Chapter 1
Introduction to Pollination

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

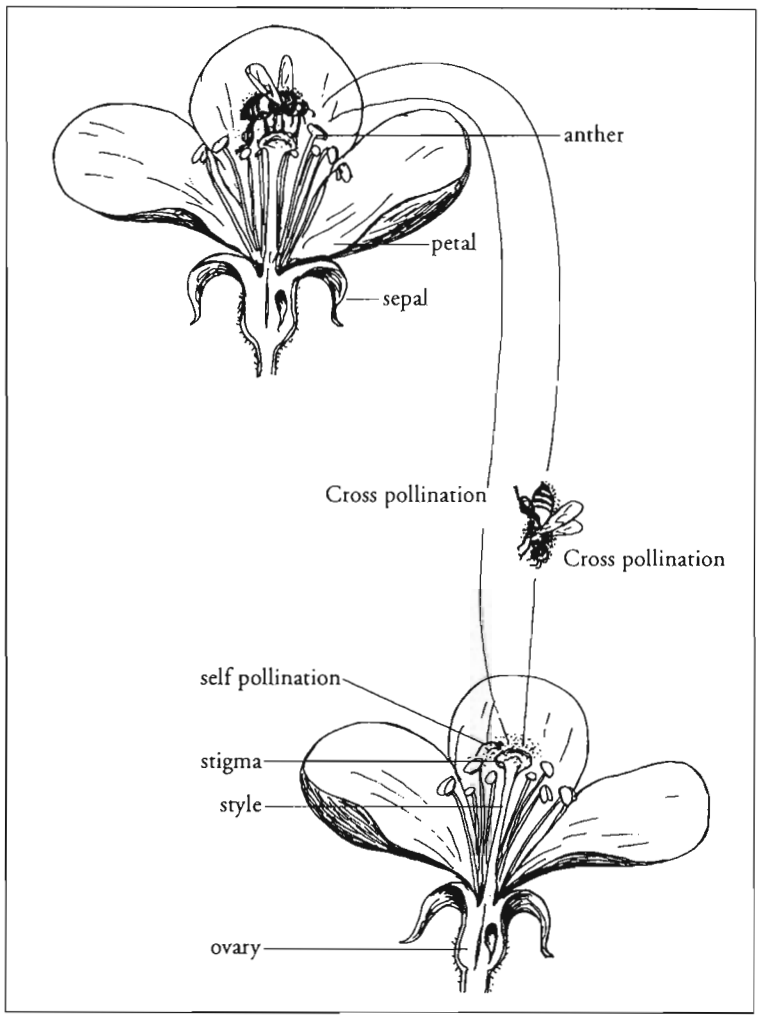

Figure 1.1: Diagram illustrating the structure of the flower and modes of pollination

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

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.