PART III

Mountain Crop Pollination and Honeybee Forage

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Beekeeping and Pollination Ecology of Mountain Crops

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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. These include use of better quality seeds and animals, bringing more wasteland under cultivation, the use of fertilizers, pesticides, and bringing in 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 utilization of under-utilized resources. One resource which concerns us here is an increase in the yield of various 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 under-estimated. As a matter of fact, the main significance of honeybees and beekeeping is pollination, whereas, hive products, such as honey and beeswax, are of secondary value. This is evidenced by the fact that income from agriculture by the use of honeybees 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 honeybees and other wild insects. Cross-pollination of entomophilous crops by honeybees 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 these may not yield the desired results without the use of honeybees 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 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 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 honeybees. These include the use of pollen dispensers, pollen bombs, scent training of bees, development of high and low preference strains of honeybees through selective breeding for pollination of specific crops, domestication and utilization of non-*Apis* pollinators and safeguarding bees against pesticides. All these techniques are at present being 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 honeybees 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 wasteland for cultivation and increased use of pesticides. This makes domesticated hive bees essential for pollination. In addition to pollinating temperate fruits, both species (*Apis cerana* 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 *Apis 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

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

— their bodies are specially adapted to pick up pollen grains
— they show flower fidelity and constancy
— have long working hours
— micro-manipulate flowers
— maintain high populations when and where needed
— 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 in a single way or in different combinations. Such hybrid effects bring the following qualitative and quantitative changes in the economic and biological characters of plants:

— stimulate germination of pollen on stigmas of flowers and improve selectivity in fertilization
— increase viability of seeds, embryos and plants
— more nutritious and aromatic fruits are formed
— increase vegetative mass and stimulates 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 oil-seed crops
— increase fruit set and reduces fruit drop. Deodikar and Suryanarayana (1977) have reported the following increase (in percentage) in seed or fruit yield in various crops due to bee pollination.

A. Oil Seeds (Seed Yield)		
Linseed	=	2–49
Mustard	=	13–222
Niger	=	17
Safflower	=	4–114
Sunflower	=	21–3,400
B. Fodder and Grain Legumes (Seed Yield)		
Alfalfa	=	23–19,733
Beans	=	3–1,000
Bird's Foot trefoil	=	900
Clovers	=	40–3,315
Sainfoin	=	2,815
Vetches	=	39–20,000
C. Vegetables (Seed Yield)		
Asparagus	=	12,405

Cabbage	=	100–300
Carrot	=	9–135
Onion	=	354–9,878
Radish	=	22–100
Turnip	=	100–125
D. Orchard Crop (Fruit Yield)		
Apple	=	180–6,950
Blackcurrant	=	81–2,200
Blueberry	=	11–9,800
Cherry	=	56–1,000
Citrus	=	7–233
Cranberry	=	19–2,153
Cucumber and squash	=	21–6,700
Gooseberry	=	29–300
Grape	=	23–54
Guava	=	12
Litchi	=	4,538–10,246
Peach	=	7–3,788
Pear	=	244–6,014
Persimmon	=	21
Plum	=	536–1,655
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 honeybee, *Apis mellifera* has been extensively utilized to increase the yield of different cultivated crops. However, 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 honeybee, however show remarkable similarities in foraging behaviour, thus the basic principles involved in crop pollination by these two species of honeybees 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 *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 is true for pollination activity also. The strength of a colony depends upon the honeybee 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 honeybee 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 the 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 the pollination of different cultivated crops depends upon the following factors:

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

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

Distribution of Colonies in the Field/Orchards

Honeybees, 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 mono-culture 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 closest to the hive, particularly when the weather is not favourable.

Time and Placement of Colonies in the Field/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 would ignore 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 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 by frost injury and also adversely affect the foraging activities of bees. As reported earlier, native hive bee *Apis cerana* can forage at lower temperatures than its European counterpart, *Apis 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/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. Theoretically, this seems to be a logical approach, but in practice it does not always yield the desired results. In Sweden, Canada and U.S.A., 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 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 quantity of nectar in the nectaries of this plant. However, by sowing other nectariferous plants such as buckwheat, a 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 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 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:

	Area (000 hectares)	Production (000 MT)
Arunachal Pradesh	4.8	3.3
Himachal Pradesh	52.3	359.3
Kashmir	65.1	723.8
Uttar Pradesh	52.0	170.0
North West Frontier Province (Pakistan)	19	212.0
Bhutan	3.6	4.6
Nepal	5.0	50.0

These figures show that in 1986–87, more than 200 thousand hectares of land of Hindu Kush-Himalaya 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 thousand 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 honeybees. The population of non-*Apis* pollinators is declining at an alarming rate due to growing deforestation, vast clearance of wasteland and increased use of pesticides. The most effective way of assuring adequate pollination is through the introduction of honeybees into the orchard at the time of blossoming, a practice well developed for apples in Canada, western and eastern Europe, Japan and so on.

Most of the orchards of the Hindu Kush-Himalayan region are small (about one ha or less) and 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 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 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 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 bee hives. 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 horticultural 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 Apple Orchards of Shimla Hills

According to Verma and Chauhan (1985), insects visiting apple blossom comprised 44 species belonging to 14 families and five orders. Of these, 16 species belonged to Hymenoptera, 11 to Diptera, nine to Lepidoptera, seven to Coleoptera and one to Hemiptera (Table 6.1).

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 honeybees and bumble bees, *Halictus dasygaster* was predominant in one experimental orchard at Thanadhar (Shimla Distt. of H.P.). Besides hymenopterous insects, dipterans were other visitors to crops in the Shimla hills. These were *Eristatlis tenax, E. angustimarginalis, Eristalis* sp., Mucids (*Musca* sp. and *Orthelia* sp.) Syrphids (*Epilobium* sp., *Scava* sp., *Metasyrphus* sp., and *Macrosyrphus* sp.).

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

TABLE 6.1

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

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

A, B, C, D, E = order
a, b, c, d, etc. = family

Source: Verma and Chauhan, 1985.

Role of Honeybees 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. Honeybees are the most efficient pollinators among insects because they can be managed in sufficient number 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 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. Dulta and Verma (1987) studied the role of honeybees on fruit set, fruit drop and fruit quality of apple in 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 metres above mean sea level, to study the effect of honeybee pollination on fruit set, fruit drop and quality of apple.

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

The results are summarized as follows:

Effect of insect pollinators on fruit set

In self-compatible varieties such as Golden Delicious, the percentages of fruit set in controlled, open and honeybee-pollinated flowers were 24.57, 30.73 and 34.53 respectively, not significantly different. Similarly, in another self-compatible variety, Red Gold, the percentages of fruit set in controlled, open and honeybee pollinated flowers were recorded as 15.76, 18.34 and 22.45, respectively, did not differ significantly either. 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 honeybee-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). No fruit set in the absence of any insect pollinator in self-incompatible varieties clearly

TABLE 6.2

Percentage of fruit set and fruit drop in three different experimental conditions

Varieties	Honeybee-pollinated flowers (H)	Open-pollinated flowers (O)	No insect pollinated control (C)
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, 1987.

indicated that there was no pollen transfer from pollinizer to the varieties to be pollinated, without an insect pollinator (Table 6.2).

The higher fruit set in honeybee-pollinated flowers than in open-pollinated flowers suggested that the degree of cross-pollination by honeybees was certainly higher than that of other natural insect pollinators (Table 6.2).

Effect of Insect Pollinators on Fruit Drop

The fruit drop in self-compatible varieties of apple was significantly higher from flowers under controlled conditions, as compared to fruits from open-and honeybee-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 respectively) in honeybee-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 honeybee-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 honeybee 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 6.2).

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, 17 and 9 per cent respectively, in the fruits which developed from flowers; exclusively pollinated by honeybees as compared to open-pollinated flowers; whereas, 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 and fruits of these two self-compatible varieties followed the pattern: fruits from honeybee-pollinated flowers > fruits from open pollinated flowers > fruits from controlled experiment (P>0.01).

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 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<0.01) of fruits from honeybee-pollinated flowers, as compared to 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 a result of heterosis. The increase in weight, size (length and breadth) and volume of the fruits which developed from honeybee-pollinated flowers might be due to a 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 6.3). The better pollinating efficiency of the honeybees 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 better sized fruit (Table 6.3).

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

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

Worker bees of *Apis cerana* started their foraging activities 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

TABLE 6.3

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

Variety	Honeybee-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	135.33	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:

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

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

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

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

* Weight in gm

** Length and breadth in cm

Source: Dulta and Verma (1987a).

1913 hours). Thus, the average duration of foraging activity in *Apis cerana* was 13.10 hours and for *Apis mellifera*, it was 12.28 hours (Table 6.4). 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 6.4).

TABLE 6.4

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

Parameter		*A. cerana*	*A. 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
Peak 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. of stigmas touched/flower		3.09 ± 0.39	3.33 ± 0.32
Time(s) on flower (sec)		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.

Observations made 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<0.01) than pollen collectors (Table 6.5).

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 6.5). 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

TABLE 6.5

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

	09.00		12.00		15.00	
Forage	*cerana*	*mellifera*	*cerana*	*mellifera*	*cerana*	*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

Percentage are based on eight observations.

P = pollen collectors; N = nectar collectors; PN = pollen and nectar collectors

At 12.00; NC > PC (P<0.05) for *A. cerana*, at 15.00, NC > PC (P<0.01) for *A. cerana*.

At 09.00 and 15.00 NC > PC (P<0.01) for *A. mellifera*; at 09.00 PC *A. cerana* > PC *A. mellifera* (P<0.01) and NC *A. mellifera* > NC *A. cerana* (P<0.01); at 12.00 NC *A. cerana* > NC *A. mellifera*; at 12.00 PC + NC *A. mellifera* > PC + NC *A. 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.

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 6.5). 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 difference (P<0.01) in the number of nectar collectors of both the species (Table 6.5). Pollen plus nectar collectors of *Apis mellifera* were maximum at 1200 hours (Table 6.5).

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 per five minutes) when the temperature ranged from 13.5 to 21.0 degrees C, and that of *Apis mellifera* was between 1100 and 1300 hours (mean 118 bees per five minutes) when the temperature ranged from 21–25 °C during the months of March and April in the Shimla Hills (Table 6.4, Fig. 6.1).

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 loads than *Apis cerana*

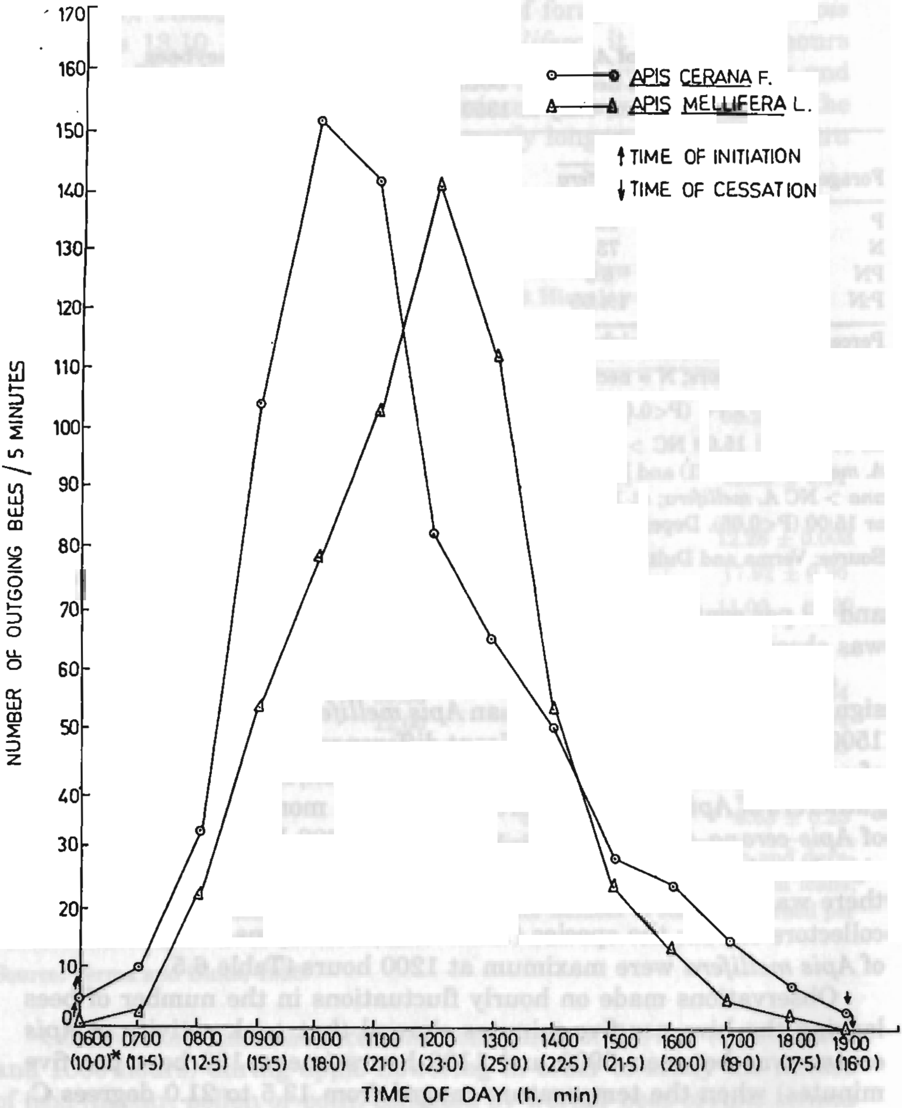

Figure 6.1: Peak hours of foraging activity (number of outgoing bees/5 min) of *A. c. indica* and *A. mellifera* honeybees on apple flowers in northwest Himalaya. Temperatures are indicated in parentheses (°C).
Source: Verma and Dulta, 1986.

throughout the day (Table 6.4).

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 6.4).

Foraging studies also showed that at 0900, 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*.

The ratio of top and side worker bees on apple bloom at particular time 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 species. For example, at 0900 hours top workers out-numbered 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 *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 for top workers (Verma, unpublished results).

Effects of altitude on the foraging behaviour of *Apis cerana* and *Apis mellifera*

Studies 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 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 the species was delayed with increasing altitude. For example, times of initiation by *Apis cerana* were 0603, 0606 and 0618 hours at 1350, 1875 and 2400 metres a.s.l.; whereas, for *Apis mellifera* the times of initiation at 1350, 1875 and 2400 metres a.s.l. were 0627, 0641 and 0648 hours, respectively. On the other hand, foraging by both species ceased earlier with increased altitudes. *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 activity at 1855, 1838 and 1804 hours at 1350, 1875 and 2400 metres a.s.l. Thus, the duration of foraging activity per day of *Apis cerana* and *Apis mellifera* bees on apple bloom decreased with 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 for both the species of honeybees 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 *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 (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 6.6).

TABLE 6.6

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

	Annu orchard		Penghumas orchard		Amin orchard	
Parameter	*cerana*	*mellifera*	*cerana*	*mellifera*	*cerana*	*mellifera*
IF	06.03 ± 0.01	06.27 ± 0.02	06.06 ± 0.01	06.41 ± 0.01	6.18 ± 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 ± 0.008
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 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.

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 *A. mellifera* and *Apis cerana* should be kept to ensure efficient pollination. During low temperatures, *Apis cerana* should be preferred to

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.

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 fruit growers at the time of apple bloom for pollination. Generally, at the onset of winter (November–December), colonies of both *Apis cerana* and *Apis mellifera* 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 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, each one gets about two to five colonies, irrespective of the size of their 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 that honeybees play in apple pollination. As a result of this practice, 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

1. 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

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 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.
3. Changes recommended for good pollination in an established orchard are:
   - Replace the whole tree
   - Top work or grafting of pollinizer cultivar
   - Provide cut flowering branches of the pollinizer cultivar to the main cultivar
   - Use of pollen dispenser
   - 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
4. Two bee hives of *Apis mellifera* per hectare of apple orchard provide adequate pollinator force. However, due to the smaller colony size of *Apis cerana*, three colonies per hectare are recommended.
5. If the weather is good, honeybees should not be kept in the apple orchard for more than two days because of the adverse effect of pesticides.
6. To obtain good economic yield of apple, 5 per cent of flowers or approximately 55,000 flowers per 0.4 hectare of orchard must be set and mature.
7. Around the orchard, such trees should be planted which act as good wind breaks.
8. The strength of bee colonies to be used for pollination can be increased by adopting the following management practices:
   1) feeding of sugar syrup,
   2) introduction of a prolific queen, and
   3) increasing the amount of brood by adding combs of an unsealed brood.
9. Remove combs containing stored pollen to create a pollen dearth in the colony.

10. Place colonies in the orchard at the time when 5–10 per cent of the crop is in bloom.
11. Shift colonies from one site to another, or even interchange them, as this will broaden the search areas of bees, which is helpful in pollination.
12. Mowing of orchards in bloom will keep away the bees from flowering weeds.

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7

Honey Plant Sources in Mountain Areas: Some Perspectives

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Past Focus and Future Needs

Apiculture is identified as a promising non-landbased farming activity in the context of sustainable development of mountain agriculture. It is a food-, nutrition- and income-generating activity which offers comparative advantages of using an unharnessed ecological niche, nectar and pollen of flowers from various plants. These plant parts cannot be harnessed for human use without honeybees acting as the mediating agents. It highlights a unique ecological phenomenon—wherein components of plants which are ostensibly of no consequence and use to man, but they benefit human beings, when used as an ecological niche by honeybees. At the centre stage of discussion on apiculture remain honeybees and hive products. Plants, the primary sources, are generally nelegated to secondary focus largely because of their abundance and the extractive nature of human activities. It is often taken for granted that development of apiculture in the context of mountain agriculture will use the immense flora available. How much abundant would honey flora be in the coming decades, if the present trends of agricultural transformation continue? The primary role of honeybees, as producers of hive products, may also see a change whereby using this insect as an agent to save biodiversity and maintain crop production may become a primary factor. Therefore, in the coming decades apiculturists may have to direct more attention to various dimensions of honey plant sources.

Past focus of research in honey plant sources gave top priority to identify and rank honey plant species according to the quality and quantity of nectar or pollen from them. The Directory of World Honey Sources (Crane et al., 1984) is a standing example of such efforts. A review of research efforts made in the Hindu Kush-Himalayan region, on honey plant sources (Verma, 1990) highlighted a similar approach being followed. Focus is on identifying and evaluating local species both for honey and pollen, besides their flowering period and geographic location. The latter point is important from the mountain context.

Researchers, designing future focus of research in honey sources will have to keep in mind rapid transformation of mountain agriculture and its impact on honey sources. It will affect beekeeping both in purpose and management style.

It is in view of this thinking, that this paper highlights issues and approaches related to honey plant sources needs for apiculture. The objective is not of only harnessing honey plants but also making apiculture activity sustainable. The paper examines apiculture and the need for honey plants from different angles. Beekeeping for different purposes will have different supportive needs from plants for sustaining it. How well the plantation needs for honey sources can be integrated with conservation of biological diversity and local development programmes, is also discussed.

Apiculture Objectives and Honey Source Needs

Today, apiculture development is promoted with anyone of the following primary objectives:

(A) Promotion of small-scale/household beekeeping by the mountain farmers as one of their off-farm activities. The goal is to supplement the nutritional needs of the families and earn some cash income from beehive products.

(B) Use of honeybees for pollination of cash crops to enhance yields.

(C) Apiculture on a commercial scale, as an industry for hive products which are in great demand, both locally and in foreign markets.

This means that although beehive products are obtained in each case and plants are also pollinated, the primary objectives of promoting the activity differ. Accordingly, the requirements of honey plant sources and approaches to fulfil these requirements will also differ.

Beekeeping as a Small-scale Activity of the Mountain Farmer

Honey plant sources at this scale were never a problem in the past, because of diversity of flora. Different agro-ecological zones may have taxonomically different plant species but from the viewpoint of the ecological niche of honeybees, many of them are similar.

Beekeeping in rural areas also benefits much from the diversity of components of farming systems. For example, if the flowering period of crops is over, the weeds and wild plants on the hedges, on wastelands and in nearby forests, would have some plant species flowering at any period of time in the year. The quality of the honey sources may differ but many of these sources act as means of survival strategies of honeybees in lean periods.

In many mountain areas, honey sources may not be a problem but a situation is increasingly arising in which traditionally existing plant diversity has given way to monocultures. Components of farming systems, e.g., nearby wastelands and forests no longer exist.

Technically, increasing inaccessibility of honey sources is a significant point, few would care to understand. All the honey sources of an area cannot be visited by the honeybees. It is against the common man's belief. Honeybees as a rule visit those sources which are within 0.3 to 0.5 km radius from the apiary (Verma 1990). At a distance of more than 0.5 km, the visits by honey bees diminish significantly (Verma 1990). Bee behaviour research has shown that generally the duration of foraging trips of honeybees varies from 15 to 25 minutes (Verma 1990). This is taking into account time to reach the honey source, collection period and return journey. These reports are of significance to judge availability of honey sources for every individual beehive.

It clearly emerges that to maintain or increase yields under small scale beekeeping a general assessment of both availability and accessibility of honey sources is desirable. A need for supplementing the honey sources specially during the lean periods might also be felt. As floral needs for small scale beekeeping are small, therefore an approach to select different species for garden plantation or as hedges around the fields is one way. Multipurpose trees or shrubs which serve as good honey sources might be selected for such plantations. The plantation approach is later discussed in detail under separate heading.

Apiculture for Crop Pollination as a Primary Aim and the Honey Plant Sources

Cross-pollination of crops by honeybees is one of the most effective and cheapest methods of increasing crop yields. The practical use of honeybees for this purpose started in 1895 in USA when honeybees were recommended as pollinators to avoid pear crop failures in Virginia (Waite 1895). Later honeybees were utilized for apple pollination (Benton 1896). Research efforts during the past few decades, included several other crops within the scope of pollination method using honey bees, namely, cauliflower (Adlaka and Dhaliwal, 1979) Cardamom (Chandran et al., 1983) Safflower (Deshmukh et al., 1985), Sunflower (Manzoor and Muhammad 1980) and Citrus fruits (Manzoor et al., 1978).

Likewise there is a body of literature available to suggest that honeybees can also be used for the pollination of several other crops (McGregor, 1976; Kozin 1976; Kevan 1984; Crane and Walker, 1984).

What are the trends on future role of honeybees in pollination? What kinds of honey plant needs may be felt under such conditions? An overview of trends shows that populations of most non-*Apis* pollinating insects are declining because of the vast clearance of wastelands for cultivation. The extensive agriculture and monocultures are reducing their hibernating and nesting places. Indiscriminate pesticidal/insecticidal sprays are killing them continuously. In such a state of affairs, we may have to depend almost entirely upon domesticated honeybees for pollination of crops in the near future. To sustain bees and encourage apiculture, varieties of bee flora are required which provide subsistence to the bees during some parts of the year and surplus during the other. The agricultural and horticultural crops that are pollinated, serve as useful and plentiful forage but the availability is restricted to short durations only.

It is not just the survival but also the strength of the colonies that matters for an effective pollination. Verma (1990) while explaining principles of bee pollination emphasized that larger and stronger colonies are better pollinators than smaller and weaker ones. Strength of a colony depends upon availability of nectar and pollen plants as food sources, management practices as well as the breed. He further stated that in the Hindu Kush-Himalayan region, the colony strengths are poor because of low temperatures and dearth of bee flora. In the early spring season when honey bee colonies are required for the cross-pollination of fruit crops like apple, these colonies do not build enough strength for effective pollination. To overcome this constraint several apiary owners in Himachal Pradesh in India migrate their colonies to lower altitudes where there is no dearth of flora. This helps build enough strength of bees for effective pollination.

Further, many of the bee-pollinated crops are not attractive enough to lure required numbers for effective pollination. Realizing this, several measures have been suggested for attracting bees to a particular crop in bloom by planting high nectar-yielding plant species or crops among the poor nectar-secreting crops. Verma (1990) cited an example of such a combination, where sweet clover, a poor nectar-secreting crop requiring bees for pollination, can be sown in a mixed cropping pattern with buckwheat, a mountain crop which is a high nectar-yielding honey source.

Thus, when pollination of crops is the main purpose behind beekeeping, the focus of honey sources aims at sustaining the bee colonies over the rest of the period. It is more important in this case than under small-scale household beekeeping, that sufficient bee flora is managed around the apiaries for most of the period of the year, particularly for the slack winter period. This has a significant bearing on the strength of the colony, that is so important for effective pollination.

Two types of honey source requirements are visualized under crop pollination objective:

a. Plants to sustain healthy bee colonies during the period other than the blooms of the crops.
b. In some cases excellent quality honey plant sources would also be needed for attracting the honey bees to pollinate the crops.

The number of honeybee colonies needed by individual households for the purpose of pollination would not be very large because of smaller size of landholdings in mountain areas. On an average, these landholdings are smaller than one hectare (Bhatti et al. 1990; Shrestha and Katwal 1990; Mulk 1990; Yanhua et al. 1990). Verma (1990) puts an educated guess of three beehives for less than one hectare of the crops needed for pollination. Therefore the demand can be met in two possible ways:

First, in the case of each household keeping an average of less than five colonies will mean that all villagers will have a collective interest in raising honey sources. Therefore, such honey plant sources could be raised on common property lands so as to meet the needs of everybody. These plant species need to be selected carefully for each locality and agroecological zone bearing in mind the following:

(i) Number of species having flowering periods spaced over lean periods.
(ii) Species that are quality honey sources.
(iii) Species which meet farming needs of the community, such as fodder plants. Growing economically important plants such as fruit trees on common land has not been a practical proposition. Moreover, fodder and fuelwood are important needs of the community and they are conventionally drawn from commons land. More novel ideas could be, raising live fences of such honey source shrubs e.g. *Prinsepia* and *Plectranthus*. *Prinsepia*,

a thorny bush, is used as a fencing material under traditional practice of the farmers in the horticulture zone of Himachal Pradesh and in several other areas of Hindu Kush-Himalaya.

However, the selection of plant species in mountain areas is highly location specific. Therefore it would be naive to prescribe general combinations. The best way is to work out a list of honey sources on agroecological zone or agroecosystem basis from which selections can be made.

Secondly, large number of bee colonies raised on commercial scale can be rented to farmers for pollination. The apiculture under such conditions could also be oriented to beehive products. It could be managed privately by individuals or farm cooperatives, and by government institutions depending on the systems.

The advantage of such a practice is that owners would have means and purpose to move colonies to places near the honey sources and farmers would also be benefited. This is further discussed under commercial apiculture.

Apiculture on Commercial Scale and Approaches to Meet Demand of Honey Plant Sources

Under commercial scale apiculture, a large number of bee colonies are owned by an individual concern for the sole purpose of producing honey and other beehive products for sale. There is enough evidence to show that it is being promoted in almost all countries of the Hindu Kush-Himalayan region (Verma, 1990). China leads other countries of the region in commercial beekeeping. It produces over 200,000 tons of honey, 800 tons of royal jelly, and 1000 tons of bee pollen every year. China is also the largest exporter of honey in the world, contributing to 16 percent of the world exports (ITC-UNCTAD-GATT, 1986).

Likewise, in mountain areas of other countries of the Hindu Kush-Himalaya e.g. Pakistan, India, Nepal and Bhutan, tremendous potential exists. In some cases such as in northern mountain areas of Pakistan, beekeeping is already a large-scale venture for many. In Himachal Pradesh, a tiny hill state of India, the government maintains a large number of colonies, along with some cooperatives and individual farmers, loaning them to apple growers for pollination.

Therefore, for maintaining such large colonies several honey plants would be needed throughout the year. Plantation for this purpose is neither suggested nor practically possible. But mountain areas provide comparative advantage in this regard. Assuming that mobility is possible, bee hives can be moved up and down the agroecological zones of mountain areas to take advantage of the natural vegetation. Spending winters in the foothills, where winter crops and other plants are abundant, will help. Colonies can be moved into mid-hills and valleys with warming up of the weather. By April, temperate fruit zone provides a most suitable niche where the honey bees would be needed for pollination of fruit crops. Plenty of flora is available during this period in this zone. Summers open up scopes for availability of flora in high mountain areas which continue until the end of rainy season.

Autumn is a lean period but by that time some of the rosaceous plants start flowering in the foothills. Colonies can then be moved straight down into these areas.

The system is in practice in China, and northern areas of Pakistan. Afghan refugees in NWFP, Pakistan can be seen moving with their colonies up and down alongside the highways, staying for a few weeks at one place. Large number of colonies can be seen in deep forests, near the wastelands, and on sides of crop fields. The practice of moving colonies in space and time is advantageous in more than one ways. It helps in harnessing honey sources in their natural state avoiding need for concentrated plantations. Also, this way honey bees provide benefits of pollination to several plant species, both cultivated and wild. At places, farmers may be willing to cooperate with commercial concerns to allow placement of colonies in their fields without costs because of mutual benefit. This alternative land use practice for agriculture through movement of colonies is possible only on commercial scale. Another constraint to the practice could be inaccessibility. It is convenient in areas connected with roads. Transporting beehives to remote areas would however be a difficult task.

Honey Sources Plantation Approaches

Plantations solely from apiculture viewpoint are rarely done. The motive is always linked to other development programmes. Hypothetically speaking even if they were to be done with the sole purpose of beekeeping, good and bad choices remain. Outline of the appropriate approach is given in Table 7.1.

As is well known, land is a scarcity in mountain areas and it would be naive to think of using large areas for plantations to meet the needs of a secondary activity like apiculture. Therefore, unconventional land-use practices are much favoured for the purpose. Plantations on common lands, roadside plantation and community forestry are some of the examples.

Roadside plantations established with the purpose of bee forage, particularly for forage scarcity periods, enhance the scope of beekeeping (Table 7.2). It increases possibilities for the farmers to get additional economic returns from honey and also increases crop yields by way of pollination services by bees. Recent experiences of using road-

TABLE 7.1

Honey plant resources systematic plantation approach

STEP 1

Honey plant resources and existing populations of honeybees of an area e.g. Kathmandu Valley

STEP 2

— Melissopalynological studies to prepare inventory of honey sources of the area

STEP 3

Carrying capacity of available flora
— in bloom (maximum)
— in lean season (minimum)

STEP 4

Honey production levels in different seasons to mark lean season/period of an area

STEP 5

To ensure sustainable yields, of honey or to maintain healthy bee colonies for pollination. Provide suggestions for plantations. Keeping in view the local farming systems and biodiversity needs

side plantation for large-scale apiculture, as a form of off-farm activity are available in China and Pakistan. Therefore apart from crops, other kinds of plantations are also needed which flower during rest of the periods in a calendar year. Several trees and other plant species that blossom during different months, so that nectar and pollen are almost continuously available to honeybees is an ideal combination. The plantation done on roadside and other common property lands would involve different climatic regions. This would give an advantage of diversity in terms of species and their blossom calendars (Table 7.2). To ensure variations in efficient utilization of this flora throughout the year, the bee colonies may need constant movement nearer to such areas.

Tables 7.2 and 7.3 list species which have their importance as honey plants for plantation on common property land, government land and private land in different agro-ecological zones, besides other uses.

TABLE 7.2

A sample survey of multipurpose honey source tree species of different climatic regimes of the Hindu Kush-Himalaya to facilitate selection of appropriate plantations on common property lands and roadsides

Species (1)	Uses (2)	Remarks (3)
A. TEMPERATE REGION COMPRISING MOSTLY OF HIGH MOUNTAIN AREAS:		
1 *Alnus nepalensis*	Timber, fuel, nitrogen fixing	Large tree suitable for growing on river banks, ravines, and newly formed soils. Useful for soil conservation in landslide areas. More common in the Eastern Himalaya. Grown by direct sowing or by entire transplanting. Good for slope stabilization.
2 *Alnus nitida*	Timber, fuel, nitrogen fixing	Similar to above. More common in the Western Himalaya on river-sides and ravines. Good for slope stabilization.
3 *Buxus almoides*	Plywood, furniture, and tool handles	A medium-sized tree. Suitable for broken marginal lands. Can be grown by entire transplanting and also by direct sowing. Can be used for slope stabilization.
4 *Corylus colurma*	Timber for shuttle making, fuel, fodder	Medium-sized tree. Wood used. Grown by entire transplanting.
5 *Eucalyptus saligna*	Fruits, timber, fuel	Medium-sized trees. Edible fruit is much relished. Can be grown by entire transplanting as well as by direct sowing. Can be planted on gentle slopy roadsides.
6 *Juglans regia* (akhrot)	Timber, furniture, and carving, gun-stock, fruits	Large tree. Grown by entire transplanting and also by direct sowing.
7 *Morus serrata* (kimu)	Fodder, sports goods, furniture, toys	Large tree. Suitable for growing on marginal slopy lands and on roadsides passing through farmlands. Can be grown by branch cuttings and direct sowing.

Contd.

Table 7.2: Contd.

Species (1)	Uses (2)	Remarks (3)
8 *Prunus cerasoides* (padam)	Timber, fuel, fodder, wood used in religious ceremonies	Medium tree. Suitable for marginal lands and around villages. Grown by entire transplanting, also by branch cuttings. Good for beekeeping.
9 *Prunus persica* (aru)	Fruits, timber, fuel	Small tree. Suitable for near habitation, gentle stable slopes, and plain valley areas. Grown by entire transplanting.
10 *Pyrus malus* (sew)	Fruits	Small trees. Suitable for growing near habitations, farming areas in valleys and marginal lands. Grown by entire transplanting.
11 *Quercus incana* (ban)	Timber for agricultural implements, medicinal, trussar silk rearing	Large tree of the eastern Himalaya. Suitable for marginal lands. Grown by direct sowing. Good for slope stabilization in high mountain areas.
12 *Robinia pseudoacacia*	Fuel, fodder, soil conservation	Medium tree. Suitable for marginal lands and for stabilizing ravinous land. Grown by entire transplanting. Commonly planted on roadsides in lower hills. Can be planted on slopes of any degree.
B. SUB-TROPICAL REGION COMPRISING THE FOOT HILLS OF THE WESTERN HIMALAYA AND CENTRAL HIMALAYAN MOUNTAINS		
1 *Albizia lebbeck* (siris)	Timber, fuel, fodder, medicinal	Large trees. Suitable for open roadside lands and along narrow pathways. Grown by entire transplanting, direct sowing, and cuttings.
2 *Bauhinia purpurea* (khairwal, guiral)	Gum, fuel, fodder	Medium tree. Suitable for roads passing through farm. Grown by entire transplanting and direct sowing.
3 *Bauhinia variegata* (kachnar)	Gum, fuel, fodder	Medium tree. Suitable for road passing through farm. Grown by entire transplanting and direct sowing.

4 *Dalbergia sissoo* (shisham)	Timber, furniture, plywood, fuel, fodder	Large or medium tree. Suitable for growing in lower to mid hill plantations, on village roads. Grown by entire transplanting, root and shoot. Suitable on slopy sites.
5 *Dendrocalamus strictus* (bans)	Paper pulp, construction, tent, poles, basket-making	Large bamboo. Suitable for growing on open marginal land, roadsides and near homesteads. Grown by entire transplanting and from rhizomes.
6 *Emblica officinalis* (sonia)	Fruits, tannin, timber, fuel, fodder	Medium tree. Suitable for roadsides near homesteads and farms. Grown by entire transplanting or direct sowing. Himachal Pradesh is already using it for roadside plantations for socioeconomic value.
7 *Eucalyptus camaidulensis*	Timber, fuel, charcoal, gum, medicinal	Large tree. Suitable for both dry and swampy areas. Grown by entire transplanting.
8 *Grevillea robusta*	Ornamental, timber, cabinet making, toys, fuel, panelling, shade tree in tea gardens	Large tree. Suitable for shade or as avenue. Grown by direct sowing.
9 *Grewia optiva* (bhimal)	Timber, cot frames, fibre, fodder	Medium tree. Suitable for farming need areas. Good as fodder, fibre and fuel. Grown by entire transplanting.
10 *Morus alba* (tut)	Fruits edible, timber, sportsgoods, fodder, leaves for silk-worm feeding.	Medium tree. Suitable for marginal lands. Grown by entire transplanting, direct sowing, or branch cuttings.
11 *Populus deltoides*	Matchwood, pulpwood, light timber, fuel	Small tree near habitation, farm land roadsides. Grown by branch cuttings.

Contd.

Table 7.2: Contd.

Species (1)	Uses (2)	Remarks (3)
12 *Prunus armeniaca* (zardalu)	Fruits, timber, fuel	Small tree near habitation, farmland, roadsides. Grown by branch cuttings.
13 *Prunus persica* (aru)	See (A) (9)	In valleys and on stable land near habitation, roadsides.
14 *Pyrus communis* (nashpati)	Fruits, fuel	Small tree. Suitable for homesteads and field edges. Grown by grafting.
C. SUB-TROPICAL CLIMATE OF CENTRAL AND EASTERN HIMALAYA		
1 *Albizia lebbeck*	See (B) (1)	
2 *Bauhinia purpurea* (khairwa, guiral)	Timber, fuel, fodder	Large tree. Suitable for growing on village commons, marginal lands, and roadsides. Grown by entire transplanting and direct sowing. Good for areas requiring fuel and fodder.
3 *Grevillea robusta*	Essential oil, fuel, charcoal, timber	Medium tree. Suitable for slopy and plain roadsides. Grown by entire transplanting.
4 *Grewia elastica* (dhaman)	Ornamental, timber, toy making, fuel, fodder	Medium tree. Suitable for slopy and plain roadsides. Grown by entire transplanting.
5 *Morus serrata* (kimu)	See (A) (7)	
D. TROPICAL REGION		
(i) HIGH RAINFALL AREAS OF NEPAL AND NORTHEASTERN PARTS OF INDIA		
1 *Dalbergia latifolia* (shisham, biti, jitengi, iti) *The* rosewood	Timber, furniture, cabinet	Large tree. Suitable for growing on village, state and national highways. Grown by entire transplanting.
2 *Lagerstroemia speciosa* (jarul)	Timber, constructional purpose, furniture agricultural implements, telegraph poles, fodder, medicinal	Large tree. Suitable along pathways. Grown by entire transplanting.

3 *Melocanna baccifera* (Bans)	House construction, mats, baskets, paper pulp	Medium bamboo. Suitable for growing in 3rd row onwards. Grown by entire transplanting.
4 *Mangifera indica* (am), Mango tree	Edible fruits, fatty oil, plywood, shoe heels, furniture fuel	Large tree. Suitable for growing on roadsides of all kinds of roads. More preferable for village roads. Good only for valleys and stable areas. Grown by entire transplanting (grafted).
5 *Parkia roxburghii* (supota)	Fruits, fuel, ornamental, medicinal	Medium tree of eastern parts. Suitable for roadsides. Grown by entire transplanting.
(ii) MEDIUM RAINFALL AREAS OF LOW TO MID HILLS		
1 *Acacla auriculiformis* (Akashmuni)	Timber, fuel, oranamental	Medium trees. Suitable for slopy lands. Grown by entire transplanting and direct sowing.
2 *Acacia nilotica* (babul, kikar)	Timber, fuel, fodder, tannin, gum	Medium tree. Suitable for sites for slopy lands, marginal lands and village commons. Grown by direct sowing.
3 *Aegle marmelos* (bel, vilva)	Fuel, gum, bark, and fruit, medicinal	Small tree. Suitable for roadsides near rural habitations and houses. Grown by entire transplanting.
E. TRANS HIMALAYAN, HIGH MOUNTAIN COLD ARID ZONE		
1 *Salix* spp.		A popular tree of the trans Himalaya.
2 *Populus* spp.	See (B) (11)	Also commonly grown by mountain communities for fuel and fodder.
3 *Prunus armeniaca* (Khurmani)	See (B) (12)	A popular oil seed and fruit tree wild as well as domesticated.
4 *Alnus* spp.	Nitrogen fixing See (A) (1 & 2)	Wild forms for roadside plantations.
5 *Betula utilis* (Bhoj Patra)		

Contd.

Table 7.2: Contd.

Species (1)	Uses (2)	Remarks (3)
6 *Hyppophae* spp.	Fruits, fuel, timber, nitrogen fixation, soil fertilization.	Shrub and tree both suitable for dry sandy or rocky locations, riversides, moist areas. Good for roadside passing through farm lands.
7 *Prunus persica*	Fruits, fuel	Wild forms of roadside plantations.

Source: Compiled from multipurpose sources.

Honey Source Plantations and Conservation of Genetic Resources

As is well known, the threat of extinction of several species and their populations is increasing. Economically important plant resources are over exploited leading to their decline. Similarly, habitats of several rare species are being destroyed leading to their extinction. This makes it desirable that development programmes based on plant resources, care for enhancing populations of those species which are dwindling.

Such threatened plant species which otherwise are a good honey source, can be promoted for both small scale plantations (say a few trees/shrubs around the houses) or large scale plantations on common property lands and roadsides. The concept is an ideal example of combining development with conservation. For deciding priorities regarding the conservation of species through plantations, selection criteria developed by (IUCN, 1980) will be most useful. It outlines that priorities should be given to these categories:

i. Species that are endangered throughout their range.

ii. Species that are the sole representatives of their family or genus. The formulation is illustrated in Table 7.4. Further, priority should be given to those plant species, that are most threatened and most needed.

Such conservation efforts, however, call for multidisciplinary efforts to prepare an inventory of appropriate species for different areas. In addition to its honey source qualities and multipurpose use value, the status of existence of species would be another added criterion of selection for plantation, under this approach. Given the national awareness, and international concerns over the issue of loss of genetic resources and biological diversity, implementing this new approach to

TABLE 7.3

A sample survey of honey source shrubs of multipurpose value found in the Hindu Kush-Himalayan region, for selective plantations as fencing, wasteland and common property lands

Plant Species	Common Name	Honey Potentialities	Flowering Period	Distribution	Type (Nature)	Other Economic Uses
Adhatoda zeylanica Nees	Basuti	N^2P^2	APR–NOV	S. Tropical, S. Temperate, Temperate	Shrub (W)	Medicinal & Soil reclamation
Strobilanthes wallichi Nees	Bankas	N^2P^2	AUG–OCT	S. Temperate, Temperate	Shrub (W)	
Agave americana L.	Century plant	N^3P^3	SEP–NOV	S. Tropical	Shrub (W)	Ornamental & Fibre
Carissa caranda L.	Karandas	N^2P^2	APR–MAY	S. Tropical, S. Temperate, Temperate	Shrub (W/C)	Preservation
Phoenix spp.	Wild date palm	N^2P^3	MAY–JUL	S. Tropical, S. Temperate	Shrub (W)	Fruit
Asclepias curassavica L.	Milkweed	N^2P^2	APR–JUN	S. Tropical, S. Temperate		Medicinal & Fibre
Berberis lycium L.	Barberry	N^2P^1	MAY–JUN	S. Tropical, S. Temperate, Temperate	Shrub (W)	Medicinal Root and Fruit

Contd.

Table 7.3: Contd.

Plant Species	Common Name	Honey Potentialities	Flowering Period	Distribution	Type (Nature)	Other Economic Uses
Corylus colurna Dence.	Hazelnut	P^2	MAR–MAY	S. Tropical, S. Temperate	Shrub (W/C)	Seeds Edible & Fuel
Opuntia spp.	Prickly pear	N^2P^2	APR–MAY	S. Tropical, S. Temperate, Temperate	Shrub (W)	Medicinal
Lonicera sempervirens L.	Honey suckle	N^3P^3	MAY–AUG	S. Tropical, S. Temperate,	Shrub (W/C)	Ornamental
Viburnum spp.	Vikurum	N^3P^3	MAY–JUN	S. Tropical, S. Temperate	Shrub (C)	
Euphorbia royleana Bros.	Euphorbia	N^3P^3	APR–MAY	Temperate	Shrub (W)	Medicinal
Ricinus communis L.	Castor oil-plant	P^3	MAY–AUG	S. Tropical, S. Temperate	Shrub (W/C)	Lubricant, Oilseed, Purgative & Medicinal
Plectranthus rugosus	Shain	N^1P^2	AUG–NOV	S. Temperate, Temperate	Shrub (W)	
Plectranthus coetsa Benth.	Shain	N^1P^2	SEP–OCT	S. Temperate, Temperate	Under Shrub (W)	
Plectranthus geradianus	Shain	N^1P^2	AUG–OCT	S. Temperate, Temperate	Under Shrub (W)	
Thymus spp.	Thyme	N^2P^3	MAY–OCT	S. Temperate, Temperate	Shrub (W)	Medicinal & Aromatic

Lagerstroemia indica L.	Pride of India	N^2P^2	JUL–SEP	S. Tropical, S. Temperate, Temperate	Shrub (W)	Purgative, Timber & Ornamental
Musa sapientum L.	Banana	N^3P^3	MAR–DEC	S. Tropical, S. Temperate	Shrub (C)	Fruit & Medicinal
Indigofera spp.	Indigofera	N^2P^2	JUN–AUG	S. Tropical, S. Temperate, Temperate	Shrub (W)	Fodder
Lespedeza spp.	Lespedeza	N^2	JUN–JUL	S. Tropical, S. Temperate, Temperate	Shrub (W)	
Punica granatum L.	Pomegranate	N^2P^1	APR–MAY	S. Tropical, S. Temperate	Shrub/ Tree (C)	Fruit, Soil reclamation & Fodder
Clematis spp.	Clematis	N^2P^2	MAR–MAY	S. Tropical, S. Temperate, Temperate	Shrub (W)	Ornamental
Potentilla spp.	Silver weed	N^2P^3	JUN–AUG	S. Tropical, S. Temperate, Temperate	Herb/ Shrub (W/C)	Medicinal
Prinsepia utilis Royle	Bekhal	N^1P^2	SEP–NOV	S. Tropical, S. Temperate, Temperate	Shrub (W)	Fatty Oil & Hydrogenation

Contd.

Table 7.3: Contd.

Plant Species	Common Name	Honey Potentialities	Flowering Period	Distribution	Type (Nature)	Other Economic Uses
Rosa macrophylla L.	Rose	N^3P^2	MAR–MAY	S. Tropical, S. Temperate, Temperate	Shrub (C)	Fruit, Hedge & Ornamental
Rubus spp.	Berries	N^2P^2	APR–JUN	S. Tropical, S. Temperate, Temperate	Shrub Climber (W/C)	Hedges & Fruit
Solanum melongena	Brinjal	N^3P^3	JUN–AUG	S. Tropical, S. Temperate, Temperate	Shrub (C)	Fruits & Ornamental
Daphne oleoides Scherb.	Daphne	N^3P^3	JUL–SEP	S. Temperate, Temperate	Shrub (C)	Ornamental & Purgative
Vitex negundo	Bannah Voilet	N^2P^2	MAY–JUN	S. Tropical, S.Temperate, Temperate	Shrub (W)	Ornamental Hedge & Medicinal
Vitis vinifera L.	Grapes	N^3P^3	MAY–JUN	S. Tropical, S. Temperate, Temperate	Shrub (W)	Fruit & Fermented Fruit Juice

N^1 = Major honey sources P^1 = Major pollen source
N^2 = Medium honey sources P^2 = Medium pollen source
N^3 = Minor honey sources P^3 = Minor pollen source

W = Wild S. Tropical = Sub-tropical
C = Cultivated S. Temperate = Sub-temperate

Source: Verma, 1990.

TABLE 7.4

Criteria for determining conservation priority of threatened species (Adopted from: IUCN, World Conservation Strategy, 1980), to be added as a point for honey source selection for plantations.

Size of Loss	Imminence of loss		
	Rare	Vulnerable	Endangered
Family	oooooooooooo oooooooooooo oooo 4 ooo oooooooooooo oooooooooooo	////////// ////////// //// 2 /// ////////// //////////	////////// ////////// /// 1 //// ////////// //////////
Genus	.... 7	oooooooooooo oooooooooooo oooo 5 ooo oooooooooooo oooooooooooo	////////// ////////// /// 3 //// ////////// //////////
Species	.... 9	.... 8	oooooooooooo oooooooooooo oooo 6 ooo oooooooooooo oooooooooooo

Note: Nos. 1–9 indicate = suggested order of priority
1, 2, 3 (//////) = highest priority
4, 5, 6 (oooooo) = intermediate priority
7, 8, 9, (·····) = lower priority

help conserve the biological resources, diversity becomes all the more important.

Acknowledgements

I am thankful to Dr. L.R. Verma for permitting me to reproduce a short list of honey plant resources from his book, in addition to his persistent efforts to force me to think on Honey Source perspectives.

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