Anurag Sharma, Rakesh Kumar Daroch, Renu Kapoor and Indra Kumar Kasi

DOI: https://doi.org/10.22271/tpi.2022.v11.i3Sd.11234

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, European 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 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) [88].

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) [88, 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 forms 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 beekeping 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 “dhindhhor” 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

Foraging range and behavior of A. cerana
Dhalwal 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°) (Dhalwal 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) [30]. 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 glycophosphosphate dehydrogenase 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<0.01; A. cerana Kashmiri > A. cerana Himachali, P<0.05. The amounts of glycogen, total lipids and activities of all the 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].
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) [6] 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) [19]. 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 Himalachi 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) [59] 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 Himalachi bees. These studies are well supported by the recent research studies which reveals that Hindu Kush/Kashmiri 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-tropical, 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 cm²) followed by the average brood area in June (2497.6 cm²). Maxim pollen area (160 cm²) 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. mel...
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. 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 27\(^\circ\)C and it was 80.68 ± 1.55 mg/bear/day for A. mellifera and 60.80 ± 1.29 mg/beear/day for A. cerana. Hoarding decreased steadily after this, reaching 49.98 ± 0.87 and 41.08 ± 0.83 mg/beear/day for A. mellifera and A. cerana, respectively, after 25-30 days (at 27\(^\circ\)C). 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) \[10\]. 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 foraging 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.
Insect pests and diseases
The Melissococcus 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 disease was treated by feeding four doses of terramycin-oxytetracycline (5% a.i.) until the disappearance of all EFB symptoms (Rana et al. 2012) [51]. At Nauni (district Solan), it was detected in colonies during spring and summer (March-May) affecting 0.39% to 5.20% of the brood where as at Jachh (district Kangra), the disease was also detected during March to June injecting 0.25% per 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 foulbroid disease 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 300ml sugar syrup/colony (Bhambra and Rana 2002) [1].

Saccbrood 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) [22, 32, 33, 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 (Bir et al. 2018) [8]. 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) [10].

Thakur and Sharma (1984) [61] 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) [72]. 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* (Leeffansni) Vecht, *Vespa orientalis* Linnaeus, *Vespa basalis* Smith, *Vespa flaviceps* Smith, *Polistes schach* and *Polistes hebraeus* (Kumar and Sharma
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].

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

No potential conflict of interest was reported by the authors.

References

1. Attri PK, Verma S, Meenakshi T. Mountain hills beekeeping and its economic efficiency of district Chamba (Himachal Pradesh). Asian Journal of Experimental Biological Science. 2010;1(1):96-100.
2. Atul K, Gill JPS, Bedi JS. Multiresidue determination of pesticides in market honey from northern India using QuEChERS approach and assessment of potential risks to consumers. Current Science. 2018;115(2):283-291.
3. Atwal AS, Dhaliwal GS. Some behavioral characteristics of Apis indica F and Apis mellifera L. Indian Bee Journal.
4. Atwal AS, Goyal NP. *Apis mellifera* turns indifferent to Shain (*Plectranthus rugosus*). Everyday Science, 1974, 1925-26.

5. Bahman S, Rana BS. Incidence of the foul brood disease in *Apis mellifera* L colonies at Solan Himachal Pradesh. Pest Management and Economic Zoology. 2002;10:87-91.

6. Brar AS, Sharma HK, Rana K. Survey studies: Integral approach towards the diseases and enemies of *Apis mellifera* L in upper and lower hills of Himachal Pradesh: Beekeepers prospective. Journal of Entomology and Zoology Studies. 2018;6:939-942.

7. Brar AS, Sharma HK, Rana K. Seasonal incidence of wasps in *Apis mellifera* L colonies at Nauni Solan (Himachal Pradesh). Journal of Entomology and Zoology Studies. 2018a;6(2):3177-3178.

8. Brar AS, Sharma HK, Rana K. Colony strength and food reserves of *Apis mellifera* L under stationary and migratory beekeeping in Himachal Pradesh. India Journal of Entomology and Zoology Studies. 2018b;6(5):1156-1159.

9. Chandel YS, Kumar A, Bali BV. Sacsoccrood disease in Italian honey bee *Apis mellifera* L in Himachal Pradesh India. Pest Management and Economic Zoology. 1999;7:181-182.

10. Chandel YS, Kumar A, Srivastva S. Comparative performance of *Apis mellifera* L vis a vis *Apis cerana* Fab on toria (*Brassica campestris* var toria) in mid hill zone of Himachal Pradesh. Indian Journal of Agricultural Research. 2000;34(4):264-267.

11. Chandra A, Mattu VK. Studies on major pests and predators of *Apis cerana* F and *Apis mellifera* L in the Chamba valley of Himachal Pradesh. Journal of Entomology and Zoology Studies. 2017;5(6):728-731.

12. Choudhary A, Sharma DC. Pesticide residues in honey samples from Himachal Pradesh (India) Bull Environ Contam. Toxicology. 2008;80:417-422.

13. Devi A, Mattu VK. Preparation of a Floral Calendar of Honey Plants of Kangra and Adjoining Areas of Himachal Pradesh. International Journal of Science and Research. 2015;6(2):371-378.

14. Dhalwals HS, Sharma PL. The foraging range of the Indian honeybee on two crops. Journal of Apicultural Research. 1973;12(2):131-134.

15. Dhalwals HS, Sharma PL. Foraging range of the Indian honeybee. Journal of Apicultural Research. 1974;13(2):137-141.

16. Divya S, Kiran R, Rana BS, Sharma HK, Chauhan A. Preliminary studies on Nosema *ceranae*: A microsporian infecting *Apis mellifera* in India. Journal of Entomology and Zoology Studies. 2018;6(3):262-265.

17. Dulta PC, Verma LR. Role of insect pollinators on yield and quality of apple fruit. Indian Journal of Horticulture. 1987a;44:274-279.

18. Dulta PC, Verma LR. Comparative morphometric studies on flight muscles of the genus *Apis*. Journal of Apicultural Research. 1987b;26(4):205-209.

19. Dulta PC, Verma LR. Biochemical studies on flight muscles of the genus *Apis*. Journal of Apicultural Research. 1989;28(3):136-141.

20. Grenier L. Working with Indigenous Knowledge. International Development Research Centre Canada. 1998.

21. Gupta JK, Kumara J, Mishra RC. Nectar sugar production and honey bee foraging activity in different cultivators of cauliflower *Brassica oleracea* var botrytis. Indian Bee Journal. 1984;46:21-22.

22. Gupta JK, Rana BS, Sharma HK. Pollination of kiwifruit in Himachal Pradesh. In Mastuka M Verma L R Wongsiri S Shrestha KK Partap U (Eds) Asian Bees and Beekeeping Progress of Research and Development (274 p) Oxford and IBH Publishing Company, 2000, 169-170.

23. Hameed SF, Adlakha RL. Preliminary comparative studies on the brood rearing activities of *Apis mellifera* L and *Apis cerana indica* F in Kullu Valley. Indian Bee Journal. 1973;35:27-35.

24. Ibrahim MM, Chandel YS, Anil. Morphometrics of *Apis cerana* from agroclimatic zones of Himachal Pradesh. Indian Journal of Entomology. 2019;81(3):406-410.

25. Ibrahim MM, Chandel YS, Anil. Morphometrics of *Apis mellifera* after five decades of its introduction in North-Western Himalayan region of India. Pakistan Journal of Zoology. 2017;49(4):1397-1403.

26. Kakkar KL. Comparative pollination efficiency of introduced colonies of Indian Honey bee *Apis cerana* Fab and European Honey bee *Apis mellifera* Linn on apple. In Veeresh G K Shankar R U Ganerhiah KN Pollination in tropics Proceedings of International symposia on Pollination in Tropics IUSSI- Indian Chapter Bangalore, 1993.

27. Kakkar KL. Effect of pollination strategy on fruit set of apple in Himachal Pradesh. In Mastuka M Verma L R Wongsiri S Shrestha KK Partap U (Eds) Asian Bees and Beekeeping Progress of Research and Development (274 p) Oxford and IBH Publishing Company, 2000, 166-168.

28. Kumar A, Rana BS, Gupta JK. Incidence and extant of damage by predatory wasps to honey bees at Solan Himachal Pradesh. Pest management and Economic Entomology. 1998;6:37-42.

29. Kumar J, Kashyp NP. Diversity of bee flora in lower Kullu valley Himachal Pradesh and its impact to honey production. Indian Bee Journal. 1996;58:131-134.

30. Kumar J, Sharma SD. Seasonal incidence of ectoparasitic mite *Tropilaelaps clareae* Delfinado and Bakar (Acarina: Laelafidae) in *Apis mellifera* L colonies in Kullu valley of Himachal Pradesh. Pest Management and Economic Zoology. 2003;11(9):15-19.

31. Kumar J, Mishra RC, Gupta JK. The effect of mode of pollination on *Allium* species with observation on insects as pollinators. Journal of Apicultural Research. 1985;24(1):62-66.

32. Kumar R, Kuondal N. Beekeeping status in Kangra district of Himachal Pradesh. Journal of Entomology and Zoology Studies. 2016;4(4):620-622.

33. Kumar R, Thakur RK. Indigenous beekeeping in the Sirmaur district of Himachal Pradesh. India Bee World. 2014;91(1):22-25.

34. Mattu VK. Scope and strategies for apiculture development in Himachal Pradesh. In Verma L R (Ed) Honey Bee in Mountain Agriculture (274p) Oxford and IBH Publishing Company, 1992.

35. Mattu VK, Verma LR. Comparative morphometric studies on the Indian honeybee of the North-west Himalayas I Tongue and Antenna. Journal of Apicultural Research. 1983;22:79-85.

36. Mattu VK, Verma LR. Comparative morphometric studies on the Indian honeybee of the North-west
Himalayas 2 Wings. Journal of Apicultural Research. 1984a;23:3-10.
37. Mattu VK, Verma LR. Comparative morphometric studies on the Indian honeybee of the North-west Himalayas 3 Hind leg tergites and sternites. Journal of Apicultural Research. 1984b;23:117-122.
38. Mattu VK, Verma LR. Morphometric studies on the Indian honeybee Apis cerana indica F Effect of seasonal variations. Apidologie. 1984c;15:63-74.
39. Mattu VK, Verma LR. Studies on annual foraging cycle of Apis cerana indica F in Simla hills of Northeast Himalayas. Apidologie. 1985;16(1):1-18.
40. Mattu VK, Raj H, Thakur ML. Foraging behavior of honeybees on apple crop and its variation with altitude in Shimla Hills of Western Himalaya. India International Journal of Science and Nature. 2012;3(1):296-301.
41. Mattu VK, Bhat T. Foraging strategies of honeybees in pollinating apple flowers and its variation with altitude in Kullu hills of western Himalaya. India Journal of Entomology and Zoology Studies. 2016;4(1):164-169.
42. Mattu VK, Sharma I. Seasonal variation of Vespa auraria S and Vespa mandarinstin S (Hymenoptera: Vespidae) attacking Apis mellifera L colonies in district Kangra of Western Himalayas Himachal Pradesh (India). Journal of Entomology and Zoology Studies. 2016;5(3):1862-1864.
43. Neha N, Thakur M, Sharma HK, Rana K. Survey studies on beekeeping with Apis mellifera in Himachal Pradesh: Beekeeper’s prospective. Journal of Entomology and Zoology Studies. 2016;8(1):315-318.
44. Nirupma S, Gupta JK, Sharma H. Effect of supplementary feeding on Apis cerana F colony development at Katrain in Kullu valley of Himachal Pradesh. Journal of Entomology and Zoology Studies. 2018a;6(5):457-460.
45. Nirupma S, Gupta JK, Sharma H. Brood rearing efficiency in indigenous honey bee Apis cerana in Kullu valley of Himachal Pradesh. Journal of Pharmacognosy and Phytochemistry. 2018b;7(5):1305-1307.
46. Nirupma S, Gupta JK, Sharma H. Diseases pests and other natural enemies of Indian honey bee (Apis cerana F) in Katrain area of Kullu valley of Himachal Pradesh. Journal of Experimental Biology and Agricultural Sciences. 2018c;6(5):895-897.
47. Radloff SE, Hepburn R, Fuchs S. The morphometric affinities of Apis cerana of the Hindu Kush and Himalayan regions of western Asia. Apidologie. 2005, 3625-30.
48. Rahman KA, Singh S. Nectar and Pollen plants of Punjab. Indian Bee Journal. 1941;3:32.
49. Rana BS, Rana R. Detection of sacbrood virus and the incidence of sacbrood disease in Apis mellifera colonies in the North- Western Himalayas. Journal of Apicultural Research and Bee World. 2008;47(1):58-62.
50. Rana BS, Rana R. Detection of sacbrood virus and the incidence of sacbrood disease in Apis mellifera colonies in the North- Western Himalayas. Journal of Apicultural Research. 2015;59:144-149.
51. Rana BS, Garg ID, Khurana SMP, Ball BV, Verma LR, Aggarwal HO. Sacbrood virus disease in Apis cerana indica F in South East Asia. In J Eder H Rembold (Eds) Chemistry and biology of social insects, Munchen: FRG, 1987, 640-641.
52. Rana BS, Garg ID, Khurana SMP, Verma L, Araggarwal HO. Sacbrood virus of honey bee (Apis cerana indica F) in the North-West Himalayas. Indian Journal of Virology 1986;2:127-131.
53. Rana BS, Garg ID, Singh MN, Mukherji K, Khurana SMP, Sharma HK. Behavior of Thai sacbrood virus in storage. Indian Bee Journal. 2001;63:6-10.
54. Rana BS, Gupta JK, Sharma HK. Status of beekeeping in Himachal Pradesh. In Mastuka M Verma L R Wongsiri S Shrestha KK Partap U (Eds) Asian Bees and Beekeeping Progress of Research and Development (274 p), Oxford and IBH Publishing Company, 2000, 33-36.
55. Rana BS, Kumar A, Gupta JK. Influence of environment factors on the population of predatory wasps of honeybees and evaluation of methods for controlling the wasps. Indian Bee Journal. 2000;62:47-54.
56. Rana BS, Rana R, Gulsan K, Sharma HK, Gupta JK, Dayal K. European foulbrood causing havoc to the native bee Apis cerana F in Himachal Pradesh. Pest Management and Economic Zoology. 2004;12(1):109-111.
57. Rana BS, Rao KM, Chakravarty SK, Katna S. Characterization of Melissococcus plutonius causing European foulbrood disease in Apis cerana F. Journal of Apicultural Research. 2012;51(4):306-311.
58. Rana BS, Sharma HK, Gupta JK, Dayal K. Sacbrood virus of exotic honey bee Apis mellifera in north India. Asian Bee Journal. 2003a;5:175-177.
59. Rana R. Studies on Thai sacbrood and sacbrood diseases of hive bees. Dissertation, University of Horticulture Forestry Solan Himachal Pradesh India, 2008.
60. Rana RS. Aggressive and hoarding behavior of Apis mellifera and Apis cerana indica F and their role in the pollination of plum and apple bloom. Dissertation, Himachal Pradesh University Shimla India, 1989.
61. Rana RS, Verma LR. Hoarding behaviour and lifespan of workers of Apis mellifera and Apis cerana. Journal of Apicultural Research. 1994;33(4):205-208.
62. Rana R, Rana BS, Garg ID, Khurana SMP. Electron Microscopic and serological studies on sacbrood virus of Apis mellifera L. In Proceedings of the 26th Annual Conference on Electron Microscopy and Allied fields, 2003b, 18-19.
63. Rana R, Rana BS, Kaushal N, Kumar P, Kaundal P, Rana K, et al. Identification of sacbrood virus disease in honey bee Apis mellifera L by using ELISA and RT-PCR techniques. Indian Journal of Biotechnology. 2011;10:274-284.
64. Rana R, Rana BS, Khan MA, Verma AK, Rana RS. Detection of Thai sacbrood virus of Apis cerana F from North- West India through RT- PCR. Pest Management and Economic Zoology. 2007;15:195-199.
65. Rana VK, Kumar S. Performance of Apis mellifera L colonies in the high hills of Himachal Pradesh. Indian Journal of Entomology. 2011;73:241-243.
66. Sharma DC, Kashyap NP. Status of pesticide residues in honey samples In Int symp prevention of residues in honey held on 10–11 October 2002, Celle Germany 2002, 145-148.
67. Sharma HK, Gupta JK. Diversity and density of bee flora of Solan region of Himachal Pradesh (India). Indian Bee Journal. 1993;55:9-20.
68. Sharma HK, Rana BS, Kiran R, Meena T. Madhumakhi paalan. Department of Entomology Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni (Solan) India 2015, 1-65.
69. Sharma HK, Verma LR, Gupta JK. Traditional beekeeping with *Apis cerana* in Kullu Valley of Himachal Pradesh. In Mastuka M Verma L R Wongsiri S Shrestha KK Partap U (Eds). Asian Bees and Beekeeping Progress of Research and Development (274 p), Oxford and IBH Publishing Company, 2000, 259-261.

70. Sharma N. Mellisopalynology and survey of honey plants in Himachal Pradesh. Dissertation, Himachal Pradesh University Shimla India, 1989.

71. Sharma N. Studies on factors influencing colony population and honey production in *Apis cerana* F under mid hill conditions of Himachal Pradesh. Dissertation, Dr. YS Parmar University of Horticulture and Forestry Nauni Solan India, 2001.

72. Sharma N, Sumit V, Sharma PK. Diversity and distribution of pests and predators of honeybees in Himachal Pradesh. Indian Journal of Agricultural Research. 2013;47(5):392-401.

73. Sharma OP, Raj D. Diversity of bee flora in Kangra Shivaliks and its impact on beekeeping. Indian Bee Journal. 1985;47:21-24.

74. Sharma OP, Raj D. Ecological studies on predatory wasps attacking Italian honeybee *Apis mellifera* L in Kangra Shivaliks. Indian Journal of Ecology. 1988;15:168-171.

75. Sharma PL. Bee work done in the Punjab upto 1950. Indian Bee Journal. 1951;13:27-35.

76. Sharma SK. Biometric and developmental biology of *Apis mellifera* L workers. Dissertation, Himachal Pradesh Krishi Vishvavidyalaya Palampur India. 1990.

77. Sharma V, Mattu VK. Biocological studies on Vespa species in honeybee colonies of Himachal Pradesh India. American Multidisciplinary International Research Journal. 2014;2:14-15.

78. Sharma V, Mattu VK, Thakur MS. Diversity distribution and seasonal variations of Vespa species in honeybee colonies of Himachal Pradesh. Annual review of Entomology. 2011a;29(2):1-3.

79. Sharma V, Mattu VK, Thakur MS. Studies on seasonal variations of ectoparasitic mites on honeybee colonies in Shivalik hills of Himachal Pradesh India. International Journal of Innovations in Bio-Sciences. 2011b;1:21-23.

80. Sumita S, Mattu VK. Mellisopalynological investigations on honey samples of Kangra hills Himachal Pradesh India International Journal of Entomology Research. 2017;2(4):41-51.

81. Thakur AK, Sharma OP. The spider as bee enemy. Journal of Bombay Natural History Society. 1984;81:208-211.

82. Thakur AK, Sharma OP, Garg R, Dogra GS. Comparative studies on foraging behavior of *Apis mellifera* and *A cerana indica* on mustard. Indian Bee Journal. 1982;44:91-92.

83. Thakur RK, Kumar R. Prospects for Beekeeping in Sirmaur district of Himachal Pradesh Training Manual on Integrated Pest Management and Bee Keeping Lana Banka Sirmaur. Himalayan Forest Research Institute Shimla India, 2009, 51-60.

84. Verma LR. Beekeeping in integrated mountain development Oxford and IBH Publishing Company, 1990, 367.

85. Verma LR. Honey Bee in Mountain Agriculture Oxford and IBH Publishing Company, 1992, 274.

86. Verma LR, Dulta DK. Foraging behavior of *Apis cerana indica* and *Apis mellifera* in pollinating apple flowers. Journal of Apicultural Research. 1986;25:197-201.

87. Verma LR. A comparative study of temperature regulation in *Apis mellifera* L and *Apis cerana indica* F. American Bee Journal. 1970;110(10):390-391.

88. Verma LR. Pollination ecology of apple orchards by hymenopterous insects in Matiana-narkanda temperate zone Final report Ministry of Environment and Forests, Govt of India, 1987, 118.

89. Verma LR. Some practical aspects of beekeeping with *Apis cerana* in Asia. Proc 4th Int Conf Apic Trop Climates Cairo Egypt, 1989, 438-441.

90. Verma LR, Partap U. The Asian hive bee *Apis cerana* as pollinators in vegetable seed production (An awareness handbook) ICIMOD Kathmandu Nepal, 1993.

91. Verma LR, Rana RS. Further studies on the behaviour of *Apis cerana* and *Apis mellifera* foraging on apple flowers Journal of Apicultural Research. 1994;33(3):175-179.

92. Verma S, Attri PK. Indigenous beekeeping for sustainable development in Himachal Himalaya Indian Journal of Traditional Knowledge. 2008;7(2):221-225.