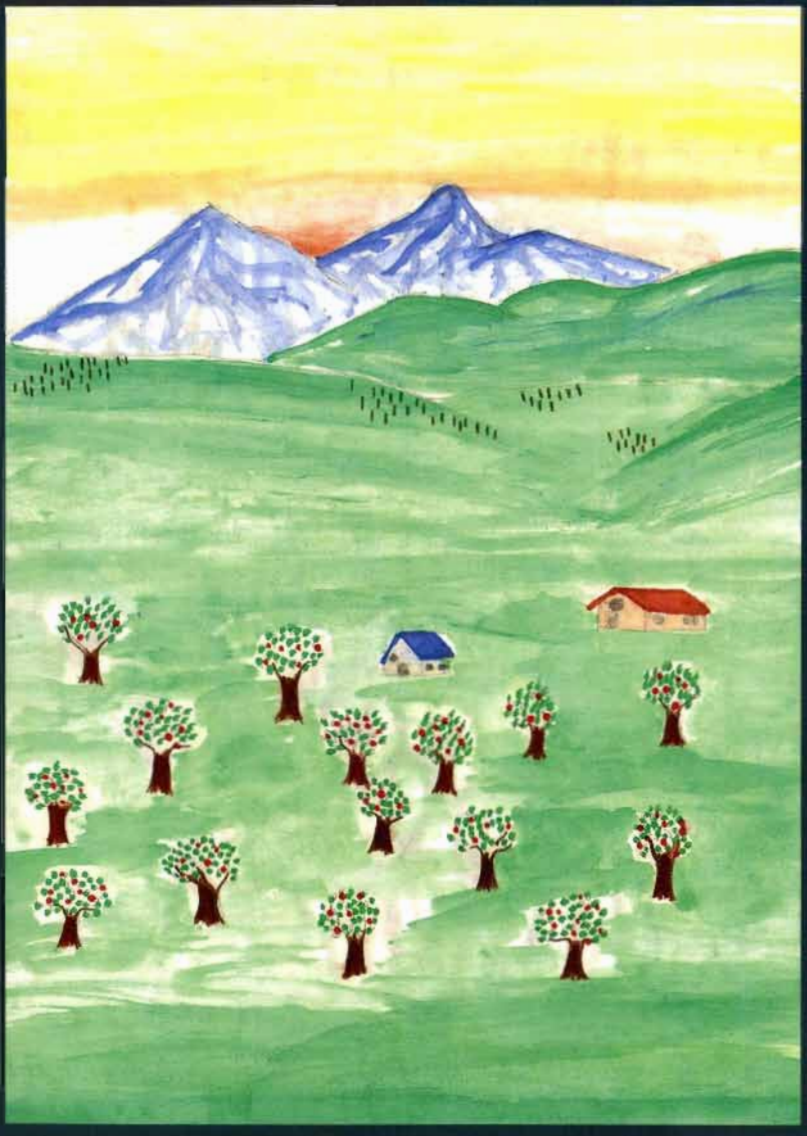
WARNING SIGNALS

From the Apple Valleys of the Hindu Kush-Himalayas

Productivity Concerns and Pollination Problems



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Tej Partap

ICIMOD

about ICIMOD

The International Centre for Integrated Mountain Development (ICIMOD)is an international organisation devoted to development of the Hindu Kush-Himalayan region covering all or parts of eight sovereign states, Afghanistan  , Bangladesh  , Bhutan  , China  , India  , Myanmar  , Nepal  , and Pakistan  . The Centre is located in Kathmandu, Nepal. The primary objective of the Centre is to promote the development of an economically and environmentally sound mountain ecosystem and to improve the living standards of mountain populations. The Mountain Farming Systems' Division at ICIMOD was established to promote improvement of farm productivity on small mountain farms without degrading the resource base.

Warning Signals from the Apple Valleys of the Hindu Kush-Himalayas

Productivity Concerns and Pollination Problems

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Foreword

The great majority of people in the Hindu Kush-Himalayan (HKH) region depend upon agriculture as their main source of livelihood; most are mountain farmers with small farms covering less than two hectares of cultivated land. Thus the well-being of mountain people is to a great extent determined by the state of mountain agriculture; and the potential for economic improvement by the ability to grow crops for sale rather than consumption.

Mountain agriculture in the HKH is slowly transforming from traditional farming of cereal crops to farming of high value cash crops. Cultivation of cash crops like temperate and sub-tropical fruits and vegetables is increasing in several pocket areas. The growing of cash crops on small plots of land has provided a certain measure of relief and income security to marginal and small mountain farmers and has helped alleviate poverty in some mountain areas. In recent years, however, this agricultural transformation has posed new challenges in terms of improving crop productivity and quality. The challenges include crop failure and reduced productivity resulting from inadequate pollination.

As a part of its focus on improving the livelihoods of mountain people, ICIMOD is implementing a project on 'Indigenous Honeybees of the Himalayas: A Community-based Approach to Conserving Biodiversity and Enhancing Farm Productivity' supported by the Austrian Government through Austroprojekt. The main aim of this project is to promote sustainable management of *Apis cerana* and other indigenous honeybees by mountain communities as a way of increasing farm productivity whilst contributing to biodiversity conservation. Research on pollination issues in mountain crops is an important component of this beekeeping project. The main objective of the pollination programme is to address the problem of declining agricultural productivity resulting from pollination failure. The programme aims to raise awareness of the need to manage pollination, and in particular the value of using honeybees for pollination purposes.

The regional case studies of pollination problems and farmers' management approaches described in this book are among the results of this work. Apples were selected as an example because they are the main cash crop in several areas of the region, and because pollination failure was identified as an emerging problem in previous work. The studies were carried out in India, China, Bhutan,

Nepal, and Pakistan, thus providing a detailed view of the commonalities and differences across the region. The advantages of using bees for pollination, and the appropriate approach and steps needed to introduce pollination management through bees in the different areas, is summarised in detail.

The publication is intended to raise awareness among agricultural planners, policy makers, and researchers about the pollination problems faced by mountain farmers, as well as suggesting strategies for change. It highlights the role of government institutions in apple pollination management and the need to strengthen their capacities and their programmes to help apple farmers. I hope that this book will prove useful in raising awareness of the need to incorporate crop pollination management as an essential component of agricultural extension programmes and packages of practices. I also hope that it will help promote increased use of bees and beekeeping for pollination of mountain crops.

Binayak Bhadra
Director of Programmes, ICIMOD

Acknowledgements

This book is the result of the efforts of a large number of people, all of whom we would like to thank.

The collaborating partners that helped us in these surveys – people and institutions in Bhutan, China, India, Nepal and Pakistan – deserve special appreciation. In particular, we wish to express our thanks to the members of the field survey teams.

We are particularly grateful to the mountain farmers, agricultural scientists, extension workers, local leaders, and others who supported us so well by taking time out of their busy schedules to provide us with valuable information related to their experiences with apple cultivation. We owe them our special thanks, particularly the farmers, for their cooperation and help.

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The draft of this book was prepared and discussed with colleagues in ICIMOD and outside. We would like to express our gratitude to many members of staff, in particular Dr. Farooq Ahmad, Mr. Min B. Gurung, Dr. Surendra R. Joshi, Mr. Anirudha N. Shukla, Mr. Satananda Upadhaya, and Ms Shova Bhandari, of the Beekeeping Project; Dr. Tang Ya and Dr. Nyima Tashi of the Mountain Farming Systems Division; Ms Greta Rana, Dr. A. Beatrice Murray, Mr. Sushil Joshi, and Mr. Asha K. Thaku of the Information, Communications and Dissemination Division; Ms. Phuntshok Tsering of the Mountain Enterprises and Infrastructure Division; and Dr. J. Gabriel Campbell and Dr. Binayak Bhadra of the Directorate for their extensive support, encouragement, and help.

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Uma Partap and Tej Partap
March 2001

Executive Summary

One of the most rapidly increasing and widespread cash crops in the HKH region is apple, not least because apple trees grow best in cool areas and can grow successfully on marginal sloping land that is otherwise unsuitable for growing food crops. At present, apples are grown on some 370,000 ha of mostly marginal land in over 140 hill and mountainous districts in India, Pakistan, Bhutan, China, and Nepal. Apples have emerged as the main cash crop in several areas of the region, accounting for as much as 60-80% of total household income for some apple farmers. Apple growing provides a major source of income not only for growers but also for many other people – including labourers working in apple orchards; those involved in picking, grading, packing, carrying, loading, and transporting apples; farmers in nearby plains areas who plant poplar wood for apple boxes; carpenters who make apple boxes; people working in factories that make cardboard boxes; truck owners and their staff; and fruit trade commission agents, wholesalers, and retailers. It is estimated that the annual production of apples in the HKH region is over 2.2 million tonnes, which helps bring in an income of over US $450 million per year to farmers and others involved in apple farming and marketing.

Although apple growing is often thought of as a major success story, over the last decade farmers in the HKH region have experienced a steady decline in apple productivity, both in yield and in quality of fruit. Farmers estimate that apple productivity has declined by about 50%, and feel that the trend continues. Studies have indicated that there are several factors affecting apple productivity. These include poor structure and nutritional status of the soil (most orchards are planted on marginal land); poor quality of planting material such as rootstock which is susceptible to various diseases and pests; poor planting practices such as inappropriate spacing and the practice of deep planting, thus burying the scion union and promoting scion rooting; poor tree training and pruning, affecting light penetration; the physiological condition of trees; and insufficient pollination and fertilisation due to lack of pollinating insects and inclement weather conditions. Most of these factors have remained constant in past years; what seems to have changed is the level of adequate pollination.

ICIMOD coordinated a series of studies in selected apple-growing valleys of the HKH region to assess the problem of declining productivity, the pollination situation, factors responsible for inad-

equate pollination, and farmers' management approaches; and to suggest ways of tackling the pollination problem. Semi-structured interviews and a survey questionnaire were used to collect information on various parameters related to apple pollination, productivity, and management practices. Apple valleys were selected and field study teams were formed in each of five HKH countries: Bhutan, China, India, Nepal, and Pakistan.

This publication presents the findings of the region-wide survey. It is divided into three parts. **Part I** contains an introduction to apple pollination issues and a brief account of the scale, definitions, and concepts related to the pollination problem. It briefly describes ICIMOD's programme and its focus on creating awareness about 'managed pollination' and using honeybees for pollination to improve crop productivity. The second chapter provides a synthesis of the results and implications of the regional case studies and an overview of the HKH regional problems. The prospects for using honeybees to manage pollination, and the constraints and limitations in promoting beekeeping for pollination are discussed, together with other options like managing non-*Apis* pollinators for pollination, and hand pollination.

Part II presents the detailed findings of the studies. The first chapter (Chapter 3) describes the approach and methodology used for the field studies. Chapters 4 to 8 describe the detailed results of the field studies carried out in each country: Himachal Pradesh (India), Maoxian County (China), Balochistan Province (Pakistan), Thimphu and Paro Valleys (Bhutan), and Jumla District (Nepal). Information is provided on the scale of apple farming, livelihood dependence on apples, the scale of the pollination problem, farmers' management approaches, and the use of honeybees for pollination, as well as pollination issues and implications in each country. Both the scale of the problem and farmers' management strategies were found to vary widely in the five countries.

In **Himachal Pradesh, India**, pollination problems were mainly related to the change to large-scale planting of a single variety, Royal Delicious, starting in the eighties. There were insufficient pollinizer trees to ensure pollination, and at the same time natural insect populations had declined greatly, partly as a result of pesticide use (including on crops grown beneath apple trees), and partly as a result of loss of habitat. The pollination problem had already been recognised and close to a half of the farmers surveyed were practising some form of pollination management. Efforts were underway to increase the proportion of pollinizers using pollinizer bouquets, grafting, and tree replacement, and to promote the use of bees for pollination by promoting systems for both renting and buying colonies. The present demand for honeybees could not be met with the present resources, however.

In **Maoxian Valley, China**, scarcity of land had also led to planting of monocultures of mostly Royal Delicious. Farmers had turned to hand pollination rather than increase the proportion of pollinizers. Commercial beekeepers were unwilling to hire out bees as farmers used high levels of insecticides, and sprayed during blossoming. In the long-term, hand pollination is unlikely to be a viable solution, however. Integrated pest management, grafting of pollinizer varieties, and beekeeping for pollination are likely to provide a more practical long-term solution.

In **Balochistan, Pakistan,** the pollination problem was less marked, although the productivity reported by farmers was markedly lower than that reported in the official statistics and farmers had observed a decline. There was very little awareness of pollination, but there were more pollinizers: orchards were planted with a mixture of varieties, particularly Red Delicious and Golden Delicious. A high proportion of the land is left wild, and farmers still benefited from extensive populations of natural insect pollinators, but the problem of insufficient insect pollinators was increasing. Migratory beekeepers brought hives into Balochistan, but did not place them near orchards. Future efforts are likely to focus on the use of these migratory bees to support apple pollination.

The pollination problems were also less marked in **Thimphu and Paro Valleys in Bhutan** than in some of the other areas. Most farmers had a good understanding of pollination issues, pollinizer varieties were planted, although generally fewer than the optimum, and the country still has much natural forest and low levels of pesticide use, so that there are reasonable populations of wild insect pollinators. Productivity could still be improved, however, and the available natural insect pollinators will be insufficient if larger areas of forest are replaced with orchards. Some farmers were already interested in keeping bees for pollination, but there were none available for renting.

The farmers in **Jumla Valley in Nepal** had only a limited knowledge of pollination. Although productivity was fairly low, this was not of great concern as the marketing possibilities from this remote area were also limited. Recent provision of marketing support had increased interest in productivity issues. As there was less commercial focus, orchards contained a mixture of trees and most probably had a reasonable number of pollinizers. Many farmers kept *Apis cerana* bees in traditional log hives for honey production, although they were not usually placed directly in the orchards, and the low levels of pesticide use mean that there are extensive populations of natural insect pollinators. Even so, there was a clear scope to improve pollination through appropriate management and placement of bees.

Part III contains the Annexes, with a bibliography, and the questionnaire used in the field surveys.

The abridged edition contains only Part 1 and Annex I.

Abbreviations and Acronyms

AKRSP	Agha Khan Rural Support Programme (Pakistan)
BKDO	Beekeeping Development Office
HMG	His Majesty's Government
HH	households
ICIMOD	International Centre for Integrated Mountain Development
INGO	international non-government organisation
IUSSI	International Union for Studies on Social Insects
masl	metres above sea level
MoA	Ministry of Agriculture
NA	not available/not applicable
NARC	National Agricultural Research Centre
NGO	non-government organisation
NWFP	North West Frontier Province
PARC	Pakistan Agricultural Research Council
PPD	Policy and Planning Division
RGB	Royal Government of Bhutan
REID	Research Extension and Irrigation Division
SD	standard deviation
4S	Surya Social Service Society
TSO	tree spray oils
UNDP	United Nations Development Programme
USA	United States of America
USAID	United States Agency for International Development
YSP	Dr. Y.S. Parmar University

Note

For convenience, all values in local currency have been converted to US$ at the rate prevailing at the time of the surveys. The exchange rates used were

1 US$ = IRs 46.05
1 US$ = Nu 46.05
1 US$ = Yuan 8.40
1 US$ = PRs 59.50
1 US$ = NRs 73.60

Glossary

Anther: Part of the stamen that produces pollen grains

Bee Colony: A social community of several thousand bees usually containing a queen and with or without drones

Cross-pollinated: Plants fertilised by pollen from other plants or varieties of the same species (also called 'self-sterile')

Fertilisation: Union of the male nucleus of a pollen grain with the female nucleus of the egg of an ovule

Forage: Food, i.e. for bees pollen and nectar

Foraging: Collection of pollen and nectar by bees

Hermaphrodite: Bisexual, i.e. a flower having both male (stamen) and female (pistil) parts

Insecticide: A substance that prevents, destroys, repels, or mitigates insects

Nectar: sweet, sugary liquid secreted by a special gland (the nectary) of a plant

Nectary: A nectar-secreting gland often associated with the petals of flowers (many plants have extra-floral nectaries)

Ovary: The part of a pistil that bears ovules

Ovule: Forerunner of the seed, present inside the ovary

Pest: Any organism that harms a crop

Pesticide: A poisonous chemical used to control or destroy pests or to prevent them from multiplying

Pistil: Female part of a flower, contains the stigma

Pollen: Granular mass (powdery substance) present in the anther of a flower

Pollinizer: A source plant for compatible pollen for a favoured (commercial) variety

Pollination: The transfer of pollen grains from an anther to a stigma of the same flower (self-pollination) or of a different flower (cross-polllination)

Pollinator: An agent that moves pollen from the anthers to the stigmas of flowers, thus enabling pollination

Self-compatible (self-fertile): A variety that can be fertilised and produce seed with pollen from flowers of the same plant or another plant of the same variety, mostly self-pollinated

Self-Pollinated: A plant in which a flower can be fertilised by its own pollen

Self-incompatible (self-sterile): A variety that requires compatible pollen from a different variety of the same species for fertilisation

Species: An interbreeding population which is reproductively isolated from other similar but morphologically distinguishable populations

Stamen: Male part of a flower, contains the anther

Stigma: The part of the pistil that receives pollen

Variety: Individuals of a species that differ in terms of size, form, colour, and/or other attributes; variety is the next classification below the species' level

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Part 1

Apple Pollination Issues in the HKH Region

Chapter 1

Concerns about Productivity in Mountain Farming

There are signs that across the Hindu Kush-Himalayas the overall productivity of many mountain crops – the amount of crop produced per unit of planted area – is going down. Possibly the worst affected crops are the cash crops like fruit, particularly apples, and off-season vegetables that are the hope of the region in terms of providing farmers with cash income and underpinning development efforts. This reduction in productivity is taking place despite extensive efforts at extension and information to support improvements in a range of management practices, and strong support for the introduction of successful commercial varieties. This book is concerned with raising awareness about and stimulating interest in one of the major factors involved, failure of pollination, and suggesting strategies for dealing with the problem.

'Managed' Pollination and Why We Need It

There are several factors that affect the productivity of mountain crops. They include soil fertility; poor quality of planting material; agronomic inputs including irrigation, fertiliser, and/or manuring; and use of pesticides – but pollination plays possibly the single most significant role. Pollination is an essential prerequisite for fertilisation and fruit and seed set. If there is no pollination, no fruits or seeds will be formed, and there will be nothing to harvest.

Pollination: the transfer of pollen from the male part of a flower, the anther, to the female part, the stigma, either of the same flower, another flower on the same plant, or another flower on another plant of the same species. If flowers are not pollinated, they cannot produce seed.

Self-fertile or self-compatible crops are fertilised by pollen from anthers of the same plant or another plant of the same variety. They are mostly self-pollinated, with pollen carried by wind or plant movement

Self-sterile or self-incompatible crops require compatible pollen from a different variety of the same crop.

Crops can be divided into two categories: self-fertile (self-compatible) and self-sterile (self-incompatible). Self-fertile crops include such plants as wheat, rice, and maize. They are largely self-pollinated and farmers rarely have any pollination problems with them. In contrast, many commercial varieties of fruit and vegetables are partially or fully self-incompatible. Successful pollination requires the presence of another appropriate compatible plant (i.e. a pollinizer), conditions that ensure synchronised or overlapping flowering in the two plants (the stigmas of the commercial variety

Good pollination – a cluster of well-developed apples

flowers must be receptive at the same time as the anthers ripen in the pollinizer flowers), and a pollinising agent like a bee. To obtain good yields, farmers must ensure that these conditions are met – this is crop pollination management.

Although mountain farmers try their best to enhance crop productivity by improving agronomic inputs, for example use of better quality planting material, better irrigation, and improved fertiliser and pesticide application, they rarely consider managing pollination – and neither do the government organisations advising them. This is probably the major reason why many crop yields are declining despite improvements in all agronomic inputs.

In 1997, ICIMOD (the International Centre for Integrated Mountain Development) published a discussion paper on 'Managed Crop Pollination: The Missing Dimension of Mountain Agricultural Productivity' (Partap and Partap 1997). In this paper we looked at the question of why farmers and agricultural institutions do not pay attention to the role of pollination in ensuring agricultural productivity. What do farmers and institutions know about it? Are mountain farmers and agricultural research and extension institutions aware of it? Do they understand the severity of the problem? Our research indicated that few farmers or institutions in the Hindu Kush-Himalayan (HKH) region were aware of the severity of the problem, and most did not have the mandate or expertise to address it. The paper highlighted the lack of information on the value of managing pollination.

Clearly more concrete information was needed to document the severity of and variation in pollination problems across the HKH region and to identify clearly the factors responsible for inadequate pollination. We chose apples as a representative, widely grown, and economically important, self-incompatible crop and carried out an extensive survey of apple-growing areas in India, China, Pakistan, Bhutan, and Nepal. The results are likely to be indicative for the many other crops like temperate and sub-tropical fruits, vegetables, and seed vegetables that require a management strategy to ensure pollination. Apple farmers, agricultural scientists, extension workers, and local leaders were interviewed to collect information on pollination-related productivity issues in a series of case studies. This book summarises the outcome of these studies.

The Importance of Apples for Farmers with Marginal Land

Agriculture is the basis of the livelihood of over 80% of the rural population in the countries of the HKH region. However, more than 90% of the farmers in the hill and mountain areas are marginal or small land-holding families, cultivating less than one hectare of land each (Banskota 1992; Partap 1995; Koirala and Thapa 1997; Partap 1999). Most agricultural land in the mountain

areas is not only marginal in terms of potential productivity, its quality also appears to be deteriorating as indicated by declining soil fertility and crop productivity. Many mountain families face food shortages of varying degrees, and these are contributing to the chain reaction process of poverty–resource degradation–scarcity–poverty (Jodha and Shrestha 1993). It is necessary to explore all possible ways of increasing the sustainable productivity and carrying capacity of the farming systems in the mountains (Partap 1998, 1999). Development efforts tend to focus on exploring farming approaches to increase the productivity and carrying capacity of farms (Partap and Partap 1997; Partap 1999).

Cabbages planted between apple trees

One option for enhancing the farm income of mountain farmers is to exploit the comparative advantage or 'niche' for the cultivation of cash crops such as fruits, off-season vegetables, and vegetable seed. Mountain farmers can never have a comparative advantage in producing grain. Crops such as apples, almonds, pears, peaches, plums, cherries, and off-season vegetables bring farmers several times the income they could expect from staple food crops, and farmers' interest in them is increasing (Partap 1995, 1999; Partap and Partap 1997). These high-value crops can be grown in the mountains at a time when they cannot be produced in the lowlands and can command a relatively high price in the market. The diversification of mountain agriculture from the farming of traditional grain crops to the farming of cash crops on small plots of land has provided relief to some marginal and small farmers (Partap 1999). Farmers can earn money to buy food and other necessities for themselves and ensure a better education for their children. In Himachal Pradesh, for example, a farmer can earn up to US $4500 per hectare annually with a net return of US $2000-2200 from fruit farming (Sikka and Saraswat 1992). In other words, a marginal farm household with between 0.5 and 1 ha of land could earn up to US $1600 per annum, and a small farm household (1-2 ha) up to US $4000. These incomes are much higher than those that could be obtained through any of the other farming activities possible on such land.

Apples have emerged as the leading cash crop in several areas of the HKH region, assuming great importance in helping many farmers move out of the poverty trap. They are found in areas as far apart as the Indian Himalayas, northern Pakistan, the mountain areas of China, and northern Bhutan. They can account for 60-80% of the total household income of those who grow them and studies indicate that in the areas where apples are grown there is now food security and reasonable economic well-being (Sharma 1996). The area of land devoted to apple orchards in the five countries studied ranged from 230,000 ha in India to 2000 ha in Bhutan, with a total annual production ranging from 1,320,000 tonnes in India to 13,000 tonnes in Bhutan (Table 1.1). The beauty of apples is that the trees can be (and are in many areas) planted successfully on cold marginal slope

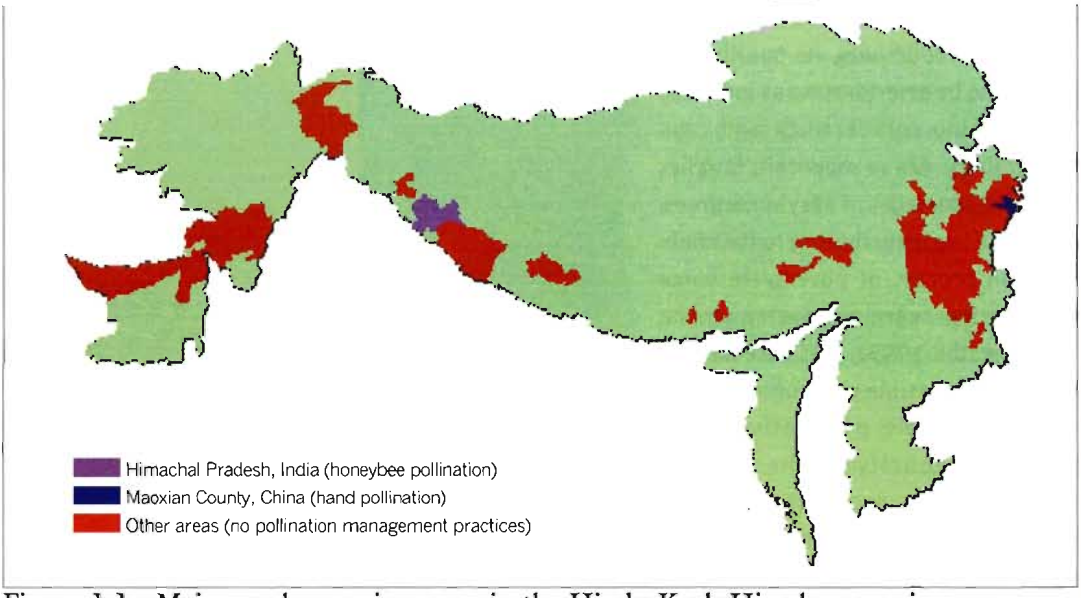

Figure 1.1: Major apple growing areas in the Hindu Kush-Himalayan region

Table 1.1: Area and productivity of apple farming in the Hindu Kush-Himalayan region

Country	Area ('000 ha)	Production ('000 tonnes)	Productivity (tonnes per ha)
Indian Himalayas[1]	228	1321	5.8
Nepal[2]	5	30	6.0
Bhutan[3]	2	13	6.5
Chinese Himalayas[4]	83	208	2.5
Pakistan[5]	49	638	12.9
Total	**367**	**2210**	**6.2**

Sources: [1]National Horticulture Board, New Delhi, India (1998), Department of Horticulture, Himachal Pradesh (1998), Verma (2000); [2]MInistry of Agriculture (1999); [3]Ministry of Agriculture, Royal Government of Bhutan (1999); [4]Government of China (1997), Government of Tibet Autonomous Region (1997); [5]Ministry of Food, Agriculture and Livestock, Government of Pakistan (1998-1999), Khan (1998).

land that is unsuitable for growing crops such as rice and wheat. Apples were grown in more than 140 hill and mountain districts in the countries studied.

Apples bring income not only to farmers but also to many other people linked to the farming, post-harvesting, and trade chain. Labourers working in apple orchards; those involved in picking, grading, packing, carrying, loading, and transporting apples; farmers supplying wood and carpenters making apple boxes; factories making cardboard boxes; truck owners, contractors, wholesalers, and retailers, all earn a good income from apples – as do those working in factories involved in post harvesting processes like making juice, jam, wine, or cider. The estimated total annual production in the HKH of 2.2 million tonnes of apples helped to bring in a gross income of over US $450 million per year to those involved in apple farming and marketing. In Himachal Pradesh alone, the estimated direct annual income from apples in 1999 was US $150-170 million, and the indirect income to the province was far higher, about US $1.5 billion per year (Toderia 2000).

The Emerging Scenario of Declining Apple Productivity

The officially reported average yield of apples in the HKH region varies from 2.5 to 12.9 tonnes per ha (Table 1.1). Our studies suggest that the real values may be even lower, particularly in Pakistan where the productivity at the sites we studied ranged from only 2.3 to 2.9 tonnes per hectare. Even the official figures are very low compared to the average yield of 25-30 tonnes per ha in Europe and other horticulturally advanced countries (Nadda and Tiwari 1998). Over the last seven to eight years, apple productivity has declined in the HKH region in terms of both yield and quality of fruit. In Himachal Pradesh, for example, apple productivity went down from 10.8 tonnes per ha in 1982 to about 4.3 tonnes per ha in 1998 (Department of Horticulture Himachal Pradesh 1998) and is declining further. Similarly, in Maoxian County apple productivity went down from 12.3 tonnes per ha in 1983 to 6.2 tonnes per ha in 1990 (Local Government Report, Maoxian County, 1998).

Several factors have been identified that affect apple productivity in the region. The social, physiographic, and physiological factors are mostly well understood and have been studied in some detail. They include the poor structure and nutritional status of soil (most orchards are planted on marginal land); poor quality of planting material such as rootstock that is susceptible to various diseases and pests; poor planting practices such as inappropriate spacing and the practice of deep planting, thus burying the scion union and promoting scion rooting; poor tree training and pruning, limiting light penetration; and the physiological condition of trees (Schilde and Bourgo 1998; High Value Agriculture Ltd 1998). The importance of pollination for maintaining apple productivity and quality is generally less well recognised, however, and the problems of inadequate pollination and poor fertilisation due to lack of pollinating insects and inclement weather conditions have received little attention in the region in comparison with other factors (Partap and Partap 1997). Although many farmers make all possible efforts to manage other factors, they almost always ignore pollination management.

The Apple Productivity Study

The studies described here were carried out under the aegis of the ICIMOD project 'Indigenous Honeybees of the Himalayas: A Community-based Approach to Conserving Biodiversity and Enhancing Farm Productivity', which is supported by the Austrian Government. One component of this project is crop pollination research; others include the state of pollinator diversity, and the importance of managing honeybees. The pollination programme is intended to address the problem of declining agricultural productivity of crops in the HKH region by raising awareness about the need

Apple flower – waiting for a pollinator

for managing pollination and the use of different species of honeybees. The survey was needed to confirm the previous indication that pollination problems were indeed a major factor in declining productivity, and to assess the extent and distribution of pollination problems in different crops – before making suggestions and implementing trials to improve the situation. Field surveys were performed in apple-growing areas in five countries – Bhutan, China, India, Nepal, and Pakistan. The surveys focused on the extent of apple productivity and pollination problems, the factors causing inadequate pollination, and farmers' management practices. The main objectives were

- to highlight the scale of the pollination problem;
- to document farmers' strategies for managing the problem;
- to analyse the role of bees and beekeeping as pioneer options for managing crop pollination;
- to analyse apple productivity, pollination issues, and options;
- to look at the level of institutional support in addressing the pollination issue; and
- to make recommendations.

A total of 530 apple growers were surveyed, and a number of key informants, including local government officials, scientists, progressive farmers, and beekeepers, were interviewed. The major findings are summarised in Chapter 2, which gives a regional overview of pollination-related productivity issues in the HKH. Both the scale of the problem and the farmers' management strategies were different in different countries. The review of the capabilities and programmes of government institutions in managing apple pollination indicates a clear need to strengthen their capacities so that they can serve apple growers better. Details of the study methodology and country results can be found in Part 2.

Chapter 2

Inadequate Pollination: The Major Cause of Declining Apple Productivity in the Region

The field surveys in selected apple growing areas of Bhutan, China, India, Nepal, and Pakistan clearly identified inadequate pollination as the major cause of declining apple productivity. Inadequate pollination not only reduces apple yield by causing poor fruit set, it also increases premature fruit drop and leads to poor fruit quality. Such fruit has poor market potential and fetches a low price, affecting the overall income of farmers.

Several factors contributed to the poor pollination. They included scarcity of pollinizer varieties in the orchards, insufficient populations of natural insect pollinators in the local environment, and changes in weather conditions during flowering. In India and China farmers were aware of the problem and the impact on apple productivity, but not in Bhutan, Nepal, and Pakistan. Farmers in the areas studied in India and China have already adopted different practices for managing pollination including the use of honeybees and hand pollination, but in Bhutan, Nepal, and Pakistan research and extension systems have yet to offer pollination management packages to farmers.

Factors Responsible for Inadequate Pollination in Apples

Pollinizer scarcity in the orchards

Many of the commercial varieties of apples planted by the farmers in the HKH region are self-incompatible and require cross-pollination with pollen from a compatible pollinizer variety. In order to ensure adequate pollination, it is necessary to plant sufficient pollinizer trees in such a position that each tree of the main variety has a pollinizer tree near it, so that pollen is available to its flowers. The optimum number and placement of pollinizers depends on several factors including the pollinizer variety, the main variety planted, and the number of pollinators. The standard requirement is for 20% of trees to be pollinizers, the normal minimum requirement is 11% if trees are planted in a strict geometrical arrangment (every third tree in every third row is a pollinizer) and closely spaced; some experts

A **pollinizer** (also spelt polliniser, pollenizer, and polleniser) is a source plant for compatible pollen that normally blooms at the same time as the target plant. For good yields, apples require a different variety of tree (for example Golden Delicious for Royal Delicious) as a pollinizer.

A **pollinator** is the agent that moves pollen from the anthers to the stigmas of flowers, thus enabling pollination. The most common pollinators are bees, but they can also be birds, butterflies, bats – and even humans.

Inadequate pollination may be the cause of ...

A.W. Jasra

... low fruit bearing

A.W. Jasra

... and premature fruit drop

recommend a proportion of 30-50% to achieve optimal pollination if the second variety has a market value (Mayer et al. 1985; Verma et al. 1997; Smith and Bradt undated; Deslauriers undated). It is equally important to select a pollinizer variety that blooms profusely and has a flowering period that overlaps with that of the commercial varieties.

Overall more than half of the farmers in the study areas had less than the minimum requirement of 20% pollinizer varieties in their orchards, most had only between 7 and 12%. The survey found the following situation.

In India, only 2% of farmers in the Shimla Hills, and Kullu Valley and none in Kinnaur met the standard requirement of 30% pollinizer trees in their orchards. About one quarter of farmers in Himachal Pradesh had between 20 and 25% pollinizer trees. It seems that in an attempt to have more trees producing commercial varieties of apple, and as a result of lack of knowledge about the importance of pollinizer–pollination systems, farmers have ignored the need to plant appropriate ratios of pollinizer apple varieties. In earlier times farmers grew

Pollination in apples

Apple flowers are hermaphrodite or bisexual, they have both male and female parts on the same flower, but most commercial varieties of apple can only be fertilised by pollen from flowers of a different, compatible, variety. In other words they are partially or completely self-incompatible. Pollination and fertilisation are a prerequisite for fruit set. To produce fruit, apples must be cross-pollinated and require pollinators to transfer pollen from the flowers of one tree to the flowers of another

Each apple flower has 5 sepals, 5 petals, 15–20 stamens with anthers producing pollen, and a pistil with a 5-chambered inferior ovary with 2 ovules in each chamber (or locule), 5 styles united at the base, and 5 stigmas. The same number of ovules must be fertilised in each chamber to produce a fruit of perfect shape and good quality. Generally, one ovule is fertilised in each chamber, rarely two. If the ovules in any one chamber are not fertilised, the fruit will be irregular in shape and size, reducing its market value.

a mixture of many varieties like Commercial, Golden, Jonathan, Red Gold, Red, and Royal Delicious. These provided pollen compatible with other varieties and there was generally good fruit set. In the early 1980s farmers started planting Royal Delicious on a large scale because of its high commercial value, and they slowly uprooted the other apple varieties – which could have been excellent pollinizers for Royal Delicious. During the past decade, the total apple-growing area has increased considerably, and all new orchards were planted only with Royal Delicious, although it is completely self-sterile and cross-pollination is essential. At the start of this trend there were still sufficient trees of the pollinizer varieties in the old orchards to ensure pollination, but over the last seven to eight years the problem has become serious.

The main reasons why farmers ignored the planting of pollinizers in China were market demand for a particular variety and scarcity of land. Apples from pollinizer varieties have a very low market value, and farmers do not want to sacrifice their land for a variety that does not bring them income. The farmers in China preferred to pollinate their apple flowers by hand, thus cutting down on the number of pollinizer trees needed.

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Inadequate pollination not only reduces yields but also causes low fruit quality

In Bhutan, farmers knew more about the need for pollinizers, and most farmers had planted pollinizer varieties – but the proportion was less than the recommended value (only 7-10%).

The farmers in Pakistan and Nepal knew little about managed pollination and planted few pollinizer trees. The majority of farmers in Nepal did not know which varieties were pollinizers or what the pollinizer proportion was in their orchards.

Whatever the reasons, the lack of appropriate proportions of pollinizer varieties in farmers' orchards is today one of the key factors in inadequate pollination of apples.

Declining populations of natural insect pollinators

Decline in the diversity and abundance of natural insect pollinators is the second most important factor affecting apple pollination, and thus productivity. A pollinator is the agent that transfers pollen between flowers. The known pollinators of apple trees include different types of insects like honeybees, bumblebees, solitary bees, and flies like dipterans and syphids (McGregor 1976; Free 1993; Verma and Chauhan 1985; Bangyu et al. 1997; Batra 1997a,b).

In recent years the diversity and populations of these natural insect pollinators have been declining for several reasons – including loss of food and nesting habitats due to clearance of forest and

grassland for agricultural purposes and indiscriminate use of pesticides. Changes in climate might also be affecting insect numbers. In all the study areas, farmers mentioned that in the past there were more insects like wild bees, butterflies, and moths during the apple-flowering season but that now most of them have disappeared. The majority of farmers identified pesticide use as the main cause of loss of natural insect pollinators. But increase in the amount of marginal land taken over for agriculture, and concomitant loss of wild habitat, must also have contributed. The increase in orchard area per se was also thought to play a role, with the natural populations of insects being too small to pollinate the newly-developed large areas of apple crops. This problem is less well understood than some others. The problem can be simply summarised as 'less insects available to pollinate more crops'. The scarcity of natural insect pollinators, and lack of replacement by 'managed' pollinators like hive bees, is another major cause of inadequate pollination in apples in the HKH region.

Changing climatic conditions

The third major reason suggested for pollination failure is climate change. Weather plays an important role in determining the success or failure of pollination as it affects both pollen production and the activities of pollinating insects (Verma et al. 1990). A drop in temperature or rainfall when apples are in flower can have an adverse effect on pollinator activity. Rain falling on the flowers can wash away the pollen grains, and hail can damage the flowers resulting in pollination failure and a decline in fruit set. The farmers in the study areas had observed an increase in bad weather conditions during the apple-flowering period in terms of the occurrence of frost, rain, hailstorms, and low temperatures.

Apple Pollination Management Today in the Survey Areas

Inadequate pollination is a relatively new problem in the HKH region and little research has been done on options to address it. In two of the HKH areas studied, Himachal Pradesh in India and the Maoxian Valley in China, productivity had dropped so severely that farmers and institutions were compelled to search for a solution. It was in these areas that the problem of insufficient pollination was first recognised, and it is here too that farmers and institutions have started investigating and testing pollination management options. The different approaches being tried are described briefly in the following.

Apple pollination management in Himachal Pradesh, India

Thanks to the efforts of government institutions, the majority of apple farmers in Himachal Pradesh are now well aware of the apple pollination problem and the factors responsible for it. They are trying different ways to improve pollination. Management efforts include planting different varieties of pollinizers, increasing the proportion of pollinizer trees, and increasing the number of pollinating insects in the orchards.

Managing the pollinizers

Now that farmers have become aware of the need for pollinizers to ensure yield and quality of apples, they are trying to increase the pollinizer proportion in the orchards, either by replacing some trees of the main variety with pollinizers, or by grafting pollinizers onto the main trees.

Grafting is sometimes necessary because grafts produce flowers more quickly than newly-planted trees. The most common varieties of pollinizer used are Commercial, Golden, Red Gold, and Tydeman's Early Worcester. Crab apple (wild apple) varieties are also being promoted as pollinizers. Crab apple varieties have considerable advantages: the trees are small and take up less space in orchards, they produce a good quantity of flowers, and they have long flowering periods of more than a month and are thus available to provide pollen to any variety, whether early or late blooming (Partap 1998).

It takes newly-planted pollinizer trees a minimum of four to five years to produce flowers, and grafts two to three years. As a short-term solution, farmers are practising 'bouquet pollination' – flowering pollinizer branches are cut and hung on the trees of the main variety, with the base placed in plastic bags filled with water to keep them fresh

Managing pollinators (hiring honeybees for pollination)

Many farmers in the valleys covered by the surveys are using honeybees (both *Apis cerana* and *Apis mellifera*) to increase the number of pollinating insects in their orchards. Some farmers keep their own honeybee colonies while others rent them from the Department of Horticulture, the University of Horticulture and Forestry, or private beekeepers. The present fee (2001) for renting honeybee colonies is IRs 300 (US $7.50) per colony for two weeks.

Increasing the pollinizer proportion ...

... crab apples placed between commercial trees

... grafting pollinizers onto trees of the main variety

... hanging pollinizer bouquets on trees of the main variety at the time of flowering

Preparing pollinizer bouquets ...

... putting pollinizer branches in plastic bags

... filling the bags

An additional IRs 500 (US $12.50) is charged as a refundable security deposit giving a total of IRs 800 (US $20). *Apis mellifera* is the main bee species provided. The colonies are kept in movable-frame hives. At present, Himachal Pradesh is the only place in the whole of the HKH region where a well-organised system has been established for hiring and renting honeybee colonies. A number of pollination entrepreneurs (beekeepers who rent honeybee colonies for crop pollination) have now started up in the state to complement the official services.

One problem that has arisen is that there are not enough colonies available for all the farmers who want to rent them. The State Government is now making efforts to encourage farmers to keep their own honeybee colonies for pollination. For this, the government has created a special section, 'The Beekeeping Development Office' (BKDO), under the Department of Horticulture. This office supports the sale of *Apis mellifera* colonies at a subsidised rate of IRs 300 (US $7.50) per colony – the market price is greater than IRs 2000 (US $50).

In addition to increasing the number of insect pollinators by renting or buying colonies of honeybees, some farmers are trying to save the populations of existing pollinators by making judicious use of carefully selected less toxic pesticides and spraying outside the apple flowering period.

Pollination entrepreneurs ...

... honeybees being transported to apple orchards

... colonies of honeybees being used for pollination

Apple pollination management in Maoxian Valley, China

A different approach is being followed in Maoxian County in China. Here, hand pollination of apples has become common practice. Since orchards are small, families try to pollinate their orchards themselves by training all members of the family (men, women, and children) making it a community effort (Partap and Partap 2000). Farmers also share days or hire labourers for the pollination of their apple orchards. These 'human pollinators' have been termed 'human bees' (Partap and Partap 2000). People do the work that could otherwise be done by honeybees. The advantage is that by far fewer pollinizer trees need to be planted, thus utilising the scarce land resources to a maximum for producing commercial varieties of fruit.

In hand pollination the anthers are picked from the flowers of the pollinizer varieties when the flowers are at the balloon stage (partially open) and then dried to release pollen grains, usually by spreading them out in the sun for a day or two, but sometimes in a cardboard box with an electric bulb, or even using an electric blanket. The pollen grains are stored in a cool, dry place and remain viable for three to four days. Pollen is mixed with a little white flour or skimmed milk powder and applied to the flowers of the main variety within two days of the flowers opening. Farmers normally apply pollen with the help of a hand-made brush, the filter side of a cigarette, or a pencil rubber. The farmers pollinate three out

Pollen is collected from the flowers of the pollinizer variety at the 'balloon stage'

Farmers in Maoxian County usually dry pollen by spreading it out in the sun ...

... some use electric blankets

Farmers apply dried pollen to the stigmas of flowers using hand-made brushes, cigarette, pencil rubbers, even camel hair brushes...

... they climb up the trees and use brushes with long sticks to pollinate distant flowers

of the five flowers in each apple inflorescence. Hand pollination is carried out three times in a season so as to cover some of the late flowers. The process is repeated in hundreds of apple orchards every year.

Apple pollination management in Pakistan, Bhutan, and Nepal

In Pakistan, Bhutan, and Nepal farmers are not yet aware of the importance of pollination or of the pollination crisis in their orchards, thus there are no clear management strategies.

In the Balochistan Province of Pakistan, apple productivity has been fluctuating and declined sharply in 1997-1998. Farmers are facing apple pollination problems both as a result of a lack of appropriate proportions of pollinizer trees and a lack of natural insect pollinators, but most apple growers are not aware of the source of their problems.

In Bhutan the apple orchard area is increasing but the yield per hectare is either static or declining. In the past there were adequate populations of natural insect pollinators, including wild honeybees (*Apis laboriosa).* The latter have survived because over 60% of land is forested and religious taboos mean there is no honey-hunting. However, the area of apple orchards has increased considerably during the past decade, with apple trees replacing forests on sloping land because Bhutan's agricultural policy prohibits fruit farming on flat irrigated cropland. This loss of natural forest is affecting the populations of natural insect pollinators and thus natural apple pollination. The process of decline of natural insect pollinator populations has just started and is expected to become more serious in the future. Already, despite religious taboos and the paucity of bee colonies, some farmers have started to keep bees for apple pollination.

In Nepal, farmers grow apples in a number of remote areas like Jumla, Mustang, and Solukhumbu. In Jumla, despite very poor yields, farmers were completely unaware that they had a pollination problem. They first realised that pollination was acting as a limiting factor in 1999 when ICIMOD

started its survey on apple pollination issues in collaboration with a local non-governmental organisation (NGO), the Surya Social Service Society (4S). In 2000, 4S organised an awareness-cum-training course on pollination problems and management for selected apple farmers of Jumla in collaboration with the Department of Agriculture of His Majesty's Government of Nepal (HMGN) and ICIMOD. Since April 2000, some leading farmers in Kholikot and Mahatgaon have started keeping honeybee colonies in their orchards.

Looking Ahead: Solutions to the Pollination Crisis

Pollination of self-incompatible crops like apple requires the presence of pollinizer trees and of pollinators, mostly insects. The problem of planting sufficient pollinizers lies outside the scope of this book, which focuses on pollinators. However, increasingly, departments of horticulture are becoming aware of this problem, which is important for many fruit crops not only apple, and activities to address the problem are underway.

Once sufficient pollinizer trees are present, the most important concern is to ensure that pollen transfer actually takes place. There are different ways of managing this including the use of honeybees (*Apis* spp.), rearing and using pollinators other than honeybees, and hand pollination.

Honeybees for pollination and the significance of honeybee diversity

For apples, one of the most practical approaches to increasing the number of pollinators is to use honeybees. Research has shown that pollination by honeybees increases fruit set, enhances fruit quality, and reduces fruit drop in apple trees (Dulta and Verma 1987). Honeybees are also the most efficient pollinators among insects because they can be managed in sufficient numbers and show flower constancy (Free 1964, 1966; McGregor 1976). The hive-kept species of honeybees (*Apis cerana* and *Apis mellifera*) are of great value because they can be moved to orchards where and when necessary. At present, pollination using honeybees is the most cost-effective method for pollinating apple and other fruit crops.

The HKH region is one of the richest in honeybee species diversity in the world. There are five species of honeybee: three wild species that cannot be kept in hives – the giant honeybee (*Apis dorsata*), the little bee (*Apis florea*), and the rock bee (*Apis laboriosa*) – and two hive species – the Asian bee (*Apis cerana*) and the introduced bee (*Apis mellifera*). All honeybees are good crop pollinators, but because the wild species' cannot be kept in man-made hives they cannot be transported to the sites where bees are needed. The honeybee species' diversity in the HKH region holds much potential for wider use in managing crop pollination in ways suited to the conditions in specific areas. In particular, the native hive honey bee *Apis cerana* offers clear advantages as a pollinator in remote and higher altitude areas.

Advantages of Apis cerana for crop pollination in high altitude areas

Both *Apis cerana* and *Apis mellifera* are excellent pollinators of mountain crops (Verma and Partap 1993; Partap and Verma 1992; 1994; Partap and Partap 1997, 2001). However, *Apis mellifera* performs better when daytime temperatures are relatively high, and temperature fluctuations are low, whereas *Apis cerana* is cold resistant and can perform well even when

daytime temperatures are relatively low, on cloudy days, and at higher altitudes with marked temperature fluctuations. In mountain areas, *Apis cerana* is a better pollinator of vegetable and fruit crops during spring and early winter than *Apis mellifera*. The race of *Apis mellifera* introduced to the HKH region is generally found to be more suitable for beekeeping under the warm agro-climatic conditions of the low hill and plains areas. In higher altitude areas, the native hive bee, *Apis cerana,* offers considerable advantages for beekeeping, whereas introduction of *Apis mellifera* can be problematic (ICIMOD 2002). Some of the advantages and disadvantages are summarised in the boxes.

If beekeepers introduce *Apis mellifera* to higher altitude areas for summer honey production, the exotic bee replaces the hardier native species, and the overall pollination of early crops is adversely affected. It can also lead to cross-infections that weaken the bees of both species. This has been shown in the mountain areas of Pakistan, where *Apis mellifera* has been introduced on a large scale for honey production – and the yield and quality of produce from early blooming mountain crops has been greatly reduced as a result of the lack of pollination (AKRSP, personal communication). At higher altitudes, *Apis mellifera* displaces the native bee without replacing its special pollination capabilities, and doesn't itself perform well.

Notwithstanding, *Apis cerana,* tends not to be popular among beekeepers (particularly commercial beekeepers), because of its lower honey yield. The institutions promoting beekeeping in the HKH region have so far focused exclusively on honey production rather than pollination, and have promoted the introduction of *Apis mellifera*, despite the considerable advantages of *Apis cerana* for pollination at higher elevations. Studies indicate, however, that some high mountain races of *Apis cerana* can match *Apis mellifera* in both behaviour and honey production. Activities are underway to select improved species, which will increase support for *Apis cerana* beekeeping.

When all these points are considered, it seems that *Apis cerana* should be promoted in higher altitude areas, and *Apis mellifera* and/or *Apis cerana* in the more accessible lower regions,

Advantages of beekeeping with *Apis cerana* in mountain areas

- Cold resistant, performs well at lower temperatures
- Available for pollination of early crops
- Flies in poor weather conditions
- Thrives on mixed, diverse crops
- No capital outlay, farmers can collect colonies from the wild and propagate them
- Minimum labour for maintenance, simple log hives can be used
- Relatively disease resistant
- Does not need feeding, fumigating, migration in winter
- Requires no external inputs, remoteness no problem
- Suitable for small-scale and stationary beekeeping

Problems with *Apis mellifera* at higher altitudes

- Poor tolerance of cold and widely fluctuating temperatures
- Requires migration to lower altitudes in winter
- Not available for pollination of early crops
- Requires intensive management practices with standardised equipment and external inputs
- Requires larger foraging grounds with monoculture-based agriculture
- Prone to diseases, parasitic mites, and wasps
- Introduces exotic diseases to which native (hive and wild) species are susceptible
- Less suitable and often unprofitable for small-scale and stationary beekeeping

particularly when bees are primarily kept for pollination. This will ensure better pollination of mountain crops and also help in conserving the indigenous species.

Decline of the native hive bee

Beekeeping with the native honeybee *Apis cerana* is a traditional household activity among several mountain communities. But the promotion of *Apis mellifera* over the past few decades has adversely affected indigenous *Apis cerana* beekeeping and led to the replacement of *Apis cerana* with *Apis mellifera* in many areas of the HKH region (Partap and Partap 1997). Studies carried out by ICIMOD have shown that at present there are only a few areas in the mountain districts of Nepal, India, China, and Pakistan where *Apis cerana* is being kept by beekeepers and farmers (ICIMOD 1998; Bangyu and Tan 1996).

Constraints to using honeybees for pollination in the HKH region

Hive bees can play an important role in pollination – and in areas like N. America, Europe, and Japan they are used extensively to ensure pollination of fruit and vegetable crops (see for example McGregor 1976, 2002; Morse and Calderone 2000). However, although beekeeping is common in the HKH region (stationary beekeeping with *Apis cerana* and migratory beekeeping with *Apis mellifera*), bees are only used specifically for pollination in a few areas. Beekeeping has only been promoted as an enterprise for honey production; neither the policies nor the institutions involved have focused on developing and promoting beekeeping for crop pollination. Considerably more research and development efforts will be needed before honeybees can be effectively promoted for pollination on a large scale in this region. The main constraints to using bees for pollination are lack of awareness among farmers, lack of beekeeping in horticultural development packages, scarcity of honeybee colonies, and lack of knowledge about honeybees' foraging behaviour.

Lack of awareness among farmers is one of the main problems. With a few exceptions, farmers in those areas of the HKH region where there is a pollination problem with apples are not aware of the value of honeybees for apple production. This is both because beekeeping has always been promoted exclusively as an enterprise for honey production, and because apple growing is a new activity and there is no indigenous knowledge on the needs for production.

Beekeeping from the perspective of crop pollination has been overlooked in agricultural development strategies for hill areas of the HKH region. Agricultural institutions offer different packages of practices for specific crops to promote high-value farming of cash crops. These packages suggest to farmers the kind of inputs needed to maintain sustainable yields of specific crops like soil preparation, irrigation, use of fertiliser, and pesticide spray schedules. However, beekeeping as an input to manage crop productivity has not yet been included. Thus farmers have no way of knowing how essential it can be. This weakness in the agricultural extension system needs to be addressed. Though a few farmers are aware of the value of beekeeping for crop pollination, in the HKH region there is no formal system for hiring and renting honeybee colonies of the sort prevalent in horticulturally developed countries of the world (see, for example, Morse and Calderone 2000).

Scarcity of honeybee colonies for pollination is the third major constraint on promoting honeybees for apple pollination. In the apple valleys where honeybees are being used for apple pollination, the number of honeybee colonies is far below that required for pollination of the whole crop in the area. In Himachal Pradesh about 78,000 ha are planted with apple trees. Theoretically some

230,000 colonies would be needed to pollinate the whole apple crop in Himachal (on the basis of 2-3 colonies of *Apis mellifera* or 3-5 colonies *of Apis cerana* needed to pollinate 1 ha of apple orchard). However, there are only about 10,000-12,000 honeybee colonies in all, and not all of them can be used for pollination. Thus, the available honeybees meet only 4-5% of the calculated total demand. It seems that the expansion of horticultural farming in Himachal has not been accompanied by a corresponding increase in the number of honeybee colonies (Nadda and Tiwari 1998). This highlights the fact that, in addition to raising awareness, training farmers, and creating the right policy environment, it is important to focus on ways of increasing the number of honeybee colonies in each area.

Lack of knowledge among farmers about the foraging behaviour of honeybees is another constraint hindering the use of honeybees in crop pollination. Even those farmers in the HKH who do know that they can use honeybees to increase apple pollination and yield don't always know how to use the bees. Few people know about the foraging or pollination behaviour of honeybees. For example, farmers in some villages in Himachal Pradesh, unaware that honeybees do not visit flowers during the night, had stolen colonies of honeybees from neighbouring orchards during the night and returned them early in the morning, in the hope that their apple trees would be pollinated.

Overcoming constraints to promoting honeybees for pollination

Diversification of mountain agriculture towards high-value cash crops requires pollination management since most commercial varieties of these high-value crops are cross-pollinated. Farmers have been looking at the ways in which institutions (government and non-government, private entrepreneurs, researchers) can help. The various suggestions are summarised below.

Raising awareness about the importance of using honeybees for crop pollination is the first step in promoting beekeeping for pollination

Horticultural extension

The first and most important step in promoting the wider use of honeybees for crop pollination is to include beekeeping as part of horticultural development efforts. Horticulture, especially apple farming, is being promoted in several areas of the HKH region. Official institutions offer packages of practices for each type of crop, but the importance of managing pollination to achieve a sustainable yield has been overlooked. Since pollination is essential for the production of fruits and seeds, crop pollination management should be included in horticultural development packages, with beekeeping for crop pollination as a 'double benefit approach'.

Influencing thinking

The second step is to change the general 'mindset' about honeybees and beekeeping, and to raise awareness about the importance of managed crop pollination. Traditional thinking is that beekeeping is for honey production, its role in crop pollination is rarely considered. Today, most government agencies are only engaged in promoting beekeeping for honey production. The move towards introduction of *Apis mellifera* to increase honey production is an example of this. Countries in Europe, the USA, and Japan have been using honeybees for pollination of crops such as apples, almonds, pears, plums, cucumbers, melons, watermelons, and a number of berries for a long time. In the USA the first colonies of honeybees (*Apis mellifera*) were rented for apple pollination in 1909 in New Jersey (Morse and Calderone 2000). In contrast, in the HKH region, renting of colonies for apple pollination only started in 1996, and is still restricted to a very few areas.

There is a need for a change in thinking about the value of honeybees as crop pollinators at many levels: policy, planning, research, beekeeping, and farming. The initial thrust of the pollination programme will need to raise awareness about the need for managing pollination through honeybees and to generate the knowledge and information needed to facilitate the formulation of strategies that will ensure the wider use of beekeeping for pollination. Honeybees should be seen as crop pollinators first, and as honey producers second. Changes in research and development investment policies may be needed to encourage this.

Training in orchard planning and management

A further important step is to train apple farmers in orchard planning and pollination management. Many farmers in mountain areas have insufficient knowledge about the best layout for orchards. More information is needed on appropriate pollinizer varieties, proportions of pollinizers, placement of pollinizers in relation to the main variety, and pruning and thinning of trees. Farmers also need to know about the importance of bees, and numbers and placement of bee colonies.

Increasing the number of colonies

The next step is to increase the number of honeybee colonies available for pollination. There are about 370,000 ha of apple orchards in the HKH region, theoretically these need about a million bee colonies to ensure optimum pollination. The actual number available is much lower. In our survey, farmers rated this as the major problem. Since beekeeping is not traditional in Bhutan or the Balochistan Province of Pakistan there are few colonies, and in China beekeepers are not willing to provide bee colonies to apple farmers for pollination, partly for fear of the effects of insecticide spraying. The number of colonies should be increased by multiplying the existing colonies through breeding and mass queen rearing. Such efforts will require more trained manpower and a large amount of scientific, management, and extension inputs.

Another part of increasing the number of honeybee colonies for pollination is to encourage private entrepreneurs to keep large numbers of honeybee colonies that they rent to farmers for pollination. In addition to the rental fee, these 'beekeeping for pollination entrepreneurs' can earn income through the sale of honey and beeswax. Such a system benefits both farmers and beekeepers. Pollination entrepreneurs have already become established in a few apple valleys in the region.

An apiary of Apis mellifera *in Kullu Valley, Himachal Pradesh, which rents honeybee colonies to farmers for apple pollination*

Promoting beekeeping

The final step is to encourage individual farmers, village communities, and commercial pollination entrepreneurs to rear and keep bees for pollination. Individual apple farmers could be encouraged to keep their own honeybee colonies for pollination if training is available and there is a supply of colonies. Honeybee entrepreneurship schemes need to be encouraged. Himachal Pradesh has recently started such a programme, as mentioned above. The government agency arranges sales of *Apis mellifera* colonies to apple farmers at a subsidised price and the State Department of Horticulture, and the University of Horticulture and Forestry provide training, and some honeybee colonies free of charge, to apple farmers.

Beekeeping for apple pollination can also be promoted at community and village level. The requirement of honeybee colonies for apple pollination is 2-3 colonies of *Apis mellifera* or 3-5 colonies of *Apis cerana* per hectare. Since landholdings are often small, individual farmers may need only 1-2 colonies of honeybees. In high elevation and inaccessible areas, and on a small-scale, only *Apis cerana* should be promoted, both because this bee is suitable for stationary beekeeping and for the other reasons summarised above. In accessible areas if *Apis mellifera* is kept, then the colonies need to be migrated to low hill or plains' areas during the winter season, and brought back at the time of apple flowering because there is no bee forage available in the winter and the *Apis mellifera* colonies are susceptible to cold. If farmers feed the bees with sugar during the winter months, the colonies are not strong enough early in the season when they are needed for apple pollination. It is not economic to migrate small numbers of bees; a truckload is needed. Thus farmers in these areas should be encouraged to migrate their colonies collectively. Community and village-level management of beekeeping can be a very useful way of ensuring both apple pollination and a good honey harvest.

Providing for increased bee numbers

Given the large number of honeybee colonies that will be required in areas with large acreages of crops; it is possible that the number of bees may exceed the present carrying capacity of an area. It may well be necessary to either increase the number of honeybee forage plants through new plantations and/or to promote migratory beekeeping as an enterprise. The latter would also help strengthen upland-lowland linkages.

Investment in crop pollination

Apples are only one example of a number of cash crops grown by the HKH farmers which require managed pollination for increased production and quality. Vegetable seed production is another

Institutional efforts to promote beekeeping for apple crop pollination in Himachal Pradesh

The Role of the Himachal Horticulture and Forestry University

- Strong scientific expertise available on honeybees, beekeeping, and pollination
- Field stations in apple-farming areas monitor problems related to horticulture and focus on problem-solving research
- On-farm research into and demonstration of the positive effects of beekeeping for apple pollination
- Special awareness programmes launched in apple-farming areas
- The Agriculture Science Centres, (the university extension centres) give beekeeping training on-demand to farmers and interested new entrepreneurs
- The university provides bee colonies for pollination; the Beekeeping and Horticulture Research Stations keep both *Apis cerana* and *Apis mellifera* for this
- Training and demonstrations on how to use bees for pollination

The Role of the Government of Himachal Pradesh Department of Horticulture

- Establishment of a Beekeeping Development Office for Pollination (BKDO), which maintains and rents honeybee colonies to farmers; *Apis mellifera* colonies sold at a subsidised rate (IRs 300 [US $7.5] per colony, against a market price of about IRs 2000 [US $50])
- Annual assessments of the demand for honeybee colonies by apple farmers, and arrangements for supply facilitated with private beekeepers
- Attractive financial support for starting a beekeeping enterprise for pollination
- Provision of honeybee colonies at a subsidised rate to promote their use for pollination

The Role of the Himachal Apple Growers' Association

- Platform for farmers to discuss emerging problems and to act as a strong pressure group to seek government intervention
- Raised the apple-pollination problem faced by farmers with the university and government and sought rapid solutions
- Raised awareness about the scale of the problem in the state and encouraged farmers to become beekeeping entrepreneurs for pollination; coordinated honeybee demand–supply aspects

crucial sector where pollination management is essential. It is necessary to evolve strategies to promote investment in research and development that will enhance the use of honeybees for pollination. This means developing area-based approaches, making full use of the existing diversity of honeybee species in the HKH region.

Strengthening research and extension systems

Beekeeping for crop pollination is a new activity in the HKH region. There are few institutions in the region with explicit mandates or expertise. Most institutions promote beekeeping as a cottage industry to increase family income through the sale of honey. Promoting the value of honeybees as reliable pollinators of apples and other fruit and vegetable seed crops will require special efforts to strengthen research and extension systems. In Pakistan, for example beekeeping with *Apis mellifera* for honey has been heavily promoted by the government, but crop pollination is not included on the agenda of the honeybee research and development agencies. The approach being taken in Himachal Pradesh is summarised in the box as an example.

Other options for pollination

Non-honey bees

Species of bumblebees and solitary bees like *Amegilla, Andrena, Anthophora, Ceratina, Halictus, Megachile, Nomia, Osmia, Pithis,* and *Xylocopa* are important pollinators of apple flowers in the

HKH region (Batra 1997b), but the natural populations of these bees are declining. In principle, many of these pollinators could be reared on a large scale and managed for the pollination of apple trees and other crops. In many developed countries various natural insect pollinators, including some species of bumblebees and solitary bees, are being reared and managed commercially for pollination of crops, particularly those that are less, or not effectively, pollinated by honeybees. Bumblebees, for example, are used for the pollination of potatoes and tomatoes, alkali bees and leaf cutter bees for the pollination of alfalfa, and various species of bumblebees and solitary bees for pollination of apple, almond, and other fruit trees, and cotton, mustards, lucerne, and berseem (Crane 1990). The solitary bee *Osmia cornifrons* Rad. is being managed on a large scale in Japan where it is used to pollinate one third of all apple crops (Batra 1995, Sekita 2001).

Some species of bumblebees and solitary bees are excellent pollinators of apple trees, and can be managed for their pollination. Batra (1997a) reported that the halictine bee (a solitary bee, *Lasioglossum (Evylaeus) matianensis*) is the predominant pollinator of apple trees at altitudes higher than 2600 m and that it can be managed simply by providing nesting sites.

According to Batra (1997b), there are two approaches to enhancing the pollination of fruit crops using solitary bees. The first is to manage the habitat around orchards to provide nesting sites for the native pollinators in the area. Making sunny plots by removing shady vegetation from any existing nest aggregations can increase the population of most species. This type of habitat management may take up too much space, however, and thus be too costly, and in many areas of the HKH, farmers (especially fruit growers) have already cleared the habitat required for these pollinators. Keeping native habitat may also interfere with orchard operations or provide a refuge for crop pests. The second approach is to keep populations of solitary bees in bee shelters and place them near the orchard. Shelters can be made from inexpensive materials. They take up little space and do not interfere with most operations or harbour crop pests. With these solitary bees, the adults are only active while the crops are in flower. After the flowers have been pollinated, the adult bees die and the dormant brood can be put into storage until the next pollination season, when the next generation of adult bees will emerge to help carry out crop pollination (Batra 1997b).

There is good potential for the managed use of non-*Apis* pollinators in the Himalayan region. There are thousands of hectares of land under cash crops that need cross-pollination. But owing to lack of expertise and institutional capability, the HKH countries have so far not been able to make real use of these pollinators. Batra (1997b) summarised the characteristics of solitary bees that make them useful as pollinators, these characteristics could be used as criteria for selection of natural insect pollinators to be reared and managed for fruit tree pollination (see box).

In cold and arid areas of the HKH region, for example Balochistan (Pakistan), Mustang (Nepal), and Lahul (Himachal Pradesh), where stationary beekeeping cannot be practised because of the prevailing cold and dry climatic conditions and lack of forage during the greater part of the year, managing non-honeybees for pollination is a good option. These areas have a number of different types of solitary bees. Since only two to three per cent of total land area is cultivated, a lot of space is available for these bees to hibernate. But major research and extension efforts will be needed

Characteristics of solitary bees that make them useful for pollination of fruit crops

Host Preference and Foraging Behaviour

- Solitary bees prefer fruit blossom and the brood can develop well on a diet of nectar and pollen
- An individual bee works rapidly, quickly dispersing a large amount of pollen
- The bees work across rows and among plants of different cultivars maximising cross-pollination
- The pollen is carried loosely in fine body hairs and is easily brushed onto stigmas of other flowers
- The bees have a short flight range and stay close to their nest in the orchard
- The bees forage in the cool, cloudy, windy, or rainy weather that is common in the spring in hill areas
- Both males and females visit and pollinate flowers

Life Cycle, Nesting Habits, and Manageability

- The period of adult activity naturally coincides with the time of fruit flowering
- The bees thrive in the climatic zones where fruit trees are grown
- They nest in inexpensive man-made or altered natural substrates and can find all their material needs in or near the crop
- They live in colonies or nests so that it is easy to manage a large population
- They are gentle, permitting human activities near their nests
- They are relatively free of parasites and predators or can be easily managed to eliminate them
- Each female makes many cells that produce next generation females, thus the population increases rapidly, and pollination is enhanced because females are better pollinators than males
- The bees can be mass reared, so that large numbers can be made available at the flowering time of the crop

Source: Batra (1997b)

before such insects can be reared and managed for pollination of crops in the region. At present, there are no government institutions or private entrepreneurs engaged in rearing and managing these insects for pollination purposes. Popularising the rearing and use of non-*Apis* pollinators in the HKH region will take many years.

Humans as pollinators

Hand pollination, although the most reliable method of ensuring pollination takes place, is expensive, laborious, and time-consuming and is unlikely to be sustainable in the long term, particularly as labour costs increase.

Making use of honeybee diversity: different approaches for different areas

The most promising approach to reversing the decline in productivity of fruit and vegetable crops in the HKH region is to introduce the approach of integrated pollination management. For apple crops, the most practical approach at present is to promote the use of honeybees.

There are various possibilities: beekeeping for pollination using *Apis cerana, Apis mellifera,* or a combination of the two, and promotion of wild honeybees. Which is best, depends on the particular conditions in an area. The most promising approaches in each of the different areas studied are summarised below.

Apis cerana and Apis mellifera beekeeping for pollination

A combined approach using both species might be most appropriate in the apple valleys of Himachal Pradesh, India, and Maoxian County, China, where apples and other temperate fruits have emerged as important cash crops. Traditional beekeeping with *Apis cerana* is common in these areas; farmers generally keep a few colonies around their houses in wall or log-hives. Equally *Apis mellifera* is

Beekeeping is common in Maoxian Valley but local institutions do not promote the use of honeybees for pollination

A commercial, migratory Apis mellifera apiary in a Juniper forest of Balochistan. The honeybees are not used for pollination

(A.W. Jasra)

also widely popular for honey production. Thus *Apis cerana* and *Apis mellifera* could be used to complement each other for pollination.

Apis mellifera beekeeping for pollination

In lower altitude hill areas of Pakistan the best approach is likely to be promoting the use of the *Apis mellifera* bees that are now kept for honey production for the pollination of apple crops. Migratory beekeeping for honey production with *Apis mellifera* has already been widely promoted by the Government of Pakistan, and *Apis mellifera* beekeeping is flourishing well in both hill and plains areas where sub-tropical fruit and vegetable crops are grown. But the bees are not being used for pollination. Hives are most commonly placed along the roadsides, in forest, or on wasteland – but not in the orchards. *Apis mellifera* is suitable for large-scale migratory beekeeping, and the colonies could be moved easily to areas requiring pollination services, for example where pollinator populations may not be sufficient and/or stationary beekeeping is not possible because of the cold winter conditions.

Apis cerana beekeeping for pollination

In Nepal the most appropriate approach for apple pollination is likely to be the promotion of *Apis cerana* beekeeping. Traditional beekeeping with *Apis cerana* is common in the mountain areas of Nepal where apples are grown, and these areas already have a gene pool of this bee. *Apis mellifera* can be more difficult to manage at these higher elevations. Introduction of *Apis mellifera* in the traditional isolated *Apis cerana* areas should be discouraged. In lower elevation areas with good access, *Apis mellifera* can be promoted for the pollination of other fruit and vegetable crops.

Wild bees for pollination

In Bhutan the best approach may be to focus on using wild honeybees for pollination. Three wild honeybee species are found in the HKH region: *Apis dorsata* and *Apis florea* in low and middle hill

areas and *Apis laboriosa* in high mountain areas. All are excellent pollinators of crops and wild plant species. They play an important role in improving farm productivity and conserving biodiversity. Their natural populations need to be maintained so that they can provide a needed pollination service for wild plants, as well as for apples and other crops. In Bhutan, support for ensuring populations of wild bees is likely to be more successful than encouraging beekeeping, the potential for which is restricted by religious taboos, as more than 60% of the land area is forested, wild bees are already widespread and play an important role in crop pollination, and religion prohibits honey hunting, which has helped natural populations of wild bees to increase.

Pratim Roy

Apis laboriosa (a wild honeybee species) is an important pollinator of apple crops in Bhutan

Conclusion

The declining productivity of fruit and vegetable crops, in particular apples, in the HKH region can be attributed to a number of factors, but among these pollination plays a major role. The approach outlined above for raising awareness of the problem and introducing integrated pollination management with bees on a large scale, should make it possible to arrest and reverse this decline, and restore faith in cash crops as a way of reducing poverty and supporting development in the region.

Part 2

Details of the Country Studies

Chapter 3
Study Methodology

The field studies were performed to explore in more depth previous indications that pollination problems were indeed a major factor in declining productivity in mountain agriculture, and to assess the extent and distribution of the problems before making suggestions and implementing trials to improve the situation. The surveys focused on the extent of apple productivity and pollination problems, the factors causing inadequate pollination, and farmers' management practices.

Apples are a leading cash crop in several hill and mountain areas of the HKH region, but for the purposes of this study we focused on those valleys where apple farming has been a dominant factor in the economy and which are quoted as successful examples of agricultural diversification.

Information was collected during semi-structured interviews and using a well-structured, pre-tested survey questionnaire on various factors related to apple pollination and productivity. The overall process included selecting the valleys, forming field study teams in each country, developing the survey questionnaire, carrying out pilot testing with sample farmers, and finally conducting the detailed surveys. The steps are described in more detail below.

Selection of Apple Valleys

The first step was the selection of appropriate apple valleys (study sites). The main criteria for site selection were (i) apples are a very important crop for the farmers, (ii) farmers are experiencing productivity problems, (iii) farmers are trying to improve productivity by various ways and means, (iv) inadequate pollination may be a factor contributing towards low productivity, and (v) there was a partner institution willing and interested to carry out the survey in the area. Keeping these criteria in mind and through meetings with farmers and local leaders, government officers, and agricultural extension workers, we selected the following areas to conduct case studies to identify pollination-related productivity problems.

- The Shimla Hills, Kullu Valley, and Kinnaur Valley in Himachal Pradesh, India
- Maoxian Valley of Aba Prefecture in Sichuan Province, China
- Thimphu and Paro Valleys in Bhutan
- Kalat, Killa Saifullah, Loralai, Mastung, Pishin, Quetta, and Ziarat Valleys in Balochistan Province, Pakistan
- Jumla Valley in Nepal

Parameters for the Household Surveys

A representative sample of farmers (with different size landholdings, different wealth rankings, and so on) from different villages were selected for the household surveys. The parameters covered included general information on physiographic and climatic conditions, including changes that farmers might have observed during recent years and their impact on agriculture in general and on apple crops in particular, information on the arable land per household, general information about agriculture, the kinds of crops that farmers grow separately and in association with apples, and the importance of apples in the household economy. Apple productivity issues including increasing or decreasing trends were given special attention.

Most of the questions concerned pollination issues. They included whether farmers knew about pollination and its role in apple productivity, how they knew about it, and who told them about it; what the role of pollinizer varieties is in apple pollination, how they effect apple productivity, and what the proportion of pollinizer varieties was in the farmers' orchard; and whether farmers knew about pollinators and their importance. Questions on pollinators included whether there were natural insects visiting apple flowers, whether these were sufficient to pollinate the apple crop, and whether their number and diversity was changing and how (whether there were similar insect populations on the apple flowers as a few years to a few decades ago). The role of prevailing weather conditions in pollination was also considered, for example whether rain, humidity, hailstorms, high or low temperatures, or frost were affecting apple pollination and fruit set, and whether farmers were taking measures to save their crop. Farmers were also asked whether they kept honeybees for pollination; whether commercial beekeepers rented honeybee colonies for apple pollination; and whether alternative practices were used like hand pollination. Finally farmers were questioned about their use of pesticides on apple crops, including which pesticides they used and how many times in a year, and whether they knew the impact of these pesticides on natural insect pollinators. The pilot questionnaire was first tested with a small sample of farmers and revised before being finalised. The English version of the survey form is shown in Annex II. It was translated into Chinese and Nepali for use by the researchers in China and Nepal. In all countries, the questions themselves were asked verbally of farmers in their own language.

In addition to the household surveys, information was sought in some areas in interviews with key informants including agricultural scientists, extension workers, lead farmers, local leaders, and government officers.

The surveys were carried out in India and China in 1998/99, in Pakistan in 1999/2000, and in Bhutan and Nepal in 2000.

The Informants

India

In India, the surveys were conducted in collaboration with Dr Y.S. Parmar University of Horticulture and Forestry in the Shimla, Kullu and Kinnaur Districts in Himachal Pradesh. A total of 209 households were interviewed in 76 villages in the 3 districts, and discussions were held with a further 50 key informants in 24 of the villages (Table 3.1).

China

In China, the surveys were conducted in collaboration with the Chengdu Institute of Biology, in Maoxian County in Aba Prefecture of Sichuan Province. A total of 100 households were interviewed in 6 villages. A further 15 key informants (4 scientists of the Chengdu Institute of Biology, the Governor of Maoxian County, 5 commercial beekeepers, and 5 lead farmers) were interviewed during the field visits (Table 3.2).

Pakistan

In Pakistan, the surveys were conducted in collaboration with the National Aridland Development and Research Institute (NADRI) in seven apple-growing valleys in Balochistan. A total of 76 households were interviewed in 32 villages. A further 24 key informants (1 professional from a local NGO, 1 from NADRI, 4 scientists from the Department of Agriculture, Balochistan, 1 beekeeper, and 17 farmers) were interviewed during the field visits (Table 3.3).

Bhutan

In Bhutan, the surveys were conducted in collaboration with a local lead farmer. A total of 85 households were interviewed in 13 villages in the two main apple-growing valleys, Thimphu and Paro, and discussions held with a further 12 key informants including scientists from the Research, Extension and Irrigation Division (REID) of the Ministry of Agriculture and lead farmers (Table 3.4).

Nepal

In Nepal, the survey was conducted in collaboration with a local NGO, the Surya Social Service Society (4S). A total of 60 households were interviewed in 10 villages in Jumla Valley in western Nepal and discussions held with a further 5 key informants (Table 3.5).

Table 3.1: Study area, households surveyed, and key informants in Himachal Pradesh, India

Area	Household survey			Key informants	
	Number of villages	Altitude range masl	Number of HH interviewed	Number of villages	Number of people
Shimla Hills	21	1800 - 2300	52	8	20
Kullu Valley	41	1600 - 2200	130	13	25
Kinnaur Valley	14	2500 - 3200	27	3	5
Total	76		209	24	50

Table 3.2: Study area, households surveyed, and key informants in Maoxian County, China

Area	Household survey			Key informants	
	Villages	Altitude masl	Number of HH interviewed	Number of villages	Number of people
Maoxian County	Suangma	1850	9	6	15
	Mati*	1670	18		
	Dagou Fengyi	1720	13		
	Jingzhou	1670	17		
	Zhongqu	1530	29		
	Jincu Nanxin	1500	14		
Total	6		100		15

* Mati lies in the Hujiang river valley, the other villages in the Minjiang river valley

Table 3.3: **Study area, households surveyed, and key informants in Balochistan, Pakistan**

Area	Household survey			Key informants	
	Number of villages	Altitude masl	Number of HH interviewed	Number of villages	Number of people
Kalat Valley	6 villages (Chori Mougachi, Gome, Mugnalazi, Khadra, Zard Abdulla, and Kalat)	2054	8	5	24
Killa Saifullah Valley	2 villages (Argus and Killa Saifullah)	1550	10		
Loralai Valley	3 villages (Sanjavi, Kasbi Khacha, and Loralai)	1433	6		
Mastung Valley	6 villages (Ganjdoor, Sharifabad, Killa Syed Aleem, Kid Kocha, Prinagabad, and Monza Qamat)	NA	16		
Pishin Valley	5 villages (Balozai, Killa Abdulla, Cercal Shabzada, Killi Khatar, and Cercal Shahjhan)	1572	13		
Quetta Valley	8 villages (Hanna, Kuchi Lak, Killi Jeao, Killi Habib, Killi Sardar, Burhnar, Killi Kachi, and Thakh Jani)	1676	14		
Ziarat Valley	2 villages (Manna and Ziarat)	2400	9		
Total	32		76	5	24

Table 3.4: **Study area, households surveyed, and key informants in Thimphu and Paro Valleys of Bhutan**

Area	Household survey			Key informants	
	Number of villages	Altitude range masl	Number of HH interviewed	Number of villages	Number of people
Thimphu Valley	Five villages (Semtokha, Tshlimaphey, Depsi Babesa, Gamchi Babesa, and Sherbithang)	2300-2400	44	2	12
Paro Valley	Eight villages (Dugyey Dingkher, Lholey Neyphug, Neyphug Shaba, Lholy Shaba, Shap Bara, Shap Shungker, Shap Shengu, and Shap Shelngo)	2200-2400	41		
Total	13		85	2	12

Table 3.5: **Study area, households surveyed, and key informants in Jumla Valley, Nepal**

Area	Household survey			Key informants	
	Number of villages	Altitude range (masl)	Number of HH interviewed	Number of villages	Number of people
Jumla Valley	10 villages (Mahat Gaon, Talium, Hanku, Patmara, Dillichaur, Patarasi, Gajyangkot, Depal, Kartik Swami, and Chandan Nath)	2150-2600	Between 3 and 14 per village	3	5
Total	10		60	3	5

Processing the Information

Data were analysed using simple means and percentages, no special statistical methods or tests were employed. Where surveys were carried out in different villages or areas, overall averages

were calculated from the averages for each village/area without weighting for numbers of respondents. The mean and standard error about the mean were calculated for parameters such as family size, apple orchard area, apple yield, income from apples, and number of sprays of pesticides per household. The standard error values are not shown for simplicity of data presentation. Farmers' and households' responses to questions like climate change, its impact on pollination, the number of farmers keeping honeybees or renting honeybees for apple pollination, the type of pollinizer varieties planted, pollinizer proportion, and the number of farmers carrying out hand pollination were calculated as percentages.

Chapter 4

Apple Farming and Pollination Issues in Himachal Pradesh, India

Himachal Pradesh: The Apple State of India

Himachal Pradesh is a mountainous state in the northwest Indian Himalayas. Its five million people live on marginal sloping lands in hills, mountains, and highlands covering an area of 55,673 km^2 where altitudes range from 350 to 6975 masl. The climate varies from hot to severely cold depending upon altitude. Agriculture is the main occupation of around three-quarters of the total rural population. The average size of landholdings is 1.62 ha, although a large number of holdings are less than 1 ha. The main agricultural crops are wheat, maize, and rice. At higher elevations, crops such as buckwheat, barley, and potatoes are grown in place of rice. Cash crops include fresh vegetables such as cabbages, cauliflower, and tomatoes, and fruit such as apples, almonds, peaches, plums, pears, and cherries in the middle hills and valleys; off-season vegetables, potatoes, pulses, beans, and fruit such as apples, cherries, and pine nuts at higher altitudes; and citrus fruits, mangoes, litchi, guavas, and loquat in the foothills and valleys near the plains.

Himachal Pradesh is sometimes called the 'Fruit State' or the 'Apple State' of India. Out of 614,000 ha of arable land, 32% is under horticultural crops. At present, about 196,000 ha are under fruit cultivation producing about 312,000 tonnes of fruit annually (Department of Horticulture, Himachal Pradesh 1998). Apples are the main cash crop, accounting for 42% of the total area under fruit cultivation and about 90% of total fruit production. About 78,000 ha are planted with apples, there are about 150,000 apple growers, and annual production is about 277,000 tonnes (Department of Horticulture, Himachal Pradesh 1998). Apple trees have been planted in Kinnaur, Kullu, Shimla, and parts of Chamba, Mandi, and Solan Districts.

Apple farming is playing a major role in the economy of Himachal. Its present contribution to the state economy is estimated at about US $1.7 billion per year, with about US $150-170 million contributed directly, and about US $1.5 billion contributed indirectly through providing jobs to thousands of people, not only in Himachal but also in Asia's biggest fruit market in Delhi during the six-month long apple-selling season (Toderia 2000).

Declining Apple Productivity

Apple productivity in the state has been declining continuously for the past few years. Farmers estimate that productivity has declined by 50%. Apple productivity reportedly dropped from 10.8 tonnes per ha in 1982 to about 4.3 tonnes per ha in 1990, which is more than 50%.

Survey Findings

The survey covered 209 households in 76 villages in Shimla, Kullu and Kinnaur Districts (Chapter 3, Table 3.1).

Agro-climatic conditions

In Shimla and Kullu Districts, information about temperatures was based on the farmers' perceptions. The farmers indicated that the winter temperature in the apple-growing areas lay between -10 and +10°C in the upper valley areas and between 3 and 15°C in the lower valley areas; and the spring temperatures between 10 and 15°C in the upper areas and 18 and 22°C in the lower areas. Farmers felt that the chilling requirement of the apples was not always met in the lower valley areas where the temperature was higher and the number of cold days less. In the upper valley areas, the lower temperatures and the greater number of cold days were sufficient to meet the chilling requirement. In some parts, frost at the time of apple flowering affected pollination and fruit set.

In Kinnaur, meteorological data was available from a meteorological station at Sharbo. The maximum winter temperature lay between 0 and 20°C and the minimum between 5 and 9°C. In spring, the maximum temperature lay between 8 and 28°C and the minimum between 0 and 11°C. Only a few districts had low enough temperatures and a high enough number of cold days to meet the chilling requirement of apples.

Humidity in all areas lay between 21 and 100% and varied with the season. Overall, the farmers felt that the climate had become warmer. During the past decade, snowfall has decreased and it now occurs later in the season. A decade ago it used to snow in December, nowadays it doesn't snow until late February or sometimes even March.

Landholdings

Figure 4.1 and Table 4.1 show details of the landholdings of the farmers surveyed in the three areas. In Shimla District the average landholding size was 2.9 ha; slightly more than half the households were small farmers cultivating between 1 and 2 ha of land. In Kullu Valley the average landholding size was 1.3 ha; nearly two-thirds of households were marginal farmers cultivating less than 1 ha of land, and 30% were small farmers. In Kinnaur, the average landholding size was 3.5 ha; overall the landholding size was more varied, with similar numbers in each of the classes of marginal, small, medium, and larger landowners. The population density in Kinnaur is lower and there is plenty of dry sloping marginal land, better known as marginal support land, which is now being used for apple plantations.

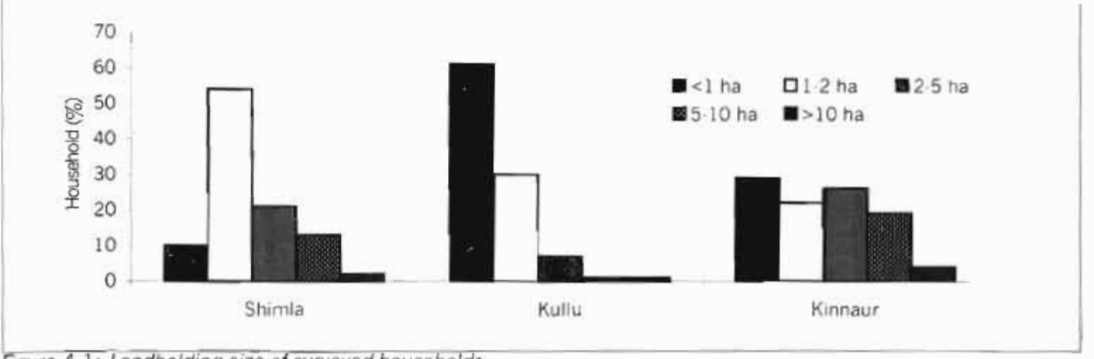


Figure 4.1: *Landholding size of surveyed households*

Table 4.1: Landholdings of the surveyed households

Landholding area per household	Shimla	Kullu	Kinnaur
Total land			
Average (ha)	2.9	1.3	3.5
Range (ha)	0.8-12	0.16-14.1	0.3-33.0
Irrigated land			
Average (ha)	0.3	0.2	1.8
Range (ha)	0.3-2.0	0.1-2.0	0.5-14.6
Percentage of total	10	15	51
Percentage of farmers	20	18	67

Overall the number of large landowners with more than 10 ha was very low, 1 farmer in Shimla with 12 ha, 1 in Kullu Valley with 14 ha, and 1 in Kinnaur with 33 ha. Most of the large landholdings comprised sloping marginal land.

Most of the land, in particular the orchard land, was not irrigated. Only 10 to 15% of the total land in the Shimla Hills and Kullu Valley was irrigated, although this rose to half in Kinnaur Valley, and less than a quarter of all farmers in Shimla and Kullu owned any irrigated land.

Land use

Figure 4.2 summarises the main use of agricultural land in the three areas. Crops were divided into 'agricultural crops' covering staple commodities like grain, potatoes, and pulses, and 'horticultural crops' like apples and vegetables grown primarily for sale. In Kullu and Shimla only 15 and 31% of the total landholdings was agricultural cropland compared with 51% in Kinnaur. The agro-climatic conditions in Kinnaur offer considerable advantages for the cultivation of off-season vegetables and pulses like kidney beans, which were cultivated as cash crops by

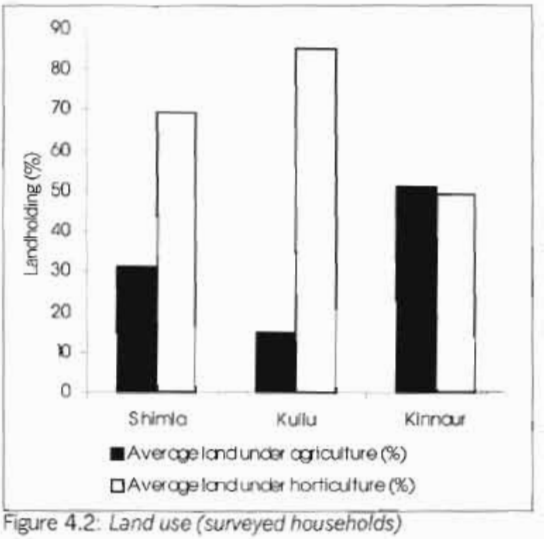


Figure 4.2: *Land use (surveyed households)*

over 95% of the farmers surveyed. Apple farming is relatively new in Kinnaur, but slowly more people are planting apple trees.

Farmers grew agricultural crops such as wheat, maize, and rice in areas at lower altitude and barley, potatoes, and pulses (beans) in areas at higher altitude. Apples were the main cash crop of all the farmers surveyed in all the districts except in Kinnaur where off-season vegetables and pulses were equally important. A few farmers were growing other fruit crops like plums (8% in the Shimla Hills, 5% in Kullu Valley), pears (5% in Kullu Valley), almonds, cherries, peaches, and other fruits (8, 2, 2, and 6% respectively in the Shimla Hills) as potential cash crops. Cultivation of off-season vegetables has emerged as an important source of cash income after apples. In Kinnaur, kidney beans *(Phaseolus vulgaris)*, off-season vegetables, pine nuts (*Pinus girardiana)*, and black grams were grown by 93, 96, 7, and 7% of farmers respectively.

Apple farming

Apples were the main cash crop for 76% of households in the Shimla Hills, 75% in Kullu Valley, and 63% in Kinnaur Valley and an important subsidiary crop for many more (Figure 4.3).

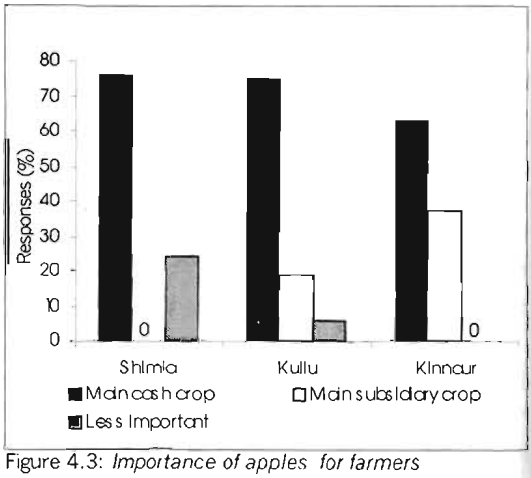


Figure 4.3: *Importance of apples for farmers*

The number and type of apple trees planted by the farmers surveyed is shown in Table 4.2. The average number of apple trees per household ranged from 317 in the Kinnaur Valley to 441 in the Shimla Hills. The proportion of bearing trees of the main variety was 46% in Shimla, 63% in Kinnaur, and 83% in Kullu, indicating that Shimla had the most newly planted orchards followed by Kinnaur, and that apple farming is expanding faster in Shimla and Kinnaur than in Kullu.

Table 4.2: Apple cultivation by surveyed households

	Shimla	Kullu	Kinnaur
Average number of trees per household			
Total number of trees	441	329	317
Number of bearing trees	205	271	202
Percentage of bearing trees	46	83	63
Main variety planted *(responses in per cent)*			
Royal Delicious	95	87	67
Red Delicious	2	8	26
Other varieties (included Golden Spur, Vance Delicious, Red Spur, Richard, Star Crimson, Crimson Gold, and Red Chief)	3	5	7
Main pollinizer variety *(responses in per cent)*			
Golden Delicious	35	70	93
Red Gold	31	14	–
Other varieties (included Tydeman's Early Worcester, Commercial, Jonathan, and Crab)	34	16	7

Royal Delicious was by far the most common main variety, followed by Red Delicious. Golden Delicious was the preferred pollinizer variety, particularly in Kullu and Kinnaur, followed by Red Gold in Shimla and Kullu. Other varieties included Tydeman's Early Worcester, Commercial, Jonathan, Crabapple, Winter Green, Snowdrift, Golden Hornet, Manchurian, and McIntosh (Table 4.2). The actual proportion of pollinizer trees is discussed below.

Changes in apple productivity

The response of the farmers to questions on problems in apple productivity is summarised in Table 4.3. The experiences in the three areas were somewhat different. Whereas in Shimla and Kinnaur most farmers felt that productivity was decreasing, three quarters of farmers in Kullu thought it was increasing or at least stable. There was a certain correspondence between the proportion of new plantations in the three areas (Table 4.2) and reports of decreasing productivity. The great majority of farmers in all three areas reported an increase in the cost of production.

Most farmers felt that lack of proper floral pollination was an important factor affecting apple productivity, changes in climate were also thought to be important, particularly in Shimla, as were disease and pests, especially in Kullu (Table 4.3).

Table 4.3: **Problems in apple productivity (percentage of responses)**

	Shimla	Kullu	Kinnaur
Apple productivity			
Increasing	16	56	44
Decreasing	76	26	56
No change	8	18	
Cost of production			
Increasing	88	97	78
No change	12	3	22
Factors affecting apple productivity*			
Change in climate	74	47	24
Diseases and pest attacks	20	89	33
Lack of pollination	86	75	78

*Individual farmers mentioned more than one factor

The farmers' perceptions of climate (weather) change and its impact on apple productivity are summarised in Table 4.4 and Figure 4.4. When asked about the overall change in climate, all the farmers surveyed responded that there was a change in the climate, and that this change was evident in a changing weather pattern, including general warming up, less snowfall, fewer days serving as a chilling period, and changes in rainfall period and pattern. Although they had different perceptions of the detailed changes, all showed a common concern that this climate change was affecting their productivity in one way or another, and most felt that the climate change was affecting pollination, and a number that it was affecting fruit set and fruit quality, causing an increase in the incidence of various diseases like scab and canker, and pests such as mites, and causing various problems such as accelerated leaf fall, delay in fruit ripening, accelerated fruit drop, and a decrease in overall productivity.

Table 4.4: **Farmers' perception of climate change (percentage of responses)**			
	Shimla	Kullu	Kinnaur
Change in temperature			
Increasing	43	53	67
Decreasing	18	4	7
Fluctuating	10	3	0
Don't know	29	40	26
Change in rainfall			
Increasing	25	31	30
Decreasing	6	4	27
Fluctuating	12	26	17
Don't know	57	39	26
Humidity			
Excess	29	5	30
Decreasing	0	1	4
Don't know	71	94	66
Snowfall			
Less	36	33	26
Don't know	64	67	74

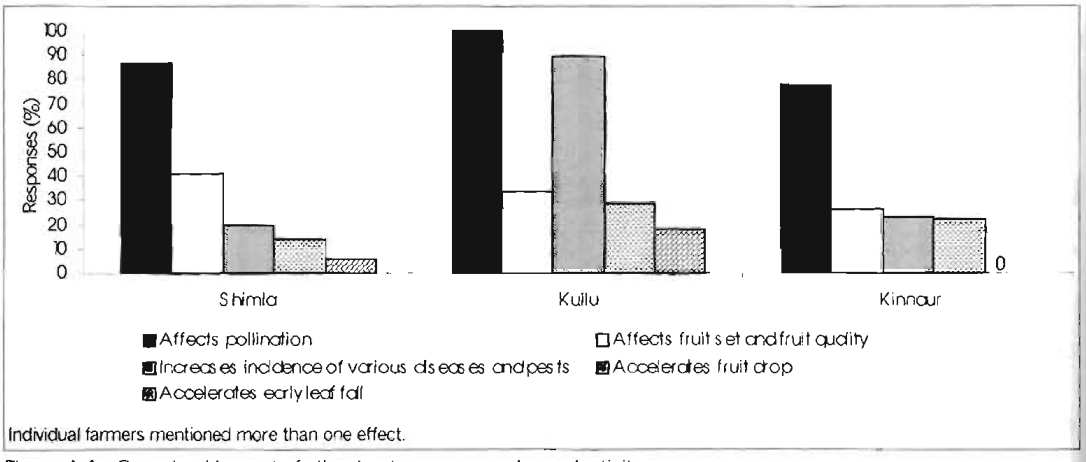


Figure 4.4: *Perceived impact of climate change on apple productivity*

Apple pollination problems

The majority of farmers felt that lack of proper floral pollination was one of the important factors in declining apple productivity (Table 4.3). The possible reasons for pollination failure include a lack of the appropriate ratio of pollinizer, scarcity of natural insect pollinators, and unfavourable climatic factors or bad weather conditions (see Chapter 2).

Farmers had different perceptions of the factors responsible for inadequate pollination (Figure 4.5). The great majority of farmers thought that weather factors were responsible at least in part.

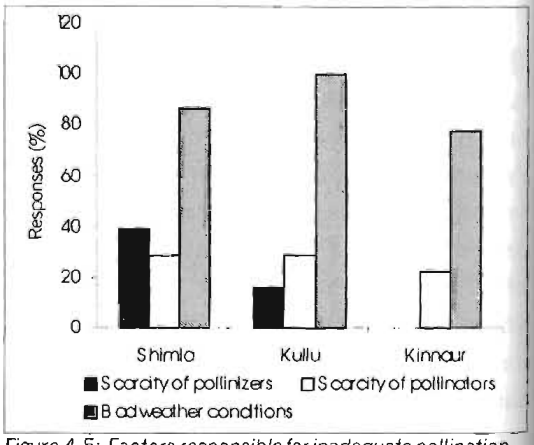


Figure 4.5: *Factors responsible for inadequate pollination in apples*

Less than half the farmers in Shimla, only 16% in Kullu, and none in Kinnaur thought that a lack of appropriate proportions of pollinizer varieties could be responsible for inadequate pollination in their orchards, and rather less than a third in all areas pointed to a lack of natural pollinating insects as another key factor. Other problems related to pollinizers included less flowering in pollinizer varieties (10% of farmers in Shimla and 3% in Kullu), their habit of flowering in alternate years (11% of farmers in Shimla and Kullu), and lack of synchronisation of flowering between the pollinizer and the main varieties (8% of farmers in Shimla and 2% in Kullu).

Scarcity of pollinizer varieties in the fields

The surveys showed that one of the key factors in inadequate pollination was the lack of sufficient pollinizer trees within the orchards. The Royal Delicious and Red Delicious varieties preferred by most farmers (Table 4.2) are completely self-sterile and require pollen from other compatible varieties (pollinizer trees) in order to set fruit. The standard pollinizer proportion recommended for adequate pollination of self-incompatible varieties of apple is 20%. But the values in the study areas were much lower. Figure 4.6 summarises the responses to the question on the proportion of pollinizer trees. The majority of farmers in Kullu and nearly half in Kinnaur had between 5 and 10% of pollinizer trees in their orchards. Some 11% of farmers in Kinnaur and about 2% in Kullu did not have a single pollinizer tree. The situation was slightly better in Shimla, nearly two-thirds of the farmers had between 10 and 20% of pollinizer trees. But only three farmers in the whole survey had the optimum 30% or more of pollinizers. Most farmers were not aware, however, that this lack of pollinizers was probably contributing to the inadequate pollination (Figure 4.5). A combination of lack of awareness and a wish to have the maximum number of trees of a single (or two) commercial varieties, has meant that farmers have not planted the appropriate ratios of pollinizer varieties of apples.

Inadequate populations of insect pollinators in the local environment

The lack of pollinating insects in apple-growing areas was almost certainly another major reason for crop pollination failure. The general observation made by farmers was that in the past there used to be lot of insects like wild bees, butterflies, and moths during the apple-flowering season, but that now they have all disappeared. Less than a third of farmers, however, realised that this

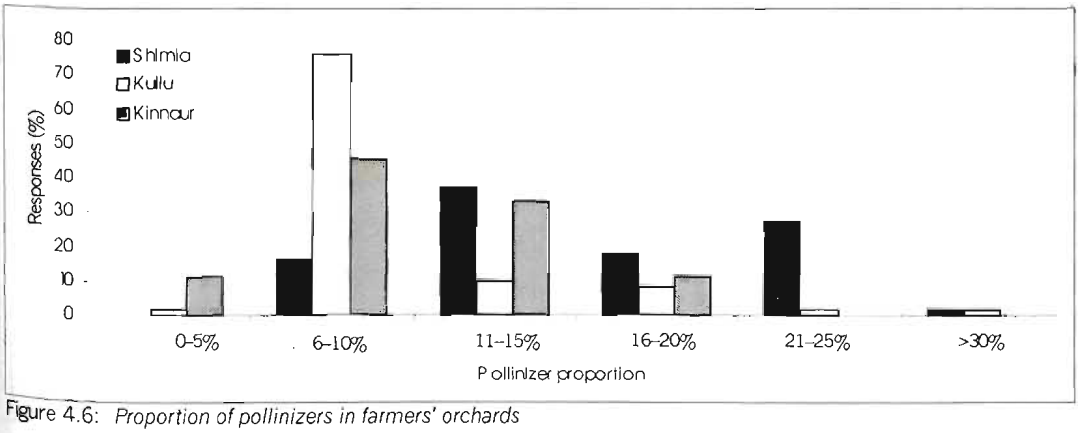


Figure 4.6: *Proportion of pollinizers in farmers' orchards*

could be affecting pollination. Insect populations are declining for a variety of reasons including loss of natural habitat (forests and grasslands) as agriculture expands, and resultant changes in their food and nesting habitats, and the excessive use of pesticides on the new generation of cash crops. Insecticides have affected both the diversity and the abundance of pollinating insects. It is also possible that even if the natural insect populations had remained stable, they would still have been too small to pollinate the new large areas of apple crops.

Use of pesticides

The surveyed farmers used a lot of pesticides, mostly fungicides but also one or two types of insecticides, to control various pests on their crop (Table 4.5). The most commonly used insecticides were metacid, metasystox, diathane M-45, durmet, thiodan, monocrotophos, fenitrothion, and melathion. Of these, fenitrothion, monocrotophos, melathion, and thiodan are highly toxic to honeybees and other pollinating insects. Apples were sprayed from 3-4 times a season in Kinnaur to as much as ten times per season in Shimla (Table 4.5). Farmers sprayed pesticides both to control existing pests and diseases and to prevent the outbreak of diseases such as apple scab and red apple mite. Some farmers believed that spraying with some of the chemicals, particularly fungicides, improved the size, colour, and overall quality of the fruit.

Around two-thirds of the farmers were aware that insecticides can kill honeybees and other useful insect pollinators. However nearly one-third were not, and nearly 30% of farmers in Shimla and Kullu and 15% in Kinnaur still used pesticides during the apple-flowering period (Table 4.5).

Changes in weather conditions during flowering

The great majority of farmers thought that bad weather conditions during the flowering period were contributing to pollination failure in the apple crops (Figure 4.5). In the years prior to the survey, farmers had experienced frost, rain, hailstorms, and low temperatures at the time of apple flowering. Low temperature and frost affect apple pollination by stopping honeybees and other natural insect pollinators flying and damaging flowers and early fruit. Mild rains also affect apple pollination by affecting insect foraging and pollination activities, whereas heavy rains wash away the pollen grains from flowers. Hailstorms can damage the apple flowers themselves.

Sources of knowledge about pollination

Table 4.5: **Pesticide use and its impact on apple pollination (percentage of responses)**

	Shimla	Kullu	Kinnaur
Number of pesticide sprays per season			
3-4	0	0	78
4-5	0	35	18
6-7	0	63	4
9-10	100	2	0
Pesticides sprayed during flowering	29	29	15
Types of pesticide			
Insecticides	100	100	100
Fungicides	100	100	100
Do pesticides kill insect pollinators and bees?			
Yes	76	67	63
No	4	4	15
Don't know	20	29	22

The great majority of farmers were aware of pollination failure and its effects on apple productivity (Table 4.3), even though they were less informed about the causes. The Government Department of Horticulture and the Dr Y.S. Parmar University of Horticulture and Forestry had played a key role in raising awareness among the apple farmers about pollination failure and the need for its management (Figure 4.7). In the relatively new apple growing area of Kinnaur, almost all information was from these sources; they were the most frequently cited source of information in Shimla too, but there other farmers were nearly as important; in Kullu where the orchards were older, farmers relied more heavily on their own experience and that of other farmers. The farmers' own experience was based on observations that there was higher productivity and better fruit quality near pollinizer varieties and when there were pollinating insects like honeybees in the orchards. Some farmers had also observed that the crop was reduced or had failed completely in the absence of pollinating insects.

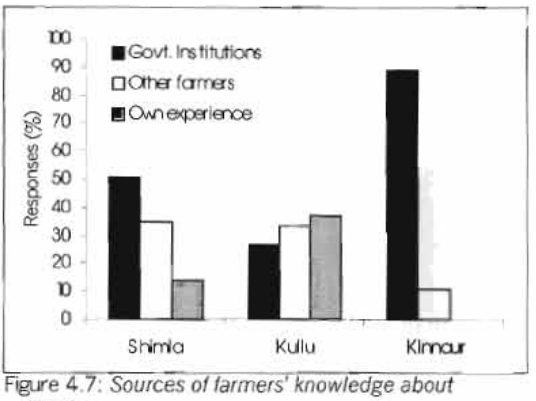


Figure 4.7: *Sources of farmers' knowledge about pollination*

Farmers' strategies for pollination management

Many farmers in Himachal Pradesh are now aware of the problem of failed pollination in apple crops and the need to consciously create optimum conditions for pollination – that is for 'pollination management'. Farmers are managing both pollinizers and pollinators, and are also using different strategies to avoid the effects of low temperatures and frost on pollination and fruit set. Some 43% of the farmers interviewed in Shimla, 33% in Kullu, and 41% in Kinnaur had introduced some form of managed pollination (Table 4.6).

Increasing the pollinizer proportion in apple orchards

When commercial apple farming started in the 1960s, farmers in Himachal Pradesh had many varieties of apples such as Commercial, Golden, Jonathan, Red Gold, Red Delicious, and Royal Delicious. These provided compatible pollen for each other and there was good fruit set. Since the early 1980s, however, farmers have focused on planting Royal Delicious on a large scale because of its better market value, and have slowly uprooted the other varieties – many of which could have been excellent pollinizers for Royal Delicious. All new orchards have been planted with pure stands of Royal Delicious without any pollinizers. Earlier, as the orchards were being changed over, there

Table 4.6: **Use of managed pollination (percentage of responses[1])**

	Shimla	Kullu	Kinnaur
Grafting pollinizers	25	21	0
Using pollinizer bouquets	30	58	4
Using honeybees for pollination	65	48	40
Own bee colonies	*38*	*37*	*75*
Rented bee colonies	*62*	*63*	*25*
Want to use bees for pollination, but not available	25	30	30
Hand pollination	8	3	0

[1]Some farmers use more than one method

were still sufficient pollinizer trees for reasonable pollination to occur, but over the last seven to eight years, the pollination problem has become serious.

Now farmers have started planting pollinizers in place of some of the trees of the main variety. But newly planted pollinizer trees take a minimum of five years to produce flowers. To accelerate the process, around a quarter of the farmers in Shimla and Kullu were grafting pollinizers onto the main trees, because grafts flower after three years.

The main pollinizer varieties planted in Kullu District were Commercial and Golden, and in Shimla, Golden, Red Gold, and Tydeman's Early Worcester. Some varieties of crab apple (wild apple) are also gaining popularity as pollinizers in Himachal Pradesh, both as trees and as grafts. This is because the plants are small, take less space in the orchards, produce many flowers, and have long flowering periods of more than a month, therefore providing pollen to any variety, whether early or late blooming.

The spread of bouquet pollination in Parvati Valley, Kullu

In 1994 Mr Gulab Singh tried out bouquet pollination in his orchard in Jalugran Village, the first person in Parvati Valley. Over the past few years, his fruit set had gone down to 10% using the bouquets the fruit yield increased by about 50%. Other farmers came from all the nearby villages to see for themselves how Mr Singh had been so successful; they were still suffering from poor fruit set. The next year most farmers in the nearby area had started bouquet pollination, and by 1998, all the farmers in Parvati Valley knew about the practice and, as they all had problems with fruit set, had started using it.

Bouquet pollination has also brought some unwanted problems. Many farmers do not have enough pollinizer trees left to be able to cut and spread the branches, the temptation is to steal from other orchards. There are many such cases of theft. Now, whenever a farmer sees somebody with scissors in his orchard, he chases the intruder away. During the survey, we met a farmer near a village in Kullu Valley carrying a load of blooming pollinizer branches. When we asked him to stop for a photo, he rapidly explained that he was not stealing but had brought the branches from a relative's orchard.

Newly-planted trees and grafts take three to five years to produce flowers (and supply pollen). As an interim solution to the immediate requirement for pollinizers, many farmers are hanging flowering pollinizer branches on the trees of the main variety, the base is kept in water in a plastic bag so that the branch stays fresh for a few days. Scientists call this 'bouquet pollination'; the pollinizer branches are 'bouquets'. More than half the farmers in Kullu Valley and a third of those in Shimla were using this method (see Box). Only one of the farmers interviewed in Kinnaur was trying this approach. Overall, the practice has become so widespread in the area that the price of plastic bags has risen from IRs 25 (US $0.75) per kg to IRs 90 (US $2.1) per kg.

Increasing the number of pollinators in apple orchards (hiring honeybees)

Until the early 1990s, pollination of apple crops in all the sample villages had depended largely upon naturally occurring pollinating insects. At the time of the survey, the majority of farmers in all three areas felt that natural pollination was not sufficient (Figure 4.8) although as can be seen from Figure 4.5 they hadn't necessarily understood the reasons for this.

About half of the surveyed farmers had started using honeybees (*Apis cerana* and *Apis mellifera*) for apple pollination (Table 4.7). The Dr Y.S. Parmar University of Horticulture and Forestry and

its Beekeeping and Horticulture Research Stations provide some honeybee colonies free of charge to apple farmers for pollination (*Apis cerana* and *Apis mellifera*). Both the University and the Government Department of Horticulture also provide training on how to use bees for pollination. The State Government is encouraging farmers to keep their own bees for pollination through the specially created Beekeeping Development Office (BKDO), under the Department of Horticulture (Chapter 2). The large-scale use of rented honeybee colonies, originally introduced as a government measure, has also helped to promote a number of commercial beekeeping entrepreneurs in the province who keep *Apis mellifera* in movable, frame hives specifically to rent out for apple pollination. There are also some small beekeepers with five to ten colonies of *Apis cerana* kept in traditional wall or log hives who rent bees for apple pollination.

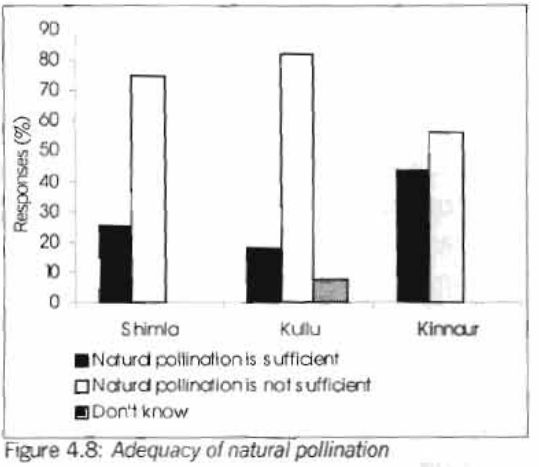


Figure 4.8: *Adequacy of natural pollination*

In Shimla and Kullu around two-thirds of the colonies that farmers used were rented, the majority from commercial sources, in Kinnaur it was one-quarter. The remainder were owned by the farmers themselves (Table 4.7).

The number of colonies available for pollination is still much lower than the demand. Between a quarter and a third of all farmers wished to rent bee colonies but were unable to obtain them (Table 4.6). Some commercial beekeepers were unwilling to provide colonies for apple pollination. These beekeepers keep *Apis mellifera* bees in movable frame hives for honey production. At the time of apple flowering these bees were kept on the Indian plains where they produced large quantities of honey from oil seed crops, clover, and eucalyptus. These beekeepers felt that renting honeybees for apple pollination might bring in less money than selling the honey produced in the plains. Moreover, it might also reduce the strength of the honeybee colonies because apples bloom only for one or two weeks.

Despite the overall success in promoting honeybees as pollinators, the survey indicated that about a quarter of farmers had still not understood the potential role of honeybee pollination in enhancing apple yield.

Table 4.7: **Rented honeybees**

	Shimla	Kullu	Kinnaur
Source of rented honeybee colonies (% of responses)			
Government institution (Dept. of Horticulture)	39	17	73
Private beekeepers	61	83	27
Rental fees (approximate in US $)			
Rental fees per colony for two weeks	6	6	6
Refundable security deposit	11	11	11

Hand pollination

Few farmers were aware of the possibility of using hand pollination. Only a small number of farmers (four in Shimla and one in Kinnaur) reported hand pollinating their apple crops using hired labour to ensure that the flowers were properly pollinated. These farmers considered that hand pollination was important in ensuring the quality and yield of apples. The method of collection and preparation of pollen was the same as in Maoxian county in China (see Chapter 2) except that in Himachal Pradesh only selected flowers on a tree (about 20-50 flowers per branch) were pollinated and honeybees were then used to transfer this pollen to other flowers on the same branch.

Safe use of pesticides

Some farmers had reduced the number of pesticide applications from 10 sprays to only 4 or 5 sprays in a year, and were mainly using the less toxic chemicals. They also sprayed when there were fewer insect pollinators present, that is a week before and/or a week after apple flowering. A few of the large farmers had started to control the apple pests using biological pest control. They reared various predator insects and used them to kill the apple pests.

Orchard management to counter the impact of low temperatures and frost

When there is low temperature and the possibility of frost occurring at the time of flowering and early fruiting, some farmers collect grass and burn it in the orchards to create smoke, this raises the temperature by 2-3°C. Some farmers in the Shimla Hills also sprayed their orchards with water in the middle of the night to avoid frost the following morning. A few farmers also sprayed chemicals such as borax or TSO (tree spray oil), or some alternative insecticides, on a limited scale to delay flowering when the temperature was very low. Such chemicals delay flowering by about a week (Chauhan and Mankotia 1998). Some farmers in hailstorm-prone areas covered their crops with hailstorm-proof nets to prevent damage.

Government support to apple farmers

More than 80% of the farmers acknowledged the State Government efforts to support apple farmers through providing training on orchard management, including managing pollination; making honeybees available for pollination; and providing subsidies for planting materials, pesticides, and orchard management equipment. They expected that the government would continue such support in the future. Needs were expressed for more training in orchard management and the use of honeybees for pollination management; financial support and subsidies to buy better planting materials, farm equipment, pesticides, and honeybee colonies, and to attend apple workshops and meetings in India and abroad to receive advanced training; and support in obtaining honeybee colonies for pollination (Table 4.8).

Table 4.8: **Expressed training and support needs (percentage of responses)[1]**

	Shimla	Kullu	Kinnaur
Training in orchard management	76	98	100
Training in use of bees for pollination	8	6	11
Financial support/subsidies	34	90	74
Support in obtaining bees	8	6	52

[1]more than one answer possible

Summary of Issues

Farmers in all three survey sites in Himachal Pradesh were aware of the pollination problem in their apple crop. As a result of support provided by the Department of Horticulture and Dr Y.S. Parmar University of Horticulture and Forestry, many farmers knew about the factors causing inadequate pollination in the orchards and between a third and a half were trying out different methods of pollination management. Himachal Pradesh is the only state in the whole of the HKH region where honeybee colonies are being used specifically for apple pollination and the only state in the region where there is an organised system of hiring and renting honeybee colonies for pollination. The government is promoting private entrepreneurship for bee pollination and arranges training and demonstrations to apple farmers on the use of honeybees. At the same time, new pollinizer varieties are being introduced, tested, and provided for farmers.

Even so, there is considerably more that needs to be done to raise productivity. Not only must various strategies be used to increase the number of pollinizer trees, but the number of honeybee colonies available is also still much lower than needed. A total of 156,000 colonies would be needed to pollinate the 78,000 ha of apple orchards in the state at the recommended rate of two colonies of honeybees to one ha of apple orchards. The 10,000-12,000 colonies available, represent less than 10% of total demand. Farmers are becoming increasingly aware of the problems and the demand for honeybee colonies is rising (Nadda and Tiwari 1998). Expansion of apple farming in Himachal Pradesh has not been accompanied by the necessary increase in pollination resources and technology, and this deficit must now be made up in order to enhance apple productivity in the state (Nadda and Tiwari 1998). Various strategies should be followed to increase the number of pollinators including reduced spraying, providing better conditions for the survival and growth of natural insect pollinators, and in particular finding ways of increasing the number of honeybee colonies available for pollination.

Chapter 5

Apple Farming and Pollination Issues in Maoxian Valley, China

Farming in Maoxian Valley

Maoxian Valley is located in Aba Prefecture in the north-west of Sichuan Province of China. The population of the county is about 91,200, the altitude varies from 890 to 4984 masl, and the total land area is 4064 km². Only about 11,000 ha of the total land area (2.6%) is counted as arable (agricultural) land. The remainder is forest (27%), shrub land (36%), meadows (22%) and dry barren land. Orchards are planted on about a quarter of the arable land, that is about 0.7% of the total land.

Agriculture is the main occupation of over 90% of the working population. Farms are mostly small or marginal, with on average less than half a hectare of land per family. Basic food crops include maize, wheat, potatoes, soybeans, and horse beans. Cash crops are grown on some 7,330 ha of land and include apples (2830 ha), Chinese prickly ash (3,000 ha), and off-season vegetables such as tomatoes, capsicum, and cabbage (1,500 ha). Other fruit crops are also planted to a limited extent including plums, peaches, pears, and grapes.

The history and scale of apple farming

Apples are the main cash crop and account for more than 80% of total farm income in the county. Apple farming started in Maoxian Valley in 1946 with 400 trees of 10 varieties. By 1953 there were 4000 trees of 46 varieties, and by 1985 some 200,000 trees covering 730 ha of land. Large-scale apple planting during the 1980s made apples an important crop in the farm economy of the valley. In 1998, apple orchards covered about 2830 ha of land, and produced around 30,000 tonnes of apples per year (Figure 5.1) with a total value of about 40 million yuan (US $4.2 million). Apples from this region, known as 'Maowen apples', are famous

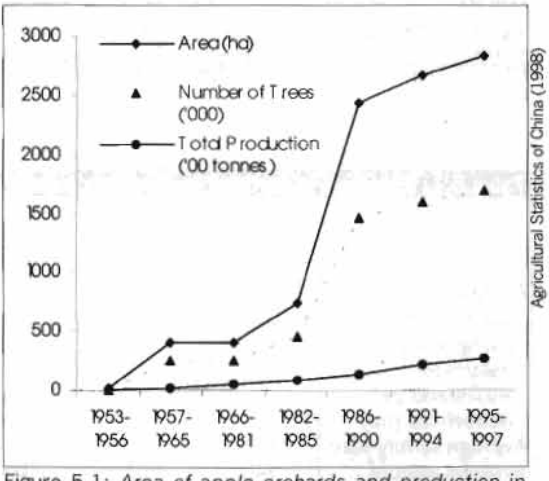


Figure 5.1: *Area of apple orchards and production in Maoxian county*

for their high quality and are sold in Chinese markets in places as far away as Beijing, Tianjing, Guangzhu, and Hong Kong. Nowadays, they are also exported to Russia and a few other southeast Asian countries.

In 1985 the Chinese Academy of Horticulture organised a national contest on apples, the Delicious varieties of apple won first prize for quality. As a result, the farmers in Maoxian County started replacing all other apple varieties with Delicious varieties. The apple trees planted in the large-scale plantations of the 1980s were more than 90% Royal Delicious. When these plantations started bearing fruit, they showed very low productivity per acre, and the average productivity for the county started to decline. By 1990, apple productivity had dropped from about 13.5 tonnes per ha in 1985, to 6.2 tonnes per ha (that is, by about 50%). Exploratory studies showed that insufficient pollination was one of the main factors for this decline in productivity.

The Survey Findings

The survey in Maoxian Valley covered 100 apple-farming families in 6 villages at altitudes ranging from 1500 to 1850 masl (Chapter 3). About 65% of the apple orchards are located on the flatter valley bottom between 1500 and 1700, the area most suitable for apples; another 30% are located on gentle slopes between 1700 and 2000m; and the remainder (5%) are above 2000m. Sixty per cent of the surveyed farmers were in the lower area and 40% in the higher (Table 3.2).

Farmers and the farm economy

Table 5.1 summarises the general agricultural parameters in the selected villages. The average landholding size ranged from 0.2 to 0.7 ha among the different villages with an overall average of 0.4 ha. In all the villages, farmers were also using so-called wasteland to grow Chinese prickly ash (on average 0.2 ha per household), the next most important cash crop in the county after apples.

The average annual income per household in Maoxian County was US $ 1200. It varied from as low as US$ 740 to US$ 1760 in different villages (Table 5.1).

Table 5.1: The state of farming in Maoxian Valley (surveyed farmers)

	Village						
	Suangma	Mati	Dagou Fengyi	Jingzhou	Zhongqu	Jincu Nanxin	Average
Average arable land per household (range) (ha)	0.6 (0.27–1.0)	0.7 (0.13–1.13)	0.3 (0.12–0.73)	0.2 (0.07–0.39)	0.3 (0.13–0.8)	0.3 (0.09–0.47)	0.4 (0.07–1.13)
Reclaimed wasteland per household (ha)	0.2	0.2	0.2	0.3	0.3	0.2	0.2
Average family size	5.2	6.1	5.4	4.4	5.4	4.4	5.1
Average annual household income (US$)	940	1410	1060	740	1760	1290	1200

Apple farming

The basic parameters of apple cultivation are summarised in Table 5.2. The average size of apple orchard per household varied among the villages from 0.1 ha in Suangma to 0.3 ha in Dagou Fengyi, with an average of 0.2 ha. On average, the farmers were using two-thirds of their arable landholdings for apple trees with percentages ranging from 92% in Dagou Fengyi to only 21% in Suangma (Figure 5.2). The actual number of trees per household varied from 91 in Jingzhou to 220 in Dagou Fengyi, and the average annual production from 2078 kg in Suangma to 8192 kg in Daguo Fengyi (Table 5.2). There was a lower yield in Suangma and Mati because apple farming had been introduced more recently and many of the trees were not yet productive. Apples were the main source of farm income in four villages, where they contributed between two-thirds and three-quarters of the total (Table 5.2). The price that apples commanded also varied between the villages, with lower prices at higher altitudes – from US$ 0.11 per kg in Suangma to US$ 0.16 per kg in Zhongqu and Jincu Nanxin (Table 5.2). This may reflect the higher transportation costs from higher altitudes.

The most popular varieties were Royal Delicious, Golden Delicious, Red Delicious, and Fuji Red; almost 90% of all apple trees in the region are Royal Delicious, and only 5-7% are Golden Delicious – the main pollinizer for Royal Delicious. The overall pollinizer proportion varied from 16% in Suangma to 6% in Jincu Nanxin (Table 5.2).

Farmers in the highest altitude village of Suangma used less pesticide than those at lower altitudes, with an average minimum of 4.2 sprays per season compared to 10.5 sprays in Zhongqu (Table 5.2). The insecticides used included

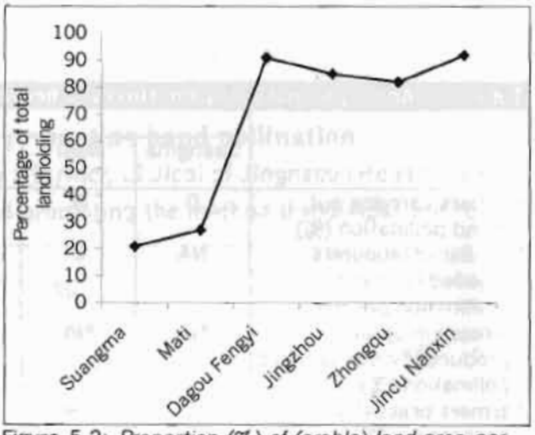


Figure 5.2: *Proportion (%) of (arable) land area per household under apple orchards*

Table 5.2: Apple cultivation by surveyed households (HH)

	Village						
	Suangma (1850m)	Mati (1670m)	Daguo Fengyi (1720m)	Jingzhou (1670 m)	Zhongqu (1530 m)	Jincu Nanxin (1500 m)	Average of all villages
Average size of apple orchard per HH (ha)	0.1	0.2	0.3	0.2	0.3	0.2	0.22
Number of apple trees per HH	113	134	220	91	181	173	152
Pollinizer proportion (%)	16	12	11	10	8	6	11
Average annual apple yield per HH (kg)	2078	2853	8192	3568	7405	5714	4970
Average contribution of apple crops to HH income (%)	26	23	64	67	67	70	53
Price per kg (US $)	0.11	0.12	0.10	0.14	0.16	0.16	0.13
Number of pesticide sprays per year	4	8	9	9	11	10	9

omechoale, phoxim, dichlorvos, dicofol, and methyl-parathion. Farmers also sprayed pesticides on vegetable and rapeseed crops that were cultivated under the apple trees.

Apple pollination management practices

The parameters of apple pollination in the six villages are summarised in Table 5.3 and Figure 5.3. In the lower altitude villages, the apple trees were mostly pollinated by hand, whereas at higher altitude they were mostly naturally pollinated. In the two lowest villages, all the farmers hand pollinated each and every flower inflorescence on all the apple trees. At higher altitudes the proportion of pollinizer trees was higher and pesticide use was lower (Table 5.2). Stationary beekeeping with *Apis cerana* was also considerably more common in higher altitude villages, around a quarter of all farmers kept bees compared with less than 10% in the lower altitude villages (Table 5.3). Taken together the results show that hand pollination was most commonly practised in the lower altitude villages where pollinizer proportions were low, beekeeping less common, and pesticide use greater; and natural pollination was relied upon in the higher altitude villages where pollinizer proportions were higher, beekeeping more common, and pesticide use

Table 5.3: **Apple pollination by the surveyed households**

	Village						
	Suangma	Mati	Dagou Fengyi	Jingzhou	Zhongqu	Jincu Nanxin	Average of all villages
Farmers carrying out hand pollination (%)	0	6	0[1]	82	100	100	48
Number of labourers needed for hand pollination per HH	NA	0	NA	12	37	31	27
Increase in apple productivity due to hand pollination (%)	NA	NA	NA	51	46	39	45.3
Farmers practising beekeeping (%)	22	39	23	6	10	7	18

[1]5% of farmers sprayed honey on apple flowers

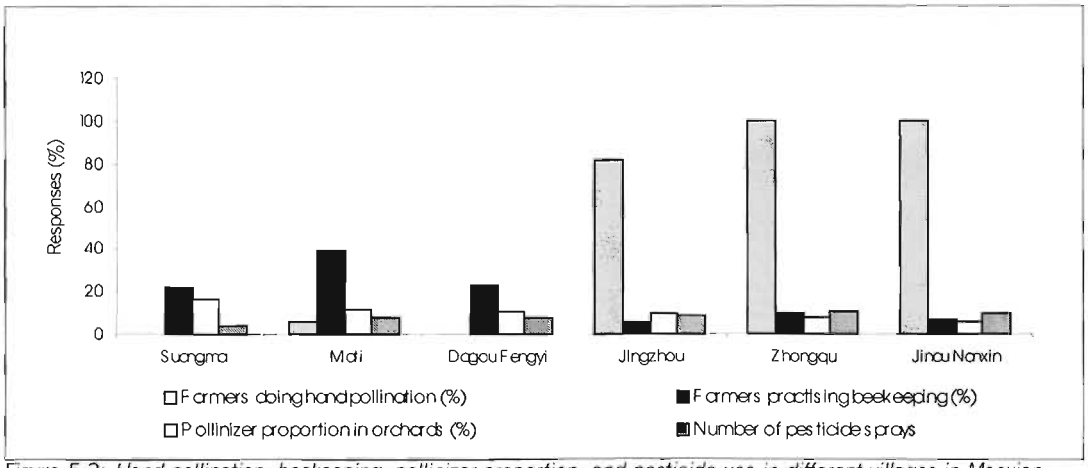


Figure 5.3: *Hand pollination, beekeeping, pollinizer proportion, and pesticide use in different villages in Maoxian County (percentage of responses)*

less (Figure 5.3). The interviews with farmers suggested that for those who used it, pollination by hand increased apple productivity by 40-50% (Table 5.3).

Hand pollination is a community effort in many of the villages. Apple flowering starts at lower altitudes and progresses upwards. As farmers at the higher altitudes do not pollinate their apples by hand anyway, they are mostly free at the time the apples bloom in the lower areas and are hired to hand pollinate the apple crops. The average number of additional labourers hired by farmers in the survey varied from 12 to 37 per family in the different villages and was related to the average number of trees per household (Table 5.3). Some larger families pollinated their apple orchards themselves.

There were some differences in the way that hand pollination was practised in the Shimla Hills of Himachal Pradesh and in Maoxian Valley. In the Shimla Hills the farmers pollinated 20-50 flowers per branch whereas in Maoxian Valley it was three out of five flowers in each apple inflorescence, and in the Shimla Hills the process was carried out only once in a season whereas in Maoxian Valley it was repeated at least three times to cover late flowering.

Hand-Pollination

The role of local government institutions in promoting hand pollination

The practice of hand pollination was introduced by a farmer, Li Jicai of Jinghzou (He et al. 1998). Noting his success, the county government started promoting the method throughout the county. Field experiments to standardise the technique were completed in 1990 and farmers were given training in 1991. At that time only a few farmers accepted the technique. As the impact of hand pollination became apparent, other farmers introduced it. In 1991, 17% of farmers in the lower altitude villages (Jinzhou, Zhongu and Jincu Nanxin) knew about hand pollination and 10% practised it; by 1997 all farmers were aware of its importance and 92% were using it for pollination of about 2000 ha of trees (Figure 5.4). The county government took no steps to raise awareness about or promote the use of beekeeping for pollination.

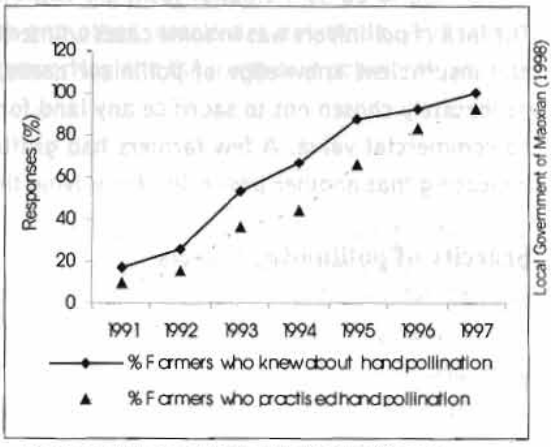


Figure 5.4: *Hand pollination in Maoxian County (farmers in Jingzhou, Zhongqu and Jincu Nanxin villages only)*

Cost-benefit analysis of apple pollination by hand and by honeybees

Hand pollination of apples and other crops (such as pears and tomatoes) is a massive effort. Table 5.4 shows a rough cost-benefit analysis of hand pollination and bee pollination as practised in the valley (additional monetary costs only, i.e., ignoring input of labour by family members and costs of keeping own bees). Hand pollination is a laborious and time-consuming method. A small farmer owning only 0.2 ha of apple farm will need the services of about 25 person days, in addition to his own family, to pollinate his apple crop, which means an outlay of US$ 60 for skilled labour

Table 5.4: **Cost-benefit analysis of pollination by hand and by honeybees**	
General Data	
Average landholding size (ha)	0.2
Average apple yield (kg) per household	4970
Price per kg (US $)	0.13
Hand Pollination	
Labourers needed (person days)	25
Cost of labourers @ US $ 2.40 per labourer per day	US$ 60
Honeybee Pollination	
Number of honeybee colonies needed @ 5 colonies per ha	1
Cost of hiring honeybees @ US $ 7.5 per hive	US$ 7.5

('farmer pollinators'). In theory, the same apple crop could be pollinated by one colony of honeybees. The rental fee for a honeybee colony in the county is only about US $7.50.

Why Don't Apple Farmers Use Honeybees for Pollination?

Lack of appropriate ratio of pollinizer varieties

One important factor that compels farmers to pollinate by hand is the lack of pollinizer trees. The great majority of trees are of the self-incompatible Royal Delicious variety; in theory each Royal Delicious tree should have a pollinizer tree near it so that pollen is available to its flowers (Gautam et al. 1994; Partap 1998; Partap and Partap 2000; Verma and Jindal 1997). The standard requirement is for 20% of trees to be pollinizers (see Chapter 2), but at lower altitudes farmers had only 6-10% of pollinizer trees (Table 5.2). If there are few pollinizers, then insects can only play a limited role in pollination.

The lack of pollinizers was in some cases unintentional, farmers and government extension agencies had insufficient knowledge of pollinizer needs, in others farmers with small landholdings had deliberately chosen not to sacrifice any land for pollinizer varieties because they were of little or no commercial value. A few farmers had grafted pollinizers onto the trees of the main variety, indicating that another possibility for solving the problem is being recognised.

Scarcity of pollinating insects

The second important factor that causes farmers to resort to hand pollination is the scarcity of pollinating insects. Both the diversity and the total populations of natural insect pollinators have declined in the region. There are several reasons, including loss of food and nesting habitats and the indiscriminate use of pesticides. After 1980, when apples became the lead cash crop of the county, the use of pesticides increased rapidly, killing many natural pollinators, (Table 5.3). In theory, these wild species could be replaced by honeybees kept in hives. Beekeeping as such is common in Maoxian County (both stationary beekeeping with *Apis cerana* and migratory beekeeping with *Apis mellifera*). Many farmers were aware that honeybees could play an important role in apple pollination and had wanted to hire honeybee colonies for this purpose, offering food and fuelwood in return for using the bees. But the most commonly used insecticides are also all highly dangerous to bees and beekeepers were not interested, preferring to keep their hives a few kilometres away from any apple orchards in order to avoid the bees being killed by pesticides. Five of the interviewed beekeepers stated that they would only rent their honeybees for apple pollination if the farmers did not spray

pesticides when the bees were in the orchard and if they paid a cash rental fee of around US $ 7-8 per colony per season.

Frequent occurrence of bad weather conditions

The third factor leading farmers to pollinate their apples by hand was the frequent occurrence of bad weather conditions during flowering. Apple pollination is adversely affected by bad weather conditions (Verma et al. 1990) for a number of reasons. Low temperatures and rain affect the foraging activities of insect pollinators, rainfall on the flowers can wash away the pollen, and hailstorms can damage the flowers. Local meteorological data show that unfavourable climatic conditions have occurred almost every other year over the past decade.

Summary

Thus there are a number of reasons why farmers rarely used honeybees specifically for pollination. Awareness about the use of honeybees was poor; the research and development institutions did not promote the use of honeybees so the farmers did not know about it, and the county government promoted hand pollination. The biggest constraint, however, was the excessive and indiscriminate use of pesticides. Even where farmers wanted to use bees they were unable to rent them as the migratory beekeepers were unwilling to expose their colonies to the dangers of insecticides. There is a need to set up a formal rental system for honeybees for pollination, to fix rental fees that are acceptable to both farmers and beekeepers, and to ensure that no insecticides are sprayed during flowering.

Overall, the farmers believed that hand pollination was the most reliable method of pollination under adverse weather conditions when honeybees and other insects are not flying, and that it ensured maximum pollination when the pollinizer proportion and the number of pollinating insects are low.

Summary of Issues

The survey results showed that the decline in apple productivity in Maoxian County was caused by insufficient or even total pollination failure. Farmers were aware of it and had understood the significance of ensuring pollination to maintain yield. Hand pollination was the most common practice adopted and had turned into a massive exercise in which every family member (men, women, and children) was involved. Various cooperation mechanisms had also evolved among farmers for sharing labour and skills. Beekeeping was more common at higher altitudes, but there were no beekeepers renting honeybee colonies to the farmers, even though this would have been cheaper for farmers than hand pollination. The two main reasons appeared to be that the practice was not being promoted and that the beekeepers were hesitant to rent out their honeybee colonies because of the excessive use of pesticide sprays on the apple trees.

Even though hand pollination is the most reliable method of ensuring apple pollination, it is unlikely to be sustainable as a long-term practice, largely because of increasing labour scarcity and costs. In mountain areas where agriculture is diversifying towards new cash crops, there is a need to raise awareness among people and local research and extension systems, not only about the significance of managing pollination but also about using honeybees for pollination as an alternative

to the prevalent practice of hand pollination. The risk of pesticides can be minimised through judicious use as well as by adopting integrated pest management practices, and the proportion of pollinizers raised by grafting where planting of new trees is inappropriate or undesirable.

Chapter 6

Apple Farming and Pollination Issues in Balochistan, Pakistan

Balochistan: The 'Fruit Bowl' of Pakistan

Balochistan is located in the western part of Pakistan. It comprises 43.6% of the area of Pakistan, but as a result of the arid climate and poor water resources it has the smallest amount of arable land of all the country's four provinces. In the northern uplands of Balochistan where these apple surveys were carried out, only about 4% of the land is potentially available for cultivation (Jasra et al. 2000). Of this, less than half is actually cultivated (242,000 of 13.2 million hectares) (Hafeez 1998). There are four major ecological zones in the province ranging from coastal belts to high altitudes of more than 2,500 masl. The soils of the uplands of Balochistan are fertile and dry. Sunny weather prevails throughout the year and is ideal for growing fruits and nuts such as apples, peaches, apricots, plums, pears, cherries, almonds, pomegranates, pistachio nuts, and grapes. Fruit production has emerged as a major farming activity and Balochistan is often called the 'fruit bowl' of Pakistan. Balochistan contributes about 50% of the total deciduous fruit production and over 80% of the total apple production of Pakistan (Government of Pakistan 1999).

Apples are considered a relatively more profitable crop among deciduous fruits and fruit growers are extending orchard farming to upland Balochistan. Apple orchards have been planted in areas at altitudes of 1,200m and above. The prime quality apples come from the highlands at altitudes above 2,000m because of the greater number of chilling hours.

Currently, apples are mainly produced in the valleys of Kalat, Killa Saifullah, Loralai, Mastung, Pishin, Quetta, and Ziarat. The area under apple cultivation has increased more than thirteen times during the past three decades (Government of Pakistan 1999), from less than 2,700 ha in 6 of the 26 districts in 1969/70, to 35,900 ha in 16 districts in 1997/8 (Figure 6.1). At present, the annual production of apples in Balochistan is about 482,600 tonnes (Government of Pakistan 1999), which brings in over PRs 9.2 billion (US $154 million).

Apple Productivity

Apple production in Balochistan has increased considerably since 1987, as a result of the increase in apple-growing area (Figure 6.1). However, apple productivity (yield per unit area) has remained far below the potential. The underlying reasons for the low productivity include lack of irrigation,

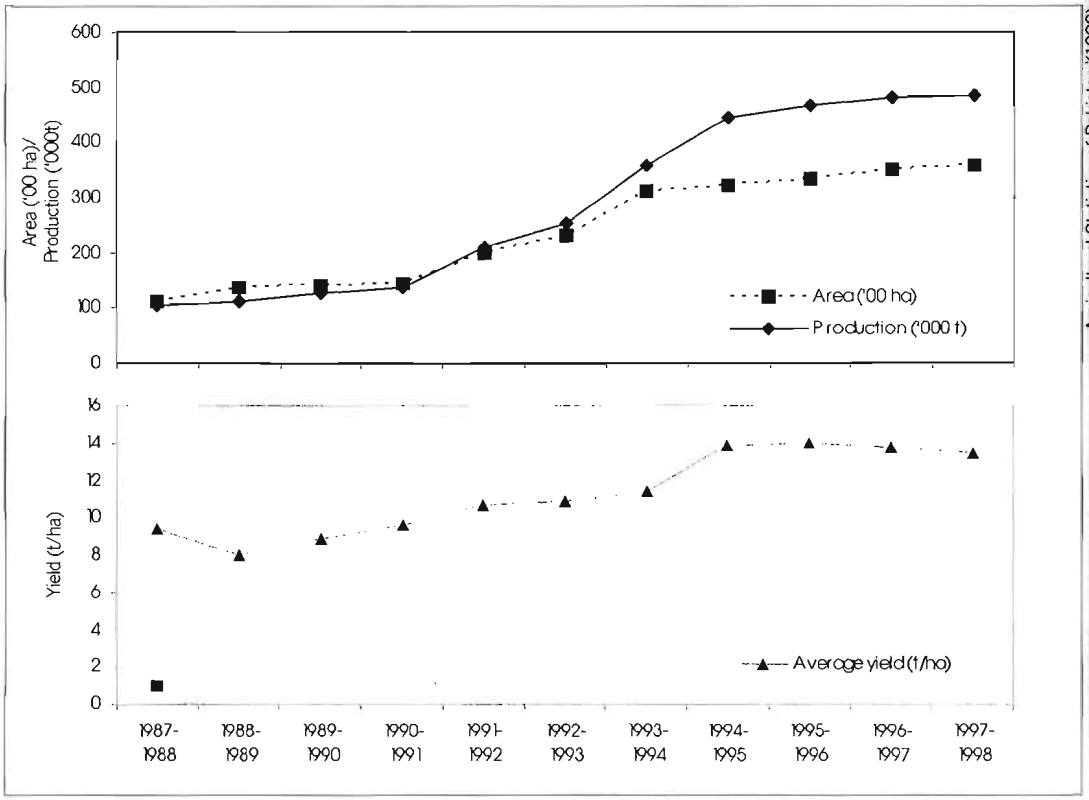


Figure 6.1: *Apple cultivating area and production of apples in Balochistan*

poor quality rootstock, low applications of organic matter, overuse of inorganic fertilisers, indiscriminate use of pesticides, and inadequate pollination. The gap between actual and potential yields of apple orchards could be reduced by using better quality planting materials, better agronomic inputs, balanced applications of organic manure and inorganic fertilisers, and by managing pollination. Inadequate pollination not only reduces apple yield, it also causes low fruit quality. The study focused on understanding the possible reasons for inadequate pollination and on farmers' management approaches, if any.

The studies focused on the major apple-growing areas of Kalat, Killa Saifullah (Zhob), Loralai, Mastung, Pishin, Quetta, and Ziarat (Sibi) Districts. A total of 76 households were surveyed, details are provided in Chapter 3, Table 3.3.

Official Statistics

Data from the Agricultural Department of Balochistan show that in 1973/74 most apple cultivation was in Quetta and Pishin Districts, with about 1,500 ha of orchards producing 10,000 tonnes of apples annually. The latest figures show 11,200 ha of orchards in these districts (8,200 ha producing 116,100 tonnes in Pishin and 3,000 ha producing 44,100 tonnes in Quetta). Of all the sample districts, apple cultivation had developed most in Pishin, from 2,000 ha of orchards in 1984/85, to 8,200 ha in 1996/97. Most of the new planting in Balochistan was done between 1984 and 1995.

On average, there were over 3,600 ha of apple orchards in each district during 1996/97, compared to 1,400 ha per district during 1984/85.

Figure 6.2 shows the district-wise scale of apple farming in the study areas as reported in the Agricultural Statistics of Balochistan for 1996/97. The area under apple cultivation ranged from 1700 ha in the Mastung District to 8,200 ha in the Pishin District. The average yield per hectare varied from 9.8 tonnes in Killa Saifulla District to 16.4 tonnes in Ziarat District, with a reported average for the whole province of 13.7 tonnes per ha (Figure 6.1). However, there was a marked discrepancy between the yields that farmers reported and the official statistics (see below).

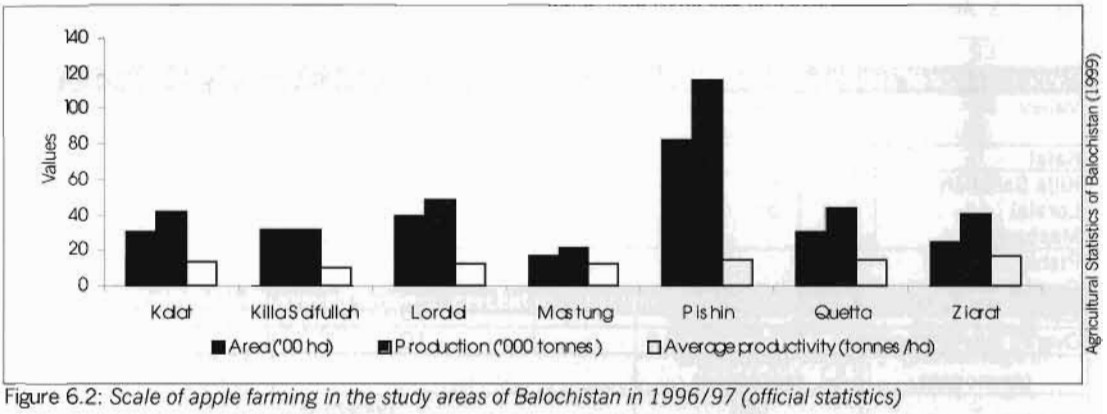


Figure 6.2: *Scale of apple farming in the study areas of Balochistan in 1996/97 (official statistics)*

Survey Findings

Landholdings and size of apple orchards

The average size of landholdings in Balochistan was very high compared to that in the other areas of the Hindu Kush-Himalayan (HKH) region covered by the survey. Figure 6.3 shows the average landholding size and area under apple cultivation in the surveyed villages. The overall average landholding size was 18.2 ha, with a range of averages in the different valleys from 27.7 ha in Killa Saifullah to 9.6 ha in Quetta and Loralai. The overall average area under apple cultivation was 9.3 ha, 57% of the farm area. The percentage of farm area with apple orchards varied from 84% in Loralai Valley to 24% in Ziarat (Figure 6.3). Overall the smaller the landholding size the higher was the proportion devoted to apples, in other words the actual area of apple orchards per farmer was less variable than the landholding size.

The apple orchards in Balochistan are relatively young (Table 6.1). The average age of apple trees reported by the surveyed farmers was 21 years in the older orchards and 10 years in the younger orchards. The oldest plantations were reported in Loralai where one farmer had an orchard that was 50 years old. The youngest orchards were in Killa Saifullah, where the average orchard age was about 11 years. The average tree density in the orchards ranged from 170 to 240 trees per ha. Intercropping with vegetables and alfalfa was common until the trees reached the fruit-bearing stage. Generally farmers did not appreciate the value of pruning the trees.

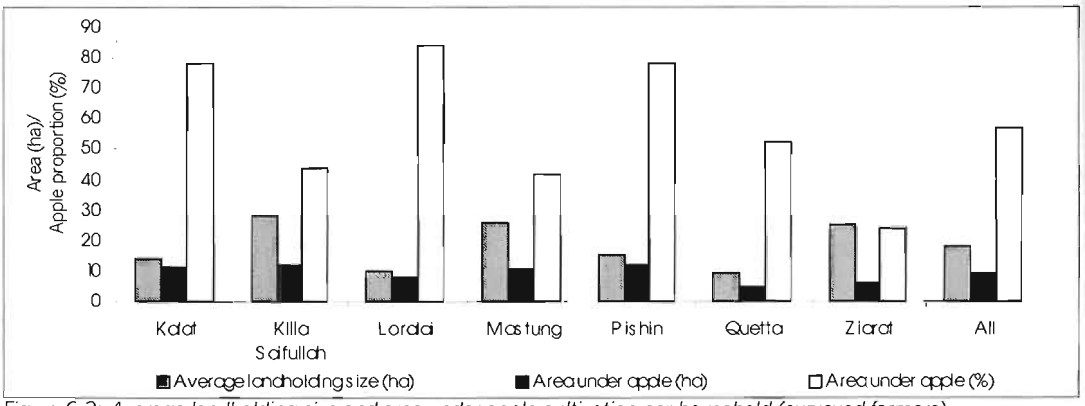


Figure 6.3: *Average landholding size and area under apple cultivation per household (surveyed farmers)*

Table 6.1: **Age of apple orchards in the sample valleys of Balochistan**

Valley	Average age of old plantations (>15 years)	Average age of new plantations (<15 years)	Average age of all plantations
Kalat	21	12	16.5
Killa Saifullah	15	6	10.5
Loralai	32	10	21
Mastung	19	12	15.5
Pishin	19	11	15
Quetta	19	10	14.5
Ziarat	19	10	14.5
Overall average (years)	20.6	10	15.5

Apple varieties

The two most popular varieties in all the sample districts were Red Delicious and Golden Delicious, which dominate all the recently developed orchards, with Gaja following behind. (Golden Delicious is a pollinizer for Red Delicious, and can also act as a self-pollinizer to a limited extent). Other varieties reported included Amri, Kashmiri, Mashadi, Katja, and Dilber, although these are now becoming less popular among the farmers. Semi-dwarf rootstock was introduced recently but had received a mixed response from farmers, despite the advantages of smaller trees and early fruit bearing (after 3-4 years).

Over half of all the orchard owners (about 53%) did not know about the need for pollinizers and did not plant specific varieties as pollinizers (Table 6.2). There were big differences among the valleys, however, the vast majority of apple growers in Mastung, Pishin, and Quetta did not know about pollinizers, whereas all of those in Killa Saifullah and Loralai did. In Killa Saifullah, 60% of the surveyed farmers planted a local variety as a pollinizer, in the Loralai Valley 60% planted Gaja.

Sales

Table 6.3 summarises the information given by farmers about the sale of their apples. Apple selling is either undertaken by the farmers themselves or by contractors who purchase the future harvest during spring when the trees are in blossom. Usually a contractor pays a third of the total agreed price to the orchard owner in advance. The majority of farmers, particularly the small and

Table 6.2: **Apple varieties grown in Balochistan (surveyed farmers, percentage of responses)**				
Valley	Main varieties	Pollinizer varieties	Farmers deliberately growing pollinizer varieties (%)	Farmers not knowing of the need for pollinizers (%)
Kalat	Traditional, Red Delicious, Golden Delicious, Gaja	Mixed	28	72
Killa Saifullah	Kashmiri, Red Delicious, Golden Delicious, Gaja, Amri	Golden Delicious Local variety	40 60	0
Loralai	Gaja, Red Delicious	Gaja Golden Delicious Mashadi	60 20 20	0
Mastung	Traditional, Red Delicious, Golden Delicious, Amri, Mashadi		0	100
Pishin	Amri, Red Delicious, Golden Delicious	Golden Delicious	7	93
Quetta	Amri, Red Delicious, Mixed, Gaja, Mashadi, Golden Delicious	Golden Delicious	7	93
Ziarat	Mixed, Red Delicious, Golden Delicious, Traditional, Gaja	Mixed Gaja	68 16	16

Table 6.3: **Apple sales (surveyed farmers, percentage of responses)**				
Valley	Price per kg (US $)	Markets	National sales (percentage in responses)	Export sales (percentage in responses)
Kalat	0.32	City market	100	–
Killa Saifullah	0.19	Quetta, Punjab, Multan, Lahore, Faisalabad, Karachi	100	–
Loralai	0.44	Quetta, Karachi, Lahore, Rawalpindi, Faisalabad	100	–
Mastung	0.32	City market Contractor	66 20	14
Pishin	0.24	Contractor City market No answer	23 23 54	–
Quetta	0.23	Contractor Sialkot, Lahore (Punjab)	69 31	–
Ziarat	0.40	City market Lahore, Multan, Karachi	83 17	–
Average	0.31			

medium-sized ones, entered into such pre-harvest contracts. Whether small farmers undertake to sell their produce directly depends upon the distance to the main market.

The apple producers in the northern highlands (Killa Saifullah, Loralai, and Ziarat) benefit from a favourable geographical position and close linkages with Punjab Province where they have a big market outlet. Most of these apples went to wholesale markets in Multan, Faisalabad, Lahore, Sialkot, and Rawalpindi, some went to markets in Quetta and Karachi. Only a few farmers in Mastung District exported apples outside Pakistan. The average price that farmers received varied from US $0.19 per kg to US $ 0.44 per kg, depending upon the fruit quality, with an overall average of U$ 0.31 per kg.

Apple productivity

The average yields reported by farmers for the different valleys ranged from 2.9 tonnes per ha in Kalat to 2.3 tonnes per ha in Killa Saifullah (Table 6.4). The average yield per ha for individual farmers depended on the site and perhaps on farmers' management practices, but less on the variety. Among all the varieties, Golden Delicious, Kashmiri, Mashadi, and Gaja were relatively higher yielding. The overall highest yield was an estimated 3.9 tonnes per ha for Mashadi in Mastung followed by 3.6 tonnes per ha for Golden Delicious in Kalat and for Kashmiri in Quetta. The lowest yield was 1.9 tonnes per ha for Red Delicious in Pishin and Katja in Mastung. Reported problems affecting the yield in many orchards included low fruit bearing and excessive fruit drop.

The reported yields were far lower than those of 10-16 tonnes per ha reported for the same areas for 1996/97 by the Government of Balochistan (Figure 6.2, Table 6.4). The official statistics for the whole province show more or less constant yields from 1994 to 1998 of more than 13 tonnes per ha. However, the majority of farmers in all the valleys except Ziarat, and three-quarters overall, reported that the yield had decreased over the last five years (Table 6.4). It seems possible that the official records are based on extrapolation of past values, or that some of the area and/or production estimates are generalised from atypical cases and do not fully reflect the real situation. Whatever the reason, the relatively high values officially reported for average apple productivity have misled institutions into believing that there is no apple productivity problem. As a result, research and extension agencies are paying no attention to problems like failed pollination that are limiting apple productivity.

The reasons given by farmers for the decline in yield are summarised in Figure 6.4. More than half (55%) thought that weather changes coupled with pest attack and disease were the major factors, 51% considered that weather changes alone were responsible, and a little less than a third believed that scarcity of pollinating insects and honeybees and absence of beekeeping was the cause.

Pesticide use

The common pests in the apple orchards of Balochistan include codling moth, mites, tip borers, shot hole borers, hairy caterpillars, aphids, and fruit flies. The agricultural extension services

Table 6.4: **Apple productivity as reported by the Government of Balochistan and the farmers' in the survey and changes observed by farmers**

Valley	Apple productivity in tonnes per ha		Apple productivity declining (percentage of responses)
	Farmers' survey (2000)	Govt. of Balochistan (1996/97)	
Kalat	2.9	16.2	100
Killa Saifullah	2.3	15.2	75
Loralai	2.6	15.1	83
Mastung	2.8	16.2	67
Pishin	NA	15.3	NA
Quetta	2.6	15.1	80
Ziarat	2.5	17.4	25
Average			72

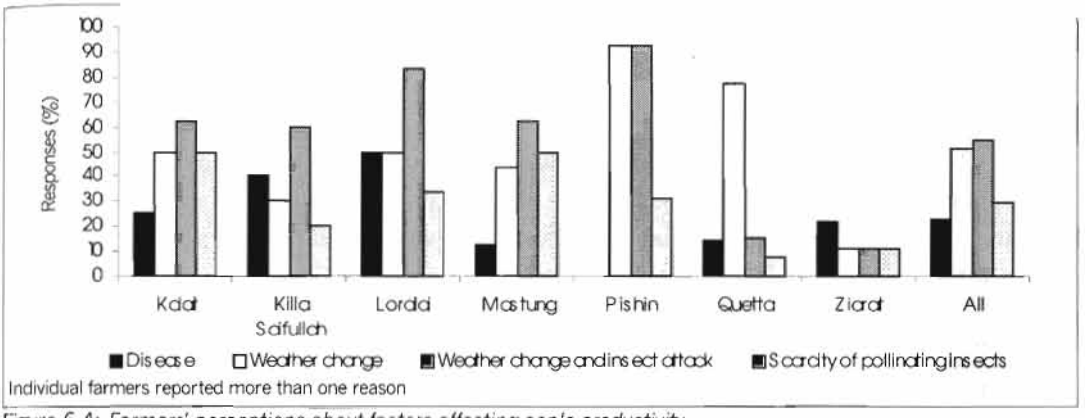


Figure 6.4: *Farmers' perceptions about factors affecting apple productivity*

recommend two sprays of a pesticide called gusathion, one in late March or early April and another 10 days later.

A part of the pattern of pesticide use in the orchards of the province since 1973/74 can be seen from the Government of Balochistan Agricultural Statistics. Between 1973/74 and 1984/85, large-scale aerial sprays were carried out supplemented by several ground sprays, and 75% of the cost of the pesticide used was subsidised. More than 14,000 ha of orchards were sprayed in 1973/74, rising to more than 30,000 ha in 1984/85, more than half of this in Pishin and Quetta. After this date, aerial spray operations were stopped, and although ground sprays continued, there was no government subsidy. The recorded area of ground sprays of orchards dropped to 6,700 ha in 1996/97. It seems that farmers continued spraying, but this is not officially recorded.

The farmers' use of pesticides is summarised in Table 6.5. Overall, 49% of the respondents regularly used different pesticides including insecticides, miticides, and fungicides in their apple orchards. The highest use was in Loralai District, where 83% of the respondents reported regular use of pesticides, the lowest was in Mastung District, where only 31% of the farmers sprayed in orchards. On average, those who sprayed did so 5 times per season, with a range from 2 to 7 sprays per season. All of those who sprayed did so at fruit set stage; except in Kalat, where between 20 and 80% did so during flowering.

Table 6.5: **The use of pesticides in apple orchards (surveyed farmers)**

Apple valley	Pesticide use (% of responses)	Number of sprays per season	Time of spraying (% responses of farmers who sprayed)		
			Before flowering	During flowering	During fruiting
Kalat	63	5	100	0	100
Killa Saifullah	50	5	20	20	100
Loralai	83	5	20	20	100
Mastung	31	5	19	19	100
Pishin	54	4	0	70	100
Quetta	36	4	19	19	100
Ziarat	56	5	20	79	100
Overall	49	5	28	32	100

Farmers' awareness about apple pollination and pollinating agents

Ninety-five per cent of all the farmers sampled (all farmers in Kalat, Killa Saifullah, Loralai, Mastung, and Quetta, 92% in Pishin, and 67% in Ziarat) had some knowledge of the apple pollination process, the majority had known about it for the last 10-12 years and those in Ziarat Valley for 18 years. About 35% had gained this awareness through their interaction with beekeepers, 39% from extension workers of the Department of Agriculture Extension, Balochistan, and 22% knew about it from other sources, including just two people who had learned from printed literature (Figure 6.5).

Half of the respondents believed wind to be an important pollinating agent for apples; about 38% regarded honeybees, butterflies, and other natural insects as pollinating agents; and 11% did not know about pollinating agents (Figure 6.6). The extent of knowledge varied considerably between valleys, 90% of respondents in Ziarat knew that insects were pollinating agents, but only 15% in Quetta and Pishin.

Ninety-seven percent of the respondents had observed various kinds of insects foraging on apple flowers in their orchards; about 45% reported honeybees, most probably the wild species, on apple

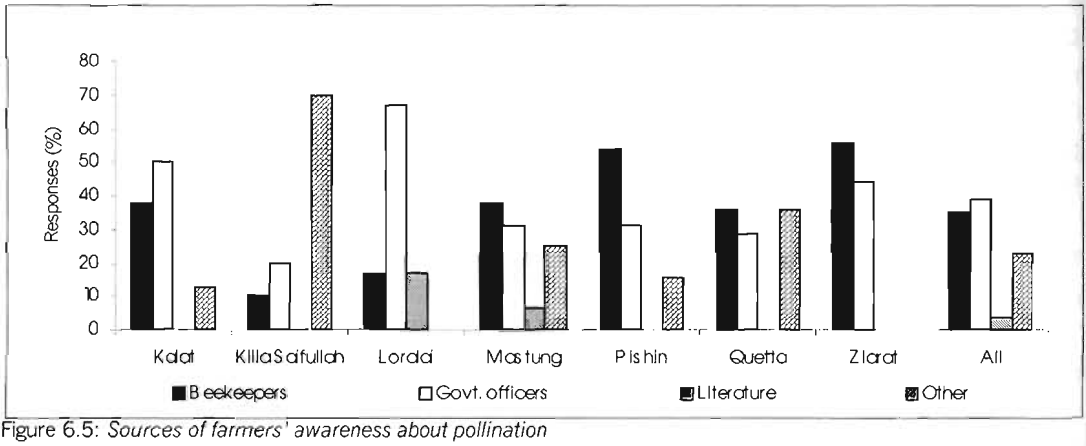


Figure 6.5: *Sources of farmers' awareness about pollination*

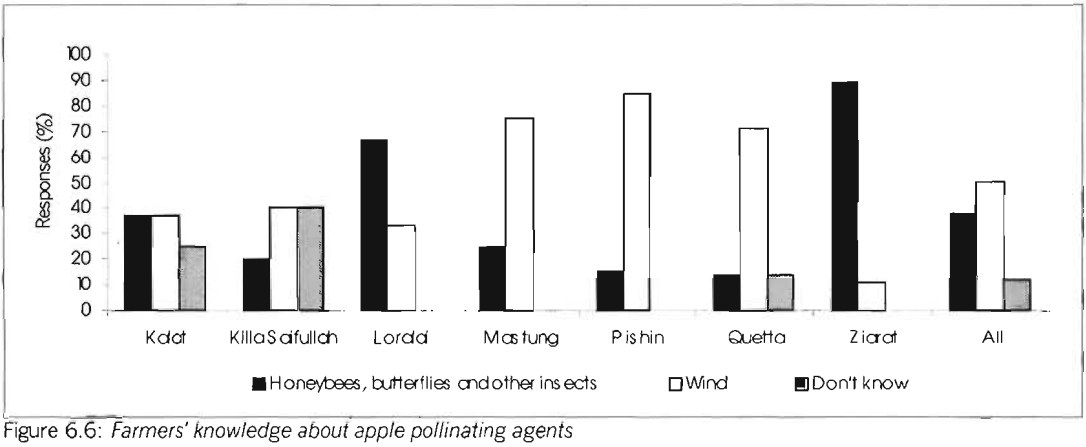


Figure 6.6: *Farmers' knowledge about apple pollinating agents*

flowers; and 86% had seen butterflies and wasps in the orchards. Figure 6.7 summarises the farmers' perceptions of the changes in populations of natural insect pollinators over time. More than three-quarters reported that insect populations were decreasing; and 17% had seen no change. Two farmers each in Pishin and Ziarat (5% of the overall total) reported that the populations of natural insect pollinators were increasing. Overall 60% of the farmers, with some in all study districts, had seen wild honeybee nests in the forests, ranging from 40% in Kalat and Mastung, to 83% in Loralai.

Farmers held multiple factors responsible for the decline in natural insect populations in orchards (Figure 6.8). Overall 84% considered pesticide use to be the major cause; nearly half thought that climate change might also be responsible; and a quarter that the increase in apple-farming areas and limited insect populations to pollinate them was a cause.

Farmers' were asked for their views on keeping honeybee colonies at apple farms, on their preferred type of bee, and on keeping bees for commercial purposes. None of the interviewed farmers kept bees and only a very small proportion (4%) were interested in keeping honeybee colonies in their orchards (one person each in Loralai, Quetta, and Ziarat). All of them preferred native bees to

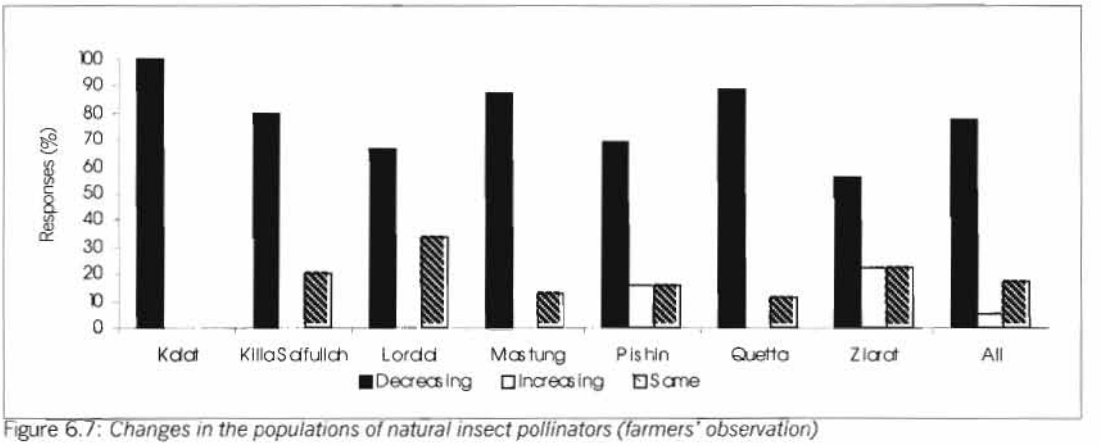
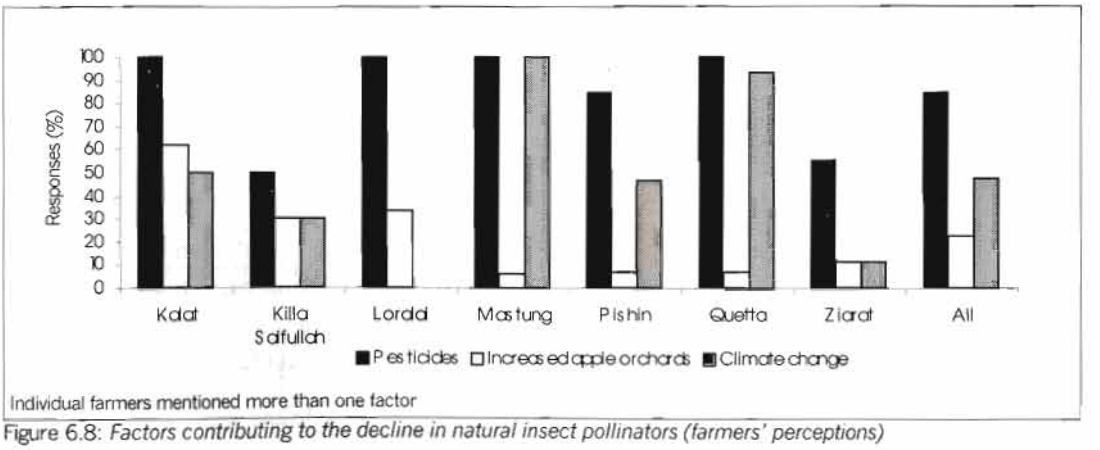


Figure 6.7: *Changes in the populations of natural insect pollinators (farmers' observation)*



Individual farmers mentioned more than one factor

Figure 6.8: *Factors contributing to the decline in natural insect pollinators (farmers' perceptions)*

European species. The majority of farmers (94%) were not keen on keeping honeybees for commercial purposes.

Migratory beekeepers from other provinces (Northwest Frontier Province (NWFP) and Punjab) do visit the highlands of Balochistan; their camps are mostly seen in the juniper forests of Ziarat during late summer, where the bees benefit from the blossom of *Perwaskis artiplicifolia*. With the onset of winter, they migrate back to their home areas. Sometimes their migratory season matches the apple-flowering season. However, very few farmers (one each in Loralai, Pishin, and Quetta) reported that the migratory beekeepers migrated colonies to their areas from Ziarat and it seems unlikely that migratory bees play more than a very minor role in apple pollination in Balochistan.

Summary

Overall the results suggest that productivity, or yield per acre, is steadily decreasing, and that the major cause is lack of pollination, mainly because there are insufficient natural insect pollinators. Only one third of farmers realised the need for natural insect pollinators, however, and even fewer were aware of the need for pollinizer trees. Even so, most farmers had noticed the decline in insect pollinators and the majority attributed it to use of pesticides and changes in climate. A number also realised that the existing populations were too small to pollinate the present and vastly increased area of orchards. There is a need to promote the integration of agricultural production practices and a wider use of strong honeybee colonies for cross-pollination. Furthermore, research is needed to determine the optimal combination of varieties for apple cultivation in Balochistan.

Summary of Issues

Apple farmers in Balochistan still benefit from extensive populations of natural insect pollinators. A high proportion of the land is left wild, and in areas near fertile valleys and water sources, wild herbs and low shrubs provide food (pollen and nectar) to a range of insects including wild bees in late spring to early autumn. Farmers also use fewer pesticides than in India and China. It is possible that overall there are adequate populations of natural insect pollinators for pollination of the state's apple crops, although there may be local deficit areas where the orchards are large in relation to the surrounding wild habitat, and apple trees too far from the insects. In addition, discussions with local non-government organisations (NGOs), agricultural scientists, and extension agents revealed that a small number of beekeepers from Abbottabad and Naushera in neighbouring NWFP regularly migrate their colonies to Balochistan in March/April and keep them there until September/October. These bees visit apple flowers in April and other wild flowers later. Thus although there is a certain lack of awareness, a certain amount of the pollination requirement is fulfilled without any intervention.

The government statistics show a much higher productivity for apples in Pakistan compared with the other countries of the HKH region, although still much lower than in more highly developed countries. These statistics did not correlate with the survey observations and appear to be misleading, but the result has been that no efforts have been made at government level to address the problem, which officially doesn't exist.

The farmers in this survey said that productivity had been declining for the past five years. However, they were essentially unaware that this could be the result of a pollination problem until 1998, when a team of scientists from the National Aridland Development and Research Institute (NADRI) of the Pakistan Agricultural Research Council (PARC), explained to them that inadequate pollination resulting from insufficient pollinizer trees and the scarcity of pollinating insects was one of the reasons for the decline in apple productivity. Thus they had never considered approaches to managing pollination.

Official institutions in Pakistan need to start thinking about possible solutions to the problem of declining yields, including pollination management to sustain apple productivity, before the situation becomes more difficult to deal with.

Issues in promoting beekeeping for pollination

Honeybees are widely recognised as being excellent pollinators and are used for pollination of various crops in most developed countries to ensure the maximum high-quality yield. There is little awareness at the policy and planning level of the potential use of honeybees to enhance the yield and quality of crops. The first effort to introduce honeybees as pollinating agents was probably made by PARC, who published a book entitled 'Honeybee Pollination of Important Entomophilous Crops' in 1987. However, subsequent research and development efforts have focused solely on commercial honey production. The Honeybee Research Institute (HBRI), under the National Agricultural Research Centre, has successfully established quite a few commercial beekeepers in Punjab and NWFP, who produce and sell honey. But honeybees are not used for pollination management.

In Pakistan, honeybees have been kept for honey production traditionally for at least two centuries. However, traditional beekeeping was exclusively with the native hive honeybee *Apis cerana*, which is well suited to the colder and more highly fluctuating temperatures encountered in the areas where apples are grown. Although bees contribute significantly towards increasing crop productivity (including mustard, berseem, shaftal, lucerne, sunflower, and sorghum), fruit bearing (including citrus species, apple, stone, and pome fruits), and seed set in forest plants (such as sisoo, eucalyptus, and willow), this is little realised by the local farmers. Commercial beekeeping has been promoted by government extension agencies in some parts of Pakistan, but the focus has been exclusively on the more productive, in terms of honey, but climatically more susceptible imported bee, *Apis mellifera*. Commercial beekeeping is rare in Balochistan because of the arid climate and lack of floral resources. The Planning and Development Department of the Government of Balochistan has published district profiles for each of the 26 administrative districts. In all these documents, beekeeping is discussed under 'Forestry', implying that it is seen as an off-farm activity for honey production only. Quotations from these official documents indicate the official perception at the policy and planning level regarding beekeeping (Table 6.6).

Although the Planning and Development Department of the Government of Balochistan considers beekeeping to be a 'wild area activity', efforts have been made from time to time to introduce beekeeping in some areas of the province. The Honeybee Research Institute of NARC, under PARC,

Table 6.6: **Beekeeping as perceived by the Planning and Development Department of the Government of Balochistan**

District profile document	Lines Quoted from Forestry Chapters
Kalat	"Because the climate of the area in general is not conducive for bee-keeping, bee-keeping activities do not exist. Some potential is available in the Harboi forest and beekeeping could be carried out on an experimental basis here. If successful, the local population could have an additional source of income". (Page 37)
Killa Saifullah	"Although honey is used in the district, bee-keeping is an alien idea as people are using wild honey only". (Page 44)
Loralai	"Due to the arid nature and scanty rainfall, there is a subsequent lack of flowers and vegetation. Thus, bee keeping is almost negligible". (Page 43)
Mastung	"Bee-keeping is not common in Mastung district. Honey is obtained from natural sources, particularly from mulberry trees. Government and the private sector could promote bee-keeping and turn it into a commercial activity". (Page 33)
Pishin	"It is surprising that, though Pishin district is one of the most important horticultural areas of Balochistan, bee-keeping is not an economic activity. The main reason put forward by the people, was that bees produce honey only in warm areas. Bees cannot survive the district's cold weather". (Page 48)
Quetta	"The district is one of the most important horticultural areas of Balochistan. Nonetheless, beekeeping as a source of economic activity does not exist on a large scale. However, in recent years this activity has been initiated in the Urak valley. The main reasons put forward by the residents for not getting involved in bee-keeping activities were that bees produce honey only in the warm areas. In the cold areas, they are not productive at all. Bees do not survive in the cold weather of the district. Thus weather is not conducive for bee-keeping. However, the area seems to have great potential for bee-keeping due to abundant flora fruit like cherries, peach, apple and mulberry". (Page 59)
Ziarat	"Bee-keepers from the North-West Frontier Province (NWFP) come to Ziarat district with their bee boxes when the fruit trees are in blossom. They stay here for two or three months and then move to other places. No information is available about local bee-keepers. On many picnic spots pure honey is sold to tourists". (Page 30)

Source: Jasra et al. 2000

has been trying since 1981 to promote beekeeping for honey production and income generation in Balochistan, but with little success. So far all attempts to initiate beekeeping in this province have failed.

What kind of beekeeping should be promoted in Balochistan?

Most of Balochistan is arid; only some high-elevation valleys in the north are capable of producing deciduous fruits like apples. Although some areas adjacent to these valleys and near water resources have flowering plants that are sources of nectar and pollen for honeybees from late spring to early autumn/ summer, the weather is cold for much of the year and there is no forage available. The main problem, however, for beekeeping in Balochistan is that temperatures fluctuate widely in the course of a single day, and *Apis mellifera* bees cannot easily be maintained under such conditions. This may be why promotion of beekeeping for honey production has been unsuccessful in this province.

In 1998, NADRI, in collaboration with HBRI and Khush-Hali Associates (a local NGO with financial assistance from ICIMOD) initiated efforts to promote beekeeping for apple pollination. The NADRI distributed colonies of *Apis mellifera* among apple growers and trained the growers to manage them for apple pollination. However, as in the past, this attempt to introduce beekeeping failed. All the colonies died within a year. In May 2000, Khush-Hali Associates sent 25 participants,

including apple farmers and agricultural development workers, to HBRI to receive more training in beekeeping and pollination management, to ensure that consistent and professionally well-equipped efforts are made to manage bees in the Balochistan environment.

The experience gained so far suggests that it may be difficult to introduce stationary beekeeping under the harsh and arid climatic conditions of Balochistan. However, it may be possible to promote migratory beekeeping because the valley areas have good weather and flora for honeybees from late spring to autumn. Some beekeepers from neighbouring NWFP already migrate their *Apis mellifera* colonies to Balochistan from spring to autumn. Thus the best approach might be to build on this and encourage migratory beekeepers to place their hives in orchards during the flowering season, whilst helping farmers to recognise the benefits and actively solicit beekeepers inputs.

Chapter 7

Apple Farming and Pollination Issues in Thimphu and Paro Valleys, Bhutan

Apple Farming in Bhutan

Bhutan has three broad agro-climatic zones. The great Himalayan zone in the north is about 30 km wide and lies above 4000m; the central inner Himalayan zone is about 70 km wide and lies at 1000 to 4000m, it contains the major forests and apple orchards of the country, and the major inhabited areas; the southern sub-tropical zone, the Himalayan foothills, is about 50 km wide and lies at 160 to 2000m. Agriculture is the main occupation of over 85% of the population (RGOB 1996). The agricultural development strategy of Bhutan lays strong emphasis on achieving self-sufficiency in food grain production, on improving the nutritional level of the rural population, and on increasing per capita income. The main food crops include rice, wheat, maize, and potatoes. Cash crops include fresh vegetables like asparagus, chillies, potatoes, and cardamom. Bhutan's agricultural policy encourages planting apples and citrus on marginal slope land that is unsuitable for cultivation of food crops like rice and wheat. Valleys and more productive land should only be used for rice or wheat farming and there is a rule that states that paddy land cannot be used to plant apples.

Apple farming (along with other temperate fruit crops) was introduced into Bhutan from Himachal Pradesh, India in the early 1960s. In the following years it emerged as the highest income earner among the fruit crops and is now the main cash crop in the country. Apple cultivation has now spread all over Bhutan, with the majority of orchards in the Thimphu, Paro, Bumthang, Ha, and Tongsa valleys in the inner Himalayan zone. The climate of these valleys is moderate at lower elevations and suitable for horticulture. The area under apple cultivation increased dramatically (about nine-fold) in the 15 years from 1980 to 1995 (Ministry of Agriculture 1999) and the total area under apple cultivation in 1997 was about 2,100 ha, about 95% in the western region and 5% in the east-central region. The average annual production increased from 3,500 tonnes in 1984 to 13,600 tonnes in 1997 (Ministry of Agriculture 1999).

Since the 1980s, apples have become an important export crop. Most of the apples that are exported go to Bangladesh. Since the 1990s, efforts have been made to export apples to other countries, especially Thailand and Sri Lanka (Ministry of Agriculture 1999). In 1998 around 4,045 tonnes of apples were exported at a rate of US $350 per tonne earning US $1.4 million (Ministry of Agriculture 1999).

Apple Productivity

The average apple productivity in Bhutan is about 6.5 tonnes per ha. Over the past few years, however, apple exports have declined slowly and steadily, from 4,314 tonnes in 1996 to 4,045 tonnes in 1998. The price per tonne has also decreased from US $ 475 per tonne in 1996 to US$ 350 per tonne in 1998. This may have been partly the result of a drop in production and fruit quality.

Several factors are likely to be responsible for the low productivity and poor fruit quality of apples in Bhutan. These include insufficient pollination of apple flowers, the physiological conditions of the trees, and unbalanced applications of mineral nutrients.

In order to study the status and problems of apple farming, the survey selected 85 households in the Thimphu and Paro Valleys, the main apple-producing areas in the country. Details of the methodology are provided in Chapter 3 (Table 3.4).

Survey Findings

Changes in climate

The temperature in both valleys generally varies from -5 to 10°C in winter, from 0 to15°C in spring, and from 10 to 30°C in summer. It usually snows two to three times between November and February. Approximately 40% of the farmers in Thimphu Valley and 20% in Paro Valley felt that the climate had been changing over the past few years. These farmers had noted an increase in temperature during winter and early spring leading to early flowering of apple trees followed by a sudden cold spell with frosts during late spring, which affected fruit set and accelerated fruit drop. Other changes observed included an increase in the frequency of hailstorms, damaging both flowers and fruit, and an increase in the incidence of various diseases and pests as a result of the warming.

Landholding size and land use

The size of landholdings of the farmers in the survey ranged from 0.4 to 8.1 ha in Thimphu Valley and from 1.2 to 14.2 ha in Paro Valley. The distribution is shown in Figure 7.1. In both Thimphu and Paro 65-70% of farmers had medium sized farms of 2 to 5 ha; only 3 of the farmers interviewed, all in Thimphu Valley, had marginal farms of less than 1 ha; 7 farmers in Thimphu and four in

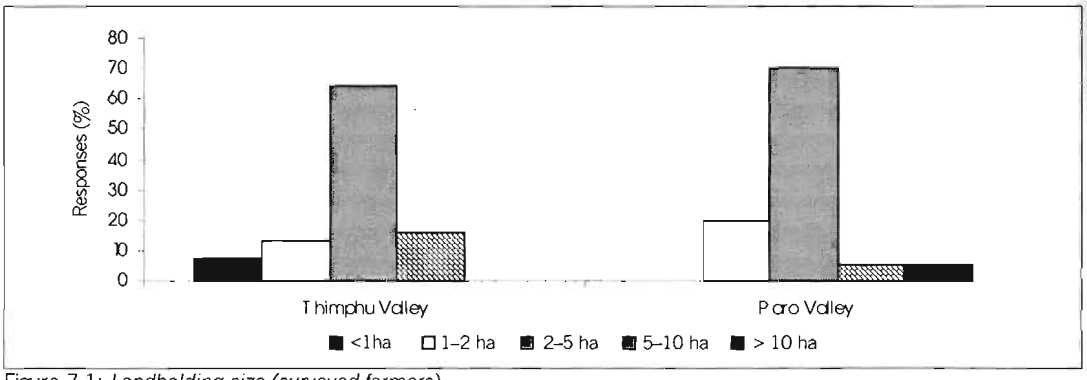


Figure 7.1: *Landholding size (surveyed farmers)*

Paro Valley had large farms of more than 5 ha. The largest farms were found in Paro Valley. The average landholding size per household in Thimphu Valley was 3.6 ha, of which 25% on average was used for staple food crops like rice and wheat, 14% for cash crops such as asparagus, potatoes, chillies, and fruit other than apples like pears, peaches, and plums (grown by a few farmers on a limited scale), and about 61% for apples. In Paro Valley, the average landholding was 3.5 ha per household, 46% of which was used for food crops, 14% for cash crops other than apples, and 40% for apples. Apples were thus the main cash crop in both valleys.

All the farmers in both valleys had apple trees, but whereas almost all the farmers in Paro Valley also grew cash crops and basic food crops, in Thimphu Valley less than half grew staple food crops and only two-thirds other cash crops (Table 7.1).

Apple farming in Thimphu and Paro Valleys

The scale of apple farming in Thimphu and Paro Valleys is shown in Table 7.2. In Paro Valley the great majority of farmers had between 100 and 300 trees or less, whereas in Thimphu half of the farmers had more than 300 trees and a third more than 500. The main commercial varieties were Royal Delicious, and Red Delicious, and occasionally Red Fuji, Golden Delicious and Jonathan were planted as pollinizers, but the proportion was only 7 to 10%. Apples were the main cash crop for 93% of the households surveyed in Thimphu Valley and for 98% of those in Paro Valley, and a supplementary source of income for the remainder.

Apple production and selling

The average total annual production of apples per household is shown in Table 7.3. Nearly two-thirds of the farmers in Paro Valley produced less than 10 tonnes per year, and nearly a quarter between 10 and 20 tonnes. In Thimphu Valley, where the average area of orchards per household was greater, only one-third of farmers produced less than 10 tonnes per year and nearly a quarter

Table 7.1: Crops grown in Thimphu and Paro Valleys (percentage of responses)

Crops	Thimphu Valley farmers	Paro Valley farmers
Apples	100	100
Cash crops other than apples	64	95
Staple food crops (maize, wheat, rice)	43	98

Table 7.2: Scale of apple farming in Thimphu and Paro Valleys (surveyed farmers)

	Thimphu Valley	Paro Valley
Average area of apple orchards per household, ha	2.2	1.4
Percentage of households with		
Less than 100 trees	11	25
100–300 trees	39	63
300–500 trees	16	5
500–1000 trees	27	0
>1000 trees	7	7
Commercial varieties	Royal Delicious and Red Delicious; a few farmers had planted Red Fuji	Royal Delicious and Red Delicious; a few farmers had planted Red Fuji
Pollinizer varieties	Golden Delicious and Jonathan	Golden Delicious and Jonathan
Pollinizer proportion (%)	7–10	7–10

Table 7.3: **The production and sale of apples in Thimphu and Paro Valleys (surveyed farmers)**

Parameter	Thimphu Valley	Paro Valley	Remarks
Percentage of farmers producing			
<10 tonnes	34	63	
10–20 tonnes	23	22	
20–30 tonnes	20	5	
30–50 tonnes	18	3	
50–100 tonnes	5	7	
range	4·75	4·65	
Apple market (% responses)			
Exported	95	56	
Sold locally	5	44	
Export destination (% responses)			
Bangladesh only	88	90	
India only	–	5	
Bangladesh and India	12	5	
Price (US$ per kg)			
Export market	0.26 · 0.43	0.26 · 0.43	The local price was the same as the export price. Some big farmers sold rejected apples locally at a lower price.
Local market	0.26 – 0.43 (0.11 · 0.17 for rejected fruit)	0.26 · 0.43 (0.11 · 0.17 for rejected fruit)	Price depends upon the grade of apple
Home consumption			A few farmers kept some apples for home consumption
Is apple cultivation increasing? (% responses)	100	100	Because apples are the main source of cash income for farmers, the area under apple cultivation is increasing.

more than 30 tonnes. All farmers felt that total apple production was increasing as more and more land was taken for apple orchards.

Almost all the farmers in Thimphu Valley and a little more than half in Paro Valley exported their produce, the great majority to Bangladesh and a few to India or to both countries (Table 7.3). The remainder, mostly farmers with low production, sold their apples in local markets. The price obtained depended on the quality of fruit and was similar whether the fruit was sold locally or exported (Table 7.3). Some windfall and low-grade fruit, including fruit rejected for export, was sold locally at a very low price of about US $ 0.06 - 0.17 equivalent per kg.

Farmers' understanding of apple pollination

Almost all farmers had a good understanding of apple pollination and its value. Most of the orchards had been planted in the 1980s or later with support from the extension services of the Ministry of Agriculture. Both commercial and pollinizer varieties of apple trees are provided to farmers through the extension system, and at the same time farmers are informed about the ecological and economic value of pollination in apple farming, and the importance of planting the appropriate proportion of pollinizer varieties in the orchard and where these should be located. Only two farmers in Paro Valley, who had planted their orchards in the 1970s, did not know about the importance of pollinizer proportion in their orchards, and these and one farmer in Thimphu had learned about pollination from neighbours rather than government sources.

About 60% of Bhutan is still forested and there is a great diversity and abundance of various insect pollinators. Moreover, since honey hunting is considered sinful, people do not hunt wild honeybee colonies for honey and there are still plenty of wild honeybee (*Apis laboriosa*) nests in these forests. Almost all farmers had seen different types of insect pollinators on apple flowers in their orchards including wild honeybee species, bumblebees, solitary bees, and flies.

Despite the prevalence of insects, only 6% of farmers in Thimphu Valley and 38% in Paro Valley felt that the existing populations of natural insect pollinators were sufficient to pollinate the increasing area under apple cultivation; 42% of farmers in both valleys thought the populations were not sufficient and the remainder had no opinion. As far as the farmers own orchards were concerned, only 11% of those in Thimphu Valley, and 56% in Paro Valley reported that their crop was being adequately pollinated (Figure 7.2). Three of the five satisfied farmers in Thimphu Valley were already keeping colonies of honeybees for apple pollination (one kept *Apis cerana* and two *Apis mellifera*), while most of the satisfied farmers in Paro Valley reported that their orchards were near forests and close to nests of the giant wild bee *Apis laboriosa*.

Close to half of the farmers in both valleys thought that the lack of pollinating insects was an important reason for the inadequate pollination, somewhat less than 20% (also) cited the lack of appropriate pollinizer proportion, and three farmers in Thimphu Valley and two in Paro Valley mentioned a lack of synchronisation of flowering between the commercial and pollinizer varieties (Figure 7.3).

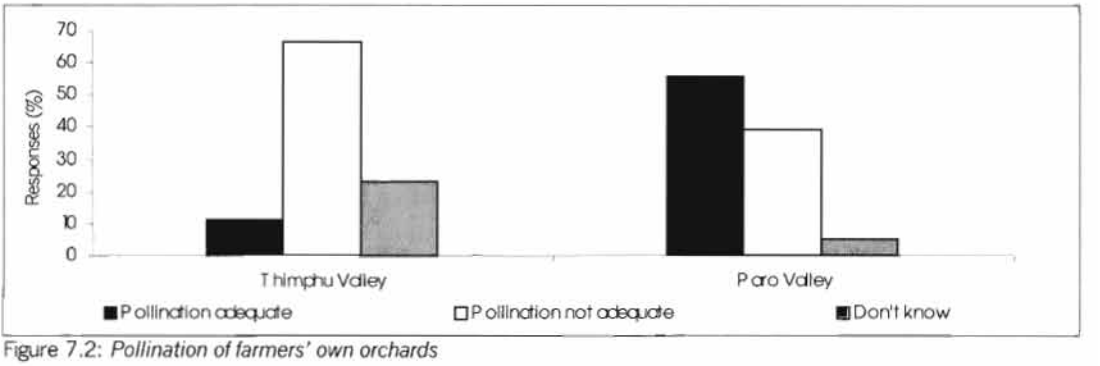


Figure 7.2: *Pollination of farmers' own orchards*

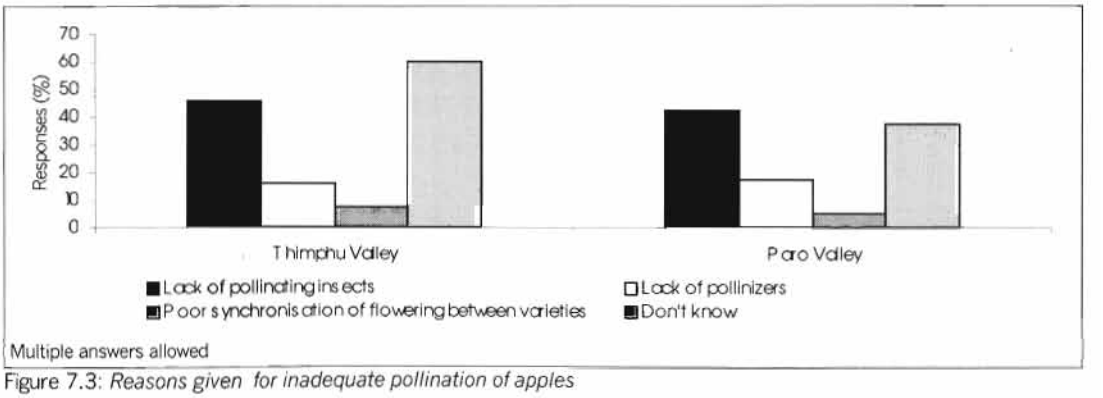


Figure 7.3: *Reasons given for inadequate pollination of apples*

Nearly a third of farmers in Thimphu Valley either kept bees already (4 farmers, 9% of the total) or would like to keep bees for pollination if they were provided with training and honeybee colonies (21%). Of the beekeepers, one had nine colonies of *Apis cerana* and the others had three, three, and six colonies of *Apis mellifera*. No farmers in Paro Valley kept bees, but 15% (6 farmers) said they would like to. There was only one commercial beekeeper in Thimphu Valley and no system for renting honeybees colonies for pollination.

Pesticide use and its impact on natural insect pollinators

All the farmers except one in Thimphu Valley used pesticides in their orchards. All used spray oils (TSO), and in addition a number used melathion, captan (only in Paro Valley), and other chemicals. These pesticides are available from government stores at highly subsidised prices. Some suggestions were made, however, that there were problems of procurement of pesticides by government research centres and that these should be looked into. Generally, government extension workers tell farmers which pesticide to use, when, and how much, but some farmers felt this information was insufficient. All the farmers sprayed 2-3 times in a season, once before flowering and one or two sprays of fungicides after fruit set, depending upon the pest infestation and expert advice. Farmers never sprayed during flowering. Thus pesticide use was much less than in Himachal Pradesh (India) or Maoxian County (China), and this could be another reason why the populations and diversity of natural insects were comparatively high in Bhutan (Table 7.4).

Although farmers were careful with spraying, they were not fully aware of the potential harmful affects. Almost all farmers in Paro Valley and more than half in Thimphu Valley (95% and 55%) thought that pesticides only kill harmful insects and that they do not kill bees and other natural insect pollinators.

Institutional support desired

All farmers reported that they were getting enough support and training on apple farming and most farmers said they would like the institutions to continue such support in the future. Less than half of those in Thimphu Valley and two-thirds in Paro Valley would have liked some financial support, without specifying for what, and a few farmers said they would require financial support if there was a bad crop or total crop failure (Table 7.5). Farmers also wanted agricultural institutions and scientists to study pollination problems and suggest ways of improving it. A small number

Table 7.4: **Use of pesticides in apple orchards (surveyed farmers, percentage of responses)**

	Thimphu Valley	Paro Valley
Use pesticides	98	100
Pesticides used*		
TSO	100	100
Melathion	16	41
Captan	–	22
Other pesticides	5	12
Number of sprays per season	2–3 once before flowering and once or twice after fruit set	2–3 once before flowering and once or twice after fruit set
Sources of pesticides	Government stores	Government stores

*Individual farmers used more than one type of pesticide

Table 7.5: **Institutional support desired (percentage of responses)**		
Type of support	Thimphu Valley	Paro Valley
Training in orchard management and the use of beekeeping for pollination	100	98
Financial support	39	73
Increasing awareness	100	98
Conduct proper studies on pollination and the advantages of beekeeping	52	24
Provide training on the use of beekeeping for pollination	5	9
Study causes of low yield and diseases and suggest solutions	68	0
*Some farmers wanted more than one type of support		

wanted to have training on pollination management through beekeeping. In Thimphu Valley 68% wanted more information on diseases and pests and their control (Table 7.7).

Summary of Issues

The area under apple cultivation and the total production of apples in Bhutan are increasing, but the productivity (yield per hectare) is not. Farmers have started to realise that productivity could be increased with better orchard management and better pollination, and some are becoming interested in keeping honeybee colonies for apple pollination despite religious taboos. Most farmers in Thimphu Valley and a large number in Paro Valley thought that pollination of their apple trees was insufficient, but the level of concern varied. The low level of pollinizers is also likely to be a contributing factor to the poor pollination but as yet it has not become a subject of concern.

Many farmers still perceive little need to manage pollination. They are satisfied with their present income from apples, which is already more than from any other cash crop. Apples are only planted on marginal slope land unsuitable for cultivation of food crops like rice and wheat, so that any yield may seem to be a bonus. Total production is increasing as more orchards are planted, and this masks the fact that productivity is still quite low.

The pollination problems also appear to be less marked in Bhutan than in some of the other areas in the study. The country still has much natural forest and orchards planted close to these forests benefit from the presence of wild honeybees and other insect pollinators. This could change, however, if too large areas of forest are replaced with orchards. Another advantage is that pesticide use is limited and natural insect pollinators are less threatened by spraying in the orchards themselves.

How to promote beekeeping

Clearly there is still room for increasing apple productivity in Bhutan. Farmers should increase the number of pollinizer trees (or grafts) in their orchards. At the same time the use of honeybees to increase the number of pollinators in the orchards should be encouraged.

The first step in promoting the wider use of honeybees for apple pollination is to create awareness among farmers and institutions about the importance of honeybees in pollination. This can be done through proper research and on-farm demonstrations of the effect of honeybee pollination on apple yield and quality. The second step is to build the capacities of farmers and institutions, which can be achieved through training farmers and extension workers in managing honeybees for crop pollination.

Chapter 8

Apple Farming and Pollination Issues in Jumla Valley, Nepal

Apple Farming in Nepal

Nepal is located on the southern flank of the Central Himalayan range. It covers an area of 147,181 km^2. It is bordered by India along the eastern, southern, and western frontiers, and by China to the north. Altitudes range from 75 masl in the Terai and inner Terai zone to over 8,000m in the greater Himalayan region.

According to official statistics, apple trees have been planted in 55 of Nepal's 75 Districts, but in most of these areas the plantations are young. Only 3,200 of the total 4,970 ha of orchards contain mature productive trees; these produce about 30,464 tonnes of apples annually. The average annual return from this crop is about US$4 million (Ministry of Agriculture 1999). The district wise distribution is highly variable, from as little as 3.3 ha in Parbat to 388 ha in Solukhumbu (Agricultural Statistical Report 1999).

This study was launched to collect information on apple productivity issues in Nepal, particularly those related to pollination. Jumla was selected as a representative area. The field surveys were conducted among 60 farmers in ten village development committee areas (VDCs). The details are given in Chapter 3 (Table 3.5).

Apple farming in Jumla

Jumla is one of the three major apple-producing districts of Nepal. It ranks third after Solukhumbu and Mustang in terms of apple-growing area, and second in terms of production. The revenue records show 382 ha of apple plantations in Jumla, of which 274 ha have mature trees, producing about 2690 tonnes of apples annually (Agricultural Statistics Report 1998/99). Recent records (2001) of the Agriculture Development Office in Jumla show an increase to 461 ha with a production of 4600 tonnes in 2001. This may still be an underestimate, under reporting occurs as a result of land tenureship problems and related to tax and revenue returns. Local farmers reported unofficial estimates of about 1,000 ha of apple plantations in 2001.

Apples were introduced to Jumla about 30 years ago, but most plantations are only 10-15 years old. Apples have only recently become an important cash crop for farmers in this area. Jumla is a

remote mountain district and the only way to transport apples to the nearest market town in Nepalgunj is to airlift the produce. The airfare is high and not affordable by poor farmers. Often the cost of airlifting makes the price of apples produced in Jumla more expensive than those imported from India or China. Thus most farmers do not try to sell apples outside the valley. The situation is changing, however. In 1999 the DoA started to help the apple farmers of Jumla District to sell their fruit. The Department provides special support in the form of subsidies towards the cost of cardboard boxes (28%) and airlifting the apples to the nearest lowland market in Nepalgunj (58%). As a result contractors from market towns have started approaching apple farmers in Jumla and some farmers now sell their apples through these contractors. Jumla apples are now available in Nepalgunj, Butwal, Surkhet, and Kathmandu, the local price has also risen, and farmers' incomes have increased.

Farmers started to become interested in using honeybees to manage apple pollination when the DoA started to help them sell their fruit. In 1999, a local NGO called Surya Social Service Society (4S) interacted widely with apple farmers and explained the importance of managing pollination in apples. Later, in collaboration with the DoA and financial support from ICIMOD, 4S organised an awareness-cum-training course for leading apple farmers in the district. As a result, since April 2000, a few farmers in Kholikot and Mahatgaon have started keeping honeybee colonies in their orchards for the first time.

Survey Findings

Climate change and its impact on apple productivity

Records from the meteorological station in Chhinalagna, Jumla show that on average the temperature in the valley varies from –12 to 10°C in winter, from 15 to 22°C in spring, and from 25 to 30°C in the summer. It snows between November and February and sometimes in March.

The great majority of farmers (93%) reported experiencing a marked change in climate during the past decade. About 50% of farmers said that it had become warmer and the same number reported less snowfall, one farmer thought the snowfall period had shifted to late winter. Thirteen per cent of farmers said that rainfall had also decreased, and 8% reported unpredictable and untimely rains accompanied by hailstorms.

All except three farmers (95%) considered that the change in climate had had an adverse impact on farming, particularly on apple farming. Two-thirds felt that climate change was contributing to a decline in yield and quality (size, colour, and taste) of apples. The early rise in temperature during the winter months was leading to early flowering of the apple crops, but then the weather suddenly became cold during spring accompanied by an increase in the frequency of hailstorms, which damage both the flowers and the fruits. Moreover, as a result of the increase in temperature the incidence of various diseases and pests was also increasing. Nearly a quarter of the farmers (22%) also considered that the change in climate was having an adverse impact on apple pollination because of more rain during flowering which washed away pollen grains leading to poor pollination of apple flowers.

Landholdings and land use

The landholding size among the surveyed farmers ranged from 0.1 to 15 ha, but 82% of the farmers had marginal holdings of less than 1 ha and only one farmer owned more than 10 ha (Figure 8.1). The average size of landholding per household was 1.1 ha, of this on average 0.6 ha (55%) was used for basic food crops, 0.1 ha (9%) for cash crops other than apples, and 0.4 ha (36%) for apple farming (Figure 8.2). Apples are an important cash crop for many households in Jumla. All the farmers had apple trees. The main food crops included rice, wheat, maize, barley, buckwheat, and millets such as finger millet and foxtail millet. Cash crops other than apples included potatoes, beans, mustard, and soybeans; and fresh vegetables such as cauliflower, cabbages, tomatoes, onions, garlic, and chillies. One farmer had started growing saffron and another walnuts and peaches (Table 8.1).

Apple farming

Most of the orchards were small, the average size was 0.4 ha and only 7% of the farmers had apple orchards bigger than 1 ha. In Nepal, apples have not assumed the same importance as a cash crop as in some other countries in the Hindu Kush-Himalayan (HKH) region. This is mainly

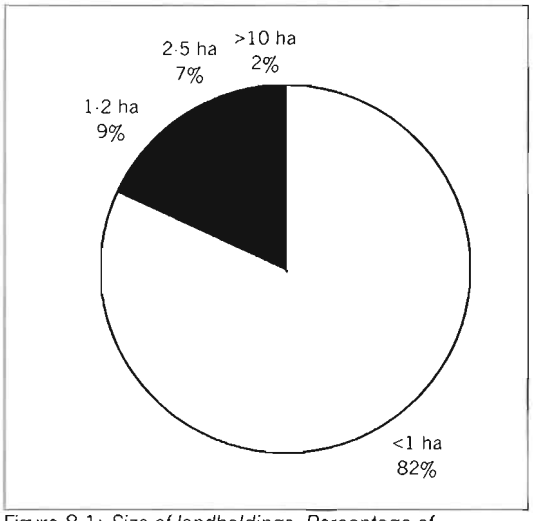


Figure 8.1: *Size of landholdings. Percentage of surveyed farmers owning different amounts of land*

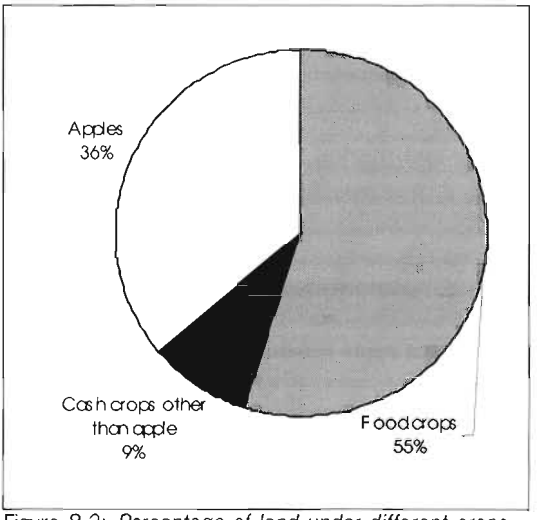


Figure 8.2: *Percentage of land under different crops (surveyed households)*

Table 8.1: **Crops Grown in Jumla Valley**

Crop	Percentage of responses*
Apples	100
Cash crops other than apples	
Potatoes	72
Beans	63
Mustard	30
Soybeans	27
Fresh vegetables	35
Basic food crops	
Rice, wheat, maize, and barley	79
Buckwheat	52
Millets (including finger millet, foxtail millet)	82

*Farmers grew more than one crop

because the best apple growing areas are in remote mountain regions with no road access. Among the farmers interviewed, almost equal numbers reported apples being their main cash crop (38%), one among a number of cash crops (27%), and not very significant as a cash crop (35%). This last group comprised those whose orchards were far away from Jumla Bazaar, for whom the cost of transportation was more than the income earned from selling the apples.

All the farmers had planted Delicious varieties of apples including Royal Delicious, Red Delicious, and Golden Delicious. A few farmers had planted other varieties like Jonathan, Chocolate, Kashmiri, and Mashadi. Most farmers had planted a mixture of varieties in their orchards but only a very few farmers knew about pollinizer varieties and none were clear about the proportion of pollinizers in their orchards. Five farmers (8%) had only one variety in their orchards, and thus no pollinizers, clearly indicating a lack of knowledge about the importance of pollinizers.

Apple production and sale

Nearly half of the farmers had no clear idea of their total annual apple production; of those who did know, nearly two-thirds were producing between one and five tonnes, only five farmers produced 10 tonnes or more (Table 8.2).

Slightly more than half the interviewed farmers sold their apples in Jumla Bazaar and about a quarter sold them locally in villages. The remainder transported the apples to outside markets including Nepalgunj, Surkhet, and Kathmandu (Table 8.2). The price of apples depended on fruit quality and market place; it was highest in markets outside Jumla and lowest in local villages (Table 8.2). Sometimes in remote villages apples were sold at a piece rate rather than by weight,

Table 8.2: **Apple production and sale (surveyed farmers, percentage of responses)**

	No. of farmers (%)	Remarks
Household apple production (tonnes)		
<1	18	One farmer produced 20 tonnes, one 12 tonnes, and three others 10 tonnes of apples each
1–2	20	
2–5	10	
>5	8	
Range	0.1-20	
No response	44	
Markets		
Outside Jumla (Nepalgunj, Surkhet, and Kathmandu)	18	Only farmers producing more than five tonnes, transported and sold apples outside Jumla
Jumla Bazaar	55	
Villages	27	
Price (US$ per kg)		
Outside Jumla District	0.27 - 0.4 (depending on fruit quality)	Farmers in villages more than six hours' walk from Jumla Bazaar sold their apples in local villages and/or converted them to other products. Farmers kept some apples for home consumption
Jumla Bazaar	0.11 – 0.20	
Local villages	0.05 – 0.13	
Home consumption		
Trends in apple cultivation		
Increasing	100	Both farmers and government agencies realise the potential for and are promoting apple farming in Jumla Valley.

221-294 fruits per US$1 depending upon the size of the fruit, and a few farmers also bartered their apples for food grain and beans (barter rate 20 apples for about 4 kg of beans). Three farmers had contracted their standing apple crop at a rate of US$ 0.13 per kg for the estimated total production.

In the remote villages the farmers were unable to sell sizeable quantities of their apple production. Much of the fruit was wasted. Some farmers dried the apples, particularly Delicious varieties, and sold them to trekkers and/or in Jumla Bazaar at a rate of US $6.7 per kg, or in a few cases exported them to other parts of Nepal. Some made apple jam, and others an alcoholic drink called syau ko rakshi (apple brandy), particularly from the sour varieties of apple, which sold at about US$ 0.33 per litre.

Information from a key informant indicated that more than 50% of the total annual apple production in Jumla (some 2,600 tonnes out of 4,600 tonnes) is sold within Jumla District and the remainder sent to lowland markets in Nepal.

Farmers' understanding of apple pollination

Just over half the surveyed farmers had some awareness about pollination, although no technical knowledge (Table 8.3). They knew that pollination was necessary for the production of fruits and

Table 8.3: **Farmers' awareness about apple pollination and pollinating insects (surveyed farmers, percentage of responses)**

	Farmers' response (%)	Remarks
Farmers aware about pollination	55	Farmers were aware of the need for pollination but had no technical knowledge of how to manage it
Insects observed in orchards	75	About 12% of farmers said they had seen insects in their orchards, but apart from honeybees and bumblebees they were all pests
Types of insects seen on apple flowers*		
Honeybees	75	There is a low use of pesticides in the valley and still large natural populations of insects
Bumblebees	22	
Syrphids	22	
Butterflies	25	
Other insects	30	
Natural insect pollinators sufficient for apple pollination?		
Yes	15	
No	13	
Don't know	72	
Natural insect populations declining?		
Yes	35	
No	10	
Don't know	55	
Pollination in own orchard adequate?		
Yes	20	
No	15	
Don't know	65	
Factors responsible for inadequate pollination		
Lack of pollinating insects	12	
Lack of pollinizer trees	3	
Don't know	85	

*Individual farmers saw more than one kind of insect on apple flowers

seeds but did not know whether it could be improved or managed. The farmers had learnt about pollination from government extension services, from reading pollination-related literature, from when they were studying in school, from beekeepers, and from Radio Nepal programmes on horticultural crops (Figure 8.3).

Three-quarters of farmers had seen different types of insect pollinators on apple flowers in their orchards including honeybees, bumblebees, syrphid flies, and butterflies. Some had also seen harmful insects (pests). Of those who reported seeing insects, most had seen honeybees and around a quarter each bumblebees, butterflies, flies, and other insects (Table 8.3). Pesticide use is very limited in this remote valley and there is a great diversity and abundance of natural insect pollinators. However, three-quarters of the farmers didn't know whether the populations of natural insects were sufficient for apple pollination, and only 15% thought they were. One-third of farmers thought that the populations of natural insect pollinators were declining, and 55% didn't know (Table 8.3). Most thought pesticides were responsible for the decline (although pesticide use is very limited in Jumla), followed by change in climate, and increasing area under cultivation (Figure 8.4).

Nearly two-thirds of farmers didn't know whether pollination in their orchards was adequate, and only 20% thought it was (Table 8.3). Another 15% thought their crop was not being adequately pollinated because they had noticed a drop in productivity. The great majority had no idea of the reasons for inadequate pollination, a few identified lack of pollinators, and two farmers lack of pollinizers (Table 8.3).

Beekeeping

Beekeeping in Jumla is a small-scale, income-generating activity where individual farmers keep a few colonies of the indigenous Himalayan hive honeybee (*Apis cerana*) in traditional log hives with minimum management. About 35% of the farmers in the survey kept from 1 to 13 colonies of *Apis cerana* in traditional log hives, but only one kept the bees in his apple orchards at the time of flowering. There are no commercial beekeepers in Jumla; the climate, lack of motorable roads, and overall poor farming, limit the potential for commercial beekeeping in this district.

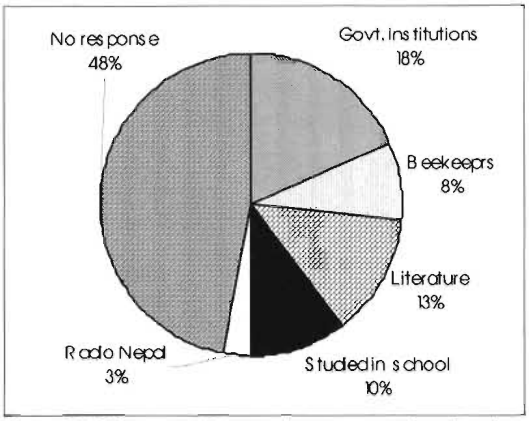


Figure 8.3: *Sources of farmers' awareness about apple pollination (percentage of responses)*

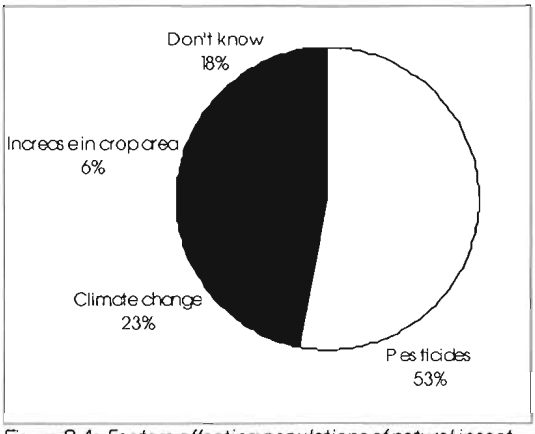


Figure 8.4: *Factors affecting populations of natural insect pollinators (percentage of responses)*

Pesticide use and its impact on natural insect pollinators

The use of pesticides is summarised in Table 8.4. Only one-third of the farmers used any pesticides in their orchards, in other words most of the apples were produced 'organically'. The commonly used pesticides include metacid, melathion, thiodan, sumithion, and Bordeaux mixture, they were obtained from government stores. The farmers only sprayed once or twice a year and never when the apples were in flower. Only 7% of the farmers sprayed twice, and only one farmer three times. Around half of the farmers thought that pesticides killed natural insects, but mainly harmful insects, and the remainder didn't know.

Institutional support desired

All except one farmer said they would like to have some form of institutional support towards increasing awareness and training in apple farming (Table 8.5); around a quarter reported that they had already received some form of awareness or training support from NGOs or government agencies. Most wanted training in orchard management, and improved methods of beekeeping, and about half wanted to have support towards increasing awareness and technical knowledge about pollination and the use of honeybees. About 40% of farmers wanted financial support to buy orchard equipment and honeybees and/or for study tours to China, India, and countries in Europe where apples are a main cash crop. Farmers also wanted government agencies and non-government organisations (NGOs) to provide colonies of honeybees for apple pollination. A few farmers wanted horticultural scientists to conduct studies on apple pollination-related issues in Jumla Valley, and some wanted government help to build cold stores to help prevent fruit rotting before it can be transported.

Table 8.4: **Use of pesticides in apple orchards (surveyed farmers, percentage of responses)**

Parameter	Responses (%)	Remarks
Pesticides used in orchards		
Yes	33	
No	67	
Types of pesticide		
Metacid	46	
Melathion, thiodan, or sumithion	24	
Bordeaux mixture	30	
Number of sprays	1–2	Usually once at the beginning of the season and occasionally after fruit set
Source of pesticides		Government stores
Do pesticides kill insects?		
Yes	52	Farmers don't spray during flowering
Don't know	48	

Table 8.5: **Desired institutional support (percentage of responses)**

Type of support	Responses (%)	Remarks
Training in orchard management and beekeeping	80	Training in orchard management, improved methods of beekeeping, and pollination management using honeybees
Financial support	40	Support for study tours to horticulturally advanced countries, to buy farm equipment, and for planting materials
Increasing awareness	65	Support towards increasing awareness of technical aspects of pollination, including honeybee pollination and the impact of pesticides

Summary of Issues

Around half of the farmers in Jumla had almost no knowledge of pollination; many farmers had not even heard the word 'pollination' before 1999. At the same time farmers perceived little need for intervention. Although apple productivity has been lower than expected, farmers have not been particularly concerned because the inaccessibility of the area by road means that there is only a small market for the fruit anyway. Even today many of the apples produced in the villages rot and go to waste due to a lack of proper post-harvest handling and selling, although some produce is dried and much is used for making brandy. Thus increasing productivity has not been a priority concern. For the past two to three years the situation has been changing. In order to promote apples as a cash crop, the government is now providing different kinds of support to apple farmers and trying to encourage farmers to plant more apples. Awareness campaigns by NGOs and improved selling facilities are creating a wider understanding among farmers about the value of apples as a cash crop.

Pollination is probably also less of an issue in Jumla than in other areas of the HKH region. Beekeeping with *Apis cerana* is a common tradition; farmers keep the bees in traditional log hives for honey production. Although the bees are not managed explicitly to pollinate apples, some pollination always takes place because many colonies are kept near apple orchards. Similarly the low levels of pesticide use mean that there are extensive populations of natural insect pollinators. Furthermore, because apple production is less commercially focused, farmers haven't been tempted into planting extensive areas of a single variety. The orchards contained a mixture of trees, and unwittingly most probably have a reasonable number of pollinizers.

Because of the facilities provided by the government, apples are gaining in importance as a cash crop. Slowly farmers are feeling the need to improve productivity, produce more apples, and earn more money. This is the ideal time to promote beekeeping for apple pollination and train more farmers.

How to promote beekeeping for apple pollination

Beekeeping with *Apis cerana* is a common income-generating tradition in Jumla. Already over 50% of farmers in the district keep colonies of the native bee, *Apis cerana* in traditional log hives for honey production. The need now is to promote the wider use of beekeeping for pollination by raising awareness about its value in apple production, and in particular to promote beekeeping in movable-frame hives so that these hives can be transferred to orchards at the time of apple flowering. This can be done through on-farm research and demonstrations on the effect of honeybee pollination on apple yield and quality. Farmers may also need some training in managing honeybees in improved hives if they are to be used for pollination.

Part 3

Annexes

Annex 1
Bibliography

Bangyu, K.; Tan, K. (1996) *Honeybee Genetic Diversity and its Value to Mountain Farming.* Paper presented at an Expert Meeting on Agro-biodiversity in the HKH Region, 11–15 June 1996, Chengdu, China

Bangyu, K.; Tan, K.; Haiou, K. (1997) *Present Situation and Expectancy of Utilising Honeybees for Pollination in the Mountain Areas of China,* a report submitted to ICIMOD, Kathmandu, Nepal

Banskota, M. (1992) *Dimensions of Unsustainability in Nepal: Economic Policies for Development.* Manila: Asian Development and Kathmandu: ICIMOD

Batra, S.W.T. (1995) 'Bees and Pollination in our Changing Environment.' In *Apidology,* 26: 361–370

Batra, S.W.T. (1997a) 'Bionomics of *Lasioglossum (Evylaeus) matianense* Bluthgen (*Hymenoptera: Halictidae*), the Predominant Pollinating Bee in Orchards at High Altitude in the Great Himalaya of Garhwal, U.P., India.' In *Proceedings of Entomological Society,* 99: 162–170

Batra, S.W.T. (1997b) 'Solitary Bees for Orchard Pollination.' In *Pennsylvania Fruit News,* April 1997

Chauhan, P.S.; Mankotia, M.S. (1998) 'Bioregulators and Mechanical Aids in Pollination and Fruit Set in Temperate Fruit Crops'. In Verma, L.R.; Jindal, K.K. (eds) *Fruit Crops Pollination,* pp 48–58. Ludhiana, India: Kalyani Publishers

Crane, E. (1976) 'The World Honey Production'. In Crane, E. (ed) *Honey: A Comprehensive Survey,* pp 115–151. Cardiff: IBRA

Crane, E. (1990) *Bees and Beekeeping: Science, Practice and World Resources.* Oxford: Heinemann Newnes

Department of Agriculture (1999) *Agricultural Statistics of Balichistan.* Quetta: Government of Balochistan

Department of Horticulture (1998) *Annual Report.* Shimla: Government of Himachal Pradesh

Deslauriers, C. (undated) *Producing Apples in Eartern and Central Canada: Pollination.* Agriculture Canada Publication 1899/E. Kentville (Canada): Atlantic Food and Horticulture Research Centre. URL: http://res2.agr.ca/kentville/pubs1899/i1899_e.htm

Dulta, P.C.; Verma, L.R. (1987) 'Role of Insect Pollinators on Yield and Quality of Apple Fruit.' In *Indian Journal of Horticulture*, 44:274–279

Free, J.B. (1964) 'Comparison of the Importance of Insect and Wind Pollination of Apple Trees.' In *Nature*, 201: 726–727

Free, J.B. (1966) 'The Pollinating Efficiency of Honeybee Visits to Apple Flowers.' In *Journal of Horticultural Science*, 41: 91–94

Free, J.B. (1993) *Insect Pollination of Crops* (2nd edn), pp 684. London: Academic Press

Gautam, D.R.; Uppal, D.K.; Jindal, K.K. (1994) 'Two New Crab Pollinizer Varieties Evaluated.' In *Horticulture Journal*, 7: 15–22

Government of Pakistan (1999) *Agricultural Statistics of Pakistan 1998-88* Ministry of Food, Agriculture and Livestock , Economy Wing. Islamabad:. Government of Pakistan

Government of Tibet Autonomous Region (1997) *Agricultural Census of Tibet.* Lhasa: Government of TAR

Government of China (1997) *Agricultural Statistics of China.* Beijing: Government of China

Hafeez, S (ed.) (1998) *Appropriate Farm Technologies for Cold and Dry Zones of the Hindu Kush-Himalayas.* Kathmandu: ICIMOD

He, Y.; Chen, K.; Xie, J. (1998) *Apple Farmers' Survey on Pollination Problems*, a report submitted to ICIMOD, Kathmandu, Nepal

High Value Agriculture Ltd (1998) *The Crisis facing Bhutan's Apple Producers*, a report submitted to REID, MOA, Royal Government of Bhutan and UNDP

ICIMOD (1998) *Promotion and Development of Beekeeping through Preservation of Indigenous Apis cerana*, a report submitted to the Federal Chancellery of Austria.

Jasra, A.W.; Ashfaq, S.; Kasi, M.A.; Sharif, M. (2000) *Apple Pollination Problems in Balochistan, Pakistan*, a report submitted to ICIMOD, Kathmandu, Nepal

Jodha, N.S.; Shrestha, S. (1993) 'Sustainable and More Productive Mountain Agriculture: Problems and Prospects'. In *Mountain Environment and Development –Part 3 (Thematic Papers)*, pp 1-65. Kathmandu: ICIMOD

Khan, D.A. (1998) *Agriculture Research Master Plan: Horticulture Component*, a report submitted to Government of Azad Jammu and Kashmir, Pakistan

Koirala, G.P.; Thapa, G.B. (1997) *Food Security Challenges: Where does Nepal Stand?* (Research Report Series No. 36). Kathmandu: HMG, Nepal and WINROCK International

Mayer, D.F.; Johansen, C.A.; Lunden, J.D. (1985) 'Bee Pollination of Fruit Trees'. In *Pollination and Fruit Set: Proceedings of the Short Course, Good Fruit Grower, Washington*

McGregor, S.E. (1976) *Insect Pollination of Cultivated Crop Plants.* Washington, DC: United States Department of Agriculture

McGregor, S.E. (2002) *Insect Pollination of Cultivated Crop Plants*, continuously updated version of book published in 1976 by US Department of Agriculture. URL: http://bee.airoot.com/beeculture/book

Ministry of Agriculture, HMGN (1999) *Statistical Information on Nepalese Agriculture 1998/99.* Kathmandu: His Majesty's Government of Nepal, Agricultural Statistical Division

Ministry of Agriculture, RGB (1999). *Agricultural Statistics of Bhutan.* Thimphu: Royal Government of Bhutan

Morse, R.A.; Calderone, N.W. (2000) *The Value of Honey Bees as Pollinators of US Crops in 2000.* URL: http://bee.airoot.com/beeculture/pollination2000

Nadda, A.L.; Tiwari, S.C. (1998) 'Economics of Apple Pollination by Honeybees in Himachal Pradesh'. In Verma, L.R.; Jindal, K.K. (eds) *Fruit Crops Pollination*, pp 393–400. Ludhiana, India: Kalyani Publishers

National Horticulture Board (1998) *Annual Report.* New Delhi: Government of India

Partap, T. (1995) *High Value Cash Crops in Mountain Farming: Mountain Development Processes and Opportunities*, Mountain Farming Systems' Discussion Paper Series No. MFS 95/1. Kathmandu: ICIMOD

Partap, T. (1998) ' Agricultural Sustainability Challenges in Upland Areas of Semi Arid and Humid Asia.' In: *Proceedings of the Study Meeting on Sloping Land Agriculture and Natural Resources Management*, pp 39–84. Tokyo: Asian Productivity Organisation

Partap, U. (1997) *Bee Flora of the Hindu Kush-Himalayas: Inventory and Management.* Kathmandu: ICIMOD

Partap, U. (1998) 'Successful Pollination of Apples in Himachal Pradesh.' In *Beekeeping and Development*, 48: 6–7

Partap, T. (1999) 'Sustainable Land Management in Marginal Mountain Areas of the Himalayan Region.' In *Mountain Research and Development*, 19: 251–260

Partap, U.; Partap, T. (1997) *Managed Crop Pollination: The Missing Dimension of Mountain Agricultural Productivity*, Mountain Farming Systems' Discussion Paper Series No. MFS 97/1. Kathmandu: ICIMOD

Partap, U.; Partap, T. (2000) 'Pollination of Apples in China.' In *Beekeeping and Development*, 54: 6–7

Partap, U. and Partap, T. (2001) *Declining Crop Production and Worried Himalayan Farmers: Solution Lies in Promoting Honeybees for Pollination*, Issues in Mountain Development Series 2001/1. Kathmandu: ICIMOD

Partap, U.; Verma, L.R. (1992) 'Floral Biology and Foraging Behaviour of *Apis cerana* on Lettuce Crop and its Impact on Seed Production.' In *Progressive Horticulture*, 24: 42–47

Partap, U.; Verma, L.R. (1994) 'Pollination of Radish by *Apis cerana*.' In *Journal of Apicultural Research*, 33: 237–241

Ptacek, V. (2000) *Some Biological Aspects of Bumble Bee (Bombus, Hymenoptera) Management.* Paper presented at the Eighth International Pollination Symposium, 10–14 July 2000, Mosonmagyarovar, Hungary

RGOB (1996). Eighth Five Year Plan Document of RGOB (1997-2002) Thimphu: RGOB

Schilde, M.J.; Bourgo, A.B. (1998) *Apple Orchard Management*, a report submitted to USAID and WINROCK International

Sekita, N. (2000) *Managing* Osmia cornifrons *to Pollinate Apples in Aomori Prefecture, Japan.* Paper presented at the Eighth International Pollination Symposium, 10–14 July 2000, Mosonmagyarovar, Hungary

Sharma, H.R. (1996) *Mountain Agricultural Development Processes and Sustainability: Micro-level Evidence from Himachal Pradesh, Indian Himalayas,* MFS Discussion Paper Series MFS 96/2. Kathmandu: ICIMOD

Sikka, B.K.; Saraswat, P.S. (1992) *Socio-economic Survey of an Affluent Village in Himachal Pradesh: A Study of Kiari in Shimla District.* Shimla: Agro-economic Research Centre, Himachal Pradesh University

Smith, M.V.; Bradt, O.A. (undated) *Fruit Pollination*, Publication No. 172. Toronto: Ontario Department of Agriculture and Food

Stanisavljevic, L.J.; Krunic, M.; Brajkovic, M.; Tomanovic, Z. (2000) *The Study of Accompanying Fauna of* Osmia cornuta *(Latr.) Populations in Yugoslavia.* Paper presented at the Eighth International Pollination Symposium, 10–14 July 2000, Mosonmagyarovar, Hungary

Toderia, R. (2000) 'Apple Farming in Himachal Pradesh Exploited on all Sides: Farmers are in Loss and Commission Agents Benefiting a lot' (in Hindi). *(Himachal Pradesh mein Chutarfa Shoshan se Ghiri Hai Seb ki Baghbani).* In *Amar Ujala Daily*, 10 August 2000, p 1)

Verma, L.R. (1993) 'Declining Genetic Diversity of *Apis cerana* in Hindu Kush-Himalayan Region'. In Connor, L.J.; Rinderer, T. E.; Allen-Sylvester, H.; Wongsiri, S. (eds) *Asian Apiculture*, pp 81-88. Cheshire, Connecticut, USA: Wicwass Press

Verma, L.R. (ed) (2000). *Natural Resources and Development in Himalayas.* New Delhi: Malhotra Publishing House.erma, L.R.; Chauhan, P. (1985) 'Distribution, Abundance and Diversity of Insect Pollinators in Apple Orchards of Shimla Hills.' In *Indian Journal of Ecology*, 12: 286–292

Verma, L.R.; Jindal, K.K.; Chandel, J.S. (1997) 'Chapter 5: Apple'. In Verma, L.R.; Jindal, K.K. (eds) *Fruit Crops Pollination, pp 61-93.* Ludhiana, India: Kalyani Publishers

Verma, L.R.; Jindal, K.K. (1997) *Fruit Crops Pollination.* Ludhiana, India: Kalyani Publishers

Verma, L.R.; Mattu, M.K.; Rana, R.S.; Dulta, P.C. (1990) *Foraging Activity of Apis cerana F. and Apis mellifera L. on Apple Bloom.* Paper Presented at 11th International Congress of International Union for Studies on Social Insects (IUSSI), Bangalore, India

Verma, L.R.; Partap, U. (1993) *The Asian Hive Bee, Apis cerana, as a Pollinator in Vegetable Seed Production.* Kathmandu: ICIMOD

Annex 2

Questionnaire Used in the Field Surveys (English Version)

Name of the Household _____

Family Size _____

Village _____

1. General Information

1A. Information on Climate

i. What is the altitude of the area? _____

ii. Agroclimatic conditions of the area (farmers' perceptions)

a. Temperature, in winter _____, in spring _____
in summer _____, rainy season _____

b. Humidity, in winter _____, in spring _____
in summer _____, rainy season _____

c. Rainfall, in winter _____, in spring _____
in summer _____, rainy season _____

iii. When do you have snowfall? In winter? _____

a. _____ (month) before apple flowering,
b. _____ (month) during apple flowering
c. _____ (month) after fruit set

iv. What kind of change do you feel in the climate (i.e. temperature, rainfall and humidity) in your area during the past ten years? _____

_____

_____

_____

_____

v. How do you think this climate change is affecting apple and other crops?

vi Any other relevant information?

1B. Information about Agriculture and Household Economy

i. How much land do you have?

ii. Family size: How many members are there in your family?

iii. Which crops are you growing?

a. Food crops

b. Cash crops

iv How much area have you given to each crop?

1C. About Apple

i. How much area have you given to apple?

ii. How important is apple for you?

iii. Which variety of apple have you planted?

iv What is the yield?

v. How much apple do you market?

a. Where do you sell your apples? (locally or city markets or export, how much in each place, and price per kg)?

i. Local market?
Quantity sold_____
Price per kg_____

ii. City Market
Quantity sold_____
Price per kg_____

iii. Export? Where?
Quantity sold_____
Price per kg_____

b. Do you keep apples for yourself (in store)? If yes, how much? And how do you store?_____

vi. Do you think that apple production is decreasing these days?_____

vii. How do you know that apple production is decreasing?_____

viii. Which variety of pollinizer have you planted?_____

ix. What is the proportion (ratio) of pollinizer variety to the main variety (i.e. how many trees of pollinizer variety and how many trees of main variety)?_____

x. Where have you planted the pollinizers?

a) In the orchard among the main variety? _____
b) away from the orchard?_____

xi. If the pollinizer is planted away from the orchard, how do you transfer pollen from its flowers to the flowers of the main variety?_____

xii Why have you planted pollinizers away from the orchard?_____

xiii. Do you spray pesticides?_____

xiv. How important do you feel is the use of pesticides on apple and other cash crops?
   a) Which pesticides do you use?
   b) How many sprays per season?
   c) Which time/stage do you use the pesticides?
      i)before flowering?
      ii) during flowering ?
      iii) during fruiting?

xv. Any other relevant information?

2. Information on Pollination

i. How long ago did you come to know that pollination is very important to produce fruit and improve the quality of apple?

ii. How did you know this?

iii. Who told you about this?
   a) government officials?
   b) some other person?

iv. Do you think your apple crop is being adequately pollinated these days naturally by wind, or insects, if not why?

v. If your crop is not adequately pollinated by wind or natural insects, how do you manage the pollination or do you suffer the loss in yield?

vi. Any other relevant information?

3. Information on Natural Insect Pollinators

i. Have you ever seen insects on apple flowers in your orchards?

ii. Which types of insects have you seen; honeybees or other insects?

iii. Do you think there were enough to pollinate your apples before?

iv. Do you find similar insects on your apple flowers these days also?
or do you find less insects?
or you do not find any insects?

v. If you do not find the same insects as before, what do you think happened to them or where have they gone now?

vi. Do you think the pesticides you use have killed those insects?

vii. Or do you think that the apple cultivation has increased these days and the insects did not increase, therefore the same number of insects is not found on apple bloom?

viii. Or do you think that due to the climate change these insects do not appear on apple flowers?

ix. Have you seen honeybee colonies in the wild in the forests?

x. Any other relevant information?

4. Information about Honeybees

i. Do you keep honeybees?
   a. Which honeybee, native or European?
   b. How many colonies do you have?

ii. Are there any commercial beekeepers (local, or migratory coming from other areas) keeping their bees in your area during the apple flowering season?

iii. Any other relevant information?

5. Manual/Hand Pollination of Apple/Other Cash Crops

i. Do you do apple pollination manually?

ii. How do you do this?

iii. Why do you feel it is necessary?

iv. How many apple trees do you have?

v. Do you pollinate them by yourself (your own family) or do you need help from other people?

vi. How much labour (persons) is required for hand pollination of your apple crop?

vii. How many trees/flowers can a man/woman/child pollinate in one day?

viii. Do you pay money to the labourers or do you help in pollinating their orchards (barter basis)?

ix. How much is the increase in the apple production by hand pollination?

x. Or do you think that if you do not pollinate your crop by hand, you will not have any apple fruit at all?

xi. If you have bees, or if you have commercial/migratory beekeepers during the apple flowering season, then why don't you use honeybees for pollination of your apple crop?

xii. Any other relevant information?

6. History of Manual/Hand Pollination

i. When did you plant your apple orchard?

ii. For how long (how many years) have you been doing hand pollination of your apple flowers?

iii. How did you realise that there is a need for hand pollination of your apple crop; what were the indicators?

iv. Are all the farmers in your area doing hand pollination of their crops?

v. How much is the apple production in your orchard at present with hand pollination?

vi. How much do you think could be the production without hand pollination?

vii. Do you think hand pollination also increases the quality of your apple fruit?

viii. Any other relevant information?

7. Miscellaneous Information

i. If there are beekeepers in your area, why don't you hire their bee colonies for pollination?

ii. Or if you want to hire them, why don't the beekeepers rent their bee colonies to provide pollination services?

iii. Any other relevant information?

8. Technical Information

i. How do you think climate change is affecting apple pollination?
   a) do you think there is high humidity making pollen heavy and therefore wind can not transfer pollen from one flower to another?
   b) the weather is too wet (rainy) during apple flowering?
   c) or the weather is still, there is no wind at all to help pollen go from one flower to another?

ii Any other, please specify?

9. Institutional Support

i. Are you getting some kind of support from government research institutions?———

ii. What kind of support are you getting?

a) awareness?———

b) training?———

c) financial support?———

iii. How many times did government officials visit you?———

iv. What kind of support do you want to get from government institutions?———

a) awareness?———

b) training?———

c) financial?———

iv Any other, please specify?———

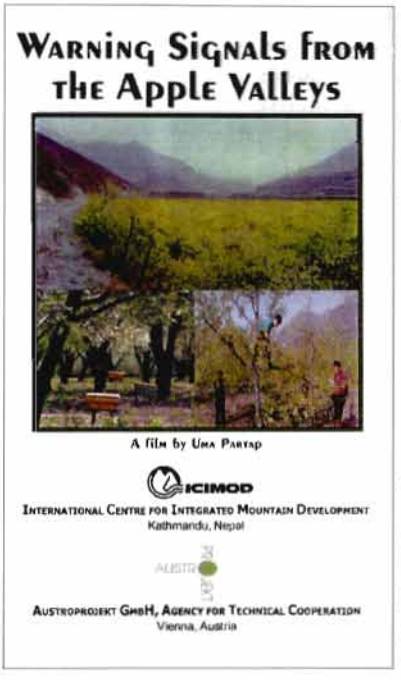
10. Do you have pollination problems in other crops? ——— (yes / no)

If yes, in which crops? ———

If yes do you recommend that ICIMOD do similar studies for other crops?———

See also ...

Warning Signals from the Apple Valleys



A film by Uma Partap
October 2001

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Playing time: 31 min 7 sec

Format: VHS

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This video, shot in apple valleys in Himachal Pradesh (India), the Northern Areas and Balochistan Province of Pakistan, and Maoxian county of China, highlights the pollination problems faced by apple farmers (and farmers of other crops) in the Hindu Kush-Himalayan region. The importance of apples in the economy of mountain areas is shown, together with the problem of declining apple productivity due to inadequate pollination. Excellent shots illustrate the major causes: insufficient pollinizers (trees), lack of pollinating insects, and bad weather conditions (climate change). The film shows how some farmers manage apple pollination — large-scale use of pollinizer bouquets to increase the proportion of pollinizers and use of honeybees as pollinating insects in Himachal Pradesh, India; and hand pollination in Maoxian county China.

about the authors

Uma Partap

Uma Partap is a Research Officer for pollination in the ICIMOD Beekeeping Project. She has a Ph.D. in Biological Sciences from Himachal Pradesh University, Shimla, India and eighteen years of research experience that covers diversified fields including drought eco-physiology and pollination ecology. At ICIMOD, Dr. Partap has been instrumental in establishing the crop pollination programme under the Mountain Farming Systems Division. At present, she is studying pollination issues in mountain crops and focusing on raising awareness among agricultural planners, policy-makers, researchers, and farmers in the Hindu Kush-Himalayan region about the importance of managing crop pollination and the use of bees for this purpose. She has published various books and manuals in English and regional languages (Hindi, Nepali, and Urdu) and about forty research papers on such topics as bee pollination, bee flora, honeybee behaviour and drought eco-physiology, as well as produced a video film highlighting apple pollination issues in the HKH region.

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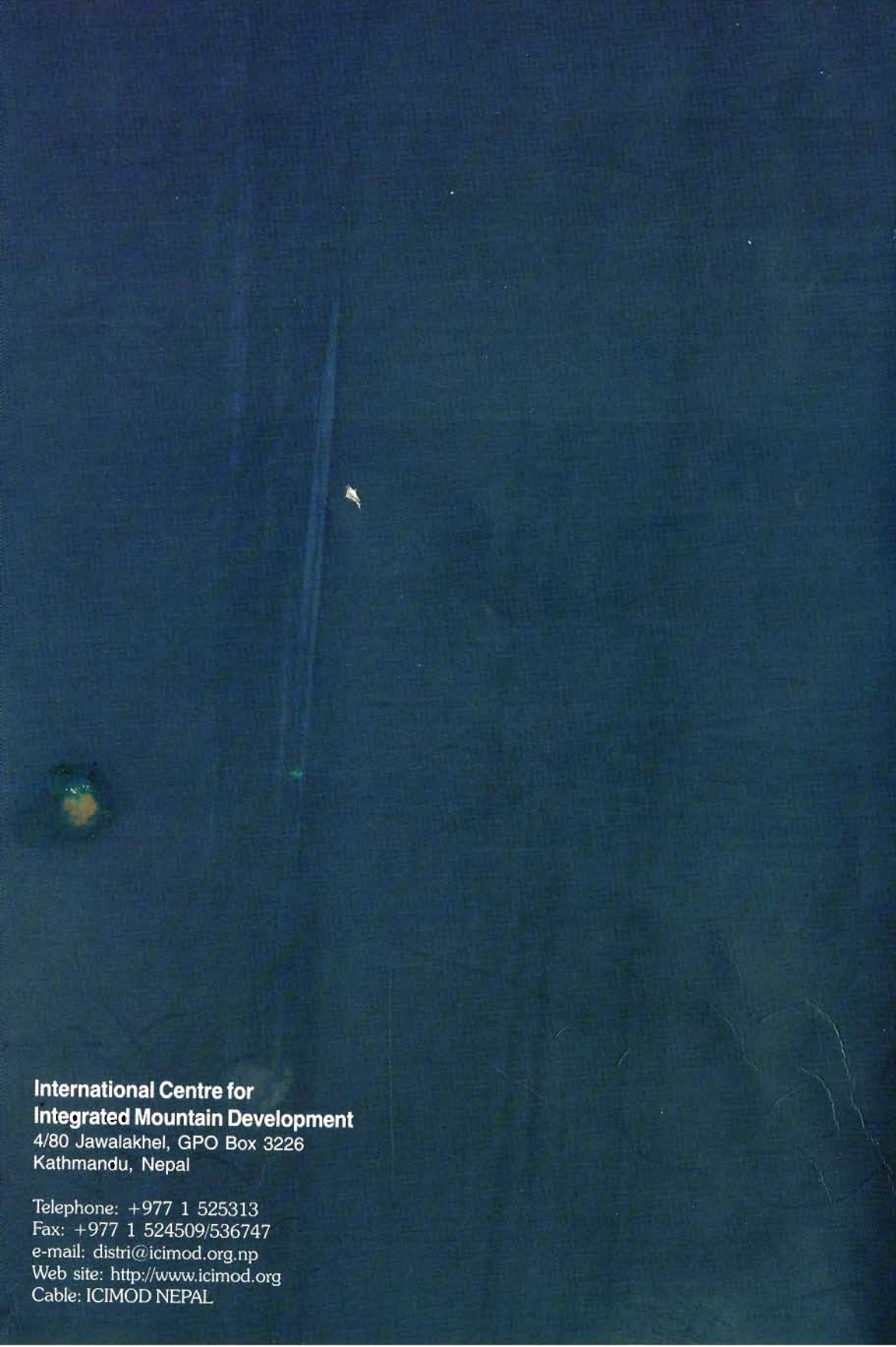
Tej Partap is Vice Chancellor of the CKS Himachal Pradesh Agricultural University, Palampur, India. He has a Ph.D in Agroecology from Himachal Pradesh University, Shimla, India and twenty-five years of experience in the field of mountain agriculture. He headed the Mountain Farming Systems Division of ICIMOD from July 1994 to December 2000. Dr. Partap is a Honorary Professor of Mountain Agriculture at the Tibet Academy of Agriculture and Animal Sciences, Lhasa, where he has been an advisor on research, planning and human resources development for highland agriculture since 1995, and an Honorary Professor in Mountain Agriculture at the Institute of Geographical Sciences and Natural Resources, Chinese Academy of Sciences, Beijing. Dr. Partap is an active promoter of cooperation and exchange of knowledge and information between the mountain regions of the world, and is currently Vice Chairman of the Himal-Andes Initiative. In 2000 he was elected representative of Asia Pacific Mountain Network on the Board of Directors of the Mountain Forum. Dr. Partap has authored/edited twelve books and over fifty research papers in peer reviewed journals, and produced five video films.



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