

Chapter 1

Bee Pollination and Crop Productivity

Introduction

The sustainable development of agriculture in the 21st century will necessitate a reorientation of the present crop production technologies. Instead of making extensive use of chemical fertilisers, biocides, irrigation facilities, and heavy machinery for yield enhancement, a shift towards biologically-based agriculture, which includes increased photosynthetic efficiency, biological nitrogen fixation, efficient nutrient uptake and biological cross-pollination, will become necessary to increase food productivity. In future, the full use of such underutilised resources, which are environmentally more friendly, should be emphasised. For example, the yields of different cultivated crops could be increased through cross-pollination by honeybees.

The vital role that honeybees play in enhancing the productivity levels of different crops, such as fruits, nuts, vegetables, pulses, oils, and forage crops, has often been underestimated, especially in developing countries all over the world. Most of the research work on crop pollination has been carried out in developed countries where the European honeybee, *Aps mellifera*, has been used extensively to increase the yield of different cultivated crops. The non-consumptive benefits of increasing crop yields through cross-pollination by

honeybees are difficult to quantify, yet these far outweigh the direct benefits of these social insects as producers of honey and other hive products. The value of bee pollination in crop production in the U.S. dollars has been estimated at 20 billion US dollars per year (USDA-ARS 1991). A recent FAO report indicated that the direct contribution of pollination to increase in farm harvests in 20 mediterranean countries was 5.2 billion US dollars per year; 3.2 billion in developing countries in the region, and two billion in the others (Cadoret 1992). These estimates suggest that there is a need to create awareness amongst policy-makers, planners, aid agencies, researchers, and extension workers about promoting bees and beekeeping as an important component of present day strategies for sustainable agriculture and integrated rural development programmes.

Pollination Mechanisms

Pollination is the transfer of pollen grains from the anther (male part of the flower) to the stigma (the female part) of the same or another flower of the same plant species. This is the first step towards fertilisation which is the union of the male nucleus of germinated pollen grains with the female nucleus (oosphere) of the egg or ovule. The ovule, after fertilisation, develops into the seed.

A plant is considered to be self-pollinated/self-fertile when its flower is pollinated by its own pollen. In this case, pollen grains from the anthers fall on the stigma of the same flower. Some self-fertile species are automatically pollinated by pollen from their own flowers but often the construction of the flowers is such that wind or insects are needed to transfer pollen from the anthers of the flowers to their stigmas.

However, in many other plants, the flower cannot be fertilised with pollen from the same plant (self-sterile) but needs pollen from another plant of the same species for fertilisation. This phenomenon is known as cross-pollination (Fig. 1.1).

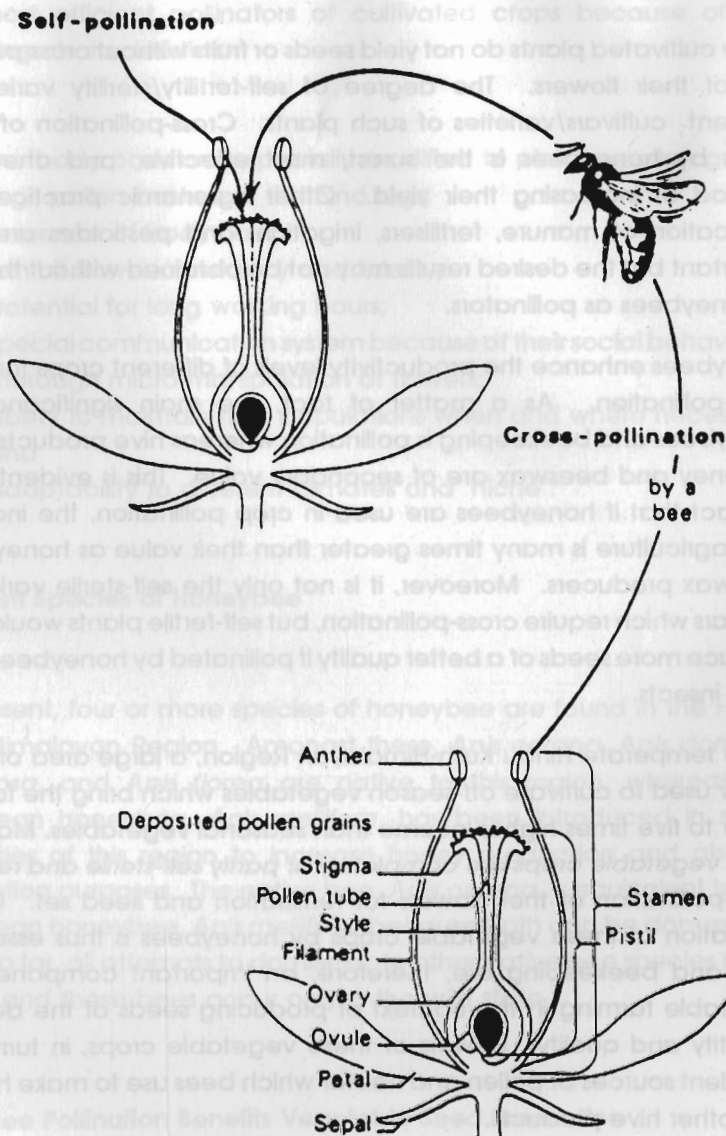


Fig. 1.1: Self-pollination and cross-pollination by a bee

Honeybees as Pollinators

Many cultivated plants do not yield seeds or fruits without cross-pollination of their flowers. The degree of self-fertility/sterility varies in different cultivars/varieties of such plants. Cross-pollination of such crops by honeybees is the surest, most effective, and cheapest method of increasing their yield. Other agronomic practices like application of manure, fertilisers, irrigation, and pesticides are also important but the desired results may not be obtained without the use of honeybees as pollinators.

Honeybees enhance the productivity levels of different crops through cross-pollination. As a matter of fact, the main significance of honeybees and beekeeping is pollination whereas hive products such as honey and beeswax are of secondary value. This is evident from the fact that if honeybees are used in crop pollination, the income from agriculture is many times greater than their value as honey and beeswax producers. Moreover, it is not only the self-sterile varieties/cultivars which require cross-pollination, but self-fertile plants would also produce more seeds of a better quality if pollinated by honeybees and other insects.

In the temperate Hindu Kush-Himalayan Region, a large area of land is now used to cultivate off-season vegetables which bring the farmer a four to five times higher income than seasonal vegetables. Many of these vegetable crops are completely or partly self-sterile and require cross-pollination of their flowers for fertilisation and seed set. Cross-pollination of these vegetable crops by honeybees is thus essential. Bees and beekeeping are, therefore, an important component of vegetable farming in the context of producing seeds of the desired quantity and quality. Flowers of these vegetable crops, in turn, are excellent sources of pollen and nectar which bees use to make honey and other hive products.

Why Honeybees are the Most Efficient Pollinators

Many different types of pollinators exist in nature. These include small mammals, bats, birds, and different types of insects such as bees,

wasps, flies, butterflies, moths, and beetles, out of which honeybees are the most efficient pollinators of cultivated crops because of the following characteristics:

- the body parts are especially modified to pick up pollen grains, e.g., pollen baskets in the hind legs;
- presence of body hairs;
- exhibit flower constancy and fidelity;
- potential for long working hours;
- special communication system because of their social behaviour;
- thorough micro-manipulation of flowers;
- ability to maintain high populations when and where necessary; and
- adaptability to different climates and 'niche'.

Different Species of Honeybee

At present, four or more species of honeybee are found in the Hindu Kush-Himalayan Region. Amongst these, *Apis cerana*, *Apis dorsata/laboriosa*, and *Apis florea* are native to this region, whereas the European honeybee, *Apis mellifera*, has been introduced in some countries of this region to increase honey production and also for pollination purposes. The native bee, *Apis cerana*, is equivalent to the European honeybee, *Apis mellifera*, because both can be domesticated. So far, all attempts to domesticate other native bee species have failed and these bees occur only in the wild state.

How Bee Pollination Benefits Vegetable Seed Production

As a result of cross-pollination by bees, hybrid effects occur in plant progeny either in a single way or in different combinations. Such hybrid effects cause the following qualitative and quantitative changes in the economic and biological characters of plants:

- stimulate the germination of pollen grains on the stigma and improve selectivity in fertilisation;
- increase the viability of seeds and embryos;
- increase the number and size of seeds;
- enhance resistance to diseases and other adverse environmental conditions;
- increase nectar production in the nectaries of plants; and
- ensure well-filled seeds, tight clusters, and uniform seed set.

Managing Honeybee Colonies for Pollination

The efficiency of a bee colony as a pollinator of a vegetable seed crop depends upon a number of factors.

Colony Strength

Larger and stronger colonies are four to five times better pollinators than smaller and weaker ones because the former have a higher percentage of older bees as foragers. Thus, good honey-yielding colonies are better and more efficient pollinators also. It has been estimated that one colony of *Apis mellifera*, with 60,000 worker bees, produces one-and-a-half times more honey than four colonies with 15,000 bees each. The same can be true for pollination activity also.

The strength of a colony depends upon the season. In the Hindu Kush-Himalayan countries, during winter the colony strengths are poor because of low temperatures and a dearth of bee flora. In the early spring season, when honeybee colonies are required for the cross-pollination of vegetable crops in this region, these colonies do not possess enough strength for effective pollination.

Keeping in mind this constraint, farmers in certain regions migrate their colonies to lower altitudes where the winters are warmer and where there is no dearth of bee flora, so that, in spring, when vegetable crops are in bloom, an adequate number of bees is available for effective pollination.

Number of Colonies Required for Pollination

The number of colonies required for pollination of different cultivated crops would depend upon the following factors:

- density of plant stand;
- total number of flowers in each plant;
- duration of flowering;
- strength of bee colonies; and
- number of flowers per hectare of land.

In general, two colonies of *Apis mellifera* per hectare of crops in bloom are recommended for sufficient and efficient pollination. Considering the smaller colony size of the *Apis cerana* colony, and also its shorter flight range, four to five colonies per hectare are recommended.

Distribution of Colonies in the Fields

Honeybees as a rule visit primarily those sources of nectar flow which are within a radius of 0.3 to 0.5km from the apiary. At a distance of more than 0.5km, the pollination activity decreases significantly.

In the Hindu Kush-Himalayan countries, because of the small size of farm holdings, and also due to the practice of mixed cropping, spacing of the colonies and their optimum arrangement do not pose a serious problem as in developed countries where monoculture is a common practice in farming systems.

For effective pollination, *Apis cerana* hives should be placed singly instead of in groups. Honeybees always tend to forage in the area which is closest to their hive, particularly when the weather is not very favourable.

The Appropriate Time for Placement of Colonies

Bee colonies should be placed in the field when five to 10 per cent of the crop is in bloom. Earlier placement of colonies results in the bees

foraging on other weeds and wild plants in the vicinity and later the bees ignore the crop in bloom. If the bees are moved in too late, they can only pollinate the late and less vigorous flowers.

Weather Conditions

Weather plays an important role in determining the success or failure of a pollination programme, as it affects both bee activities as well as seed/fruit setting. For example, in the temperate climate of the Hindu Kush-Himalaya, some vegetable crops bloom in early spring when the temperature is low. Flower buds may die due to frost injury. Weather also adversely affects the foraging activities of bees. Wind velocity of 15 miles per hour or more also adversely affects the foraging behaviour of bees. It is, therefore, recommended that a wind break should be constructed around the crop field.

Attracting Bees to a Crop in Bloom

A crop that requires cross-pollination can be made more attractive to honeybees if nectar production in the nectaries is increased by breeding techniques or by improving other agronomic practices such as application of fertilisers and manure, and by providing better irrigation facilities. Another method of attracting bees to a particular crop in bloom is by sowing high nectar-yielding crops amongst the other crops which secrete low amounts of nectar. For example, sweet clover requires cross-pollination by bees for good seed yield. But this crop is not very attractive to bees due to poor or very low quantities of nectar in the nectaries of this plant. However, if other nectariferous plants, such as buckwheat, are sown, a larger number of bees would be attracted to this crop.

Isolation Distance in Relation to Pure Vegetable Seed Production

It is now well-known that cross-pollination by honeybees helps to increase the yield and quality of vegetable seeds. This activity of honeybees also hampers pure seed production in such crops due to intercrossing. This problem can be solved by providing the necessary

isolation distance between different cultivars of the same crop in order to avoid crossing and contamination. The foraging areas where the adult worker bees forage are always limited, and they confine their foraging activities to a particular area only during their successive field trips to collect pollen, nectar, or both. If fields with compatible varieties/cultivars are adjacent, there are more chances of intercrossing or contamination. However, in distant fields with compatible varieties or cultivars, the foraging areas of bees will not overlap, and pure seed production is possible. The actual isolation distance would depend upon the degree of seed purity required, i.e., whether the seed is being produced as foundation seed or certified seed by the grower. The actual distances required for different vegetable crops to produce pure seeds are given in Table 1.1.

In Britain, the isolation distance required varies from 193 to 214m for different crops. In Canada, isolation distances for certified, registered, and foundation seeds are 46m, 91m, and 183m respectively. However, these data have been collected from experiments carried out in western countries, and related information on this issue collected under the local ecological conditions of the Hindu Kush-Himalayas is unavailable.



Beekeeping Demonstration to Potential Beekeepers

Table 1.1: Pollination Requirements and Mechanisms for Main Vegetable Crops

Crop	% of cross-pollination	Total blooming period	Peak receptivity period of stigma to pollen	Nectar or pollen potentials	Chief pollinators	Honeybee pollination requirements (number of hives per hectare)	% increase in yield due to honeybee pollination over self-pollination	Isolation distance required for pure seed production (in metres)
Cole Crops: Cauliflower, Cabbage	72-95	1 month	3-4 days	N ² P ³	Honeybees, bumblebees, wildbees, flies	5	100-300	3000 for breeder seeds and 1500 for certified seeds
Tomato	Less than 2	12-15 days	4-8 days	N ² P ³	Solitary bees, thrips, honeybees	No specific recommendation	No specific data	250-400
Chillies: Green Pepper, Chilli Pepper	7-36	2-3 weeks	2 days	N ² P ³	Honeybees, ants	No specific recommendation	No specific data	200 for foundation seeds and 100 for certified seeds
Radish	85	22-30 days	3-4 days	N ² P ³	Honeybees only	5	22-100	1600 for foundation seeds and 1000 for certified seeds
Carrot	Mainly cross pollinated	1 month	One week or longer	N ² P ³	Honeybees, house flies	8 bees per square metre	9-135	1000
Turnip	Mainly cross pollinated	1 month	2-3 days	N ² P ²	Honeybees	2-5	100-125	1600 for foundation seeds and 1000 for certified seeds
Cucurbits	60-80	1 month	2 hours	N ² P ²	Honeybees <i>Halictus</i>	2-4	21-6700	800-1000
Okra	4-42	22-30 days	2 days	N ² P ³	Honeybees, bumblebees	None	No specific data	No specific recommendations

Source: Compiled by author from different sources.

N¹ = Major source of nectar
N² = Medium source of nectar

P¹ = Major source of pollen
P² = Medium source of pollen