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Role of insect pollinators in pollination of seed spices-A review

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Abstract

A large population of insects visits several seed spices and other crops right from initiation of flowering to harvesting of crops for foraging in seed spices coriander and fennel normally received 25 and 24 floral visitors, respectively in semi-arid and arid conditions of Rajasthan and honeybees are to be considered as primary pollinators of all seed spice crops. Among honeybee species, *Apis florea* contributed greatest percentage followed by *A. mellifera* and *A. dorsata* for pollination. Beekeeping with *A. mellifera* is profitable because of huge bee flora is available in Indian continent round the year, provide nectar and pollen to the honeybees. The manmade pollination with honeybees, adequate knowledge about bee flora, bee management, pollinator's management and managed pollination are the common practices to enhance the yield and quality in seed spices (highly cross pollinated) and promote beekeeping industry to produce good quality honey. In view of the great role of honey bees in pollination of cross pollinated crops especially seed spices, there is a need to popularize bee-cultivation with *A. mellifera* in the country.

Key words: Bee flora, beekeeping, pollinators, pollination, seed spices, yield

Introduction

Seed spices are the most important segment of aroma and test of cooked vegetables and countless dishes over the world and predominantly in Indian sub-continent. India is blessing with 63 spices crops, among them, 20 spices are considered as seed spices, producing 6.32 million tonnes of seeds from 35.41 lakh hectare area but the foremost seed spices group includes coriander (*Coriandrum sativum* L.), cumin (*Cuminum cyminum* L.), fennel (*Foeniculum vulgare* Mill.), fenugreek (*Trigonella foenum-graecum* L.), ajwain (*Trachyspermum ammi* L.), celery (*Apium graveolens* L.), dill (*Anethum* sowa Roxb., *A. graveolens*), nigella (*Nigella sativa* L.), caraway (*Carum carvi* L.) and few others crops (Free, 35; Singh *et al.*, 103 and Kumar *et al.*, 54). Among these, most of the seed spice crops are cross pollinated in nature i.e. coriander (Deodikar and Suryanarayana, 30; Baswana, 11 and Sihag, 100), ajwain (Kant *et al.*, 44), nigella (Munawar, 71), fennel (Narayana *et al.*, 72 and Baswana, 11), cumin (Sihag, 100), celery, dill (McGregor, 63 and Warakomska *et al.*,127) and anise (Free, 35). Pollination in these crops is a very simple practice involving transfer of pollens from the anther to the stigma of flower of same or different plants. In cross pollinated crops like seed spices, an external carrier is required to accomplish this process.

A number of insect visitors have been reported to visit the floral component of a range of seed spices under natural field conditions. Twenty five insect pollinators (*Apis dorsata* F., *A. florea* F., *A. mellifera* L., *Ceratina sexmaculata* Smith, *Polistes hebraeus* and unidentified hymenoptera sp. 1(Hymenoptera); *Episyrphus balteatus*, *Eristalis* sp., *Musca domestica*, *Musca* sp. 1, *Musca* sp. 2, *Musca* sp. 3 (Diptera); *Dysdercus koenighii* F., *Oxycarenus leatus* Kirby., *Bagra dahilaris* Burmeister (Hemiptera); *Coccinella septempunctata* L., *Menochilus sexmaculatus* F., Yellow beetle-unidentified (Coleoptera); *Chrysoperla zastrowi sillemi L.* (Neuroptera); *Plutella xylostella* L., *Lampiedis boeticus* L., *Pieris brassicae* L., and *Hellula undalis* Fabr. (Lepidoptera) are visiting the coriander crop, amongst them, honeybees like *Apis mellifera*, *A. dorsata* and *A. florea* were the most prominent pollinators of this crop during entire flowering period showed in a study carried out at experimental farm, NRC on Seed Spices, Ajmer (Unpublished data). Thirty four insect species of different orders and families were visited the coriander flowers and apoidea was prominent group among all flower visitors (Chaudhary and Singh, 23). Similarly, a number of insect pollinators including honeybees were reported to visiting fennel and many other seed spice crops in the country. In the midst of all insect pollinators in seed spices, honeybee species privileged utmost percentage in their pollination, is the key factor of higher and quality production. The value of insect pollination for worldwide agricultural production is estimated to be 153 billion, which represents 9.5% of the value of the world agricultural production used as human food in 2005 (Gallai *et al.*,36).

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Honeybee species and their role in pollination

Honeybees are the main pollinators in most of the cross pollinated crops particularly in seed spices. A large number of species of honeybees have been conserved and utilized for their services for pollination of various crops in the world. In the Asia, there are ten species of honeybees are to be considered and could be exploited for pollination in different agro-climatic conditions. These species are rock bee, *Apis dorsata* Fab., Indian bee, *Apis cerana indica* Fab., little bee, *Apis florea* Fab., European bee, *Apis mellifera* Lin. (introduced from native Europe for commercial beekeeping); dammer bee, *Trigona irridipennis* (sting less bee); *Apis laboriosa* Smith (the largest bee species in the world was confirmed from high altitudes of Himalayan range); red bee, *Apis koschevnikovi* Enderlein; *Apis andreniformis* Smith (world's smallest bee species, naturally available in southeast Asia); Malaysian bee, *Apis nuluensis* Lin., and black bee, *Apis nigrocinta* Smith are the native of Sulawasi Island and Indonesia (Sakagami *et al.*,91). Among these species of honey bee, five species: *Apis mellifera* L., *A. cerana* F., *A. dorsata* F., *A. florea* F. and *Trigona irridipennis* L. are the main pollinators and abundantly available in different part of the country (Deodikar and Suryanarayana, 30; Shelar and Suryanarayana, 96; Baswana, 11 and CCSHAU, 21). Two domesticated bee species (*Apis mellifera* and *Apis cerana*) have special value because their population can be managed according to the need of crops and flowering duration. Other wild bee species especially *Apis dorsata* and *Apis florea* also play an important role in many horticultural and seed spices crops. (Sihag,100) and detailed information of these species are as follow.

Apis dorsata Fab. (Hymenoptera: Apidae)

Apis dorsata, (the rock bee or giant bee) is a native of Asia, found in foot hills of Himalayas and northern regions of the country (Thomas *et al.*, 119). The Sunderban forests in West Bengal are rich in *Apis dorsata*, the organic honey from these forests are of great demand today. It is ferocious in nature and has almost black coloured abdomen. It is found mainly in the open branches of trees, along the sides of steep rocks in the forest and comparatively high places of isolated unused buildings. Each colony consists of a single comb. A colony normally comprises of one queen, thousands of workers (female sterile bees) and several hundreds of drone (male bees) in all the species of honeybees. They have high stinging reflex and frequent migratory habit. Honey production is good, produce plenty of honey about 35-40 kg per year from a single productive colony. In northern parts of India there are large number of *A. dorsata* colonies and they contribute large share of total honey production in India. The rock bee represents a major portion in pollination of coriander, fennel, dill, ajwain and rapeseed mustard but it cannot be domesticate and use in manmade pollination in these crops. *A. dorsata* preferred more to forage on bottle brush followed by litchi, citrus and summer squash flowers. These bees are never visiting to the flowers of radish and cucumber through out its entire period of flowering showing a distinct foraging preference. This species also shows their high level of stinging habit during dearth period in the month of mid April-June due to lack of bee flora as well as high temperature even resulting few casualties in terms of death of some of people working in fields in some parts of Rajasthan, Gujarat and adjoining states. (Anonymous, 9).

Apis florea F. (Hymenoptera: Apidae)

It is commonly known as little bee because of small size, golden in colour and quiet by nature. The species is common in central part of India and also occurs in arid and desert region of extreme climates, and also in plains and forests. Large quantity of *Apis florea* honey is collected from the Kutch area of Gujarat (Soman and Chawda, 107). Single colony have single comb, construct openly on branches of small trees, bushes, hedges, sunshade of building, caves, empty cases, etc. Honey production capacity is very less, about half a kilo of honey per year from a productive colony but the quality of honey is very good. It has not been domesticate as commercial beekeeping due to low yield of honey but play a foremost duty in pollination in seed spices crops like ajwain, cumin, dill, fennel, coriander etc. (Kant *et al.*, 44 and Sihag, 100) because of small flowers are very congenial for them for landing.

Apis mellifera L. (Hymenoptera: Apidae)

Bees of *A. mellifera* are medium sized, golden colour and quiet in nature. They are less prone to swarming, absconding and each colony has many combs and prefers darkness. In India, *A. mellifera* has been imported initially to agricultural plains of Punjab in 1960 and has become popular among commercial beekeepers because of good beekeeping source or bee-plants, migratory habits and higher honey yield. *A. mellifera* gradually spread to Himachal Pradesh, Bihar, Uttar Pradesh, West Bengal (Agrawal, 4) and recently in Kerala, Karnataka and Maharashtra. Since *A. mellifera* beekeeping need sound financial support it is difficult for the poor farmers to afford (Thomas *et al.*, 119). Generally beekeepers produce on an average 45-50 kg of honey per year from a single colony in India, 52-94 kg honey and 2-5 kg wax/colony/year in Bangladesh (Moniruzzaman and Rahman, 68). Rich bee farmers come in trucks bringing hundreds of colonies of *A. mellifera* to apple orchards in Himachal Pradesh. They move to the mountain areas of Himachal Pradesh, Uttrakhand, Punjab and foothills during summer and come down to plain during winters, when maximum seed spices crops are in blooming stage, contribute major portion of pollination in coriander (Kumar and Jaiswal, 50), fenugreek, nigella and many other field crops.

Apis cerana indica **Fab. (Hymenoptera: Apidae)**

Apis cerana is supposed to native of India or some parts of Asia. Twelve subspecies of *A. cerana* are scientifically identified till now. Bees are medium sized (larger than *Apis florae* but smaller than *A. dorsata* and *A. mellifera*), golden colour and comparatively quiet in nature. They make multiple parallel combs on trees, cavities and sunshade of buildings etc. preferably in dry and dark places. They have less migratory habit and easy to domesticate. Medium stinging habit but it is high during swarming period. In south India, on an average 10 kg of honey are producing from a productive colony of *A. cerana*/ year and it can be increase up to 15-20 kg/colony/year by adding supplementary feeding (Sarangarajan, 93) and honey quality is good (Saha, 90). The species is being cultivated in domestic way throughout the country. It is very prominent at higher altitude area of the country on coriander, buckwheat and many fruit trees.

Trigona irridepennis **(Hymenoptera: Apidae)**

Trigona sp. (dammar bee) is common in all parts of the country and remains long periods in the same abode. It is a very small bee and collects nectar from small flowers. Since the quantity of honey produced is small, these bees are not commercially used. It is a very important insect pollinator in many crops, and their honey has repute in folk medicine (Thomas *et al.*, 119).

Beekeeping status in India

Honey and beekeeping have a long history in India. Honey was the first sweet food tasted by the ancient Indian inhabiting rock shelters and forests. He hunted bee hives for this gift of god. India has some of the oldest records of beekeeping in the form of paintings by prehistoric man in the rock shelters. With the development of civilization, honey acquired a unique status in the lives of the ancient Indians. 'Honey hunting'- collecting honey from wild bee colonies, is an ancient practice as shown, for example, in cave paintings dating back to 11,000 BC found in Madhya Pradesh, India (Suryanarayan, 110), and in Ancient Egyptian drawings and paintings (Crane, 29). The history of beekeeping is rooted in and linked to honey hunting and associated practices. As settled farming became common, so too did the idea of keeping bees in hives, but beekeeping complemented rather than replaced wild collection. Gathering wild honey is still a common practice in many parts of the world; in India it is estimated that 22,000 tonnes of wild honey is collected by honey hunters annually - twice the amount of honey produced by the managed beekeeping sector (Wakhle and Pal, 126). Today, beekeeping is an important, sustainable, integral agricultural activity under the rural development programme in India, since it provides nutritional, economic, and ecological security and balance. The knowledge of agro-climatic conditions, the diversified flora, changing agri/horticultural pattern of crops, the types of bees and the management practices etc. play a pivotal role in transforming the beekeeping industry in the country.

In India, production of honey is very low compared to China, the highest producer, which exports 80,000 tonnes annually compared to India's 7,000 tonnes. Its consumption is also very low in India. Honey production in the country is only about 27,000 tonnes a year. Only about 20 per cent to 25 per cent of the bees are being exploited at present. Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal are the major honey producing states. Germany is the world's largest consumer, importing 90,000 tonnes of honey products annually. The per capita consumption of honey in Germany is 1.5 kg compared to a desimal 3 g in India. According to a survey, there is Rs 1,500 world market for health foods and India's share is stated to be negligible. In the world market the demand for honey is around one million tonnes. There is an immense possibility for India to increase its export share from 7,000 tonnes to three lakh tonnes if more people invest in bee colonies (Sarangarajan, 93).

India has a potential to keep about 120 million bee colonies that, can provide self-employment to over 6 million rural and tribal families. In terms of production, these bee colonies can produce over 1.2 million tons of honey and about 15,000 tons of beeswax. Organized collection of forest honey and beeswax using improved methods can also result in an additional production of at least 120,000 tons of honey and 10,000 tons of beeswax. This can generate income to about 5 million tribal families in the country.

Diversity of bee flora in Indian continent

Insect pollinators particularly bees visit floral plants for collecting food in the form of nectar and pollens. This floral fidelity of bees is due to their preference for nectars having sugar and pollen contents with higher nutritive values. Besides getting food for bees in their visit, they pollinate a large number of crops. Hence, the adequate knowledge about bee flora (bee forage) is the prerequisite to initiate the beekeeping in two ways are business i.e. enhancement of yield of cross pollinated crops and quality production of honey and its by products. The Indian continent offer huge potential for beekeeping with its vast bee forage resources. Nearly 50 per cent of total seed propagated crop plants depend on insect pollination worldwide. These forage source may be horticultural, agricultural crops, agro-forestry, wild and weed species are available in the agricultural fields and waste lands.

Beekeeping not only increases the production of agricultural and horticultural crops but it also conserve the forest and grassland ecosystems, thus maintaining biological diversity. The various fruit trees, vegetables, spices, ornamentals and medicinal plants, listed below (Table1) are available in the country round the year. The study showed that over 50 species of insects visited flowers of different species of selected crops during their flowering periods. The visiting preferences of insects to flowers of different crops differed among the crop species and insect species as well (Devkota, 32; Dhakal, 33; Neupane, 74 and Thapa, 117). The blossoming periods of bee-plants varied region to region due to variations in altitudes, topography, climate and other cultural and farming practices. They have good source of pollen and nectars to produced better quality of honey. There are 123 agricultural, horticultural and wild plants available in Indian continent are listed for beekeepers. The common and botanical names of, uses and flowering period of different bee flora are given in table1.

Table1: Enumeration of bee flora in Indian continent

Sl. No	Common/ local name	Botanical name	Flowering period	Bee food value	Other purpose	Reference
Fruit trees/plants						
1.	Kagzi-nimbu	*Citrus aurantifolia* (Christ)	Jan-Feb	N2, P2	Ed, Md	Hassanein and Ibrahim (38)
2.	Orange	*Citrus reticulata* Blanco	Mar- May	N2	Ed	Hassanein and Ibrahim (38)
3.	Malta	*Citrus sinensis* L.	Mar-May	N2, P2	Ed, Md	Lange and Vincent (57)
4.	Lemon	*Citrus limon* (L.) Burn	Jan-Dec	N1	Ed	Moffett and Rodney (66)
5.	Bael	*Aegle marmelos* (L.) Correa	Feb-Mar	N1	Ed, Md	Saha (90)
6.	Apple	*Pyrus malus* L.	Apr-May	N2, P2	Ed	Kurennoi (56)
7.	Naspati	*Pyrus communis* L.	Mar-Apr	N1, P1	Ed	Weiss (132)
8.	Apricot	*Prunus armeniaca* L.	Mar-Apr	N1, P1	Ed, Md	
9.	Almond	*Prunus dulcicis* (Miller)	Feb-Mar	N2, P2	Ed	Tufts (123)
10.	Peach	*Prunus persica* L.	Mar-Apr	N2, P2	Ed, Md	Bultatovic and Konstantinovic (18)
11.	Alu-bhukara	*Prunus cerasifera Ehrhart*	Feb-Mar	N1, P1	Ed, Md	
12.	Strawberry	*Fragaria* spp.	Nov-Feb	P2	Ed	Free (35)
13.	Loquat	*Eriobotrya japonica* (Thunb.)	Mar-May	N2, P2	Ed	Mann and Sagar (62)
14.	Pomegranate	*Punica granatum* L.	Apr-June	N2P1	Ed	Nath and Randhawa (73)
15.	Ber	*Ziziphus mauritiana* L.	June-Sept	N3	Ed	Singh (105)
16.	Jangliber	*Ziziphus jujube* L.	Nov-Mar	N3	Ed	Singh (105)
17.	Jamun	*Syzygium cumini* L.	Mar-June	N1, P1	Ed, Md	Partap (79)

18.	Guava	*Psidium guajava* L.	Mar-Apr	P1	Ed	Purseglove (82)
19.	Banana	*Musa paradisiaca* L.	Mar-May	N1	Ed, Md	Mahadevan and Chandy (61)
20.	Mango	*Mangifera indica* L.	Feb-Apr	N3	Ed	Neupane (74), Thapa, (117), Anderson *et al.* (8); Wolfenbarger (135)
21.	Date-palm	*Phoenix humilis* Royle	Mar-Apr	N2	Ed	McGregor (63)
22.	Lasora	*Cordia dichotoma* Forster	Mar-Apr	N1	Ed, Md	
23.	Tamarind	*Tamarindus indica* L.	Jan-Dec	N1	Ed, Md	Bhaskar and Mahadevaiah (12)
24.	Aonla	*Phyllanthus emblica* L.	Feb-Apr	N1	Ed	Tiwari *et al.* (121)
25.	Litchi	*Litchi chinensis* Sonnerat	Feb-May	N1	Ed	Pandey and Yadava (77)
26.	Avocado	*Persea americana* Mill.	Jan-Mar	N1	Ed	Vithanage (124)
27.	Mulberry	*Morus serrata* Roxb.	Mar-May	N1, P2	Ed	Kaur and Sihag (47)
28.	Phalsa	*Grewia asiatica* Lin.	Mar-May	N2, P2	Ed	Parmar (78)
29.	Passion fruit	*Passiflora* spp.	Jan-Mar	N1, P1	Ed, Md	Cox (26); Nishida (75)
30.	Custard apple	*Annona squamosa*	Aug - Oct.	N1P2	Ed, Md	Waykar *et al.* (129)
Vegetables						
31.	Radish	*Raphanus sativus* L.	Feb-Apr	N1, P1	Ed	Muhammad *et al.* (69), Hussein and Abdel-Aal (40)
32.	Cucumber	*Cucumis sativus* L.	Jul-Aug	N1	Ed	Alex (6)
33.	Pumpkin	*Cucurbita maxima* (Duch)	Jul-Aug	N1	Ed	Free (35)
34.	Muskmelon	*Cucumis melo* Lin.	Mar-Jun	N1, P1	Ed	McGregor and Todd (64)
35.	Watermelon	*Citrulus lanatus* (Thunb.)	Mar-Jun	N1, P2	Ed	Free (35)
36.	Tumba	*Citrullus colocynthis* L.	Jul-Sept	N2	Ed, Md	
37.	Ridge gourd	*Luffa acutangula* (L.) Roxb.	Mar-Nov	N1	Ed, Md	Free (35)
38.	Bitter gourd	*Memordica charantia* L.	Apr-Sept	N1	Ed, Md	Grewal and Sidhu (37)
39.	Onion	*Allium cepa* L.	Apr-June	N2	Ed, Md	Caron *et al.* (20); Bohart *et al.* (16)
40.	Dolichos bean	*Lablab purpureus* L.	Nov-Dec	N2, P2	Ed	Free (35)
41.	French bean	*Phaseolus vulgaris* L.	Aug-Sept	N2	Ed	Webster *et al.* (131); Mackie and Smith (60)
42.	Okra	*Abelmoschuse sculentus* L.	Apr-May	N1, P1	Ed, Md	Mishra *et al.* (65)
43.	Brinjal	*Solanum melongena* L.	Jan-Feb	N2	Ed, Md	Levin (59)
44.	Tomato	*Lycopersicon esculentum* Mill.	Jan-Mar	N2	Ed	Free (35)
45.	Pigeon pea	*Cajanus cajan* L.	Sept-Jan	N1, P1	Ed	Williams (134)
46.	Alfalfa	*Medicago sativa* Lin.	Feb-Apr	N1, P1	Ed	Ahmed *et al.* (5); Bohart (15); Tasei (112)
47.	Turnip	*Brassica rapa* L.	Sept-Dec	N1, P1	Ed	Sihag (100)
48.	Sweet potato	*Ipomea batatas*	June-Jul	N1	Ed	Thompson (120)
49.	Amaranthus	*Amaranthus* spp.	Jul-Sept	P2	Ed	Thomas *et al.* (119)
50.	Cluster bean	*Cyamopsis tetra-gonooloba* (L.) Taub	Jul-Sept	-	Ed	Free (35)
51.	Carrot.	*Dacus carota* Lin	Jan-Feb	P2	Ed	Hawthorn *et al.* (39)
52.	Makoi	*Solanum nigrum* L.	Jan-Dec	N1	Md	
Seed spices and oilseed crops						
53.	Coriander	*Coriandrum sativum* L.	Jan-Mar	N1, P1	Ed, Md	Shelar and Suryanarayana (96)
54.	Black cumin	*Nigella sativa* L.	Dec-Mar	-	Ed, Md	Zaitoun *et al.* (137)

55.	Chilli	*Capsicum annum* L.	Mar-Oct	N1	Ed	Tanksley (111)
56.	Fenugreek	*Trigonella foenum-graecum* F.	Jan-Mar	N1, P1	Ed, Md	
57.	Fennel	*Foeniculum vulgare* Mill	Jan-Mar	N1, P1	Ed, Md	Sagar (89)
58.	Cumin	*Cuminum cyminum* L.	Jan-Mar	N1, P1	Ed, Md	Sihag (100)
59.	Dill	*Anethum sowa* Roxb.	Jan-Mar	N1, P1	Ed, Md	Warakomska *et al.* (127)
60.	Anise	*Pimpinella anisum* Lin.	Jan-April	N1, P2	Ed	Free (35)
61.	Celery.	*Apium graveolens* Lin	Feb-Mar	N1, P2	Ed, Md	Warakomska *et al.* (127)
62.	Parsley	*Petroselinum crispum* (Mill) Nym.	Jan-Feb	P2	Ed	Burgett (19)
63.	Rapeseed mustard	*Brassica compestris* var. *toria*	Dec-Feb	N1, P1	Ed, Md	Mohammad (67)
64.	Indian mustard	*Brassica juncea* Lin.	Dec-Feb	N1, P1	Ed, Md	Sihag (100)
65.	Sarson	*Brassica compestris* var. *sarson* Lin.	Dec-Feb	N1, P1	Ed	Mishra *et al.* (65)
66.	Taramira	*Eruca sativa* Lam.	Jan-Feb	N1, P1	Ed, Md	Kapil *et al.* (45)
67.	Sunflower	*Helianthus annus* Lin.	May-Jun	N1, P1	Ed, Or	Sanchez and Ranera (92)
68.	Safflower	Carthanus tinctorius Lin.	Jan-Mar	N2	Ed, Md	Boch (14); Deshmukh *et al.* (31)
69.	Sesame	*Sesamum indicum* Lin.	Aug-Sep	N1	Ed	Panda *et al.* (76); Rashad *et al.* (86)
70.	Peanut	*Arachis hypogea* L.	Aug-Sep	N1	Ed	Rashad *et al.* (85)
71.	Chickpea	*Cicer arietinum* Lin.	Dec- Mar.	N2	Ed	Waykar *et al.* (129)
72.	Maize	*Zea mays*	Aug - Sep	P2	Ed	Waykar *et al.* (129)
Ornamentals, medicinal plants and timbers						
73.	Cosmos	*Cosmos bipinnatus*	Mar-May	N1	Or	Bista and Shivakoti (13)
74.	Candy-tuft	*Iberis* spp.	Jan-Mar	N21	Or	
75.	Calendula	*Calendula officinalis* L.	Dec-Feb	N2, P2	Or	
76.	Cotton	*Gossypium* spp.	Aug-Sep	N2, P2	Fb, Or	Sidhu and Singh (99)
77.	Guldawadi	*Chrysanthemum cinera-riaefolium* (Trev) Bocc	Dec-Mar	N2, P2	Or, Md	Smith (106)
78.	Cineraria	*Senecio cruentus*	Jan-Feb	N1	Or	
79.	Orchids	*Cymbidium, Dendrobium* etc.	Jan-Dec	N1, P2	Or, Md	
80.	Pansy	*Viola wittorckiana*	Oct-Dec	N2	Or, Md	
81.	Hollyhock	*Althea rosea*	Jul-Aug	N1, P1	Or	
82.	Buckwheat	*Phagopyrum esculentum* Moench	Jan-Mar	N1, P2	Ed	Dhakal (33)
83.	Malti	*Quisqualis indica* L.	May-Oct	N2	Or	
84.	Champa	*Pterospermum acerifolium* L.	Mar-Jan	N2	Or	
85.	Gulmohar	*Delonix regia*	Apr-June	N2	Or	
86.	Shoe flower	*Hibiscus rosasinensis*	Jan-Dec	N1	Or	Jones and Tamargo (42)
87.	Golden rod	*Salidago Canadensis*	Jan-Dec	N1, P1	Or	
88.	Indian borage	*Trichodesma indicum*	Aug-Oct	N1, P2	Or, Md	
89.	Zinnia	*Zinnia elegans*	May-Aug	N1	Or	
90.	Rose	*Rosa* spp.	Apr-June	N1, P1	Or, Md	

91.	Marigold	*Tagetes erecta* L.	Jan-Dec	N1, P2	Or, Md	Bista and Shivakoti (13)
92.	Chakunda	*Caesalpinia occidentalis* L.	May-Nov	N2	Md	
93.	Tulsi	*Ocimum sanctum* L.	Apr-Nov	N2	Md	
94.	Biskhapara	*Kalanchoe integra* Kuntz	Sept-Dec	N1, P1	Md	
95.	Arandi	*Ricinus communis* L.	Feb-Mar	N2	Md	Alex (7)
96.	Titapatti	*Artemisia* spp.	Aug-Oct	N1, P1	Md	
97.	Dhak	*Butea monosperma* (Lamk.)	Mar-May	N2	Dy, Md	Bista and Shivakoti (13)
98.	Karanj	*Pongamia pinnata* (L.) Pierre	Mar-May	N1	Or, Md	
99.	Chilaune	*Schima wallichii*	May-Jun	N2, P2	Md, Tm	Bista and Shivakoti (13)
100.	Burans	*Rhododendron arborium* Smith	Mar-May	N1, P2	Md, Fw	Tiwari *et al.* (121)
101.	Sisam	*Dalbergia sisoo* Roxb.	Mar-June	N1	Md, Tm	
102.	Mehandi	*Lawsonia inermis* L.	Jun-Oct	N3	Md, Dy	
103.	Neem	*Azadirachta indica* A. HLJuss	Mar-Apr	N1, P3	Md, Tm	Bista and Shivakoti (13)
104.	Primrose	*Oenothera rosea* L.	Apr-Jul	N1, P2	Or	
105.	Harsringar	*Nyctanthus arbor-tritis* L.	Aug-Nov	N2	Or, Md	
106.	Safeda	*Eucalyptus citriodora* Hook	Oct-Mar	N1, P1	Md, Or, Tm	Ibrahim and Salim (41)
107.	Safeda	*Eucalyptus oblique* L.	Sept-Nov	N1, P1	Md, Tm	Ibrahim and Salim (41)
108.	Safeda	*Eucalyptus camaldulensis*	Jan-Mar	N1, P1	Md, Or, Tm	
109.	Silver oak	*Grevillea robusta* A. Cunn.	Mar-May	N1	Or	
110.	Kunja	*Rosa brunonii* Lindley	Mar-May	N1, P1	Md	
111.	Duranta	*Duranta repens* L.	Jul-Sept	N2	Or	
112.	Sagaun	*Tectona grandis* L.	Mar-Apr	N1	Md, Tm	
113.	Siwanli	*Vitex negundo* L.	Mar-Oct	N1	Md	
114.	Jute	*Corchorus aestuans* L.	May-Sept	N3	Md	Kundu *et al.* (55)
115.	Berseem	*Trifolium alexandrinum* Lin.	Apr-Jun	N1, P1	Fd	Wafa and Ibrahim (125)
116.	Liskuru	*Triumfetta rhomboidea* Jacqin	Aug-Nov	N2	Md	
117.	Gokhru	*Tribulu sterrestris* L.	Jul-Nov	N2	Md	
118.	Sahjana	*Moringa oleifera* Lam.	Nov - Feb.	N1, P2	Md, Ed	Waykar *et al.* (129)
119.	Shia-kanta	*Mimosa himalayana* Gamble	Jun-Aug	N1	Md, Fd	
120.	Bottle brush	*Callistemon citrinus* (Curtis)	Mar-Oct	N1, P1	Or	Neupane (74)
121.	Ghania	*Salvia lanata* Roxb.	Mar-Jun	N2, P2	Md	
122.	Siris	*Albizzia lebbek*	Apr-May	N2, P2	Or, Fw	
123.	Amaltas	*Cassia fistula* L.	Feb-Apr	N2	Or, Md	
124.	Lantana	*Lantana camera*	Jul-Sep	N2	Md	Waykar *et al.* (129)

Abbreviations used:

1. N= nectar source, P- pollen source, 1= major source, 2= medium source, 3= minor source

2. Ag. Imp= Agricultural implements, Ed= edible, Fd= fodder, Fw= fuel wood, Md= medicinal, Or = ornamental, Dy= dye, Tm= Timber, Fb=fibre

Management of bees

Quality honey production is the major objective of the beekeepers or bee industrialists, whereas, the healthy swarm with higher population governed equal importance to the farmers for getting more yield of cross pollinated crops. Zamarlicki (138) reported that the knowledge of honey plants is the most important factor in bee management and that the survival of honey bees is related to the abundance of bee plants. The honey bee management is essential both in traditional method of beekeeping as well as modern beekeeping. All these are possible only with a proper management of bees, utilization of local plant resources and adapting to the local climatic conditions (Thomas *et al.*119). Modern beekeeping makes heavy use of beekeeping equipments and honey processing plant. This results the high efficiency and also the quality of processed honey. Site selection, flow management, dearth management, seasonal management, swarm management, provision of feeding, control and cure of bee disorders, bee diseases, pests and their natural enemies are the routine measures to keep bee colonies healthy and strong. There are some special management techniques like queen rearing, migration of bee colonies for good honey production or for colony multiplication, supering etc, by which the beekeeper takes up sufficient knowledge and experience in handling bee colonies. The some of these practices are given below.

Seasonal management of bees

The nectar acts as source of honey and provides heat and energy for bees and pollen provides the protein, vitamins, fatty substance and other nutrients to bees (Fluri and Bogdanov 34, Crailsheim *et al.* 28, Crailsheim 27) and, a direct consequence of nutritional deficiency (pollen shortage) is a decrease in the colony population (Keller *et al.* 48). Therefore seasonal management of bee colonies varies in different parts of the country, although the basic management practices are the same. Bee forage (pollen and nectar) are available only during certain period in a particular places. When surplus food source are available it is known as honey flow season. In contrast during dearth period, there will be scarcity of food. During extremes of these climates like summer, winter and monsoon, a certain specific management tactics are required.

Management of bees during summer season

Favourable weather and availability of bee forage is important. In dearth period when agro-horticultural crops are not in blooming, then weeds and wild flowering plants were observed as alternate food source for honeybees. Survival of any species in a geographical area follows the law of minimum. Wild flora provides nourishment to bees in adverse situations when cultivated plants are not in flowering state (Waykar *et al.*,129). Bees do much better when the weather is warm and dry. Summer season is critical dearth period with high temperature (over 35^{0}C), scarcity of water and few flowering plants mainly in arid and semi-arid areas of India. The few agricultural plants like *Coriandrum sativum, Vigna aconitifolia, Arachis hypogaea, Punica granatum,* and wild plants like *Barleria prionitis, Justicia betonica, Jacarandaa mimosifolia, Trichodesma* spp., *Cassia tora, Tridax procumbens* were blossomed during the season. However, their number per unit area is less or having lesser quantity of pollen or nectar. These minor sources are utilized by bees during the time of scarcity of major bee flora. Because of high temperature and scarcity of water for flowering plants this period was found unfavorable for honeybee foraging. Similar studies have also been carried out by some investigators (Kumar *et al.*,53; Singh,101; Thapa and Pokhrel,113 and Adhikari and Ranabhat,3). In addition, the bees have to survive intense heat and dearth period by following means.

- Provide sufficient shade under trees in cold places or provide artificial structure.
- Increase relative humidity and reduce the heat by sprinkling of water twice a day on gunny bags or rice straw puts on hive.
- Provide additional food as sugar syrup, pollen supplement, substitute and water to complete the pollen and nectar dearth.
- Increase ventilation by introduction of a splinter between brood and super chamber.
- Remove empty combs and store in air tight container.
- Use dummy division board to confine bees to small area and unite the weak colonies.
- Migrate the bee colonies in high altitude area if possible to escape the summer season.

During late summer and early autumn, brood production and honey production drop. Unlike in spring, crowd the bees by giving them only one or two honey supers. This forces bees to store honey in the brood nest.

Management of bees during winter season

During winter season in high altitude regions like Jammu and Kashmir, Uttarakhand, Himachal Pradesh, Sikkim etc., the temperature goes in very low level (below 10°C), honeybees activity adversely affected and need to be provide artificial feeding. Honey bees put it away for later use during the winter season. Honey bees do not hibernate. They remain active even on cold days. It is estimated that a hive of honey bees will consume more quantity of honey in the winter season because bees have to spend lot of energy in maintaining the temperature of the brood during winter and lowering the temperature in summer by fanning and water evaporation, respectively. Considering these facts CBRTI had designed a hive "Millennium Hive" with adequate insulation and ventilation. It is noticed on warm days during winter season that bee leaves the hive to take a flight. It is necessary because the bees hold its waste until it can leave the hive to get rid of it. Honey bees do not generally defecate in their hive. In winter, maintain strong and disease free colonies and provide new queen to the hives, if necessary (necessity). Must be provide winter packing in the cooler area especially in hilly regions.

Management of honey flow season

This season coincides with spring. The peak periods of honeybee foraging activity (honey flow period) were recorded during mid-December-February of winter season and mid-July to September of monsoon season of the year (Waykar *et al.* 129). *Brassica rapa, Cicer arietinum, Triticum aestivum,* are nectar yielding, *Zea mays, Solanum melongena* were pollen yielding, and some plants species viz *Coriandrum sativum, Lagenaria siceraria, Moringa oleifera, Citrus limon, Citrus aurantifolia, Foeniculum vulgare, Brassica* spp. are both nectar and pollen yielding (Waykar *et al.*, 129, Singh, 101 and Thapa and Pokhrel, 113). Pollen and nectar available easily in the nature and as nectar is processed to honey, excess moisture is produced inside the hive. Use millennium hive to provide a direct flow of air current to remove the excess moisture. It also includes the followings.

- Beekeepers should provide more space for honey storage by giving comb foundation sheet or built combs.
- Confine queen to brood chamber using queen excluder.
- Divide strong colonies into two-three new colonies, if colony multiplication is needed.
- Queen rearing technique may be followed to produce new queens for new colonies.

In rainy season, always avoid the dampness at apiary site, provide proper drainage when bees are confined to the hive and also provide sugar syrup feeding.

Swarm management

Bee swarm is managed by following means:

- Remove the brood frames from strong colony and provide to weak colony.
- Pinch off the queen cells during inspection.
- Divide strong colonies into 2-3 new colonies and queen.
- Trap and hive primary swarm.

Hence, beekeepers should take into account that weather conditions influence the bee behaviour and plan to work bees when conditions are favourable.

Impact of bee pollination on yield and quality in seed spices

Beekeeping has positive ecological consequences. Bees visit plants for searching food in the form of nectar and pollen. In this process of pollen collection, bees visit the number of flowers as resulted pollination of horti-agricultural crops and wild plants. It increases yield in terms of seed yield and also improves the quality of seeds/fruits and vegetable. Bee pollination also increases oil contents of seeds in seed spices, sunflower and mustard. In India, the total area under bee pollination dependent crops is around 50 million hectares and one hundred and fifty million colonies are needed to meet this height at the rate of 3 colonies/hectare. At present, there are only 1.2 million colonies existing in the country, hence, there is a wide scope for expansion of beekeeping for pollination in cross pollinated crops.

Coriander (*Coriandrum sativum* L.) blooms in the months of January-March and produces pinkish-white flowers in compound umbels. The flowers produce a good amount of nectar and pollen, and are visited by the insects. Honey bees are the primary pollinators and bee pollination can increase the yield by 122.2% over without bee pollination (Chaudhary and Singh, 23) and 187.3% higher using bee-Q (bee attractant). Study shows that bee pollination increases seed weight (Sihag, 100). Honey bees are reported to play a vital role in enhancing the productivity level of different crops including most of seed spices crops (Abrol, 1 and Sihag,100). Similarly higher seed yield (96.55%) and germination percentage (79.75%) of coriander due to insect pollination was recorded in a study carried at Pusa, Bihar (Kumar and Jaiswal, 50). There is no specific recommendation on the number of bee colonies for use but in general 2-3 colonies of *A. mellifera* or 4-6 colonies of *A. cerana* per hectare is sufficient for pollination. Kakar (43) reported that the germination of seeds harvest from bee pollinated plants was found to be extent of 92.50% as against 20% in plots without bee pollination and it was 96.55% in open pollinated. Rao and Suryanarayan (84) reported that in addition to quantity, the insect pollination in general also brought about high germination in onion seeds.

Fennel (*Foeniculum vulgare* Mill.) is highly (80-90%) cross pollinated crop and *A. florea* is the most abundant pollinator comprising 81% of the total visitors (unpublished data). Chaudhary (2006) reported 39 insect species accountable for pollination in fennel. The crop is highly entomophilous with only 45-52% fruit set due to self-pollination (Shilova, 97). Honey bees (*Apis* cerana F., *A. florea* F. and *A. mellifera* L.) and syrphid *flies* are the most common pollinators (Youngken 136; Narayana *et al*.,72; Sagar 89; Baswana 11; CCS HAU 21; Chaudhary et al.24). Bee pollination abundantly increases the seed yield in fennel. Bee pollinated plants gave twice the yield compared to plants incaged plots (Youngken 136; Narayana *et al*.,72 and Sagar 89). Artificial pollination has been found to improve yield (Choudhry, 25 and Sundararaj *et al*.,109). Fennel is protendrous in nature, and within each flower, pollen is shed before the stigma become receptive (Sundararaj *et al*.,109). Within each umbel and within each umbellate flowers at the periphery reach anthesis first and those in the center last. This is directly related to ontogeny (Peterson, 81). There are differences between varieties but generally the five stamens of each flower emerge sequentially over a 6-8 h period (Sundararaj *et al.*,109). Mean seed yield of fennel in caged plots was 5.2 g $plant^{-1}$ compared to 29.7 g $plant^{-1}$ in open pollinated and 26.6 g $plant^{-1}$ in bee pollinated crop, this is an increase of 474.7% and 413.5%, respectively (Chaudhary, 22).

The honey bees in cumin (*Cuminum cyminum*) not only increased the production but also produce honey which is viscous, contain higher quantity of iron and unsaturated sugar with attractive aroma. In India, plants of *C. cyminum* caged to exclude insects and plants not caged, yielded 209 and 501 seeds per plant, 0.92 and 1.82 g seeds per plant, and 1000 seeds weighed 7.2 and 8.8 g, respectively (Sihag, 100).

In nigella (*Nigella sativa*), honeybees are the predominant pollinators (Mukherjee *et al.*,70). *A. mellifera* is a major pollinator among honey bees increased number of seeds set and yield produced in India. Hence, strategies to promote pollination by honeybee may be helpful in enhancing seed yield in *N. sativa*. Many flies and bees have been mentioned as pollinators of dill, play a significant role in enhancement of yield. Irregular of yield is a common problem in seed set of Nigella cultivated under semiarid conditions, the variations in crop production have been related to pollination failure (Wilcock and Neiland, 133) or drought effect (Strid, 108). Some researchers reported that the bees is the main pollinator to most plant flowers in natural and semi-natural condition during flowering stage (Richards, 88; Buchmann and Nabhan, 17) and sometimes flies and butterflies. The main Nigella flower pollinators were honeybees (Ricciardelli and Persano, 87) as well as bumble-bees (*Bombus lucorum*, *Bombus lapidarius*), wasps (*Polistes dominulus*, *Eumenes pedunculatus*, *Cerceris arenaria*, *Philanthus triangulum* and *Ammophila sabulosa*), *Halictus* sp., *Chrysis* sp. and *Lasioglossum* sp. are major flower visitors in Austria (Weber, 130). Munawar *et al.* (71) showed the significantly higher yield of *N. sativa* in the plots caged with *A. mellifera* in comparison to plots caged without pollinators.

In celery (*Apium graveolens*), the attractiveness of the flowers, honeybees visit the flowers and considered as main pollinating agent of the crop. The flowers of *A. graveolens*, celery (var. *duke*) and celeriac or turnip root celery (var. *rapaceum*) are markedly protandrous so pollen must be transferred from other flowers to achieve set. In Poland, Diptera (mostly pollen-feeding Syrphidae) are the main pollinators of cultivar rapaceum, few bees (mostly Andrenidae) visiting the flowers (Warakomska *et al.*, 128). Schlessman *et al.* (94) showed that in the case of mountain parsley, *P. montanus*, there is a clear correlation between the sexual phase of the umbels and the number of visits - insects visited male stage umbels three times more frequently. In protendrous Apiaceae however the nectar production pattern may be different. In *Carum carvi* (Langenberger and Davis, 58), *C. sativum*, *Dacus carota* (Koul *et al.*,49), nectar is produced in either sexual phase, and it may be even more abundant in female stage flowers. Female stage flowers of *C. carvi*, for instance, produced approx. 70% of the total flower nectar volume (Langenberger and Davis, 58). In anise, open pollination produced the highest significant eight of seeds/feddan (1024.12 kg) followed by honeybee pollination (781.55kg), but insect exclusion plots were of the lowest value (300.24 kg).

Out of the ten seed spice crops, four *viz.*, cumin, coriander, fennel and fenugreek are considered to be the major seed spices, whereas, the remaining six seed spices *viz.*, ajwain, dill, nigella, celery, anise and caraway are considered as minor seed spices. Out of these ten seed spices eight belong to Apiaceae family, whereas, nigella belongs to Ranunculaceae and fenugreek belongs to Fabaceae. Most of these seed spices which belongs to Apiaceae are cross pollinated and protandrous in nature and the level of natural cross pollination varied from crop to crop. Several experiments have been conducted in the past to study the level of natural cross pollination in these crops by many workers in country. Extent of natural cross pollination under Anand conditions was observed to be 2.35 per cent (Patel *et al.*, 80). Ramanujam *et al.* (83) reported the natural cross pollination 55.86 % in coriander, 70.05 to 77.83 % in ajwain and 82.20 to 91.4 % in fennel.

In addition to seed spices, bee pollination also increases the yield in several folds in many other crops *viz.*, in sunflower, yield increases even up to 600 per cent due to bee pollination. It improves quality and quantity of seeds and oil content also increases by 6.5 per cent in seeds. Cucurbits are monocious with staminate and pistillate flowers in same plant. Due to bee pollination fruit set increases up to 30 to 100 per cent. *A. mellifera* plays a key role in pollination of muskmelon (*Cucumis melo*) and improve the fruit set and fruit yield under protected conditions (Singh, 102). Cardamom is an important commercial crop depending on bees for pollination wherein, yield increases up to 21 to 37 %. Similarly the yield increases by 112 % in Lucerne, 17-19 % in cotton, 93 % in onion, 44 per cent in apple and 43 % in mustard due to bee pollination in different region in India.

Bee poisoning

Irrational and indiscriminate use of highly toxic pesticides on the cross pollinated crops especially during blooming season give devastating set back to the non-target fauna (predator, parasitoids and pollinators like honeybees). Death of bees in the field as well as brood poisoning in the hives due to poisoned nectar collected by the bee causes big loss to the beekeeper and farmers. Many cases occur because farmers are not aware of the hazard of insecticides to bees, pesticide handling, safe application and pollution to the environment (Thapa *et al.*, 114 and Thapa, 118). Hence, the selection of insecticides used in insect control and the timing of application programme can accordingly modify or changed to reduce bee poisoning without increasing the cost or inconvenience to the farmers.

Both the misuse and excessive use of pesticides really disturb the natural ecosystem and produce serious environmental problems adding costs in four ways to the people: i) health related expenses, ii) environmental pollution, iii) yield loss due to non-target pesticide application resulting in pesticide induced pest resurgence and destruction of natural enemies and iv) financial burden both to poor farmers and the country as a whole (Baker and Gyawali 10). Pesticide problem on pollinators is severe in the developed country like USA (loss of about 320 million US$/year) and is equally important for other countries as well. After the heavy use of chemical pesticides all domesticated bees were wiped out in Ilam and Nuwakot and many colonies were destroyed in Chitwan (Thapa, 115 and Thapa, 116).

Honey bee pests and diseases

Honey bee brood and adults are attacked by a numbers of diseases like, bacterial, viral, protozoan and fungal *Viz.*,Thai Sacbrood virus, American Foulbrood disease caused by *Bacillus larvae* to the larvae and pupa of honeybees, European Foulbrood caused by bacteria *Streptococcus pluton* in larvae of honeybees, Chalk brood and Stone brood disease are caused by fungi which is most frequent during damp conditions. Nosema is a widespread protozoan disease of adult bees. In spring season, infected colonies build-up very slowly. Bees appear weak and may crawl around in the front of hive. The spread, intensity and control of disease are affected by climatic factors, forage availability and quality (Sharma, 95).

Bees also suffered with exotic species of parasitic mites and other natural enemies. Mites are microscopic in size and are ecto or endo parasites of honey bees. Generally three mite species cause damage to honey bees, *i.e.* Varroa mite, *Varroa jacobsoni*, *Tracheal mite*, *Acarapis woodi* and brood mite, *Tropilaelaps clareae*. *Acarapis woodi* causes acarine disease in the honeybees. Inside tracheae, it blocks air exchange and pierce the walls of the tube to suck the blood. Symptoms resemble to those of nosema. Bees become weak and seen crawling in front of the hives. Sometimes uncouple their wings so that all four wings are visible and bees are unable to fly. The other natural enemies are greater wax moth, *Galleria mellonella* L., lesser wax moth, *Achroia grisella* Fabricius, yellow banded hornet, *Vespa cincta*; bee hunter wasp, *Palarus orientalis* and *Philanthus ramakrishnae* are notice to attack on bees. *P. ramakrishnae* cause damage especially in hilly regions. It was reported problem of bee pests and diseases, while (Kaur, 46) found that 55 percent of the respondents were bothered by the attack of bee enemies. Additionally, bee equipment is attacked by other insects. The diseases and pest control in bees require constant vigilance by the beekeepers.

Unwanted honeybee colonies

In nature, when honeybees swarm establishes new colonies, they often move into hollow trees or voids inside walls of house or any other suitable dark place nearby hive. Beekeepers are not accustomed to the slight of natural bee colonies and they may react toward them with fear and hostility. Beekeepers are frequently asked to rid someone of unwanted bee colonies to save the bee forage (nectar and pollen) for reared honeybees to the nearby vicinity to permanently solve this problem, the beekeepers must be removed the entire nest and bees from the site of beekeeping. It is not enough to simply spray on the nest with an insecticide because after some time, insecticide degrades the cavity and combs are attractive to future swarm of bees. Hence an experienced beekeeper can expose the nest and remove the bees and combs.

Constraints of apiculture in India

At present, beekeeping is an agri-horticultural based industry in the developing countries like India offer better livelihood to the farmers of rural background. It provides high returns as honey, royal jelly, bee wax, bee venom, propolis, etc. However, there are many constraints which affect the promotion of beekeeping in India (Kumar and Singh, 52).

Consistent de-forestation is the major challenge in promotion of commercial bee cultivation in the country other wise which provides the huge resources of bee flora during off season. Indiscriminate use of insecticides, pesticides, weedicides etc. on the crops causes heavy losses to colonies ultimately discouraging beekeeping. Some researchers reported that problem of pesticide sprays was faced by majority of the respondents, resulted in killing of honey bees, which caused great loss (Shinde and Phadke, 98 and Kumar, 51). Wild fires and mono-culture are the common practices of many farmers in Rajasthan, Madhya Pradesh, Maharashtra and other adjoining states. Wild fire is also practices in Jhoom cultivation in north eastern region of the country.

The problem of bee diseases and natural enemies is a major constraint in beekeeping industry. Sometimes, the diseases remain undetected for long and when they appear, cause catastrophic destruction. Lack of awareness among farmers and involvement of Extension functionaries *i.e.* Welfare Organizations, Women Clubs, Tribal Development Institutions and missions to take modern beekeeping to remote and interior areas. Also there is less interaction between local beekeepers and extension staff to evolve new techniques and management (Abrol, 2).There are non-availability of good qualities of bees, public dispute due to bees, lack of skilled labour, high octroi charges on honey, non-availability of quality equipment/tools, difficulty in getting training and subsidy. Unfavorable weather conditions are also a major setback for beekeeping. Extreme hot and cold weather reduced bee population. In parallel, cloudy atmosphere and rainy season also affect bee population adversely. Tonapi (122) inferred that the natural factors put great limitation in expansion of beekeeping whereas (Singh *et al.*,104) found bad weather conditions as a major constraint in honey production.

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