketing systems are in operation in Tsirang. In Barshong, most farmers sell their produce to Thimpu-based collectors at nearby road heads. The second popular option is selling directly in the market, in places like Damphu. For better returns, farmers could be organized into a group or cooperative and the cooperative can market the product directly to big cities. As vegetables produced in Tsirang area are known to be of good quality, farmers' groups or cooperatives from the area would not face difficulty marketing their product.

Production and marketing of cabbage are two sides of the same coin in a market-oriented production system. As it is a commercial venture, farmers have to analyse potential markets and risks beforehand to get better returns. Farmers involved in commercial vegetable farming should consider the following points:

- It is very important to keep a record of all production costs in order to fix the minimum price. A rough calculation of the cost of cabbage production is provided in the table below.
- Farmers should have a fair idea about the area under cultivation and the variety grown in the vicinity. This will give them a sense of potential competition in the local market and enable them to estimate the volume of production for distant markets.
- Farmers should focus on high-quality produce rather than on average produce.
- Farmers should analyse available marketing channels and select the most appropriate one based on the socioeconomic situation of farming households.
- Market vigilance is necessary to assess niche market demand for crop, variety and quality. Be prepared to switch to a new crop if that promises better returns.
- Vegetable market is highly dependent on trust. Trust should be maintained by all market actors including producers.

Table 5: **Estimated production cost and net profit from cabbage cultivation (Nu/acre)**

Particular	Unit	Quantity	Nu/unit	Total
1. Variable cost				**44,577**
a. Human labour	Day	97	300	29,100
b. Bullock labour	Day	5	650	3250
c. Seed	kg	0.25	2500	625
d. Manure	kg	6000	1	6000
e. Mineral fertilizer	kg	0	0	0

f. Pesticides	LS		p300	300
g. Management cost	LS		2000	2000
h. Interest on variable cost	LS	8%		3302
2. Fixed cost				**400**
a. Land tax	LS		300	300
b. Repair and maintenance	LS		100	100
3. Total cost				**44,977**
4. Gross income at farm gate				**55,800**
a. Main product		2790		
i. Cabbage head		2790	20	55,800
5. Net profit at farm gate				**10,823**
6. Production cost per kg				**16.120**

Summary

Table 6 summarizes the current practices in cabbage cultivation and interventions needed to promote climate smart farming in Barshong area.

Table 6: **Current practices and interventions for climate-smart cabbage cultivation**

Issue	Current practice	New intervention
Field selection	Unplanned	Systematic crop rotation planning
Land preparation	Field ploughing	Pit digging, maintaining appropriate plant-to-plant and row-to-row distance
Soil fertility management	Use of poor quality FYM, spreading in field	Application of localized organic manure in planting pit, crop rotation with legume
Nursery	Everywhere and unplanned	Permanent nursery structure
Seed sowing	Broadcasting	Line sowing with proper spacing
Planting season	Seasonal planting	Year round production in upper mid hills
Mulching	Not in practice	Mulching immediately after transplanting
Crop protection	As per availability	IPM based crop production More focus on bio-pesticides
Irrigation	Flood irrigation	Drip and/or sprinkler irrigation
Postharvest operation	Not taken into consideration	Harvesting during the cooler part of the day Wrapper leaves management as per market distance Packaging in rigid container
Market information	Selling directly to local market or selling to local collectors	Encouraging farmers to record the cost of cultivation and calculate unit price Selection of most efficient marketing channel

6

Onion

Introduction

Onion (*Allium cepa*) is a popular spicy vegetable primarily grown for its pungent bulbs. The mature bulbs are used as vegetable, spice and salad. Green leaves with immature bulbs are also consumed as green vegetable. The bulb is an enlarged leaf base also known as scales, and is fleshy. The scales thicken as the bulb develops but the outer layer become scaly due to moisture loss. It is rich in starch, protein, carotene, vitamin B and vitamin C.

Climate

Onion is a biennial crop, though the bulb production is completed within a year. It is a cool season crop and tolerates frost. If the right variety is selected, it can also be cultivated in the rainy season. Optimum temperature for plant development ranges from 13 to 24°C but 20–25°C is ideal for seedling growth. High temperatures are suitable for bulbing and curing. Exposure to low temperature (below 6°C) results in a high rate of thick and elongated necks. Bulbing is also influenced by the varietal response to the day length threshold requirement. Additionally, interactions of temperature and day length might modify the bulbing response. Increasing temperature generally accelerates the bulb formation process in all cultivars. Photo-insensitive varieties are needed for rainy season planting.

Soil

Onion can be successfully grown in fertile, well drained and light loamy soil. Bulb development is hindered in clay soil due to soil compactness. Sandy soil is also unsuitable for onion as it is difficult to maintain soil moisture in this type of soil. Sandy soil demands frequent irrigation, which leads to a high rate of cat ions (nutrients responsible for making soil alkali) leaching. Onion does well in soil with high organic matter. The optimum pH range for onion is 6.0 to 6.8. Its performance is not satisfactory below 6.0 pH level because of micro nutrient deficiency and occasional aluminum or manganese toxicity.

Planting Season

Onion is primarily a winter season crop for river basin areas and the mid hills. It is also grown in the rainy season in the high hills (>2,000 masl). Seeds are sown in August to October in the mid hills and at lower elevations. In the high hills, seeds can be sown during March–April. As onion is planted after rice in Barshong Geog, land availability should be taken into consideration while sowing seeds in the nursery in order to transplant seedlings of appropriate stage. In the winter season, onion seedlings become ready for transplanting in about 6 weeks. The number of leaves formed before bulbing determines the yield of onion as the scales are the thickened leaf base. Specific day length of the variety triggers bulbing, which checks further leaf development. Early planting allows sufficient growing time and helps improve bulb size, thus enhancing the yield.

Summer season onion cultivation is not common in the Barshong area. But onion bulbs can be successfully produced in the hills in May by sowing seeds of day neutral varieties. Due to high temperature, seedlings are ready for transplanting in 4 weeks. Rainy season cultivation technology would be more suitable for farmers with rainfed farmlands. Furthermore, commercial rainy season cultivation would be appropriate in areas where only fair weather roads are in operation, as onion is harvested in December. More importantly, farmers could get good market prices because the produce is available even in off-season. Likewise, sets can be planted to the produce bulb onion in the winter season. Sets are miniature bulbs that can be planted in the hills in July (<1,500 masl).

Variety

Open pollinated and hybrid cultivars of onion are available in markets. Hybrid varieties are dominant in mechanized farming conditions of developed countries. However, open pollinated varieties are also common and offered by seed companies where agriculture is just moving towards commercialization. Onion cultivars are grouped into short, long and day-neutral based on the light requirements. Short-day onions are suitable for winter season cultivation in Bhutan. Short-day onions (12 to 13 hour threshold) are generally mild, soft fleshed and suitable for storage. Salient features of open-pollinated varieties are presented below:

Bombay Red: Bombay Red is a short-day variety. Bulbs are red in colour, semi round in shape and medium to large sized. Flesh is firm with a high level of pungency.

Red Creole: Red creole could be another variety suitable for Barshong area. It is a short-day variety and can be harvested in 160 days. Bulbs are somewhat flat in shape, deep red in colour, have high pungency and are good for cooking and storage. Bulb size ranges from 80 to 120 g. This variety is also suitable for sets planting.

Agrifound Dark Red: Agrifound Dark Red is a day-neutral variety, thus can be cultivated even in the rainy season. Bulbs are globular in shape and dark red in colour. They mature in 95–110 days. This variety is equally good for sets planting.

Land Preparation

Land should be ploughed 2–3 times and clods and debris should be removed with a spade. Soil should be friable enough. Minimum tillage is cumbersome in the case of onion because of the close planting distance and shallow root system. A flat bed about 1 m (90–100 cm) wide and up to 10 m long, with a 15 cm high border should be built to make irrigation convenient for winter season planting. The border made around the flat bed helps retain irrigation water by reducing surface runoff. The beds can be 30 cm apart to allow room for irrigation and other intercultural operations. Beds and paths of the same size are appropriate for the rainy season. But raised beds of about 30 cm height should be prepared for proper drainage for rainy season cultivation.

Soil Fertility Management

Onion plants respond to high amounts of nutrients such as those found in organic manure. While yielding 7.3 t/acre bulbs, onion plants exhaust an average of 26.7 kg of nitrogen, 4.5 kg of phosphorus and 28.3 kg of potash. Nitrogen management is very important for onion. Insufficient nitrogen will lead to early maturity, resulting in reduced bulb size. In contrast, high amounts of nitrogen contribute to large bulb size but simultaneously cause large neck and soft bulbs with poor storage ability. It is worth noting that the improved FYM has about five times higher nitrogen content than traditionally prepared organic manure. Intercropping legume with maize enriches the nitrogen in soil. Farmers should check the nodulation level and take action accordingly, as mentioned in the earlier section (this is a common practice in Barshong area). Manure and fertilizers should be adjusted taking all these facts and soil nutrient status into account. In poor soil condition, farmers may apply 10,000–15,000 kg of compost, 24 kg of nitrogen, 16 kg of phosphorus and 20 kg of potash per acre. All of the phosphorus and potash, as well as two-thirds of the nitrogen, are applied in the planting rows 5–10 cm below the seedlings. Broadcasting of mineral fertilizers is common but this method reduces the plant's ability to utilize the minerals. The remaining one-third of the nitrogen is further divided into two portions and side-dressed 30–35 and 80–90 days after transplanting. Field should be clear of weeds and properly moist before side-dressing nitrogen. Zinc and copper deficiencies are common in onion. Apply 4 kg of zinc and 8 kg of copper per acre in the field where onion is regularly grown; this process can be repeated every two or three years.

Seed Rate

Onion seed is delicate and loses its viability very easily. It should not be stored for long as it does not have long seed viability. Onion is also sown directly but this method is not common in the hills. For nursery and seedling transplanting, 4 kg of seed or about 200 thousand seedlings are required for an acre of land. The nursery area should be about 80 m^2 for the seedlings to cover a one-acre field. Soaking the seed for 24 hours quickens germination. Seeds should be sown sparsely in a line so as to grow healthy and stout seedlings in the nursery. Dense sowing leads to weak and lanky seedlings.

Transplanting

Irrigate the nursery 2–3 hours before uprooting the seedlings. Uproot the seedlings without damaging the roots. Select only healthy and stout seedlings for transplanting. Remove the yellow leaves and de-top one third of the leaves to minimize water loss through transpiration. Spacing varies according to the growing season and soil fertility status. Generally maintain 15 cm row-to-row and 10 cm plant-to-plant distance. Like other crops, onion seedlings should be transplanted during late afternoon, and planting beds should be irrigated immediately after transplanting. It is important to maintain constant soil moisture till transplants get established. The erect leaf structure and non-tillering behaviour of the crop may lead to wide gaps if a few seedlings die after transplanting. Gaps should be filled within a week of transplanting so as to properly utilize the space with cent percent plant establishment.

Intercultural Operations

Onion has a fibrous root system with weak root growth and poor lateral rooting behaviour. The roots spread just beneath the soil surface to a distance of 30 to 46 cm. These behaviours under the soil surface should be properly understood while performing intercultural operations.

Weed management: High weed infestation in the onion field significantly reduces the yield because of its weak root system. Unlike in other crops, weed problem in onion remains severe even in the later crop stage. Manual weeding with the help of a hand hoe must be shallow to avoid root damage. Generally 3–4 rounds of weeding is needed in the hills during winter and early spring.

Water management: Uniform moisture level in the field is necessary throughout the onion growing season. However, excessive moisture must be avoided. Onions utilize a substantial amount of water at the bulbing stage. Higher rates of bulb splitting are recorded in the fields, where plant growth is retarded. Sprinkler irrigation is the best option in the hills, where gravitational force is sufficient to run a sprinkler. Surface irrigation through a pipe or furrow irrigation can also be adopted.

Side dressing: Spraying *Jholmal* and cattle urine solution is beneficial to onion. It can be done at monthly intervals if time and resources permit. Wood ash is rich in potash and its application to onion is beneficial to the crop. As described above, two rounds of nitrogen side-dressing can improve the yield.

Insect Pest and Diseases

Onion thrips

Both adults and larvae of the insect scratch or cut the leaf or stem surface (epidermis) and suck the plant sap (Figure 27). The infested parts have white or brown blotches. Severe infestations lead to leaf blasting and collapse.

Management practices

- Application of wood ash 2–3 times drastically reduces this type of infestation.
- Commercially available bio-pesticides based on *Beauvaria bassiana* can be used at a rate of 2 g powder formulation and 4 ml liquid formulation per litre of water.
- Spray astringent *Jholmal* at a rate of 10 ml per litre of water every two weeks.
- Spray Neem based (*Azadirachtin*) insecticides like Margosom or Nimbicidine at a rate of 2–3 ml per litre of water.

Figure 27: **Onion thrips**

Purple blotch

Small, white, sunken lesions develop on the leaves at the initial stage and zonate in the later stage, with a purplish centre under moist conditions (Figure 28). These spots gradually enlarge and eventually girdle the leaf or inflorescence stalk. Infection can cause a semi-watery rot on the neck of the bulb, which turns yellow-red in colour.

Figure 28: **Purple blotch**

Management practices

- Some varieties like Red Creole are reported to be less susceptible. Use such varieties if they are available in the insect-prone areas.
- Since the fungus is seed borne, always use disease-free seeds or seedlings.
- Avoid other crops of *Allium* species during crop rotation.
- Practice clean cultivation by destroying infected onion debris.
- Bordeaux mixture is also effective in fighting the disease.
- As a last resort, spray a mixture formulation of carbandazim (12%) and mancozeb (63%) at a rate of 2 g per litre of water.

Downy mildew

Downy mildew first attacks the older leaves of young plants (Figure 29). White specks develop on the leaves and later turn bluish and light yellow. Chlorotic zones appear at the point of infection and the plant falls off at one point.

Figure 29: **Mildew on onion**

Management practices

- Since fungus over-winter in infected plant debris, destroy all infected onion plant parts.
- Always use disease-free seeds and seedlings.
- Avoid other crops of *Allium* species during crop rotation.
- Application of *Fusarium proliferatum* at a rate of 2 g per litre is also found to be effective.
- If disease occurrence is annual phenomenon, spray mancozeb (45%) at a rate of 2 g per litre of water at weekly intervals until bulbing as a last resort.

Maturity Indices

Onions are ready to harvest when growth stops (dormant) and the neck is no longer slippery and feels completely dry to the touch. Other signs of maturity are: leafy green tops begin to turn yellow, leaves collapse and the tops (pseudo-stem) bend over just above the top of the bulb. Commercial farmers harvest onions at once when about 50% of the tops have bent over. Small-scale farmers can harvest only the mature plants (tops bent over) for long-term storage and sale in distant markets. If they want to harvest at once, tops can be bent two weeks before the harvest in order to enhance bulb maturity. Onions should not be over-mature in the field, or they will begin to sprout roots and shoot, which increases respiration (use of deposited food). Care should be taken not to disturb the actively growing plants while carrying out periodic harvest.

Harvesting

Harvesting should not be done when the soil is very dry. Very hard and dry soil makes harvest difficult. Farmers irrigate the onion field to ease harvest but the practice is wrong. Onion bulbs contaminated with wet soil during and after harvest are prone to rot. Therefore it is strongly recommended that farmers do not irrigate the field before harvest. Soil must be dry at harvest time but not very dry and hard. Damage during harvest can be easily avoided if onions are grown in raised beds with soft crumbly soil. The crop is harvested using a hoe or a fork; the bulbs and their roots are gently removed from underneath. Special care must be taken not to cause any damage. The uprooted onions should be left in the field for a short while (1–2 hours in the dry season) to allow the soils around the roots to dry before collection for curing. While collecting them, the surplus soil should be shaken off.

Yield

Planting season, crop variety and management techniques determine the yield of onion. Hybrid varieties in the hills yield about 10,000 kg per acre with the application of recommended dose of mineral fertilizer. For open pollinated varieties, the expected yield is about 3,000 kg per acre under proper management and with minimum external input (side dressing by urea and plant protection measures), along with the application of improved organic manure. However, the average productivity of Tsirang in 2014 was 1800 kg/acre, which suggests there is ample opportunity to increase the yield.

Postharvest Care

Curing: Onions need warm, well-ventilated and low relative humidity for curing. The process is needed to dry out root base, neck and 2–3 layers of outer scales. Collected onion plants are heaped in the shade and covered with jute sacks or bamboo mats for about two days. The roots and soil are removed after the plants are heaped and the tops cut off 2.5 cm above the bulbs with a sharp knife. The cleaned bulbs are placed in well-ventilated shady areas till the outer scales dry up and the necks dry up and shrink. Generally 3–5% weight reduction is expected during the curing process. Hanging storage is also common among small-holder farmers. In such a situation, the tops should not be cut off and the onion plants can be hung on a rope for curing and storage.

Grading and packaging: After curing, diseased, sprouted and split bulbs should be separated from the good ones. The selected bulbs should be divided into three grades: large (bulb diameter more than 6 cm), medium (bulb diameter 4–6 cm) and small (bulb diameter less than 4 cm). Onions of different grades have to be packed separately in plastic crates or open mesh netting, or placed in different racks. The sorted onions (thick neck, split, sprouted and wounded bulbs) have to be marketed as soon as possible, preferably in local markets. Open mesh netting is the most widely used packaging option for onions. Netting is available in different sizes; netting of 25–30 kg capacity is most appropriate for this purpose.

Storage: Onion bulbs for storage should be firm with dry and thin necks. In ambient conditions, optimum storage temperature is 24 to 300C. Onion sprouts more readily at temperatures between 4 and 240C. Hence, care should be taken to avoid low night temperature. Onions lose weight rapidly due to moisture loss at temperatures over 350C. Humidity is also important for storage. Optimum relative humidity (RH) for onion storage is 60–75%. High RH causes rotting, and very low (below 60%) RH causes the splitting of the bulbs' outer skins due to excessive water loss.

Long-term storage under controlled temperature and humidity conditions is not viable in the hilly areas of Barshong. Onions packed in nylon mesh or plastic crates can be placed in racks in a well-ventilated shed. Never place them on the floor. Onion bulbs can be placed in a single layer in wooden or bamboo racks in the shed for two months. The store should be inspected regularly and rotted and sprouted bulbs should be removed. Ethylene encourages onions to sprout. Therefore onions should not be stored together with large quantities of ethylene producing crops like tomatoes.

Transportation: Allow little pathways for ventilation during transportation while stacking the sacks. To avoid compression, damage and bruising, do not stack them up too high. Protect onions from wind, rain, dust and direct sunshine by covering them with a white waterproof sheet. The cover should be 20–25 cm above the top of the stack for ventilation. It's better to transport them during the coldest part of the day, i.e., early morning or at night

Marketing

Market vigilance is important for obtaining a higher price for the onions. Since onions can easily be stored for two months in local conditions, farmers should be patient until they can sell their produce. They can decide the time of sale after analysing the price trends of the previous years. Market-oriented farmers have to explore different marketing channels. The appropriateness of a particular marketing channel is primarily determined by the scale of production and the distance between the production site and the end market. For example, small-scale farmers who live near the market can sell their produce directly. This allows the farmers get a good price and the consumers to get very fresh produce. But selling small quantities of onions in distant markets would not be profitable for farmers. A marketing intermediary becomes necessary when the production site is far from the end market. Visits to the markets of Thimphu and Damphu revealed the existence of four marketing channels in Bhutan: i) Producer to consumer, ii) Producer to retailer to consumer, iii) Producer to collector to retailer to consumer, and iv) Producer to collector to wholesaler to retailer to consumer. The involvement of more marketing actors simultaneously increases the product cost because the profit margin increases at each step of the supply chain. Increase in the number of marketing intermediaries also lengthens the time it takes for the produce to reach the market. This leads to postharvest losses and quality deterioration as normal vans are used for vegetable transport. Therefore the shortest possible marketing channel is desirable for vegetable marketing. Since commercial farmers do not have the time to market their produce themselves, one marketing intermediary is highly desirable. A farmers' group or cooperative would be the best option.

Market-oriented production and product marketing are two sides of the same coin; one cannot move forward in the absence of the other. A market-oriented production system has to analyse potential markets along with associated risks beforehand to get better returns. To earn higher incomes from market-oriented production, farmers should consider the following points:

Table 7: **Estimated cost of cultivation and profit from onion bulbs (Nu/acre)**

Particular	Unit	Quantity	Nu/unit	Total
1. Variable cost				**33,696**
a. Human labour	Day	63	300	18,900
b. Bullock labour	Day	5	650	3250
c. Seed	Kg	0.3	2,500	750
d. Manure	Kg	6,000	1	6000
e. Mineral fertilizer	Kg	0	0	0
f. Pesticides	LS		300	300
g. Management cost	LS		2,000	2000
h. Interest on variable cost	LS	8%		2496
2. Fixed cost				**400**
a. Land tax	LS		300	300
b. Repair and maintenance	LS		100	100
3. Total cost				34,096
4. Gross income at farm gate				**47,000**
a. Main product		2,000		
i. Onion bulb		1,800	25	45,000
ii. By-product (culled)		200	10	2000
5. Net profit at farm gate				**12,904**
6. Production cost per kg				**17.04**

- Farmers should keep a good record of all costs of production. This will allow them to accurately estimate the minimum price of the produce. A rough calculation of the production cost of onion is provided in the table below for reference only.
- Farmers should find out how much area is under onion cultivation in the village. This will give them an idea about potential competition or the volume of production required for distant markets.
- Focus on high-quality produce rather than on average quality produce. High-quality produce gives higher returns in high-end markets.
- Analyse existing marketing channels taking the geophysical and social conditions into account and identify the most profitable channel.
- Farmers should even be prepared to switch to a new crop if there is demand for that particular crop in the market.
- Vegetable market is highly dependent on trust. Trust should be maintained by all market actors including producers.
- Since onions can be stored in local conditions for a few months, short-term storage will enable farmers to get a high selling price.

Summary

The interventions needed to promote climate-smart farming of onions are briefly summarized in the Table 8.

Table 8: **Interventions for climate-smart Onion farming**

Issue	Current practice	New intervention
Land preparation	Field ploughing	Minimum tillage
Soil fertility management	Use of poor quality FYM, spreading in field	Application of localized organic manure in planting row, crop rotation with legume
Nursery	Unorganized	Permanent nursery structure
Seed sowing	Dry seed sowing Broadcasting method	Seed priming Line sowing with proper spacing
Planting season	Seasonal planting for winter season cultivation	Introduction of rainy season cultivation for production season expansion
Mulching	Not in practice	Mulching immediately after transplanting
Crop protection	As per the availability	IPM based plant protection practices More focus on bio-pesticides
Irrigation	Flood irrigation	Sprinkler irrigation
Postharvest operation	Not taken into consideration	Harvest when soil moisture level is right Proper curing before storage Adoption of local storage after production Proper grading before packing Packaging in nylon mesh bag
Market information	Selling directly to local market or selling to local collectors	Encouraging farmers to record the cost of cultivation and calculate unit price Selection of most efficient marketing channel

7

Ginger

Introduction

Ginger (*Zingiber officinale* Rosc.) belongs to the plant family Zingiberacea. Botanically, ginger is a perennial plant but agriculturally categorized as an annual crop because it produces about a metre long leafy stem every year. Rhizome, the modified stem that grows under the soil, is the most widely used part of ginger. Ginger rhizome is primarily used as a spice. Fresh and dried rhizome is marketed by small-holder farmers. However, value can be added to fresh ginger by making it into candy, ginger crystal, Murrabba, squash and alcoholic drinks. Fresh ginger contains 12.3% carbohydrate, 2.3% protein, 0.9% fat and trace amounts of vitamins and minerals. Dried ginger contains 12% moisture, 15% volatile oil and 6% oleoresin.

Climate

Ginger performs better in warm and moist climate. Hence it can be successfully grown from the sea level to 1,600 metres above sea level (masl) in tropical and subtropical zone. The crop yield is better in temperatures between 20 and 30°C but it can thrive in temperatures up to 35°C. Since ginger is a shade tolerant crop, it can also be successfully cultivated in areas of moderate shade in addition to open fields. The partial shade-loving characteristic of ginger has special significance for Tsirang, where agro-forestry is predominant. It can also be a suitable intercrop in orchards that grow tropical and subtropical fruit like mango and citrus.

Ginger is mainly grown in rainfed conditions. Well-distributed rainfall during crop growth season is essential for successful cultivation of ginger. Light rainfall during planting and sprouting periods and senescence of rainfall (dry spell) one month before harvest is essential. Total rainfall of 1,500–3,000 mm during the growing season is appropriate for the crop. Monsoon rainfall pattern of South Asia (June-September) has made ginger cultivation successful in Bhutan. A south-east facing hillside is more appropriate for ginger cultivation because rain water does not become stagnant in such a condition.

Soil

Light soil with high organic matter is most suitable for ginger cultivation. For this reason, ginger yield is always better in virgin soils. Waterlogging causes rhizome rot disease in ginger. Loamy soil with good drainage facility is hence most suitable for ginger cultivation. Heavy clay soil, sandy soil and soil with gravels are unsuitable. The crop yield is good in the pH range of 5.5–6.5.

Planting Season

The planting month primarily depends on the altitude of the site and the onset of pre-monsoon rainfall. Ginger has to be planted in March at higher altitudes (1,600 masl). If the altitude is 1,000 masl, ginger rhizome planting can be delayed by a month. The last week of April would thus be an appropriate planting date in the Sunkosh river basin areas. At the lower altitudes, rhizome can be planted after the onset of monsoon rainfall (beginning of May) because of high temperature. But planting at the higher altitudes should preferably be completed just before the pre-monsoon showers. Evidence from the mid hills suggests that under similar agro-ecological conditions, delay in planting (beyond April) decreases ginger yield.

Variety

Many ginger varieties have been released for similar agro-ecological conditions of India and Nepal. These varieties can be introduced and evaluated with local genotypes. In its commodity price list, the National Seed Centre (NSC) of Bhutan has mentioned local genotypes that are being formally marketed in Bhutan. The local genotypes marketed at Barshong and Damphu were found to be of good quality and disease-free. These genotypes can therefore be used for commercial production. Use of local genotypes has additional advantages: they are well adapted to the area and more resilient to adverse climate conditions.

Land Preparation

Since ginger needs well-prepared soil for better rhizome growth, 2–3 deep ploughing are necessary for planting. Weeds and debris should be removed after ploughing. Furrow for drainage should be made according to the features of the land on hilly slopes, where raised bed preparation is not necessary. Care should be taken while making drainage furrows to ensure that the drained water does not gradually flow into the lower terraces. Making a drainage furrow across the slope is also necessary to prevent soil erosion. In the flat land, planting beds of 1 m width, 15 cm height and length as per the plot size should be made. This will facilitate drainage and enhance production. Apply well-decomposed organic manure just before the last ploughing in order to mix the organic manure properly in the soil. Biochar can be applied just below the seed rhizome.

Soil Fertility Management

Soil fertilization is crucial for making plant nutrients available to the crop and to replenish the nutrients mined by the crop. Since ginger is a heavy feeder (it needs more nutrients for better growth and yield), proper attention needs to be paid for soil fertility management. Organic manure supplies major nutrients like nitrogen, phosphorus, potash and micronutrients in small amounts but in a steady fashion. In contrast, inorganic fertilizers release high amounts of macronutrients quickly and easily. In climate-smart farming, more focus should be on organic sources of nutrients. This would entail the application of well-decomposed manure, biochar and mustard cake and nutrient-rich organic mulching. If available, mustard cakes should be applied at a rate of 800 kg per acre. Use green mulch of *Artemesia vulgaris*, *Eupatorium adenophorum* and *Adhatoda vacica* whatever easily available locally.

In the case of mineral fertilizer application, N, P_2O_5 and K_2O in the ratio of 30:20:20 and 12 t compost per acre is recommended. Apply all organic manure and phosphorus, half of the potash and one third of the nitrogen at the time of land preparation. Side-dress one third of the nitrogen a month after sprouting. The remaining one third of the nitrogen and half of the potash should be side-dressed two months after sprouting.

Seed Rate and Seed Treatment

Ginger is propagated asexually, where rhizome is the propagule. Seed rate varies according to the size of the rhizome, its thickness and variety, and the planting method. It also depends on whether or not the mother rhizome is harvested. Use of smaller rhizomes results in less production. On the other hand, using large rhizomes would not be economical if mother rhizome harvest is not a common practice. Using 50–60 g rhizomes is recommended if harvesting is done only in the main season (without mother rhizome harvest). About 1600 kg of seed rhizomes of the aforementioned weight is required for an acre of land. In areas where mother rhizome harvest is common, such as Barshong Geog, using larger rhizomes (about 90 g) is recommended; this would mean about 2450 kg of rhizomes would be required for an acre of land.

Selection of good seed rhizome is the most crucial activity for successful ginger cultivation. Poor quality rhizome leads to low production. As the seed rate required is high, farmers in the interior parts do not purchase ginger seeds from the formal system. Alternatively, they produce seeds themselves or obtain them from the informal system in the vicinity. The following points should be considered to maintain the quality of ginger seed at the local level:

- Seed should be taken from a disease-free plot (with special attention to rhizome rot disease).
- Rhizome should be free from insect attack.
- Seed rhizome should have at least one bud but no sprouts.
- Seed rhizome should be well developed and plump, not shriveled.
- Rhizome seed should not have any cuts.
- Rhizome skin should be intact and not peeled off.

Seed treatment is a preventive measure against insects and pests. Seed treatment of ginger is particularly focused on rhizome rot disease management. This disease needs most attention as it is transmitted through the seed from one place to other. Details of seed treatment are described below.

Rhizome rot is the most destructive disease in ginger. If seed rhizomes appear infested with disease, they should only be planted after being treated. Prepare a fungicide solution of mancozeb 45% WP 2.5 g and carbandazim 50% 1 g per litre of water and put it in a cement tank or a big plastic bucket. In rural areas, a small plastic pit (75 x 75 x 75 cm) can be constructed for seed treatment. Put the seed rhizome in a plastic crate or any other perforated vessel and dip it in water for an hour. Take the rhizome out of water and surface dry in the shade. One batch of fungicide solution can be used to treat 3–4 batches of seeds.

The toxicity level of the suggested fungicide is low. However, the utmost precaution should be taken to ensure safe use of pesticide. Use only the recommended dose of fungicide and check the date of expiry before using it. Do not expose the solution to direct sunlight after dipping the seed. Store or plant the seed rhizome only after it is dried in the shade. The fungicide solution should be disposed in a deep pit after use.

Rhizome Planting

Seed rhizome should be planted as early as possible after it is taken out of the storage pit. It should be planted within a week after exposure to ambient conditions. Moisture loss from the rhizome will negatively affect the yield. Furrows 8–10 cm deep and 30 cm apart have to be built in the prepared field to sow the seeds. The seed rhizome should be planted 30 cm apart. If the rhizome seeds are smaller, the plant-to-plant spacing can be smaller (25 cm). Leave 45–50 cm wide space after every 4–5 rows. This will allow room for intercultural operations, mulch management and harvesting of the mother rhizome.

Mulching

Ginger is generally planted on a hill slope with limited or no irrigation facility. Mulching the field immediately after planting conserves soil moisture, prevents runoff erosion, suppresses weed and augments soil organic matter after decomposition during the rainy season. Unlike with other crops, even green mulch can be applied to ginger, as ginger takes 1–3 months to sprout up to the ground level. 4-5 cm thick mulch derived from available plant materials should be spread over the field. The most suitable plants are those that decompose easily. If dried leaves are used, make sure that the leaves are not blown away. When green mulch is used, there are chances of open patches forming after they are dried. Check the field every two weeks and cover the open patches with dried plant materials.

Intercultural Operations

Weeding: Weed infestation in the ginger field is higher in the early stage (within 2–3 months of planting) because of the high organic matter and moisture in the soil. Competition for nutrients and light is more intense in the early plant stage (June) than in the later stage (September). Weeding should be done twice or three times depending on the weed intensity. Weeding should be done just before top-dressing. Applying sufficient mulch will reduce weed.

Earthing-up: Earthing-up is not necessary if the mulch is thick enough. If there is no mulching or the mulch is very thin, earthing-up should be done one month after emergence. Extra earthing-up might be needed to cover the exposed rhizomes in the later stage.

Irrigation: Generally ginger does not require irrigation as it is mainly grown in the rainy season. However, in case of prolonged drought after planting, irrigation is needed for rhizome sprouting. If there is about three-week-long drought in June and no rainfall during October-November, irrigation might be needed at two-week intervals. Check the moisture content in the soil before irrigation. Special care must be taken to prevent water stagnation in the field during irrigation and during the rainy season, because ginger cannot withstand water stagnation.

Harvesting of mother rhizome: Mother rhizome harvest involves detaching the seed rhizome from the newly emerged plant after seed establishment. About 80% of the seed rhizomes can be harvested with this technique without hampering the subsequent yield. Seeds contribute 50-60% of the ginger production cost. Mother rhizome harvest will allow farmers to recover nearly half of the production cost before they obtain the main yield. Further, this technology gives provides good returns even to growers who have no access to storage facilities. Mother rhizome should be harvested in August. Rhizomes harvested in August can be sold at better prices than those harvested during the in-season. To get better prices on rhizomes, farmers should plan from the outset taking the following points into consideration:

- Use large seed rhizomes that weigh about 90 g each.
- Leave 50 cm path space after every four rows, so that one can harvest two rows from a path without damaging the plants.
- While planting, the mother rhizome should be upside down facing the buds on the same side.
- Be vigilant of the market price before harvesting mother rhizomes.
- Mother rhizome should be harvested on sunny days.
- Gently remove the soil and mulch and carefully break the mother rhizome at the point between the seed and the newly emerged shoot and roots.
- Refill the soil after harvest and rearrange mulch materials.

Insect Pests and Disease

Ways to manage major disease and insect pests in ginger are briefly described below.

Borer

The larvae eat the newly emerging leaves from the core. The tip dies as a result and comes out easily when pulled. Holes made by the borer can be seen in the infested pseudo-stems and excreta underneath.

Management practices

- Use light trap for the adult larvae to reduce the insect population.
- If the insect probem is severe, spray a solution of Dimethoate 30% one ml per litre of water twice at 15-day intervals.

White grub

White grub (Figure 30) lives beneath the soil. The larva has a brown head and curls up when touched. It feeds on the rhizome and make deep scars. It is a polyphagous insect, which means it damages a large number of vegetables besides ginger.

Figure 30: **White grub**

Management practices

- Plough the land deeply so as to expose the different stages of the insect, namely egg, pupa and larva.
- Never use un-decomposed farmyard manure.
- Apply Metarhizium anisopliae (entomopathogenic fungi) mixed with compost at a rate of 10 g per kg of compost. Apply chlorpyrifos 1.5% DP at a rate of 1 kg per 500 m^2 area of land.

Red ant

Adult ants (Figure 31) eat the soft tissue and make small holes in the rhizome.

Figure 31: **Red ants**

Management practices

- Apply chlorpyrifos 1.5% DP at a rate of 1 kg per 500 m^2 area of land.

Rhizome rot

Rhizome rot is the most destructive disease in ginger and caused by fungus. There are two species of fungus that cause the disease. Infection by *Pythium* spp. is common in the lower belt (river basin area of Sunkosh), which has a high temperature. Diseased spots appear in the new suckers, which start dying if the disease is carried by the seed rhizomes. The yellowing of leaves is the first symptom of the disease. Pseudo-stems of the plant that show the yellowing symptom easily detach from the rhizome or fall on the ground. The rhizome of diseased plants rot. Infection by *Fusarium* spp. is more prevalent in the hilly areas. The yellowing begins from the leaf margin and gradually covers the entire leaf, but the pseudostem does not fall. Rhizome growth is retarded due to poor photosynthesis and it finally dries out.

Management practices

- Since the pathogen thrives up to two years in soil, practice crop rotation compulsorily.
- Seed rhizome is also a means of disease transmission. Therefore only use disease-free seed rhizomes from authentic sources.
- Water stagnation exacerbates the disease. Therefore, have a good drainage system in place.
- Treat the seed rhizomes with *Trichoderma viride* at a rate of 5 g per kg of seed before planting. Dissolve 5 g *T. viride* in 15 ml water or rice gruel and dip the seeds in it. Keep them in the shade for half an hour for surface drying prior to sowing.
- To minimize disease, apply 800 kg mustard cakes mixed with 20 kg prickly ash (*Zanthoxylum armatum*) in the planting furrows for each acre of the field.
- Dip the seeds in a solution of carbandazim 50% WP at a rate of 2.5 g per litre of water and surface dry in the shade before planting.
- Mix 0.5 g of metalyxil 8% and mancozeb 64% formulation in one litre of water and drench the diseased plants immediately after noticing disease symptoms.

Bacterial wilt

Bacterial wilt is caused by *Ralstonia solanacearum* and the problem generally appears in September. At the early stage, leaves start wilting and the margin drops downwards. In the severe stage, pseudo-stems dry up, bringing rhizome development to a halt. The diseased rhizome rots afterwards and gives off a nasty odor. Pus like viscous liquid oozes from the rotted rhizome when squeezed.

Management practices

- Since the disease is transmitted through the seed rhizome, use only disease-free seeds. Seeds should be from authentic sources.
- Seed rhizomes can be treated by dipping them for 10 minutes in hot water (50°C).
- Adopt crop rotation for three years. Crops belonging to the solanaceae family like potato should be avoided while selecting crops for rotation.
- Dip the seeds in a Streptocycline solution (2 g per 10 litres) for an hour before planting. The same solution could be used for soil treatment.
- Drenching the soil with 0.2% copper oxychloride at the initial stage of infection is also found to be effective.

Storage mold

Different species of fungi are responsible for storage mold. *Pythium ultimum* causes soft rot, *Fusarium oxysporum* causes dry rot and *Verticillium chlamydosporium* causes red rot in ginger. The disease symptoms might be different (red, black, green, white, brown) depending on the fungus species. Skin peeling of rhizome due to mishandling and improper storage triggers the mold infestation in ginger.

Management practices

- Only store disease-free rhizomes. A few diseased rhizomes can spoil the entire batch.
- Maintain storage temperature at 12–14°C with 65–75% RH. In pit storage, adopt the recommendations provided earlier.
- Care should be taken not to damage the rhizome during handling and storage.
- Inspect the stored ginger at monthly intervals.

Maturity Index

Generally the crop is ready to harvest when 75% of the pseudo-stems dry up and fall. The harvesting time of ginger varies according to the cropping season and the intended use of harvested ginger. In any case, ginger should be harvested at least six months after planting. The following conditions determined the appropriate harvesting time.

- Harvest in 6–7 months of planting: Immature rhizomes may be harvested if they have a very high market price, for sale in the nearby market, for fresh consumption, and for ginger candy preparation. The desirable variety of fresh ginger is succulent and tender with low fibre content, low pungency and relatively mild flavour. Since the crop is in the active growth stage, low yield is expected when it is harvested at this stage. However, farmers could plant winter crops in the same piece of land following early harvest of ginger. Small farmers with limited land could take advantage of this technique to maximize crop intensification.

- Harvest in 8–8.5 months of planting: Ginger should be harvested in a mature stage for dried ginger preparation. Farmers could harvest at this stage for long distance markets or for storage on the farm for a few months.

- Harvest after 9 months of planting: Fully mature rhizomes should be harvested for seed purpose. Such harvesting should be done nine months after planting.

Harvesting

Dig around the ginger plant with the help of a spade, removing soil from underneath. Dig about 10 cm away from the edge of the plant, without touching the rhizome. Once the soil is loose, pull the entire plant from the ground, shaking it gently. Put the plant on the ground and cut the stems with a clean knife. Care must be taken not to break or cut the rhizomes. Ginger should be harvested when the weather conditions are dry and soil is dry but soft enough so that the rhizome can be pulled out easily without breakage. While harvesting young rhizomes in six months, care should be taken not to dehydrate it by direct sun exposure. To avoid the strong mid-day sun, harvest should be carried out in the morning or evening.

Roots, pseudo-stems and soils attached to the rhizome should be removed after the harvest. Likewise, the stumps of mother rhizomes and diseased, damaged, and cut rhizomes should be separated from the good ones. Rhizomes should be washed properly, leaving no trace of soil. Rhizomes that have to be marketed should be washed either manually or with the help of a ginger washing machine. The washed rhizomes should be spread in the shade for about a week for curing. Curing enhances storage capacity and minimizes pest problems.

Yield

Ginger yield greatly varies according to cultivation practices and the land under cultivation. Yield reduces drastically if the crop is planted in the same field every year even under good management. About 6 mt/acre can easily be harvested from the new field with the application of sufficient organic manure and the use of clean seed. The current level of production in Tsirang (2.25 mt/acre) is very low compared to areas in neighbouring countries with the same geophysical features.

Postharvest Care

Storage: Fresh ginger rhizome contains 80–85% moisture. Therefore, special care should be taken during storage and transportation. It is estimated that 5–10% loss occurs during the production process between harvesting and marketing. Proper storage of ginger is necessary to prevent moisture loss, shriveling, sprouting and rotting. Improper storage of seed rhizomes causes sprouting during storage, which reduces their chances of growing stout and strong pseudo-stems. It is estimated that improper storage results in about 20% loss. Proper storage of ginger rhizomes is hence necessary for reducing postharvest losses.

Ginger can be stored safely for 5–6 months in 65–70% relative humidity at a temperature of 12–14°C. This temperature and humidity range can easily be maintained in soil pits in the hilly areas. Storing ginger in pits is a common practice in Barshong area. The following points should be considered to make storage more effective.

Storage pit

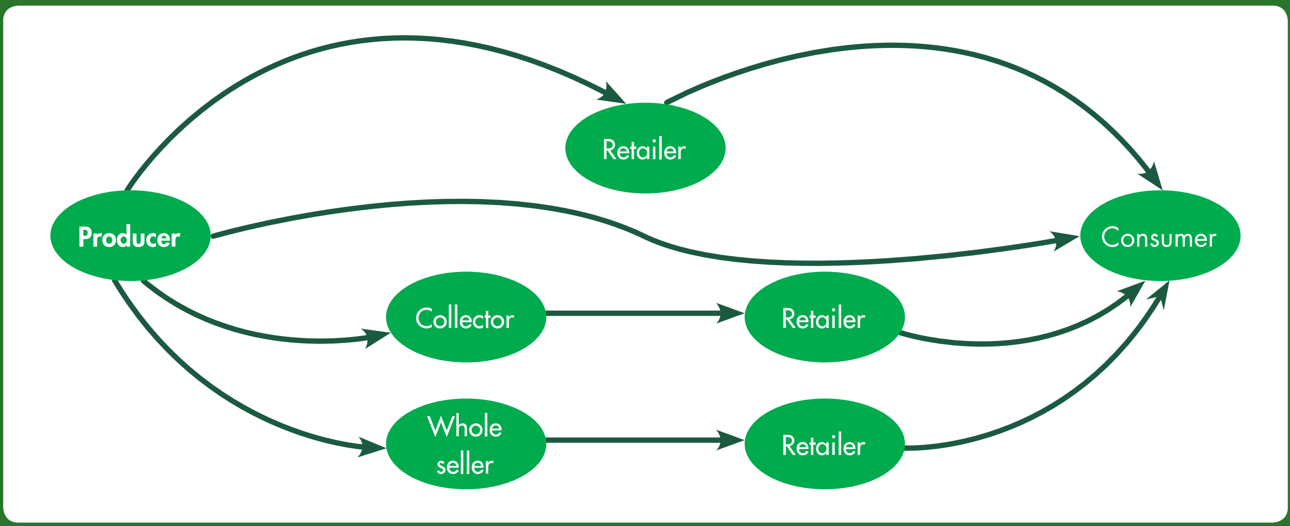
1. The pit should be dug in a shady area with a gentle slope (avoid water stagnation).
2. The size of the pit should be 1 m^3. A pit of this size can contain 350 kg of ginger rhizomes. A pit deeper than 1 m would be uneconomical and would also cause breakage while lifting the rhizome from the pit.
3. Expose the pit for a week and disinfect it by burning dried leaves or twigs.
4. Put a 1 inch-thick layer of sand, rice husks or wood ash at the base of the pit.
5. Put the rhizomes on stakes up to 6 inches below the brim. Cover the pit with wooden planks and make a 2 inch-deep hole at the centre. Put a 3 feet long polythene pipe (bamboo after removing the node) for ventilation.
6. Make a thatch to protect the rhizomes from rain. It also helps maintain/minimize temperature inside the pit.
7. Make a ridge around the pit to prevent runoff water from entering the pit.

Marketing

Fresh and dried gingers are marketed from the major ginger growing areas in the hilly areas of India and Nepal. Dry ginger preparation will add value at the local level and improve farmers' bargaining position because dried ginger has a very low rate of perishability. It can be exported to distant markets within the country and abroad. But preparing dried ginger requires additional skills. As this manual focuses on fresh rhizome production and marketing, techniques of dry ginger production and marketing are not discussed here.

The farming system of Barshong Geog is primarily subsistence and has been moving towards commercial farming in recent years. Interactions with marketing actors of Thimphu and Damphu revealed that there are four marketing channels for fresh horticultural commodities including ginger. The channel is presented below (Figure 32).

Figure 32: **Schematic diagram of the current marketing channels for fresh horticultural products** (including ginger)



Market research has shown that the shortest marketing channel is more beneficial to producers and consumers. Increase in marketing channels simultaneously increases the profit margin at each step and increases the price of the product in the end market. Paradoxically commercial farmers do not have the luxury to spare time for direct marketing. In such a situation, it would be better to send fresh ginger directly to retailers based in big markets provided they have the capacity to handle it. Even selling to wholesalers based in big cities might be profitable. National statistics show that the average price of ginger was Nu 60/kg in 2014 but farmers were selling ginger in Nu 30/kg at Damphu market. Market price in different cities may be different. Thus farmers should be aware of market prices in major cities for direct marketing. Individual farmers or a group of farmers may contact delivery points in the big cities to sell their product. In addition to the higher market prices, farmers should also be careful about the payback date. Timely payment from the recipient parties is equally important.

Market-oriented production and product marketing are two sides of the same coin and one cannot move forward in the absence of the other. The traditional approach of finding a market after production is not beneficial. Commercial farmers have to analyse potential markets to get better prices and also be aware of the risks involved in selling in the big markets. Farmers who are planning to go into commercial farming should consider the following points.

- A farmer has to keep a good record of all the production costs including her/his own labour cost. It helps farmers to judge which crop would be most profitable and what would be the minimum price to cover the cost of cultivation. A rough calculation of the cost of production of ginger is provided in the table below for reference only.
- Preparation of dry ginger is more profitable in the interior areas. Explore the potential with wholesalers based in Thimphu or get advice from agricultural experts.
- Focus on high quality products rather than on high quantity of mediocre quality. High quality products give better return in high end markets.
- Analyse existing marketing channels and identify the most profitable channel based on geophysical and social circumstances.
- Farmers are advised to grow a new crop at the request of credible parties if the production of that particular crop is more remunerative than existing crops.
- Vegetable market is highly dependent on trust. Trust should be maintained by all market actors including producers.

Table 9: **Estimated cost of cultivation and profit of ginger (Nu/acre)**

Particular	Unit	Quantity	Nu/unit	Total
1. Variable cost				**93,002**
a. Human labour	Day	36	300	10,800
b. Bullock labour	Day	5	650	3,250
c. Seed	Kg	1,600	38	60,800
d. Manure	Kg	6,000	1	6,000
e. Mineral fertilizer	Kg	0	0	0
f. Pesticides	LS		300	300
g. Mulching materials	Kg	1,600	2	3,200
h. Management cost	LS		2,000	2,000
i. Interest on variable cost	LS	8%		6,652
2. Fixed cost				**400**
a. Land tax	LS		300	300
b. Repair and maintenance	LS		100	100
3. Total cost				**93,402**
4. Gross income at farm gate				**111,560**
a. Main product		3352		
i. Fresh ginger		2252	30	67,560
ii. Mother ginger		1100	40	44,000
5. Net profit at farm gate				**18,158**
6. Production cost per kg				**27.86**

Summary

Suggested interventions against the current practices have been summarized in Table 10 in order to promote climate smart ginger farming.

Table 10: **Interventions for climate-smart ginger farming**

Issue	Current practice	New intervention
Land preparation	Field ploughing Bed preparation not in practice	Minimum tillage Preparation of drainage furrow across the slope Planting bed preparation in flat areas
Soil fertility management	Use of poor quality FYM, spreading in field	Application of localized organic manure in planting row, adoption of field rotation
Cropping system	Sole cropping	Demonstration of ginger – maize intercropping for better returns
Seed treatment	Not in practice	Demonstration of seed treatment in locally produced seed
Mulching	Thin mulching	Promotion of thick mulching with nutrient rich plant materials
Crop protection	As per the availability	IPM based crop production practices More focus on bio-pesticides
Irrigation	Not in practice	Sprinkler irrigation in absolutely needy situations
Postharvest operation	Not taken into consideration	Harvesting according to market distance and market price Adoption of grading and sorting Demonstration of short-term storage in pit at local level
Market information	Selling directly to local market or selling to local collectors	Encouraging farmers to record the cost of cultivation and calculate unit price Selection of the most efficient marketing channel

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Project funded by the European Union

International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu, Nepal
Tel +977 1 5003222
Fax +977 1 5003299
Email info@icimod.org
Web www.icimod.org

ISBN 978 92 9115 XXX X