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The Role of Beekeeping in the Development of Horticulture in the Himalayan Mountains of India

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At present, several countries of the Hindu Kush-Himalaya are making desperate efforts to achieve self-sufficiency in food production by physical expansion of the area under cultivation and better management of resources. This includes use of better quality seeds and animals, bringing more waste land under cultivation, the use of fertilizers and pesticides, and more irrigation. However, in the past decade or so, food production has come to a point of stagnation for some cultivated crops. Emphasis in the future, therefore, should be on the full use of underused resources. One resource which concerns us here is an increase in the yield of various cultivated crops through cross-pollination by honey bees. The vital role which honey bees play in the pollination of large numbers of agricultural and horticultural crops is often underestimated. As a matter of fact, the main significance of honey bees and beekeeping is pollination; hive products, such as honey and beeswax, are of secondary value. This is evidenced by the fact that income from agriculture by the use of honey bees for 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 honey bees and other wild insects. Cross-pollination of entomophilous crops by honey bees is one of the most effective and cheap methods of increasing their yield. Other agronomic practices such as the use of manure, fertilizers, pesticides, and irrigation are cost-effective, but they may not yield the desired results without the use of honey bees to enhance the productivity levels of different cultivated crops through pollination. It is not only the self-sterile varieties or cultivars which require cross-pollination, but also the self-fertile forms, which produce more and better quality seeds and fruits if pollinated by honey bees and other insects.

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

In recent years, a number of techniques have been developed to increase the productivity of certain agricultural crops through cross-pollination by honey bees. These include the use of pollen dispensers, pollen bombs, scent training of bees, development of high and low preference strains of honey bees through selective breeding for pollination of specific crops, domestication and use of non-*Apis* pollinators, and safeguarding bees against pesticides. All these techniques are at present used only in developed countries; however, there is now growing awareness in the developing countries of the fact that agricultural crops give better yield and higher financial returns if honey bees are used for 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 in increasing the yield of cross-pollinated crops different species of honeybees and solitary bees are being utilized in North 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 are under temperate fruit cultivation and they require more than 2,00,000 colonies of honeybees against the present number of 10,000. The population of non-*Apis* pollinators is declining at an alarming rate owing to growing deforestation, the clearance of waste land for cultivation and increased use of pesticides. This makes domesticated hive bees essential for pollination. In addition to pollinating temperate fruits, both species (*Apis cerena* and *Apis mellifera*) are also being utilized for the pollination of vegetables, oil seed crops and clovers. Himachal Pradesh has taken the lead in renting *A. cerana* colonies to orchardists for the pollination of apple crops. This programme has helped to create awareness among the orchard owners about the importance of honeybees for pollination.'

Advantages of Bee Pollination

Honey bees are the most efficient pollinators of several cultivated and wild plants because:

- Their bodies are specially adapted to pick up pollen grains.
- They show flower fidelity and constancy.
- They have long working hours.

- They micro-manipulate flowers.
- They maintain high populations when and where needed.
- They are adaptable to different climates and niches.

As a result of cross-pollination by bees, somatic, reproductive, and adaptive heterosis or hybrid effects occur in plant progeny, either singly or in different combinations. Such hybrid effects bring the following qualitative and quantitative changes in the economic and biological character of plants:

- stimulate germination of pollen on stigmas of flowers and improve selectivity in fertilization
- increase viability of seeds, embryos, and plants
- form more nutritious and aromatic fruits
- increase vegetative mass and stimulate faster growth of plants
- increase number and size of seeds and yield of crops
- enhance resistance to diseases and other adverse environmental conditions
- increase nectar production
- increase oil content in oilseed crops
- increase fruit set and reduce fruit drop

Deodikar and Suryanarayanan (1977) have reported the following increase (in percentage) is seed or fruit yield in various crops due to bee pollination:

Oilseeds (seed yield)	
Linseed	2–49
Mustard	13–222
Niger	17
Safflower	4–114
Sunflower	21–3400
Fodder and grain legumes (seed yield)	
Alfalfa	23–19,733
Beans	3–1000
Bird's foot trefoil	900
Clovers	40–3315
Sainfoin	2815
Vetches	39–20,000
Vegetables (seed yield)	
Asparagus	12,405
Cabbage	100–300
Carrot	9–135
Onion	354–9878
Radish	22–100
Turnip	100–125
Orchard crop (fruit yield)	
Apple	180–6950
Black currant	81–2200

Contd.

Blueberry	11–9800
Cherry	56–1000
Citrus	7–233
Cranberry	19–2153
Cucumber and squash	21–6700
Gooseberry	29–300
Grape	23–54
Guava	12
Litchi	4538–10,246
Peach	7–3788
Pear	244–6014
Persimmon	21
Plum	536–1655
Raspberry	291–463
Strawberry	17–92
Buckwheat	63

Principles of Bee Pollination

Most of the investigations of crop pollination have been carried out in developed countries where the European honey bee, *Apis mellifera*, has been extensively used to increase the yield of different cultivated crops. However, there is very little information available on the role of the Asian hive bee, *A. cerana*, in pollinating agriculture crops in the developing countries of south and southeast Asia. Both these species of honey bee, however, show remarkable similarities in foraging behaviour, thus, the basic principles involved in crop pollination by them should not differ significantly. The efficiency of a bee colony as pollinator would depend upon the following 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. Good honey-yielding colonies are better and more efficient pollinators also. It has been estimated that one colony of *A. mellifera* with 60,000 worker bees produces one and a half times more honey than four colonies with 1500 bees each. The same is true for pollination activity also. The strength of a colony depends upon the honey bee breed, the availability of nectar and pollen plants as food resources, and the management practices employed, and also upon the season. In the Hindu Kush-Himalayan countries, during winter the colony strength is poor because of low temperatures and dearth of bee flora. In early spring, when honey bee colonies are required for the cross-pollination of apple blossom in this region, these colonies do not build up enough strength for effective pollination. Keeping in view this constraint, apple growers in Himachal Pradesh move their colonies to lower altitudes, where winters are warmer and there is no dearth of bee flora, so that in spring, at the time of apple blossom, they are available in adequate strength for effective pollination.

Number and Time of Placement of Colonies for Pollination

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

- density of plant stand
- total number of flowers in inflorescence of one plant
- number of flowers over an area of one hectare of land
- duration of flowering
- strength of bee colonies.

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

Distribution of Colonies in the Field or Orchard

Honey bees, as a rule, primarily visit 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, 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 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. Honey bees always tend to forage in the area closest to the hive, particularly when the weather is not favourable.

Time of Placement of Colonies in the Field or Orchard

Bee colonies should be placed in the field or orchard when 5 to 10 per cent crop is in bloom. Earlier placement of colonies would result in foraging of the bees on other weeds and wild plants present in the vicinity of the orchard and their ignoring the crop in bloom. If the bees are moved late, they only pollinate the late and less vigorous flowers.

Weather Conditions

Weather plays an important role in determining the success or failure of pollination programmes, as it affects bee activities as well as seed or 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 by frost injury and also adversely affect the foraging activities of bees. As reported earlier, native hive bee *A. cerana* can forage at lower temperatures than its European counterpart, *A. mellifera.* 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 or orchard should be provided.

Attracting Bees to a Crop in Bloom

Russian bee scientists have strongly advocated the theory that bees should be fed a flavoured syrup of the flowers required to be pollinated in order to attract large numbers of them for effective pollination. This seems to be a logical approach, but in practice does not always yield the desired results. In Sweden, Canada, and the United States, various research workers have also tried essential oils or flavours, especially from apple flowers, and their results are inconclusive.

Another method of attracting bees to a particular crop in bloom is by sowing a high nectar-yielding crop among other crops that 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 quantity of nectar. However, if other nectariferious plants such as buckwheat are sown nearby, a larger number of bees are attracted to sweet clover. A crop to be pollinated can also be made more attractive to honey bees if nectar production is increased by breeding techniques or by improving other agronomic practices such as addition of fertilizers and manure or better irrigation facilities.

Apple Pollination in Hindu Kush-Himalaya

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

	Area ('000 hectares)	Production ('000 mt)
Arunachal Pradesh	4.821	3.373
Himachal Pradesh	52.380	259.320
Kashmir	65.107	723.826
Uttar Pradesh	52.00	170.00
North West Frontier Province (Pakistan)	19	212.000
Bhutan	3.656	4.6
Nepal	5.00	50.000

These figures show that in 1986/87, more than 200,000 hectares of land of Hindu Kush-Himalayan region was under apple cultivation. Every year approximately 10 per cent of the total area already under apple cultivation is being added and according to this estimate, about 250,000 hectares of land should be under this crop in the entire region of the Hindu Kush-Himalaya.

With such a drastic increase in the area coming under apple cultivation, some management problems inevitably have arisen. The major problem has been found to be in pollination. The Delicious and other commercial varieties of apple are self-incompatible and require cross-pollination by honey bees. The population of non-*Apis* pollinators is declining at an alarming rate due to growing deforestation, vast clearance of wasteland, and increasing use of pesticides. The most effective way of assuring adequate pollination is through the introduction of honey bees into the orchard at the time of blossoming, a practice well developed for apples in Canada, Europe, Japan, and elsewhere.

Most of the orchards of the Hindu Kush-Himalayan region are small (about 1 hectare or less) and owned by local farmers. Thus, each orchard requires about three hives of bees (this figure is only an educated guess). A conservative estimate of the number of beehives needed exclusively for pollination of the apple crop 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 available for beekeeping is not *A. mellifera*, but the native Asiatic honey bee, *A. cerana*. At present, there are only a few thousand colonies of *A. cerana* kept in modern hives by 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 corresponding increase in pollination resources and technology through availability of appropriately managed beehives. It is not surprising that it has been noticed that many orchards do not bear sufficient fruit because the population of bees is too small. Moreover, with the increased 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 the domesticated hive bee essential for pollination and beekeeping an essential part of fruit production.

A large horticulture undertaking such as that of the Hindu Kush-Himalayan region cannot 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 spent on hive rental, pollination, and honey production.

Distribution, Abundance and Diversity of Insect Pollinators in the Shimla Apple Orchards

According to Verma and Chauhan (1985), insects visiting apple blossom comprised 44 species belonging to 14 families and 5 orders. Of these, 16 species belonged to Hymenoptera, 11 to Diptera, 9 to Lepidoptera, 7 to Coleoptra and 1 to Hemiptera (Table 13.1).

Data on the relative abundance of different insect pollinators in the Shimla hills indicated that *A. cerana* constituted 24.01 to 43.03 per cent of the total pollinator population.

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

The relative abundance of all the insects varied from place to place. Differences in the environmental conditions, location and altitude of orchards are possible reasons for such variation (Verma and Chauhan, 1985).

Role of Honey Bees in Yield and Quality of Apple in Shimla Hills

Most of the commercial varieties of apple give good yields only after cross-pollination. Cross-pollination is done mostly by insects, the role of wind in cross-pollination of apple bloom being negligible because of the heavy and sticky nature of apple pollen. Honey bees are the most efficient pollinators among insects because they can be managed in sufficient numbers and show flower constancy (Free, 1970). 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 honey bees 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. Dulta and Verma (1987) studied the role of honey bees on fruit set, fruit drop, and fruit quality of apple in the Shimla hills of Himachal Pradesh.

The following experiments were conducted in three different apple orchards of 0.8 hectare each, located in Kotkhai and Jubbal area of Himachal Pradesh (India) at heights of 1350, 1875, and 2400 m above sea level, to study the effect of honey bee pollination on fruit set, fruit drop, and quality of apple:

- No insect pollinator
- Open-pollinated flowers (natural insect pollinators)

TABLE 13.1

Insect species visiting apple flowers with their taxonomic status in Northwest Himalaya

Order				
HYMENOPTERA	DIPTERA	LEPIDOPTERA	COLEOPTERA	HEMIPTERA
Family and Species				
APIDAE	DIPTERA	NOCTUIDAE	COCCINELLIDAE	PENTATOMIDAE
Apis cerana	*Musca* sp.	*Plusia onchaicea*	*Cocinella*	*Apodiphus* sp.
Apis mellifera	*Orthelia* sp.	*Heliothis armigera*	*septumpunctata*	
Bombus tunicatus		*Agrotis flammantra*		
Bombus sp.	SYRPHIDAE	*Agrotis ipsilon*	CHRYSOMELIDAE	
Bombus sp.	*Melanosatma*		*Altica* sp.	
	Eristalis tenax	NUMPHALIDAE	*Alticinae* sp.	
NANTHOPHORIDAE	*Eristalis angustimarginalis*	*Neptis* sp.	*Nonartha variabilis*	
Anthophora sp.	*Eristalis arvorum*	*Vanessa cashmirensis*	*Minastra cymura*	
	Eristalis sp.			
HALICTIDAE	*Epilobium bolteatus*	PIERIDAE	SCARABAEIDAE	
Nomodo sp.	*Scaeva pyrastri*	*Pieris canidia*	*Protaetia neglecta*	
Halictus dasygaster	*Metasyrphus corollae*	*Delias belladona*	*Brahmina crinicolis*	
Halictus sp.	*Macrosyrphus* sp.			
Halictus sp.		LYCAENIDAE		
Xylocopa sp.		*Heodes* sp.		
VESPIDAE				
Polistes maculipennis				
Vespa magnifica				
Vespa auraria				
Vespa flaviceps				
ICHNEUMONIDAE				
Netalia tatra				

Source: Verma and Chauhan (1985).

- Honey bee-pollinated flowers

The results are summarized in the following paragraphs:

Effect of Insect Pollinator on Fruit Set

In self-compatible varieties such as Golden Delicious, the percentages of fruit set in control, open, and honey bee-pollinated flowers were not significantly different. Similarly, in another self-compatible variety, Red Gold, the percentage of fruit set in control, open and honey bee-pollinated flowers did not differ significantly. These small differences in fruit set for Golden Delicious and Red Gold under different conditions could be due to the self-compatibility of these varieties. In self-incompatible 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 in honey bee-pollinated flowers of Royal Delicious (23.33 per cent) and Red Delicious (19.69 per cent) than inopen-pollinated flowers of Royal Delicious (13.21 per cent) and Red Delicious (11.42). 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 (Table 13.2). The higher fruit set in honey bee-pollinated flowers than in open-pollinated flowers suggested that the degree of cross-pollination by honey bees was certainly higher than that of other natural insect pollinators.

TABLE 13.2

Percentage of fruit set and fruit drop in three experimental conditions

Varieties	Honey bee-pollinated flowers (H)	Open-pollinated flowers (O)	No insect pollinator (C)
Golden Delicious	34.53 (25.22)	30.73 (27.62)	24.57 (38.45)
Red Gold	22.45 (25.02)	18.34 (28.38)	15.76 (38.07)
Royal Delicious	23.33 (25.50)	13.21 (28.69)	0.00 (0.00)
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 Royal Delicious and Red Delicious: $H > O > C$ ($P > 0.01$).
For fruit drop in Golden Delicious and Red Gold: $C > O, H$ ($P < 0.01$).
$P < 0.01$ = Highly significant.
Source: Dulta and Verma (1987)

Effect of Insect Pollinators on Fruit Drop

The fruit drop in self-compatible varieties of apple was significantly higher from flowers under controlled conditions then for fruits from open and honey bee-pollinated flowers. For example, in Golden Delicious and Red Gold, the fruit drop was maximum (38.45 and 38.07 per cent respectively) under control, and minimum (25.22 and 25.02 per cent respectively) in honey bee-pollinated flowers. In open-pollinated flowers of Golden Delicious and Red Gold, the fruit drop was 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 honey bee-pollinated flowers were 28.69 and 25.50 per cent respectively, without any significant difference. The same trend was observed in the other self-incompatible variety, Red Delicious, where the fruit drop in open and honey bee-pollinated flowers was 28.86 and 25.73 per cent respectively with no significant difference. The high percentage of fruit drop in controlled experiments was due to poor pollination whereby the number of ovules fertilized was less (Table 13.2).

Effect on Fruit Quality

In Golden Delicious, there was an increase in the weight, length, breadth, volume, and number of seeds per fruit by 22, 9, 7, and 17 per cent respectively in the fruits which developed from flowers exclusively pollinated by honey bees as compared to open-pollinated flowers; in Red Gold, the weight, length, breadth, volume, and number of seeds per fruit increased to 18, 9, 9, 9, and 32 per cent respectively. In these two self-compatible varieties, fruits from honey bee-pollinated flowers were greater in number than fruits from open pollinated flowers, which were greater in number than fruits from control ($P > 0.01$).

In Royal Delicious, 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 honey bees as compared to 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 honey bees was 19, 9, 10, 16, and 30 per cent respectively as compared to fruits developed from open-pollinated flowers. In these self-incompatible varieties, the quality of fruits from honey bee-pollinated flowers was significantly better ($P < 0.010$) than that of fruits from open-pollinated flowers. The improvement in the quality of fruits due to cross-pollination by honey bees (also other natural insect pollinators) might be a result of heterosis. The increase in weight, size, and volume of the fruits which developed from honey bee-pollinated flowers might be due to a greater number of seeds per fruit (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 13.3). The better pollinating efficiency of the honey bee helps in the fertilization of the maximum number of ovules and thereby more seeds are formed. In this way, the maximum amount of auxin, a growth hormone, is produced, which results in larger fruit.

Comparative Foraging Behaviour of A. cerana and A. mellifera on Apple Bloom

Verma and Dulta (1986) studied the comparative foraging behaviour of *A. mellifera* and *A. cerana* on apple bloom and the results of their investigations are reviewed. Worker bees of *A. cerana* started their foraging activities earlier in the morning (mean time, 0603 hours) than *A. mellifera* (mean time, 0627 hours). In the evening, *A. mellifera* ceased its foraging activity earlier (mean time, 1855 hours) than *A. cerana* (mean time, 1913 hours). Thus, average duration of foraging activity in *A. cerana* was 13.10 hours and in *A. mellifera*, 12.28 hours (Table 13.4).

The mean duration of a foraging trip by *Apis cerana* and *Apis mellifera* was 11.85 and 17.92 minutes respectively. Thus the duration of a foraging trip was significantly longer for *Apis mellifera* ($P < 0.01$) than for *Apis cerana* (Table 13.4).

Observation at three different times of the day (0.900, 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 ($P < 0.0.$) than pollen collectors (Table 13.5).

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 13.5). 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 number of pollen collectors of *Apis cerana* and *Apis mellifera* (Table 13.5). Nectar gatherers of *Apis mellifera* were significantly more ($P < 0.01$) than that of *Apis cerana* at 0900 hours, whereas at 1200 hours, the trend was significantly more ($P < 0.01$) than that of *Apis mellifera*. At 1500 hours, there was no significant different ($P < 0.01$) in the number of nectar collectors of both the species (Table 13.5). Pollen plus nectar collectors of *Apis mellifera* were maximum at 1200 hours (Table 13.5).

Observations made on hourly fluctuations in the number of bees leaving the hive per five minutes showed that peak activity of *Apis cer-*

TABLE 13.3

Effect of insect pollinators on quality of apple fruit in different cultivars grown in Northwest Himalaya

Variety	Honey bee-pollinated flowers (H)				Open-pollinated flowers (I)				No insect pollinator (control I)			
	Weight	Length	Breadth	Seeds (no.)	Weight	Length	Breadth	Seeds (no.)	Weight	Length	Breadth	Seeds (no.)
A. Golden Delicious	208.88	7.34	7.74	8.92	188.00	6.76	7.26	8.11	104.44	5.58	6.12	6.00
B. Red Gold	152.67	5.97	7.00	9.11	135.53	5.81	6.85	7.77	82.00	4.94	5.75	7.00
C. Royal Delicious	266.55	7.88	8.13	6.78	201.16	6.87	7.41	6.20	No fruit set			
D. Red Delicious	217.67	7.21	7.69	6.78	183.80	6.61	7.00	5.33	No fruit set			

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

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

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

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

TABLE 13.4

Foraging data for *A. cerana* and *A. mellifera* on apple flowers at 1350 m in the Northwest Himalaya in April-May

Parameter		*A. cerena*	*A. mellifera*
Initiation of foraging (time of day)		06.03 ± 0.01	06.27 ± 0.02
Cessation of foraging (time of day)		19.13 ± 0.01	18.55 ± 0.01
Duration of foraging activity (min.)		13.10 ± 0.002	12.28 ± 0.003
Duration of foraging trip (hours)		11.85 ± 0.36	17.92 ± 0.36
Peak foraging hours (time of day)		09.00 –11.30	11.00–13.20
Weight of pollen load (mg)	09.00	09.06 ± 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 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 load, 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).

TABLE 13.5

Percentage of *A. cerana* and *A. mellifera* collecting pollen, nectar, or both from apple at different hours of the day in April-May at 1350 m in the Northwest Himalaya

Forage	0900 hours		1200 hours		1500 hours	
	A. cerana	*A. mellifera*	*A. cerana*	*A. mellifera*	*A. cerana*	*A. 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

At 1200 hours Nc > Pc ($P < 0.05$) for *A. cerana*, at 1500 hours Nc > Pc ($P < 0.01$) for *A. cerana*.

At 0900 and 1500 hours Nc > pc ($P < 0.01$) for *A. mellifera*; at 0900 hours P *A. cerana* > Pc *A. mellifera* ($P < 0.01$) and Nc *A. mellifera* > Nc *A. cerana* ($P < 0.01$); at 1200 hours, Nc *A. cerana* > Nc *A. mellifera*; at 1200 hours Pc + Nc *A. mellifera* > Pc + Nc *A. mellifera* at 09:00 or 15:00 ($P < 0.05$). Depending on the hour, 1–5 per cent of bees might collect water.

Source: Verma and Dulta (1986).

ana was between 0900 to 1100 hours (mean 132 bees/5 minutes) when the temperature ranged from 13.5 to 21.0 degrees C, and that of *Apis mellifera* was between 1100 to 1300 hours (mean 118 bees/5 minutes) when the temperature ranged from 21–25° during the months of March and April in Shimla Hills (Table 13.4, Fig. 1).

Pollen loads carried by *Apis mellifera* 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+ and 8.64 mg+ at 0900, 1200 and 1500 hours respectively. A worker bee of *Apis mellifera* carried significantly heavier ($P < 0.01$) pollen than *Apis cerana* throughout the day (Table 13.4).

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

Apis cerana spent an average of 5.90 seconds per flower, whereas *Apis mellifera* spent 6.63 seconds on a single visit to an apple flower at a height of 1350 metres a.s.l. (Table 13.4).

Foraging studies also showed that at 0.900, 1200 and 1500 hours, *Apis mellifera* visited significantly ($P > 0.01$) more apple trees in the same rather than in different rows. However, for *Apis cerana*, the number was significantly ($P < 0.01$) more in the same than in different rows at 1500 hours only. No significant difference ($P < .05$) was observed between *Apis cerana* and *Apis mellifera* with regard to their visits to the same or different rows of apple trees. 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 ($P < 0.01$) and 1500 hours ($P < 0.05$) than the *Apis cerana* (Table 13.5).

The ratio of top and side worker bees on apple bloom at particular times of the day did not differ significantly in *Apis mellifera* and *Apis cerana*. However, the percentage of side and top worker bees varied according to the time of day in both. For example, at 0.900 hours top workers outnumber 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 top workers for *A. cerena*. 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 *A. cerana* was significantly greater than for top workers, (Verma, unpublished results).

Effects of Altitude on the Foraging Behaviour of A. cerana and A. mellifera

Studies on the foraging behaviour of *A. cerana* and *A. mellifera* at three different altitudes, 1350, 1975 and 2400 m, showed that worker bees of

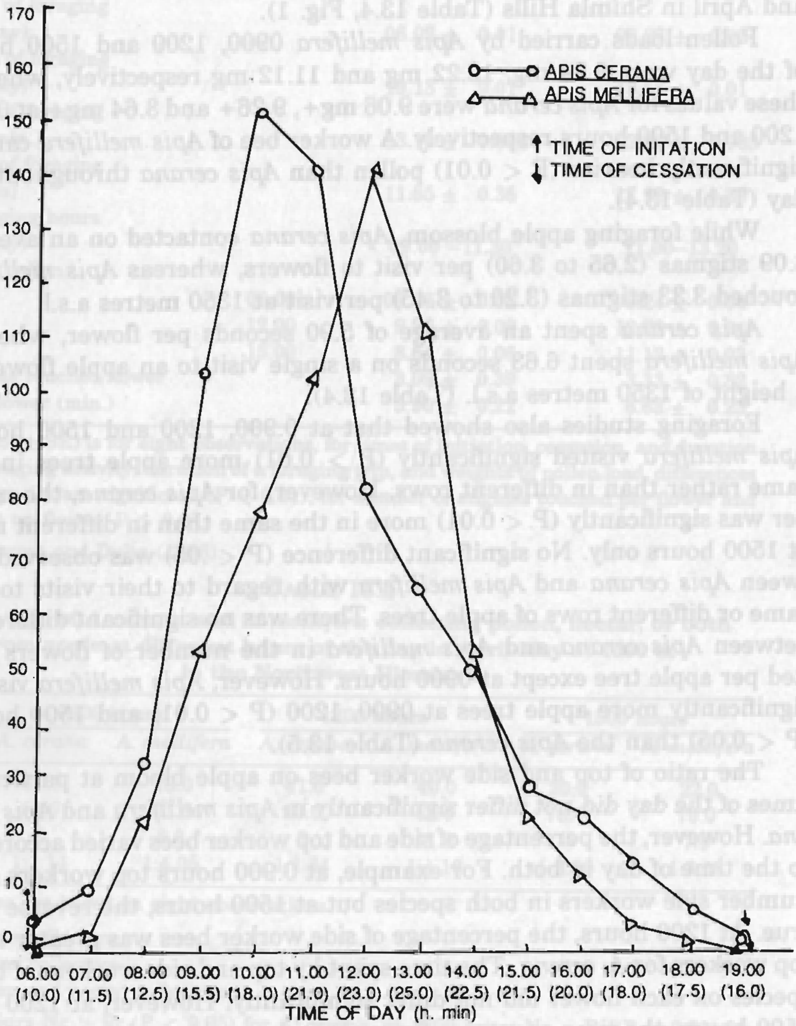

Figure 13.1: Peak hours of foraging activity (number of outgoing bees/5 min.) of *A. cerana indica* and *A. mellifera* on apple flowers in the northwest Himalayas. Temperatures are indicated in parentheses (° C).

Source: Verma and Dulta (1986).

the former species started their foraging activities earlier in the morning and ceased later in the evening at all three altitudes. Initiation of foraging activity by both species was delayed with increasing altitude. For example, times of initiation by *A. cerana* were 0603, 0606, and 0618 hours at 1350, 1875, and 2400 m, whereas for *A. mellifera* the times to initiation at 1350, 1875, and 2400 m were 0627, 0641, and 0648 hours, respectively. Foraging by both species ceased earlier with increased altitudes. *A. cerana* ceased its foraging activity at 1913, 1902, and 1825 hours at 1350, 1875, and 2400 m and *A. mellifera* ceased activity at 1855, 1838, and 1804 hours at 1350, 1875, and 2400 m. Thus, the duration of foraging activity per day of *A. cerana* and *A. mellifera* bees on apple bloom decreased with increase in altitude (mean duration, 13.10, 12.56, and 11.76 hours for *A. cerana* and 12.28, 11.57, and 11.16 hours for *A. mellifera* at 1350, 1875, and 2400 m (Verma and Dulta, 1986).

The duration of each foraging trip for both species of honey bee increased with increase in altitude of orchard location and it was found to be maximum (mean time, 17.83 minutes and 22.67 minutes in *A. cerana* and *A. mellifera*, respectively) at 2400 m, followed by 17.58 minutes and 22.25 minutes at 1875 m and 11.85 minutes and 17.92 minutes at 1350 m.

Altitude had no significant effect ($P > 0.01$) on other parameters such as bee preference for pollen or nectar or both during a visit, peak hours of foraging activity, pollen load, number of stigmas touched per visit, and time spent per flower (Table 13.6).

The above data on comparative foraging behaviour of *A. mellifera* and *A. cerana* suggest that both species of honey bee 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 of each should be kept to ensure efficient pollination. During low temperatures, *A. cerana* should be preferred to *A. mellifera*. Additional research on comparative foraging behaviour of *A. cerana* and *A. mellifera* on other agricultural and horticultural crops in the Hindu Kush-Himalayan Region should be carried out to augment the present data.

Renting of Beehives for Pollination in Himachal Pradesh

The state horticulture department and a few private beekeepers rent *A. cerana* and *A. mellifera* colonies to fruit growers at the time of apple bloom for pollination. Generally, at the onset of winter (November-December), colonies of both species are brought from the temperate hilly region to 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 its maximum and this is also the time when flowering begins in apple orchards. These colonies are transported in trucks directly to the apple-growing belt of the state and distributed to fruit growers at

TABLE 13.6

Effect of altitude on foraging of *A. cerana* and *A. mellifera* on apple flowers at different altitudes in the Northwest Himalaya in April-May

Parameter	Annu orchard		Penghunas orchard		Amin orchard	
	A. cerana	*A. mellifera*	*A. cerana*	*A. mellifera*	*A. cerana*	*A. mellifera*
IF	06.03 ± 0.01	06.27 ± 0.02	06.06 ± 0.01	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 ± 0.39	17.83 ± 0.41	22.67 ± 0.32

Annu orchard is at 1350 m, Penghumas at 1375 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 significantly by altitude. Duration of a foraging trip by either species at 2400 or 1875 m > duration at 1350 m ($P < 0.01$).

IF = initiation (time) of daily foraging activity

CF = cessation (time) of daily foraging activity

DF = duration (hours) of daily foraging activity

DT = duration (min,) of an individual trip

Source: Verma and Dulta (1986).

the rate of Rs. 25 per colony for one flowering season. However, private beekeepers charge higher rental fees than 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 his 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, nevertheless, created awareness among apple growers of the important role honey bees play in apple pollination. Fruit growers now maintain their own colonies of bees for the purpose of pollination and honey production.

Bee Management Practices in Relation to Apple Pollination

It is now well documented that bee pollination improves the size, shape, colour, storage capacity, and taste of apples. Inadequate pollination in an 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 the 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.

Some of these 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 a pollinizer variety should overlap with the flowering period of the main cultivar to be cross-pollinated.
- The pollinizer variety, besides helping in cross-pollination of the main cultivar, should also have commercial value.

Changes recommended for good pollination in an established orchard are:

- Replacing the whole tree.
- Top working or grafting the pollinizer cultivar.
- Providing cut flowering branches of the pollinizer cultivar to the main cultivar.
- Using pollen dispenser.

- Keeping in view the shorter flight range of *A. cerana*, the beehives should be spread throughout the orchard, or possibly around the perimeter, rather than kept in groups.

Two beehives of *A. mellifera* per hectare of apple orchard provide adequate pollinator force. Due to the smaller colony size of *A. cerana*, three colonies per hectare are recommended for this species.

If the weather is good, honey bees should not be kept in the apple orchard for more than two days because of the adverse effect of pesticides.

To obtain good economic yield of apple, 5 per cent of flowers or approximately 55,000 flowers per 0.4 hectare of orchard must set and mature.

Bees scrabbing for pollen set a greater percentage of flowers than those collecting nectar.

Trees should be planted around the orchard which act as good wind breaks.

The strength of bee colonies to be used for pollination can be increased by: feeding of sugar syrup; introduction of a prolific queen; and increasing the amount of brood by adding combs of unsealed brood.

Combs containing stored pollen should be removed to create a pollen dearth in the colony.

Colonies should be placed in the orchard when 10–15 per cent of the crop is in bloom.

Shifting colonies from one site to another, or even interchanging them, will broaden the search areas of bees, which is helpful in pollination.

Mowing of orchards in bloom will keep the bees away from flowering weeds.

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