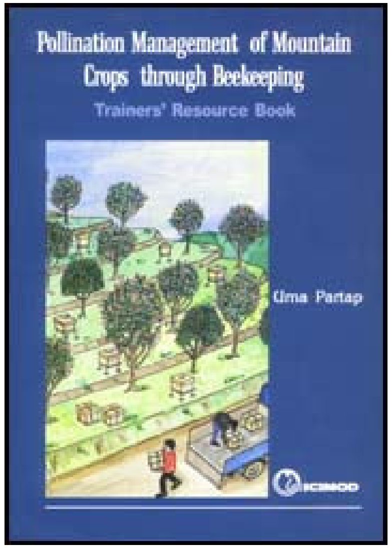

Pollination Management of Mountain Crops through Beekeeping - Trainers' Resource Book

***Author(s)*:**	***Uma Partap***
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Preface

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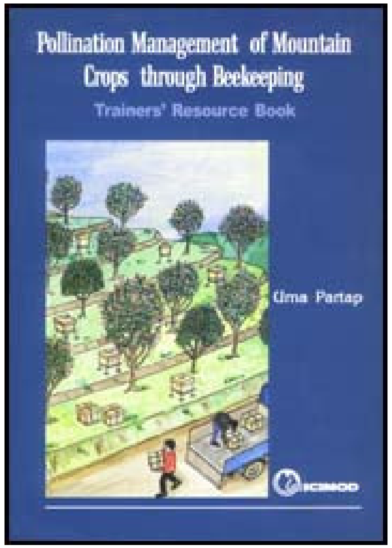
The ongoing transformation of mountain agriculture from subsistence to cash crop farming poses new challenges to improving and maintaining crop productivity. Among these challenges are crop failure due to lack of pollination. Evidence of this problem has been documented by ICIMOD through work carried out in several mountain areas of the Hindu Kush-Himalayan region. This work has revealed that pollination failure could be due to a number of reasons: scarcity of insect pollinators, continuous increase in the cultivation of self-incompatible crop varieties, lack of an appropriate polliniser ratio, climatic factors, and so on. Among these, the scarcity of natural insect pollinators is a key factor. While progressive farmers are trying various ways, such as hand pollination and bouquet pollination, to make up for the scarcity; others are suffering the losses. However, these methods of pollination management are expensive and time consuming. Alternatively, the use of the hive bees, *Apis cerana* and *Apis mellifera,* is a possible low-cost and farmer-friendly method of managing crop pollination.

The present publication is a part of ICIMOD's initiative to promote wider use of honeybees to contain declining crop productivity due to pollination failure. This resource book is for training extension workers and mountain farmers to use bees for pollination. It covers several topics related to managing bees for crop pollination. Several illustrations have been added to facilitate understanding of the various processes. The book provides a general introduction to pollination; explains the reasons why different kinds of bees are important crop pollinators; and describes how they pollinate a crop. It describes the limitations in using bees in traditional fixed-comb hives for crop pollination and explains the advantages of movable-frame hives. The role of the hive bees, *Apis cerana* and *Apis mellifera,* as crop pollinators rather than wild bees, and how to manage them for pollination of crops in general are described in detail. Descriptions of the management of hive bees for pollination of particular crops have also been given.



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Chapter 7. Protecting Honeybees from Pesticide Poisoning

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What is a pesticide?

Pests harm crops by feeding on or drawing nutrition from various parts of a plant - including the roots, stem, leaves and fruits, etc and thus decrease yield and crop quality. Pests include fungi, various insects and their caterpillars, rodents, and some plants (weeds). In order to have higher yields and a better quality crop, farmers must control pests. There are various methods of control: non-chemical, chemical, and integrated (combining both chemical and non-chemical). Chemical methods kill pests using poisonous chemicals called pesticides. There are different types of pesticides to control different organisms. For example, insecticides kill insects; acaricides kill mites; herbicides kill weeds; and fungicides kill fungi.

What problems are associated with indiscriminate pesticide use?

Controlling pests by the indiscriminate use of pesticides creates a number of environmental problems. These include elimination of beneficial insects - insect pollinators (such as honeybees and other wild bees) and natural enemies of the pests - resurgence of secondary pests owing to the elimination of their natural enemies, and pollution of the environment. Moreover, the use of pesticides on fruits and vegetables can be dangerous for human beings: fruits and vegetables should not be marketed soon after spraying. Pesticides should be used with great care.

How do pesticides kill bees?

A pesticide kills a bee when it is absorbed by the bee in one of three ways: orally, respiratorily, or dermally.

Oral Intake

This happens when nectar and pollen are contaminated. Contamination of nectar occurs in plants treated with systemic pesticides. For example, if dimethoate is applied at the rate of 11 kg/ha it can kill bees by nectar contamination. Contamination of pollen with micro-encapsulated insecticides is a major cause of bee poisoning. Foraging bees collect insecticide along with pollen and store it in the brood frames. Nurse bees feed the contaminated pollen to the developing brood. This results in the total loss of the colony: foraging bees are killed while collecting and transporting contaminated pollen, nurse bees are killed while storing and feeding pollen, and the brood are killed by eating poisoned pollen.

Respiratory Intake

Some pesticides, for example, DDVP and chlordane, remain present in the air after application in sufficient concentrations to be absorbed by bees through their respiratory system (trachea). The bees then die. Also, pesticides with fumigant properties release toxic volatile compounds that are absorbed by beeswax. Bees exposed to contaminated combs die within two to six minutes.

Dermal Intake

The major way by which pesticides are absorbed is through the bee's outer surface ('skin') by direct contact (dermal intake). The most likely sources of contamination are interception of pesticide droplets in the air during spraying operations and contact with sprayed surfaces. The toxicity of airborne droplets varies according to the method of application and the amount of pesticide available to the bees.

What are the effects of pesticide poisoning on honeybees?

A pesticide usually kills only the type of pest for which it is developed. For example, insecticides are developed to kill insects and do not usually kill plants or other organisms. Bees are insects and are most likely to be killed by insecticides. They are either paralysed or killed or made susceptible to disease. Some insecticides are more harmful to bees than others. However, all pesticides should be used very carefully. Consequences of pesticide poisoning are described below.

- **Bees visit flowers to collect nectar and pollen, therefore, pesticide application during flowering kills many bees. Insecticides and acaricides kill bees directly, whereas herbicides kill them by reducing their food sources when plants are killed. Pesticide poisoning of bees results in partial or total loss of colonies.**

- **Bees exposed to sub-lethal doses of some pesticides, for example, parathion, can lose their sense of time -either because of changes in their biological clock or changes in the manner they communicate time to other bees.**

- **Sub-lethal doses of some pesticides also result in disruption of a bee's communication system.**

- **Pesticide poisoning can make colonies more susceptible to disease. Reports show that outbreaks of European Foulbrood and Sacbrood Virus infections were observed after applications of carbaryl insecticide. The first record of Chalkbrood disease in *Apis mellifera* came from colonies exposed**

to fenetrothion spray.

- **Pesticide poisoning affects colony strength because there is a break in the brood-rearing cycle. Such colonies cease foraging, and as a result there is a sharp decline in food storage. Bees in these colonies also attack incoming foragers at the hive entrance.**

What are the symptoms of bee poisoning?

Honeybees react differently to different pesticides. Most fungicides and herbicides are less toxic to bees. Common symptoms of pesticide poisoning include the following.

- **One of the obvious signs of pesticide poisoning is the presence of a large number of dead or dying bees at the hive entrance (Figure 7.1). These bees are foragers who have been exposed to pesticides sprayed on to flowering plants. FAO has produced mortality figures that can be used as guidelines to assess the extent of bee poisoning by pesticides (Table 3).**

- **Another sign is the presence of a moist and sticky mass of dead bees at the hive entrance. This results from poisoning by some fast-acting pesticides, e.g., organophosphorus pesticides. Dying bees extend their tongues through which nectar is regurgitated resulting in sticky and moist dead bees.**

- **Fast-acting insecticides kill foraging bees in the field itself. Only some of them manage to return to the hive. Sometimes, the whole colony may die**

instantly. Stronger colonies suffer greater losses from pesticide poisoning than weaker ones because they have larger numbers of foraging bees.

- **Foraging bees often carry residual pesticides in their pollen loads while returning to the hive. As a result, the behaviour of bees in the hive changes abruptly. Honeybees in such colonies become more aggressive or agitated. When a hive containing pesticide-affected bees is opened, the bees fly out of the hive sometimes straight at the face of the beekeeper handling them.**

- **Other symptoms include stupefaction, paralysis, and abnormal, jerky, or spinning movements. Carbaryl poisoning causes bees to crawl around the hive entrance. They lose their ability to fly and ultimately die two or three days after poisoning.**

- **The hive entrance of pesticide-affected colonies is completely blocked because nurse bees lose their ability to clean dead bees from the hive.**

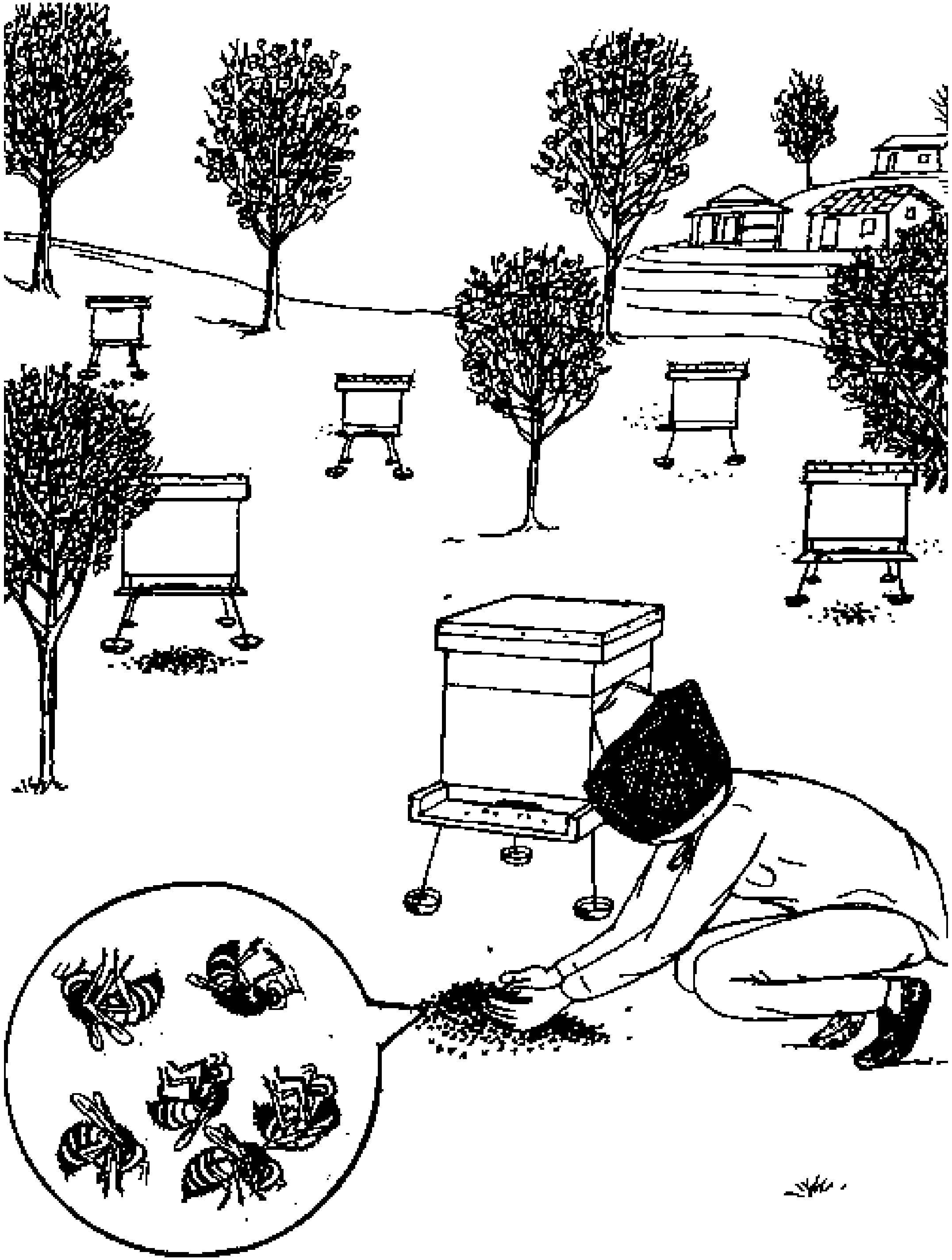


Figure 7.1: Presence of a large number of dead or dying bees in front of the hive entrance is the main symptom of pesticide poisoning.

Table 3: Extent of bee poisoning by pesticides	
Number of dead bees per day at hive entrance	Level of poisoning
100	Normal death rate
200-400	Low
500-1000	Medium
Over 1000	High
Source: FAO (1986) 63/3	

How can bee deaths from pesticide poisoning be prevented?

In the Hindu Kush-Himalayan region, fruit and vegetable growers use hive bees for pollination of their crops. These growers also use pesticides indiscriminately. For example, apple growers in the north-west Indian Himalayas and in the Chinese Himalayas treat their crops with pesticides seven to eight times a season. Natural insect pollinators and honeybees are frequently killed.

Methods are now available that ensure the selective use of pesticides at the right time and in the appropriate formulation and concentrations. As a result of this, bee poisoning by pesticides can be reduced to a minimum. Both crop growers and beekeepers should take measures to prevent bee losses resulting from pesticide

poisoning.

Prevention of bee poisoning by crop growers

Pollination by honeybees is of great importance to farmers. The death of bees caused by pesticides means reduced yields and quality of crops. The safe use of pesticides and prevention of bee death by pesticide poisoning are explained below.

• If a crop is pollinated by bees and other insects then try to use non-chemical methods of pest control, i.e., either physical, cultural, biological, or integrated methods. Pesticides should be used only if it is really necessary: when pests cannot be controlled by non-chemical methods. Non-chemical methods of pest control are described in Annex I.

• As far as possible, do not apply pesticides during the flowering period of crops. Apply them either a week before or a week after flowering (Figure 7.2).

• If the use of pesticides during flowering is unavoidable, then warn local beekeepers 2-3 days before pesticide application (Figure 7.3).

• Use a pesticide that is least toxic to bees. Pesticides can be classified into three groups: highly toxic, moderately toxic, and least toxic (see Annex II).

• Select a formulation that is less toxic to bees. It is recognised that liquid or spray formulations are safer than wettable powder or dust formulations. Insecticide formulations are classified in order of toxicity: dust > wettable

powder > liquid suspensions > emulsifiable concentrate or soluble powder or liquid solution.

• Select pesticides that have a short residual effect (Annex II).

• Avoid using broad-spectrum pesticides because they are much more hazardous than selective pesticides, which are safer for bees and other insect pollinators.

• Before applying pesticides, make sure that there are no bees or other pollinating/beneficial insects on the crop. Do not apply pesticides during the daytime when most bees and other natural insect pollinators are foraging. Apply them during late evening or at night when bees are in their hives (Figure 7.4).

• Apply pesticides in still weather, not when it is windy. If applied when it is windy, pesticides can drift on to other flowering plants and directly on to bees and beehives (Figure 7.5).

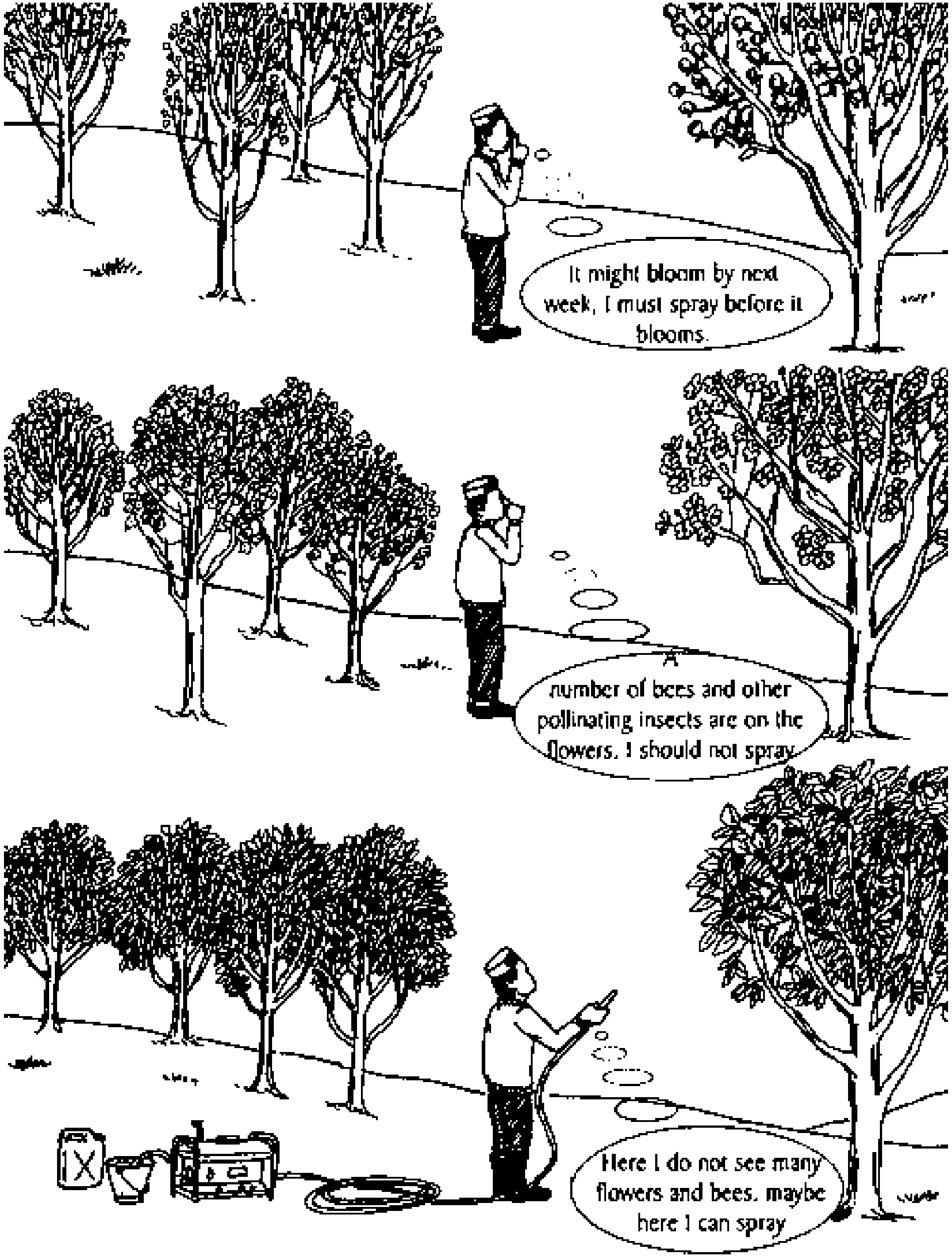

It might bloom by next week, I must spray before it blooms.
A number of bees and other pollinating insects are on the flowers. I should not spray.
Here I do not see many flowers and bees. maybe here I can spray

Figure 7.2: To avoid killing the bees (and other insect pollinators) foraging on a crop, pesticides should be sprayed a few days before or after the flowering of the crop.

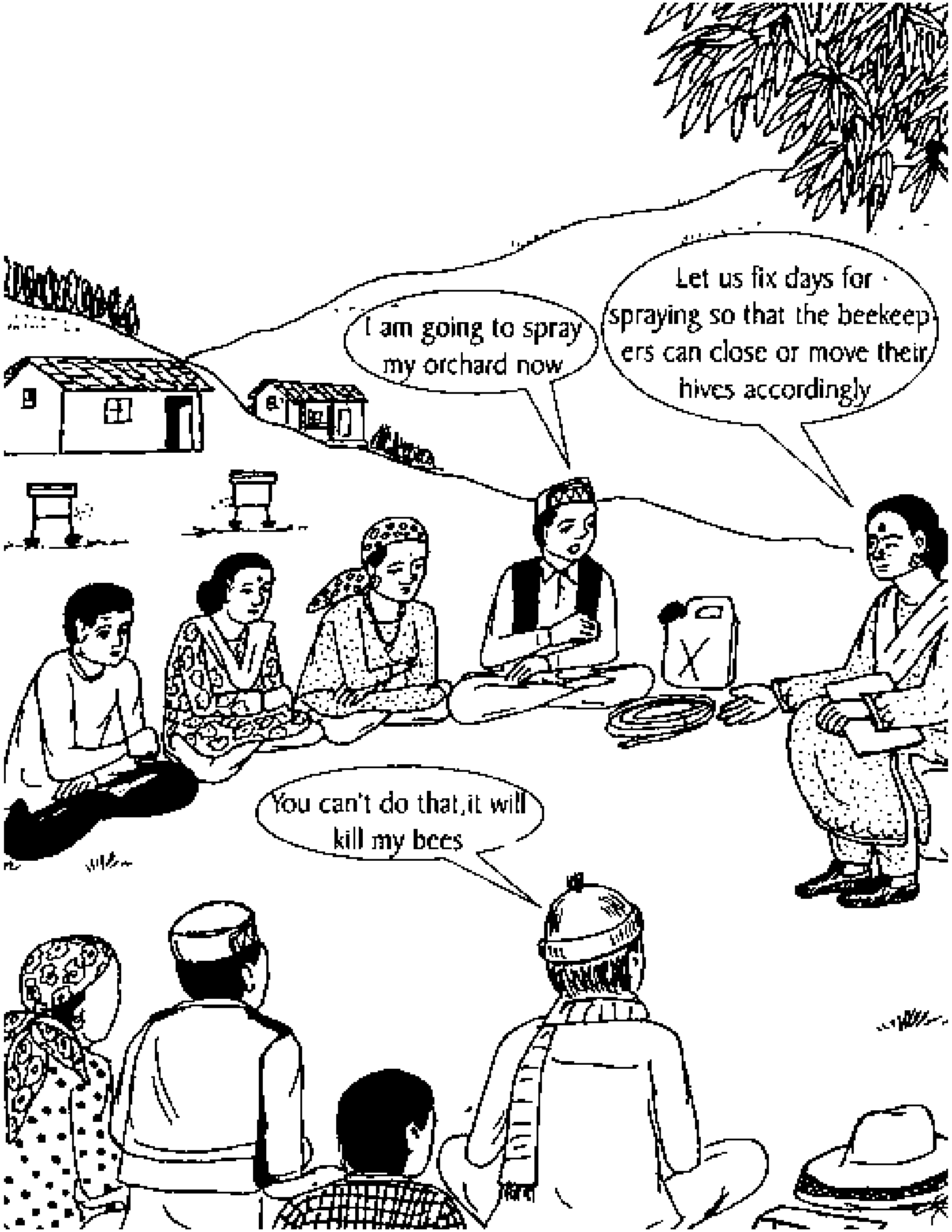

I am going to spray my orchard now
Let us fix days for spraying so that the beekeepers can close or move their hives accordingly
You can't do that,it will kill my bees

Figure 7.3: Villagers need to take a collective decision on spray schedules so that beekeepers can protect their honeybees during that period.


Why are you spraying your orchard at the night?
During the daytime honeybees and other insects visit the crops, to avoid killing these, I am spraying now or else I have to do it early in the morning

Figure 7.4: Spraying pesticides either early in the morning or during the late evening avoids killing bees and other insect pollinators visiting the crop.

Protection of bees by beekeepers

• When pesticides are applied to a flowering crop (even when all protective measures to save bees are taken), there is still a risk that bees visiting flowers will be killed. Therefore, for a beekeeper, it is important to do the following when pesticides are to be applied. Move hives temporarily to another site at least 2 km away for *Apis cerana* and 5 km away for *Apis mellifera* (Figure 7.6). Return them to the first site only after the pesticide is no longer toxic to bees.

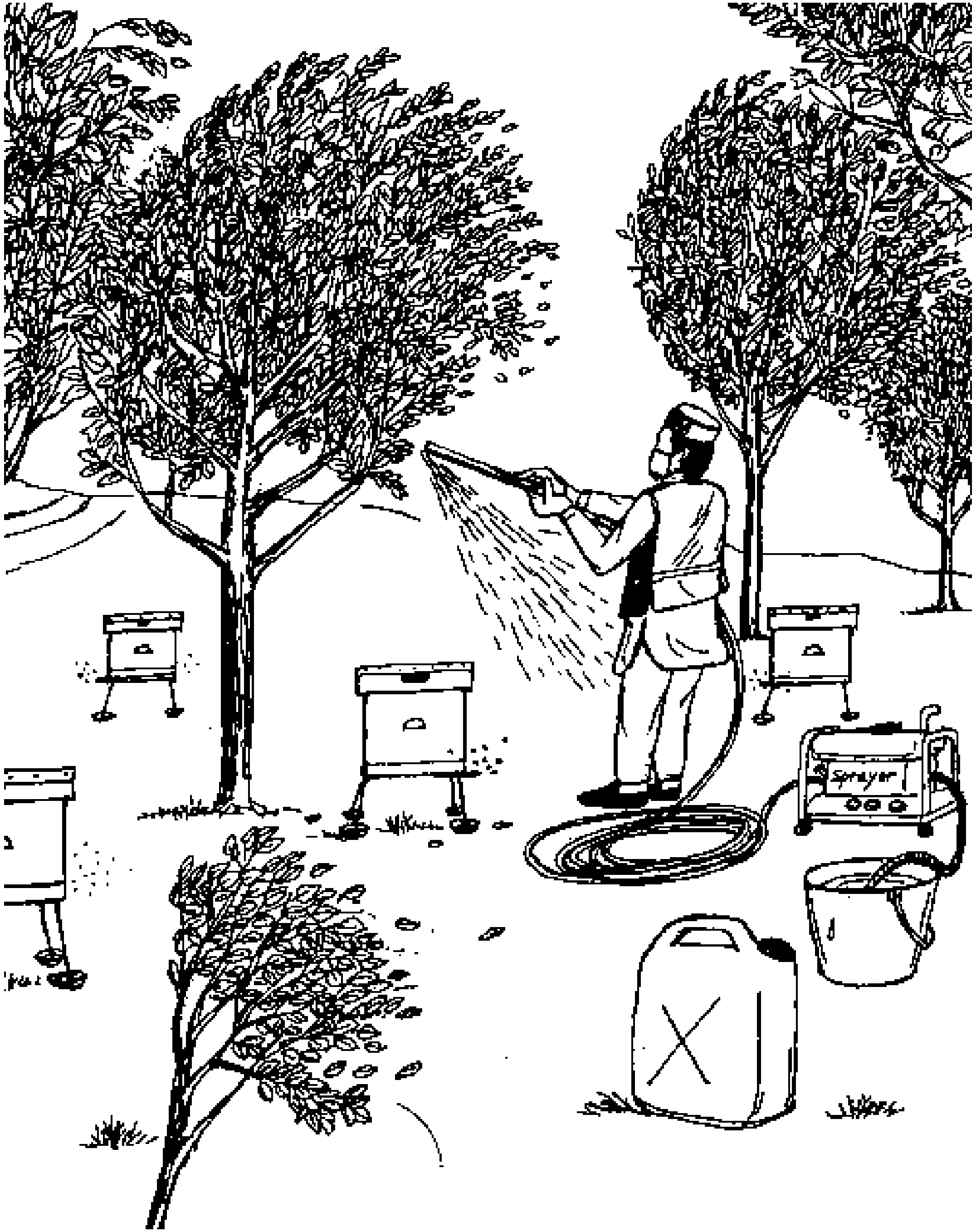


Figure 7.5: Pesticides should be applied in still weather; if applied in windy

weather the pesticides can drift on to other flowering crops or directly to the bees and beehives and kill them.

• Close the hives before moving and ensure that they are properly ventilated. If you cannot move the hives, close them in the field. To move bees to another area, close the hives in the evening when all forager bees are inside

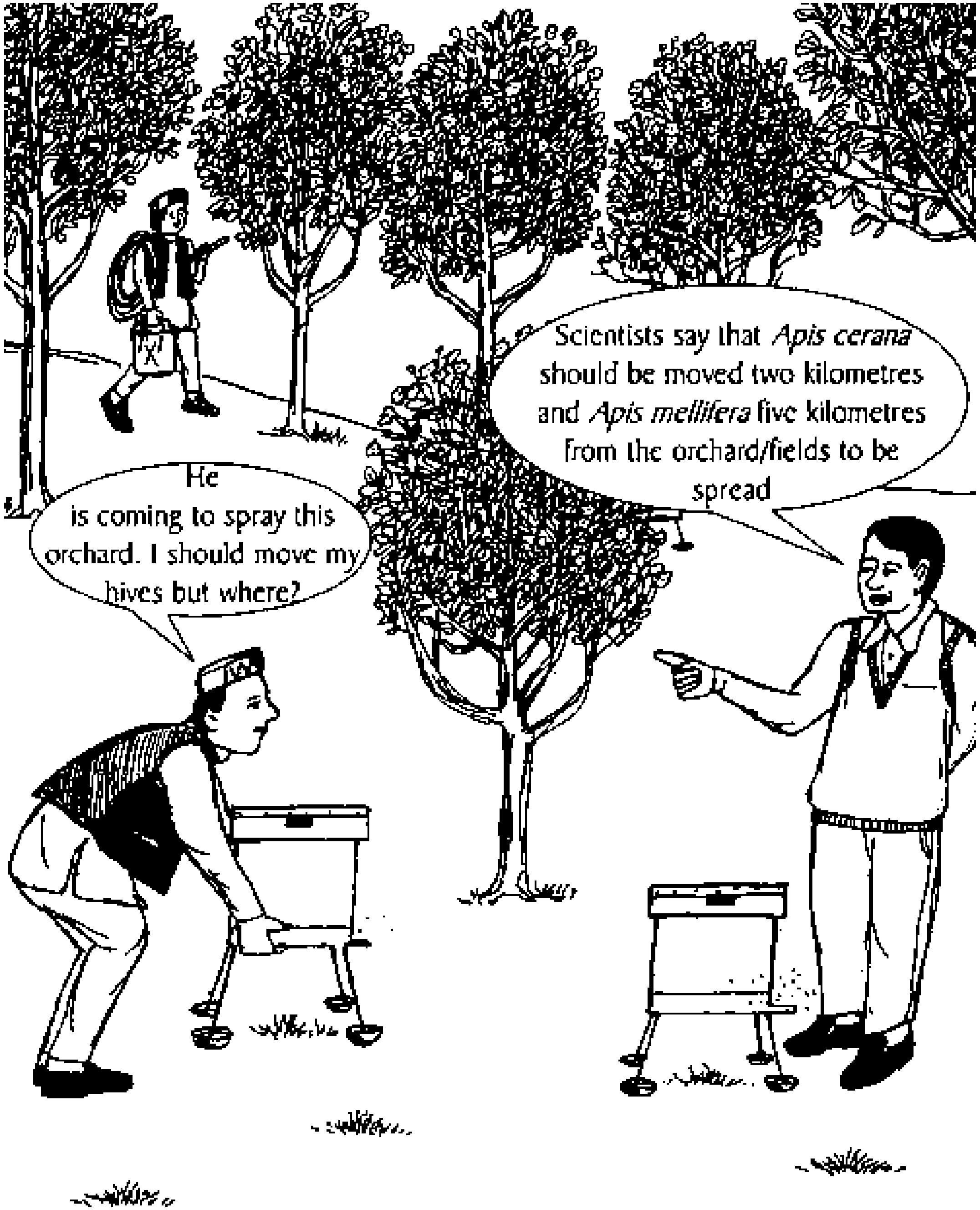


Figure 7.6: If it is absolutely necessary to spray pesticides during flowering,

beehives should be closed or moved away from the orchard/field to be sprayed.
and secure them properly with ropes or plastic belts (see Chapter 4). If possible, transport the hives at night.

• If hives cannot be transported to another place then close hive entrances with material that allows proper ventilation and does not allow the bees to fly out, e.g., 3-4 mm wire mesh or loosely woven material. Hives should be kept closed until the pesticide that has been applied it is no longer toxic. To calculate how long a pesticide will remain toxic, learn its name from the person applying it and look it up in one of the three toxicity groups given in Annex II.

How can human beings and livestock be protected from pesticide poisoning?

Pesticides are not only toxic to bees and other insects but also to humans, livestock and other living beings. Therefore, while applying pesticides, the following things should be kept in mind to avoid poisoning.

- **Carefully read the instructions given on the label of the pesticide container and follow them.**

- **Use protective clothing such as a hat, long-sleeved shirt, long trousers, face mask, goggles, and rubber or neoprene gloves and shoes while spraying pesticides**

- **Do not eat, drink, or smoke while handling and applying pesticides.**

- **After applying pesticides, wash hands, face, and body thoroughly with soap.**

- **Do not keep pesticides within the reach of children**

- **Do not allow children to touch/apply pesticides.**

- **Never use defective or leaking equipment.**

- **Do not apply dust or powdered formulations on windy days because they can be blown into your face and body.**

- **Avoid contact with recently sprayed crops.**

- **If pesticide contamination occurs, change your clothes and thoroughly wash the contaminated area of the skin with soap as soon as possible.**

- **Do not wash pesticide containers in ponds, streams, or other water sources.**

- **Dispose of pesticides and their containers safely, e.g., in a pit, so that they will not endanger people and other living beings.**

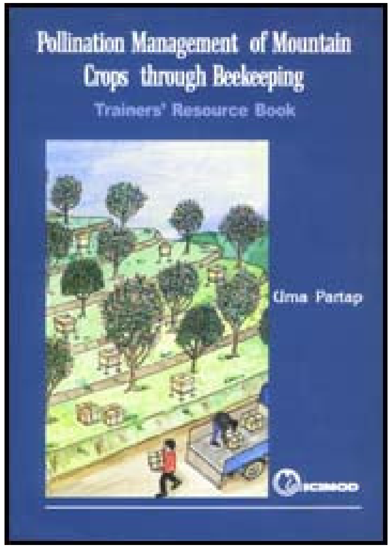
- **Do not use empty pesticide containers for any other purposes, such as food or water carriers or as cooking pots, because they cannot be cleaned thoroughly enough to make them safe.**

- **Always keep pesticides in their original labelled containers.**

- **Before harvesting crops, observe the recommended safety interval.**

- **In the case of poisoning, obtain medical help quickly and show the**

pesticide label to the person giving medical attention.



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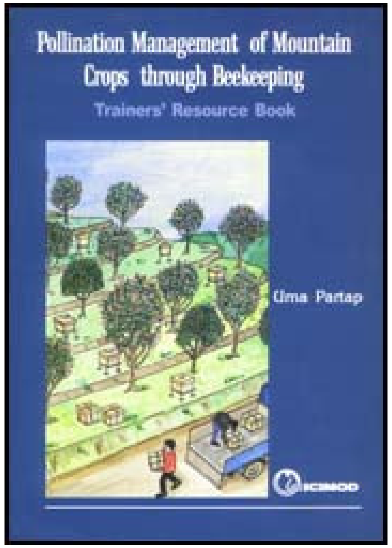

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Annex I: Non Chemical Methods of Pest Management

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Mechanical Methods

Physical methods of pest control include picking pests from plant parts and killing them and removing plants or parts of the plant (e.g., leaves, buds or flowers) affected by pests and destroying them (Figure A1).

Cultural Methods

Cultural methods of pest control include choosing a variety that is either resistant to pests or is less susceptible to pest attack; produces an acceptable crop even when attacked by pests; or grows at a time of the year different from the time when pest numbers are high. Information on such varieties is available from agricultural extension workers and agricultural departments. Pests can also be controlled by adopting cultural practices such as sowing the crop at a different time of the year so that pests are absent when the crop is most susceptible to attack; pruning, thinning, or allowing the crop to grow profusely depending on the crop. Mixed cropping and crop rotation also help to a great extent. The presence of weeds increases either the number of pests or the pests' natural enemies. Therefore, for some crops, weeding, and for other crops, not weeding, also help in pest control.

Biological Pest Control

Biological pest control means killing the pests using their natural enemies. Natural

enemies of pests include predators that feed on them, parasites that live on them, and pathogens such as bacteria, viruses, and fungi that infect them. These enemies keep pests at low levels over a long period. Therefore, such insects or parasites should be encouraged. If they are not present in nature in sufficient numbers, they can be reared and released on the crop when required (Figure A2).

Figure A1: Pests can be controlled mechanically by picking them up and destroying them.

The insect that causes San Jose apple scale is controlled biologically using its enemy the parasitoid, *Encarsia perniciosi.* This insect can also be controlled by ladybird beetles, *Chilocorus* spp (*C. infernalis* and *C. nigritus*), and *Pharcoscymnus flexibilis.* Ladybirds are good predators of

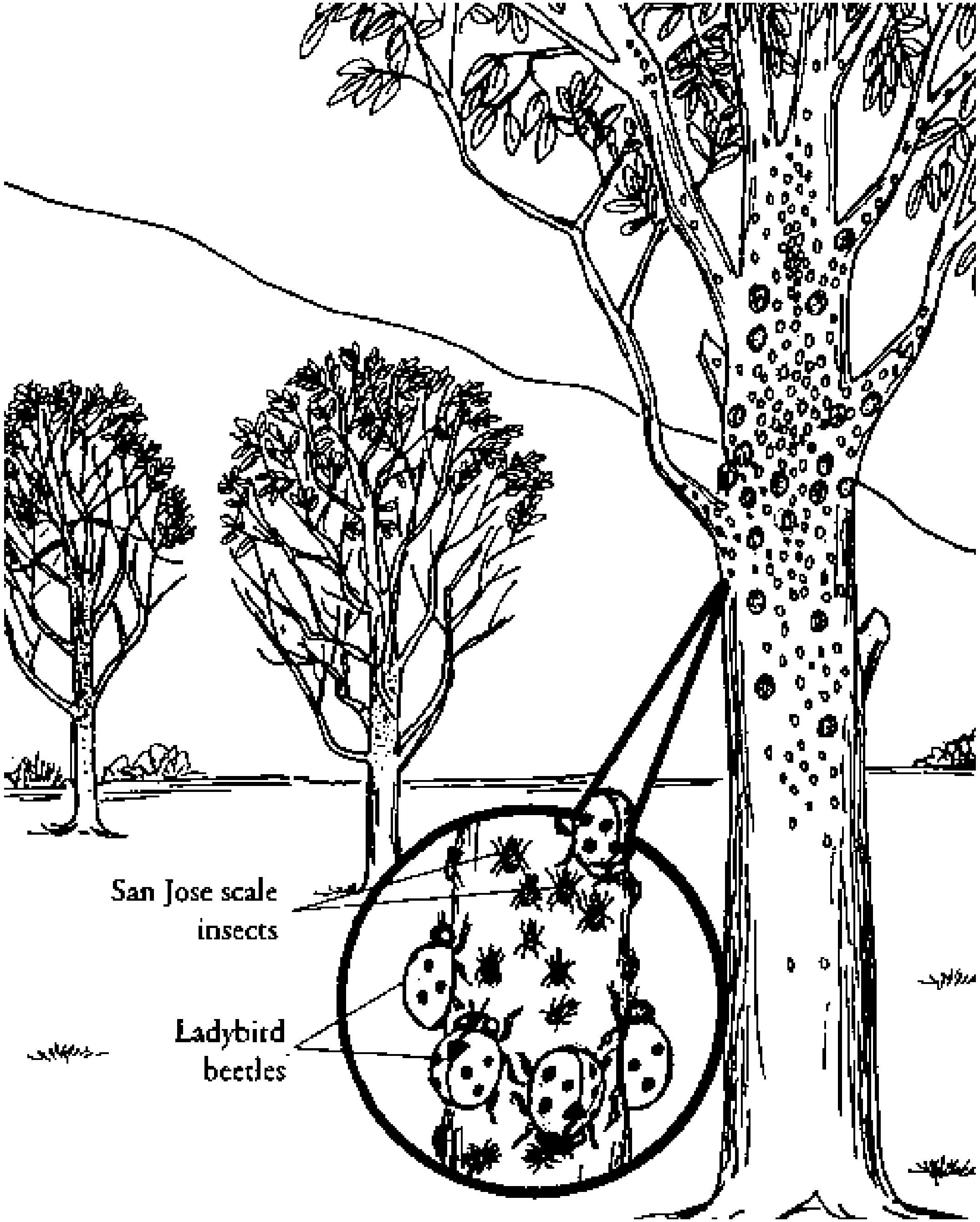
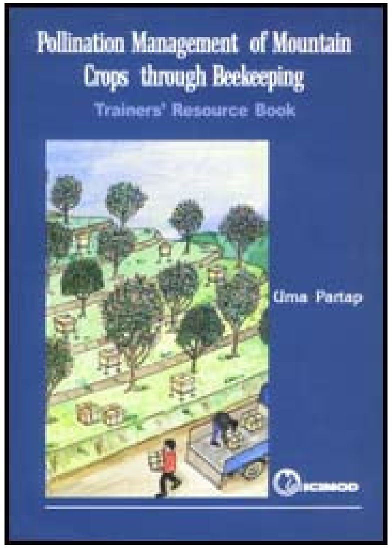


Figure A2: Biologically, pests can be controlled by using their natural enemies.

San Jose scale insect and keep its population below economic-injury level. In addition, white cabbage butterfly (*Pieris brassicae*), a serious pest of cabbage, cauliflower, and other members of the *Cruciferae* family, is controlled by the parasitoid, *Pteromalus puparum*. Farmers can obtain such biological control agents from biological control laboratories where they are mass-reared.

Integrated Pest Management (IPM)

Integrated pest control uses a combination of physical, cultural and biological methods together with a low amount of least toxic chemicals (pesticides). IPM is the best method of ensuring long-term pest control.



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Annex II: Relative Toxicity of Some Pesticides to Honeybees

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Pesticides have been classified into three groups: highly toxic, moderately toxic, and least toxic.

Highly Toxic Pesticides

These pesticides are highly toxic to bees and residual toxicity is usually high even 10 h after their application. When applied on blooming crops or weeds, they may cause severe damage to bees. Crop growers should inform beekeepers in advance when they are using these insecticides, so that colonies can be moved to safer locations. This group includes the following pesticides.

- **Carbaryl D; WP; XLR; ULV**
- **Carbophenothion D**
- **Cypermethrin 10 EC**
- **Deltamethrin 20 EC**
- **Diazinon**
- **Dichlorvos 100 EC**
- **Dimethoate 30 EC**
- **DDVP 100 EC**
- **Fenitrothion**
- **Fenthion**
- **Formothion**
- **Gamma BHC**
- **Lindane**
- **Melathion D; ULV; EC**
- **Methylparathion**
- **Mevinphos**
- **Monocrotophos 36 WSC**
- **Parathion**
- **Permethrin 25 EC**

- **Phorate**
- **Phosphamedon 100 EC**
- **Quinalphos 25 EC**
- **Thiometon**

Moderately Toxic Pesticides

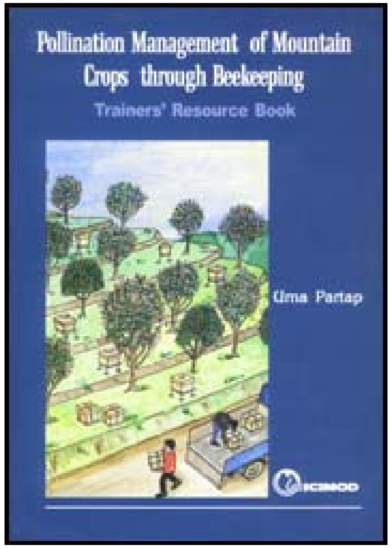
These pesticides are relatively less toxic to bees. Their residual toxicity is usually low within 3 h after their application. These pesticides can be applied during late evening when bees are not foraging. The following fall into this group.

- **BHC**
- **Carbryl G**
- **DDT 50%**
- **Dieldrin G**
- **Endosulfan 35 EC**
- **Endrin**
- **Ethyl Parathion 46%**
- **Heptachlor G**
- **Hinosan 50 EC**
- **Malathion 50 EC**
- **Metasystox 25EC**
- **Metacid 50 EC**
- **Methyl demeton**
- **Trichlorfon 50 EC**

Least Toxic Pesticides

These pesticides cause minimum hazard to bees. These can be applied during late evening, night, or early morning with reasonable safety to honeybees. Their relative toxicity is usually low straight after application. This group includes the following.

- **Allethrin**
- **Amitraz**
- **Azocyclothin**
- **Bavistin 50 WP**
- **Carbofuran G**
- **Diathane M-45 75 WP**
- **Dicofol**
- **Dienochlor**
- **Difolitan 50 WP**
- **Dinocap**
- **Dienochlor**
- **Fenazoflor**
- **Foltaf 80 WP**
- **Hexacap 50 WP**
- **Melathion G**
- **Menazon 70 DP**
- **Phosalone 35 EC**



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I started working on crop pollination during 1991 under the guidance of Professor L.R. Verma (now Vice-Chancellor, Dr Y.S. Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India), who introduced me to this field. Under his supervision, I conducted many experiments on the impact of honeybees on the yield and quality of various fruit and vegetable seed crops. During 1996, while reviewing issues related to crop pollination, we found a serious problem in many crops of the Hindu Kush-Himalayan region. I then thought of sharing my experiences of crop pollination management using friendly insects particularly hive bees. As a result, I prepared the framework of this manual and discussed it with colleagues in ICIMOD.

Many individuals were instrumental in producing the final version of this book. In ICIMOD, I am particularly grateful to Mr Egbert Pelinck, Director General; Dr Mahesh Banskota, Deputy Director General; Dr Tej Partap, Head, Mountain Farming Systems Division; Mr K.K. Shrestha, Co-ordinator, Beekeeping Project; Dr Naomi Saville, Beekeeping Research and Extension Officer; Mr A.N. Shukla, Beekeeping Extensionist; Ms Greta Rana, Senior Editor, DITS; Ms Anita Pandey,

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The final draft of the manual was critically reviewed by experts including Dr Nicola J. Bradbear, President Bees for Development, UK; Dr Harish K. Sharma, In-charge, Beekeeping and Horticultural Research Station of University of Horticulture and Forestry, Katrain, District Kullu, Himachal Pradesh, India; Dr D. R. Gautam, Horticultural Research Station of University of Horticulture and Forestry, Katrain, District Kullu, Himachal Pradesh, India; Mr Pratim Roy, Keystone, Nilgiris, India. Their comments were of great help in improving the manual.

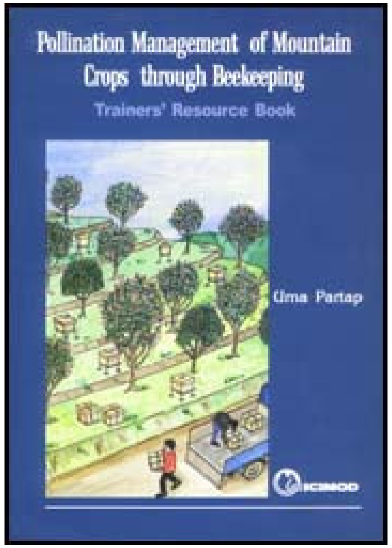
I benefited greatly from earlier publications with ideas for illustrations. I especially acknowledge Pest Control Safe for Bees by Dr Margarate Adey, Dr Penelop Walker and Dr Peter Walker; Pollination of Cultivated Plants in the Tropics by Dr D.W. Roubik; Training Leaflets by HMG/SNV Beekeeping Training and Extension Support Project; Bees and Beekeeping: Science, Practice and World Resources by Dr Eva Crane.

Planning this publication was possible only with financial support from the ICIMOD Beekeeping Project grant-funded by the Federal Chancellery of Austria through Austroprojekt. I gratefully acknowledge its support.

I express my heartfelt thanks to my daughters Bhoomika and Uttara for the support, patience, and understanding they showed when I was busy in the

preparation of this manual.

Uma Partap
May 1998



Pollination Management of Mountain Crops through Beekeeping - Trainers' Resource Book

Author(s):	***Uma Partap***
Publication date:	***1999***
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Summary

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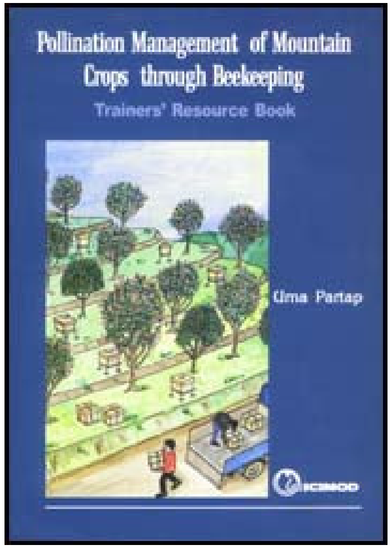
At present, both yield and quality of mountain cash crops are declining mainly because of a decrease in the populations of natural insect pollinators. This has created the need for managing hive bee species such as *Apis cerana* and *Apis mellifera* for crop pollination. This manual has been prepared to help mountain farmers/orchardists/extension workers manage hive bees for pollination of crops.

This manual consists of seven chapters supported by illustrations intended to help those who cannot read or understand English. Chapter 1 provides a general introduction to pollination: self-pollination and cross-pollination; agents of cross-pollination; and the role/importance of cross-pollination in enhancing productivity and yield of mountain crops. Chapter 2 describes the reasons why different kinds

of bees are important crop pollinators; how a bee pollinates a flower; a honeybee colony, its reproduction/multiplication (swarming) and absconding; and species of honeybees found in the Hindu Kush-Himalayan region.

Chapter 3 describes types of beehives including traditional fix-comb hives and modern movable-frame hives. Chapter 4 explains the role of hive bees in crop pollination and why they are better crop pollinators than wild bees. It also describes ways to manage hive bees for pollination of crops in general. Chapter 5 details the management of hive bees for pollination of particular cash crops. Chapter 6 provides examples of managed crop pollination using hive bees and wild bee species; and the economic value of bee pollination. In response to the increasing use of pesticides, Chapter 7 suggests ways that crop growers and beekeepers can protect bees from their harm effects.



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Chapter 1: Introduction to Pollination

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Agriculture is the main occupation for most people in the hills of the Hindu Kush-Himalayan region. Ninety-three per cent of farmers survive by cultivating small

plots of land of less than 2 ha. The agroclimatic conditions are suitable for cash crops such as seasonal and off-seasonal vegetables, seed vegetables, and various subtropical and temperate fruits. Farmers are changing from the cultivation of traditional grain crops to high-value cash crops. They are keen to increase the yield and enhance the quality of these crops.

How can crop productivity be enhanced?

Farmers would like to enhance the yield and quality of their crops in order to earn better economic returns. Methods for increasing crop yield and quality are as follow.

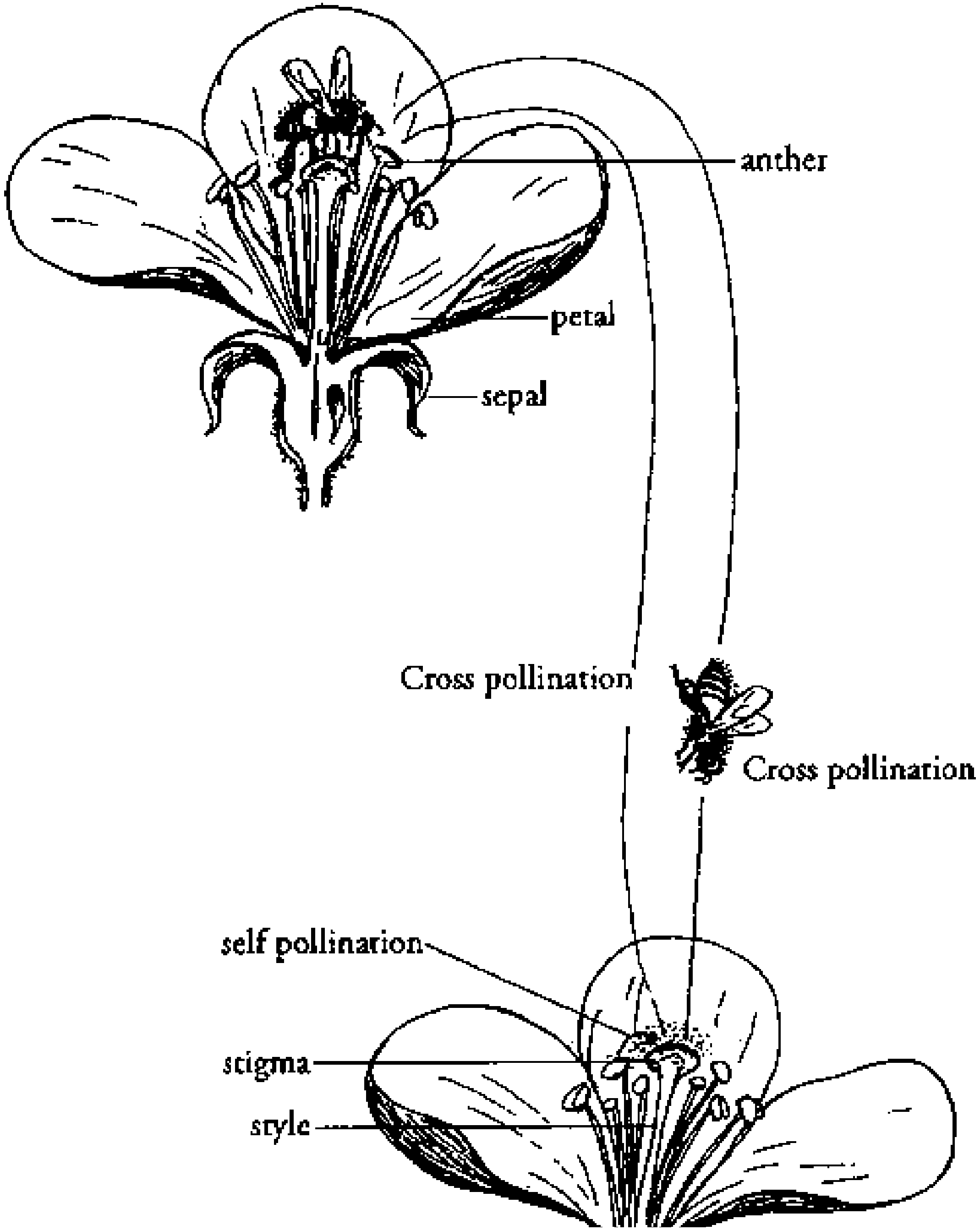
- **Use of improved agronomic methods: good-quality seed, fertilizers and organic manure, irrigation, and pesticides.**

- **Use of biotechnological methods: manipulating the role of photosynthesis, incorporating biological nitrogen fixation, and genetic engineering, etc.**

- **Management of crop pollination.**

Many varieties of commercial crops are self-sterile and require cross-pollination of their flowers in order to produce fruit or seeds. In such crops, productivity can be enhanced by managing cross-pollination through insects such as honeybees and other natural pollinating insects. Pollination is essential for sexual reproduction and the formation of abundant seeds and fruit. It is, therefore, important for enhancing crop productivity. Other methods will not yield the desired results

without cross-pollination; many crops will not even produce seeds or fruit.



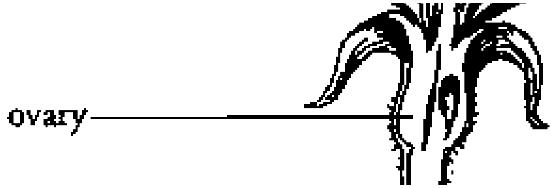


Figure 1.1: Diagram illustrating the structure of the flower and modes of pollination

What is pollination?

Flowering is a vital process in the reproduction of most crops. A flower consists of the organs essential for reproduction. A typical hermaphrodite (bisexual) flower has four parts: calyx, corolla, androecium, and gynoecium (Figure 1.1). The calyx (sepals) is usually green and provides protection to other floral parts in the bud stage. The corolla (petals) is variously coloured. It helps in the attraction of insect pollinators. Androecium is the male part of the flower comprised of the stamens (male sex organs). A stamen consists of a filament and an anther. Anthers produce male spores called pollen grains. After pollen grains have matured, the anther wall opens and the ripe pollen is released. The female part of the flower is called the gynoecium. It is made up of pistils, also called carpels. A pistil consists of an ovary having one to many ovules, a style, and a stigma. When the pistil is ready to perform reproduction the stigma becomes receptive by developing a sticky surface. Pollen grains become attached to the surface when they touch it.

Many crops - apples, citrus, peaches, pears, plum, sunflowers, cabbage, cauliflower, and mustard - produce hermaphrodite (bisexual) flowers that have both male and female sex organs. However, there are crops - various cucurbits - that produce monosexual (either male or female) flowers on the same or different branches of the same plant. There are also crops - kiwi fruit and *lapsi* - that

produce male and female flowers on different plants.

The transfer of pollen grains from the anther to the stigma of the same flower or another flower of the same plant or another plant of the same species is called pollination (Figure 1.1). An agent that helps in the transfer of pollen is a pollinator. Pollination leads to fertilization, i.e., the union of male and female nuclei. After pollen grains attach to the surface of the stigma, they send pollen tubes through the style to the ovary. The male nucleus of each pollen tube then unites with the ovule effecting fertilization. After fertilization, the ovule and associated tissues develop into seeds and fruits. Therefore, pollination is crucial for fertilization and the development of seeds and fruits. Plants generally exhibit two pollination modes: self-pollination and cross-pollination.

Self-pollination

Self-pollination is the transfer of pollen from the anther of a flower to the stigma of the same flower, i.e., pollination within a flower (Figure 1.1). When this happens the plant is considered to be self-pollinated.

Self-pollination takes place automatically in nature when anthers and stigma are of the same height (i.e., of equal length); both mature at the same time; and fresh pollen comes into contact with a receptive stigma. Self-pollinated crops usually produce plenty of dry pollen. A crop that is fertilized by its own pollen and can produce seed and fruit is called self-fertile or self-compatible. A crop that cannot be fertilized by its own pollen but needs pollen from another plant of the same species is called self-sterile or self-incompatible.

Cross-pollination

Cross-pollination is the transfer of pollen from the anthers of one flower to the stigma of another flower of the same or a different plant of the same species (Figure 1.1). When this takes place the plant is called cross-pollinated. Cross-pollination always requires a pollinator: an agent that carries the pollen grains from the anthers of one flower to the stigma of another flower. There are two types of cross-pollination as follow.

- **When pollen is transferred to a flower of the same plant, cross-pollination is equivalent to self-pollination. It tends to decrease the likelihood of genetic variation in the crop.**
- **The other type of cross-pollination takes place when pollen from the flower of one plant is transferred to a flower of another plant of either the same or a different variety. This type of cross-pollination increases the likelihood of genetic variation.**

Cross-pollination occurs if

- **flowers are unisexual and are borne on either the same or different plants (for example, the pumpkin has male and female flowers on the same vine and kiwi fruit has male and female flowers on separate vines);**
- **anthers and stigma are physically excluded, i.e., they are present at different heights, for example, sunflower, safflower;**

- **anthers and stigma mature at different times, for example, onion and tree fruits such as jujube, peaches, plums, and almonds; and**
- **plants are self-incompatible (flowers are not fertilized by the pollen of the same variety); for example, many varieties of apples, almonds, and pears.**

Commercial varieties of many fruit crops are self-sterile or self-incompatible, e.g., almonds, apples, plums, cherries, and various vegetable crops. Flowers of these plants do not produce seeds or fruit unless cross-pollination takes place. Cross-pollination also occurs in self-pollinated plants when pollen is transferred from one flower to another flower of the same or a different plant by wind or insects.

What are agents of cross-pollination?

Self-pollinated plants are pollinated automatically when receptive stigmas come into contact with freshly released pollen from the same flower. However, many plants are not pollinated automatically. Moreover, in self-sterile crops, such as almonds and apples, flowers cannot be fertilized by pollen from the same flower or even the same plant. Pollen is needed from some other compatible source. Such crops need external agents (pollinators) to help them transfer pollen. Two types of pollinating agents occur in nature: abiotic and biotic.

Abiotic pollinating agents

Good examples of abiotic pollinating agents are wind, water, and gravity. This type of pollination is random and not reliable.

Wind. Many crop plants are successfully pollinated by wind, especially those that produce dry pollen; for example, grain crops such as wheat, rice, maize, and millet and nuts such as chestnut, pecan nut, and walnut. Wind pollination is also called anemophily. Wind-pollinated plants have specific characteristics that include reduced leaf-surface area, exposed flowers, reduced perianth (sepals and petals) since there is no need to attract biotic pollinating agents, long stamens and sometimes explosive anther dehiscence (pollen release), production of large amounts of pollen, smooth and dry pollen grains, winged pollen grains, balloon-shaped pollen grains, lack of nectar and nectaries, and flowers without colour or scent.

Water. Water pollination, also called hydrophily, is only found in some water plants, for example, *Trapa*. Inflorescences (flowering branches) float on the water or are submerged. Many fresh water plants produce flowering branches that are raised into the air (aerial inflorescence).

Gravity. Pollination by gravity, also called geophily, is found in self-pollinated crop plants. In this case, pollen falls because of gravity on to receptive stigma of other flowers. However, gravity is highly unreliable and a rare and insignificant pollinating agent.

Biotic pollinating agents

Biological pollination agents (biotic agents) include insects, birds, and various mammals. Biological pollination is also called zoophily. Animals visit flowers for nectar and/or pollen, and they incidentally transfer pollen grains from one flower to another flower of the same or another plant. Characteristics of crop plants that

are pollinated by biotic agents include

- **some kind of relationship between the pollen vector and the flowers,**
- **the production of relatively small amounts of pollen,**
- **pollen grains that vary in size and external sculpture and are sticky in nature,**
- **the production of flowers of attractive colours and odours, and**
- **flowers that have nectaries that produce nectar.**

Birds. Pollination by birds, called ornithophily, occurs in a few plants in the Hindu Kush-Himalayan region but is very common in some places, e.g., South America and Australia. Some birds - bronzy hermit humming bird, broad-tailed humming bird, male purple sunbird, cape sugar bird, and tawny crowned honey eater - visit flowers of a particular plant species for nectar, and so pollinate them. These pollinating agents visit only those few crop plants that produce plenty of nectar, for example, avocado and pineapple are visited by humming birds.

Mammals. Certain mammals - Queensland blossom bat, short-nosed fruit bat, honey possum, and Namaqua rock mouse - visit flowers of a particular plant species for nectar, and so pollinate them. Mammals are, however, the pollinating agents of only a few plants.

Insects. Insect pollination, also called entomophily, is found in many agricultural

and horticultural crops. Different kinds of insects such as bees, flies, beetles, butterflies, moths and wasps are important pollinators of many plants. Crops that require insect pollination to set fruit and seed are called entomophilous. Entomophily occurs in many plants. Agricultural crops, horticultural crops, forage crops, ornamental plants, and other wild plants are all effectively pollinated by insects that visit flowers for nectar and/or pollen. Bees are one of the most effective and reliable pollinators.

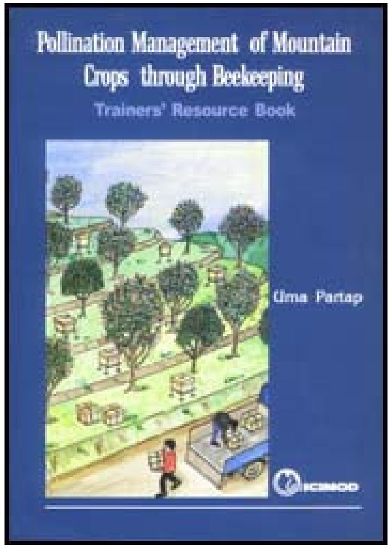
Why is cross-pollination important?

Pollination is crucial for the production of fruit and seed. There are many plants that cannot produce fruit and seed if pollinated by their own pollen and so require cross-pollination. Such plants include those in which male and female parts are either borne on separate plants or on separate parts/flowers of the same plant. Cross-pollination is also essential in those crops in which male and female parts are borne on the same flower but they are physically excluded from each other. Cross-pollination in normally self-pollinated crops also results in higher yields and better quality fruit and seed.

- **Cross-pollination is important in many partially or fully self-incompatible/self-sterile varieties of agricultural and horticultural crops; for example, commercial varieties of cabbage, cauliflower, broccoli, radish, apple, almond, peach, pear, plum, etc.**

- **Cross-pollination is also important for fruit and seed production in plants that produce unisexual flowers; for example, species belonging to the families *Actinidiaceae, Anacardiaceae, Cucurbitaceae*.**

- **Cross-pollination enhances the yield and quality of many self-pollinated crops.**



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Chapter 2: Bees As Crop Pollinators

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Why are bees important pollinators?

There are about 20,000 species (types) of bees found in the world. Many of these are found in the Hindu Kush-Himalayan region. They include honeybees, bumble bees, stingless bees and solitary bees as described in Chapter 6. All bees depend on food (nectar and pollen) provided by flowers: they cannot survive without it. While visiting flowers for food they also aid pollination by transferring pollen from one flower to another. A close relationship exists between plants that require cross-pollination and bees that use nectar and pollen for food.

Bees are important to farmers because they are better than other insects at pollinating flowers of many agricultural, horticultural, and forage crops, as well as

other plants (Figure 2.1). Therefore, a large number of bees on a crop ensures good pollination that results in higher yields and better quality produce. Without bees many crops would produce little or no fruit or seed.

Bees have the following characteristics that make them the most important pollinators.

- **Bees are social insects. Other insects collect nectar mostly to satisfy their individual needs whereas bees collect nectar and pollen to feed their young.**

- **Bees have body hairs. When a bee visits a flower some pollen becomes attached to its body and is transferred to the stigma of another flower that the bee visits. This accomplishes pollination.**

- **Bees show flower constancy: i.e., a foraging bee usually moves from one flower to another of the same species for as long as nectar and pollen are available. Other insects haphazardly visit flowers of different species. This constancy in foraging is important for effective cross-pollination.**

- **Many species of bees, e.g., honeybees and stingless bees, are kept in man-made nest sites and are mass-reared for honey production. They are also managed for crop pollination.**

- **Many species of bees (other than those kept for honey production) can also be managed for crop pollination. The most important are bumble bees and solitary bees, e.g., alkali bees, horn-faced bees, and leaf-cutter bees.**

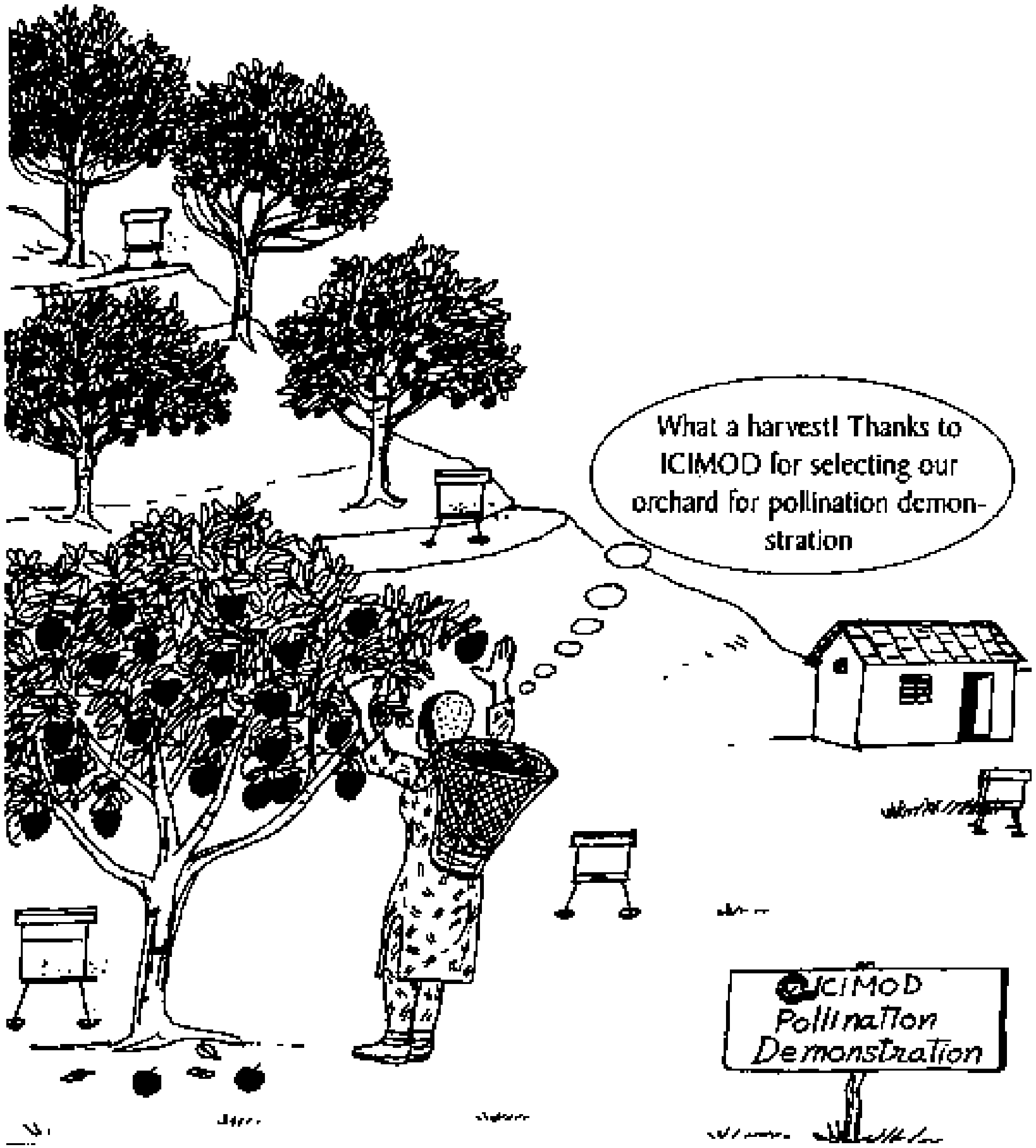


Figure 2.1: Bees are important pollinators of many agricultural and horticultural crops.

How do bees pollinate a crop?

A bee visiting the flowers of a crop becomes conditioned to that particular crop. During a single foraging trip, it visits a number of flowers of the same crop. While collecting nectar and pollen, the bee brushes against the anthers of a flower and some pollen grains are picked up by the hairs on its body and head. When the bee visits another flower some of the pollen grains are captured by the sticky surface of a receptive stigma, thus effecting cross-pollination (Figure 2.2).

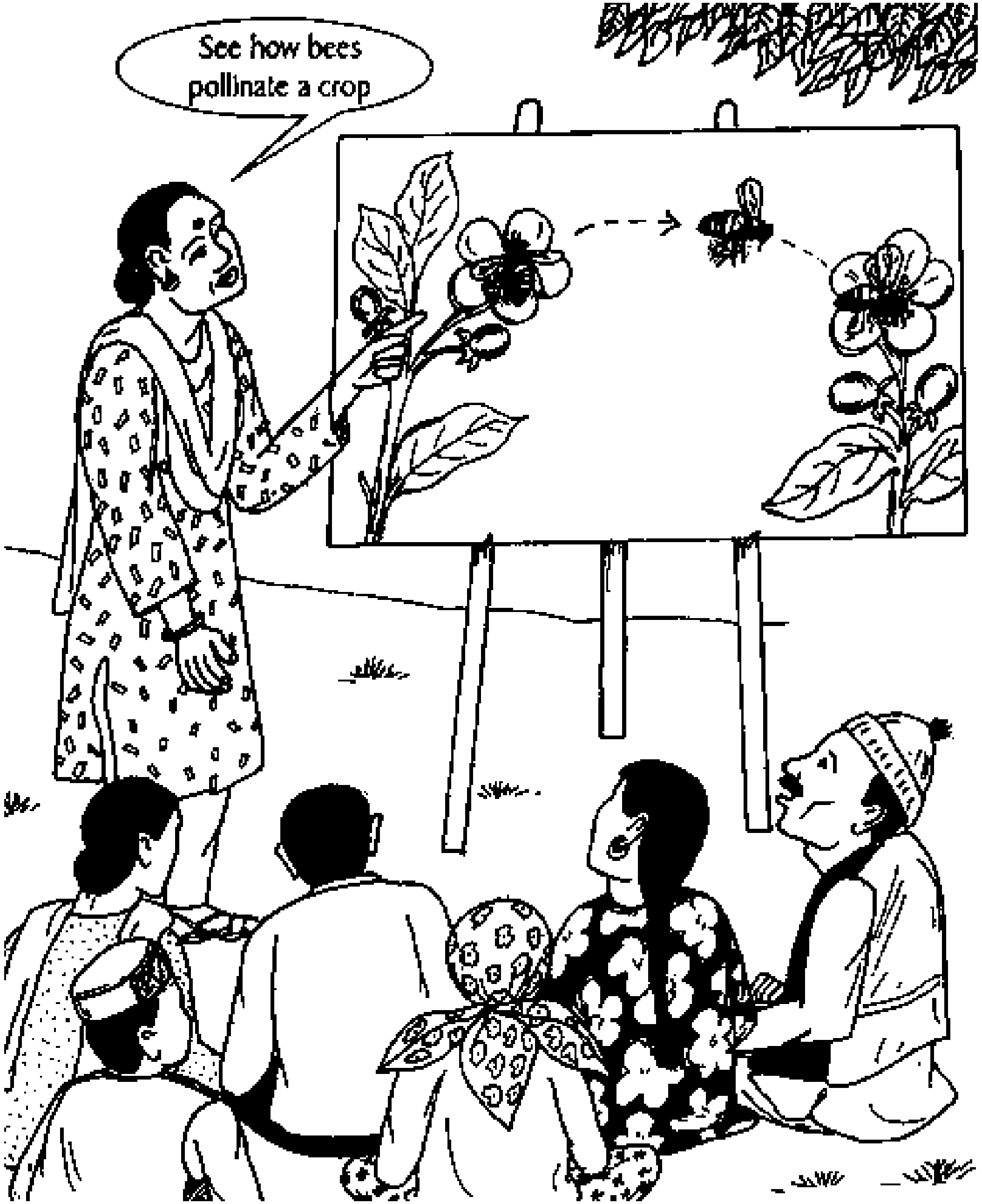


Figure 2.2: A bee pollinates a crop by transferring pollen from one flower to another of the same or different plant of a crop.

Why are honeybees the most important of all bee species in pollination?

Honeybees are the most widely known of all bees because they provide honey, beeswax, and other products such as pollen, propolis, and royal jelly. Beekeeping is a prevailing tradition among mountain farming communities. The Himalayan honeybee, *Apis cerana*, is kept in traditional fixed-comb hives such as log hives, wall hives, and pitcher hives, as well as in modern movable-frame wooden hives. Beekeeping is becoming an entrepreneurial activity in mountain areas. Honeybees have certain characteristics - social and behavioural - that make them the most effective and reliable crop pollinators.

- **Honeybees live in colonies where the young are nursed and fed with a mixture of honey and pollen by adults throughout the year. A colony is defined as a group of insects living in a common nest that they have constructed (Figure 2.3). They work together to supply each other's needs and cooperate to raise offspring. Honeybee colonies are large compared to those of other bees consisting of 10,000 to 80,000 individuals depending upon the species.**

- **They have the potential for working long hours. They start their foraging early in the morning and cease late in the evening, working many hours a day.**

- **Honeybees have evolved a special communication system by which thousands of foragers can be deployed when a good food source is present.**

- **Compared to other bee species, they visit many flowers per unit time.**

- **They are adapted to different climates.**

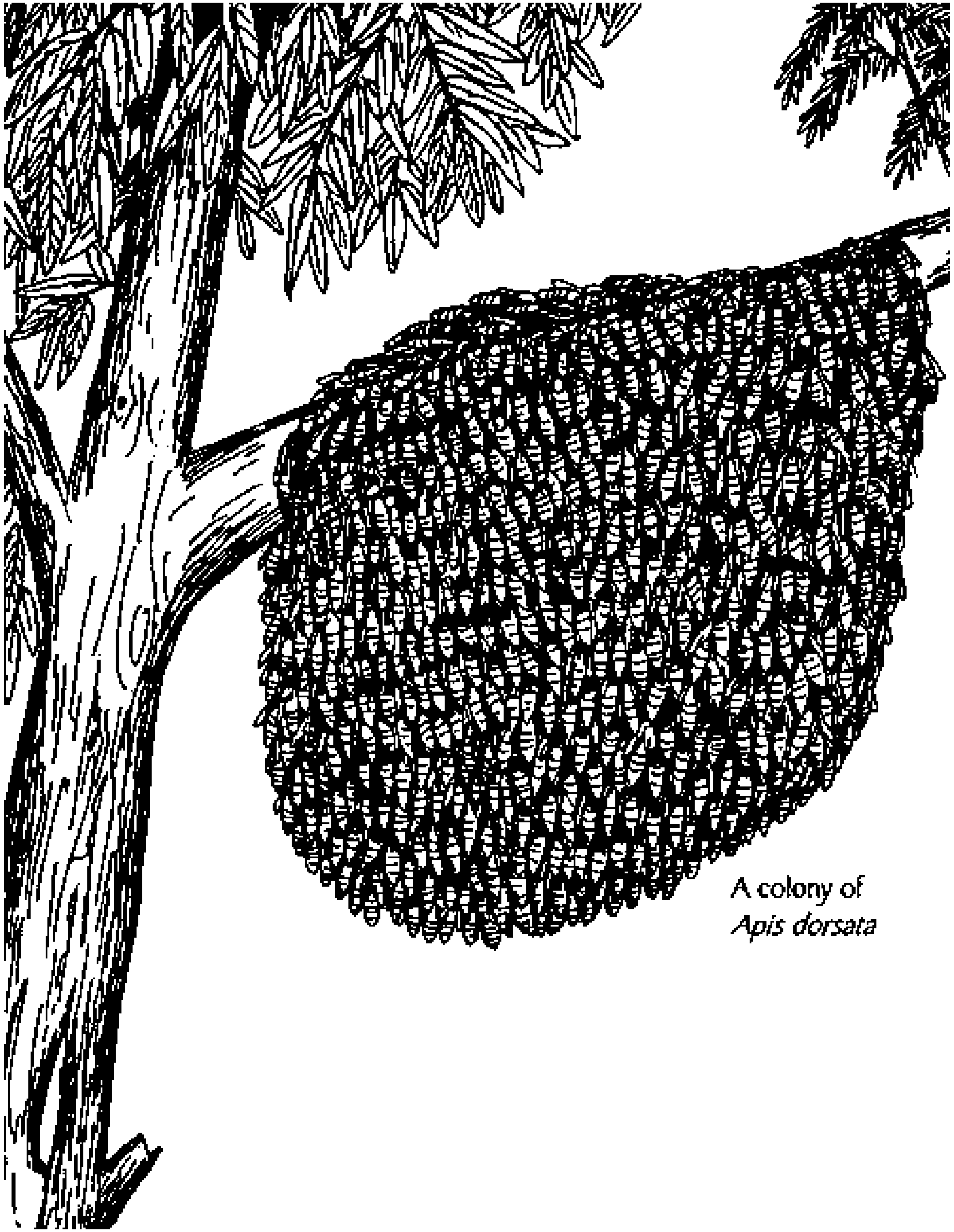
- **They are micro-manipulators of flowers.**

- **Some species can be managed in large numbers and moved to crops where and when necessary.**

- **Most importantly, honeybees provide honey, beeswax, and other hive products for man.**

What are the members of a honeybee colony?

Honeybees live in colonies. A honeybee colony can contain up to 80,000 bees, depending on the species. A colony of honeybee consists of one queen, a few drones, and thousands of workers (Figure 2.4). The queen is the only fertile female in the colony. She is much longer and darker than drones and worker bees. However, it is difficult to find her in the colony because she is usually covered by many worker bees.



A colony of
Apis dorsata

Figure 2.3 A colony of honeybees: honeybees live in colonies (10,000 -80,000 bees) in which food (honey and pollen) is stored and the young are nursed.

The queen is the mother of all other bees in the colony. The most important function of the queen is to lay eggs to produce offspring. Immature stages (eggs, larvae, and pupae) are collectively called the brood. The majority of fertilized eggs laid by the queen develop into worker bees or daughters. She also lays a few unfertilized eggs during the swarming or reproduction season that develop into drones (male bees).

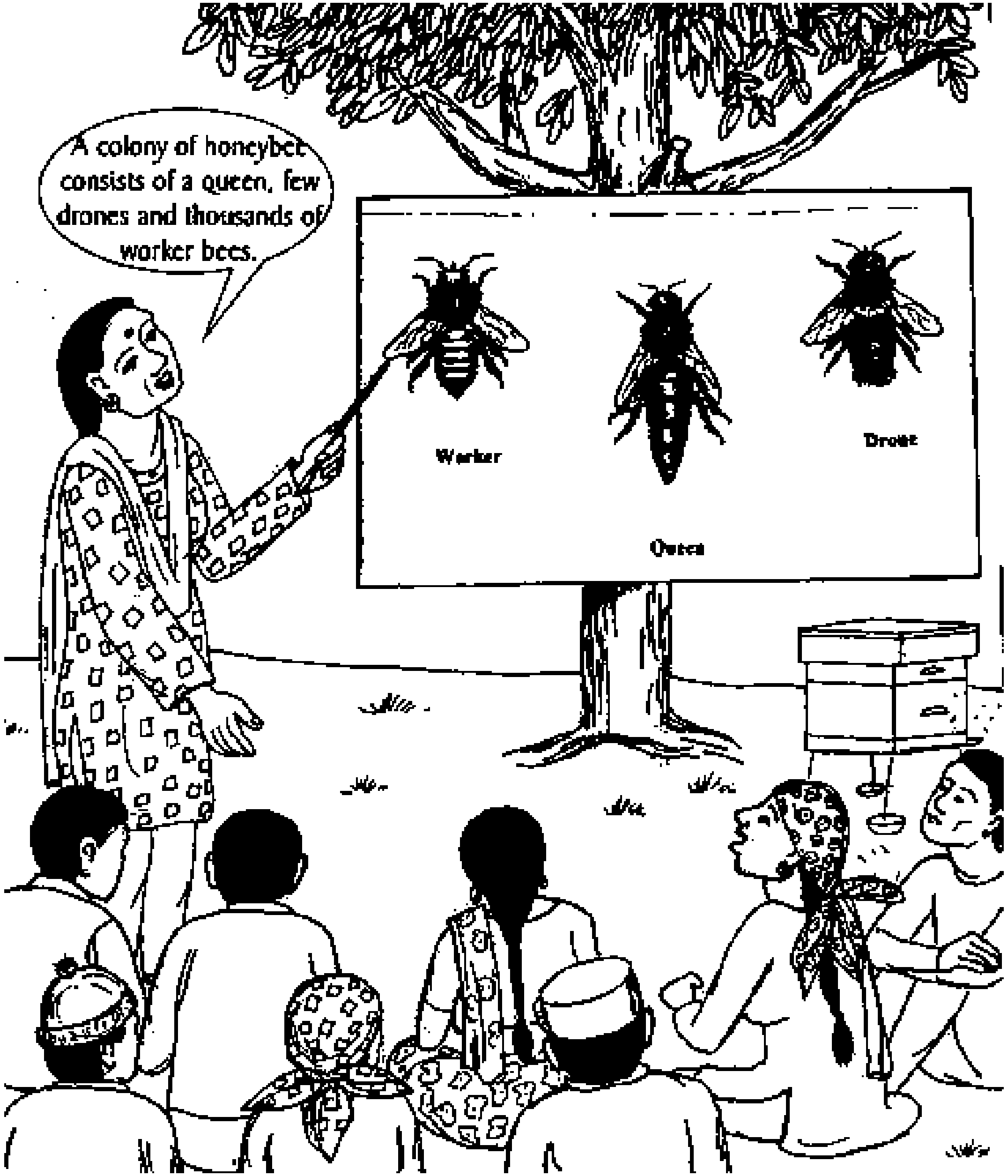


Figure 2.4: A honeybee colony consists of a queen, a few drones, and thousands of worker bees.

Workers are sterile females and are produced in thousands. They are the smallest members of the colony. They do all the work required for its survival. They feed the brood, take care of the young, build the nest, clean the hive, defend the colony from pests and predators, and regulate colony temperature. They store both nectar and pollen in the hive to provide food for the colony. Workers also collect nectar and convert it into honey. Although worker bees are sterile, in the absence of a queen over a long period of time, they develop functional ovaries and lay unfertilized eggs that develop into drones.

Drones are generally produced when a colony is preparing for swarming. In this situation, the colony will also construct queen cells. Thus both drones and queens are reared together. The drones fly from the colony to mate with a queen. Drones are bigger than workers and smaller than the queen and have large eyes.

The honeybee colony lives in and between combs called a nest. The nest consists of wax combs made by the bees in which the young are reared, and the adults live with their food stores (Figure 2.5). Worker bees construct the combs from wax produced by wax glands in their bodies. Honeybee nests are located in protected places. While some species prefer dark places, such as hollow tree trunks, others live in the open, in bushes, tall trees, etc. The combs are two sided and are composed of hexagonal cells. The combs contain stored honey at the top, followed by a layer of stored pollen, and below are the brood of all stages (eggs, larvae, and pupae).

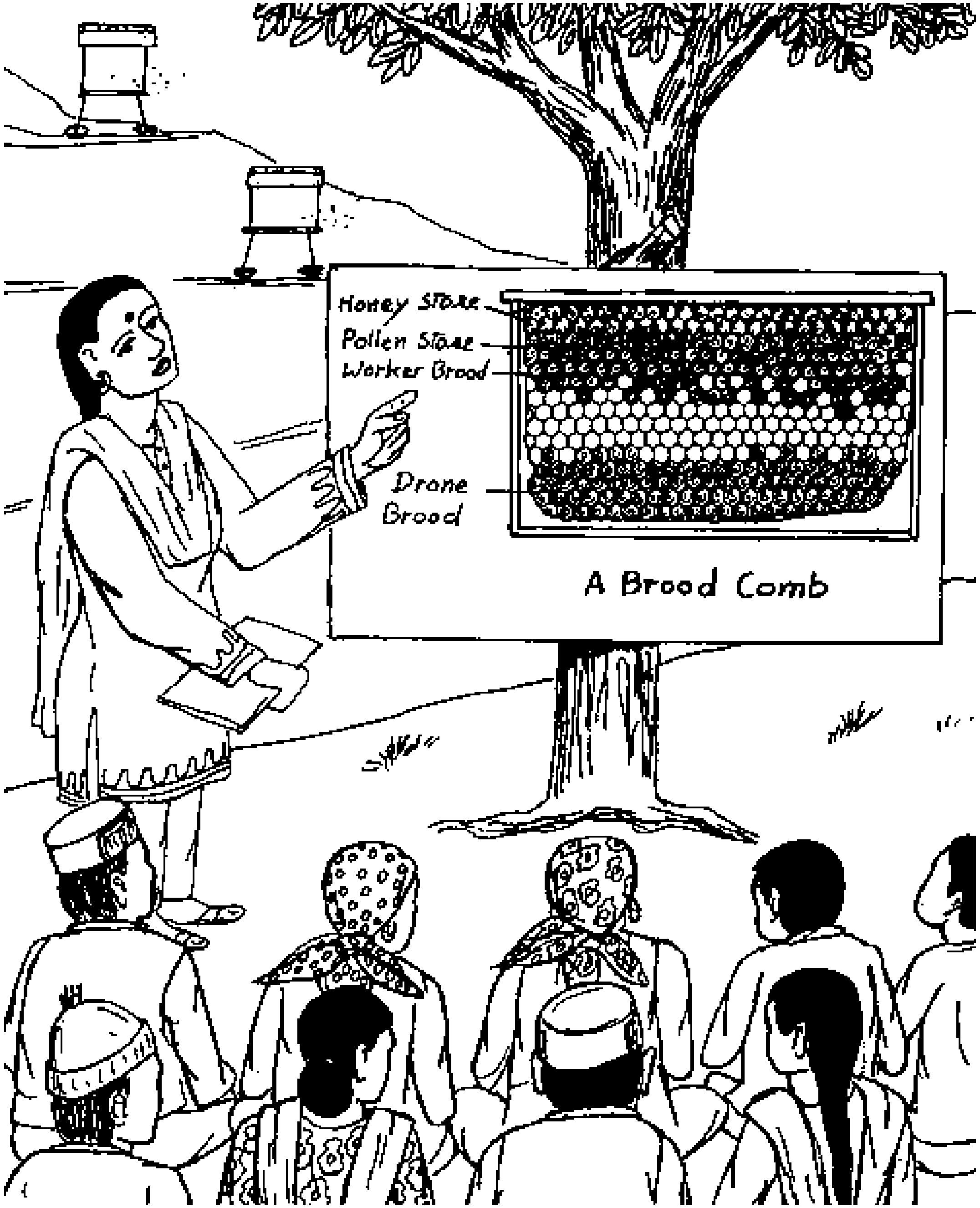


Figure 2.5: A honeybee nest consists of wax combs in which honey and pollen are stored and the brood is reared.

What is swarming?

Swarming

Swarming is defined as the departure from its nest of a portion of the adult worker bees of a colony, with a queen and a few drones (Figure 2.6). Swarming is the natural way for colonies to multiply. A part of the colony with the old queen leaves the hive or old nest site to search for a new site. The remaining members continue living at the original site with a newly emerged queen. This queen becomes fertile, mates with drones, and lays eggs.

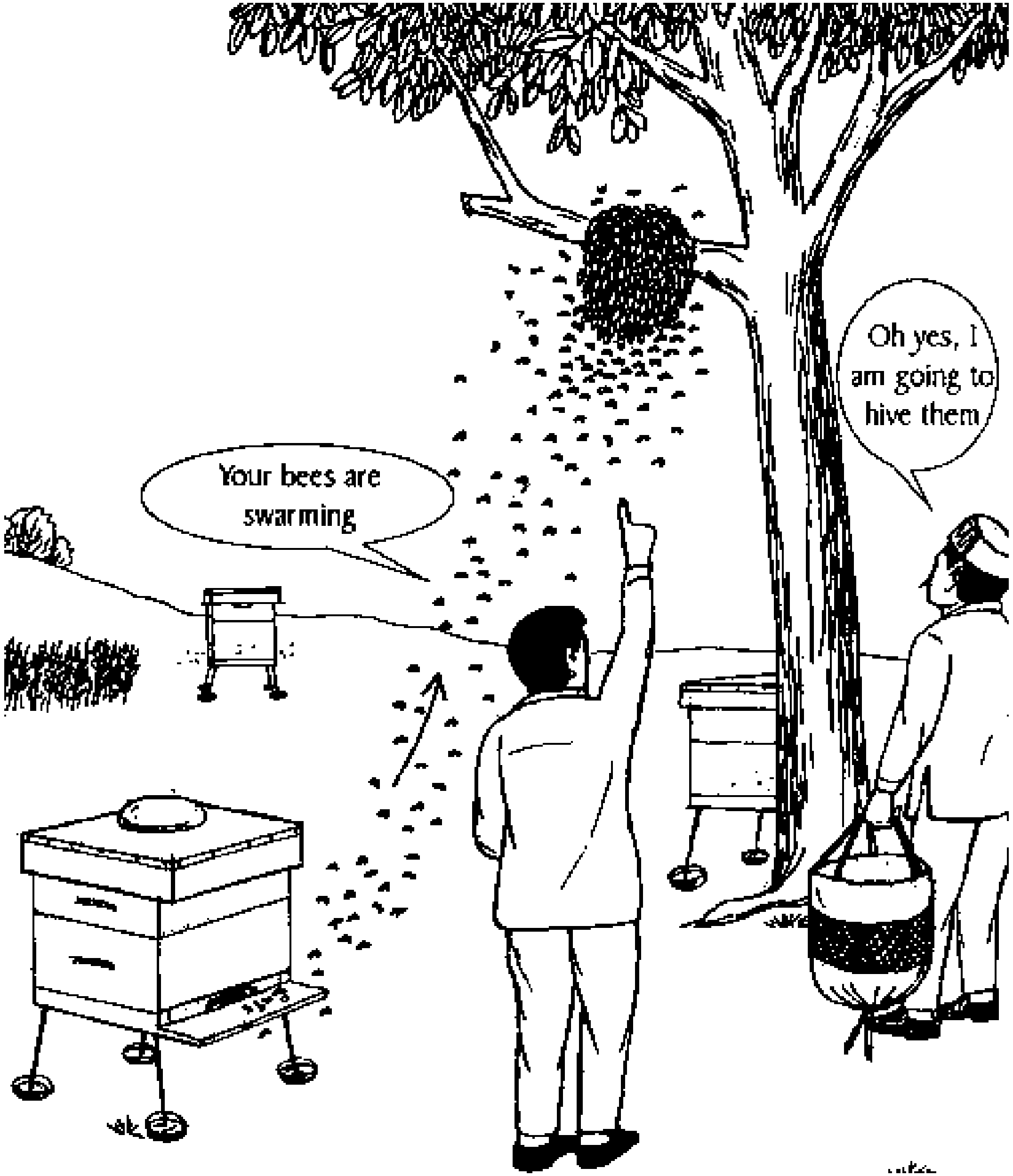


Figure 2.6: Swarming of a honeybee colony means some of the adult worker bees and few drones led by the old queen leave the old nest site and form a new colony.

Swarming generally occurs during the active brood-rearing season, usually between February and June, depending on climatic conditions. In low hill areas it occurs during February to March, and in high mountain areas it takes place during May-June.

Predicting swarming

Colonies generally prepare for swarming when food is plentiful, i.e., when there are plenty of suitable flowering plants. The main symptom of a colony preparing for swarming is the construction of drone cells and the appearance of a drone brood (Figure 2.5). This is followed by the construction of queen cells. In *Apis cerana,* queen cells are generally constructed on the bottom margins of the brood combs (Figure 2.7). In *Apis mellifera*, queen cells are also constructed on the face of brood combs. It may not always be necessary to examine the combs for the presence of a drone brood. Swarming can also be predicted by the presence of adult drones in the colony. They can be seen at the hive entrance when they leave during the afternoon (15.00-17.00 h).

Need to prevent swarming and how it is done

Swarming of bee colonies may be beneficial for reproduction, but, for a beekeeper, swarming means the loss of half of his bees (especially if he is unable to catch and hive the swarm). Frequent swarming (especially outside the active brood-rearing season) - as is common with the Himalayan honeybee, *Apis cerana* - is not beneficial for the beekeeper. For example, swarming four or five times will result in small, weak swarms that may not be able to establish healthy colonies and will probably die sooner or later. Swarming has a negative impact on honey production

and crop pollination because weak colonies are not effective, either at the production of honey or at pollination, since they have a small percentage of foragers. Therefore, it is necessary to control frequent swarming in order to maintain strong, healthy colonies. This can be achieved in the following ways.

Figure 2.7: Presence of queen cells and a drone brood is an important symptom of a colony preparing for swarming.

• Inspect the colony regularly and check whether it is preparing for swarming. This means checking whether queen cells or a drone brood are present as these are the main indicators.

• If queen cells or a drone brood are present, assess the strength of the colony. Judge whether it can be divided into two without having a negative impact on honey production, crop pollination and survival. If it is strong enough, destroy all queen cells except for one and divide the colony; i.e., put half of the bees with one queen cell into another hive. The other bees with the old queen will remain in the same/parent hive.

• If the colony is not strong but is still preparing for swarming, destroy all the drone brood and the queen cells. This will help control swarming.

• If the colony is strong but the bees are congested, provide more space by placing a super over the brood chamber (Figure 2.8).

• Try to keep the colony free from disease and enemies.

• If the colony has decided to swarm, it is important to break its swarming impulse by pseudo-swarming (false swarming). This can be done by allowing the bees to fly away without a queen. This is affected by putting a queen gate at the hive entrance (Figure 2.9) or by caging the queen (Figure 2.10). The bees will come back because the queen remains in the hive.

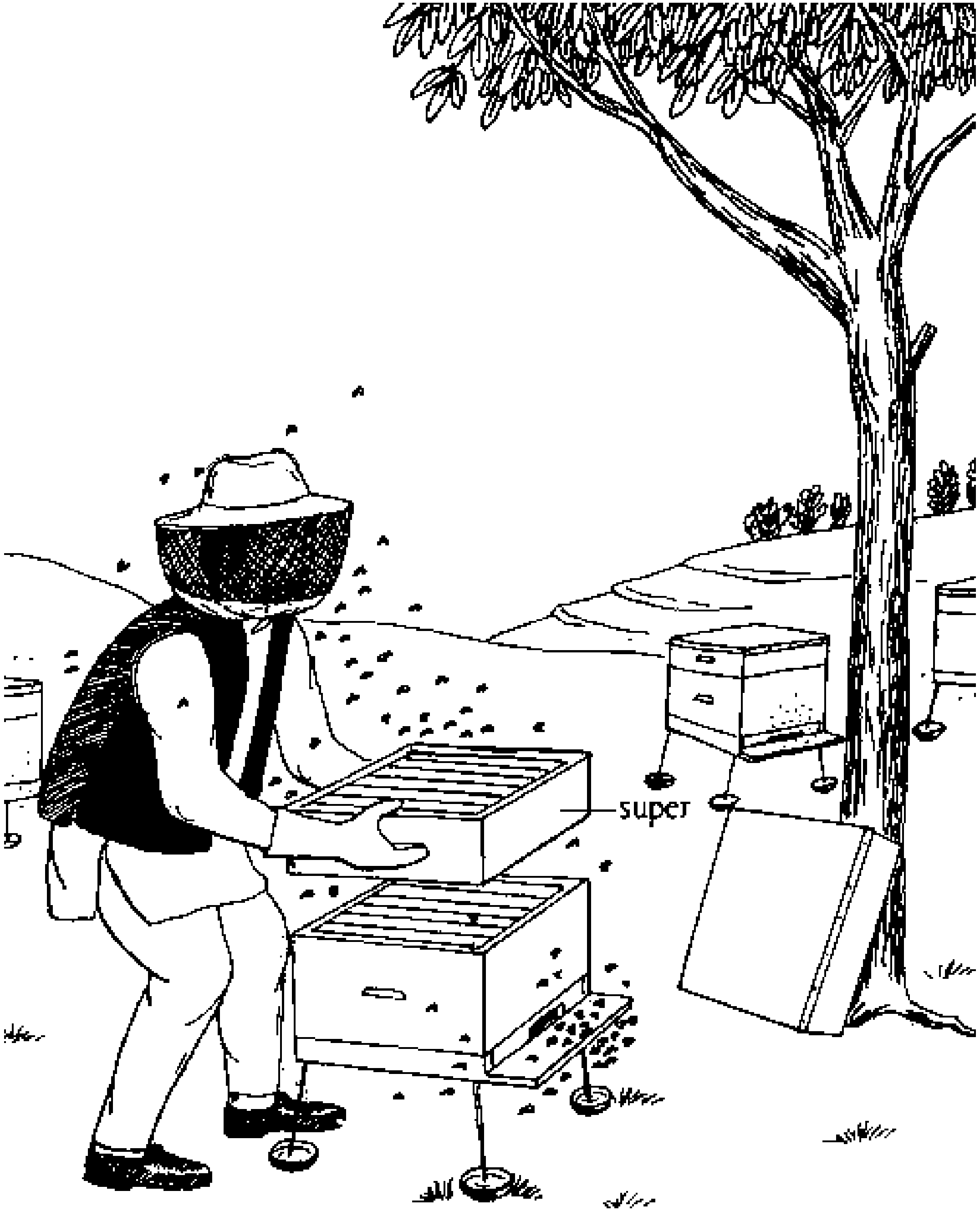


Figure 2.8: Swarming is often due to congestion in the colony and can be prevented by providing bees with more space.

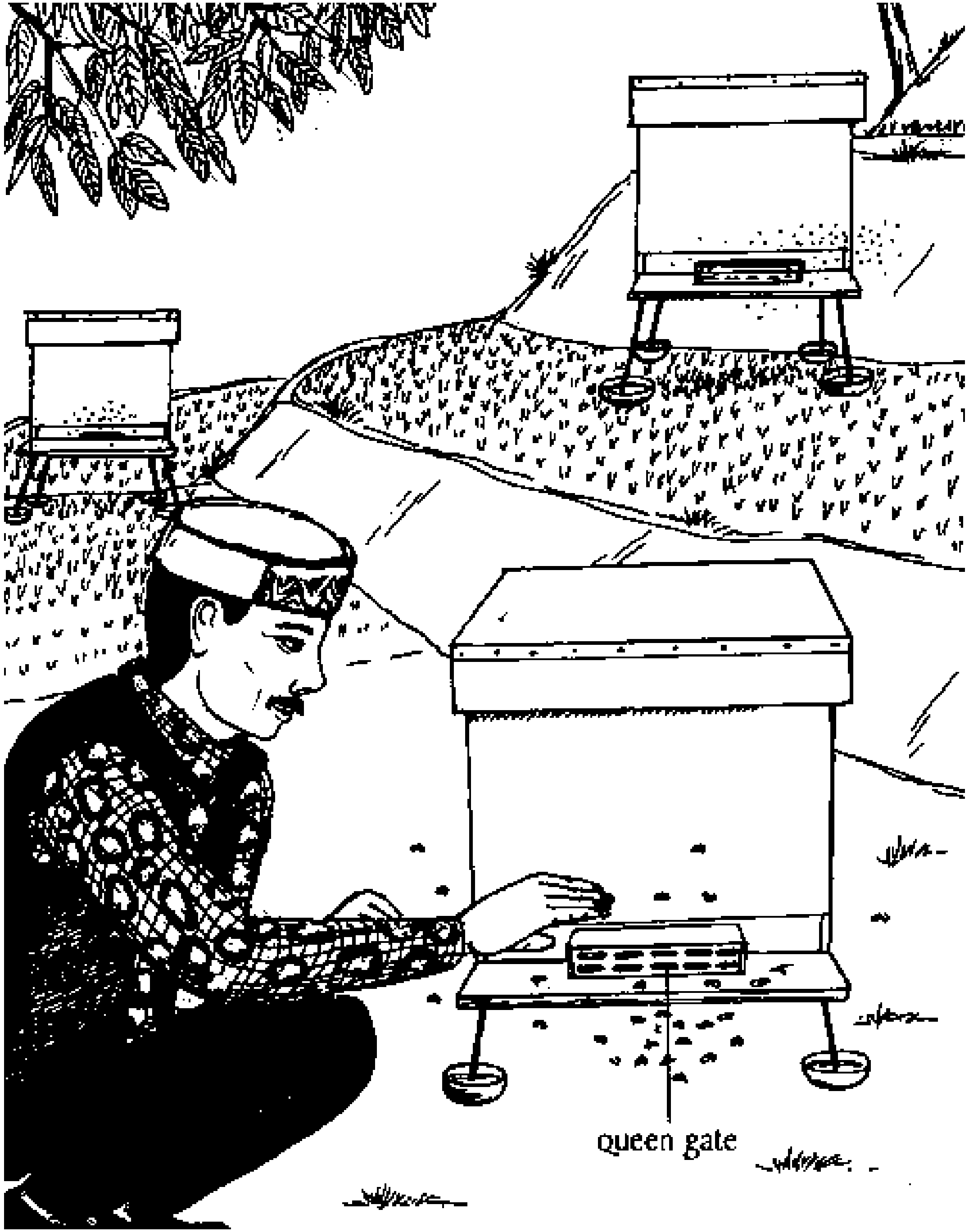


Figure 2.9: Providing the queen gate at the hive entrance can help prevent

swarming and absconding. Since the queen can not leave the hive, the bees also come back.

Figure 2.10: Caging the queen is another way to control swarming and absconding. Even if the bees fly away, they will come back because the queen is in

the hive itself.

What is absconding?

Absconding and migration

Absconding is the departure of all adult bees of a colony from their nest leaving behind whatever brood and food stores are in it. Absconding may be due to a shortage of food, disturbance to the bees, excessive heat and cold, poor ventilation, presence of old and defective combs, and attack by enemies and disease.

Figure 2.11: The main symptom of a colony preparing for absconding is that it has very little or no food (honey or pollen stores) and has no brood.

Migration is the periodic movement of a colony. The term is restricted to the regular seasonal movements of the honeybee colonies that result from an inherited response to geographic cues and not from a direct response to a lack of food.

Predicting absconding

Shortage of food and excessive disturbance of the nest are common causes of colonies preparing for absconding. When a colony is in this state it can show the following peculiar behaviour.

- **It does not defend itself against enemies.**
- **It ceases brood-rearing although the queen continues to lay eggs.**
- **It has a small, scattered brood or no brood (Figure 2.11).**
- **There is very little or no food stored (Figure 2.11).**
- **Bees stop cleaning the hive.**
- **Cannibalism is observed: adult bees first devour young larvae, then older larvae, and finally pupae.**
- **There is a progressive reduction in the relative number of pollen carriers entering the hive. This is an external but important symptom of a colony preparing to abscond.**

Prevention of absconding

Absconding has an adverse effect on farmers/beekeepers as bees are lost. It also has a serious negative impact on honey production and crop pollination. Therefore, it is necessary to control absconding. Listed below are some of the ways it can be done.

- **Lack of suitable pollen and nectar sources is the most important reason for absconding. So provide sugar syrup (prepared by dissolving two parts of sugar in one part of water [2:1 weight to volume ratio]) and feed this to the colony every evening (Figure 2.12). This will meet the bees' requirement for nectar and help to control absconding.**

- **When preparation for absconding has reached an advanced stage - pollen collection is zero, there is no response to sugar feeding, and there is no brood - it is important to break the so-called absconding impulse by pseudo-absconding (false absconding). This can be done by allowing the bees to fly away without the queen, either by using a queen gate at the hive entrance (Figure 2.9) or by caging her (Figure 2.10). Open the hive and allow the bees to leave; they will come back because the queen cannot escape. Remove all empty combs. When the bees return to the hive, feed them with sugar syrup. In this way, they will establish themselves in the hive as a new swarm. Give them combs or comb foundation sheets to build new combs.**

- **The provision of shade during summer and warmth during winter will**

help to control absconding.

• Provide adequate ventilation to the hive as poor ventilation can lead to absconding.

• Remove old and defective combs from the hive.

• Keep the bottom board clean.

• Take measures to control diseases and enemies as these can also make a colony abscond.

1. Make holes in the lid of a small plastic or tin container to use as a feeder

2. Make sugar syrup by dissolving two parts of sugar in one part of water

3. Pour the sugar syrup in the feeder and close the lid

4. Remove the hive cover and place the feeder upside down quickly over the feeding hole of the inner cover (or directly over the frames.

Figure 2.12: Feeding the colony with sugar syrup is an effective way of preventing absconding, especially if absconding is due to the dearth of bee floral resources.

What are the principal honeybee species in the Hindu Kush-Himalayan region?

Five species of true honeybees (*Apis* spp) and a few species of stingless honeybees are found in the Hindu Kush-Himalayan region. True honeybees include the giant honeybees or rock bees (*Apis dorsata*) and *Apis laboriosa,* the little honeybee (*Apis florea*), the Asian honeybee (*Apis cerana*), and the European honeybee (*Apis mellifera*). Several types of stingless honeybees, including species

of *Melipona* and *Trigona,* are also found in the region. As described below, some species can be kept in hives and others cannot.

Honeybees that cannot be kept in hives

The giant honeybees or rock bees (*Apis dorsata* and *Apis laboriosa*) and the little honeybee (*Apis florea*) cannot be kept in hives. They make their nests in the open on vertical cliffs, on branches of tall trees, and on bushes. They cannot be managed for honey production and crop pollination. Honey from these bees is harvested by traditional honey-hunting methods.

***Apis dorsata,* also known as the giant honeybee or rock bee, is found throughout the Himalayas up to 1,000m. It builds single comb nests in the open on branches of tall trees and on tall buildings and chimneys, in shady places during summer, and in sunny places during winter. As many as 70 or more colonies can be found on a single tree (Figure 2.13). This species is migratory in nature; a colony never stays in the same place for more than six months. *Apis dorsata* is an abundant producer of honey and an important pollinator of many agricultural and horticultural crops. It nests in low hill areas during winter and migrates to the high hills in summer.**

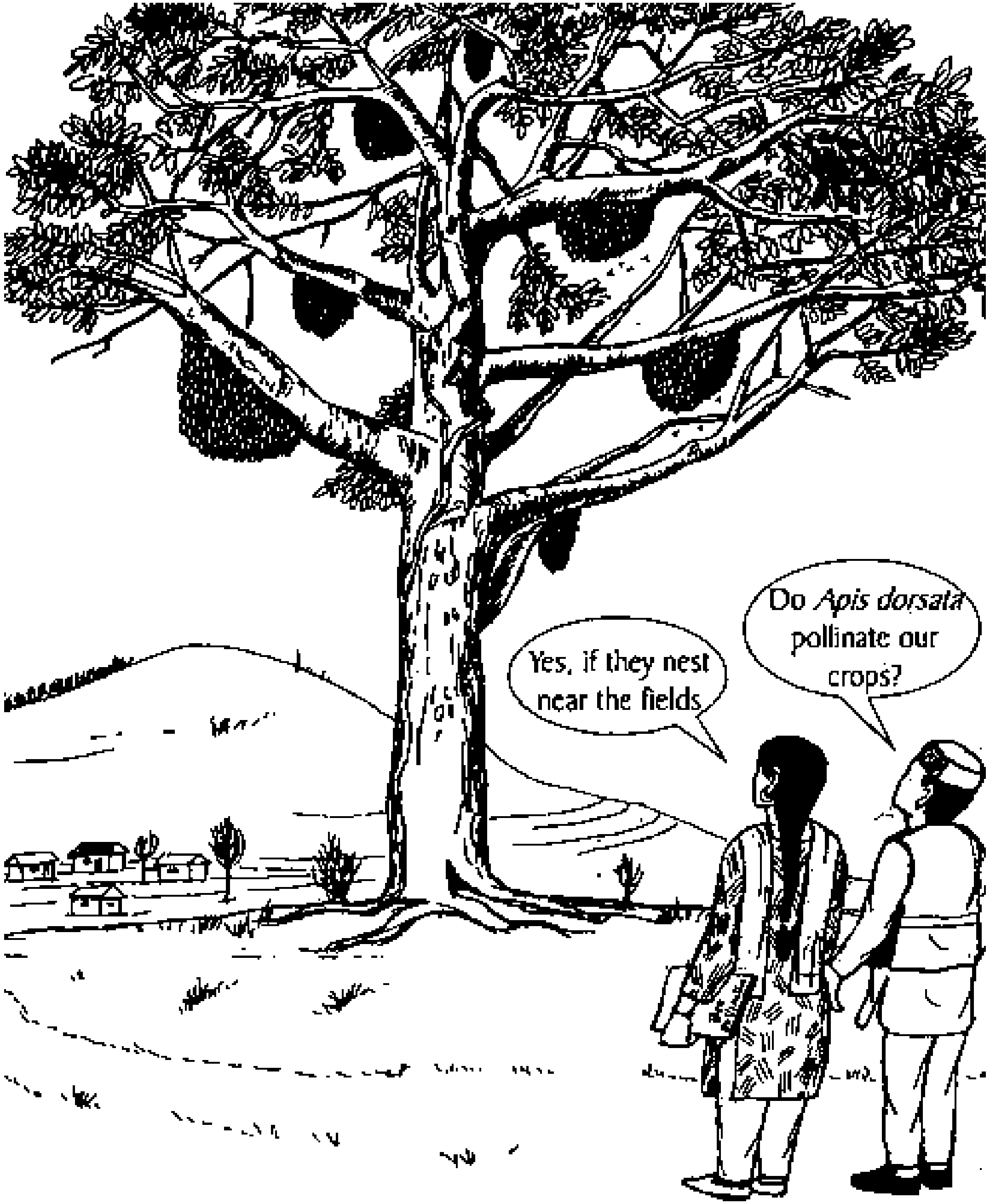


Figure 2.13: Apis dorsata makes single comb nests on tall trees; many nests can

be found on a single tree.

Apis laboriosa **is found from 1,200 to 3,500m in remote mountainous areas of Bhutan, China, India, and Nepal. It nests beneath rock overhangs on vertical cliff faces (Figure 2.14). It is also migratory in nature and a colony does not remain in one place the year round. Colonies are found at a height of at least 10m above the ground and occur in groups. Like** ***Apis dorsata,*** **70 or more colonies can be found at a single cliff site. It is also an important crop pollinator.**

Apis florea *** is the smallest honeybee species and is called the little bee. It also builds single comb nests on the branches of bushes, hedges, small trees, and chimneys (Figure 2.15). This species is found in the plains and in hilly areas up to 500m. It is also migratory in nature and a colony seldom stays in one place for more than six months.** ***Apis florea*** **is another pollinator of agricultural crops.**

> **** Recently more species of*** **Apis** ***have been identified in Asia and firm confirmation of this species of little bee as*** **Apis florea** ***is yet to be completed.***

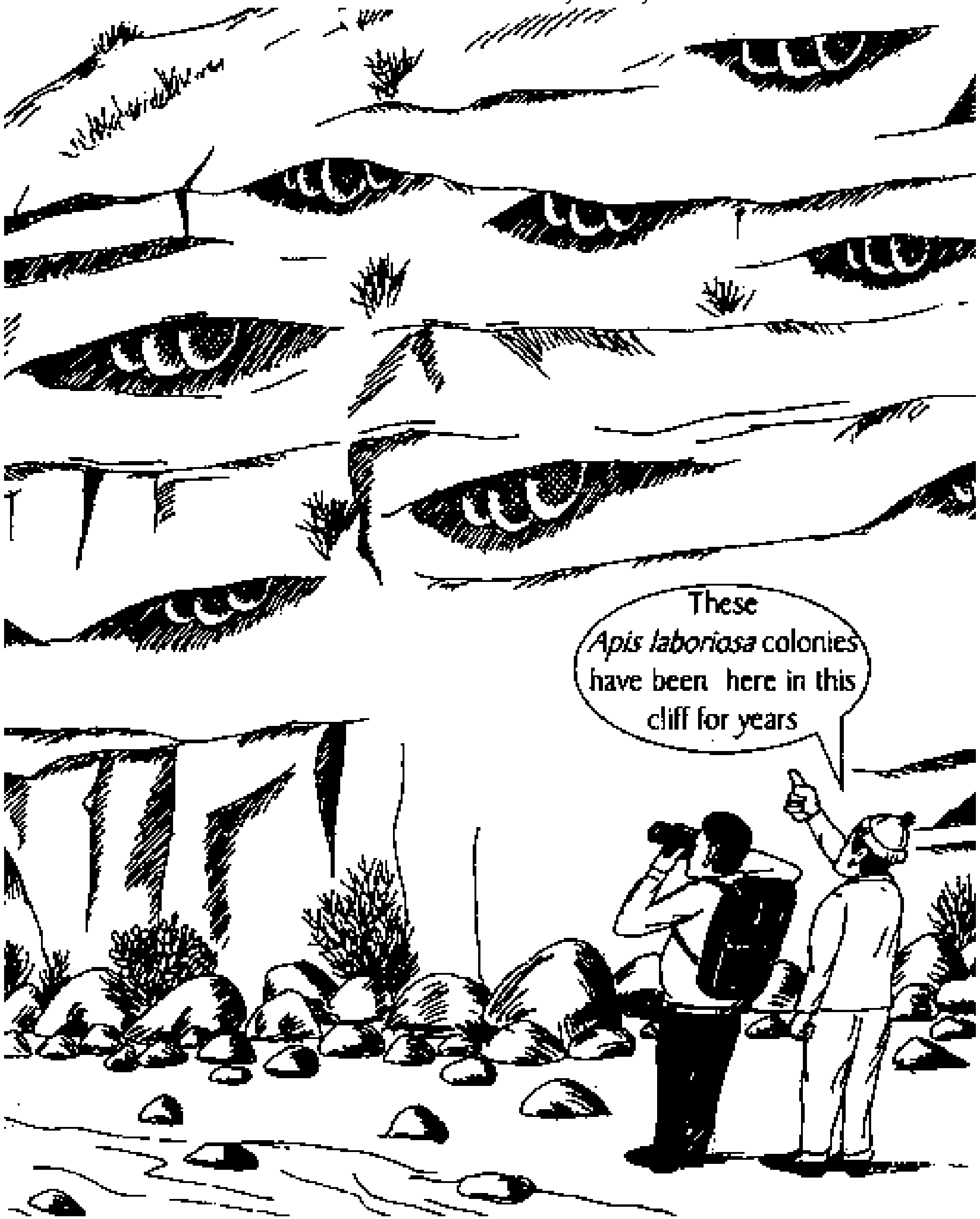


Figure 2.14: Apis laboriosa nests on cliffs. There can be many colonies on a single cliff site.

Honeybees that can be kept in hives

Two of the species of honeybee present in the Hindu Kush-Himalayan region can be kept in hives and managed for honey production and crop pollination. These include the Asian honeybee, *Apis cerana,* and the European honeybee, *Apis mellifera.* These are cavity-nesting bees and are also called hive bees.

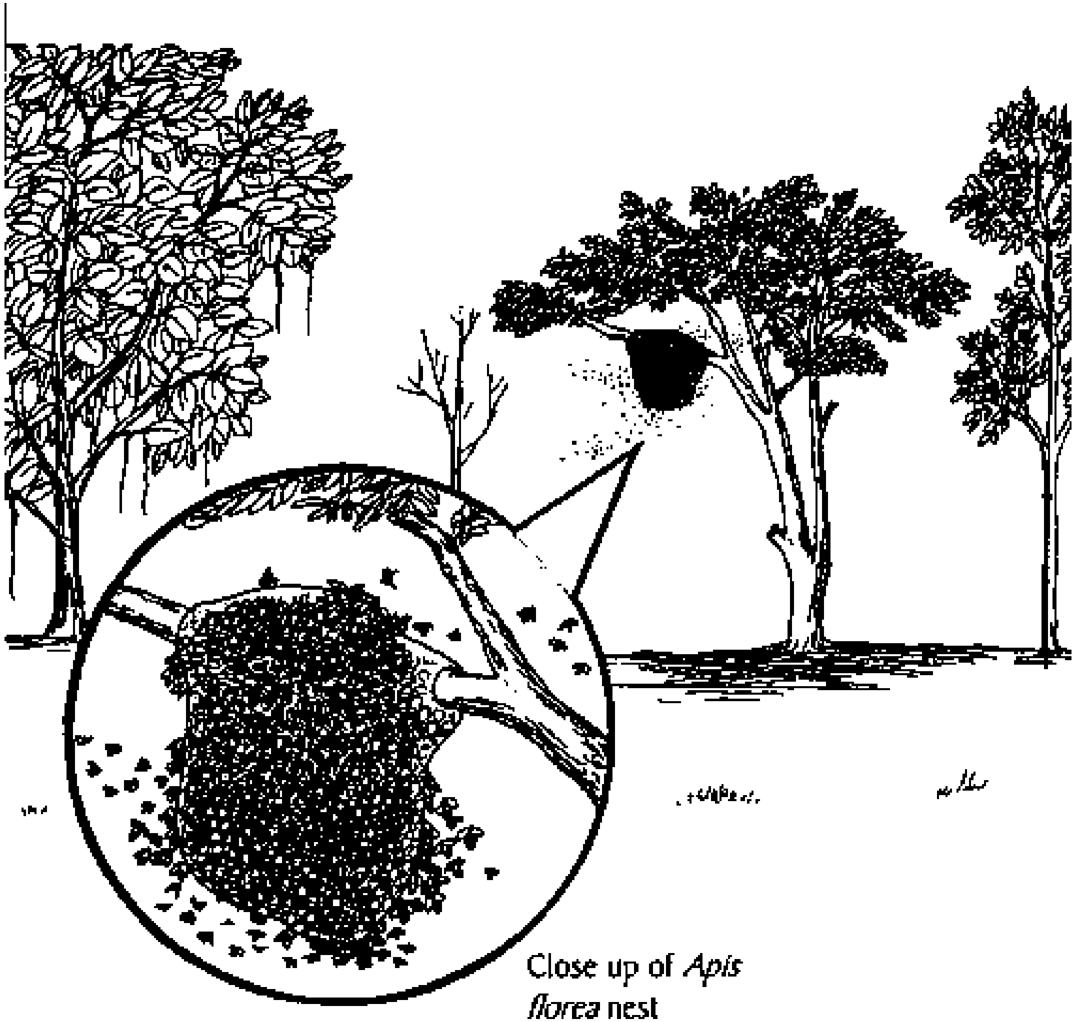


Figure 2.15:* Apis florea *makes single comb nests on small trees, bushes, hedges, chimneys etc.

***Apis cerana*, the Asian hive bee or Himalayan hive bee, is widespread up to 3,000m throughout the Hindu Kush-Himalayan region. It has a gentle**

temperament, an industrious nature, and good cleanliness qualities. Unlike *Apis dorsata, Apis laboriosa,* and *Apis florea* that build single comb nests in the open, *Apis cerana* makes multiple parallel combs inside a cavity. Beekeeping with this bee is a common tradition among several mountain communities. Farmers keep it in traditional fixed-comb hives such as log, wall, and earthen-pitcher hives and in movable-frame wooden hives (Figure 2.16). A colony of *Apis cerana* produces 5-20 kg of honey per year and is an excellent crop pollinator. This species has not become popular among commercial beekeepers because of its low honey production and undesirable behavioural traits such as frequent swarming, absconding, and robbing habits.

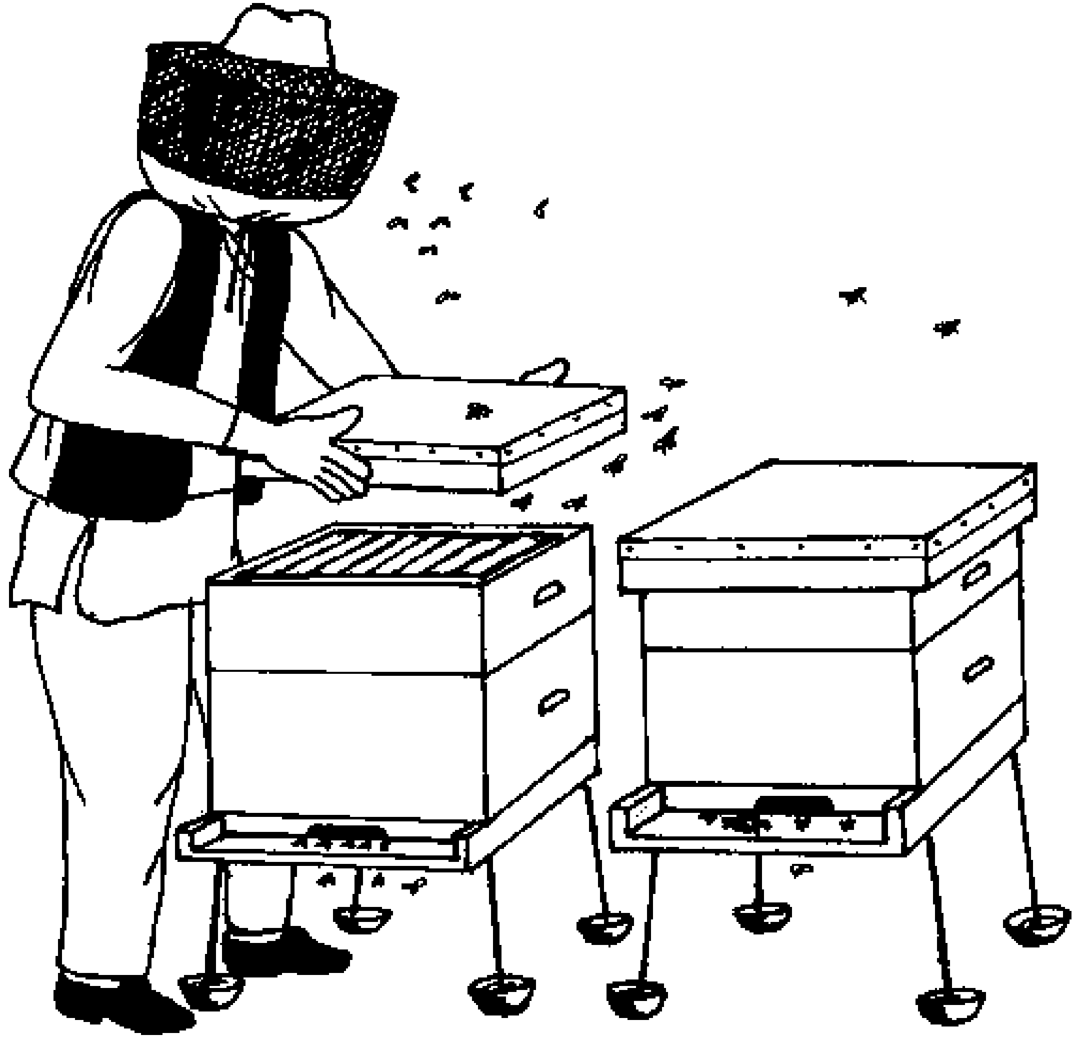
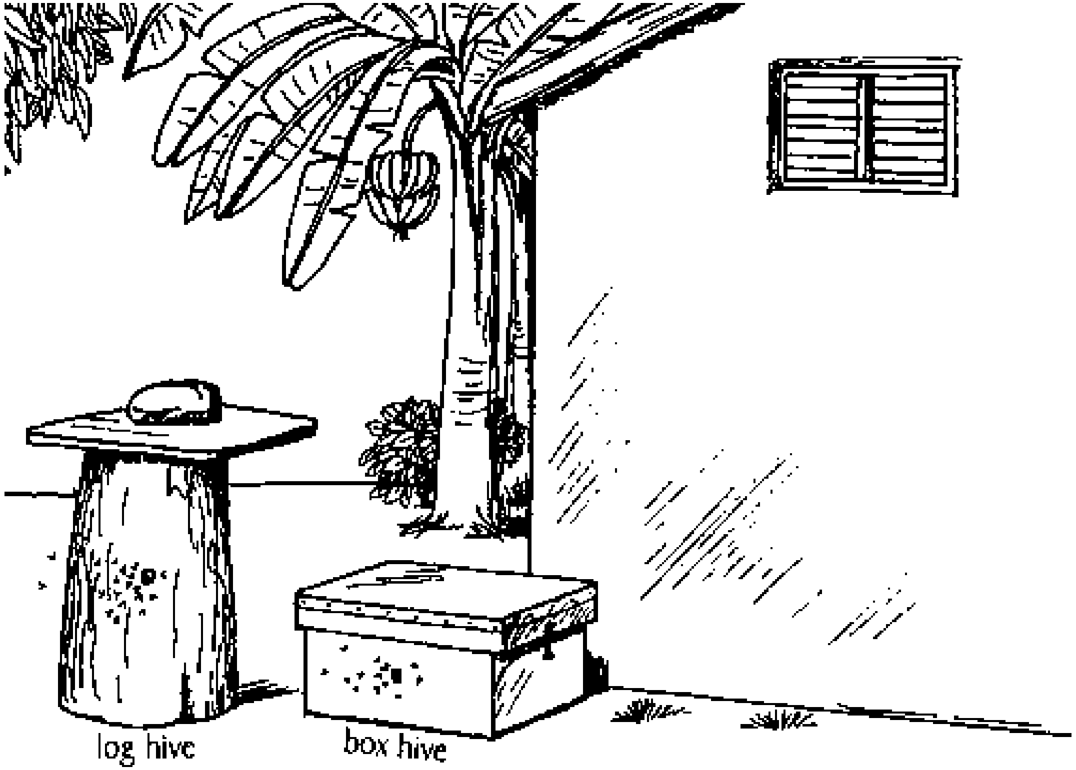


Figure 2.16: Hive bees, Apis cerana and Apis mellifera can be kept in the hives and managed for honey production and crop pollination.

European races of *Apis mellifera* have been imported to the Himalayan region for commercial honey production. This species is kept in hives and makes parallel combs. It is popular among commercial beekeepers because it produces more

honey than *Apis cerana*, maintains a prolific queen, has low swarming and absconding tendencies, and has good honey-gathering qualities. However, beekeeping with this species requires expensive technology and a high degree of chemical treatment to control diseases and parasites to which it is more susceptible.



Hives used for keeping stingless bees

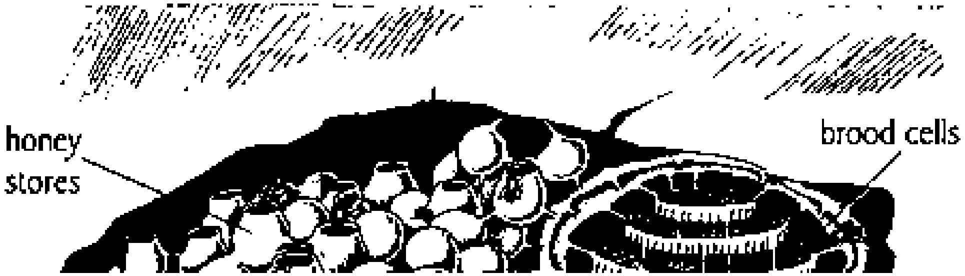
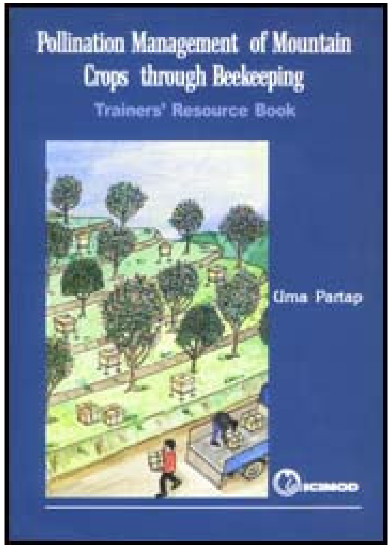


Figure 2.17: Stingless bees, Melipona and Trigona can also be kept in the hives

Like true honeybees, the stingless honeybees, *Melipona* spp and *Trigona* spp, can also be kept in hives and managed for honey production and crop pollination. They are called dammar bees. Several wild species of *Melipona* and *Trigona* are found in parts of India, Nepal, Pakistan, and Bangladesh. They are the smallest honey-yielding bee. They do not sting but bite. They build their nests in hollows of trees and rocks or walls. They store honey in special pots separate from the brood cells (Figure 2.17). A substance called bee dammar can also be obtained from their colonies. Beekeeping with these bees is a prevalent tradition among the Maya people of the Yucatan peninsula on the east coast of Mexico, Brazil, Colombia, and adjacent areas. In the Hindu Kush-Himalayan region, a few farmers in Dang, Rolpa, and Surkhet districts in Nepal practise beekeeping with *Melipona* spp.

Pollination Management of Mountain Crops through Beekeeping - Trainers' Resource Book

Author(s):	***Uma Partap***
Publication	***1999***



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Annex II: Relative Toxicity of Some Pesticides to Honeybees

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What is a beehive?

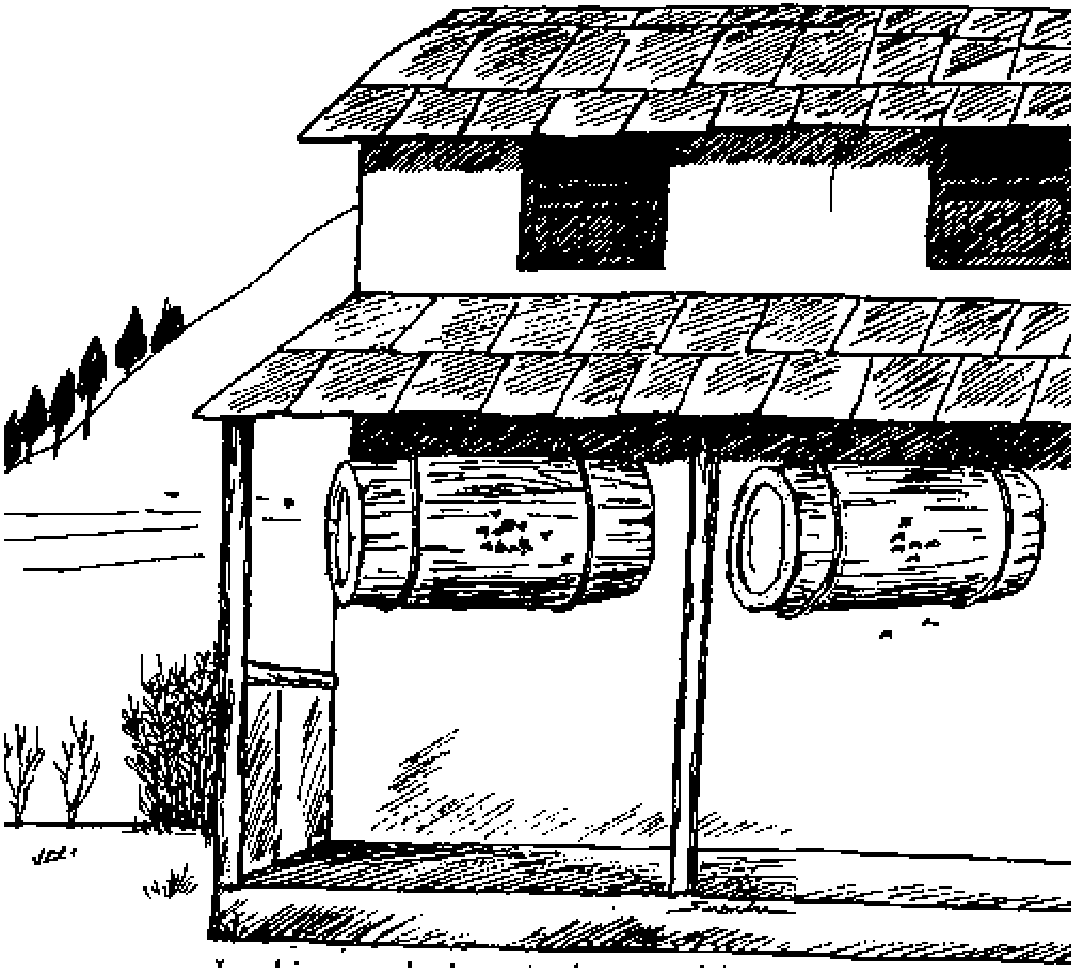
A beehive is a container provided in which honeybees build their nests. It is an artificial nesting site. The beekeeper can then manage the bees to his/her advantage, i.e., for the production of honey and other bee products as well as for crop pollination. In the Hindu Kush-Himalayan region, farmers keep *Apis cerana* in both traditional fixed-comb hives, such as log hives, wall hives and pitcher hives, or in movable-frame wooden hives. Commercial beekeepers keep both *Apiscerana* and *Apis mellifera* in movable-frame wooden hives.

Traditional fixed-comb hives

A log hive is a simple hollowed-out tree trunk without any frames or bars. The open ends of the log are sealed with a piece of tin, a wooden plank, or a mixture of mud and cow-dung. The entrance is made in the middle of the wooden cylinder. Farmers either hang their log hives in the verandas of their houses or on branches, or place them on a piece of raised ground (Figure 3.1).

A wall hive is a rectangular or square recess in a wall. A small hole is provided at the base, middle, or top as an entrance. The side walls are plastered with mud and cow-dung, and the roof and the bottom are wooden planks. The back of the recess is closed on the inside of the house with a wooden plank that is temporarily fixed to the wall with mud and cow-dung (Figure 3.2).

A pitcher hive is a cavity formed by a clay pitcher. A clay lid serves as a covering for the opening. In temperate mountain areas the pitcher is inserted horizontally into a wall of a house, and in warm tropical and subtropical areas it is hung from a tree.



Log hives can be hung in the varandahs

Figure 3.1: Bees can also be kept in fixed-comb log hives.

Traditional fixed-comb hives have the following disadvantages for beekeepers, farmers, and honey consumers.

- **Honey is harvested by squeezing. This honey may become contaminated with brood extracts, parts of bee bodies, hive debris, and dirt. Such honey does not fetch a good price.**

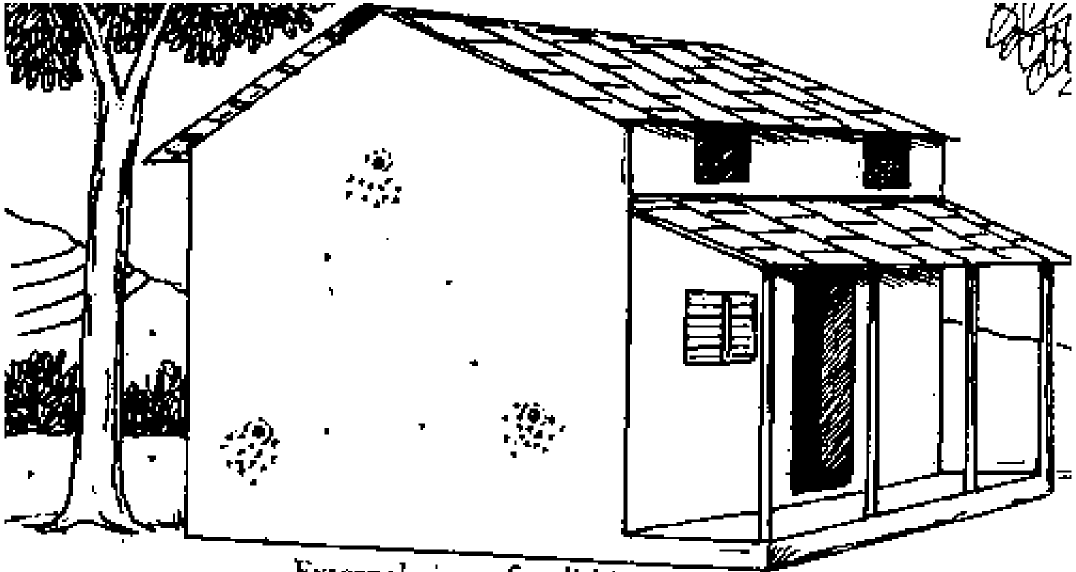
- **Honey yield can be relatively low. However beeswax yield is higher than from frame hives.**

- **A large proportion of brood and adult bees are killed during honey harvesting. This leads to a reduction of the colony strength.**

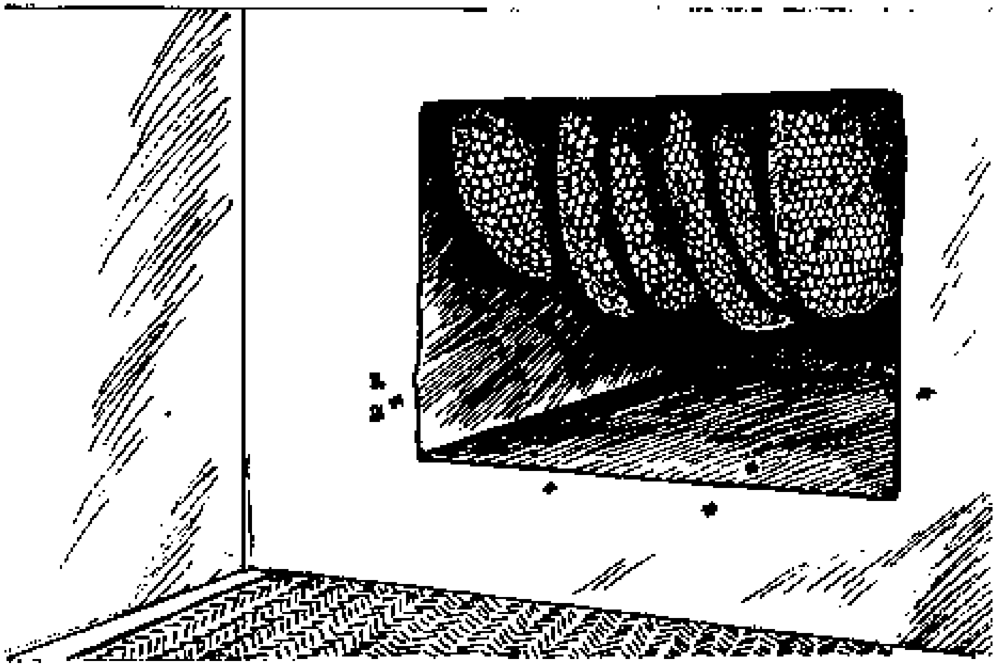
- **Old combs are destroyed while squeezing honey. This means that bees waste a lot of energy making new combs.**

- **The inspection of colonies for disease, re-queening, supplementary feeding during dearth periods, and cleaning is not possible. This often leads to the absconding of bees.**

- **Bees kept in traditional hives cannot be transported to crops to aid pollination.**



External view of wall hives



Inside view of wall hive

Figure 3.2: Farmers can keep bees in traditional fixed-comb wall hives.

Improved beehives

To tackle the disadvantages associated with traditional hives, efforts have been made to improve them, particularly log hives and wall hives. Log hives have been improved by putting in top bars (Figure 3.3); and wall hives have been improved by putting in movable frames (Figure 3.4). These improvements mean that inspection of the bees is possible and that honey can be harvested without disturbing bees or brood because it is stored in the outer frames. This honey is of better quality than that from traditional hives.

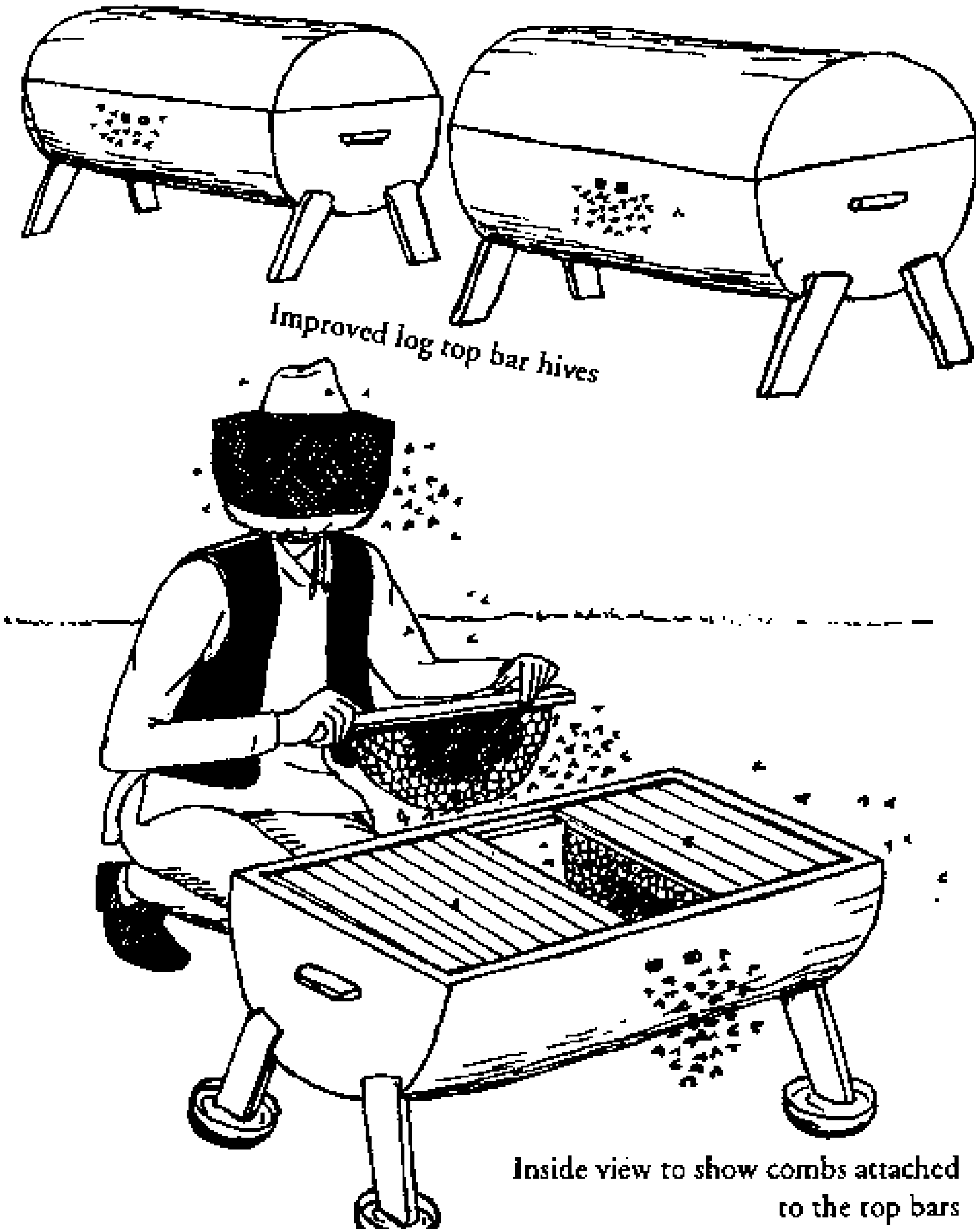


Figure 3.3: Improvement of log hive by putting top bars makes colony inspection

easy and yields better quality honey than traditional fixed comb log hives.

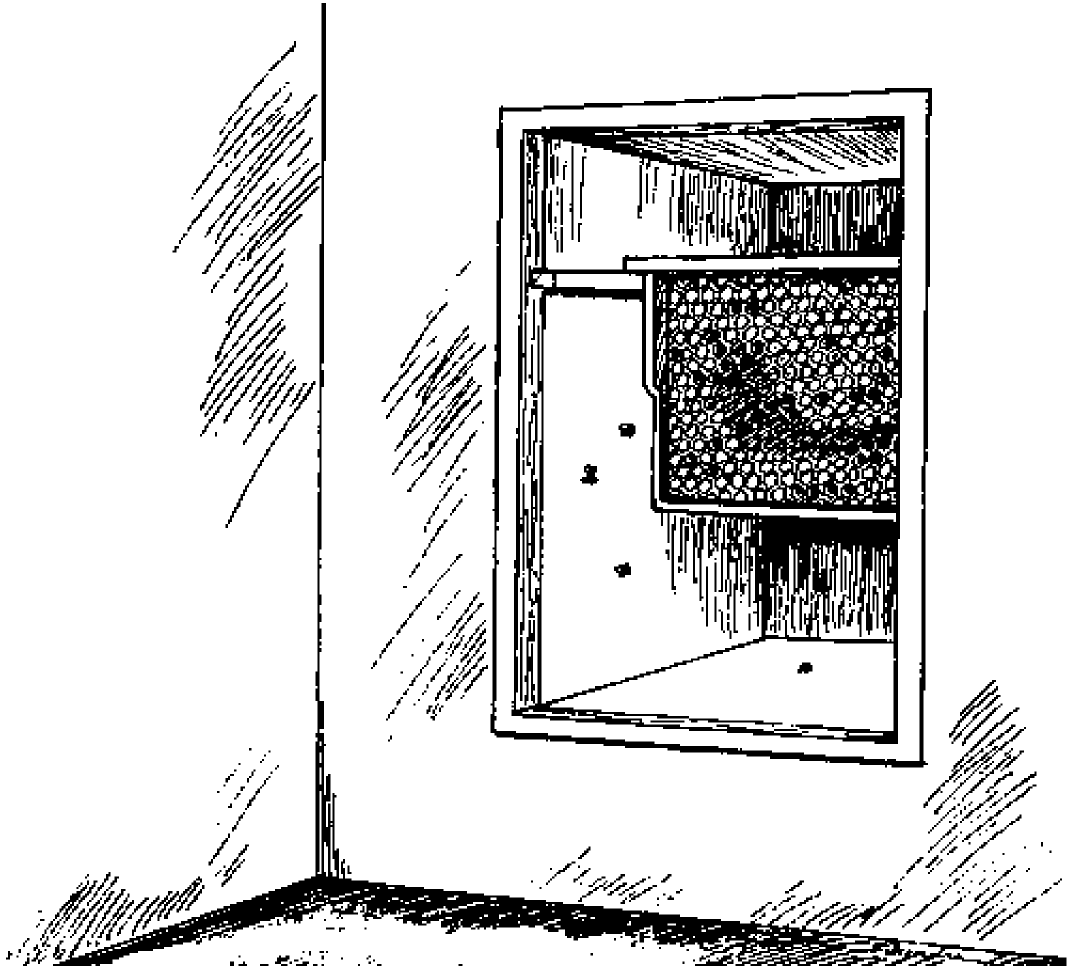


Figure 3.4: Improvement of wall hive by putting movable frames makes colony inspection easy and yields better quality honey.

Another type of hive consists of a box that has a series of bars across the top to which bees attach their combs. It can be made from locally available materials such as straw, bamboo, or wood, although wood is the best material. Top-bar hives are useful for inspection of colonies, but are difficult to transport without

breaking the comb. Therefore, they are not suitable for migratory beekeeping and cannot be moved to fields for crop pollination.

Movable-frame wooden hives

A movable-frame hive consists of a hive body - also called the brood chamber - that provides space for bees and brood. In this chamber the queen lays eggs, the brood is reared, and honey is stored for consumption by the colony. The hive body is placed on a bottom board where the hive entrance is located. For surplus honey production, a shallow super is placed above the brood chamber. An inner cover is placed over the super. A hive cover (often covered with an aluminium sheet to protect the wood) is placed on top of the hive to protect it from rain and wind (Figure 3.5). The hive is placed on a stand made of either wood or iron to keep its bottom dry. Bowls of water are placed under each leg to prevent ants entering the hive.

The use of movable-frame wooden hives is the most advanced form of beekeeping. This method allows for any manipulation of the colony such as brood-nest adjustment, inspection for diseases and pests, verification of food store levels, supplementary feeding during dearth periods, queen rearing, and addition of supers during honey-flow season. The movable-frame hive has several advantages over traditional hives.

- **Honey yield is two to three times greater than from traditional hives, but the input costs are also higher.**

- **The quality of honey is superior because it is harvested with a honey**

extractor. Such honey can fetch a better price.

• Combs remain intact and can be recycled to the hive.

• Bees and brood remain undisturbed during honey extraction because honey is stored separately in the super.

• Colony inspection is easy. However, scientists believe that it is only the introduction of the movable frame hives that has spread diseases so widely

• These hives are suitable for migratory beekeeping because they can be moved to allow bees to exploit flora in different places.

• Honeybees in movable-frame hives can be transported to fields and managed for crop pollination (Figure 3.6).

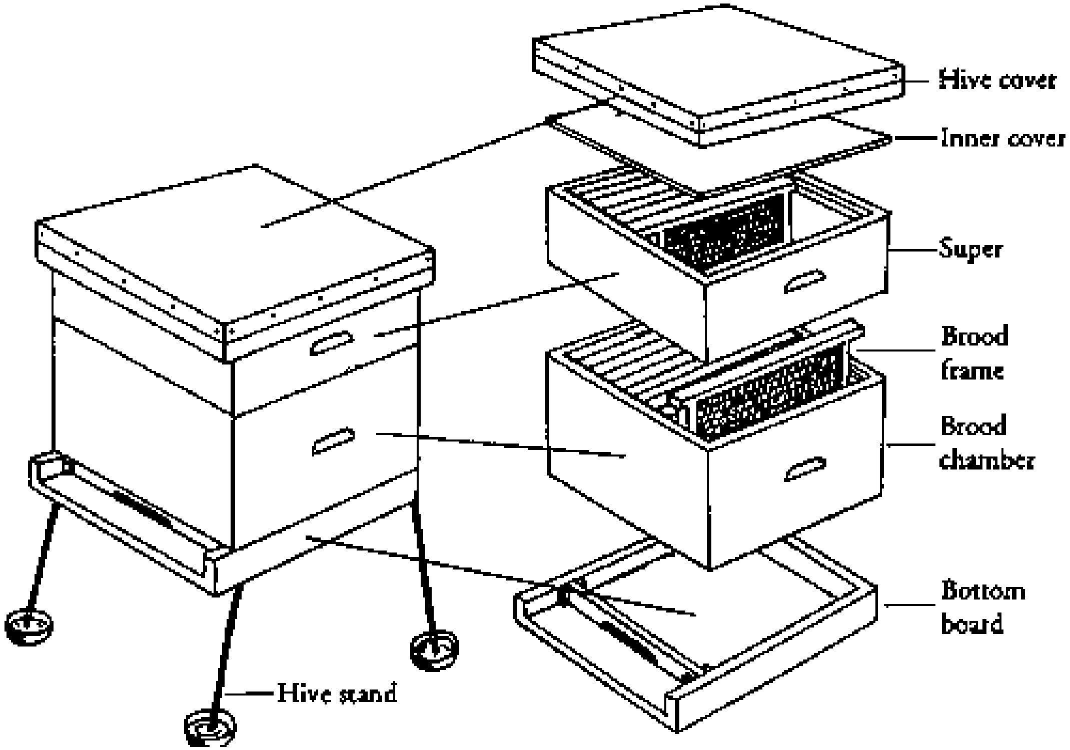


Figure 3.5 A movable frame wooden hive allows any manipulation of the bee colony.

Movable frame hives are usually made from wood but they can also be constructed using locally available materials such as rice or wheat straw, thatch grass, cement, sand, clay, glauconite, used newspaper, dry agave leaves, and rice husks. However, with the exception of straw, these materials are not suitable for transporting and so cannot be moved to fields for crop pollination.

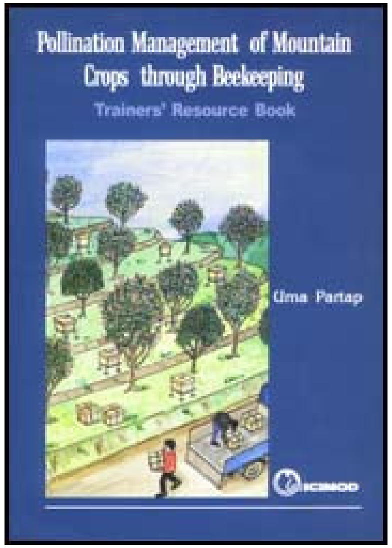
What is beekeeping?

Beekeeping refers to the rearing of honeybees for honey and beeswax production. A person who rears honeybees is called a beekeeper or an apiarist. The beekeeper

can keep and manage a few or many colonies of honeybees in many different types of beehive. The place where the bee colonies are kept is called an apiary. The Himalayan honeybee, *Apis cerana,* and European honeybee, *Apis mellifera,* are the only species of honeybee that are managed for honey production. Beekeeping is practised not only for honey and beeswax production but also for the pollination of various cash crops, especially apples. In Himachal Pradesh, a northwestern Indian state, apple farmers hire honeybee colonies from beekeepers for pollination purposes. Movable-frame wooden hives are the most suitable for transporting to a crop for pollination.

Figure 3.6: Bee colonies in the movable frame hives can be transported to the field for pollination of crops.

Figure 3.7: In Himachal Pradesh beekeeping is being promoted for apple pollination.



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Chapter 4: Hive Bees As Crop Pollinators

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Which crops are pollinated by honeybees?

Honeybees are important for the pollination of many vegetable, fruit, oilseed, and fodder crops (Figure 4.1). Many of these crops, especially commercial varieties of cash crops, depend on cross-pollination by honeybees to produce fruit and seed. Others (self-pollinated crops) benefit from it for the production of good quality fruit and seed and higher yields (Table 1).

Why are hive bees better than other bees for crop pollination?

The Hindu Kush-Himalayan region has many species of bees and all are useful as crop pollinators. However, some cannot be relied on as efficient pollinators. Wild honeybee species (*Apis dorsata, Apis florea,* and *Apis laboriosa*) are restricted in distribution and number and, being migratory, they are not available at any particular place throughout the year. Other bee species, such as solitary bees (including the carpenter bees), are truly seasonal in nature and may not be

available when required for pollination. Hive bees (*Apis cerana* and *Apis mellifera*) are the most practical for crop pollination for the following reasons (Figure 4.2).

- **Bees that are kept in hives can be managed unlike non-hive honeybees and wild bee species.**
- **Hive bees can be reared in sufficient numbers for effective pollination.**
- **When kept in movable-frame wooden hives, colonies can be transported to fields or orchards.**

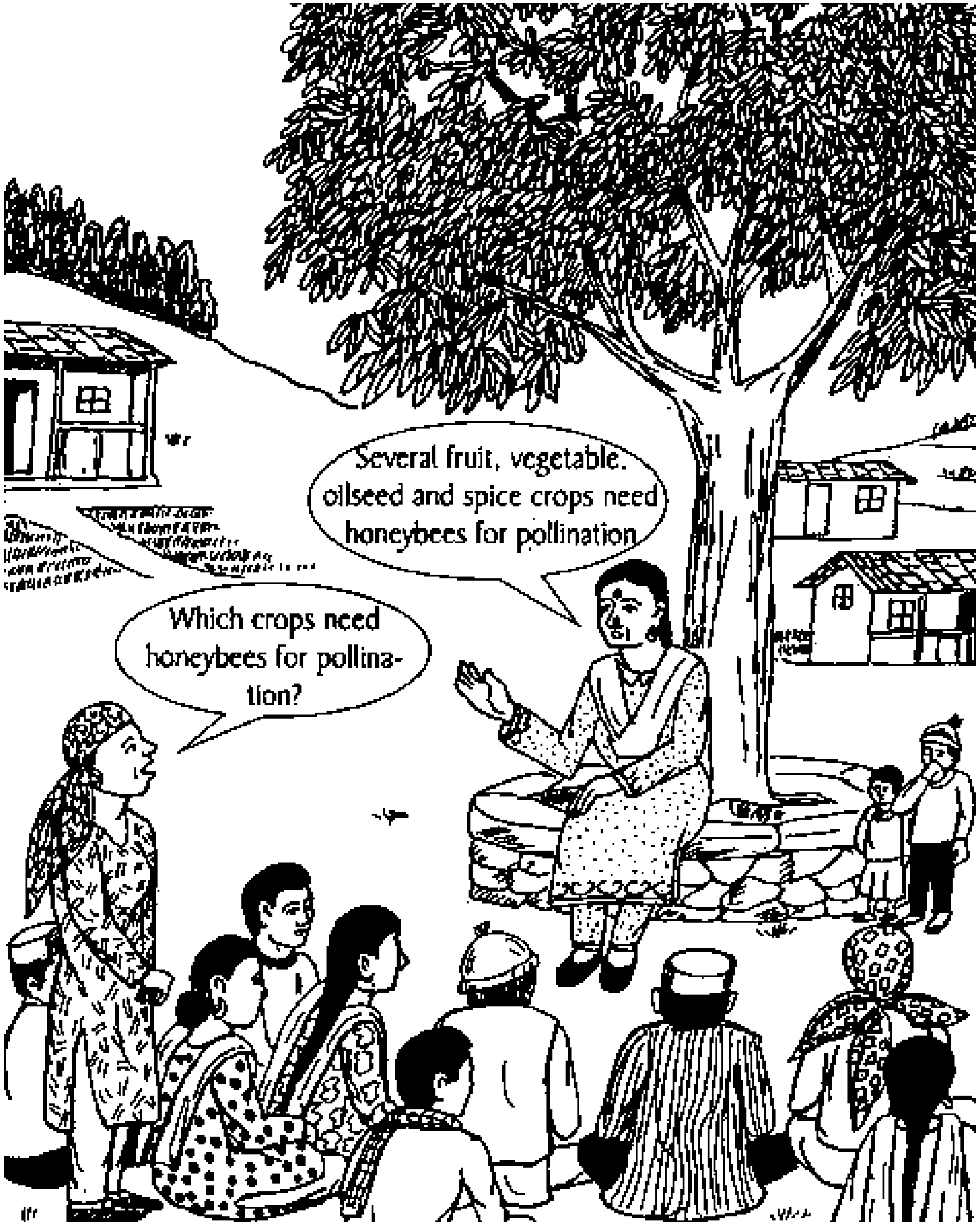


Figure 4.1: Awareness of farmers about the value of honeybees for pollination of

their crops is important to promote managed crop pollination through beekeeping.

Hive bees are used for pollination of agricultural and horticultural crops in many countries. It has been found that the use of hive bees results in a manifold increase in yields and an improvement in the quality of produce. For example, experiments conducted in India show that compared to self-pollination, seed yield is increased in mustard by 131 per cent, in safflower by 511 per cent, in niger by 1,121 per cent, in sunflower by 675-3,600 per cent, in onion by 178 per cent, in carrot by 500 per cent, in radish by 700 per cent, in citrus by 35-900 per cent, and in guava by 200 per cent. It is calculated that the value of honeybees as crop pollinators is many times greater than their value as honey and beeswax producers.

Table 1: Crops That Are Dependent on Or Benefit from Honeybee Pollination	
Crops dependent on bee pollination	**Crops benefitting from bee pollination**
Fruit and nut crops	
Almond Avocado Apple (all commercial varieties) Apricot (some varieties) Cherry (many varieties) Kiwi fruit Litchi Mango Plum (many varieties)	Apricot (few varieties) Blackberry Citrus Peach Persimmon Strawberry

Pear (many varieties)	
Vegetable seed crops	
Cabbage Carrot Cauliflower Cucumber Onion Pumpkin Radish Squash Turnip	Beans Capsicum Eggplant Okra Tomato
Vegetable crops	
Bitter gourd Bottle gourd Muskmelon Pumpkin Sponge gourd Squash Watermelon	
Oilseed crops	
Sunflower Niger	Mustard Rape Cotton

Spice crops	
	Greater cardamom Chillies Coriander

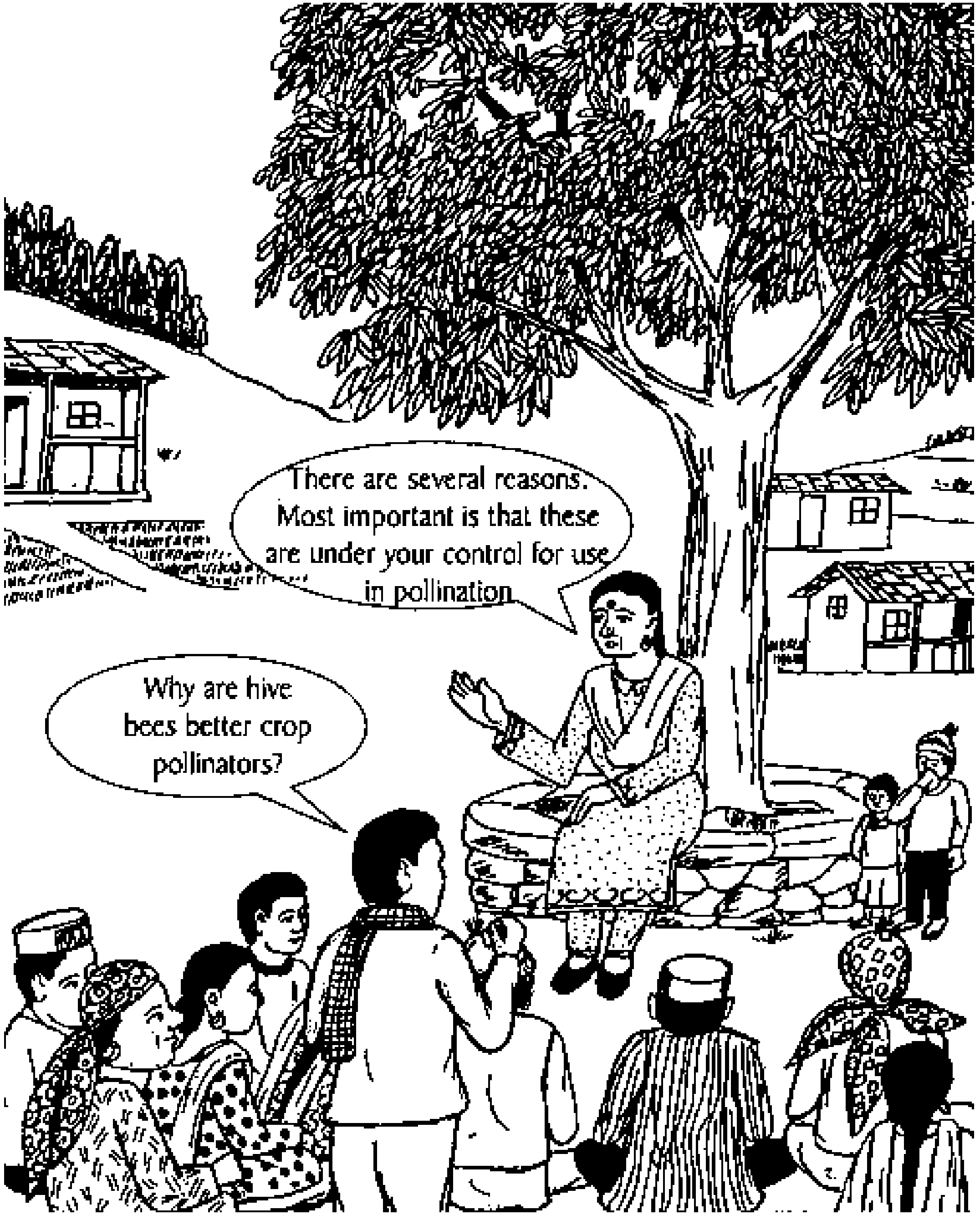


Figure 4.2: It is important to know why honeybees are better crop pollinators than other insects.

Why do we need to manage hive bees for crop pollination?

There are limitations in the natural pollination system, resulting in a need to manage honeybees (Figure 4.3).

- **Natural insect pollinators play an important role in the pollination of summer crops cultivated in hilly and mountain areas. However, most are absent during the winter and early spring and are not available for pollination of early-blooming mountain crops such as cabbage, cauliflower, radish, broadleaved mustard, winter rape, apple, peach, pear, plum, etc. Moreover, natural insects cannot be managed for pollination.**

- **Some crops - especially temperate fruit crops such as almond, apple, plum and pear - bloom for only a short period early in the bees' active season when numbers of natural pollinators are low.**

- **Populations of natural insect pollinators are declining, meaning that there are not sufficient numbers for adequate pollination. There are two main reasons for the decline: a reduction in nesting habitats and food sources and use of pesticides. Clearing of forests and grasslands for agriculture and horticulture has reduced the habitat necessary for hibernation and nesting of natural insect pollinators. Moreover, cultivation of large areas of the same crop (monoculture) has reduced the diversity of plants that provide nectar and pollen. Commercialisation of agriculture has increased the use of pesticides that kill, in addition to target pests, many natural insect pollinators - including species of wild bees.**

- **As a result of cash-crop farming, large areas are under crops that require cross-pollination. With the decline of natural pollinator populations, the lack of insects results in low productivity and inferior quality fruit and seed.**

- **Management of hive bees is also important for the pollination of crops grown in greenhouses. One such cash crop becoming popular in the Hindu Kush-Himalayan region is the strawberry.**

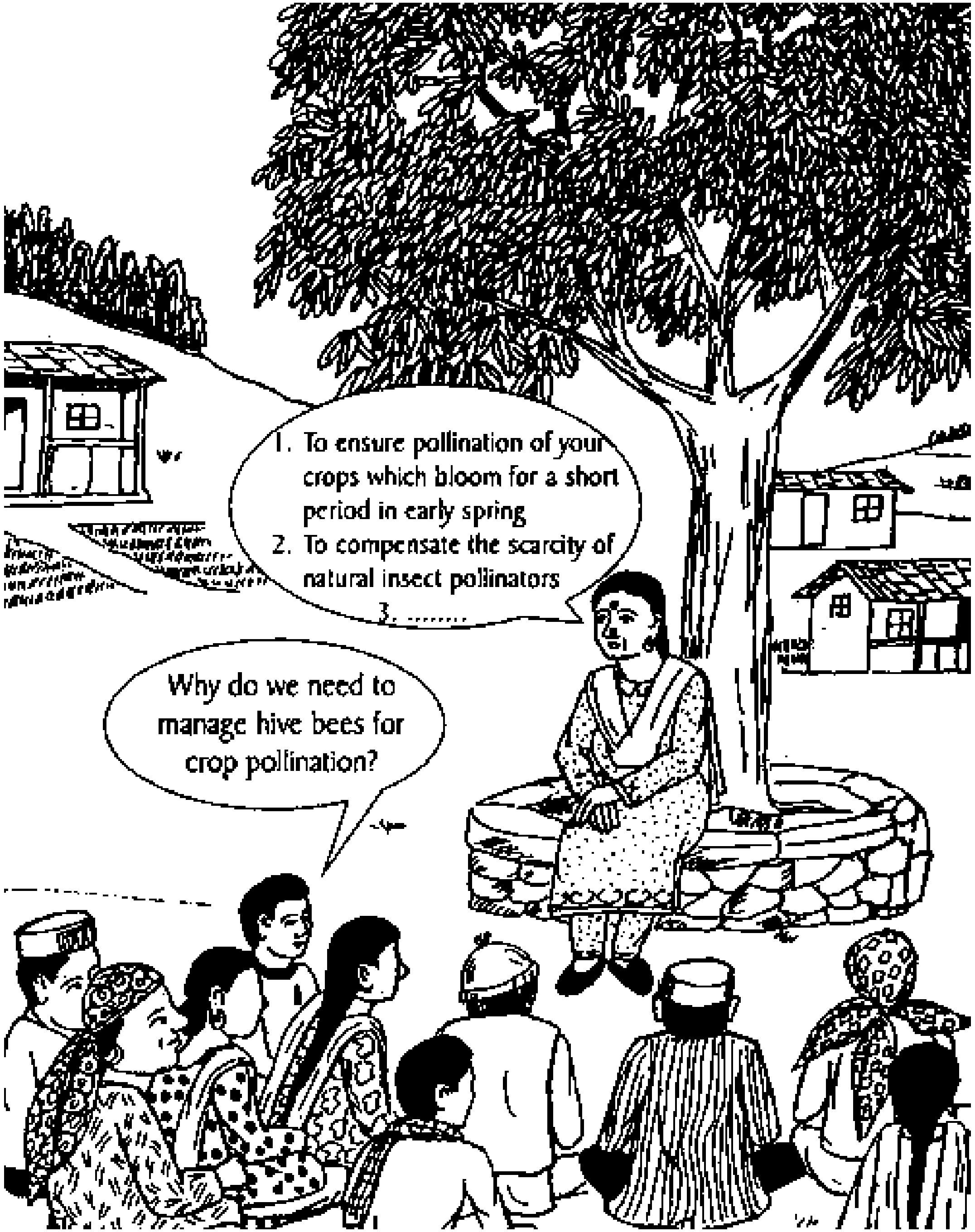


Figure 4.3: An understanding of the limitations with natural pollinators can

encourage farmers to manage pollination of their crops.

How should we use hive bees for crop pollination?

Farmer-friendly techniques have been developed for using honeybees for pollination. Both *Apis cerana* and *Apis mellifera* are used. However, for early flowering mountain crops, the native honeybee, *Apis cerana,* is more efficient. The race of *Apis mellifera* that has been introduced into the Hindu Kush-Himalayan region is more suitable to the low hill and plains' areas. A simple method of crop pollination is to place honeybee colonies in a field when the crop starts flowering. However, for effective pollination, a farmer should remember the following (Figure 4.4).

• Large, strong colonies are better pollinators than small colonies because larger colonies have more forager bees. Also, good honey-yielding colonies are more efficient pollinators.

Research has shown that a bee colony with 60,000 worker bees produces one-and-a-half times more honey than four colonies with 15,000 workers each. The same is true for pollination. Thus, as far as possible, farmers should use strong colonies. The colonies should be well settled, disease free, and have young, laying queens. The strength of a honeybee colony depends above all on the season. In the Hindu Kush-Himalayan region, colony strength is poor during winter because of low temperatures and a dearth of bee flora. Thus, when required in early spring for pollination of temperate fruit crops, these colonies do not have enough strength to act effectively. To help colonies maintain their strength, mountain farmers and commercial beekeepers should move colonies to low hill/plains' areas

during winter, because it is warmer and floral sources are available, and return them to the hills in spring when temperate fruit and vegetable crops are blooming. Such a migration of bee colonies is the practice in Himachal Pradesh in India, the North-West Frontier Province (NWFP) and Punjab in Pakistan, and northern parts of China.

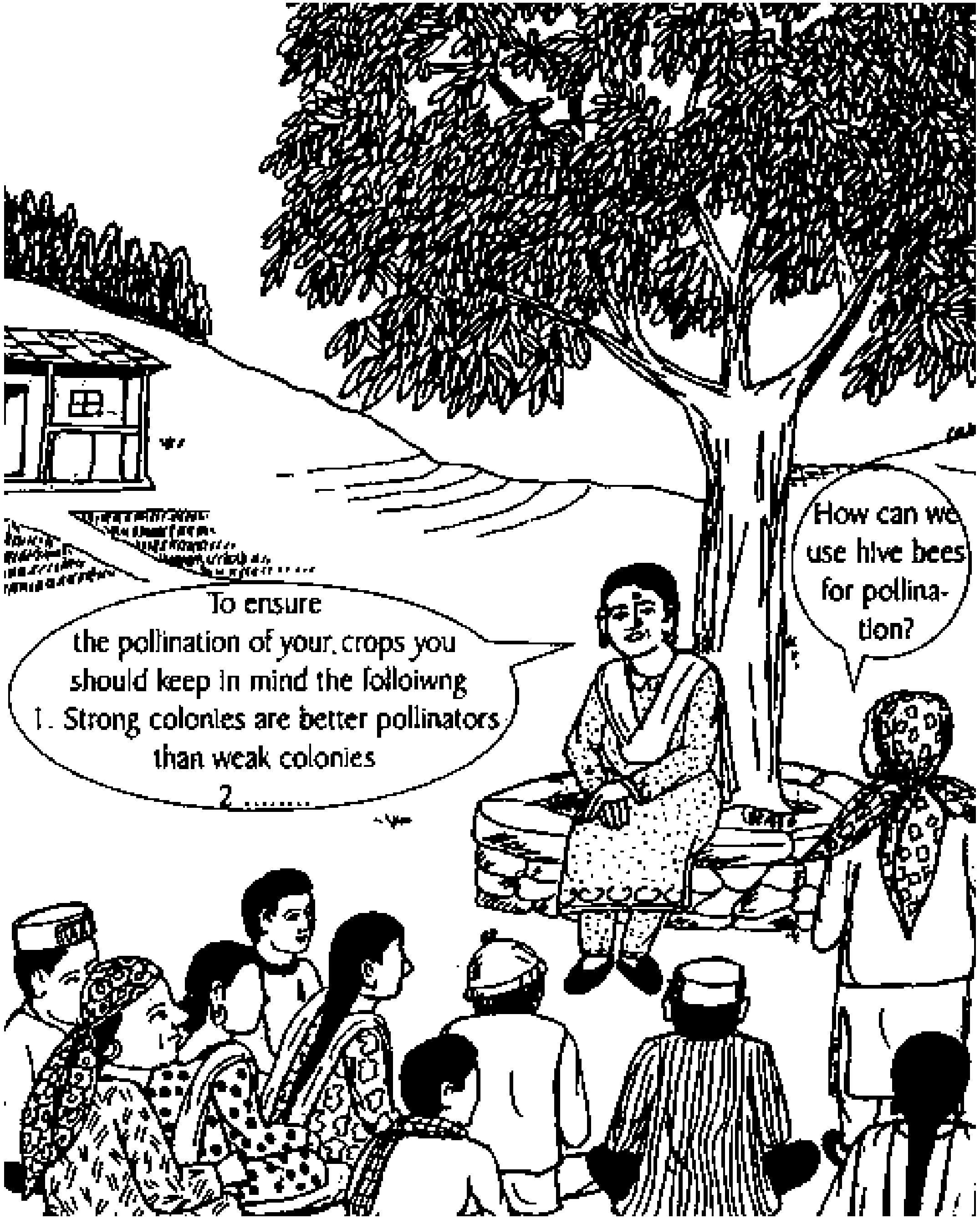


Figure 4.4: Making farmers aware of how to use hive bees for pollination of their

crops is essential for managed crop pollination.

• The number of colonies required for pollination varies for different crops.

This depends on the total number of plants; the total number of flowers per plant; attractiveness of flowers to bees; duration of flowering; amount of nectar and pollen; bee species used; strength of colonies; number of pollen foragers; and amount of unsealed brood in the colonies. In general, three strong colonies of *Apis mellifera* per hectare of crop are recommended for adequate pollination. Colonies of *Apis cerana* are smaller: a 10-frame full-strength colony of *Apis mellifera* is three times larger than a 10-frame full-strength colony of *Apis cerana.* However, the foraging rate of *Apis cerana* is 1.5 times greater than *Apis mellifera*. Therefore, 4-5 strong colonies of *Apiscerana* per hectare of crops are required. The number of colonies required also varies from crop to crop and from season to season for the same crop. This is discussed in detail in Chapter 5.

• The time of placement of bee colonies is important for high yields and good-quality produce.

It is important to synchronise flower opening and foraging activities of bees. Freshly migrated colonies are more likely to visit a crop than those in place for a long time. Colonies should be brought to the field when 5-10 per cent of the crop is in bloom. If colonies are placed early, bees will forage on flowers of wild plants nearby, becoming conditioned to these and ignoring the target crop when it blooms. If bees are moved late, they will only pollinate late and less vigorous flowers, resulting in poor yields and low-quality produce. For effective pollination of crops that flower for a short period, such as plums, bees should be moved when

plants just start blooming because 50 per cent flowering is achieved within 3-4 days.

• Cool weather and wind affect foraging activities of bees.

Place colonies in sunny, sheltered locations giving protection from wind to encourage maximum flights in spring (Figure 4.5). Where no natural windbreak is available, provide a temporary wind shelter. Placement of honeybee colonies in the field is important.

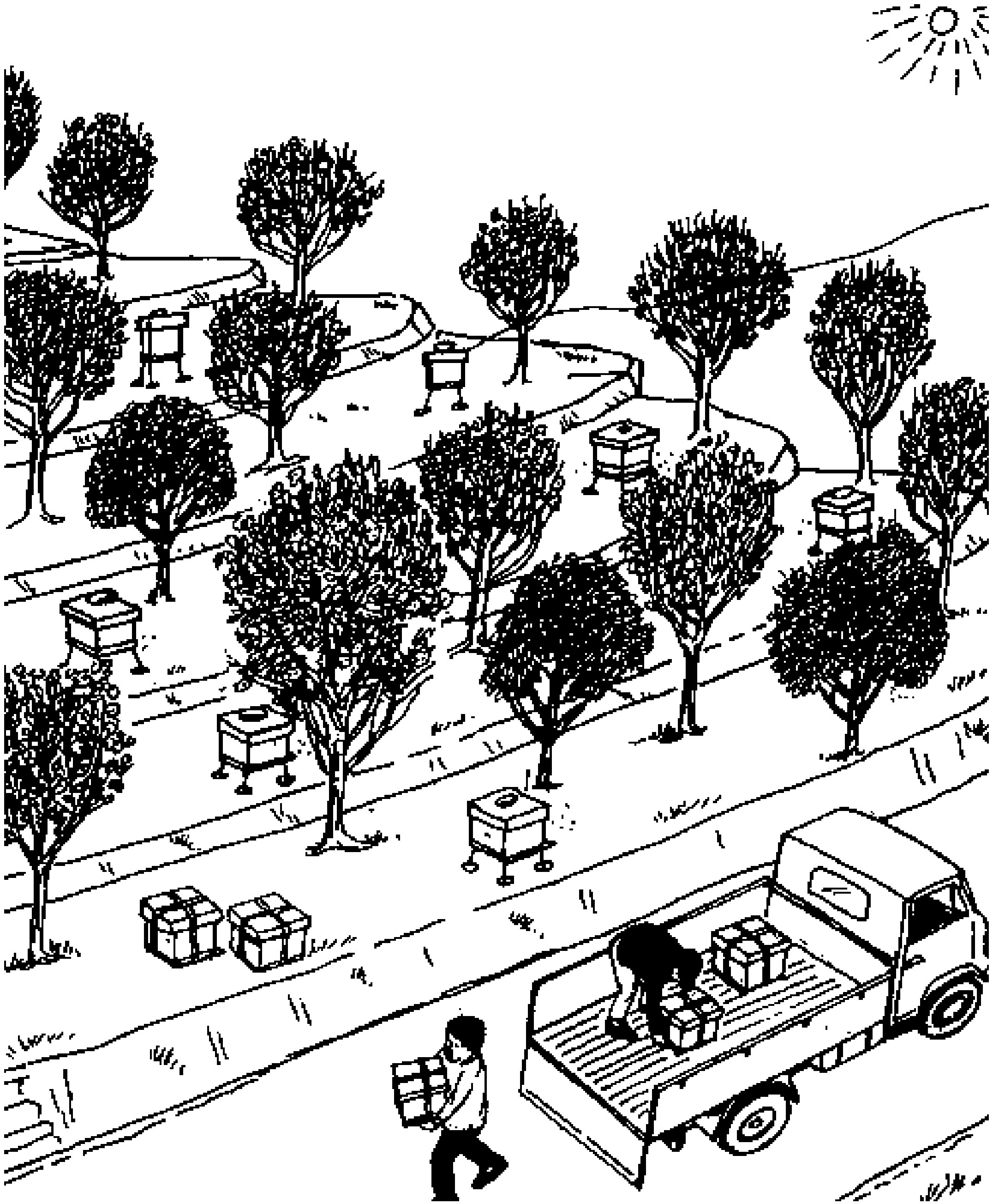


Figure 4.5: To ensure better pollination of all trees, beehives should be placed evenly in the sunny locations in the orchard and protected from the direct wind.

Honeybees prefer to visit sources of nectar and pollen that are near to their colonies (200-300m). At over 500m pollination activity diminishes greatly. For effective pollination, colonies should be placed singly instead of in groups and distributed evenly in the field (Figure 4.5).

- **Bees that forage for pollen (pollen collectors) are known to be better pollinators than nectar collectors.**

Colonies being used for pollination should have large amounts of unsealed brood. This will increase the pollen requirement and the colony will recruit more pollen foragers. The amount of unsealed brood in a colony can be increased by adding frames of unsealed brood from another colony that is not being used for pollination (Figure 4.6). Pollen collection can also be increased by taking out frames in which the bees have stored pollen.

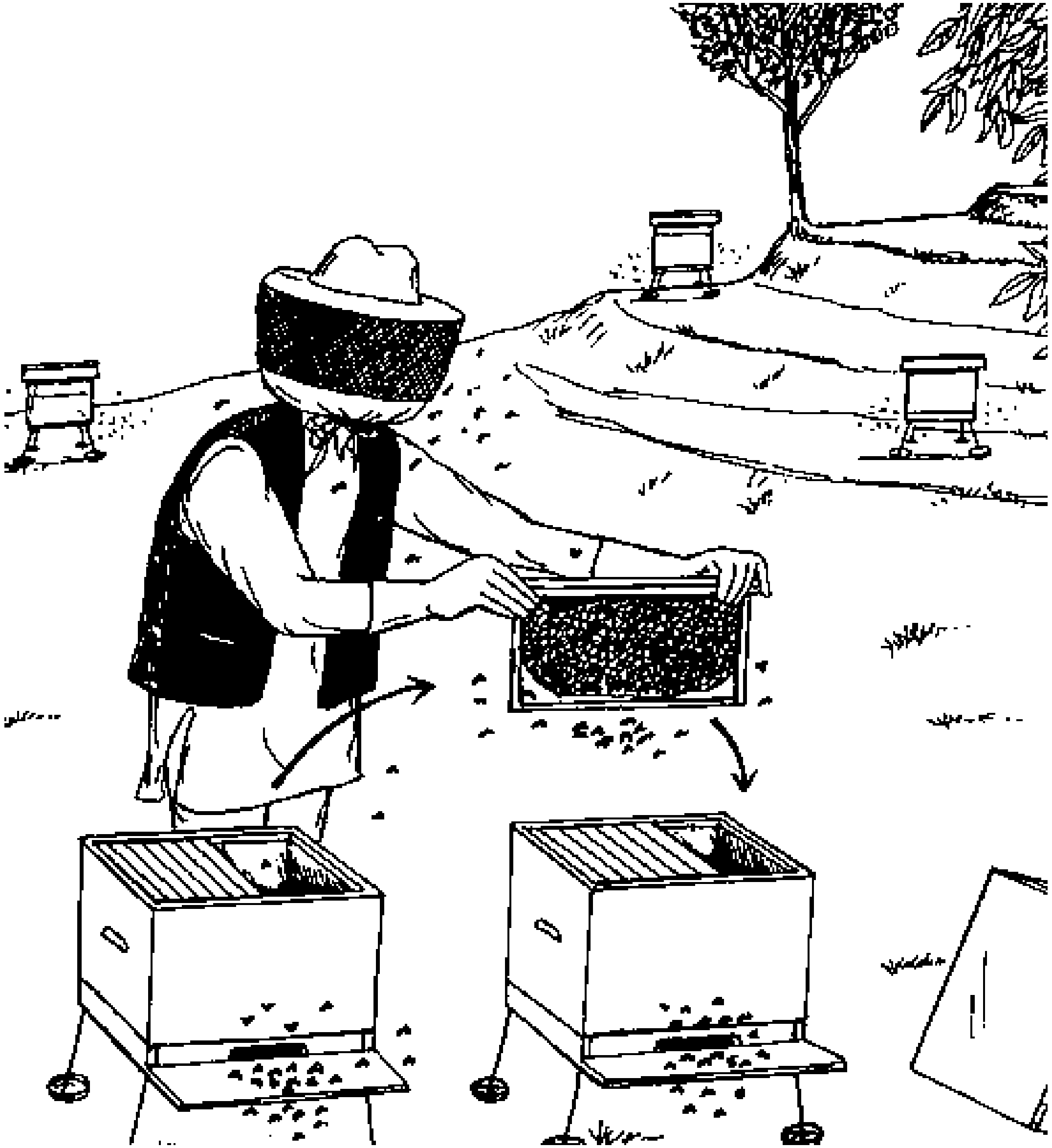


Figure 4.6: Putting frames of unsealed brood increases the number of pollen collectors and enhances pollination.

• For crops that are poor nectar producers and relatively unattractive to honeybees, e.g., kiwi fruit, bees should be fed sugar syrup in which a few fresh

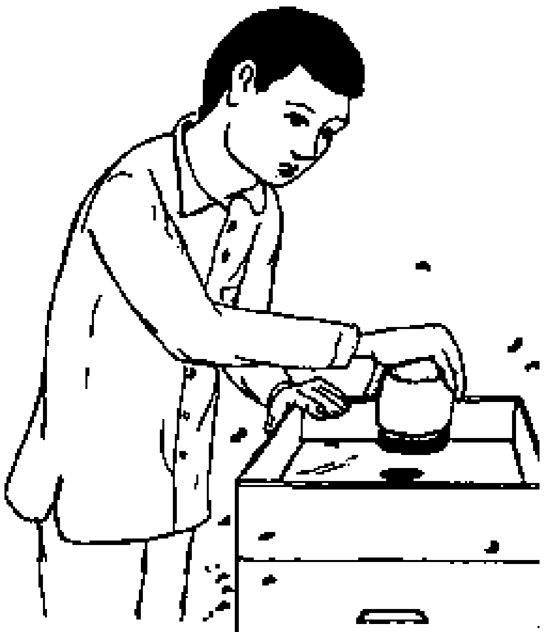
flowers and pollen from the crop have been soaked for some hours (Figure 4.7). Feeds should be given at night or early morning before bees go foraging. This increases pollen collection and thus pollination.

• Sometimes the crop to be pollinated is ignored. Bees may forage on other more attractive plants, e.g., weeds nearby. In such cases, remove the weeds to avoid competition in attracting bees (Figure 4.8), and use good agronomic practices for a healthy crop such as proper manuring, irrigation, and pesticide application. Usually, however, weeds are useful as they provide additional nectar and pollen sources.

1 Soak the flowers (of the crop to be pollinated) in sugar syrup

2 Keep it for a few hours

3 Pour the syrup in the feeder



4 Feed this flavoured syrup to the bees at night or early in the morning before the bees go out foraging

Figure 4.7: To enhance pollination, feed the bees with sugar syrup flavoured with the flowers of the crop to be pollinated.

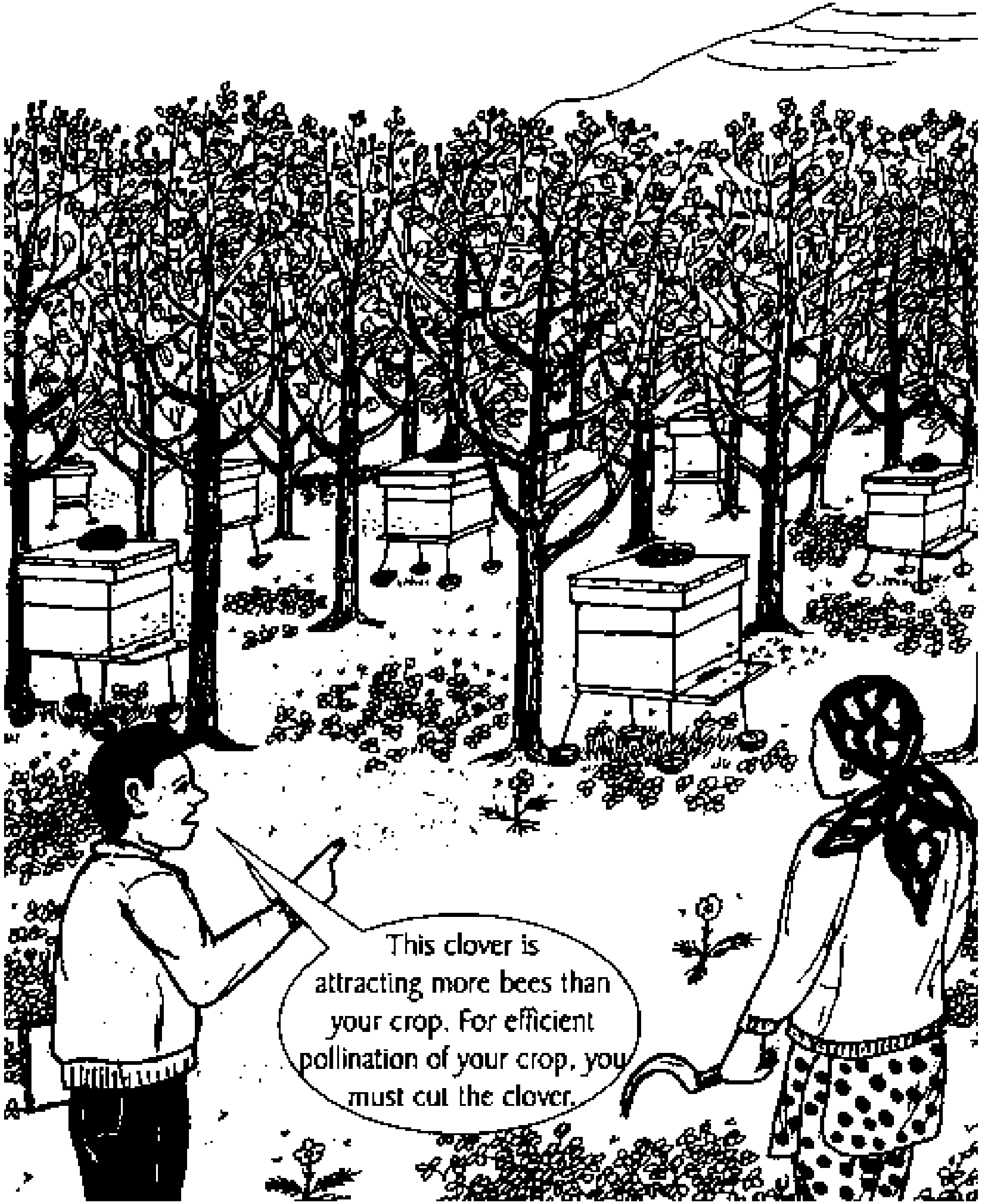


Figure 4.8: For efficient pollination of the target crops by bees, it is important to remove non-target plants (weeds etc.) that may be more attractive to bees.

• Some crops are not attractive to bees. In such crops, flowers can be sprayed with honey or sugar solution to attract more foragers.

• Do not spray pesticides while the crop is flowering and bees are visiting it (Figure 4.9). Remove colonies immediately after petal fall and before pesticides are applied.

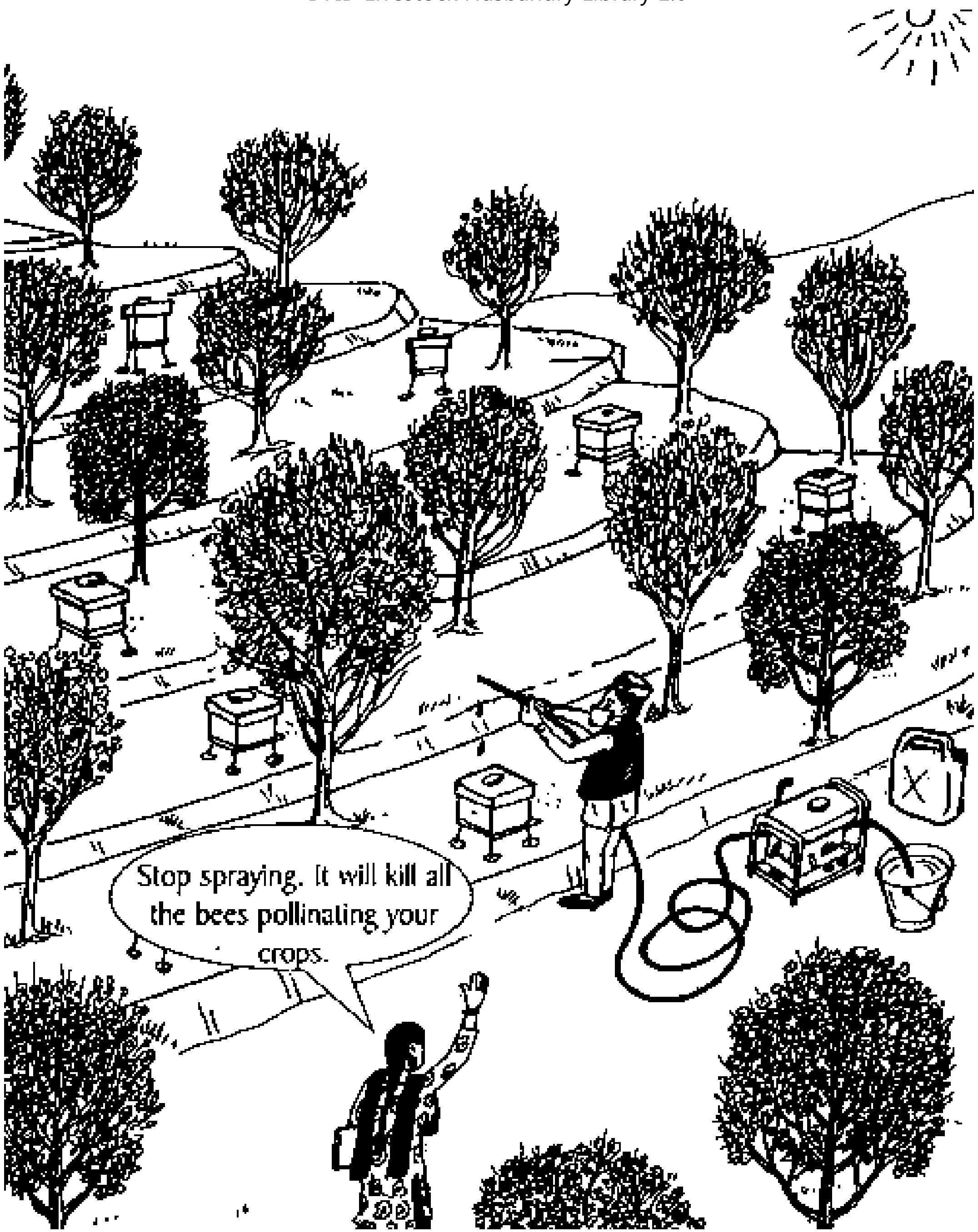


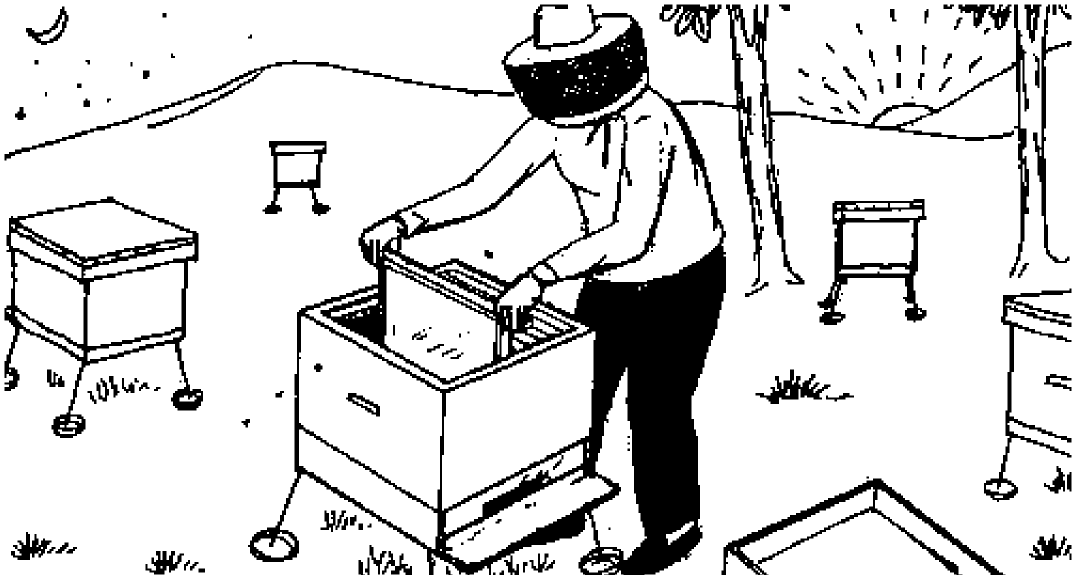
Figure 4.9: To save bees and other insect pollinators from pesticides, these should

be not sprayed during the flowering period when the bees and other insect pollinators are visiting the crop.

How should honeybee colonies be transported?

Before moving the hives, close them and ensure that they are properly ventilated. Hives should be closed during the night because most foragers return in the late evening.

• Pack the inside of the hive to keep frames tight. This is important to avoid combs detaching from frames, particularly if all the frames in the brood chamber are not covered with bees. Push full frames to one side and nail a dummy board against them (Figure 4.10). Place empty frames on the other side of the dummy board to transport them safely (optional). If a super is being used, do the same for the frames covered with bees in the super. If all the frames in the brood chamber and the super are covered with bees, there is no need for a dummy board.



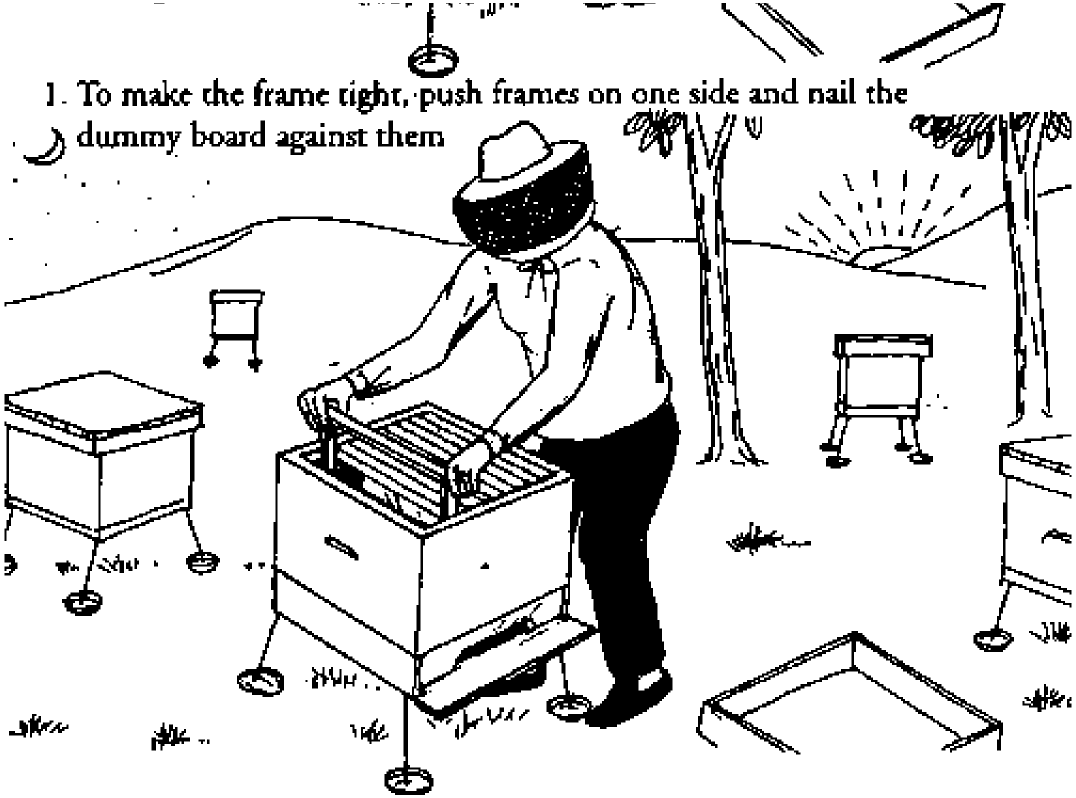
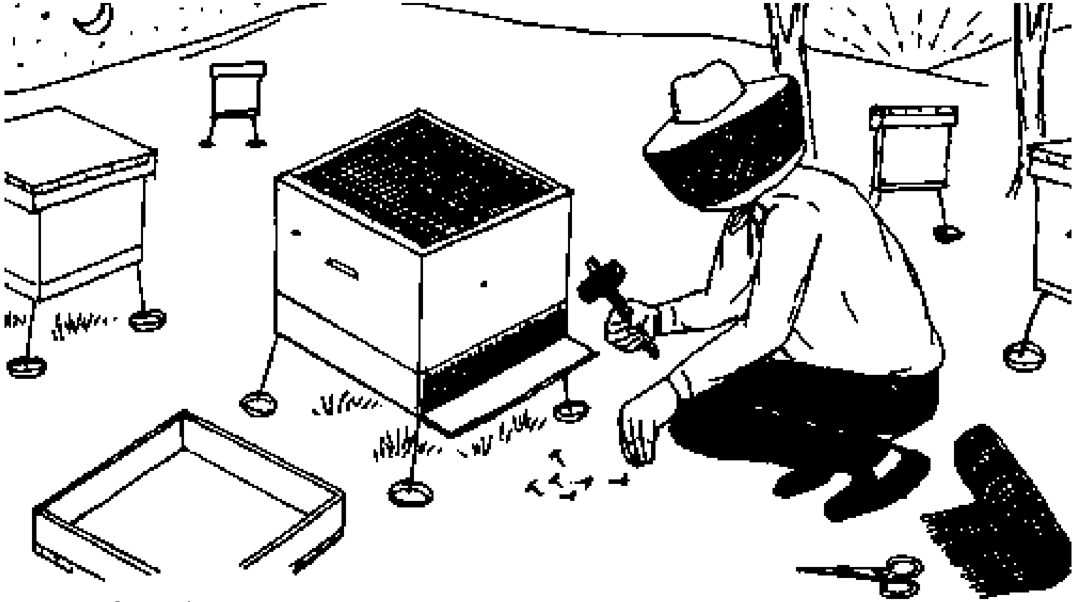


Figure 4.10: Different steps in the inner packing of the beehives before transporting them.

• Close the hive entrance with a material that allows proper ventilation and does not allow bees to fly out, e.g., 3-4 mm wire mesh or loosely woven cloth (Figure 4.11. If a super is being used, nail the super to a brood chamber. Nail the inner cover in place.

• Secure hive with belts (Figure 4.11).

• Load hives on to a vehicle and transport them (preferably at night) to crop to be pollinated (Figure 4.12).



1. Close the hive enrance and hive top with a material that allows proper ventilation and does not let the bees fly away

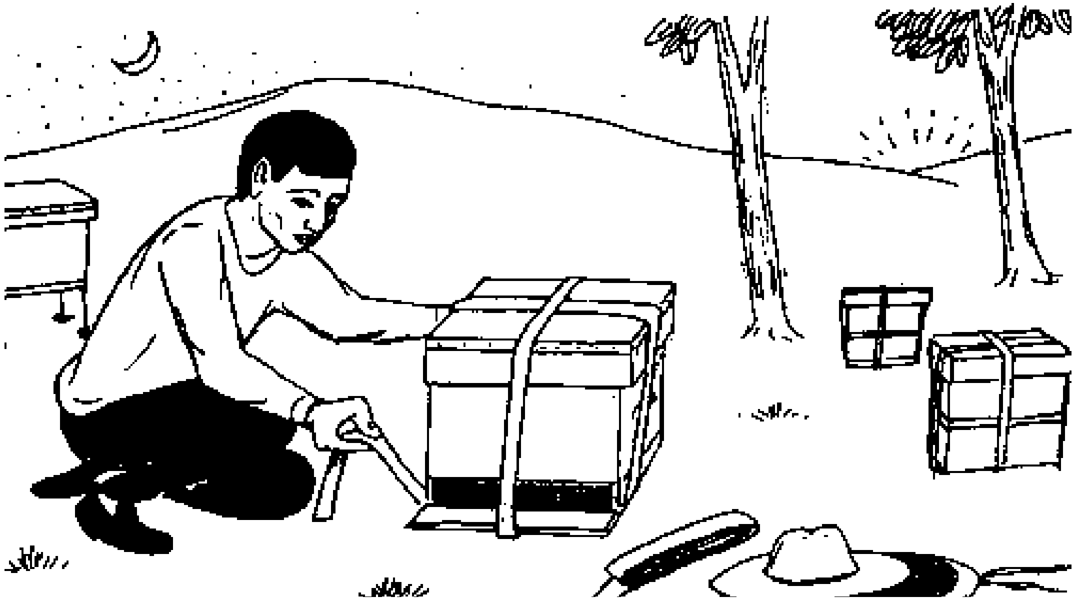
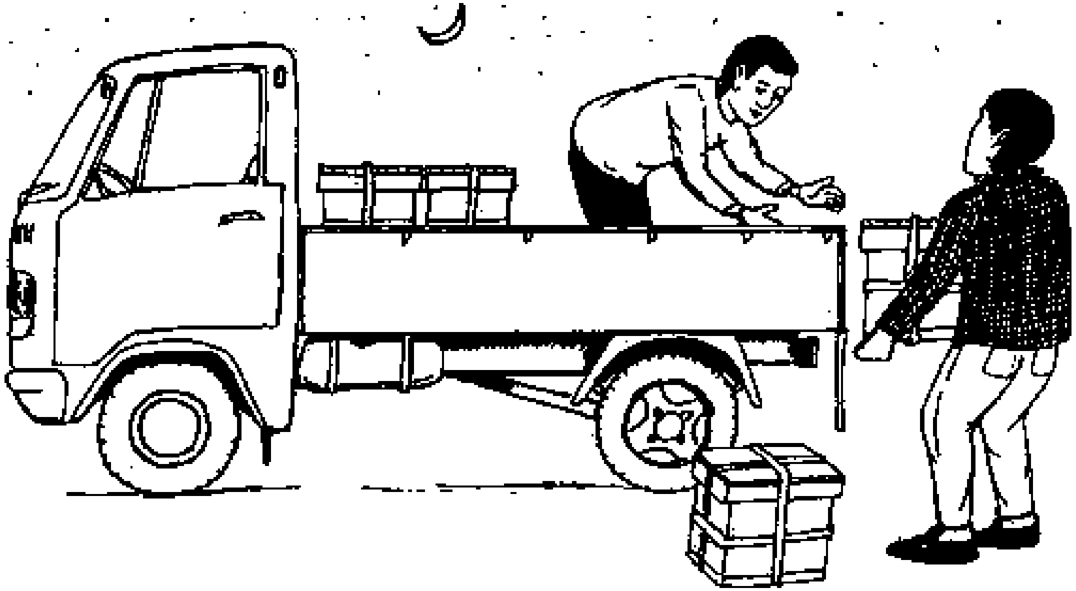
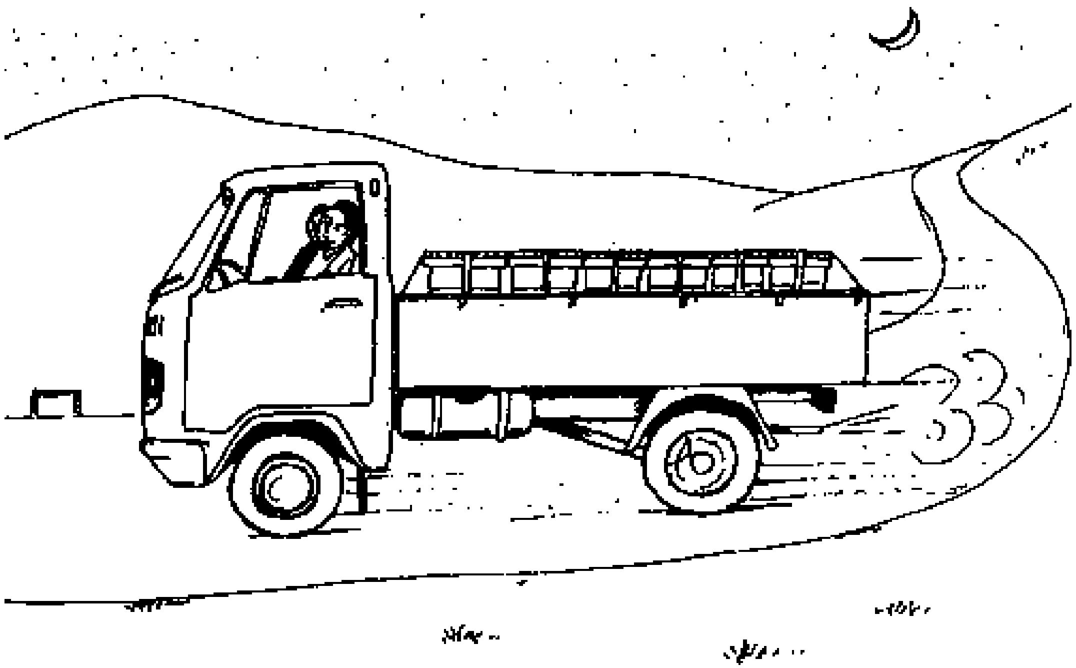


Figure 4.11: Different steps in the outer packing of the beehives.



1. Load beehives, preferably during the night



2. Transport the beehives, preferably during the night

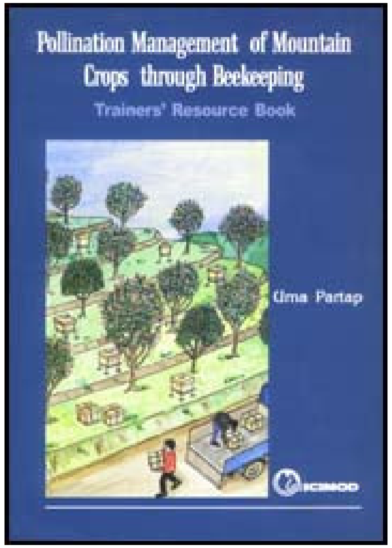
Figure 4.12: Loading and transporting beehives

Prevent overheating of hives during transportation. This can happen while transporting colonies from warmer areas and may cause many bees, or sometimes the whole colony, to die. To prevent overheating, unload hives and open the lid above the ventilation screen (Figure 4.13) and then continue the journey. Do not close the hives for more than 24 hours.

How are bee colonies obtained for pollination?

Crop growers can obtain bee colonies for pollination of their crops from either local beekeepers or the governmental Beekeeping Departments. In some states of India and China, the government has created the institutional infrastructure to rear and manage large numbers of bee colonies and rent these to farmers. For example, in Himachal Pradesh in India, the Department of Horticulture rents bee colonies to farmers for apple pollination. In China, the government promotes beekeeping for crop pollination by encouraging farmers to rent bee colonies for the pollination of their crops and by educating them to protect bees from pesticide poisoning. It is important to rent only strong and healthy bee colonies, because weak and diseased colonies are of little value for crop pollination, especially of crops that bloom during early spring when cold weather is often encountered in mountain areas.

Figure 4.13: Overheating of bee colonies (while transporting in warmer areas) can be prevented by unloading the colonies and opening the ventilation screens.



Pollination Management of Mountain Crops through Beekeeping - Trainers' Resource Book

Author(s):	***Uma Partap***
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Chapter 5: Managing Crop Pollination

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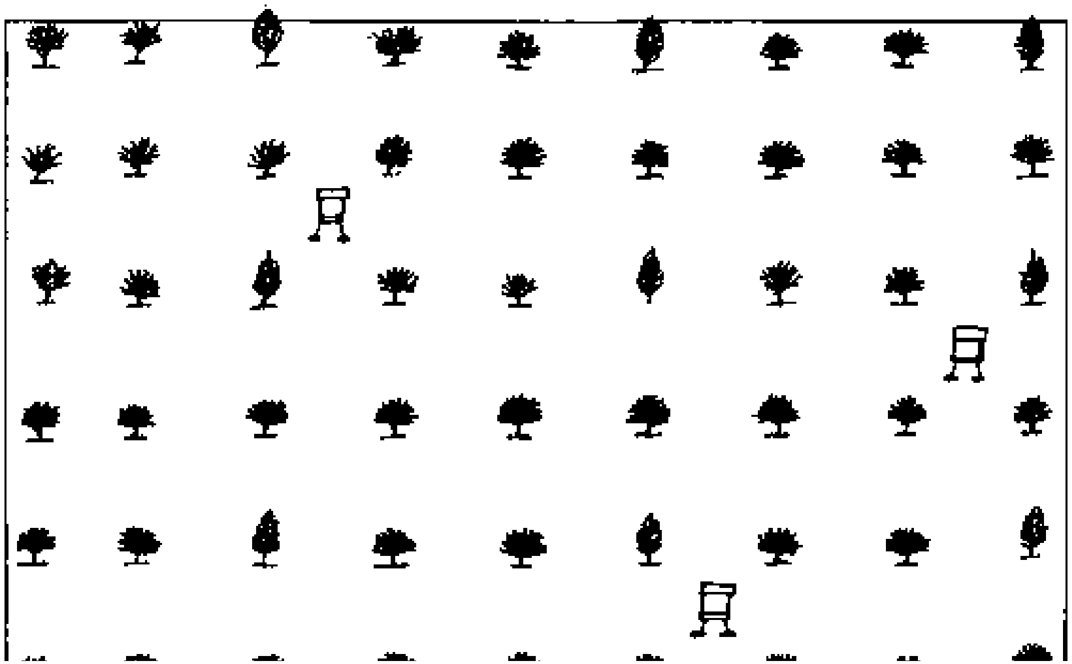
In mountain and hilly areas of the Hindu-Kush Himalayan region, farmers cultivate cash crops such as subtropical and temperate fruits, vegetables, seed vegetables, oilseeds, and spices. Some varieties of these crops are able to set fruit when pollinated by pollen from the same variety (self-compatible). They are considered commercially self-fruitful. Many other varieties fail to produce good crops unless they receive pollen from another variety of the same species (self-incompatible). They are essentially cross-pollinated and depend for pollination on honeybees and other insects. These varieties are commercially self-unfruitful. In such cases, the variety that supplies pollen is called the polliniser. Flowers of commercially self-unfruitful varieties open without producing either sufficient fertile pollen (male sterile) or fertile eggs (female sterile). This section explains how to plan an orchard and manage a polliniser. It also provides information on how to manage crop pollination using hive bees.

How should an orchard be planned?

Planting a new orchard

Choice of polliniser*. Before planting a new orchard, a farmer should know the pollen requirements of the varieties he intends to plant. He should also have some knowledge about the behaviour of bees and the principles of pollination. The normal habit of a honeybee is to work thoroughly in a restricted area rather than to wander around the orchard. Thus, nearness of a pollen source is essential for the best fruit set. This means that ideally every tree of a variety requiring cross-pollination should have a tree of the polliniser variety next to it. Moreover, the flowering period of the polliniser should overlap with the flowering period of the commercial variety; the polliniser must produce good pollen; the two varieties must be compatible; and they should both have commercial value. The polliniser should be an annual bearer because if it has a biennial tendency it may result in regular-bearing commercial varieties also developing the biennial habit.



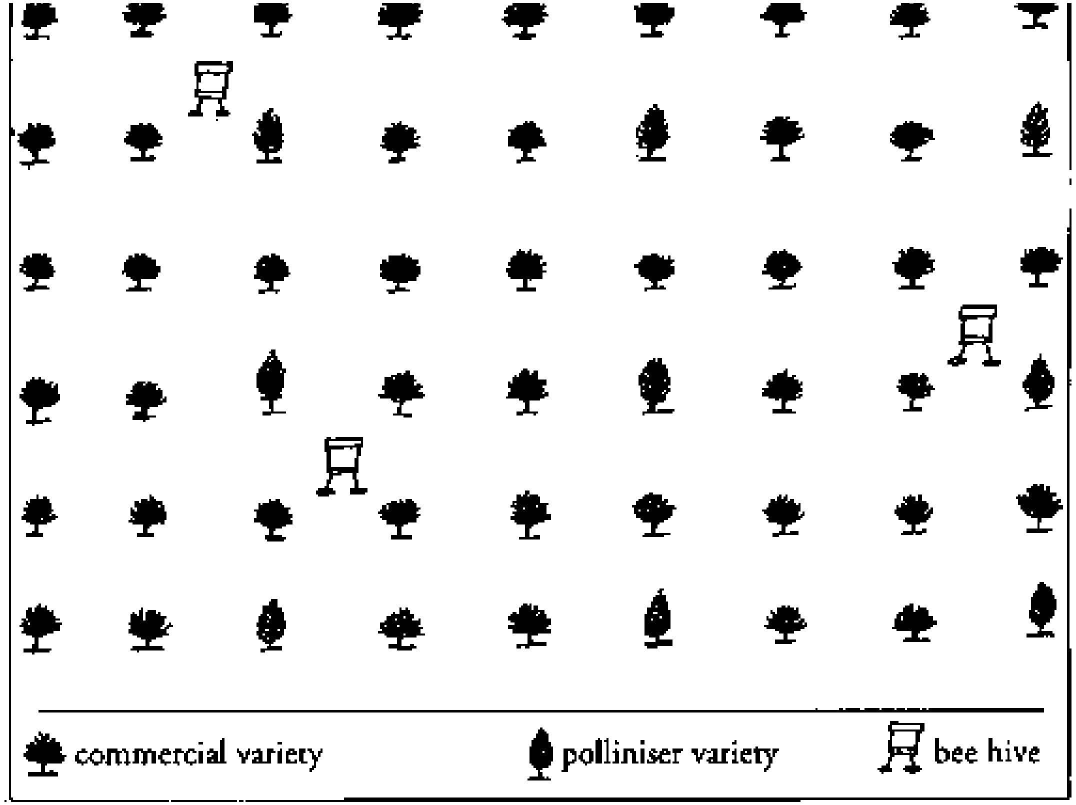


Figure 5.1: Layout plan for a fruit orchard with respect to polliniser proportion; every third tree in every third row is a polliniser variety.

Proportion of polliniser. For effective pollination of a self-sterile variety (e.g., apple) the minimum requirement is to plant a polliniser as every third tree in every third row (Figure 5.1). Where solid rows are preferred, at least every fifth row should be of the polliniser variety. The actual arrangement will depend to a great extent on the importance of the varieties. If two varieties of equal importance are to be planted, plant the rows two by two. If only half the number of the second variety is desired, then plant the first two rows of the first variety and the third row of the second variety. If three or more varieties are to be used, they can be arranged in such a way that every row has a polliniser next to it. The

number of polliniser trees varies from crop to crop. In pear and sweet cherry orchards, polliniser planting should be increased to every third row.

Changing an established orchard

When a farmer finds that he has not planted an adequate number of polliniser trees and there is a problem with cross-pollination, he should correct the situation as soon as possible. The principles involved are similar to those involved in planning a new orchard. The deficiency of suitable varieties can only be overcome by replacing a certain number of trees. In newly set orchards, this is best done by removing some trees and planting the polliniser. However, if the orchard is well established, top-working is more practical because a graft will produce pollen earlier than a new tree (Figure 5.2).

Short-term solutions for managing pollinisers

<u>Hanging branches of polliniser on trees of the main variety.</u> Grafts or replacement trees may take two or more years to produce enough pollen for adequate pollination and fruit set. Therefore, before these grafts or replanted trees are productive, branches of a polliniser can be cut and placed in buckets of water or other containers such as plastic bags. The containers filled with polliniser branches can be hung on the trees to be pollinated (Figure 5.3). The containers should be regularly topped up with water and the branches should be replaced if they wilt before pollination is complete. Honeybees working on these trees will transfer pollen from flowers in the containers to flowers of the main variety on nearby branches. This method of pollination management is called 'bouquet pollination'. Apple farmers in the Kullu Valley of Himachal Pradesh, India, use this

method to manage pollination of their crops.

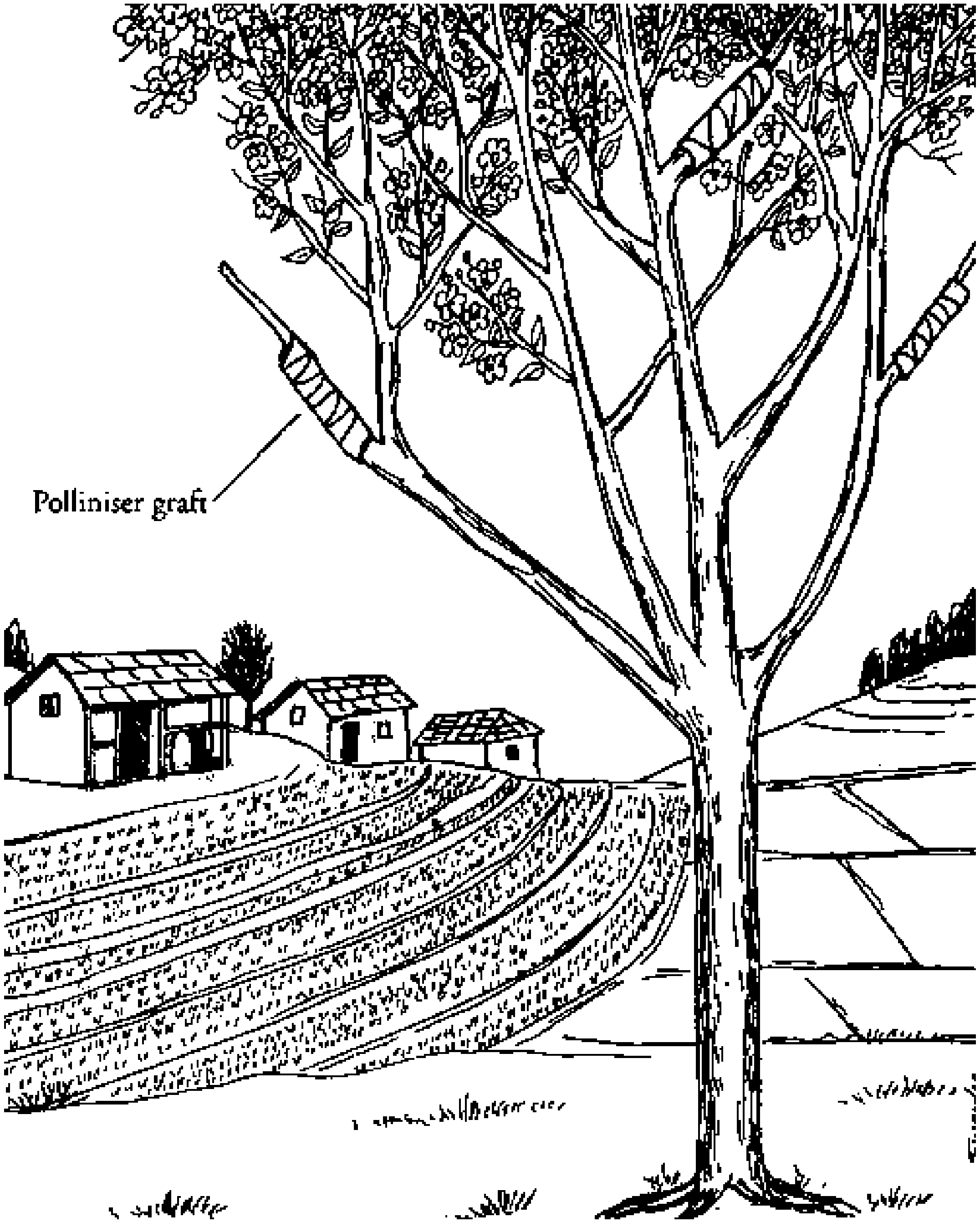


Figure 5.2: Grafting polliniser branches to the main variety is a good way to increase the polliniser in an established orchard; grafts will produce pollen earlier than a newly planted tree.

Hand pollination. Another method is to extract pollen from a compatible variety and distribute (apply) it to flowers of the main variety with the help of a brush (Figure 5.4). This method is called hand pollination. Hand pollination produces satisfactory results but the labour cost is high. This method of pollination management is practised by apple farmers in the Maoxian Valley in Aba Prefecture of Sichuan Province, China, and Shimla district in Himachal Pradesh, India.

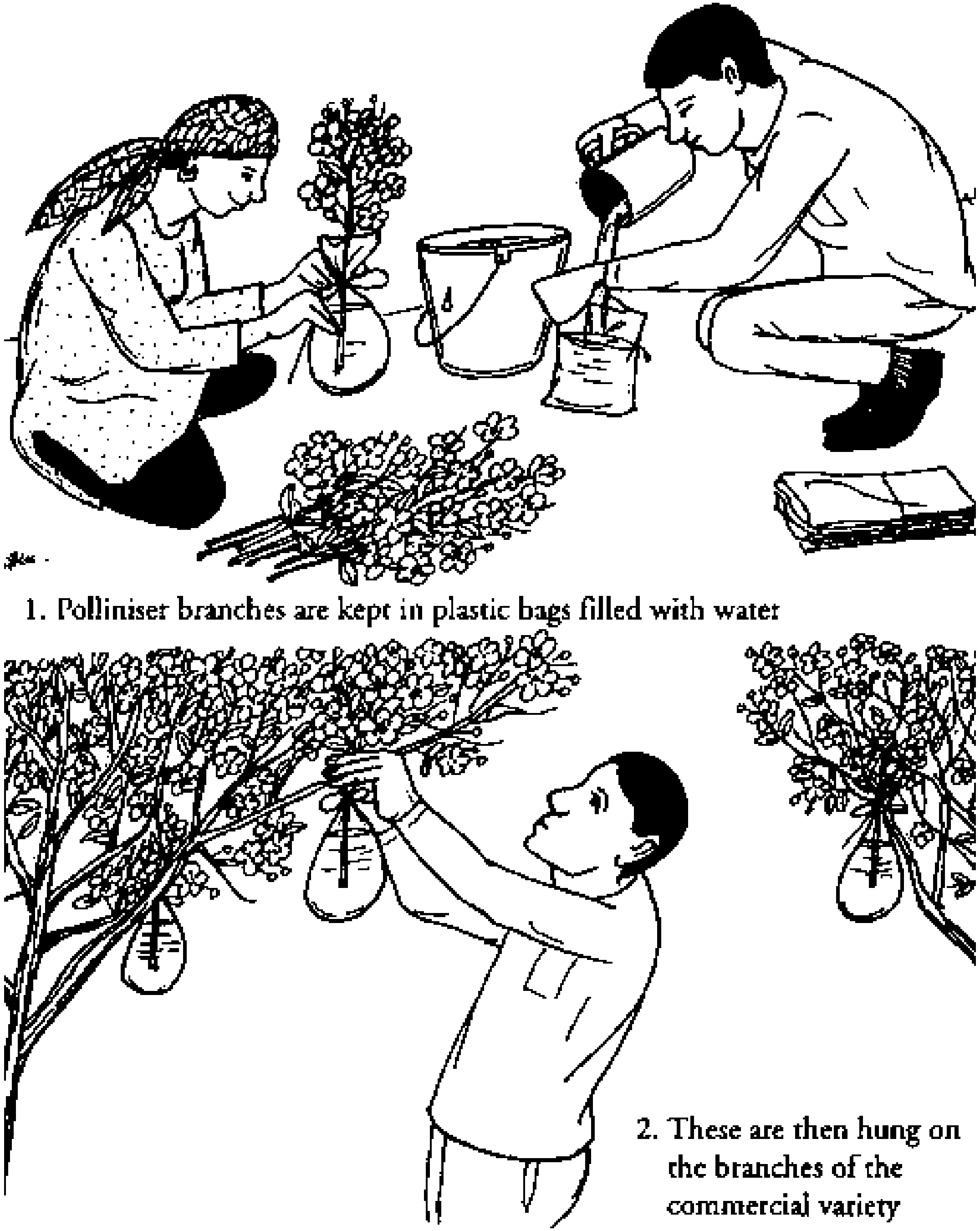


Figure 5.3: Bouquet pollination: hanging polliniser branches (in a plastic bag or

bucket, tin, bottle or other container etc filled with water) on the branches of the commercial variety is an excellent short-term solution for managing polliniser.

How are hive bees used for pollination management?

Figure 5.4 Hand pollination is the most reliable method of pollination but the

labour costs are very high.

Some crops (e.g., almond, avocado, citrus, litchi, some vegetable crops) produce good amounts of nectar and pollen and blossom for a long period. There are other crops that produce good amounts of nectar and pollen but blossom for only a short period. There are still other crops, e.g., kiwi fruit, that require cross-pollination but bloom for a short period and produce little or no nectar, but good pollen. These crops can be grouped into the following categories.

- **Crops secreting a good amount of nectar and pollen and having a long blooming period.**
- **Crops secreting a good amount of nectar and pollen and having a short blooming period.**
- **Crops secreting little nectar but good pollen and having a short blooming period.**

The use of honeybees for pollination management of crops grown in the Hindu Kush-Himalayan region is described in the following sections. A summary can be found in Table 2.

Managing pollination of crops secreting a good amount of nectar and pollen and having a long blooming period

Some fruit crops and almost all vegetable and vegetable-seed crops, oilseed crops, and spices cultivated in mountain and hilly areas of the Hindu Kush-Himalayan

region fall into this category. Crops secreting good quantities of both nectar and pollen and having a long blooming period include

- **fruit crops such as almonds, avocados, citrus, litchi, and peaches;**
- **vegetable crops such as cabbage, carrot, cauliflower, cucumber, pumpkin, squash, various gourds, okra, radish, and turnip; and**
- **oilseed crops such as Indian mustard, mustard and rape, niger, safflower, and sunflower.**

Fruit crops

Almond (Prunus amygdalus; Prunus dulcis)

Almond blooms from mid-February to mid-March for over a month and produces large quantities of nectar and pollen. The flower has five sepals, five petals, 10-30 stamens, and one carpel with two ovules. After fertilization, one or both of the ovules develop into seeds. Almost all varieties are self-incompatible and depend on cross-pollination with other compatible varieties. Since fruit size is not a consideration, all flowers should develop into fruits, i.e., 100 per cent fruit set is required for a commercial crop. An orchard should be planted with two rows of the main variety and one row of the polliniser variety.

Table 2: Summary of pollination management of different crops

Crop	Blooming	Number of *A.*	No. of *A. cerana*	Time of

	period of the crop	***mellifera*** **colonies/ha**	**colonies/ha**	**colony placement**
Fruit crops				
Almond	Mid-February to mid-March	5-8	10-12	5-10% bloom
Apple	April (7-10 days)	5-8	10-12	5% bloom
Apricot	Mid-February (2-3 weeks)	2-3	4-6	5-10% bloom
Avocado	April-May	5-8	10-12	10-15% bloom
Cherry	February (7-10 days)	2-3	4-6	5% bloom
Citrus	March-April	2-3	4-5	5-10% bloom
Kiwifruit	March-April	8-9	16-20	5-10% bloom
Litchi	March-April	2-3	4-6	5-10% bloom
Mango	February	2-3	4-6	5-10% bloom
Peach	February-March (3-4 weeks)	1-2	2-3	5-10% bloom
Pear	February-March	5	8-9	5% bloom

	(7-10 days)			
Persimmon	March-April (2 weeks)	2-3	4-6	5-10% bloom
Plum	February (1-2 weeks)	2-3	4-6	5% bloom
Strawberry	February-April (2 months)	as many as 15	25	5-10% bloom
Vegetable Crops				
Cabbage	February-March	5	8-10	10-15% bloom
Carrot	March-April	5-8	10-12	10-15% bloom
Cauliflower	March-April	5	8-10	10-15% bloom
Cucumber	June-September	1 for monoecious plants	2-3 for monoecious	10-15% bloom
		8 for gynoecious plants	12-16 for gynoecious	
Cucurbits				
(pumpkin,	June-September	5-8	10-12	10-15% bloom
squash, gourd)				
Okra	June-September	1-2	2-3	10-15% bloom

Okra	June-September	1-2	2-3	10-15% bloom
Onion	April	5-8	10-12	5-10% bloom
Radish	March-April	2-3	4-6	10-15% bloom
Turnip	February-March	2-3	4-6	5-10% bloom
Oilseed crops				
Mustard and	December-January	3-5	5-8	10-15% bloom
rape	February-March			
Niger	August-September	3-5	6-8	5-10% bloom
Safflower	March-April	5	4-6	5-10% bloom
Sunflower	June	5	8-10	5-10% bloom
Spice crops				
Cardamom	March-April	2-3 *	4-6	10-15% bloom
Chilli	July-September	2-3 *	4-6	10-15% bloom
Coriander	February-April	2-3 *	4-6	10-15% bloom

* No specific recommendation

The flowers are highly attractive to honeybees. Since it blooms during early spring, hive bees are the best pollinators. For effective pollination, place 5-8 strong colonies of *Apis mellifera* or 10-12 colonies of *Apis cerana* per hectare at the time of 5-10 per cent flowering. Colonies should be distributed evenly throughout the orchard and not in groups.

Avocado (Persea americana)

Avocado blooms during April-May and may have a flowering period of about six months depending on the weather. A fully grown tree may produce about a million flowers in one blooming season. The flower has six sepals in two whorls, one carpel with a single one-chambered ovary, a short style and simple large stigma, and nine stamens inserted in three whorls; each whorl has three stamens. The anthers release pollen through a small hinged flap.

The flower opens in two stages. It opens first for a few hours during which the stigma is receptive but anthers do not release pollen. The flower then closes and opens again on the next day. This time anthers release pollen but the stigma is shrivelled and no longer receptive. After anthers release pollen, the flower closes and never opens again. Thus, flowers are structurally bisexual and functionally unisexual. Cross-pollination is essential for fruit set. In some varieties, the first stage occurs in the morning of the first day and the second stage in the afternoon of the second day. These varieties are called Type A. In other varieties, the first stage occurs in the afternoon of the first day and the second stage in the morning of the second day. These varieties are called Type B. Therefore, both varieties are planted in the same orchard so that pollen is always available when stigmas are receptive.

Flowers produce plenty of nectar and pollen and are visited by insects and birds (such as humming birds in America). Honeybees are the most important pollinator. In order to have maximum fruit set, place 5-8 colonies of *Apis mellifera* or 10-12 colonies of *Apis cerana* evenly per hectare at the time of 10-15 per cent blooming.

Citrus (Citrus spp.)

Many species of *Citrus* - including grapefruit, lemon, orange, sweet orange, and lime - bloom during March-April and produce plenty of nectar and pollen. A citrus flower usually has five sepals, 4-5 petals, 10 stamens united to form two groups of three and one group of four stamens, and one pistil with one ovary having 8-10 chambers with many ovules in each chamber, a small style, and a capitate stigma.

Citrus flowers are usually self-compatible and do not depend on insects for pollination but benefit from cross-pollination by honeybees. For pollination, place 2-3 colonies of *Apis mellifera* or 4-6 colonies of *Apis cerana* evenly per hectare.

Litchis (Litchi chinensis)

***Litchi* blooms during late March or early April for 3-4 weeks, depending on the weather, and produces small, greenish-yellow flowers in terminal clusters. There are three types of flower. The male flower has 5-8 stamens with functional anthers arising from a fleshy disc, but no style. The imperfect hermaphrodite flower has functional anthers, but the style is small and the stigma lobes never separate. The pollen from this type of flower is more viable than that from the male flower. The other type of hermaphrodite flower has a style that grows to full size and the**

stigma opens to 2-3 lobes, but the anthers do not release pollen. Some varieties produce only male flowers and do not set fruit in some years.

Litchi is self-fruitful but flowers need to be cross-pollinated. Flowers secrete plenty of nectar and are visited by a number of insects. Honeybees are the most important pollinators. To obtain a higher yield and better quality fruit, place 2-3 colonies of *Apis mellifera* or 4-6 colonies of *Apis cerana* evenly per hectare.

Peach (Prunus persica)

Peach blooms during February to March, depending on the variety, for 3-4 weeks. The flowers are bright pink or reddish- pink and produce large quantities of nectar and pollen. Usually a flower consists of five small sepals, five oval, bright pink petals, and 15-30 stamens surrounding a single erect pistil having a single ovary containing two ovules, a style, and a stigma. Only one ovule normally develops into seed, leading to an asymmetrical fruit. Many varieties produce pollen at the time the stigma is receptive.

The flowers are highly attractive to honeybees and other insects. The fact that only one ovule must be fertilized for fruit set simplifies pollination. Many varieties are self-fertile and a few are self-sterile. A satisfactory crop from either self-sterile or self-fertile varieties can be obtained when plenty of honeybees and other pollinating insects are present. Since pollination is simple and flowers are attractive to bees, only 1-2 colonies of *Apis mellifera* or 2-3 colonies of *Apis cerana* per hectare of orchard are sufficient.

Strawberry (Fragaria ananassa)

Strawberry blooms in February-April or November-January depending on the variety. Two to three white flowers are produced on each plant every day. The flower consists of five sepals, five petals, many stamens, and many pistils -each with one carpel on a fleshy conical receptacle. The strawberry is an aggregated fruit; each carpel forms a true fruit called an achene. Achenes containing a fertilized ovule release a hormone that stimulates the growth of the receptacle. If an achene does not contain a fertilized ovule, the receptacle in its area does not grow. When groups of such achenes occur together, the fruit is deformed. These deformed fruits have low market value. Most modern varieties are self-fertile and have bisexual flowers.

Flowers produce good amounts of nectar and pollen and are visited by honeybees. In order to produce a commercial crop, there should be a large number of pollinating insects. It requires as many as 60 visits by a bee (or other insect pollinator) per flower to produce a well-formed, heavy fruit. Therefore, place 15 colonies of *Apis mellifera* or 25 colonies of *Apis cerana* evenly per hectare of field.

Vegetable crops and vegetable-seed crops

Carrot (Daucus carota)

Carrot blooms during March-April and produces small white flowers in terminal or primary and secondary umbels. Secondary umbels are classified as second-, third-, fourth-order umbels. First- and fourth-order umbels are important in seed production. The flower is usually hermaphrodite, but there is a tendency to produce male flowers. A flower has five functional stamens and an ovary with two locules containing one ovule each. There are two styles, each terminated by a

stigma. Carrot blooms for over a month, and flowers produce good quantities of nectar and pollen which are collected by different insects.

Only two pollen grains are required to fertilize two ovules, and the stigma is receptive to pollen from flowers of the same or another plant for a week or more. However, only about 15 per cent of plants set seed from their own pollen. Honeybees are the most reliable pollinators and increase yield by 9-135 per cent depending on crop variety. For effective pollination, place 5-8 colonies of *Apis mellifera* and 10-12 colonies of *Apis cerana* in one hectare at a time of 10-15 per cent flowering. Carrots should not be grown in the vicinity of crops that are more attractive to honeybees.

Cole crops (Brassica oleracea)

Cole crops include cabbage (*Brassica oleracea capitata*), cauliflower (*Brassica oleracea botrytis*), broccoli (*Brassica oleracea cymosa*), kohlrabi (*Brassica oleracea gongylodes*), Brussels sprouts (*Brassica oleracea gemmifera*), etc. They bloom during March-April for over a month. Flowers open early in the morning and remain open for 2-3 days. Flowers are yellow and have four sepals, four petals, six stamens (two short and four long), and a long ovary containing 10-30 ovules depending on the variety. The style is short and is terminated by a capitate stigma.

Flowers produce good amounts of nectar and pollen. They are generally self-sterile and require cross-pollination to set fruit. Honeybees are the primary pollinators and enhance crop yield. To obtain high yield and good quality seed, place five colonies of *Apis mellifera* or 8-10 colonies of *Apiscerana* evenly per hectare.

Cucumber (Cucumis sativus)

Cucumber blooms from June to September. Many varieties are monoecious and some are gynoecious. Monoecious varieties produce male and female flowers on the same vine, and gynoecious varieties produce mainly female flowers. Pollen for gynoecious varieties is provided by monoecious plants cultivated alongside them. Generally 10 per cent of the monoecious variety is cultivated with a gynoecious variety. Male flowers appear about 10 days before female flowers and are more numerous. In general the ratio between male and female flowers is 10:1. The male flower has three anthers, two of which have two anthers each (united) and the third has only one. The female flower has an inferior ovary with three locules, each containing many ovules, a short broad style, and three stigma lobes. The stigma is receptive throughout the day but most receptive in early morning. Since anthers and stigma are present separately on male and female flowers, the mechanical transfer of pollen is essential for fruit set.

Cucumbers bloom for a long period and produce good amounts of nectar and pollen. They are visited by various insects. Since the ovary contains a large number of ovules, a large number of pollen grains - and pollinators - are required for effective pollination and good quality fruit. For satisfactory fruit set, a cucumber flower requires 8-10 bee visits, however fruit weight and number of seeds per fruit are improved when bees make up to 50 visits. Honeybees are the most reliable pollinators because they can be managed in large numbers. The amount of pollen that needs to be transferred depends on the ratio between male and female flowers. Since the male:female ratio is higher in monoecious varieties, one colony of *Apis mellifera* or two colonies of *Apis cerana* are required for their pollination. Gynoecious varieties have more female flowers, so eight colonies of

***Apis mellifera*or 12-16 colonies of *Apis cerana* should be distributed per hectare of field.**

Pumpkin and squash (Cucurbita spp)

Pumpkin (*Cucurbita pepo*), squash (*Cucurbita moschata*),and other cucurbits bloom for a long period from June to September. Plants are monoecious and produce creamy-yellow to deep orange-yellow male or female flowers on the same vine. In general, male and female flowers occur in the ratio 10:1. Each male flower has three stamens with united filaments and anthers. The female flower has a thick style and two-lobed stigma. It has an easily recognised underdeveloped fruit (ovary) having three chambers, each containing many ovules. The corolla consists of five united petals. Since anthers are present in one flower and stigma on another, mechanical transfer of pollen is essential to fruit set.

Male flowers produce good amounts of pollen, and both male and female flowers produce a large quantity of nectar. Flowers are visited by insects - including honeybees. Pollination is most effective in the early morning because flowers open early and the stigma is most receptive at this time. Honeybees are the primary pollinators and increase production by 3-4 times. Fruit set, seed set, and fruit weight increase with an increase in the number of pollen grains deposited on the stigma. For higher yield and better quality fruit, place eight colonies of *Apis mellifera* and 12-16 colonies of *Apis cerana* evenly per hectare at 10-15 per cent flowering.

Okra (Abelmoschus esculentus)

Okra blooms for about 3-4 months from June to September. It produces large, solitary, light yellow flowers with a maroon spot at the base of the petal in the leaf axils. The flower has five sepals, five petals, many stamens having filaments united to form a tube around the style and monothecus (one-celled) anthers, and a pistil having a five-chambered ovary with many ovules in each chamber, a style, and five stigmas. Nectar is produced by both floral and extrafloral nectaries.

Flowers are generally self-pollinated, but cross-pollination increases fruit and seed set. Honeybees are the most important pollinators. For effective pollination, place 1-2 colonies of *Apis mellifera* and 2-3 colonies of *Apis cerana* evenly per hectare at 10-15 per cent flowering.

Onion (Allium cepa)

Onion blooms during April for 3-4 weeks and produces ash-grey flowers in simple oval umbels. Each umbel consists of 40-200 flowers. The flower consists of six petals in two whorls of three petals each, six stamens also in two whorls of three stamens each, and a pistil with a three-celled ovary with two ovules in each cell, a style, and a small stigma. Anthers release pollen within 24-36 hours of the flower opening and before the stigma is receptive, therefore self-pollination within the flower is not possible.

Flowers produce a good amount of nectar and pollen. Cross-pollination is carried out by insects - including honeybees. Commercial production of onion seed depends on honeybees as the primary pollinators. For effective pollination, place 5-8 colonies of *Apis mellifera* or 10-12 colonies of *Apis cerana*evenly per hectare at 10-15 per cent flowering. Onion flowers have a typical smell of sulphur and are

comparatively less attractive to honeybees; this may cause bees to neglect the crop if other more attractive crop/weeds are blooming in the vicinity.

Radish (Raphanus sativus)

Radish blooms during March-April for over a month. The white or purplish-pink flowers open in the morning and remain open for 2-3 days. The stigma is receptive for only a few hours. The flower consists of four sepals, four petals, six stamens (four long and two short), and a pistil consisting of an ovary containing 6-12 ovules, a style, and a stigma. Many commercial varieties are self-incompatible, therefore require cross-pollination.

The flower produces a good amount of nectar and pollen. Honeybees are the most effective pollinators. Honeybee pollination increases fruit set, seed set, number of seeds per pod, and seed weight. Seed yield is greatly influenced by the number of honeybees visiting flowers. In order to have higher yields and better-quality seed, place 2-3 colonies of *Apis mellifera* and 4-6 colonies of *Apis cerana* evenly per hectare at 10-15 per cent flowering.

Turnip (Brassica rapa)

Turnip blooms from March-April for over a month. It produces dark yellow flowers that open in the morning for 2-3 days. The structure of the flower is similar to that of other *Brassica* species. Honeybees are the most important pollinators and increase fruit set, seed set, number of seeds per pod, and seed weight. For higher yields and better quality seed, place 2-3 colonies of *Apis mellifera* or 4-6 colonies of *Apis cerana* evenly per hectare at 10-15 per cent flowering.

Oilseed crops

Rape and mustard (Brassica spp.)

Many species of *Brassica,* such as rape (*Brassica napus*), sarson (*Brassica campestris* var. sarson), toria (*Brassica campestris* var. toria), Indian mustard or broadleaved mustard or trowse mustard or rai (*Brassica juncea*), white mustard (*Brassica alba*), and black mustard (*Brassica nigra*) are cultivated widely as oilseed crops throughout the Hindu Kush-Himalayan region. Most of these crops bloom during February-March for over a month. The flowers are bright yellow and are produced in long terminal racemes. They are similar to other cruciferous crops, e.g., cole crops, radishes, and turnips. Some crops, such as winter rape, bloom during December-January. The flower consists of four sepals, four petals, six stamens (four long and two short), and a pistil having a single two-chambered ovary with 6-12 ovules, a style, and a capitate stigma. These crops are usually self-pollinated, but some degree of cross-pollination occurs in *Brassica campestris*.

The flower produces a good amount of nectar and pollen and is highly attractive to honeybees and other natural insect pollinators. Cross-pollination by honeybees increases yield and quality and oil content of seed. Since crops are mainly self-pollinated and flowers are attractive to bees, place 3-5 colonies of *Apis mellifera* or 5-8 colonies of *Apis cerana* evenly per hectare.

Niger (Guizotia abyssinica)

Niger blooms from September-October for over a month and produces deep yellow

flowering heads. A flowering head consists of two types of florets: ray florets and disc florets. Ray florets are a conspicuous yellow and consist of an inferior ovary without stamens or pistils. Disc florets are hermaphrodite (bisexual) and consist of five united petals, five stamens with united anthers, and a pistil having a one-chambered ovary with one ovule, a style, and a bifid stigma. Disc florets produce plenty of nectar and pollen.

Pollination is accomplished by insects, particularly honeybees. Honeybee pollination increases both yield and quality of seed. To produce high yields with a high oil content, place 3-5 colonies of *Apis mellifera* or 6-8 colonies of *Apis cerana* evenly per hectare.

Safflower (Carthamus tinctorius)

Safflower blooms from March-April and produces 15-150 orange-yellow flowering heads terminating the main axis and branches. The flowering head that terminates the main axis blooms first, then flowering proceeds downwards with those flower heads on the lowest branches opening last. A flower head consists of from 20-100 yellow and orange florets surrounded by bracts. Each floret consists of five petals united to form a long corolla tube. The stamens consist of five filaments and five anthers. Anthers are united around the style. The pistil consists of a single one-chambered ovary having one ovule. In many self-fertile varieties, anthers release pollen early in the day, and soon afterwards the style elongates and the stigma appears above the top of the anther tube covered with pollen grains. Thus self-pollination occurs. In self-sterile varieties, the style elongates and passes through the anther tube before anthers release pollen. In such varieties, self-pollination does not occur and cross-pollination is carried out by insects.

Florets produce plenty of nectar and pollen, and the crop is a major source of honey in areas where it is cultivated on a large scale. Honeybees are the most important pollinators. Honeybee pollination not only helps seed production in self-sterile varieties, but also enhances yield and quality of self-fertile varieties. For effective pollination, place five colonies of *Apis mellifera* and 4-6 colonies of *Apis cerana* evenly per hectare at 10-15 per cent flowering.

Sunflower (Helianthus annuus)

Sunflower blooms during June for 3-4 weeks. The primary stalk has a primary head and one to many secondary heads. However, most commercial varieties are almost all single-headed plants. The corolla is made of five united petals. The main head consists of from 1,000-4,000 individual florets and the secondary head has 300-1,500 florets depending on the variety and the size of the head. The flowering head is composed of two types of florets: outer conspicuous yellow ray florets and inner less conspicuous disc florets. Ray florets are sterile and have inferior ovaries without stamens or pistils. Disc florets constitute most of the head. They are hermaphrodite, and anthers mature and release pollen before stigmas are receptive. Disc florets open from the periphery inward, 2-4 circles each day.

Florets produce plenty of nectar and pollen and are visited by insect pollinators. Honeybees are the most important pollinators, and increase yield and quality of seed. A floret sets seed if pollinated early: its ability to produce seed decreases with the length of time it has been open. Therefore, honeybee colonies should be moved to the field at 5-10 per cent flowering. The recommended number of *Apis mellifera* colonies is five and of *Apis cerana* colonies is 8-10, evenly distributed, per hectare.

Spices

Large cardamom (Amomum subulatum)

The large cardamom blooms during March-April for about 3-4 weeks and produces pinkish-white flowers on long pedicels in 20 or more lateral racemes of 2-5 flowers each. The flowers subsequently open from the base to the top of the panicle. A cardamom flower consists of a pale green, slender calyx tube from which pinkish or white narrow lobes of corolla (the inside of the corolla is white and the outside pinkish-white) and a large white obovate labellum or staminodium with violet nectaries emerge. The flower has a single functional stamen with a short filament and a large anther. The stigma is in close contact with the distal end of the anther. The pistil consists of a single, inferior, tri-locular ovary with several ovules. The flowers open in the morning and wither by evening. The anthers release pollen when the flower opens and the stigma is receptive till late morning, thus providing an opportunity for self-pollination.

Flowers produce both nectar and pollen and are visited by insects. Honeybees are the main pollinators. Pollen collectors pass over anthers and stigma, and thus ensure pollination; whereas nectar collectors can reach the nectar without touching anthers and stigma (i.e., without pollinating the flower). Honeybees enhance both fruit and seed set. There is no specific recommendation on the number of colonies to use: 2-3 colonies of *Apis mellifera* and 4-6 colonies of *Apis cerana* per hectare would be sufficient for pollination.

Chillies (Capsicum annum)

Chillies bloom for a long period from July to September and produce white flowers in extra axillary cymes. A chilli flower has five sepals, five petals, five stamens, and a pistil with a single two-chambered (bilocular) ovary having many ovules in each locule, a style, and a bifid stigma. The flowers produce 1.1-2.6 mg of nectar per flower of 67-69 per cent sugar concentration, depending on the variety. Chillies are generally self-compatible and produce fruits and seeds by self-pollination, but some varieties are self-incompatible. The self-incompatible varieties require cross-pollination by insects.

Honeybees are the most important pollinators. Honeybee pollination increases both the number of fruits per plant and the number of seeds per fruit. There is no specific recommendation on the number of bee colonies to use. Place 2-3 colonies of *Apis mellifera* or 4-6 colonies of *Apis cerana* evenly per hectare at 10-15 per cent blooming.

Coriander (Coriandrum sativum)

Coriander blooms during February-March for about 3-4 weeks and produces small pinkish-white flowers in compound umbels. A coriander flower has five sepals, five unequal petals, five stamens and a pistil having a single inferior, bilocular ovary with one ovule in each locule, two styles and two stigmas. The flowers produce a good amount of nectar and pollen and are visited by insects. Lack of pollinators generally decreases the seed yield. Honeybees are the primary pollinators. Bee pollination can increase yield by 187 per cent. There is no specific recommendation on the number of bee colonies to use: 2-3 colonies of *Apis mellifera* or 4-6 colonies of *Apis cerana* per hectare should be sufficient for pollination.

Managing pollination of crops secreting a good amount of nectar and pollen but having a short blooming period

Some fruit crops; apple, apricot, cherry, pear, persimmon, and plum; fall into this category.

Apple (Malus domestica)

The apple blooms during April for a short period of 7-10 days depending on the altitude and weather. The flowers are fragrant and borne in groups of six. Each flower consists of five sepals, five pinkish-white petals, and 20-25 stamens surrounding the carpel having a single ovary, a style, and five stigmas. The ovary is divided into five chambers, each having 1-4 ovules. Although fertilization of every ovule in the ovary is not necessary for fruit development, for a larger perfect fruit, a larger number of ovules should be fertilized. Inadequate pollination results in a low number of seeds, which may result in lop-sided or asymmetrical fruits. Moreover, fruits with few seeds are more likely to drop. Almost all commercial varieties are self-incompatible and require pollen from compatible polliniser varieties. Moreover, the pollen is sticky and so wind pollination is not effective. Pollination largely depends on insects, especially honeybees. The flower produces plenty of nectar and pollen, which helps to increase the strength of honeybee colonies. Strong colonies also collect surplus honey from its flow.

Since the blooming period is very short and 50 per cent of the flowering occurs within 3-4 days, farmers must move bee colonies to the orchard as soon as trees start blooming. Also, because the shape and size of the fruit depends on the number of ovules fertilized, there should be plenty of bees in the orchard. Farmers

must place 5-8 colonies of *Apis mellifera* or 10-12 colonies of *Apis cerana* evenly per hectare. To prevent bees foraging on other flowers in the vicinity, remove all weeds and wild plants.

Apricot (Prunus armeniaca)

The apricot blooms in February-March for 2-3 weeks, depending on the weather. The flower is usually white and occurs either singly or doubly. It has five sepals, five petals, and about 30 stamens surrounding a carpel having a single ovary containing two ovules, one style, and one stigma. It produces plenty of nectar and pollen. Some varieties are self-compatible and some are completely self-incompatible and require pollen from a compatible polliniser. Cross-pollination is essential for self-incompatible varieties and is beneficial to self-compatible varieties. Honeybees are its primary pollinator. For effective pollination, place 2-3 colonies of *Apismellifera* or 4-6 colonies of *Apis cerana* evenly per hectare at 5-10 per cent flowering.

Cherry (Prunus avium)

The cherry blooms during February for 7-10 days. The flower is pinkish-white and produces plenty of nectar and pollen. It has five sepals, five petals, 20-25 stamens, and one pistil consisting of an ovary having one or two ovules, a style, and a stigma. While cross-pollination is essential for self-incompatible varieties, it is also beneficial to self-compatible varieties. Honeybees are the primary pollinators. Pollination is simple. Since its blooming period is short and 50 per cent of the flowering occurs within 3-4 days, place 2-3 colonies of *Apis mellifera* or 4-6 colonies of *Apis cerana* evenly per hectare as soon as flowering starts.

Mango (Mangifera indica)

The mango blooms during February and produces 60-cm long panicles; each panicle from contains 200-6,000 red, pink or almost white male and bisexual flowers. Male flowers are more numerous and the percentage of bisexual flowers varies from 1-35 depending on the variety. A flower has 4-5 ovate, lanceolate petals inserted in the base of an almost hemispherical disc. The disc of the bisexual flower is surmounted by a greenish-yellow ovary with a slender lateral style. The ovary has one chamber containing one ovule. There are five stamens; one single fertile stamen arises from the disc on the side of the ovary, and sometimes there are two and rarely three fertile stamens. The other stamens are sterile. The male flower is similar but has no ovary and style. The stamens are surrounded by five nectaries. The stigma is receptive at least one hour before the anther releases pollen, thereby offering an opportunity for cross-pollination. Varieties vary from self-compatible to self-incompatible.

Flowers are visited by pollinating insects. Honeybees collect pollen, nectar from flowers, and juice from damaged fruits. They increase yield and quality of fruit in self-fertile varieties and are essential for fruit set in self-sterile varieties. For high yield and better quality fruit, place 2-3 colonies of *Apis mellifera* or 4-6 colonies of *Apis cerana* evenly per hectare.

Pear (Pyrus communis)

The pear blooms during February-March for about 7-12 days. The flowers are white and produced in clusters of 7-8. The flower has five sepals, five petals, 20-25 stamens, and one pistil consisting of an ovary, a style, and a stigma. The

stigma is receptive before its anthers release pollen. Some varieties are self-incompatible and some are self-compatible. Cross-pollination is essential for self-incompatible varieties and beneficial to self-compatible varieties.

Flowers produce plenty of nectar and pollen. Honeybees visit mainly for its highly attractive pollen. Pears produce a large number of flowers and, for a satisfactory crop, only five per cent are required to set fruit. Commercial varieties are self-incompatible and the blooming period is short with 50 per cent of the flowering occurring within 3-4 days. Therefore, for sufficient pollination, place 5-6 colonies of *Apis mellifera* or 8-9 colonies of *Apis cerana* evenly per hectare as soon as flowering starts.

Persimmon (Diospyros kaki)

Persimmon blooms during March-April for 1-2 weeks depending on the weather. It produces creamish-yellow flowers. Different varieties of persimmon produce five types of flower: pistillate, pistillate and sporadically monoecious, monoecious, monoecious and sporadically staminate or pistillate, and staminate. The flower has outfolded, prominent, green sepals extending beyond the corolla. The staminate flower has 16-24 stamens and the pistillate one has eight staminods. The blossom hangs downwards and the stigma is sometimes exposed beyond the petals, thus offering an opportunity for wind pollination. However, wind plays a minor role. Some varieties have a high degree of parthenocarpy and develop fruit to maturity without pollination whereas other varieties drop their fruit prematurely or entirely fail to set fruit without pollination. Such varieties produce seedy fruits if pollinated but set a few seedless fruits without pollination.

Flowers produce both nectar and pollen. Honeybees and bumble bees are the dependable pollinators agents. Although there are no recommendations about the number and time of placement of bee colonies, 2-3 colonies of *Apis mellifera* or 4-6 colonies of *Apis cerana* per hectare should be sufficient for adequate pollination.

Plum (Prunus domestica)

The plum blooms during February for 1-2 weeks depending on the weather. It produces white flowers in clusters of 2-3. The flower consists of five sepals, five petals, 25-30 stamens and a single pistil that has an ovary with a single ovule, a style and a stigma. Varieties vary from completely self-compatible to completely self-incompatible. However, the major varieties are self-incompatible.

Flowers produce a good amount of nectar and pollen and are visited by many species of insects. Honeybees are the primary pollinators. The blooming period is short and 50 per cent of the flowering occurs within 3-4 days. Therefore, place 2-3 colonies of *Apis mellifera* or 4-6 colonies of *Apis cerana* evenly per hectare as soon as flowering starts.

Managing pollination of crops secreting little or no nectar but good pollen and having a long blooming period

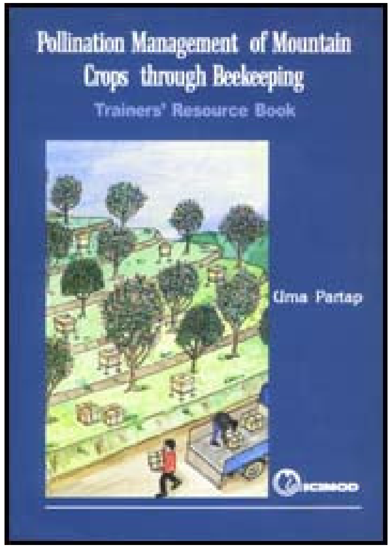
Only one crop - kiwi fruit - cultivated in the mountain and hilly areas of the region - falls into this category.

Kiwi fruit; Chinese gooseberry (Actinidia deliciosa)

The Kiwi fruit is native to China and is now cultivated in mountain areas of other

countries of the Hindu Kush-Himalayan region, especially India. The plants are dioecious: male and female flowers are produced on separate vines. Male and female vines bloom for 2-4 weeks and 2-6 weeks respectively. The pendulous flowers are 3-5 cm in diameter, and have 5-6 creamy-white petals. They occur singly or in groups of three, and at times have a characteristic scent. The female flower has a many-celled ovary containing up to 1,400 ovules, up to 40 stigmas, and several stamens that produce sterile pollen. The male flower has a vestigial ovary and numerous functional stamens producing fertile pollen. The female flower remains receptive for 7-10 days. Anthers of the male flower release pollen early in the morning of the day it opens. Flowers produce plenty of pollen but little or no nectar. Since male and female flowers are produced on separate vines, mechanical transfer of pollen is necessary. More than 700 ovules in each flower need to be fertilized to produce a commercial crop. There is a positive correlation between the number of seeds and the fruit size. Moreover, because female plants produce only a few flowers, more than 90 per cent fruit set is required for a good commercial crop. Although wind is sufficient to set the fruit, to achieve commercial quantity and quality of fruit, additional pollination by insects, especially honeybees, is necessary. Therefore, place 8-9 colonies of *Apis mellifera* or 16-20 colonies of *Apis cerana* evenly per hectare. Feed the colonies with 60 per cent sugar syrup every evening since flowers do not produce nectar. Sugar feeding also increases pollen collection by bees. Colonies should have large amounts of unsealed brood because this also increases pollen collection.

Pollination Management of Mountain Crops through Beekeeping - Trainers' Resource Book



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Chapter 6: Crop Pollination Using Honeybees and Other Bee Species: Some Examples

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Many species of bee, e.g., honeybees, bumble bees, stingless bees, and solitary bees, are managed for pollination of agricultural and horticultural crops in many countries. There are examples of both scientific experimentation and use by farmers.

How do scientists use honeybees for crop pollination experiments?

Scientists have conducted experiments on the effect of bee pollination on the yield and quality of agricultural and horticultural crops. Each experiment consists of three sets: (i) a control where part of the crop is covered with cages of nylon or muslin cloth to prevent any pollinating insects visiting flowers; (ii) open pollinated where part of the crop is left open to allow all pollinating insects, including free-ranging honeybees, to visit flowers; and (iii) honeybee pollinated where part of the crop is covered with cages of nylon or muslin cloth and 1-2 colonies of honeybees are placed inside the cages throughout flowering. When the crop is ripe, it is harvested and the yield and quality of each set (experimental plot) is measured. The results of some studies are given below.

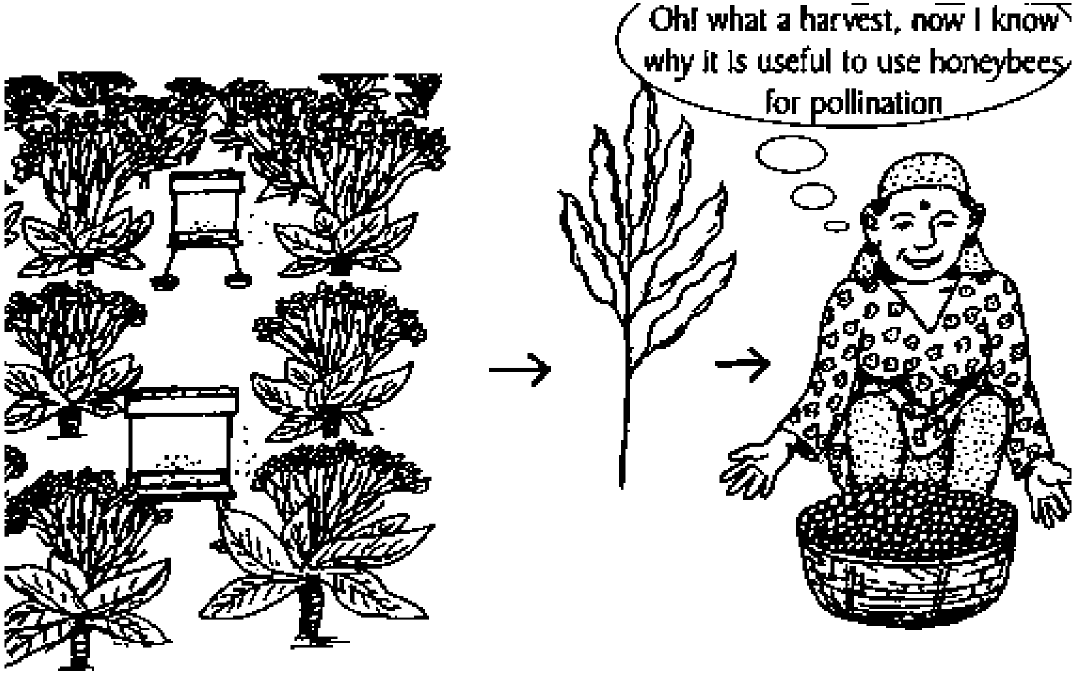
- **Dr Eva Crane reviewed experimental findings on the increase in fruit and seed**

production due to *Apiscerana* pollination. She found that fruit production increased 24 times in apple, 15 times in lemon, two times in litchi, two times in peach, 1.2 times in persimmons and six times in plums. She also found that seed set was increased 10 times in large cardamoms, 1.4-1.6 times in mustard, 1.2 times in turnips, 1.3 times in sesame, 1.5 times in sunflower, and 1.7 times in onions.

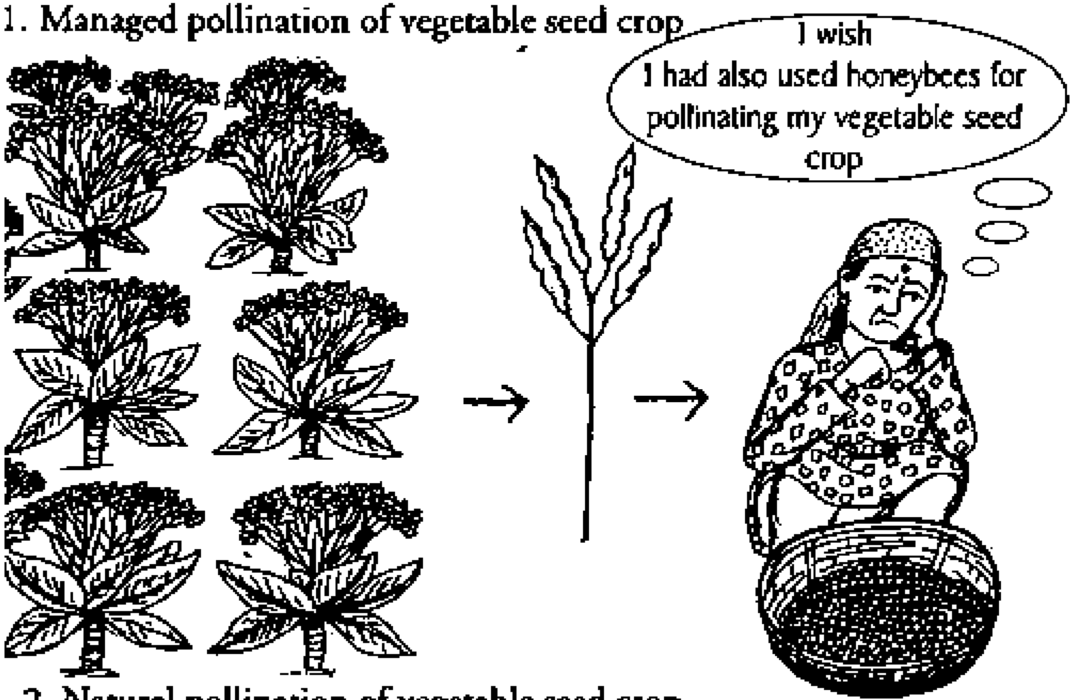
• Experiments conducted in the former USSR show that bee pollination increased the seed yield of buckwheat by 300 kg/ha.

• Experiments conducted by ICIMOD used *Apis cerana* for pollination of vegetable and fruit crops in the Kathmandu Valley of Nepal. Results showed pod set, seed set, and seed weight of cabbage, cauliflower, Indian mustard, lettuce, and radish increased (Figure 6.1). Fruit set increased, fruit drop decreased, and fruit quality was enhanced in peaches, plums, pears, and citrus.

• Experiments conducted in the Shimla hills in India show that bee pollination increased fruit set, decreased fruit drop, and enhanced fruit quality in terms of length, breadth, volume, and weight in apples (Figure 6.2).



1. Managed pollination of vegetable seed crop

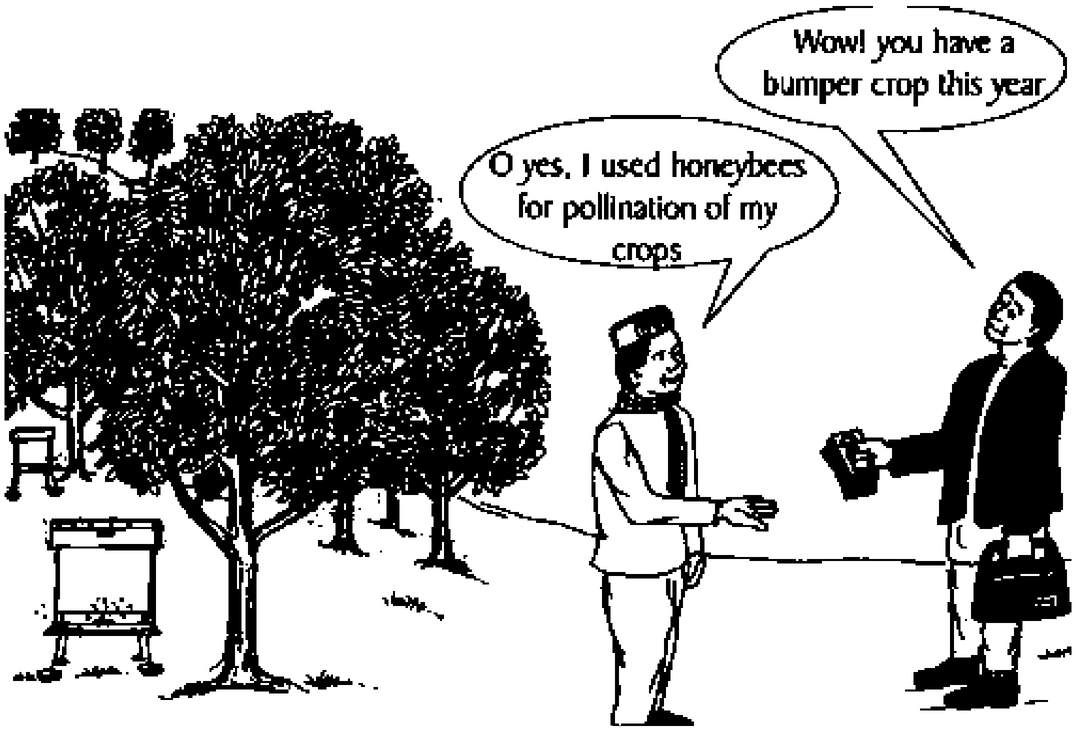


2. Natural pollination of vegetable seed crop

Figure 6.1: Experiments carried out in the Kathmandu valley showed that managed pollination enhances the yield and size of vegetable seeds.

How do farmers use honeybees for crop pollination?

In the Hindu Kush-Himalayan region, apple farmers in Himachal Pradesh, India, and in the Chinese Himalaya use honeybees for pollination. In the US, *Apis mellifera* is used for pollination of vegetable and fruit crops such as almond, apple, melon, alfalfa seed, plum, avocado, blueberry, cherry, vegetable seeds, pear, cucumber, sunflower, cranberry, and kiwi fruit. Over 2,035,000 colonies are rented out each year for crop pollination. In Japan, honeybees are used for pollination of strawberries in greenhouses, and for apple and other crops. Honeybees are also used by farmers in Europe for pollination.



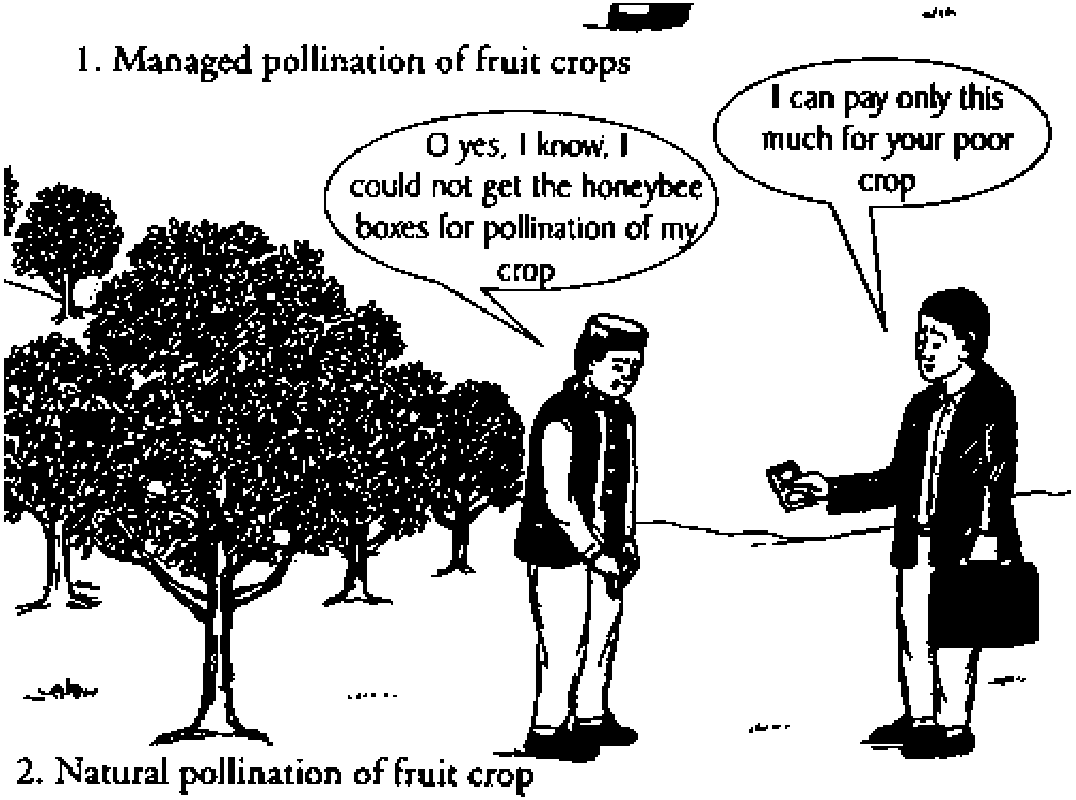


Figure 6.2: Bee pollination increases the number and size apples.

What are the comparable costs of raising apiaries for crop pollination?

The comparable costs of raising apiaries depend upon the crop to be pollinated. The costs include the labour of the apiarist who prepares the bees, depreciation and mortality of the bees, the expense of feeding sugar to the bees, and so on. It also includes the cost of transporting bee colonies to the crop. In general, it is estimated that the cost of raising apiaries for pollination is 30 per cent of the benefit gained through additional crop yields.

What is the estimated value of managed crop pollination using honeybees?

Many economic estimates of the value of managed crop pollination using honeybees have been worked out.

- **For example, the value of bee pollination in crop production is estimated to be US$ 20 billion per year in the US; Canadian dollars 1.2 billion (US$ 0.8 billion) in Canada; and US$ 3 billion in the European Community.**

- **The value of bee pollination for the New Zealand economy has been calculated at around US$ 2.2 billion per year, 113 times greater than the sale of bee products. This also includes the value of nitrogen fixed and added to pastures by honeybee-pollinated legumes.**

- **In the former USSR, researchers have shown that bee pollination of buckwheat gives an average additional yield of 300 kg/ha. For the whole of East Siberia, this increase would amount to 9,000 tonnes of additional buckwheat grain.**

- **In the Hindu Kush-Himalayan region, the value of bee pollination is only estimated in China and for a few crops. The value of bee pollination for four major crops - rape, cotton, tea, and sunflower - is more than 6 billion *yuan* (US$ 0.7 billion) per year, which is six to seven times greater than the direct income from bee products.**

Although attempts have not been made to estimate the value of bee pollination in other countries of the Hindu Kush-Himalayan region, it is most probably high.

Can bees other than honeybees be managed for pollination?

There are about 20,000 bee species worldwide. These include honeybees, bumble bees, stingless bees, and solitary bees. Although honeybees are efficient pollinators of many crops, there are certain crops that are more efficiently pollinated by other bees. Some of these bees can be managed for pollination, e.g., species of bumble bees (*Bombus* spp.), stingless bees (*Melipona* spp and *Trigona* spp), and some species of solitary bees. Although these bees are not being reared and managed for pollination in the Hindu Kush-Himalayan region, they are used in developed countries. A brief account is given below.

Stingless bees

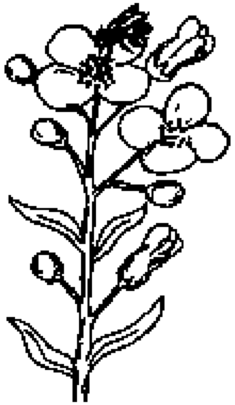
Stingless bees include species of *Melipona* and *Trigona*. They are described in Chapter 2. They are important pollinators of many crops, for example, mustard (Figure 6.3).

Bumble bees

Many species of bumble bee occur in temperate areas of the Hindu Kush-Himalayan region. These bees are large in size, have hairy bodies, and occur abundantly. Like honeybees, they also live in colonies.

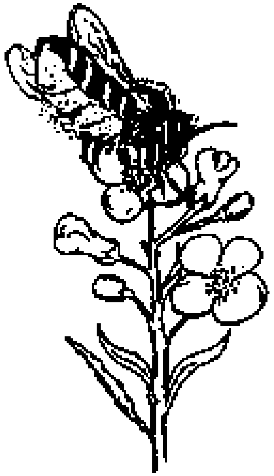
Bumble bees are important pollinators of many crops that honeybees cannot pollinate as efficiently, e.g., tomato and potato (Figure 6.3). There is a category of crops that requires buzzing of the flowers before pollen can be released. Bumble bees are the most effective at buzzing flowers. Honeybees cannot buzz flowers and visit only to collect pollen released by bumble bee buzzing. The bumble bee species with a long tongue are pollinators of plants that produce nectar deep in

their flowers. Bumble bees will fly at lower temperatures than honeybees and are ideal in greenhouses because their colonies are small.

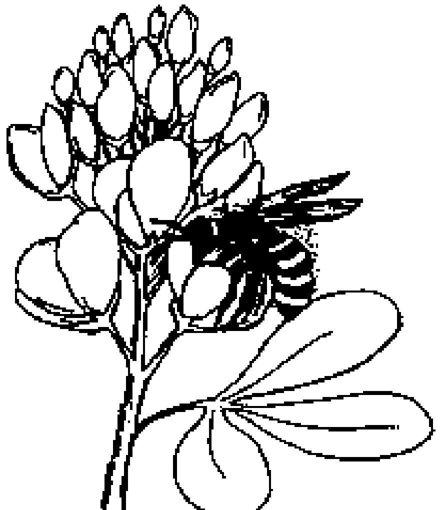


A stingless bee on a mustard flower

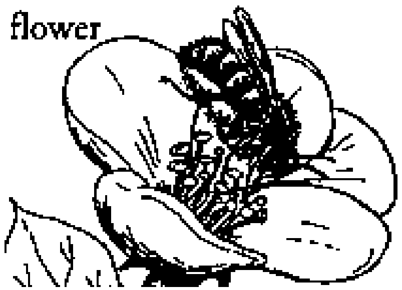
A bumble bee on an apple flower

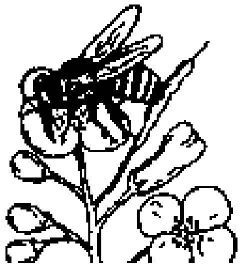


A leaf cutter bee on a mustard flower



An alkali bee on an alfalfa flower





A horn-faced bee on an apple flower

An anthophorid bee on a mustard flower

Figure 6.3: Wild bees are important crop pollinators; some species can be reared in artificial nest sites and managed for crop pollination.

At present, there are 10-15 companies in western Europe, Israel, New Zealand, the US, and Canada that rear bumble bees commercially and sell them to growers for crop pollination. In 1992, these companies sold about 300,000 colonies worth US$ 60 million. In Japan, bumble bee colonies are imported for pollination of potato and tomato.

Solitary bees

About 85 per cent of all bee species are solitary. Each female bee mates, constructs a nest with about ten brood cells, stocks each cell with a mixture of pollen and nectar as food for the larva, lays an egg in each cell, and dies before the young emerge. The young adult bees emerge at the time of blooming of their host plant.

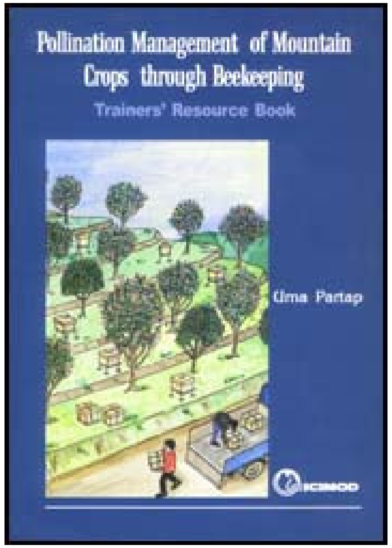
Thousands of species of solitary bee occur in the Hindu Kush-Himalayan region. They nest in a variety of places, e.g., in the ground, plant stems, dead branches, etc. Solitary bees do not store honey and beeswax, rarely sting, and cannot be kept in hives. They do not live in colonies but nest gregariously. Most species are active for only a few weeks in the year. The rest of the year, they live in their nests as larvae, pupae, or dormant adults. Their active period coincides with the

flowering of their preferred hosts. These bees are therefore excellent pollinators of their hosts (more effective than honeybees), for example, the alkali bee, *Nomia megachile,* and the leaf-cutter bee, *Megachili rotundata,* are excellent pollinators of alfalfa (Figure 6.3). These bees trip the alfalfa flower, which is essential for effective pollination; honeybees collect nectar from the base of the flower without tripping it and therefore do not pollinate it.

Some species can be kept in artificial nest sites (man-made nests), can be mass-reared, and can be managed for crop pollination. For example, the leaf-cutter bee, *Megachile rotundata,* and the alkali bee, *Nomia melanderi,* are managed for pollination of alfalfa in the US and Europe. In Japan, *Osmia cornifrons,* the large horn-faced bee, is the first solitary bee to be used on a commercial scale to pollinate apples (Figure 6.3). Other species of *Osmia - O. coerulescens, O. cornuta, O. fulviventris, O. latreillei, O. lignaria, O. rufa, O. sanrafaelae,* and *O. submicans -* are managed for pollination of tree fruits, cotton, berseem, almond, mustard, and lucerne in countries such as France, Spain, US, Egypt, Denmark and Egypt. In the plains of India, *Andrena ilerda* is managed for the pollination of sarson.

Halictine bee, *Lasioglossum (Evylaeus) metianensis,* is an excellent pollinator of apples at altitudes over 2,600m. Farmers can manage this species by leaving some uncultivated land in or around their orchards as nesting habitat. Other species of solitary bee that can be managed for pollination of orchard crops (apples, almonds, cherries, peaches, pears, plums, and other fruit crops) in the Hindu Kush-Himalayan region include *Amegilla, Andrena, Anthophora, Bombus, Ceratina, Halictus, Megachile, Osmia, Pithis,* and *Xylocopa.* These insects are much more gentle than honeybees and are easily reared and managed for pollination. Although they are already managed for pollination in developed countries, to rear

and manage them on a commercial scale for crop pollination in the Hindu Kush-Himalayan region would require a great deal of research.



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