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Status of bee keeping in Himachal Pradesh, India: A review

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Abstract
Beekeeping in Himachal Pradesh is very primitive. Indigenous beekeeping with *Apis cerana* is an integral part of the social and cultural heritage of rural and tribal communities. Comparative morphological studies have revealed that Himachali bees are smaller than Kashmiri bees. Beekeeping with *Apis mellifera* is migratory and it helps in increasing the honey production through exploitation of different bee flora thereby providing opportunity for overcoming unfavorable climatic conditions as well as attack of local bee enemies. Comparative studies have revealed that *A. mellifera* bees were very prone to stinging and were easily distributed as compared to *A. cerana* which were less excitable and could be safely handled. Major bee enemies of the state include Thai sac brood, Nosema, Europeon Foul Brood, ectoparasitic mites, Wasps, birds and bear. *Plectranthus* is one of the major honey flow flora for the winter months in Himachal Pradesh.

Keywords: *Apis cerana*, *Apis mellifera*, Himachal Pradesh, history, honey flora, indigenous bee keeping, insect-pests and diseases, migration, pollination

Introduction

History and Status of beekeeping in Himachal Pradesh

The earliest record of beekeeping in Himachal Pradesh was reported in 1882-1884 when Sir Louis Dane, an assistant commissioner in Kullu and hobbyist beekeeper, kept bees in modern hives. Later, Lieutenant Governor of Punjab, introduced modern bee hives in Shimla in Barnes Court. In 1909, Punjab Beekeepers association was formed in Shimla under the patronage of Sir Louis Dane. Mr. F. S. Cousin (Retd. Lieutenant) was appointed as apiarist in the department of Agriculture and Industries, with its headquarters at Sanawar (Himachal Pradesh) in 1913. Mr. Dorafeef, an engineer employed in the hydro-electric scheme, Joginder Nagar (Himachal Pradesh) established an apiary at Kahul (Kullu) in 1930. This apiary was later shifted to Raison (Kullu) by Litenkov. Commercial bee farms with improved beekeeping equipments were established at Nagrota in district Kangra (1936) and one at Raison (Kullu) which was shifted to Katrain (Kullu) in 1939 (Verma 1990) [84]. Only *Apis cerana indica*, the Indian honeybee was reared in the State until the year 1961 when *Apis mellifera* from Italy was introduced in the State at Bee Research Station, Nagrota in Kangra (Sharma *et al*. 2015) [68].

India has enormous potential of beekeeping due to abundance of bee flora and bee friendly climatic conditions. For the development of beekeeping in Himachal Pradesh, floral calendars have already been developed (Rahman and Singh 1941; Sharma and Gupta 1993; Sharma and Raj 1985) [48, 67]. Himachal Pradesh is unique in having different agro-climatic zones with varying bee flora that helps to sustain beekeeping in the state. The state is divided into four agro climatic zones viz. Sub tropical and low hills (upto 914 m); sub temperate, sub humid mid hills (915-1523 m); wet temperate high hills (1524-2472 m) and dry temperate high hills and cold deserts (above 2472 m). All the four species of honey bees are found in different climatic zones of Himachal Pradesh. At present, both *A. cerana* and *A. mellifera* are complementary to each other as far as beekeeping is concerned in temperate and subtropical regions, respectively, (Verma 1990) [84].

Prior to April, 1971 there were only 1250 bee colonies managed in modern bee hives in whole of Himachal Pradesh. Beekeeping with European honey bee, *A. mellifera* is practiced in Himachal Pradesh as migratory beekeeping. According to the survey carried out by Rana *et al*. (2000) state Horticulture Department had 1300 colonies of *A. mellifera* and 25 *A. cerana* at

various locations. In addition to this, there were about 300 professional beekeepers having about 9800 *A. mellifera* and 100 *A. cerana* colonies. There were about 600 *A. cerana* colonies in log and wall hives (traditional). The number increased to about 90,000 colonies of *A. mellifera* and the number of beekeepers increased to 1500 with production of 1700 MT honey in low to high hills of Himachal Pradesh (Neha *et al*. 2020). Mattu (1992) [34] has reported 3- kg honey per *A. cerana* colony from Himachal Pradesh. Sharma (2001) reported in a survey of 60 beekeepers in district Kangra, Himachal Pradesh that migratory bee keeping resulted in higher honey yield (41.60 kg/colony) as compared to stationary beekeeping (15.66 kg/colony), the cost structure of the two was not statistically significant. The net returns were higher in former as compared to the later. Sharma *et al*. (2015) [68] also reported 20 kg average honey per *A. mellifera* and 3 kg honey per *A. cerana* colony. Kumar and Kaundal (2016) [32] reported annual honey production of 8.15 kg per colony in Kangra district which was quite low.

Indigenous honey bee keeping with *A. cerana*

Honey bees have been serving mankind since time immemorial and beekeeping is one of the most traditional practices in India. Indigenous knowledge refers to the unique local knowledge existing within, and developed around a particular geographic area (Grenier 1998) [20]. Beekeeping with *Apis cerana* is an indigenous industry and forma an integral part of the social and cultural heritage of rural and tribal communities. The beekeeping industry forms an integral part of the social and cultural heritage of rural and tribal communities in the country. It is also an environment friendly occupation (Verma 1989; Verma and Partap 1993) [89, 90]. *A. cerana* is gentle in temperament, industrious and well adapted to the ecological conditions of South and Southeast Asia. In this Himalayan region bee colonies require special care particularly in the winter and monsoon seasons. In these seasons, bee activities are reduced to a minimum due to the low outside environmental temperatures particularly during January and February, and the prolonged wet conditions during July-August. Consequently there are problems of inadequate food reserves, queenlessness, reduced fecundity and diseases. As a result of this *Apis cerana* colonies often abscond or desert the hives (Verma 1990) [84]. Indigenous bee keeping methods in log and wall hives are still in common in Kullu valley despite of the fact that modern beekeeping started here in 1934. Bees are kept in traditional hives made from wood of *Pinus wallichiana* (kail) and *Picea smithiana* (rai). Log hives are locally known as “dhindhor” in Kullu valley are made from hollowing out the tree trunk (Sharma *et al*. 2000) [69]. They reported that sealed honey is harvested twice in a year during June (summer) and November (winter). According to survey conducted in Chamba, there were 2.45 traditional wall hives per house with occupancy rate of 53.94%, testifying the richness of the culture. These indigenous hives are locally known as “Ganari” in Chamba district (Verma and Attri 2008) [92]. In Sirmaur district of Himachal Pradesh *Apis cerana* are kept in traditional wall hives of different sizes, dimensions and designs (Thakur and Kumar 2009) [83]. A survey conducted in the Sirmaur district revealed that there are 2.92 wall hives per house and the occupancy rate of each hive is 71.94% testifying to the success of traditional methods (Kumar and Thakur 2014) [33].

Various substitutes and substrates have been tried as feed for *A. cerana* in Himachal Pradesh. The one of the earliest such references reported by Sharma (1951) [75] who reported that buckwheat flour prepared in the form of half-cooked sweetened pancake was the best among the cereals tried on *A. cerana* in Himachal Pradesh for bee colonies. But since then no major work was carried out for supplement feeding in Himachal Pradesh. An experiment was conducted to work out the optimum schedule for supplementary feeding to *A. cerana* in Katrain village in Kullu valley. The study revealed that there is no need of giving traditionally practiced supplementary feedings as in the form of pollen and sugar during the prolonged wet months of July to August in Katrain area as sufficient bee flora is available to the colonies during this period in this region. It may thus be possible to start economical bee keeping with *Apis cerana* on small scale at orchardist level (Nirupma *et al*. 2018a) [44]. In another study conducted at Kullu valley on brood rearing efficiency in indigenous bee *A. cerana*, it was revealed that per cent adult emergence on egg basis during the months of March and August averaged to 55.22 and 61.22, respectively. The per cent adult emergence from sealed brood was observed to be 70.08 + 22.86 and 90.20 +0.59 during March and August, 2010-11 respectively (Nirupma *et al*. 2018b) [45]. The colonies of *A. mellifera* are restricted only to modern hives. Hence *A. cerana* plays an important role even in forest ecosystem for maintaining biodiversity. Due to promotion of beekeeping with *A. mellifera*, the population of *A. cerana* is declining rapidly threatening its existence in the Himalayan region (Nirupma *et al*. 2018b) [45].

Foraging range and behavior of *A. cerana*

Dhaliwal and Sharma (1973) [14] in their studies on flight range of *A. cerana* on cauliflower and barberry flowers reveals that maximum foraging range in cauliflower was 900m and on barberry was 1,100m. Further, studies on flight range of *A. cerana* reveals that all the foraging bees collected syrup upto about 650 m from the hive along gentle gradients (below 10°), and up to 250-300 m along steep gradients (above 20°) (Dhaliwal and Sharma 1974) [15]. Foraging behavior of *A. cerana* in Shimla hills revealed that foraging activity was greater in summer and autumn as compared to other seasons of the year and the peak nectar collection was observed after the peak of pollen collection (Mattu and Verma 1985) [39]. Verma and Dulta (1986) [86] reported that the duration of a foraging trip in both the species of honeybees increased with the increase in altitude of the place and this duration was significantly longer at 24.00 and 18.75 m than at 13.50 m in Jubbal area of Shimla hills. At higher altitudes, both the species may make less trips per day than at lower altitudes.

Biochemical studies

The extraction and quantitative extraction of the thoracic flight muscles of different species of the genus *Apis* and two ecotypes (Himachali and Kashmiri) of *Apis cerana* were done in summer (active) and winter (inactive) seasons. Glycogen was the major fuel source in the flight muscles of the different species of honeybees, and the ecotypes of *A. cerana*. The amounts of glycogen, total lipids, glycogen phosphorylase, succinic dehydrogenase and glycerophosphate dehydrogenase per mg of thoracic flight muscle (fresh weight) of the 4 species of honeybee and two ecotypes of *A. cerana* followed the pattern, *A. dorsata* > *A. mellifera* > *A. cerana* > *A. florea*, $P<0{\cdot}01$; *A. cerana* Kashmiri > *A. cerana* Himachali, $P<0{\cdot}05$. The amounts of glycogen, total lipids and activities of all the

enzymes were significantly higher (P<0.01) in summer than in winter, for all the species and ecotypes (Dulta and Verma 1989) [19].

Morphometric studies on honey bees

Dulta and Verma (1987b) [8] reported that all four species of honeybees and two ecotypes of *A. cerana* (Kashmiri and Himachali bees) differ from each other in the size of flight muscles. With a few minor exceptions the length and breadth of indirect and accessory indirect Right muscles followed the order *A. dorsata* > *A. mellifera* > *A. cerana indica* > *A. florea*, with statistically significant differences between species (P<0.01). The order of size for direct flight muscles differed from the indirect muscles, with *A. cerana indica* > *A. dorsata* > *A. florea* > *A. mellifera*. Mattu and Verma (1983, 1984a, b) [35] reported three different ecotypes of *A. cerana indica* in the Manipur, Himachal and Kashmir regions of the north-east and north-west Himalayas, and arbitrarily called them Manipuri, Himachali and Kashmiri bees. The order of body size of these ecotypes was Kashmiri > Himachali > Manipuri. In the studies on tongue length of Indian honey bees collected from Himachal and Kashmir, it was indicated that this character was not related to altitude. A significant positive correlation was established between altitude and different parts of the antenna for bees of the Himachal region (Mattu and Verma 1983) [35]. Similar studies were done with wings. The results revealed that length and breadth of both fore and hind wings, proportions of several wing-vein cells, size of some cell angles, and number of hamuli of Himachali bees was positively correlated with altitude (Mattu and Verma 1984a) [36]. Comparative morphometric studies on hind leg, tergites and sternites of Indian honey bee indicated that these tended to be larger among Kashmiri bees as compared to Himachali bees (Mattu and Verma 1948b). Sharma (1990) [76] found higher dimensions of metatarsus in *A. mellifera* from Himachal Pradesh (India).There was significant variation with locality and a positive correlation with altitude for all measured parameters of the hind leg in Himachali bees. These studies are well supported by the recent research studies which reveals that Hindu Kush/Kashmir bees are somewhat larger than those of Himachal Pradesh (Radloff *et al*. 2005) [47].

Morphometric studies on *A. mellifera* samples collected from different locations of Himachal Pradesh revealed that head height × width, proboscis length, thorax length, abdomen length, fore wing length × width, cubital index, hind wing length × width, number of hamuli, coxa length, trochanter length, femur length, tibia length and metatarsus length × width were found to be 3.19±0.10 × 3.68±0.09 mm, 6.29±0.06 mm, 4.26±0.20 mm, 5.91±0.93 mm, 9.13±0.18 × 3.00±0.08 mm, 2.20±0.36, 6.38±0.14 × 1.80±0.05 mm, 20.88±1.32, 1.10±0.09 mm, 0.79±0.10 mm, 2.45±0.10 mm, 2.91±0.13 mm and 1.92±0.07 × 1.08±0.07 mm, respectively (Ibrahim *et al*. 2017) [25]. While studying the morphometrics of *A. cerana* in various agroclimatic zones of Himachal Pradesh, it was reported that head height × width, proboscis length, thorax length, abdomen length, fore wing length × width, cubital index, hind wing length × width, number of hamuli, coxa length, trochanter length, femur length, tibia length and metatarsus length × width varied from 2.87-3.07× 3.49-3.78 mm, 5.35-5.46 mm, 3.97-4.39 mm, 5.18-6.01 mm, 8.46-8.93 × 2.86-3.03 mm, 2.70-3.38 mm, 5.97-6.37 × 1.62-1.72 mm, 18.64-19.90 mm, 0.91-1.08 mm, 0.63-0.76 mm, 2.29-2.42 mm, 2.72-2.95 mm and 1.83-1.97× 0.98-1.07 mm, respectively (Ibrahim *et al*. 2019) [24].

Stationary and migratory beekeeping with *A. mellifera*

Migratory beekeeping helps in increasing the honey production through exploitation of different bee flora thereby providing opportunity for overcoming unfavorable climatic conditions as well as attack of local bee enemies (Sharma and Raj 1985) [73]. Kumar and Kashyap (1996) conducted studies at sub-temperate, sub-humid mid hills and wet temperate high hills and found that sugar feeding is necessary during different seasons for maintaining *A. mellifera* as stationary beekeeping. Rana and Kumar (2011) [63, 65] recorded the performance of *A. mellifera* colonies in high hills of Himachal Pradesh and observed increase in bee strength from 8 to 11 frames during February-May owing to flowering of the temperate fruits. Brar *et al*. (2018a) [7] conducted survey studies from six districts viz., Kullu, Kinnaur, Sirmaur, Solan, Shimla and Una of Himachal Pradesh during July 2015 to June 2016 to know the status of rearing of *A. mellifera* colonies both under stationary and migratory conditions. The studies on colony strength and food reserves under stationary and migratory beekeeping with *A. mellifera* in Nauni, Solan, Himachal Pradesh reveals that with the onset of spring colonies gained strength during February (4.2 bee frames/ colony) and March (4.6 bee frames/ colony). Thereafter, colonies increased in their average strength to 6.2 and 6.6 bee frames/ colony during June and May, respectively. Average brood area was significantly higher during May (3143.6 cm^2) followed by the average brood area in June (2497.6 cm^2). Maxim pollen area (160 cm^2) was recorded in the month of April (Brar *et al*. 2018b) [8]. To overcome harsh conditions of the state, the beekeepers keep their colonies from April to October in Himachal Pradesh and migrate to plain areas of Haryana, Punjab, Rajasthan and Uttar Pradesh during the rest period of the year (Neha *et al*. 2020). According to their studies, the beekeepers of Himachal are following different migratory cycles for *A. mellifera*: 1) District Kangra: 3 migratory cycles (a) from September to November to neighboring states i.e. Punjab, Rajasthan to avail the mustard flora, (b) from December to January to Haryana for eucalyptus and (c) March to April back to Himachal Pradesh for apple pollination (2) District Kinnaur: 2 migratory cycles a) migration to Punjab and Haryana in the months of October-February for mustard and eucalyptus (b) back to Himachal Pradesh in the months of March- April for apple pollination; (3) District Solan: 2 migratory cycles a) from November to December to Punjab and Rajasthan for mustard and b) January to February to Haryana for Eucalyptus.

Comparative studies between *Apis cerana* and *Apis mellifera*

A. mellifera bees were found to be very prone to stinging and were easily distributed as compared to *A. cerana* which were less excitable and could be safely handled (Atwal and Dhaliwal 1969) [3]. *A. cerana* is more tolerant of low temperatures, compared to *A. mellifera*. Verma (1970) [87] found that *A. cerana* started working early in the day when the temperature was quite low during autumn and winter. The brood rearing activity of *A. mellifera* and *A. cerana* was compared by Hameed and Adlakha (1973) [23] in Kullu valley. It was observed that *A. mellifera* reared 38 per cent more brood than *A. cerana* during spring season. Mattu and Verma (1984a, b, c, 1985) [36, 38, 39] reported that heavier pollen load is carried by *A. mellifera* compared with *A. cerana* which is contributed to the larger body parts of the former. Gupta *et al*. (1984) [21] studied the foraging activity of *A. cerana* and *A.*

mellifera on *Plectranthus* flowers at Rampur, Himachal Pradesh and noticed the variations in the rate of foraging activity during different day hours. Maximum number of pollen gatherers of *A. cerana* were seen during 0700-0900 h, while nectar collection activity reached the peak at 1200 h. Whereas *A. mellifera* showed peak pollen collection activity between 0900 and 1000 h. Comparative foraging behavior of *A. cerana indica* and *A. mellifera* was reviewed by Verma and Dulta (1986) [86] in Shimla which reveals that worker bees of *A. cerana* started their foraging activity earlier in the morning (mean time 0603 hours) than *A. mellifera* (mean time 0627 hours). In the evening also, *A. mellifera* ceased their foraging activity earlier (mean time1855 hours) than *A. cerana (*mean time1913 hours). Foraging trips by *A.mellifera* lasted significantly longer. According to studies conducted on apple orchard at Mashobra (2282 m), it was reported that maximum number of bees visited blooms viz. 3-4 bees/10 flowers for *A. cerana* and 2-4 bees/ 10 flowers for *A. mellifera*, when kept in the center of the orchard. Comparative hoarding behavior of *A. mellifera* and *A. cerana* in terms of amount of sugar syrup hoarded per bee per day revealed that *A. mellifera* hoards significantly more sugar syrup than *A. cerana* (Rana 1989) [60]. Aggressive behavior of both bees was also studied by Rana (1989) [60] which revealed that *A. mellifera* took 18.6 seconds for initiation of the first sting as compared to 27 seconds by *A. cerana*. In another studies it was reported that hoarding was maximum at 27ºC and it was 80.68 ± 1.55 mg/bee/day for *A. mellifera* and 60.80 ± 1.29 mg/bee/day for *A. cerana.* Hoarding decreased steadily after this, reaching 49.98 ± 0.87 and 41.08 ± 0.83 mg/bee/day for *A. mellifera* and *A. cerana*, respectively, after 25-30 days (at 27ºC). *A. mellifera* bees hoarded significantly more syrup (P<0.01) than *A. cerana*, probably because of their larger size (Rana and Verma 1994) [61]. In their further studies on the foraging behavior of *A. cerana* and *A. mellifera* on apple flowers it was reported that *A. mellifera* visited significantly more flowers (mean, 164-193) than *A. cerana* (mean, 129-172) during single foraging trips at selected orchards in Shimla district of Himachal Pradesh. However, there was no significant difference between the two species for number of flowers visited per minute (Verma and Rana 1994) [61].

Foraging activity of *A. cerana* and *A. mellifera* at Nagrota Bagwan reveals that average foraging activity was 11.18hrs in *A. cerana* compared to 10.12 hrs in *A. mellifera*. *A. mellifera* is found to bring nectar load ranging from 6.9 to 18.9 mg (mean 12.1 mg) as compared to 10.2 to 18.3 mg (mean 13.8 mg) in the study site were recorded to be 19.3-23.6 and case of *A. cerana* (Chandel *et al*. 2000) [10]. Economic efficacy of *A. cerana* and *A. mellifera* was compared and results revealed that ten *A. cerana* colonies required capital investment of Rs. 119.70, whereas for beekeeping with 46.25 *A. mellifera* colonies it was Rs. 31,152.05 (i.e. Rs.6,735.50 for 10 colonies). Thus, beekeeping with *A. cerana* required less investment than with *A. mellifera* (Attri *et al*. 2010) [1]. It was reported that middle branches of apple, plum and kiwi crops were more attractive for honeybees than lower and upper heights (Mattu *et al*. 2012) [40]. Mattu and Bhagat (2016) [41] reported that *A. cerana* foraged for significantly longer time and visited more flowers per minute than *A. mellifera*, however, *A. mellifera* took greater time for completing a single forging trip and spent significantly more time per flower than *A. cerana* in Kullu Hills of the state. Peak foraging activity for *A. cerana* occurred at 1000 to 1300 hours and it was between 1200 to 1500 hours for *A. mellifera*.

Honey bee flora of the state

Atwal and Goyal (1974) [4] identified *Plectranthus rugosus* as an important honey plant in Kullu valley. Sharma and Raj (1985) [73] on their surveys reported *Adhatoda* vasica, *Bauhinia variegate*, *Brassica campetris*, *Dalbergia* sissoo, *Ehretia* spp., *Eucalyptus* spp., *Litchi chinensis*, *Mangifera indica*, *Rubus* spp., *Sapindus detergens* and *Syzigium cumini* as important bee plants in Shivalik Hills of Himachal Pradesh. Sharma (1989) [70] reported *Bauhinia variegate*, *Brassica napus*, *Dalbergia* sissoo, *Ehretia acumionata*, *Eucalyptus* spp., *Eruca sativa*, *Fagopyrum sagittatum*, *Impatience glandulifera*, *Litchi chinensis*, *Malus domestica*, *Medicago sativa*, *Melilotus* spp., *Plantago* spp., *Plectranthus* spp., *Prunus* spp., *Pyrus* spp., *Sapindus* spp., *Syzigium cumini*, *Tilia* spp., *Toona ciliate* and *Trifolium* spp. as important bee flora of Himachal Pradesh. Devi and Mattu (2015) [13] prepared the calendar for Kangra and its adjoining areas and reported *Centaure acynus*, *Helianthus annus*, *Taraxacum officinale*, *Bombax ceiba*, *Brassica* sp., *Eruca sativa*, *Raphanus sativus*, *Rhododendron arboreum*, *Carica papaya*, *Cucurbita* spp., *Terminalia* spp., *Kalanchoe integra*, *Cucumis* spp., *Delbergia sissoo*, *Trifolium* spp., *Acacia catechu*, *Aesculus indica*, *Woodfordia fruticos Moringa oleifera*, *Callistemon citrinus*, *Eucalyptus camaldulensis*, *Psidium gaujava*, *Syzygium cumini*, *Sesamum indicum*, *Grevillea robusta*, *Eriobotrya japonica*, *Prunus amygdalus*, *Prunus armeniaca*, *Pyrus persica*, *Citrus* spp., *Litchi chinensis*, *Sapindus mukorosii*, *Camellia sinensis and Grewia optiva* as major sources of pollen and nectar to honeybee in Kangra and its adjoining areas.

Melissopalynology and bee Botanical exploration of 16 honey samples of *A. cerana* F. were accomplished from Kangra hills of Himachal Pradesh, India during 2010 to 2012. The highest pollen frequency for various honey samples were noted for Fabaceae (12), succeeded by Asteraceae (7), Rosaceae (6), Malvaceae (4), and Myrtaceae (4). The pollen were also categorized, as per economic value i.e. ornamental, medicinal, timber etc. and as per plant's nature i.e. wild (22), wild as well as cultivated (23) and cultivated (29) (Sumita and Mattu 2017) [80]. *Callistemon lanceolatus*, *Eucalyptus* spp. *Toona ciliate*, *Rosa moschata*, *Zizyphus jujuba*, *Acacia catechu*, *Aesculus hippocastanum* and *Trifolium repens* etc. are the major honey flow sources of Himachal Pradesh. Sarson (Una, Nalagarh and Solan), eucalyptus (Una and Nalagarh), horse chestnut (Shimla, Kullu and Kinnaur) and wild clover (Shimla, Kullu and Mandi) are reported as sources of honey production in the state (Brar *et al*. 2018) [6].

Role of honey bees in Pollination

A. cerana is reported as the predominant visitor of mustard accounted for 27% of the total flower visitors of mustard in Himachal Pradesh, India (Thakur *et al*. 1982) [82]. In another study, *A. cerana* was found to be the most frequent insect visitor in *Allium* spp. *A. dorsata* foraged exclusively for nectar, but although most *A. cerana* collected nectar, a small percentage collected both nectar and pollen. The amounts of pollen adhering to the bodies of foraging insects varied greatly (Kumar *et al*. 1985) [31]. A lot of work has been done regarding the role of honey bees in pollination of apple bloom in many developed countries but very little has been done in the temperate regions of Hindu-Kush Himalayas. Verma (1987) [88]; Dulta and Verma (1987a) [17] studied the role of honey bees on fruit set, fruit drop and fruit quality of apples in Shimla Hills. Higher fruit sets reported in honey bees

pollinated flowers than in open pollinated flowers suggested that degree of cross pollination done by honey bees was greater than that done by other natural insect pollinators. Most apple cultivars grown on a commercial scale in Himachal Pradesh are self unfruitful. They require a compatible cultivar for cross pollination to get a good fruit set. Orchardists rely on honey bees for effective pollination. In order to supplement bee population during flowering, The Europeon honey bee, *A. mellifera* was tried on apple (Verma 1992; Kakkar 1993) [85, 26]. In another study on kiwi fruit conducted at kiwi orchard (var Allison) of Dr. Y. S Parmar University of Horticulture and Forestry, Nauni University farm, it was reported that six species of insect pollinators visited the kiwi fruit bloom; *A. mellifera*, *A. cerana*, *A. dorsata*, *Eristalisn* sp., *Episyrphus* sp. and *Orthellia* sp. However, *A. dorsata* was the predominant visitor constituting 40.5 per cent of total, *A. mellifera* and *A. cerana* constituted 7.87 and 4.42 per cent respectively. Average fruit set at various distances from bee colonies kept in the orchard was 81.03 per cent at 8 m, 93.35 per cent at 12 m, 92.85 per cent at 25 m and 96.05 per cent at 55 m (Gupta *et al*. 2000) [22]. Maximum fruit set (6.08 per cent) was recorded when pollinizers were located at the shortest distance (Kakkar 2000) [27].

Insect pests and diseases

The *Melissococus plutonius* infection killed about 60% of the native bee colonies during 2002 in Himachal Pradesh, north India. The disease exhibited field symptoms similar to those of mite infestation, Thai sac brood virus and also to the symptoms of European foulbrood disease (EFB). In *A. cerana*, symptoms similar to TSBV (Figure 1) were tongue-like projection, mortality of brood at the second day after sealing in perforated diseased combs, and change in color of the brood which can be easily removed and absconded. (Rana *et al*. 2004). EFB is still prevalent in *A. cerana* throughout the country. In 2003, sac brood virus was detected at two locations in Himachal Pradesh. EFB disease affected 6.18 to 18.56% colonies and and 7.88 to 25.33% brood of *A. cerana*. The diseased colonies were treated by feeding four doses of 10 mg of ciprofloxacin (98% a.i.) until the disappearance of all EFB symptoms (Rana *et al*. 2012) [57]. At Nauni (district Solan), it was detected in colonies during spring and summer (March- May) affecting 0.39 per cent to 5.20 per cent of the brood where as at Jachh (district Kangra), the disease was also detected during March to June infecting 0.23per cent to 2.10 per cent of brood (Rana and Rana 2015) [50]. Survey studies in six districts of Himachal Pradesh reveals that the period of incidence of European foulbrood was different in Kullu (April-May), Solan (May-June) and Sirmaur (June-July) districts. In Himachal Pradesh, the disease was effectively controlled by feeding terramycin/ oxytetracycline in *A. mellifera* within 10 days of feeding it @ 200mg (5% a.i.) in 300 ml sugar syrup/ colony (Bahman and Rana 2002) [5].

Sacbrood disease was recorded for the first time in India during 1998 from the Kangra district of Himachal Pradesh, Northern India (Chandel *et al*. 1999) [9]. The severity of the TSBV gets reduced in due course of time in Himachal Pradesh. According to different studies, it killed 80% brood in 95% colonies in mid-eighties (Rana *et al*. 1986) [52], 27.5% brood in 25% colonies in late nineties (Rana *et al*. 2001) [53], and 7% brood in 47% colonies during 2005–2006 (Rana 2008) [59]. Later, Sac Brood Virus (SBV) was detected in two locations of Himachal Pradesh viz. Nauni and Jachh. At Nauni, it was detected in colonies during spring and summer (March to May) when it affected 0.39% to 5.20% of the brood. At the second location, Jachh, the disease was also detected during spring and summer (March to June) when it affected 0.23% to 2.10% of brood. The incidences of the disease were found to be significantly correlated with colony strength and brood rearing (Rana and Rana 2008) [59]. Studies conducted on disease and other natural enemies on *A. cerana* in Kullu valley indicated that colonies were highly infected with Thai sac brood disease whole year. Due to this disease, absconding in 10 bee colonies was also observed (Nirupma *et al*. 2018c) [46].

In India, studies on etiology of the disease have not been done. However, characterization with regard to isolation, purification, serology, antigenecity, electron microscopy, and molecular level has been conducted at HP University, Shimla, and University of Horticulture and Forestry, Solan, in collaboration with Central Potato Research Institute (CPRI), Shimla (Rana *et al*. 1986; Rana *et al*. 1987; Rana *et al*. 1991; Rana *et al*. 2001; Rana *et al*. 2003a, b; Rana *et al*. 2007; Rana *et al*. 2011; Rana and Rana 2008) [52, 51, 53, 63, 65, 52]

Nosema disease infestation was observed by beekeepers during May- June at Una and August-September at Nalagarh (Solan). Among enemies, bear and lizard were observed by beekeepers to attack *A. mellifera* colonies during different timings of year. Bear was reported as a major problem in Kinnaur area (Telangi and Reckong Peo) during May to July. *A. mellifera* colonies migrated to Kinnaur were also attacked by lizard in May-June. As per as concerned with the management of *Varroa*, beekeepers are using sulphur (Nalagarh, Kinnaur, Kullu and Lahaul and Spiti), Thymol (Nalagarh and Kinnaur) and Formic acid (Bajaura) in *A. mellifera* colonies (Brar *et al*. 2018) [6]. Five apiaries of *A. mellifera* were surveyed during autumn and winter months to study the symptoms of *Nosema ceranae* in Himachal Pradesh. The results revealed that the infected bees were crawling in front of hives with swollen abdomens. They were unable to fly and walk properly. In diseased bees, the ventriculus was white with less constriction. The microscopic studies revealed the presence of several, oval to sausage shaped spores (4.5 µm ± 0.109 x 2.1 µm ± 0.093). Pathogenic studies showed that 81.06% bees died at 16th day of post infection which confirms the virulence of the disease. Confinement of *A. mellifera* bees in hives was avoided by feeding sugar syrup (50%) to each colony in order to manage the disease was not found to be effective (Divya *et al*. 2018) [16].

Thakur and Sharma (1984) [81] found spiders as enemies of *A. mellifera* at Palampur, Himachal Pradesh. Large mammals such as skunks and bears are classified as the pests because they do a little damage to the colony, generally thought as predators (Sharma and Raj 1988) [74]. Kumar and Sharma (2003) [30] reported that September to October was the period of high incidence of ectoparasitic mite, *Tropilaelaps clareae* in *A. mellifera* at Bajaura in Kullu valley. Wasps are the one of the major threat to beekeeping industry. Wasps are not only mortal to the bees, but also burgle their egg, brood and honey stores. Maximum incidence of *V. auraria* was reported during July to November when temperature and relative humidity was high (Kumar *et al*. 1998; Rana *et al*. 2000) [28, 54, 55]. The diversity and seasonal variations of predatory wasps in 41 apiaries of Himachal Pradesh revealed the occurrence of 8 species of wasps i.e. *Vespa auraria* Smith, *Vespa mandarina* Smith, *Vespa tropica* (Leefmansi) Vecht, *Vespa orientalis* Linnaeus, *Vespa basalis* Smith, *Vespa flaviceps* Smith, *Polistes schach* and *Polistes hebraeus* (Kumar and Sharma

2003; Sharma and Mattu 2014) [30, 77] also reported that September to October was the period of high incidence of *Tropilaelaps clareae* in *A. mellifera* at Bajaura in Kullu valley. Maximum predatory activity of *V. auraria* and *V. mandarinia* was observed during August, September, October and November months of the year in Himachal Pradesh (Sharma *et al*. 2011a) [78]. In other studies in Shivalik Hills of Himachal Pradesh, the incidence of ectoparasitic mites, *Varroa* spp., was found maximum in the months of November, whereas peak attack of *Tropilaelaps clareae* was recorded in the month of September (Sharma *et al*. 2011b) [79]. An intensive survey was conducted in 30 apiaries, located in different agro climatic zones of Himachal Pradesh reveals, among invertebrates, insects and arachnids were the most prominent pest of honeybees. Hymenoptera (17), Diptera (3), Lepidoptera (2) and Coleoptera (2) and Orthoptera (1), Dictyoptera (1), Odonata (1) and Thysanura (1) were prominent (Sharma *et al*. 2013). A positive correlation between number of *V. auraria* and *V. mandarina* in honey bees colonies was established by Sharma and Mattu (2014) [77] in Himachal Pradesh. Survey conducted in Kangra district revealed that ectoparasitic mite, *Varroa jacobsoni* caused a severe damage. Beekeepers also reported the presence of pests like lesser wax moths (*Achroia grisella*), Greater wax moth (*Galleria mellonella*) and Hawk moth (*Acherontia styx*) (Kumar and Kaundal 2016) [32].

The occurrence and distribution of pests and predators of honey bees (*A. cerana* F. and *A. mellifera* L.) was surveyed in Chamba district which reveals that *Varroa destructor*, *Vespa auraria*, *Vespa orientalis*, *Galleria mellonella*, *Dicrurus* and *Ursus* species were most serious and destructive however some other pests of minor importance were also recorded (Chandra and Mattu 2017). *V. auraria* and *V. mandarinia* caused heavy mortality to honeybees during floral dearth period when colony strength was low due to reduced worker bee population. The population of *V. auraria* was maximum in month of September (21.92 percent) and minimum in month of January (0.82 percent). Peak predatory activity of *V. mandarinia* was in month of October (26.7 percent) and minimum in month of July (8.9 percent) than other months of the year (Mattu and Sharma 2017). Two species of wasps, *Vespa auraria* and *Vespa magnifica* were found visiting the apiary of *Apis mellifera* L. colonies at Nauni, Solan district, Himachal Pradesh, in 2015-16. The incidence of *V. auraria* was found maximum in September (366.23±30.38/day) followed by wasp's visits in August (297.77±28.89/day), October (280.69±32.62/day), November (238.26±23.69/day) and July (129.23±6.89/day). No visits of wasps were observed during December, 2015 to March, 2016 in University apiary at Nauni. The wasps reappeared again in April (1.8±0.32), May (4.45±0.58) and June (12.54±0.88). *V. magnifica* was also noticed visiting apiary only on few occasions during October to November months at Nauni. Its visits ranged between 1 to 3 wasps per day (Brar *et al*. 2018) [6]. Ectoprasitic mites, Nosema, Sac Brood and EFB have been reported in Kangra, Kinnaur, Solan districts of Himachal Pradesh. Wasps were reported as major insect pest in these three districts causing 15-18 per cent (July- October 2017, Solan), 12-15 per cent (June- October 2017, Kangra) and 8-10 per cent (June- August, Kinnaur) damage to *A. mellifera* colonies. Hand killing of wasps by flapping and burning wasp nests were the management practices adopted by beekeepers (Neha *et al*. 2020).

Pesticides residues in honey

Pesticides consumption in the state of Himachal Pradesh is very low compared to other states of India. So it is speculated that honey collected from the state is free from the pesticide residues. In contrary to this Sharma and Kashyap (2002) [66] recorded pesticide residues in honey. Among different pesticides analysed in honey, HCH and its isomers were the most frequently detected followed by DDT and its isomers. Cypermethrin was the only synthetic pyrethroid found in honey samples. Residues of organophosphates viz. acephate, chlorpyriphos, ethion and monocrotophos were not detected, however malathion's residue was found exceeding the MRL (5 ppb) proposed by the Ministry of Commerce, Government of India (Choudhary and Sharma 2008) [12]. Pesticides poisoning has been reported by Kumar and Kaundal (2016) [32] in Kangra district where dead or dying bees were seen in the entrance of bee colonies. In the recent studies, residues of pesticides were detected in 12 per cent of samples, of which a majority contained organophosphate residues. Assessment of human health risks suggests that contaminated honey at current levels has minimal contribution to toxicological risks (Atul *et al*. 2018) [2].

a b

Fig 1: Symptoms of Brood diseases of *Apis cerana* F. (a) Larvae infected with Thai sacbrood with tongue like projection (b) Infected larvae having sac like appearance due to Thai sacbrood

Conclusion

With the introduction of *A. mellifera* into the state a decline in the population of *A. cerana* has been noticed threatening its existence in the Himalayan region. Conservation of Indian bee should be encouraged with the promotion of organic farming and avoiding excessive use of pesticides. Crop diversification is required especially in winter months to reduce the periods of floral scarcity. Farmers need to be trained and get aware about the benefits of beekeeping and role of honeybees on pollination of fruits, vegetables and cereals. Queen rearing techniques should be popularized and surplus mated queen must be maintained in nucleus hives.

Disclosure statement

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