Chapter 5
Managing Crop Pollination

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.

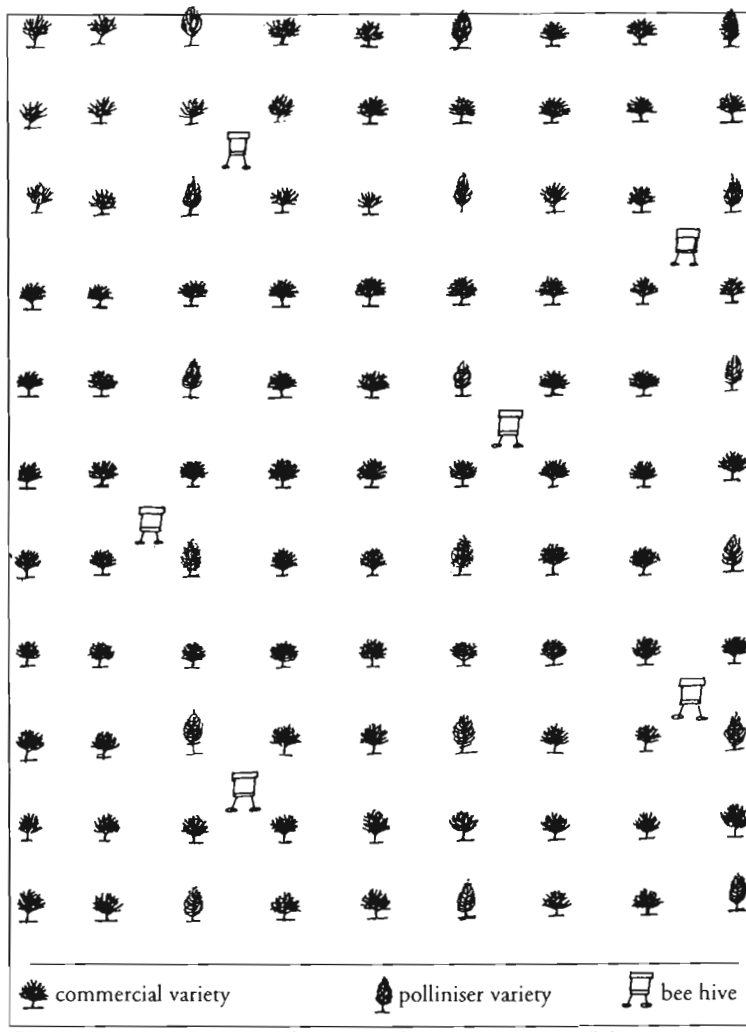

Figure 5.1: Layout plan for a fruit orchard with respect to polliniser proportion; every third tree in every third row is a polliniser variety.

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

Hanging branches of polliniser on trees of the main variety. 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

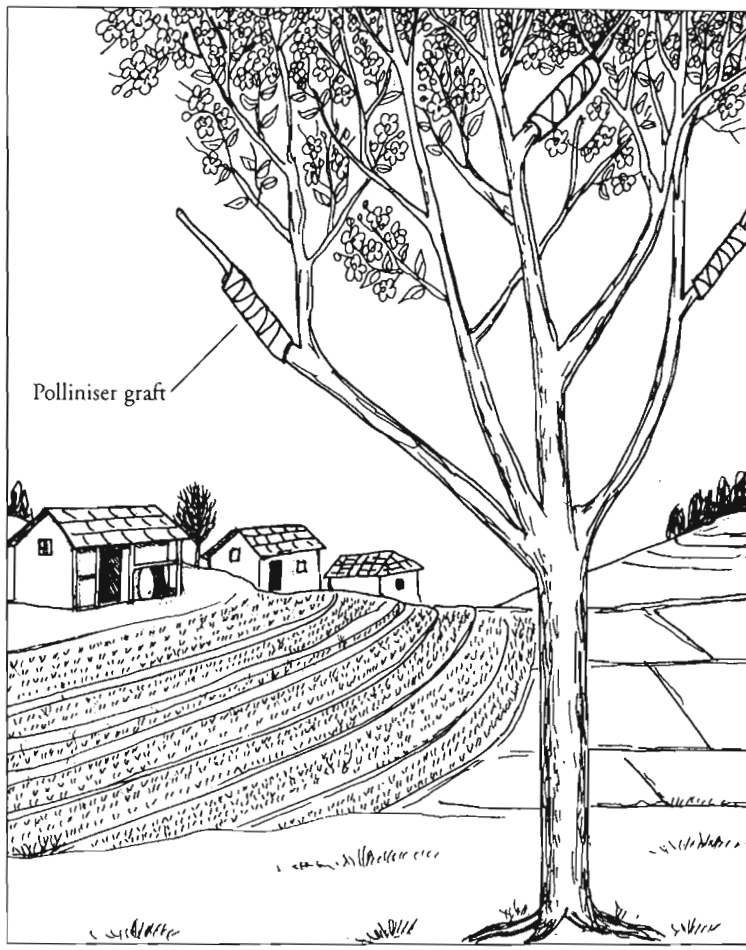

Figure 5.2: Grafting polliniser branches to the main variety is a good way to increase the polliniser in an established orchard; grafts will produce pollen earlier than a newly planted tree.

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.

Hand pollination. Another method is to extract pollen from a compatible variety and distribute (apply) it to flowers of

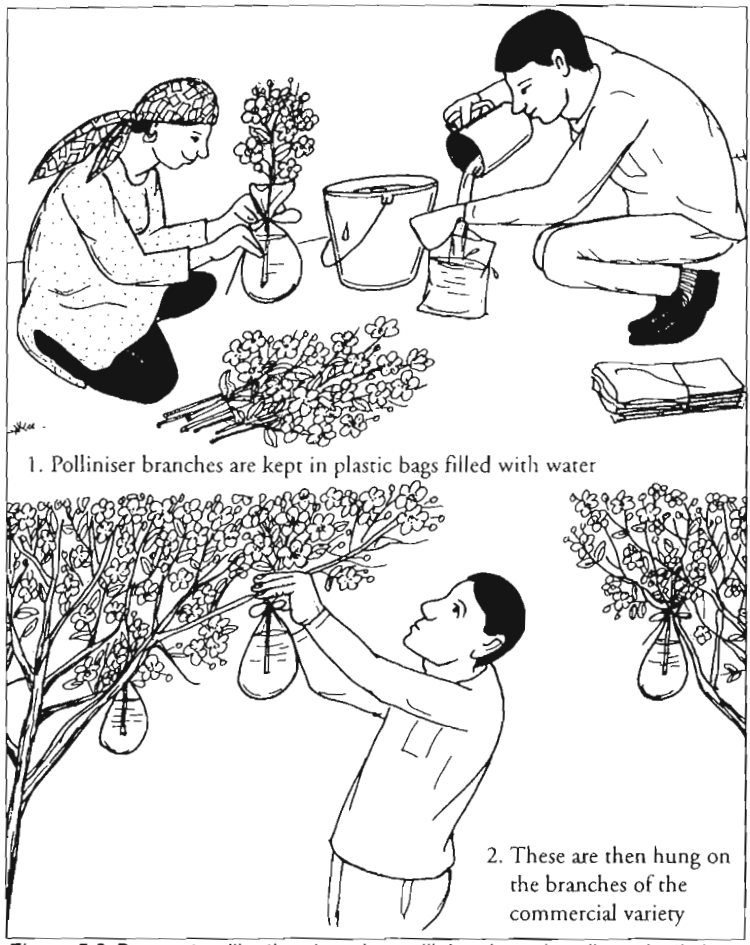

Figure 5.3: Bouquet pollination: hanging polliniser branches (in a plastic bag or bucket, tin, bottle or other container etc filled with water) on the branches of the commercial variety is an excellent short-term solution for managing polliniser.

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.

How are hive bees used for pollination management?

Some crops (e.g., almond, avocado, citrus, litchi, some vegetable crops) produce good amounts of nectar and pollen

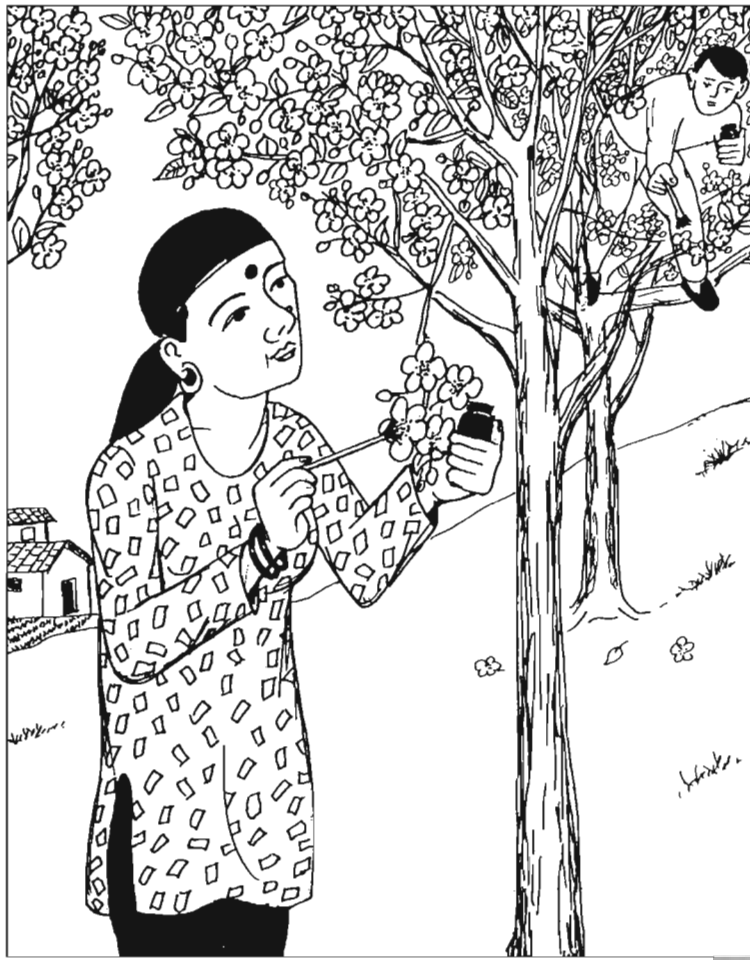

Figure 5.4 Hand pollination is the most reliable method of pollination but the labour costs are very high.

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 period of the crop	Number of *A. mellifera* colonies/ha	No. of *A. cerana* colonies/ha	Time of 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 (7-10 days)	5	8-9	5% bloom
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

Table 2: Summary of Pollination Management of Different Crops (cont'd)

Crop	Blooming period of the crop	Number of *A. mellifera* colonies/ha	No. of *A. cerana* colonies/ha	Time of colony placement
Cauliflower	March-April	5	8-10	10-15% bloom
Cucumber	June-September	1 for monoecious 8 for gynoecious	2-3 for monoecious 12-16 for gynoecious	10-15% bloom
Cucurbits (pumpkin, squash, gourd)	June-September	5-8	10-12	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 rape	December-January February-March	3-5	5-8	10-15% bloom
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 *Apis cerana* 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 stigmá (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 *Apis mellifera* 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.