CHAPTER 4

Apiculture and Mountain Crop Productivity

4.1 INTRODUCTION

At present, several countries of the Hindu Kush-Himalaya are making desperate efforts to achieve self-sufficiency in food production. This is being done by physical expansion of the area under cultivation and better management of resources. These include use of better quality seeds and animals, bringing more wasteland under cultivation, use of fertilizers, pesticides and more irrigation facilities. However, in the past decade or so, food production has come to a point of stagnation and it is no longer possible to enhance the productivity levels in certain cultivated crops. Emphasis in the future, therefore, should be on the full utilization of underutilized resources which are probably of unknown limitations. One resource which is of concern here is an increase in the yield of different cultivated crops through cross-pollination by honeybees.

The vital role which honeybees play in the pollination of large numbers of agricultural and horticultural crops is often underestimated. As a matter of fact, the main significance of honeybees and beekeeping is pollination, whereas hive products, like honey and beeswax, are of secondary value. This is evident by the fact that income from agriculture by the use of honeybees in crop pollination is many times greater than their value as honey and beeswax producers. Many cultivated crops do not yield seeds or fruits without cross-pollination of their flowers by honeybees and other wild insects. Cross-pollination of entomophilous crops by honeybees is one of the most effective and cheapest methods of increasing their yield. Other agronomic practices like manuring, fertilizers, pesticides and irrigation are quite cost-effective and these may not yield the desired results without the use of honeybees for enhancing the productivity levels of different cultivated crops through pollination. It is not only the self-sterile varieties/cultivars which require cross-pollination, but also the self-fertile forms, which would also produce more and better quality seeds and fruits if pollinated by honeybees and other insects.

Despite the great economic and biological significance of honeybees as pollinators of agricultural crops, it has not yet been made an integral part of agricultural and horticultural management technology, particularly in the developing countries of Hindu Kush-Himalaya.

4.2 HISTORICAL PERSPECTIVE OF POLLINATION ECOLOGY

The idea of the occurrence of sex in plants was given by Theophastus in the fourth century B.C., but it was during the end of the nineteenth century, only, that plant reproduction and the mechanism of pollination was discovered by Muller (1882–83). He wrote a book *The fertilization of flowers* in German which was translated into English in 1883. Later, Knuth published three volumes on flower pollination in German and these were translated into English in 1906–1908. Aristotle had the idea of a relationship between bees and flowers, but is was. Koelreuter and Dobbs in 1870 who first described the detailed flower structure and the role of insects in pollination. Sprengel (1793) put forward a theory stating that "every peculiarity of plant anatomy and physiology is related to the peculiarity of the structure and behaviour of the insects which visit and pollinate the flowers." Darwin (1887) used both hand and insect pollination techniques, and his research work helped greatly in understanding the theories of plant perpetuation and vigour maintenance through cross-pollination. These are being followed even today.

The practical use of honeybees, for the cross-pollination of cultivated crops and increasing their yield started with the practise of moving honeybee colonies to the crops in bloom. Mr. M. B. Waite was deputed by USDA in 1890 to learn the causes of crop failure in an orchard of 22,000 Barlett pear trees in Virginia, USA. He found that it was due to the problem of self-sterility in the pear plants, and reported that cross-pollination was necessary for a good fruit set. Because pear pollen was too heavy and sticky to be transferred by wind, Waite (1895) recommended the use of honeybees for pear pollination by moving them into the pear orchards. Similarly, honeybees were utilized for apple pollination in the late nineteenth century. In Australia and on the banks of Margabi River in central Asia, apple fruit trees became sterile as honeybees did not exist there prior to the turn of the present century. After the introduction of bees to these regions, apple orchards started bearing fruit. Benton (1896) also suggested five to six colonies of *Apis mellifera* per 100 trees for the pollination of self-sterile commercial varieties of apple in USA.

After this period, moving honeybee colonies to the crop for the purpose of cross-pollination of cultivated crops has become a standard practice in several developed countries. Beekeepers rent out bee hives to fruit growers and charge rental fees from the grower for this service. For example, McGregor (1976) proposed a fee of US$ 10.50 per 10 frame colony to be used for pollination purposes. Now, in all developed countries where the practice of renting bee colonies for the purpose of pollination has become a regular practice, there exist specific rules and regulations regarding pollination agreements and contracts between beekeepers and fruit growers.

In recent years, a number of techniques have been developed for increasing the productivity of certain agricultural crops through cross-pollination by honeybees. These include the use of pollen dispensers, pollen bombs, scent training of bees, development of high and low preference strains of honeybees for the pollination of specific crops through selective breeding, domestication and utilization of non-*apis* pollinators and safeguard of bees against pesticides. All these techniques are not solely used in developed countries, there is now a growing awareness in developing countries of the fact that agricultural crops give better yield and higher financial returns if honeybees are used for their optimal pollination. For example, Verma (1984) made the following observation in a report submitted to FAO Expert Consultation on Beekeeping:

"In view of the importance of bees for increasing the yield of cross-pollinated crops, different species of honeybees and solitary bees are being utilized for this purpose in northern India. Himachal Pradesh, Uttar Pradesh and Kashmir are the principal temperate fruit-growing regions of the country. In Himachal Pradesh, more than 75,000 hectares of land is under temperate fruit cultivation and more than 200,000 colonies of honeybees are required against the present number of 10,000." The population of non-*Apis* pollinators is declining at an alarming rate, owing to growing deforestation, vast clearance of wasteland for cultivation, and increased use of pesticides. This makes domesticated hive bees essential for pollination. In addition to pollinating temperate fruits, both the species (*Apis cerana* and *Apis mellifera*) are also being utilized for the pollination of vegetables, oil seed crops and clovers.

Considering the importance of bees in pollination, Himachal Pradesh has taken the lead in renting *Apis cerana* colonies to orchardists for the pollination of apple crops. This programme has created great awareness among orchardists about the importance of honeybees for pollination.

4.3 ADVANTAGES OF BEE POLLINATION

Honeybees are the most efficient pollinators of several cultivated and wild plants because of their following characteristics.

— body parts are specially modified to pick up many pollen grains
— flower fidelity and constancy
— potential for long working hours
— thorough micro-manipulation of flowers
— maintainability of high populations when and where needed
— adaptability to different climates and niches

Deodikar and Suryanarayanan (1977) have reviewed the increase in seed or fruit yields in various crops due to be pollination in India. As a result of cross-pollination by bees, somatic, reproductive and adaptive heterosis or hybrid effects occur in plant progeny either in a single way or in different combinations. Such hybrid effects bring the following qualitative and quantitative changes in the economic and biological aspects of plants:

— stimulates germination of pollen on stigmas of flowers and improves selectivity in fertilization
— increases viability of seeds, embryos and plants
— more nutritious and aromatic fruits are formed
— increases the vegetative mass and stimulates faster growth of plants
— increases number and size of seeds and yield of crops
— enhances resistance to diseases and other adverse environmental conditions
— increases nectar production in the nectaries of plants
— increases fruit set and reduces fruit drop
— increases oil content in oil-seed crops

4.4 PRINCIPLES OF BEE POLLINATION

Most investigations on crop-pollination have been carried out in developed countries where the European honeybee, *Apis mellifera*, has been extensively utilized for increasing the yield of different cultivated crops. A detailed account about the role of *Apis mellifera* in the pollination of different cultivated crop plants is discussed by several authors (McGregor, 1976; Free, 1970; Kozin, 1976 and Crane and Walker, 1984). There is very little information available on the role of the Asian hive bee, *Apis cerana*, in pollinating agricultural crops in the developing countries of South and Southeast Asia. Both these species of honeybees show remarkable similarities in foraging behaviour. Thus, the basic principles involved in crop pollination by these two species of honeybees should not differ significantly. Efficiency of a bee colony as a pollinator would, however, depend upon the following factors:

4.4.1 Colony Strength

Large 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 honeybee breed, availability of nectar and pollen plants as food resources, and management practices being employed. It also depends upon the season. In the Hindu Kush-Himalayan countries, during winter the colony strengths are poor because of low temperatures and dearth of bee flora. In the early spring season, when honeybee colonies are required for the cross-pollination of apple bloom in this region, these colonies do not build enough strength for effective pollination. Keeping in view this constraint, apple growers in certain region in northern India migrate their colonies to the lower altitudes where the winters are warmer and there is no dearth of bee flora, so that in the spring at the time of apple bloom, an adequate strength of bees is available for effective pollination.

4.4.2 Number and Time of Placement of Colonies

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

1) Density of plant stand
2) Total number of flowers in inflorescence of each plant
3) Duration of flowering
4) Strength of bee colonies
5) Number of flowers over an area of one hectare of land.

In general, two colonies of *Apis mellifera* per hectare of crop in bloom are recommended for sufficient and efficient pollination. Keeping in view the smaller body and colony size of *Apis cerana* and also its shorter flight range, three colonies per hectare are recommended.

4.4.3 Distribution of Colonies in the Field/Orchards

Honeybees as a rule visit primarily those sources of nectar flow which are within 0.3 to 0.5 km radius from the apiary. At a distance of more than 0.5 km the pollination activity diminishes 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 in farming systems is a common practice. 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.

4.4.4 Time and Placement of Colonies

Bee colonies should be placed in the field or orchard when 5 to 10 per cent of the crop is in bloom. Earlier placement of colonies result 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.

4.4.5 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, apple trees are in bloom in early spring when the temperature is low. Flower buds may be killed due to frost injury. It also adversely effects foraging activities of the bees. As reported earlier, the native hive bee *Apis cerana* can forage at lower temperatures than its European counterpart. *Apis mellifera* (Verma, 1986b). 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 around the crop field/orchard should be provided.

4.4.6 Attracting Bees to a Crop in Bloom

Russian bee scientists have strongly advocated the theory that bees should be fed syrup flavoured by the flowers required to be pollinated in order to attract large numbers of bees for effective pollination (Kozin, 1976). Theoretically this seems to be a logical approach, but in practice does not always yield the desired results. In Sweden, Canada and the USA, different research workers have also tried essential oils or flavour, especially from apple flowers, and their results are inconclusive.

Another method of attracting bees to a particular crop in bloom is by sowing high nectar-yielding crops amongst the other crops which are poor in nectar secretion. 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, by sowing the other nectiferous plants like buckwheat, larger number of bees are attracted to this crop. A crop to be pollinated can also be made more attractive to honeybees if nectar production in the nectaries is increased by breeding techniques or by improving other agronomic practices like addition of fertilizers and manures, or better irrigation facilities.

4.5 APPLE POLLINATION IN THE HINDU KUSH-HIMALAYA

Apple is the most important of the temperate fruits cultivated in the Hindu Kush-Himalayan countries. Of the total land in this region under fruit cultivation, more than two-third is under apple cultivation. The areas under this crop in different parts of the Hindu Kush-Himalaya are as follows[1]:

	Area (000 hectares)	Production (MT)
Arunachal Pradesh/India	4.821	3,373
Himachal Pradesh/India	52.380	359,320
Kashmir/India	65.107	723,826
Uttar Pradesh/India	52.000	170,000
Pakistan	19.000	212,000
Bhutan	3.656	4,600
Nepal	5.000	50,000

The above data show that in 1986-87, more than 17.5 thousand hectares of land was under apple cultivation in temperate India alone. Every year approximately 10 per cent of the total area already under apple cultivation is being added, and according to one estimate, about 250 thousand hectares of land should be under this crop in the entire region of the Hindu Kush-Himalaya.

With such a vast increase in the area coming under apple cultivation, various management problems have inevitably arisen, and pollination is the important one. The delicious and commercial varieties of apple are self-incompatible and require cross-pollination by honeybees. Populations of non-*Apis* pollinators are declining at an alarming rate due to increasing deforestation, vast clearance of wasteland, and

[1] Compiled from multiple sources.

wider use of pesticides. The most effective way of assuring adequate pollination is by the introduction of honeybees into the orchard at the time of blossoming, a practice well developed for apples in places like Western Europe, Eastern Europe and Japan.

Most of the orchards of the Hindu Kush-Himalayan region are small (about one hectare or less) and are owned by local farmers. Thus, each orchard requires about three hives of bees (although this figure is only an educated guess). Nevertheless, a conservative estimate of the number of bee hives needed exclusively for the pollination of apple crops in the entire region of the Hindu Kush-Himalaya is more than one million. In the temperate mountainous region of the Hindu Kush-Himalaya, the bee species which is available for beekeeping is not the European honeybee, *Apis mellifera*, but the native Asiatic honeybee, *Apis cerana*.

At present, there are only a few thousand colonies of *Apis cerana* kept in modern hives by a few farmers and orchardists. A major problem, therefore is that, the present large-scale expansion of the horticultural industry in the region has not been accompanied by a corresponding increase in pollination resources and technology through the availability of appropriately managed bee hives. Many orchards do not bear sufficient fruit because the population of bees is too small. Moreover, with the increase in the use of pesticides for the control of apple pests, the population of pollinators, as represented by various species of naturally occurring solitary ground nesting bees, is decreasing at an alarming rate. This makes domesticated hive bees essential for pollination, and beekeeping as an essential part of fruit production.

A large horticultural undertaking as present in the Hindu Kush-Himalayan region will not be able to flourish in the long run without the large-scale development of scientific beekeeping. Nevertheless, there are problems to be addressed and overcome. The wealth contributed by beekeeping, as a cottage industry, would run into several millions of dollars from hive rentals, pollination and honey production.

4.5.1 Distribution, Abundance and Diversity of Insect Pollinators

According to Verma and Chauhan (1985), insects visiting the apple bloom in the Shimla hills (Himachal Pradesh) comprised 44 species belonging to 14 families and five orders of these: 16 species belonged to Hymenoptera, 11 to Diptera, nine Lepidoptera, seven to Coleoptera and one to Hemiptera (Table 4.1). The data on relative abundance of different insect pollinators of apple in Shimla hills indicated that, *Apis cerana* was the most abundant insect species, whereas *Bombus tunicatus* was the least abundant (Table 4.2). Further, comparative abundance studies on various orchards indicated that *Apis cerana* constituted 24.01 to 43.03 per cent of the total pollinator population. Rai and Gupta (1983) also reported that honeybees, *Apis cerana*, constituted 39 to 84 per cent of the insects which visited apple flowers in the Uttar Pradesh hills of India.

Besides honeybees and bumble bees, *Halictus dasygaster* was predominant in one experimental orchard at Thanadhar (Shimla distt. of Himachal Pradesh). Besides hymenopterous insects, dipterns were other visitors of this crop in the Shimla hills. These were *Eristalis tenax*, *Eristalis angustimarginalis*, *Eristalis* sp., *Muscids* (*Musca* sp.), *Orthelia* sp. and *Syrphids (Epilobium* sp., *Scava* sp., *Metasyrphus* sp., and *Macrosyrphus* sp.).

The above results show that the relative abundance of all the insects varied from place to place (Table 4.2). Differences in environmental conditions, location and altitude of the orchards could be possible reasons for such variations (Verma and Chauhan, 1985).

4.5.2 Role of Honeybees on Yield and Quality of Apple Fruit

Most of the commercial varieties of apples give good yields only after cross-pollination. Cross-pollination is mostly done by insects because the rôle of the wind in cross-pollination of apple bloom is negligible due to the heavy and sticky nature of apple pollen. Honeybees are the most efficient pollinators among insects because they can be managed in sufficient number, and because they show flower constancy (Free, 1964). Although self-compatible varieties of apple do not need as many insect visits as self-incompatible varieties to give an adequate fruit set, yet some visits are essential. A lot of work has been done regarding the role of honeybees in the pollination of apple bloom in many developed countries (McGregor, 1976), but very little has been done in the temperate region of the Hindu Kush-Himalaya. Verma (1987b) and Dulta and Verma (1987a) studied the role of honeybees on fruit set, fruit drop and fruit quality of apples in the Shimla Hills, and the results are summarized as follow:

The following treatments were conducted in three different apple orchards of a size of 0.8 hectare each located in Annu, Kotkhai and Jubbal areas of Himachal Pradesh at heights of 1350, 1875 and 2400 metres above sea level, to study the effect of honeybee pollination on fruit set, fruit drop and fruit quality of apple fruit.

i) No insects pollinator

ii) Open pollinated flowers (natural insect pollinators)

iii) Honeybee-pollinated flowers

In these experiments, it was found that insect pollinators, mainly honeybees, play a significant role in improving fruit set and quality, and in reducing fruit drop.

Table 4.1: Insect species visiting apple flowers with their taxonomic status in the northwest Himalaya

(A) HYMENOPTERA	(B) DIPETRA	(C) LEPIDOPTERA	(D) COLEOPTERA	(E) HEMIPTERA
(a) APIDATE	(f) MUSCIDAE	(h) NOCTUIDAE	(l) COCCINELLIDAE	(o) PENTATOMIDAE
(1) *Apis cerana*	(17) *Musca* sp	(28) *Plusia onchaicea*	(37) *Cocinella septumpunctata*	
(2) *Apis mellifera*	(18) *Orthelia* sp.	(29) *Heliothis armigera*		(44) *Apodiphus* sp.
(3) *Bombus tunicatus*		(30) *Agrotis flammatra*	(m) CHRYSOMELIDAE	
(4) *Bombus* sp. (i)	(g) SYRPHIDAE	(31) *Agrotis ipsilon*	(38) *Altica* sp.	
(5) *Bombus* sp. (ii)	(19) *Melanostoma univitattum*		(39) *Alticinae* sp.	
	(20) *Eristalis tenax*	(i) NYMPHALIDAE	(40) *Nonartha variabilis*	
(b) ANTHOPHORIDAE	(21) *Eristalis angus-timarginalis*	(32) *Vanessa cashmirensis*	(41) *Minastra cymura*	
(6) *Anthophora* sp.		(33) *Neptis* sp.		
	(22) *Eristalis arvorum*		(n) SCARABAEIDAE	
(c) HALICTIDAE	(23) *Eristalis* sp.	(j) PIERIDAE	(42) *Protaetia neglecta*	
(7) *Nomodo* sp.	(24) *Epilobium boleatus*	(34) *Pieris canidia*	(43) *Brahmina cronicolis*	
(8) *Halictus dasygaster*	(25) *Scaeva pyrastri*	(35) *Delias belladona*		
(9) *Halictus* sp. (i)	(26) *Metasyrphus corollae*			
(10) *Halictus* sp. (ii)	(27) *Macrosyrphus,* sp.	(k) LYCANIDE		
(11) *Xylocopa* sp.		(36) *Heodes* sp.		
(d) VESPIDAE				
(19) *Polistes maculipennis*				
(13) *Vespa magnifica*				
(14) *Vespa auraria*				
(15) *Vespa flaviceps*				
(e) ICHNEUMONIDAE				
(16) *Netalia tatra*				

A,B,C,D,E = ORDER a,b,c,d. etc. = FAMILY *Source*: Verma and Chauhan, 1985.

Table 4.2: Comparitive abundance of different insect pollinators/branch/10 minutes at various apple orchards in the Northwest Himalaya

Pollinator species	Kotgarh A	Kotgarh B	Thanedhar A	Thanedhar B	Matiana R	Matiana G	Narkanda
Apis cerana	3.55* ±0.28** (26.10)	2.94 ±0.39 (24.01)	6.49 ±0.47 (26.02)	8.33 ±0.56 (33.63)	8.40 ±1.40 (39.05)	7.36 ±1.59 (40.15)	19.30 ±11.13 (43.03)
Eristalis tenax	2.38 ±0.21 (17.51)	1.94 ±0.26 (15.84)	2.77 ±0.35 (11.10)	3.11 ±0.36 (13.67)	1.29 ±0.36 (5.99)	0.77 ±0.27 (4.20)	6.63 ±0.39 (14.78)
Eristalis sp.	NR	NR	2.66 ±0.61 (10.66)	2.66 ±0.24 (9.01)	0.59 ±0.28 (2.74)	0.48 ±0.04 (2.61)	0.48 ±0.22 (2.74)
Eristalis angusti-marginalis	0.44 ±0.12 (3.23)	0.44 ±0.16 (3.59)	0.28 ±0.14 (1.12)	0.38 ±0.10 (1.67)	0.29 ±0.09 (1.34)	0.37 ±0.08 (2.01)	1.89 ±0.32 (4.21)
Orithelia sp.	0.88 ±0.17 (6.45)	1.05 ±0.10 (8.57)	1.10 ±0.24 (4.41)	1.16 ±0.22 (5.10)	NR	NR	NR
Peiris canidia	0.38 ±0.10 (2.79)	0.41 ±0.12 (3.59)	0.33 ±0.13 (1.32)	0.39 ±0.14 (1.71)	0.07 ±0.05 (0.32)	0.18 ±0.06 (0.98)	NR
Bombus tunicatus	0.33 ±0.19 (2.42)	0.33 ±0.19 (0.69)	0.05 ±0.001 (0.20)	0.11 ±0.06 (0.48)	NR	NR	0.29 ±0.09 (0.64)
Syrphids	2.83 ±0.30 (20.80)	2.44 ±0.18 (19.93)	3.97 ±0.51 (15.90)	3.27 ±0.77 (14.37)	2.84 ±0.38 (13.20)	2.14 ±0.40 (11.67)	3.56 ±0.37 (7.93)
Muscids	2.81 ±0.28 (20.66)	2.66 ±0.19 (21.73)	4.91 ±0.31 (19.68)	3.94 ±0.21 (17.32)	8.03 ±0.75 (37.33)	7.03 ±0.83 (38.30)	11.89 ±0.68 (26.85)

*Each value is overall average for an insect species at a place.

**Standard error about the mean.

NR = Not recorded.

Figures within parentheses indicate per cent population A and B are two orchards studied

R = Number of insect pollinators on Royal Delicious variety.

G = Number of insect pollinators on Golden Delicious variety.

Source: Verma and Chauhan, 1985.

1) Effect on fruit set

In self-compatible varieties like Golden Delicious, the percentage of fruit set in control, open and honeybees pollinated flowers were 24.57, 30.73 and 34.53, respectively, which did not differ significantly. Similarly, in another self-compatible variety, Red Gold, the percentages of fruit set in control, open and honeybee-pollinated flowers recorded 15.76, 18.34 and 22.45, respectively, did not differ significantly. Non-significant differences in fruit set of Golden Delicious and Red Gold under different conditions may be due to self-compatibility of these varieties. In self-compatible varieties like Royal Delicious and Red Delicious, there was no fruit set in the absence of insect pollinators but the fruit set was significantly higher ($P<0.01$) in honeybees-pollinated flowers of Royal Delicious (23.33 per cent) and Red Delicious (19.69 per cent) than in open pollinated flowers of Royal Delicious (13.21 per cent) and Red Delicious (11.42 per cent). No fruit set in the absence of any insect pollinator in self-incompatible varieties clearly indicated that there was no pollen transfer from pollinizer to pollinated varieties without an insect pollinator.

Moreover, higher fruit set in honeybee-pollinated flowers than in open pollinated flowers suggested that the degree of cross-pollination done by honeybees was certainly higher than that done by other natural insect pollinators. This is due to the fact that the bodies of honeybees are more efficient pollinators of apples (Table 4.2).

2) Effect of insect pollinators on fruit drop

The fruit drop in self-compatible varieties of apple was significantly higher ($P<0.01$) from flowers under the controlled condition as compared to the fruits from open and honeybee-pollinated flowers. For example, in Golden Delicious and Red Gold, the fruit drops were maximum (38.45 and 38.07 per cent, respectively) under control and minimum (25.22 and 25.02 percent, respectively) in honeybee-pollinated flowers. In open-pollinated flowers of Golden Delicious and Red Gold, the fruit drops were 27.62 and 28.38 per cent, respectively, with no significant difference. In self-incompatible varieties like Royal Delicious, the fruit drops in open-pollinated and honeybee-pollinated flowers were 28.69 and 25.50 per cent, respectively, without any significant difference ($P<0.01$). The same trend was observed in an other self-incompatible variety, Red Delicious, where the fruit drops in open- and honeybee-pollinated flowers were 28.86 and 25.73 per cent, respectively, with no significant difference ($P<0.01$). The high percentage of fruit drop in the control experiment was due to poor cross-pollination, whereby, the number of ovules fertilized was fewer (Table 4.3).

Table 4.3: Percentage of fruit set and fruit drop in three different experimental conditions

Varieties	Honeybee pollinated flowers (H)	Open pollinated flowers (O)	No insect pollinator (control)
A. Golden Delicious	34.53 (25.22)	30.73 (27.62)	24.57 (38.45)
B. Red Gold	22.45 (25.02)	18.34 (28.38)	15.76 (38.07)
C. Royal Delicious	23.33 (25.50)	13.21 (28.69)	0.00 (0.00)
D. Red Delicious	19.69 (25.73)	11.42 (28.86)	0.00 (0.00)

* Data in parentheses pertain to fruit drop.
For fruit set in C and D varieties: $H<O>C$ ($P>0.01$).
For fruit drop in A and B varieties: $C>O,H$ ($P<0.01$)
$P<0.01$ = Highly significant.

Source: Dulta and Verma, (1987a).

3) Effect on fruit quality

Honeybee pollination greatly improves the quality of apple fruit. For example, Verma (1987b), Dulta and Verma (1987a) showed that in Golden Delicious, there was an increase in the weight, length, breadth, volume and number of seeds per fruit by 22, 9, 7, 17 per cent, respectively in the fruits which developed from flowers exclusively pollinated by honeybees as compared to the open-pollinated flowers. Whereas, in Red Gold, the weight, length, breadth, volume and number of seeds per fruit increased 18, 9, 9, 9 and 32 per cent, respectively and the fruits of these two self-compatible varieties followed the pattern: Fruits from honeybee-pollinated flowers > fruits from open-pollinated flowers > fruits from the control experiment (Table 4.4).

In the Royal Delicious variety of apple, the increase in weight, length, breadth, volume and number of seeds per fruit was 33, 15, 10, 51 and 49 per cent, respectively in fruits which developed from flowers exclusively pollinated by honeybees as compared to the open-pollinated flowers. Similarly, in Red Delicious, the increase in weight, length, breadth, volume and number of seeds per fruit which developed from flowers exclusively pollinated by honeybees was 19, 9, 10, 16 and 30 per cent, respectively, as compared to those fruits which developed from open-pollinated flowers. In these self-incompatible varieties, the fruit quality was significantly better ($P<0.010$) in the fruits from honeybee-pollinated flowers as compared to the fruits from open-pollinated flowers. The improvement in the quality of fruits due to cross-pollination by honeybees (also other natural insect pollinators) might be as a result of heterosis. The increase in weight, size (length and breadth) and

Table 4.4: Effect of insect pollinators on the quality of apple fruit in different cultivars grown in the northwest Himalaya

Variety	Honeybees pollinated flowers (H)					Open pollinated flowers (I)					No insect pollinator (Control, J)				
	Weight* (WH)	Length** (LH)	Breadth** (BH)	Volume (VH)	No. of seeds (SH)	Weight (WI)	Length (LI)	Breadth (BI)	Volume (VI)	No. of seeds (SI)	Weight (WJ)	Length (LJ)	Breadth (BJ)	Volume (VJ)	No. of seeds (SJ)
A. Golden Delicious	208.88	7.34	7.74	193.33	8.92	188.00	6.76	7.26	165.77	8.11	104.44	5.58	6.12	82.86	6.00
B. Red Gold	152.67	5.97	7.00	138.00	9.11	135.53	5.81	6.85	133.00	7.77	82.00	4.94	5.75	63.67	7.00
C. Royal Delicious	266.55	7.88	8.13	268.39	6.78	201.16	6.87	7.41	177.00	6.20	No fruit set				
D. Red Delicious	217.67	7.21	7.69	184.44	6.78	183.80	6.61	7.00	159.80	5.33	No fruit set				

Statistical significance:

$A^{WH} > A^{WI} > A^{WJ}$ ($P < 0.01$); $A^{LH} > A^{LI} > A^{LJ}$ ($P < 0.01$); $A^{BH} > A^{BI} > A^{BJ}$ ($P < 0.01$); $A^{VH} > A^{VI} > A^{VJ}$ ($P < 0.01$); $A^{SH} > A^{SI} > A^{SJ}$ ($P < 0.01$).

$B^{WH} > B^{WI} > B^{WJ}$ ($P < 0.01$); $B^{LH} > B^{LI} > B^{LJ}$ ($P < 0.01$); $B^{BH} > B^{BI} > B^{BJ}$ ($P < 0.01$); $B^{VH} > B^{VI} > B^{VJ}$ ($P < 0.01$); $B^{SH} > B^{SI} > B^{SJ}$ ($P < 0.01$).

$C^{WH} > C^{WI}$ ($P < 0.01$); $C^{LH} > C^{LI}$ ($P < 0.01$); $C^{BH} > C^{BI}$ ($P < 0.01$); $C^{VH} > C^{VI}$ ($P < 0.01$); $C^{SH} > C^{SI}$ ($P < 0.01$).

$D^{WH} > D^{WI}$ ($P < 0.01$); $D^{LH} > D^{LI}$ ($P < 0.01$); $D^{BH} > D^{BI}$ ($P < 0.01$); $D^{VH} > D^{VI}$ ($P < 0.01$); $D^{SH} > D^{SI}$ ($P < 0.01$). — Highly significant.

*Weight in gm

**Length and Breadth in cm

Source: Dulta and Verma (1987a).

volume of the apple fruits which developed from honeybee-pollinated flowers might be due to the greater number of seeds per fruits (mean number of seeds, 8.92, 9.22, 7.31 and 6.78 in Golden Delicious, Red Gold, Royal Delicious, and Red Delicious, respectively, Table 4.4). Rai and Gupta (1983) also found that in honeybee-pollinated flowers of Red Delicious, Esopus and Spitzenberg cultivars of apple, yield was 5.8 and 1.6 kg per 100 flowers in comparison to open-pollinated flowers which yielded only zero and 0.75 kg, respectively. The better pollinating efficiency of honeybees helps in the fertilization of maximum number of ovules and thereby a greater number of seeds are formed. In this way, the maximum amount of auxin, a growth hormone, is produced which results in better size of the fruit (Table 4.4).

4.5.3 Comparative Foraging Behaviour of *Apis cerana* and *Apis mellifera* on Apple Bloom

Verma and Dulta (1986) studied comparative foraging behaviour of *Apis mellifera* and *Apis cerana* on apple bloom and the results of those investigations are reviewed as follows:

Worker bees of *Apis cerana* started their foraging activity earlier in the morning (mean time, 0603 hours) than *Apis mellifera* (mean time 0627 hours). In the evening *Apis mellifera* ceased its foraging activity earlier (mean time 1855 hours) than *Apis cerana* (mean time 1913 hours). Thus, the average duration of foraging activity in *Apis cerana* was 13.10 hours and in *Apis mellifera*, 12.28 hours (Table 4.5).

The duration of the foraging trip by *Apis cerana* was 11.85 minutes, and *Apis mellifera* was 17.92 minutes. Thus, the duration of a foraging trip was significantly longer for the latter than the former (Table 4.5).

Observations made at three different hours of the day (0900, 1200 and 1500 hours) during apple flowering in order to study the nature of food (nectar, pollen or both) collected by worker bees of *Apis cerana* and *Apis mellifera* revealed that, in both the species, nectar collectors were significantly more than pollen collectors (Table 4.6).

In *Apis cerana*, no pollen plus nectar collectors were observed; whereas, in *Apis mellifera*, the percentage of such worker bees varied from 6 to 11 during different hours (Table 4.6). However, in *Apis mellifera*, the number of nectar collectors was significantly higher than pollen collectors (41 and 20 per cent, respectively). For *Apis mellifera*, the number of nectar collectors was significantly higher at 0900 and 1500 hours (73 and 70 per cent, respectively) than pollen collectors (48 and 22 per cent, respectively). At 1200 hours, no significant difference was observed in the proportion of pollen and nectar collectors.

At 0900 hours, the number of pollen collectors of *Apis cerana* was significantly higher ($P<0.01$) than *Apis mellifera*; whereas, at 1200 and 1500 hours, there was no significant difference ($P<0.01$) in the num-

Table 4.5: Foraging data for *Apis cerana* and *Apis mellifera* honeybees on apple flowers at 1350 m in the northwest Himalaya in April-May

Parameter	*Apis cerana*	*Apis mellifera*
Initiation (time of day) of foraging	06.03 ± 0.01	06.27 ± 0.02
Cessation (time of day) of foraging	19.13 ± 0.01	18.55 ± 0.01
Duration (h) of foraging activity	13.10 ± 0.002	12.28 ± 0.003
Duration (min) of foraging trip	11.85 ± 0.36	17.92 ± 0.36
Peaking foraging hours (time of day)	09.00 – 11.30	11.00 – 13.20
Weight (mg) of pollen load: 09.00	9.06 ± 0.02	9.24 ± 0.04
12.00	9.26 ± 0.02	12.22 ± 0.04
15.00	8.64 ± 0.06	11.12 ± 0.03
No. stigmas touched/flower	3.09 ± 0.39	3.33 ± 0.32
Time(s) on flower (min)	5.90 ± 0.22	6.63 ± 0.23

Each mean (± SE) is for eight observations. For times of initiation, cessation and duration of daily foraging activity, duration of a foraging trip and weights of pollen loads, differences between species are significant (P<(0.01); for number of stigmas touched per flower and time spent on flower P>0.01.

Source: Verma and Dulta, 1986.

ber of pollen collectors of *Apis cerana* and *Apis mellifera* (Table 4.6). Nectar gatherers of *Apis mellifera* were significantly more (P < 0.01) than those of *Apis cerana* at 0900 hours; whereas, at 1200 hours the trend was reverse, i.e. the number of nectar collectors of *Apis cerana* was significantly greater (P<0.01) than that of *Apis mellifera*. At 1500 hours, there was no significant difference (P<0.01) in the number of nectar collectors of both the species. Pollen plus nectar collectors of *Apis mellifera* were maximum at 1200 hours (Table 4.6).

Observations made on hourly fluctuations in the number of bees leaving the hive per five minutes showed that peak activity of *Apis cerana* was between 0900 and 1100 hours (mean 132 bees/5 minutes) when the temperature ranged from 13.5 to 21.0°C, and that of *Apis mellifera* it was between 1100 and 1300 hours (mean 118 bees/5 minutes) when the temperature ranged from 21 to 25°C during March and April in the Shimla Hills (Fig. 4.1) (Table 4.5).

Pollen loads carried by *Apis mellifera* at 0900, 1200 and 1500 hours of the day were 9.24 mg; 12.22 mg and 11.12 mg, respectively, whereas, these values for *Apis cerana* were 9.06 mg, 9.26 mg and 8.64 mg at 0900, 1200 and 1500 hours, respectively. A worker bee of *Apis mellifera* carried significantly heavier (P<0.01) pollen loads than *Apis cerana* throughout the day (Table 4.5).

Table 4.6: Percentage of *Apis cerana* and *Apis mellifera* honeybees collecting pollen, nectar, or both from apple flowers at different hours of the day in April-May at 1350 m in the northwest Himalaya

	09.00		12.00		15.00	
Forage	*Apis cerana*	*Apis mellifera*	*Apis cerana*	*Apis mellifera*	*Apis cerana*	*Apis mellifera*
P	46.0	18.0	41.0	40.0	20.0	22.0
N	51.0	73.0	55.0	44.0	76.0	70.0
PN	0	6.0	0	11.0	—	7.0
P:N	1:1.11	1:4.05	1:1.34	1:1.10	1:3.80	1:3.18

Percentages are based on eight observations.
P = pollen collectors; N = nectar collectors; PN = pollen and nectar collectors.
P:N = ratio of pollen to nector collectors.

At 12.00, NC>PC (P<0.05) for *Apis cerana*; at 15.00, NC>PC (P<0.01) for *Apis cerana*; At 09.00 and 15.00 NC>PC (P<0.01) for *Apis mellifera*; at 09.00 PC *Apis cerana*>PC *Apis mellifera* (P<0.01) and NC *Apis mellifera*>NC *Apis cerana* (P<0.01); at 12.00 NC *Apis cerana*>NC *Apis mellifera* (P<0.01); at 12.00 PC+NC *Apis mellifera*>PC+NC *Apis mellifera* at 09.00 or 15.00 (P<0.05). Depending on the hour, 1–5% of bees might collect water.

Source: Verma and Dulta, 1986.

While foraging on apple bloom, *Apis cerana* contacted on an average 3.09 stigmas (2.65 to 3.60) per flower visit, whereas, *Apis mellifera* touched 3.33 stigmas (3.20 to 3.45) per visit at a height of 1350 metres a.s.l. (Table 4.5).

Apis cerana spent on an average 5.90 seconds per flower, whereas *Apis mellifera* spent 6.63 seconds on a single visit to an apple flower at height of 1350 metres a.s.l. (Table 4.5).

Foraging study results also showed that at 0.900, 1200 and 1500 hours *Apis mellifera* visited significantly more apple trees in the same row than in a different row. However, for *Apis cerana*, the number was significantly more in the same than in a different row at 1500 hours only. No significant difference (P<.05) was observed between *Apis cerana* and *Apis mellifera* with regards to their visits in the same or different rows of apple trees (Table 4.7).

There was no significant difference between *Apis cerana* and *Apis mellifera* in the number of flowers visited per apple tree except at 0900 hours. However, *Apis mellifera* visited significantly more apple trees at 0900, 1200 and 1500 hours than *Apis cerana* (Table 4.7).

The ratio of top and side worker bees on apple bloom at a particular time of the day did not differ significantly between *Apis mellifera*

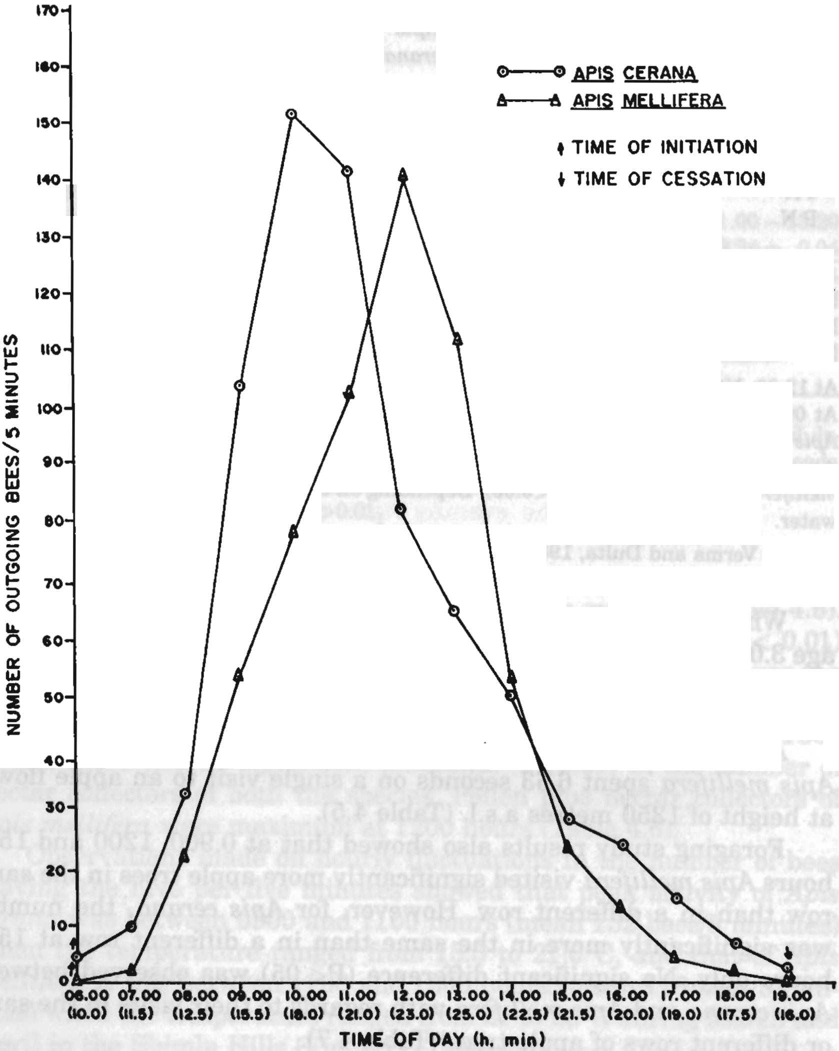

Figure 4.1: Peak hours of foraging activity (number or outgoing bees/5 min) of *A. c. indica* and *A. mellifera* honeybees on apple flowers in northwest Himalaya. Temperatures are indicated in parentheses (°).

Source: Verma and Dulta, 1986.

Table 4.7: Foraging behaviour of *Apis mellifera* and *Apis cerana* during pollination of apple bloom in the northwest Himalaya

Parameter		*Apis mellifera*	*Apis cerana*
A. No. of flowers visited per minute		6.4 ± 0.2	6.4 ± 0.3
B. No. of flowers visited per foraging trip by individual bee		193.1 ± 2.4	172.1 ± 2.6
C. No. of bees on sunny (SN) or shady (SH) sides of apple trees	SN	16.8 ± 1.4	17.8 ± 1.3
	SH	12.4 ± 1.3	14.3 ± 1.1
D. No. of trees visited in the same (SR) or different row (DR)	SR	2.7 ± 0.1	2.4 ± 0.1
	DR	3.5 ± 0.2	3.0 ± 0.1
E. Percentages of multi-floral (MF) or unifloral loads (UF)	MF	95.71	97.86
	UF	4.29	2.14
F. Preferences for foraging distance (No. of bees at different distances)	100 m	9.0 ± 0.7	9.8 ± 0.8
	250 m	8.5 ± 0.8	9.1 ± 0.8
	500 m	4.8 ± 0.6	5.1 ± 0.6

A, B = mean ± standard error of 210 observations
C = mean ± standard error of 21 observations
D = mean ± standard error of 105 observations
E = mean ± standard error of 140 observations
F = mean ± standard error of 63 observations
Statistical significance:
B = *A. mellifera* > *A. cerana* ($P<0.01$)
C = No bees of each species; SN>SH ($P<0.05$)
D = No bees of each species; DR>SR ($P<0.05$)
E = MF>UF in each species ($P<0.01$)
F = No. of bees at 100 m>500 m) ($P>0.05$)
F = No. of bees at 250 m>500 m) ($P>0.05$)

Source: Rana, 1989.

and *Apis cerana*. However, the percentage of side and top worker bees varied according to the time of the day in both the species. For example, at 0900 hours the top workers outnumbered side workers in both species, but at 1500 hours the reverse was true. At 1200 hours the percentage of side worker bees was greater than the top workers for *Apis cerana*. The time spent by top and side workers of both species on each flower did not differ significantly. However, at 1200 and 1500 hours the time spent per flower by side workers of *Apis cerana* was significantly greater than that by top workers (Table 4.8).

Table 4.8: Percentage of top or side worker bees at different hours

	0900 hours		1200 hours		1500 hours	
	Apis mellifera	*Apis cerana*	*Apis mellifera*	*Apis cerana*	*Apis mellifera*	*Apis cerana*
Top workers (TW)	65.0	67.1	42.9	41.9	36.0	41.4
Side workers (SW)	35.0	32.9	57.1	58.1	64.0	58.6
TW : SW	1.86:1	2.04:1	1:1.3	1:1.4	1:1.8	1:1.4

Each value is a mean of 140 observations

At 0900 hours, TW > SW for *Apis mellifera* and *Apis cerana* ($P<0.01$)

At 1200 hours and 1500 hours, SW > TW for *Apis mellifera* and *Apis cerana* ($P<0.05$)

Source: Rana, 1989.

4.5.4 Effects of Orchard Altitude on the Foraging Behaviour of *Apis cerana* and *Apis mellifera*

Studies by Verma and Dulta (1986) on the foraging behaviour of *Apis cerana* and *Apis mellifera* at three different altitudes, 1350, 1875 and 2400 metres a.s.l., showed that worker bees of the former started their foraging activities earlier in the morning and stopped later in the evening than the latter at all the altitude. Initiation of the foraging activity of both the species was delayed with the increasing altitude of the place. For example, time of initiations of *Apis cerana* were 0603, 0606 and 0618 hours at 1350,1875 and 2400 metres a.s.l.; whereas, for *Apis mellifera* the time of initiation at 1350, 1875 and 2400 metres a.s.l. were 0627, 0641 and 0648 hours, respectively. On the other hand, the foraging of both the species ceased earlier with the increase in the altitude of the place. *Apis cerana* ceased its foraging activity at 1913,1902 and 1825 hours at 1350, 1875 and 2400 metres a.s.l., and *Apis mellifera* ceased its activity at 1855, 1838 and 1804 hours at 1350,1875 and 2400 metres a.s.l. (Table 4.8). Thus, the duration of the foraging activity per day of *Apis cerana* and *Apis mellifera* bees on apple bloom decreased with the increase in altitude (mean duration, 13.10, 12.56 and 11.76 hours for *Apis cerana* and 12.28, 11.57 and 11.16 hours for *Apis mellifera* at 1350, 1875 and 2400 metres a.s.l. (Verma and Dulta, 1986).

The duration of each foraging trip in both the species of honeybees increased with the increase in altitude of the place where the orchard is located and it was found to be maximum (mean time, 17.83 minutes and 22.67 minutes in *Apis cerana* and *Apis mellifera*, respectively) at 2400 metres a.s.l., followed by at 1875 metres a.s.l. (mean time, 17.58 minutes and 22.25 minutes in *Apis cerana* and *Apis mellifera*, respectively) and at 1350 metres a.s.l. (11.85 minutes and 17.92 minutes in *Apis cerana* and *Apis mellifera*, respectively).

Altitude had no significant effect on other parameters, such as the bees' preference for pollen or nectar or both during a visit, peak hours of foraging activity, pollen load, number of stigmas touched per visit, or time spent per flower (Table 4.9).

The above data on comparative foraging behaviour of *Apis mellifera* and *Apis cerana* suggest that both species of honeybees are complementary to each other for sufficient and efficient pollination of horticultural and agricultural crops. Instead of providing two colonies of the same species per hectare of crop in bloom, one strong colony each of *Apis mellifera* and *Apis cerana* should be kept to ensure efficient pollination. During low temperatures, *Apis cerana* should be preferred over *Apis mellifera*. Additional research on comparative foraging behaviour of *Apis cerana* and *Apis mellifera* on other agricultural and horticultural crops in the Hindu Kush-Himalayan region should be carried out to augment the present data.

4.5.5 Renting of Bee Hives for Pollination

In Himachal Pradesh, the State horticulture department and a few private beekeepers rent *Apis cerana* and *Apis mellifera* colonies to the fruit growers at the time of apple bloom for pollination. Generally, at the onset of the winter season (November–December), colonies of both *Apis cerana* and *Apis mellifera* are migrated from the temperate hilly region to the sub-tropical plain areas, where brood rearing usually starts in the first or second week of February. By the middle of March, the colony strength reaches maximum and this is the time when flowering in apple orchards starts. These colonies are transported in trucks directly to the apple-growing belt of the state and distributed to the fruit growers at the rate of Rs. 25 per colony for one flowering season. However, private beekeepers charge a higher rental fee as compared to state Government-owned apiaries. At present, such colonies are distributed to about 1000 fruit growers, and each gets about two to five colonies irrespective of the size of the orchard. Although the number of colonies distributed for pollination is perhaps too small, keeping in view the large areas of land under fruit cultivation in Himachal Pradesh, it has created awareness among apple growers regarding the important role honeybees play in apple pollination. As a result of this practice, some growers maintain their own colonies of bees for the purpose of pollination and honey production (Verma, 1989b).

Table 4.9: Effect of altitude on foraging of *Apis cerana* and *Apis mellifera* honeybees on apple flowers in orchards at different altitudes in the northwest Himalaya in April–May

Parameter	Annu orchard		Penghunas orchard		Amin orchard	
	cerana	*mellifera*	*cerana*	*mellifera*	*cerana*	*mellifera*
IF	06.03 ± 0.01	06.27 ± 0.02	06.06 ± 0.00	06.41 ± 0.01	06.18 ± 0.01	06.48 ± 0.01
CF	19.13 ± 0.01	18.55 ± 0.01	19.02 ± 0.01	18.36 ± 0.01	18.25 ± 0.01	18.04 ± 0.01
DF	13.10 ± 0.002	12.28 ± 0.003	12.56 ± 0.003	11.57 ± 0.004	12.07 ± 0.004	11.16 ± 0.003
DT	11.85 ± 0.36	17.92 ± 0.36	17.85 ± 0.25	22.25 ± 039	17.83 ± 0.32	22.67 ± 0.32

Annu orchard is at 1350 m, Penghumas at 1875 m and Amin at 2400 m above sea level. Means (± SE) are for eight observations. Times of initiation and cessation, and duration of daily foraging activity in an orchard were not affected signigcantly by altitude. Duration of a foraging trip by either species at 2400 m or 1875 m > duration 1350 m (P<0.01).

IF = initiation (time) of daily foraging activity; CF = cessation (time) of daily foraging activity; DF = duration (h) of daily foraging activity; DT = duration (min) of an individual trip.

Source: Verma and Dulta, 1986.

4.5.6 Orchard and Bee Management Practices in Relation to Apple Pollination

1) It is now well documented that bee pollination improves the size, shape, colour, storage capacity and taste of apple fruit. To obtain good economic yield of apple, 5 per cent of flowers per 0.4 hectare of orchard must set and mature. Inadequate pollination in the apple orchard may be due to the following reasons:

— lack of pollinizer varieties suitable for cross-pollination
— non-overlapping of blooming period of main cultivar and pollinizer variety
— inadequate pollinator force in the orchard
— unfavourable weather conditions
— production of non-functional pollen or ovules
— irregularities in the development of embryo sacs.

2) Some of the above problems of orchard management can be overcome by adopting the following pollination practices:

— When planning a new apple orchard, the planting pattern should be such that every third tree in every third row is a pollinizer.
— The flowering period of pollinizer varieties should overlap with the flowering period of the main cultivars to be cross-pollinated.
— The pollinizer variety, besides helping in cross-pollination of the main cultivar, should also have commercial value.

3) Changes recommended for good pollination in the established orchards are:

— Replacing the whole tree
— Top working or grafting of pollinizer cultivars
— Providing cut flowering branches of pollinizer cultivar to main cultivar
— Hand application of collected pollen
— Use of pollen dispensers

4) Keeping in view the shorter flight range of *Apis cerana*, the bee hives should be spread throughout the orchard or possibly around the perimeter, rather than in groups.

5) Two bee hives of *Apis mellifera* per hectare of apple orchard provide an adequate pollinator force. However, due to smaller body and colony size of *Apis cerana*, three colonies per hectare are recommended.

6) If the weather is good, honeybee colonies should not be kept in the apple orchard for more than two days because of the adverse effects of pesticides.

7) Plant such trees around the orchard which act as good wind breaks.

8) Increase the strength of bee colonies to be used for pollination by adopting the following management practices:

— feeding sugar syrup,

— introducing a prolific queen, and

— increasing the amount of brood by adding combs of unsealed brood.

9) Remove combs containing stored pollen to create a pollen dearth in the colony.

10) Place colonies in the orchard at time when 10–15 per cent of the crop is in bloom.

11) Shift colonies from one site to another or even interchange them to broaden the search areas of bees, which is helpful in pollination.

12) Mow orchards in bloom to keep the bees away from the flowering weeds.

4.6 POLLINATION OF TEMPERATE FRUIT CROPS OTHER THAN APPLE

In the Hindu Kush-Himalayan countries, Apricot, Almond, Peach, Pear, Plum, Cherry, Grape, Citrus, Litchi, Olive and Persimmon are temperate fruit crops other than apple which are now being grown, and quite a considerable area is being brought under the cultivation of these fruit crops.

Information on the pollination ecology of these fruit crops in terms of their cross-fertilization status, ratio of pollinizer variety to main variety required for sufficient pollination, total bloom period, peak receptivity period of stigma to pollen, nectar and pollen potentials, chief insect pollinators, percentage of bloom required for optimum fruit set and economic yield, and number of colonies required per unit orchard area for sufficient pollination, are summarized in Table 4.10.

In the practical sense, very little is known (Atwal and Grewal 1968, Sharma, 1961) about the pollination requirements of these fruit crops under the ecological conditions of the Hindu Kush-Himalaya, and most of the information given in Table 4.10 has been compiled from western literature particularly Europe and America (McGregor, 1976; Free, 1970). In the western countries, beekeeping is an integral part of orchard management technology, and honeybees are extensively utilized for the pollination of temperate fruit crops. These results suggest that cross-pollination by honeybees increases the yield and quality of the different temperate fruit crops.

Rai and Gupta (1983) reported that honeybees were the main (48 to 76 per cent) pollinators of pear flowers in the Uttar Pradesh hills. Mann and Singh (1980) reported that *Apis mellifera* and *Apis dorsata* were dominant flower visitors of pear in the Punjab (India). The maximum population was that of *Apis mellifera* followed by *dorsata*. Their results also revealed that the yield of different pear cultivars such as Victoria, Jargonella, Burehardy and Conference increased significantly due to honeybee pollination.

Kumar et al. (1985) studied pollination requirements of 15 different peach cultivars in Solan district of Himachal Pradesh and concluded that insect pollinators do not play any significant role in fruit set of peach cultivars. Phadke and Naim (1974) concluded that honeybees were important for litchi pollination. *Apis florea* was the most important pollinator followed by *Apis cerana*. However, *Apis dorsata* did not seem to prefer litchi. Pandey and Yadava (1970) reported that litchi was highly self-sterile, and that insect-pollination was essential for good fruit set. Among the different species of insects visiting litchi flowers, the genus *Apis* was predominant. These authors also observed that *Apis cerana* visited litchi flowers mainly between 0630 and 1200 hours in the Uttar Pradesh hills.

Rao et al. (1984a) also reported *Apis cerana* as the major (78 per cent) pollinator of litchi flowers. Even in self-compatible cultivars like Shahi and China of litchi, honeybee pollination significantly increased the fruit set in trees caged with *Apis cerana* in comparison to open-pollinated flowers. Manzoor-ul-Haq et al. (1978) studied the usefulness of *Apis dorsata* and *Apis florea* in fruit set and maturation of kinnow. All results like fruit set, maturation, juice content, and the number of seeds were positive and significant.

4.7 APICULTURE AND VEGETABLE SEED PRODUCTION

Availability of the desired quantity of quality seed is one of the most important aspect for a successful vegetable industry. For the production of such quality seed, sufficient or adequate cross-pollination of vegetable crops is essential, especially under mountain conditions. Further, many of the vegetable crops are completely or partly self-incompatible and incapable of pollinating themselves (Tewari and Singh, 1983b). Cross-pollination by honeybees is, therefore, important. Vegetable flowers in return are excellent sources of pollen and nectar for bees.

In the Hindu Kush-Himalaya, seed production of temperate vegetable crops was initiated in 1942-43, in Quetta, Baluchistan (Pakistan) by a private company. Simultaneously, vegetable seed production farms were established in Kulu (Himachal Pradesh) and Kashmir

Table 4.10: Floral biology and pollination requirements of fruit crops in the Hindu Kush-Himalayan region

(Per cent)

Crop	Per cent degree of cross-pollination	Ratio of pollinizer variety to main variety	Total bloom period	Peak receptivity period of stigma to pollen	Nectar or pollen potentials	Chief pollinators	Percentage bloom required for good fruit set	Increase in yield due to cross-pollination	Pollination requirements (No. of hives/ha)
Apple	All commercial varieties require cross-pollination	Every third tree in every third row should be a pollinizer	9 days	2–3 days	NP	Honeybees Bumblebees Halictus	50–95	180–6950	2
Almond	Cross-pollination essential	One pollinizer row for two rows of main variety	one month	3–4 days	N^1P^1	Honeybees Wildbees	90–100	50–75	5–8

Apricot	Cross-pollination beneficial and for some cultivars, it is essential	Same as for apple	15–20 days	4–5 days	NP	Honeybees	50–95	5–10	2.5
Black currants	Cross-pollination essential	No specific recommendation	21 days	5–6 days	N^2P^2	Honeybees	90–100	81–2200	Occur in wild state in the Hindu Kush-Himalayan region
Blueberry	Cross-pollination essential	No specific recommendation	21 days	5–8 days	NP	Honeybees Bumblebees	50–80	11–9800	Occur in wild state in the Hindu Kush-Himalayan region
Cherries	Cross-pollination is essential	One pollinizer for 10 trees of main cultivar	7–8 days	First two days after opening of flowers	N^1P^1	Honeybees	21–32	56–1000	2.5–3

Table 4.10 (Cont'd...)

(Per cent)

Crop	Per cent degree of cross-pollination	Ratio of pollinizer variety to main variety	Total bloom period	Peak receptivity period of stigma to pollen	Nectar or pollen potentials	Chief pollinators	Percentage bloom required for good fruit set	Increase in yield due to cross-pollination	Pollination requirements (No. of hives/ha)
Citrus	Vary from self-sterile to self-fertile form	No specific recommendation	1 month	6–8 days	N^2P^2	Honeybees	80–90	7–233	1–2
Cranberry	Cross pollination essential	No specific recommendation	2–3 weeks	3 days	NP	Honeybees Bumblebees	90–100	9–2153	1 hive per 2.5 ha
Gooseberry	Cross pollination essential	No specific recommendation	Less than one month	2–3 days	NP	Honeybees	90–100	29–300	No specific recommendation

Grapes	Self-fertile to self-sterile	Inter-planting of different cultivars essential	20–25 days	3 days	N^3P^3	Honeybees halictus	90–100	23–54	One
Guava	Cross-pollination beneficial	Every third row should be a pollinizer	25–45 days	1–2 days	N^3P^3	Honeybees	80–86	12	No specific recommendation
Litchi	Cross-pollination beneficial	Inter-planting of diffe-rent cul-tivars un-necessary	3 days 26–36 days	3 days	N^1P^2	Honeybees Flies, Ants, Wasps	50–90	4538–10246	No specific recommendation
Peach	Most vari-eties self-fertile and a few self-sterile	Same as for almond	20–24 days	3 days	N^1P^1	Honeybees	50–90	7–3788	1 to 2 in young orchard and 2.5 in old orchard

Table 4.10 (Cont'd. . .)

(Per cent)

Crop	Per cent degree of cross-pollination	Ratio of pollinizer variety to main variety	Total bloom period	Peak receptivity period of stigma to pollen	Nectar or pollen potentials	Chief pollinators	Percentage bloom required for good fruit set	Increase in yield due to cross-pollination	Pollination requirements (No. of hives/ha)
Pears	Partly or entirely self-sterile	"Barlett" variety be interplanted with other varieties	One week	4–5 days	$N^1 P^1$	Honeybees Flies Beetles	6–7	240–6014	1–5
Persimmon	Mainly self-fertile	No specific recommendation	25–30 days	3–4 days	—	Honeybees Bumblebees	75	21	No specific recommendation

Plums	Vary from self-fertile to self-sterile forms	Every fourth tree in every fourth row be a pollinizer	5 days	2 days	N[1]P[1]	Honeybees Bumblbees Blow flies	50–90	5–10	2.5
Rasberry	Cross-pollination beneficial	No specific recommendation	3–6 weeks	2–3 days	N[2]P[2]	Honeybees	90–100	291–463	1–2
Strawberry	Cross-pollination beneficial	No specific recommendation	45–60 days	3 days	N[2]P[2]	Honeybees Wild bees	90–100	5–10	1 to 10, 25 or even more

Source: Compiled from multiple sources.

Valley (North-West India). After partition in 1947, a vegetable seed production station was established in Katrain, Kulu Valley under the administrative charge of Indian Agricultural Research Institute, New Delhi (Gowda et al., 1986). Now temperate vegetable seeds are being produced in Solan, Kulu Valley, Kalpa Valley of Himachal Pradesh and also in Kashmir Valley Uttar Pradesh Hills by many private growers. Incidentally, most of these areas have a very old and rich tradition of beekeeping. Farmers kept bees in these areas for honey production, but they were quite ignorant about the role of honeybees in enhancing the yield and quality of vegetable seeds through cross-pollination. In recent years, with this new awareness, beekeeping is becoming an important and integral part of vegetable seed production technology. Among the Hindu Kush-Himalayan countries, India has taken the lead in making apiculture an essential component for vegetable seed production.

In India, the pollination requirements of different cultivars of cauliflower have been studied in great detail. A large number of insect pollinators visit cauliflower at the time of bloom and predominant among them are different species of honeybees, *Eristalis* sp., *Ceratina* sp., *Halictus* sp. (Kakkar, 1983; Verma and Joshi, 1983). Among the different species of honeybees, *Apis cerana* was found in maximum concentration (49.9 per cent). Adlakha and Dhaliwal (1979) reported that native *Apis cerana* was a better pollinator of cauliflower than the exotic *Apis mellifera*. Gupta et al. (1984a) reported that peak periods of foraging activities of honeybees on cauliflower were during noon and evening hours, and the minimum activity was observed during morning hours. Among the five different cultivars of cauliflower tested, honeybees preferred flowers of section-25, section-1 and snowball-16. Tewari and Singh (1983a) observed that *Apis cerana* preferred to visit the cauliflower bloom nearer the hive. For example, the maximum number of forager bees were observed at a distance of 12.5 m away from the location of the hive, and the minimum at 200 m. Fruit set, length of siliqua, number of seeds per stigma and yield of cauliflower seed decreased as the distance of flowering plants from the hive increased. Verma and Joshi (1983) reported that pollination by honeybees increased the percentage of setting buds by 44.70 to 74.20, the number of seeds per pod by 2.32 to 4.07, and weight of the single seed by 0.19 to 1.17 mgm in comparison to pollination by other insects and under controlled experimental conditions or self-pollination. Kumar et al. (1988) and Rao et al. (1984b) also confirmed the results of the earlier work that seed set and seed weight in cauliflower increased significantly due to bee pollination.

In the temperate Indian Himalaya, a large area of land is coming under off-season vegetable production which brings to the farmer four to five times higher income than the normal seasonal vegetables. Similarly, in other parts of the Hindu Kush-Himalaya, vegetable cultivation is expanding rapidly because of the change in the food habits of the people, and also because it is a source of cash income. Keeping this in view, the demand for high quality vegetable seed at a cheaper rate will increase tremendously in the future. One way to meet such demands will be through the utilization of pollination services of honeybees, and including beekeeping as an essential component of vegetable seed production technology. Data on the floral biology of different vegetable crops and their pollination requirements is summarized in Table 4.11.

4.7.1 Isolation Distance in Relation to Pure Seed Production

It is now well-documented that cross-pollination by honeybees helps in increasing 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. Foraging areas of the adult worker bees are always limited and they keep their foraging activities confined to this particular area only during their successive field trips to collect pollen, nectar or both. In cases where fields with compatible varieties/cultivars are quite adjacent, chances of intercrossing or contamination will be more. However, in distant fields with compatible varieties or cultivars, foraging areas of bee visits will not overlap, and pure seed production is possible. Such actual isolation distance would depend upon the degree of the purity of seed required, i.e. if the seed is being produced as foundation seed or certified seed by the grower. The actual distance required by the different vegetable crops for the production of pure seed is given in Table 4.11.

In Britain, the isolation distance required varies from 193 to 214 m for different crops. In Canada, isolation distances for certified, registered and foundation kinds of seeds are 46, 91 and 183 m respectively (Goyal and Kandoria, 1988). However, these figures have been taken from the work carried out in western countries, and no such information is available on this aspect under local ecological conditions of the Hindu Kush-Himalaya.

4.8 APICULTURE AND OILSEED PRODUCTION

Oilseeds play an important role in the national economy of many countries. Oils and fats derived from oilseeds not only constitute an essential part of human and animal diet but are also indispensable. It has been noticed that oilseed production in the Hindu Kush-Himalayan

Table 4.11: Floral biology and pollination requirements for vegetable seed production in the Hindu Kush-Himalayan region

Crop	Per cent degree of cross-pollination	Total bloom period	Peak receptivity period of stigma to pollen	Nectar or pollen potentials	Chief pollinators	Honeybee pollination requirements (number of hives per hectare)	Per cent 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	9 days	N^2P^3	Honeybees Bumblebees Wildbees Flies	5	100–300	3000 for breeder seed and 1500 for certified seed
Tomato	Less than 2	12–15 days	4–8 days	P	Solitary bees Thrips Honeybees	No specific recommendations	No specific data	250–400
Chilli Pepper green Pepper chilli	7–36	2–3 days	2 days	NP	Honeybees Ants	No specific recommendation	No specific data	200 for foundation seed and 100 for certified seed

Radish	85	2 days	A few hours in a day	N^3P^3	Honeybees only	5	22–100	1600 for foundation seed and 1000 for certified seed
Carrot	Mainly cross pollinated	1 month	One week or longer	N^3P^3	Honeybees House flies	8 bees per square metre	9–135	1000
Turnip	Mainly cross pollinated	22–30 days	2–3 days	N^2P^2	Honeybees	2.5	100–125	1600 for foundation seed and 1000 for certified seed
Cucurbits	60–80	1 day	2 hours	N^2P^2	Honeybees Halictus	2–4	21–6700	800–1000
Okra	4–42	After sunrise till noon	2 days	N^3P^3	Honeybees Bumblebees	None	No specific recommendation	No specific recommendation

Source: Compiled from multiple sources.

region is either stagnant or declining gradually (Rao et al., 1984b). Efforts are being made by different Government of the region to bring more area under oilseed production in order to meet the growing demand. One way of increasing oilseed production is by introducing a planned honeybee pollination programme as one of the essential inputs which has not been so in this region. The main reason for which is ignorance on the part of the agriculture extension agencies and farmers.

Among the important oilseed crops, groundnut, mustard, sesame, safflower, niger and sunflower are extensively grown in this region. Since most of these crops, except groundnut, are cross-pollinated, adequate pollination is vital for increasing the yield per unit area of the land. It is also now well-documented that pollination by honeybees ensures uniform maturity and early harvest of these oilseed crops,thus facilitating timely sowing of the next crop in rotation. The percentage increase in yield due to honeybee pollination in different oilseed crops is given in Table 4.12 along with the pollination requirements and floral biology of these crop plants. Rao et al. (1984b) has shown that in India, honeybee pollination also enhances the oil contents of seed crops. For example, there was 6.5 per cent increase in the oil content of the seed harvested from honeybee-pollinated flowers of sunflower.

In view of such encouraging results, farmers in India are being given honeybee pollination demonstrations by different extension agencies in various parts of the country to create awareness of the beneficial effects of honeybee pollination. Panchabhavi and Deviah (1977) Panchabhavi et al. (1976) and Thakar (1974) reported that *Apis florea* was the main pollinator of sunflower plants. Deshmukh et al. (1985) reported *Apis cerana* and *Apis dorsata* were the main insect pollinators of safflower. As a result of bee pollination, seed yield of the this oilseed crop increased by 23 and 28 per cent in NRS-209 and No. 83 cultivars, respectively. Similarly, Pande et al. (1988) also observed that, both in bee-pollinated as well open-pollinated flowers of sesamum and niger, an increase up to 50 to 59, and 22 to 33 per cent, respectively was found respectively as compared to control experiments. Thakur et al. (1982) compared the foraging behaviour of *Apis cerana* and *Apis mellifera* on mustard in the Kangra valley (Himachal Pradesh). *Apis cerana* initiated foraging activity earlier in the morning, whereas *Apis mellifera* ceased foraging later in the evening. In both species, the pollen collectors outnumbered the nectar collectors and the peak periods of foraging activity were recorded at 1200 to 1400 and 1530 hours.

4.9 MISCELLANEOUS CROPS

1) Fodder crops

Improvement of animal products such as beef, pork, poultry, lamb or dairy products, is strongly dependent upon improving the quality and quantity of fodder and livestock ration feed. Availability of such quality fodder in sufficient quantities would depend upon reliable, cheap and good quality seed supplies. Three conventional components of seed quality (i.e. physical, genetical and vital quality) are greatly improved if the flower in bloom is pollinated by honeybees. Many of the fodder crops are dependent on or benefited by honeybee pollination. Major fodder crops grown in the Hindu Kush-Himalayan countries are alfalfa, clover, trefoil, vetch and sainfoil. For all these crops, cross-pollinating is either essential or beneficial to enhance their seed production. Floral biology and pollinating requirements of these crops have been summarized in (Table 4.12).

2) Cardamom (Ellettaria Cardamom)

Cardamom is one of the world's costliest seed species. It is also a cross-fertilized crop and depends exclusively upon honeybees for pollination. A large number of insect pollinators such as different species of honeybees, wild bees, ants, thrips and aphids visit cardamom flowers. However, honeybees are the main pollinators constituting more than 88 per cent of the total insect pollinators. Even a single visit to a cardamom flower by *Apis cerana* is enough for fruit set (Siddappaji and Channabasavanna, 1983, Chandran et al., 1983). Joseph and Mohandas (1985) recommended four colonies per hectare for effective cardamom pollination. Pattanshetti and Prasad (1973, 1974) reported 66 and 11 per cent fruit set and 27.4 and 2.1 seed pods per panicle from bee-pollinated flowers and control experiments, respectively. Similarly, Chandran et al. (1983) observed 37.2 and 21.9 per cent fruit set from honeybee-pollinated and open-pollinated flowers.

Verma (1987) reported that greater Cardamom (*Amomum subulatam*); an important spice crop of sub-Himalayan region, is greatly benefited by bee pollination. *Apis* sp. constituted more than 60 per cent of the insect pollinators. In open-pollinated flowers, the per cent fruit set, green and dry fruit weight, number of seeds per capsule were significantly more than in bagged inflorescences with no access to insects at all.

3) Buckwheat

Buckwheat, an underutilized genetic resource in the Hindu Kush-Himalayan region, is unable to self-pollinate, and honeybees are es-

Table 4.12: Floral biology and pollination requirements for oilseed and fodder crops in the Hindu Kush-Himalayan region

Crop	Per cent degree of cross-pollination	Total bloom period	Nectar or pollen potentials	Chief pollinators	Per cent increase in yield due to cross pollination	Pollination requirement number of hives per hectare	Isolation distance in metres
Mustard	Mainly cross-pollinated	3 days	P^1N^2	Wind Honeybees	13 to 222	2.5 to 5	–
Sarson (rape)	Mainly cross-pollinated	22–45 days	P^1N^2	Honeybees Bumblebees Beetles	131.63	2–6	—
Safflower	5 to 40	10–40 days	P^2N^2	Honeybees	4–114	2	—
Sesame	5–65		P^1N^1	Honeybees	24.41	No specific recommendation	180–360
Sunflower	20–75	2 or more days	P^2N^2	Honeybees Bumblebees	21–3400	1 to 2 and for hybrid seed production 2 to 4	800

Alfalfa	Mainly cross pollinated. Bees are necessary for tripping	One week	P^1N^2	Honeybees Wild bees	23–19733	5–10	
Trefoil	Cross-pollination necessary	8–10 days	P^1N^1	Honeybees Bumblebees Wildbees	900	2	
Clovers	Cross-pollination essential	—	P^2N^2	Honeybees	40–33150	2–5	
Vetch	Cross-pollination beneficial	—	P^3N^3	Honeybees Bumblebees	39–20000	Several colonies	3
Sainfoin	Cross-pollination essential	—	P^1N^2	Honeybees	2815	2–3	90

Source: Compiled from multiple sources.

sential for its cross-pollination. It is an excellent sources of nectar to which large numbers of bees get attracted. Farmers in the entire Hindu Kush-Himalaya harvest surplus honey from this plant. According to Deodikar and Suryanaryana (1977) due to bee pollination, buckwheat seeds yield can be increased by 63 per cent. For optimum seed set, two-and-a-half to eight colonies per hectare have been recommended in Canada or the USSR (Crane and Walker, 1984).

4.10 APICULTURE AND PESTICIDES

Beekeeping and pesticides are both essential inputs of modern agriculture management technology. By ignoring either of the two, global food production would be seriously impaired. Since the advent of synthetic pesticides several decades ago, the beekeeping industry, both in the developed and developing countries, has been incurring heavy losses. In developed countries large-scale monoculture cultivating of crops and a high degree of mechanization has greatly amplified the problem of honeybee poisoning by pesticides. On the other hand, in developing countries the basic problem is lack of information about the harmful effects of pesticides to honeybees. Side-by-side agricultural scientists also prescribe pesticides indiscriminately. With the tremendous increase in apple cultivation in the Hindu Kush-Himalayan region, the incidence of pest and diseases has increased which is adversely affecting crop yields. Apple blossom thrip, a serious pest of apple especially at the time of flowering, requires insecticide application for its effective control. Similarly, apple scab caused by *Venturia inaequalis* has gradually spread to all the apple-growing areas of the Hindu Kush-Himalayan region, crossing the high mountain barriers. For example, in 1983, the severity of the disease was such that more than 25 per cent of the crop was destroyed. Therefore, in Himachal Pradesh the use of fungicides has become necessary as these chemicals act as protectants against this disease. Other insecticides, fungicides and herbicides are also coming into use in orchard management, and attention needs to be paid to their effects on insect pollinators, especially honeybees. Such over-reliance on chemical methods for the control of pests and diseases is also causing serious pollution problems. Fruit growers in this region use blanket applications. This is caused by a lack of knowledge as to what and how much to use, and when. As a result of this, there is a danger of the extinction of wild pollinating insects due to the excessive use of pesticides. Unlike developed countries, there is also a lack of legislation to prohibit the use of pesticides to the extent that it kills bees. Thus, there is a need to develop integrated pest-management strategies for protecting honeybees from broad-spectrum biocides. Literature on pesticides in relation to beekeeping has been reviewed by Adey et al., 1986; Crane and Walker, 1983; Anonymous, 1981; Anderson and Atkins 1968; and Indian Standards Institution (1973a, b).

4.10.1 Bee Poisoning Symptoms

One of the obvious signs of poisoning is the presence of a large number of dead or dying bees at the hive entrance. These adult bees are foragers who would have made contact with pesticides sprayed on flowering plants. The mortality figures in Table 4.13 are used as guidelines to assess the extent of bee poisoning by pesticides.

Table 4.13: Extent of bee poisoning by pesticides

Number of dead bees per day at entrance	Level of poisoning
100	Normal death rate
200– 400	Low
500–1000	Medium
Over 1000	High

Source: FAO Bulletin 68/3, 1988.

As a result of organophosphorus poisioning, dying bees extend their tongue through which nectar is regurgitated and a moist and sticky mass of dead bees is often found at the hive entrance. The fast-acting insecticides kill the foraging bees in the field itself, and only a small number of such bees manage to return to the hive. Sometimes, the whole bee colony may die instantly. Strong bee colonies suffer greater losses due to pesticide poisioning than the weaker ones because the former have a larger foraging bees.

Foraging bees often carry residual pesticides into the hive in their pollen loads. As a result of this, the behaviour of bees in the hive changes abruptly. Honeybees in such colonies become more agitated or aggressive. As and when the hive with pesticide-affected forager bees is opened, they often fly off the top bars of the hive and sometimes straight into the face of the beekeeper handling them. Other symptoms of pesticide poisoning include stupefaction, paralysis, abnormal, jerky or spinning movements. Carbaryl poisoning causes bees to crawl around at the hive entrance, they lose their ability to fly, and ultimately die in two to three days after poisoning.

Nurse bees in pesticide-affected colonies lose their ability to clean the dead bees from the hive, as a result of which the hive entrance is completely blocked.

Pesticide poisoning also affects the colony strength because there is a break in the brood rearing cycle and often dead or deserted colonies cease foraging, as a result of which there is a sharp decline in food storage, and incoming foragers are attacked at the hive entrance by other bees.

4.10.2 Protective Strategies Recommended

i) As far as possible, biocide applications should always be recommended outside the blooming period.

ii) Pesticides which have short residual effects and are the least hazardous to honeybees should be selected.

iii) Ignorance and lack of extension programmes to educate the farmers about the harmful effects of pesticides is the biggest problem in developing countries. Both the orchardists and beekeepers should be educated properly about pesticide application schedules and how to reduce poisoning in a particular area.

iv) Broad-spectrum pesticides should be avoided as they are much more hazardous than selective pesticides which are safer for bees and other beneficial insects.

v) Night or early morning application of pesticides is always desirable because foraging honeybees are at that time in the hive and thus out of danger. Night application of pesticides allows adequate time for the pesticide to dissipate or break down to substances non-toxic to bees.

vi) It has been recognized that spray or liquid formulations are safer than dust or wettable powder formulations. There is an almost sixfold greater kill with powder formulations than with liquid ones. The addition of solvents or oily substances to spray material reduces bee losses significantly.

vii) Insecticide formulations can be classified as follows in order of their toxicities:

Dust > wettable powder > flowable > emulsifiable concentrate or soluble powder or liquid solution > granular formulation (Johansen and Kleinschmidt, 1972).

viii) It is always advisable to keep bee colonies as far away from the pesticide-treated fields as possible. Even a distance of 1 km from the site of the spray will reduce honeybee mortality ninefold.

ix) Remove all the flowering weeds from the orchards either by mowing or beating so that they do not act as a source of poison to the bees. This practice will force the bees to forage in longer distances, free from the adverse effect of pesticides.

x). In the temperate Hindu Kush-Himalayan regions, residues would remain toxic for a longer time due to lower temperatures. But at the same time, low temperatures delay the initiation of foraging activities of honeybees in the morning. Keeping this in view, pesticide application times should be shifted accordingly.

xi) Primary emphasis should be on the use of an integrated pest management programme which mainly relies on biological or cultural methods of insect-pest control and minimizes the use of poisonous chemicals.

4.10.3 Relative Toxicity of Some Biocides to Asian Hive Bee, *Apis cerana*

In several developing countries of southeast Asia, beekeeping with *Apis cerana* has been sustaining heavy losses since the advent of synthetic pesticides several decades ago. Such widespread and careless use of toxic pesticides during the blooming periods of agricultural and horticultural crops not only kills bees but also contaminates hive products.

In India several research workers have compared the relative toxicities of commonly used pesticides on *Apis cerana*, and these have been classified as highly toxic, moderately toxic and non-toxic. The results of these investigations are reviewed as follows:

Group I: Highly toxic insecticides

Application of these pesticides on blooming crops or weeds may cause severe damage to bees. Beekeepers should be warned in advance by the growers when these insecticides are to be used so that they can move the colonies temporarily to safer locations. Even after 10 hours of spray these pesticides are still highly toxic to bees.

Insecticide	*Reference*
Carbaryl 50% WP	Bai and Reddy (1977) Singh *et al.* (1974)
Carbofuran 3% WP	Bai and Reddy (1977)
Carbophenothion 20 EC	Bai and Reddy (1977)
Cypermethrin 10 EC	Prakash and Kumaraswami (1984)
Decamethrin 20 EC	Prakash and Kumaraswami (1984)
Dichlorovos 100 EC	Bai and Reddy (1977)
Dimethoate 30 EC	Attri and Sharma (1969), Singh *et al.* (1974)
DDVP 100 EC	Singh *et al.* (1974)
Monocrotophos 36 WSC	Rana (1989) Bai and Reddy (1977)
Oxydemeton-methyl 25 EC	Bai and Reddy (1977)
Parathion	Kapil and Lamba (1974)
Phosphamidon 100 EC	Bai and Reddy (1977) Kapil and Lamba (1974) Singh *et al.* (1974)

Phorate	Kapil and Lamba (1974)
Permethrin 25 EC	Prakash and Kumaraswami (1984)
Quinalphos 25 EC	Bai and Reddy (1977)
Sumithion 50 EC	Rana (1989)
Thiometon 25 EC	Attri and Sharma (1969)
	Singh *et al*. (1974)

Group II: Moderately toxic insecticides

The following pesticides should be applied during late evening when bees are not actively foraging. Bee hives should not be directly exposed to these insecticides. For minimal hazards to honeybees, the dose, the timing and the application methods are very important.

Insecticide	*Reference*
BHC 50 per cent	Bai and Reddy (1977)
Carbyl 50 WP	Prakash and Kumaraswami (1984)
DDT 50 per cent	Bai and Reddy (1977)
Dieldrin	Kapil and Lamba (1974)
Endrin	Kapil and Lamba (1974)
Hinosan 50 EC	Thakur *et al*. (1981)
Heptachlor 10 WP	Bai and Reddy (1977)
Malathion 50 EC	Singh *et al*. (1981)
Methyl demeton	Kapil and Lamba (1974)
Monocrotophos 40 EC	Prakash and Kumaraswami (1984)
Trichlorfan 50 EC	Thakur *et al*. (1981)
Diazinon 20 EC	Singh *et al*. (1981)
Ethyl parathion 46%	Singh *et al*. (1981)
Fenitrothion 100 EC	Thakur *et al*. (1981)
50 EC	Bai and Reddy (1977)
Fenthion 100 EC	Thakur *et al*. (1981)
Formothion 25 EC	Kapil and Lamba (1974)
	Singh *et al*. (1981)
Gamma BHC 20%	Singh *et al*. (1981)
Lindane	Kapil and Lamba (1974)
Metacid 50 EC	Rana (1989)
Metasystox 50 EC	Rana (1989)
25 EC	Attri and Sharma (1969)
	Singh *et al*. (1981)
Mevinphos	Kapil and Lamba (1974)
Methyl parathion 50 EC	Bai and Reddy (1977)
	Singh *et al*. (1981)

Moderately toxic fungicides

Insecticide	*Reference*
Dithane M-45 75 WP	Rana (1989)
Foltaf 80 WP	Rana (1989)
Difolitan 50 WP	Rana (1989)
Hexacap 50 WP	Rana (1989)
Bavistin 50 WP	Rana (1989)

Group III: Relatively non-toxic insecticides

These pesticides cause minimum damage to the bees. They should be applied during late evening, night or early morning.

Insecticide	*Reference*
Endosulfan 35 EC	Attri and Sharma (1969)
Menazon 70 DP	Singh *et al.* (1981)
Phosalone 35 EC	Prakash and Kumaraswami (1984)