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Prototype development for composite mud house for *Apis cerana* using local ingredients to conserve indigenous beekeeping

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Abstract
Apis cerana indica, an indigenous bee of Himalayan region used to inhabit mud houses since time immemorial. These traditional wall hives are commonly known as *Khadra, Jaala* or *Jalota.* But, since last two decades, the population of *Apis cerana* is drastically declining due to increasing modern cement houses. This is the main reason of demolition of habitat of *Apis cerana*. Decreasing population of *Apis cerana* tends toward the loss of our social and cultural heritage. During current study efforts were made to design low cost, eco-friendly movable mud houses for *Apis cerana* to conserve the traditional beekeeping.

Keywords: *Apis cerana*, habitat, mud house, tradition beekeeping

Introduction
Beekeeping is an ancient and traditional method of maintaining honey bee colonies, commonly in artificial hives, to collect valuable products (honey beeswax, propolis, bee venom, royal jelly and pollen) produced by bees. It is a fascinating hobby to make plentiful earning and table honey. Besides, various medicinally important products, beekeeping also have strong relationship with agriculture and horticulture because of significant contribution of honeybees in pollination of many edible and fruit crops. It is reported that the honeybees pollinate about 70% of vegetation globally. Some researchers also found that native bees pollinate around 15% of the hundred significant crops. Because of all these properties, these little creatures are considered a special gift to human beings. There are 44 species of honey bees reported globally, out of which seven species are available in India. However, four species *Apis dorsata* (giant/rock honeybee or dumna), *Apis florea* (dwarf honeybee), *Apis mellifera* (occidental or European honeybee) and *Apis cerana indica* (oriental honeybee)) significantly contribute to the production of honey. All these species have different temperament, foraging habit, nesting behaviour and honey production. Nest-construction behaviour in social insects is complex and highly cooperative [17, 2, 19]. *Apis dorsata* are generally found all over the landmass, mainly in the forests. They construct a nest at an altitude of 2700 m in the hilly regions. *Apis florea* honeybees construct a single vertical comb [5, 18]. Dwarf honeybees also build a palm-sized nest near bushes, hedgerows, buildings, empty cases, caves, etc. The little bees build the comb by encircling the branches, whereas the rock bees build their comb underside of the branches, and this is the significant difference between giant bees and dwarf bees. Only *Apis cerana indica* and *Apis mellifera can be* domesticated for commercial beekeeping. Moreover, the habitat of the Italian honeybees is similar to that of Indian bees as they build parallel combs in the dark spaces and store honey at the upper part of the hive [1, 9, 11, 14]. *Apis mellifera* is the only bee species that cannot survive under wild conditions and kept in artificial wooden hives only. Generally, Langstroth hives are preferred all over the world with multiple supers as per requirement and honey flow. *Apis cerana* species can survive both in natural/wild as well as in artificial wooden hives. The hive made by *Apis cerana* has a parallel comb to each other, having a uniform distance. *Apis cerana* mainly prefers wall hives and these traditional wall hives are commonly known as *Khadra, Jaala* or *Jalota. Apis cerana* construct their hives in dark places. A Wall hive is a cavity left in the wall when the house is under construction; usually located at the height of about 150 cm from the floor.

It has an entrance hole of about two-centimetre diameter toward the outside; inside, it is usually covered with wood, slate/stone, and plastered with mud [15]. *Apis cerana* descended naturally and settled in the hive, making a parallel comb. The wall hive is opened at the time of harvesting the honey and never otherwise. Secondly, *Apis cerana* also prefer a log hive commonly known as *Ganari* (hollow tree trunk) with various undesirable sizes. The harvest of honey is best in log hives as the hive can be opened from both sides and the comb are easy to cut. Besides this, all the other factors, such as heat properties, cost, resistance to rain, and durability, are best adjusted in-wall hive compared to log hive. The hill inhabitants leave several rectangular spaces in the walls of houses at the time of construction because *Apis cerana* built a nest in the dark cavities [4, 13, 6]. *Apis cerana* is also reared in Newton and Marthandam hive. François Huber (1792) [7] from Geneva was the first bee scientist who did actual scientific studies on honeybees in Switzerland. The history of beekeeping took commercial growth during the 19th century when box type movable hive was developed by L. L. Langstroth, having various frames on which bees build their nest. In the year of 1857, the artificial comb foundation sheet was also designed by Johannes Mehring in Germany. In the year of 1896, wax foundation sheets were made available in the market for commercial beekeeping.

The evidence of the rearing of honeybees in a log hive (*Ganari*) is available, dating back to 1470 AD [12]. For quite a long time, Indigenous bee *Apis cerana* was domesticated in-wall hives, with no any facility for transportation of the colonies. In 1910, Newton designed an artificial hive named "Newton Hive", and this hive is still widely popular for domesticating Indigenous bees. But these hives might not provide insulation for honeybees during summer and winter. However, the *Apis cerana* chiefly prefers the wall hives in mud houses as their habitation. The internal wall of the houses in hilly area is coated with cow dung and clay which provide substantial insulation throughout the cold situations in the hilly areas. So, indigenous bees are capable to live in local conditions [3]. During survey and literature review, present study divulged that the number of traditional wall hives and colonies are decreasing parallel to increasing modern cemented houses. The total average number of wall hives/houses decreased from 11.23 hives per house in 1980 to 8.44 in 2010 [15]. This is the main reason for the demolition of *Apis cerana*'s habitat.

A study conducted by Tiwari *et al*. (2013) [15] in district Chamoli, Uttarakhand revealed that number of hives were 11.23 wall hives/ house in the houses which were constructed before 1980 whereas, the number was 5 wall hives/ house in the houses constructed during 1991-2000. Further, decrease was observed during 2001-2010, when number of hives drastically reduced to 0.87 hives/ house. The total average number of wall hives/houses decreased from 11.23 hives per house in 1980 to 8.44 in 2010 [15]. It was predicted that if this reduction in wall hives was not checked in coming time, then there will be no wall hives in the region during next 20 years. Thus, an urgent need is there to conserve the traditional beekeeping by providing nesting site for honey bee.

Therefore, in the present study, efforts were made to design low cost, insulated, movable mud house for indigenous bee *Apis cerana* similar to their natural habitat, so as to revive the habitat/nests and conserve their population.

Materials and Methods

The present study was conducted in the research laboratory, Zoology Division, Career Point University, Hamirpur (H.P.), situated in the western Himalayan region of North India. The study area is situated between 31.6182128º N latitude and 76.6223175º E longitude with 981 meters above sea level. A comprehensive survey was carried out in two districts of Himachal Pradesh, *i.e.*, Hamirpur and Mandi, on the habitat and nesting behaviour of *Apis cerana*. A questionnaire was designed, and the information was collected from beekeepers, villages and scientific personals from beekeeping research centres. It was concluded that *Apis cerana* used to dwell in mud houses. In the present study, clayey soil was used to construct artificial hives for *cerana* bees. The soil was procured from the Palampur region of district Kangra (H.P.). This soil has been reported to construct houses by villagers and has powerful binding qualities. The soil was digged manually and shifted to the laboratory for practical use (Figure 1).

Fig 1: Procurement of soil

Indigenous bee prefers wall hives which are made of soil and wood. We focused upon lightweight wood with long-lasting property, which will provide internal rigidity and strength to the hive. Various types of woods like mango plant, kail, taali *etc*., were tried so that weight might remain the same as that of standard hives. The plant fibre, i.e., *Grewia optiva* bark (shail) was also mixed with soil while preparing it for mud house manufacturing. The composite mud house was manufactured using wood and soil mixed with *Grewia optiva* bark (shail). The dimensions were kept as that of *cerana* hives (Newton Hive) already available in the market.

The soil was grinded manually to form fine powder of it. The stone (if any) were scrutinized and separated from the soil. It was then stored in a container till further use. Also, some *Grewia optiva* bark (locally called shail) procured from the local forest and cut into small pieces. They were also stored separately.

Soil and *Grewia optiva* bark were mixed in a large-sized container, and water was added to it in optimum quality. It was then appropriately mixed to prepare a dough-like texture (Figure 2).

Fig 2: Mixing of Soil and *Grewia optiva* bark (shail)

Required numbers of *A. cerana* colonies were procured from the registered beekeeper to check the habitat suitability and survival.

Results and Discussion

The results obtained during the study are as under:

1. Composite Mud House

The composite mud house was manufactured using wood and soil mixed with *Grewia optiva* bark (shail) (Figure 3). The dimensions were kept as that of *cerana* hives already available in the market.

Fig 3: Manufacturing of Mud Hive

The tensile strength of pure soil is generally less [10], so clayey soil undergoes problem of swelling and shrinkage during and dry conditions respectively, which generate cracks or voids in the soil (Figure 4). The dry density of pure soil is higher, but to avoids such problems of swelling and shrinkage, the plant fibre, i.e., *Grewia optiva* bark (shail) was mixed with the soil [8]. *Grewia optiva* fibre is reasonable, intense, economical, light in weight, less hazardous, and can potentially be used as structural materials [8].

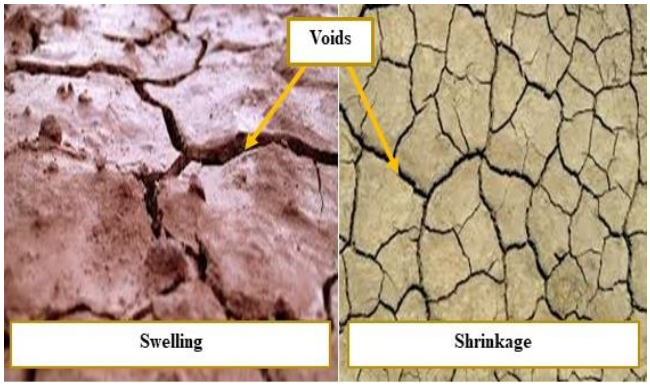

Fig 4: Swelling and shrinkage of soil

Secondly, mixing of fibre with the clayey soil can provide insulation to the mud hive because natural fibre has much insulation strength (Kumar *et al*., 2017). The plant fibre mixed with clayey soil may help to maintain the internal temperature of the mud hive. Therefore, after the addition of plant fibre, the coating was made on the wood and composite mud house was prepared (Figure 5).

Fig 5: Mud House coated with soil and *Grewia optiva* bark (shail)

2. Survival efficiency of *Apis cerana* in a mud house

Required numbers of *A. cerana* colonies were procured from the registered beekeeper. Colonies were checked for infection, if any. The *cerana* bees were kept in composite mud hive, and observations were made on the following parameters to check the habitat suitability and survival:

a. Bee Foraging

The foraging activity of honeybees was noticed and recorded from the first day of establishing the composite mud hive in the university campus. It was observed that the bees start working/foraging early in the morning. Bees were seen moving in and out of the hive around 600 hours, and their foraging rate increased as the day progresses. After that, the activity slowly decreases during noon time and almost ceases at 1300 hours. Bees again started foraging in the evening, i.e., after 1530 hours and keep on foraging till 1930 hours. There was a significant difference in the bee activity on a cloudy day. It was observed that bees work/forage with more interest on bright sunny days than cloudy/windy weather. Activity of bees was also noticed on some weeds available in university campus like *Parthenium* and *Cannabis* etc. Average number of bees leaving the hive was found to be 22±1.20 in the month of February which increased to 30±1.36 in May 2020 which further decreased to 28±1.06 in Jine when temperature was high in the environment. Number of bees entering the hive varied in the range of 18±0.23 to 23±0.11 bees/hive/minute (Table 1).

Table 1: Showing number of bees leaving and entering the hive and honey stores

Month and Year	Number of bees leaving hive/minute	Number of bees entering hive/minute	Honey Stores
Feb 2021	22±1.20	18±0.23	---
Mar 2021	24±0.56	23±1.01	--
Apr 2021	22±0.12	22±0.75	+
May 2021	30±1.36	19±0.82	++
Jun 2021	28±1.06	23±0.11	++++

b. Honey Production

Honey storage and its production were also observed in the mud hives. Movement of bees in and out of hives refers to collection of food (pollen, water and nectar). However, hives were not checked for the honey stores initially but after a period of 3 months, ample honey stores were observed in the composite mud houses (Table 1).

Conclusion

Honeybees survive best in their natural habitats. These small creatures are losing their attention in this modern world. Time is not so far that these small creatures will reach the stage of extinction. Revival of nests/habitat may prove helpful in conserving indigenous bee species which is otherwise drastically declining.

Recommendations

The composite mud hive designed and manufactured during the study is sort of effort to revive the habitat and nest of indigenous honey bee, *Apis cerana* which is otherwise disappearing from the Himalayan region. Following are the recommendations for conserving honeybees:

i. Provisions may be made with wooden hives in the brick walls.
ii. Awareness may be created and training be provided to the villagers to propagate *cerana* bee colonies, through the use of wall hives.
iii. Existing beekepers should be encouraged to adopt cerana beekeeping by providing various subsidies and loans by the Government.
iv. Old sheds, houses and other buildings (if any) may be utilized for creating nests for *Apis cerana*.

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