

DOI No.: <http://doi.org/10.53550/EEC.2023.v29i03s.057>

Nesting sites of cavity nesting honey bees (*Apis* spp.) in natural ecosystems of Kerala, India

Chinchu P. Babu¹ and Amritha V.S.²

¹Department of Entomology, Kerala Agricultural University, Vellayani, Thiruvananthapuram 695 522, Kerala, India

²AICRP on Honey Bees and Pollinators

Department of Entomology,

Kerala Agricultural University, Vellayani, Thiruvananthapuram 695 522, Kerala, India

(Received 23 December, 2022; Accepted 16 February, 2023)

ABSTRACT

Natural colonies of cavity nesting honey bees are important for the conservation of bees. This study was aimed to determine the nesting habitat, nesting sites, nest height, and nest characteristics of naturally occurring cavity nesting honey bees in Kerala. The results showed that primary forests, disturbed or agricultural land as well as undisturbed lands were found to be the nesting habits of cavity nesting bees in Kerala. Among the nesting sites, tree hollows were the prevalent nesting sites of cavity nesting bees in Kerala wherein, the predominant tree species was *Tectona grandis*. The nest height of honey bee colonies from ground level varied from 0 cm to 600 cm and the number of combs in a colony varied from five to twelve. No significant differences were observed in the nest height and number of combs in the honey bee colonies in hill and plain regions of Kerala. Biserial correlation analysis revealed that in the plain regions, the proportion of parallel arrangement of combs to the direction of nest entrance was high (0.83) whereas in hilly regions the proportion of comb arrangement at right angles to the nest entrance was high (0.88).

Key words: Cavity nesting honey bees, Nesting habitat, Nesting site, Kerala

Introduction

Honey bees (Order: Hymenoptera, Family: Apidae) are social insects with astounding degree of complex social behaviour and division of labour among the different members of the colony. Apiculture, or beekeeping dates back millennia and has evolved multiple times all through human history. It is the domestication of honey bees (Genus: *Apis*) in bee hives for the purpose of harvesting honey and other hive products (Starr, 2021). Apart from the domesticated colonies, the cavity nesting honey bees occur naturally in wild or feral colonies. A wide range of

nesting habitats were exhibited by the cavity nesting bees including tunnelling in bare ground, using pre-existing cavities, excavating dead wood, and constructing nests inside larger cavities in or on trees, in rocks or rodent nests and in active termite nests (Roubik, 2006; Kremen *et al.* 2007).

Kerala state has the potential to cultivate honey bees because of the abundant floral resources. Honey bee hunting and gathering has long been known by the rural communities around forests in Kerala. Bee hunting has always been performed by the rural communities to obtain additional income in addition to their consumption.

(²Prof. and Principal Investigator)

The changes in ecosystem may highly affect the bees (Steffan-Dewenter, 2003) and these changes might have detrimental effects on the bees such as affecting the nesting dynamics (Vaudo *et al.*, 2011). Due to their paramount importance in pollination services, studies on the ecology, spatial distribution and diversity are essential for the conservation of the bees (Inoue *et al.*, 1990; Baum *et al.*, 2005; Coulson *et al.*, 2005; Sheffield *et al.*, 2008; Murray *et al.*, 2009; Vaudo *et al.*, 2011). The present study was aimed to investigate the nesting habitat, nesting sites and nest characteristics of feral colonies of cavity nesting bees in Southern, Central and Northern zones of Kerala.

Materials and Methods

A survey was conducted in three zones of Kerala, *viz.*, Southern, Central and Northern zones. The feral colonies of cavity nesting bees in Kerala were identified by random searching, enquiry with honey bee farmers and Kerala Forest Department. Survey locations are given in Figure 1. Based on elevation, the colonies were classified as 'Plain' (<300 m) and 'Hill' (>300m) populations. The observations on nesting habitat, nesting sites, nest height, and nest characteristics were documented.

Statistical analysis

Nest height and number of combs in the colony were analysed for their variations between honey bee colonies inhabiting the hilly and plain regions of Kerala using 't' test analysis. The relation between arrangement of combs to the direction of nest entrance and elevation (hill and plain) were investigated by biserial correlation analysis. Calculations were performed using 'R' software.

Results

A total of 35 feral colonies of cavity nesting bees were observed in Kerala. Eighteen colonies were observed in Plain region (elevation < 300 m) and seventeen colonies were observed in the hilly regions (elevation > 300 m).

Nesting habitats

Feral colonies of cavity nesting honey bees were found to inhabit the primary forests, disturbed or agricultural land as well as undisturbed lands in Kerala. Twenty out of 35 colonies were found to inhabit in primary forests, twelve colonies were found

in agricultural or disturbed lands and three colonies in undisturbed areas.

Nesting sites

The cavity nesting bee colonies in Kerala were generally found in tree hollows, rock crevices, mud wall, termite mound, letter box and mud pot (Plate 1). Of the 35 sampled populations, maximum number of bees in Kerala were found to occur in tree hollows (46%) followed by rock crevices (23%), mud wall (20%), termite mound (5%), letter box (3%) and mud pot (3%) (Figure 2). The nest site selected was partially shaded, moderately exposed to wind and moderately wetted by rain. The space in front of the nest entrance was generally clear which provided an open flight path for the bees.

Tree species used as nesting sites by the bees consisted of ten genera belonging to ten families (Table 1). The trees were *Grevellia robusta*, *Terminalia bellirica*, *Calophyllum inophyllum*, *Tectona grandis*, *Lagerstroemia parviflora*, *Eucalyptus* sp., *Casuarina equisetifolia*, *Vateria indica*, *Syzygium cumini* and *Artocarpushirsutus*. The highest number of honey bees were found to nest in *Tectona grandis* (27%) followed by *Calophyllum inophyllum* (13%) and *Terminalia bellirica* (13%). The trees selected as nesting sites by bees were very solid which provided sturdy nest walls.

Nest height

The nest height of honey bee colonies from ground level varied from 0 cm to 600 cm (Table 1). Majority of the bees were found to occur at a nest height of 0 cm to 200 cm (86%) from ground level followed by 201 cm to 400 cm (8%) and only 6 per cent were found to occur at a nest height of 401 to 600 cm (Figure 3). The nest height of the colonies of cavity nesting bees in Kerala revealed no significant differences ($P > 0.01$) between the hilly and plain regions (Table 2).

Nest characteristics

Cavity nesting bees in Kerala build multiple parallel combs with a uniform distance between them. The number of combs in the colony varied from five to twelve with an average of 7.7 (Table 1). No significant differences ($P > 0.01$) were observed in the number of combs of cavity nesting bees in Kerala between the hilly and plain regions (Table 2).

Biserial correlation analysis of arrangement of combs to the direction of nest entrance with eleva-

Table 1. Details of nesting habitat, nesting site, tree species and arrangement of combs of cavity nesting bees in Kerala.

Sl. No.	Sampling Locations	Elevation	Nesting habitat	Nesting site	Nest height from ground level	Tree	Number of combs	Arrangement of combs
I. Plain								
1	Achencovil	139	Primary forest	Tree hollow	0	<i>Grevelia robusta</i> (Proteaceae)	8	Parallel
2	Aryankavu	158	Primary forest	Tree hollow	150	<i>Tectona grandis</i> (Lamiaceae)	10	Parallel
3	Edamon	175	Agricultural / Disturbed land	Rock crevice	55	-	12	Parallel
4	Edavanna	35	Agricultural / Disturbed land	Tree hollow	156	<i>Tectona grandis</i> (Lamiaceae)	8	Parallel
5	Iritty	56	Agricultural / Disturbed land	Rock crevice	58	-	12	Parallel
6	Kalichamaram	22	Agricultural / Disturbed land	Rock crevice	45	-	9	Parallel
7	Kallar	140	Primary forest	Rock crevice	134	-	7	Parallel
8	Kallikode	64	Undisturbed land	Mud wall	590	-	6	Right angle
9	Kannara	64	Agricultural / Disturbed land	Mud wall	92	-	8	Parallel
10	Kumbukuthi	70	Primary forest	Tree hollow	128	-	12	Right angle
11	Mangalapuram	47	Agricultural / Disturbed land	Letter box	150	-	5	Parallel
12	Nelliampathi	110	Primary forest	Tree hollow	304	<i>Tectona grandis</i> (Lamiaceae)	8	Right angle
13	Palakkayam Thattu	78	Agricultural / Disturbed land	Mud wall	148	-	7	Parallel
14	Panathady	122	Agricultural / Disturbed land	Rock crevice	89	-	9	Parallel
15	Pandha	114	Agricultural / Disturbed land	Mud wall	65	-	5	Parallel
16	Pattikkad	131	Primary forest	Tree hollow	70	<i>Calophyllum inophyllum</i> (Guttiferae)	7	Parallel
17	Thenmala	248	Primary forest	Tree hollow	30	<i>Terminalia bellirica</i> (Combretaceae)	6	Parallel
18	Vaniyampuzha	79	Primary forest	Tree hollow	64	<i>Tectona grandis</i> (Lamiaceae)	9	Parallel
II. Hill								
19	Ambalavayal	790	Undisturbed area	Mud wall	600	-	7	Right angle
20	Ayyappancovil	757	Primary forest	Mud wall	354	-	6	Right angle
21	Goodrickal	409	Primary forest	Tree hollow	105	<i>Lagerstroemia parviflora</i> (Lythraceae)	7	Right angle
22	Gundumalai	1847	Agricultural / Disturbed land	Tree hollow	259	<i>Eucalyptus</i> sp. (Myrtaceae)	8	Right angle
23	Gundumalai 2	1866	Agricultural / Disturbed land	Tree hollow	147	<i>Casuarina equisetifolia</i> (Casuarinaceae)	8	Right angle
24	Kalpetta	755	Primary forest	Termite mound	15	-	5	Right angle
25	Kanchiyar	898	Agricultural / Disturbed land	Rock crevice	32	-	6	Right angle
26	Kulathupuzha	426	Primary forest	Mud wall	20	-	5	Right angle
27	Mananthavady	765	Undisturbed area	Rock crevice	139	-	12	Right angle
28	Mariyankudi	755	Primary forest	Mud wall	34	-	8	Right angle
29	Naduvathumuzhi	435	Primary forest	Termite mound	50	-	5	Right angle
30	Palode	401	Primary forest	Rock crevice	76	-	8	Right angle
31	Ponnudi	786	Primary forest	Tree hollow	23	<i>Terminalia bellirica</i> (Combretaceae)	8	Parallel

Table 1. Continued ...

Sl. No.	Sampling Locations	Elevation	Nesting habitat	Nesting site	Nest height from ground level	Tree	Number of combs	Arrangement of combs
32	Sholayar	609	Primary forest	Tree hollow	200	<i>Vateria indica</i> (Dipterocarpaceae)	7	Right angle
33	Thamarassery	489	Primary forest	Tree hollow	108	<i>Artocarpus hirsutus</i> (Moraceae)	8	Right angle
34	Thirunelli	804	Primary forest	Tree hollow	10	<i>Syzygium cumini</i> (Myrtaceae)	7	Parallel
35	Vengollum	340	Primary forest	Tree hollow	0	<i>Calophyllum inophyllum</i> (Guttiferae)	6	Right angle

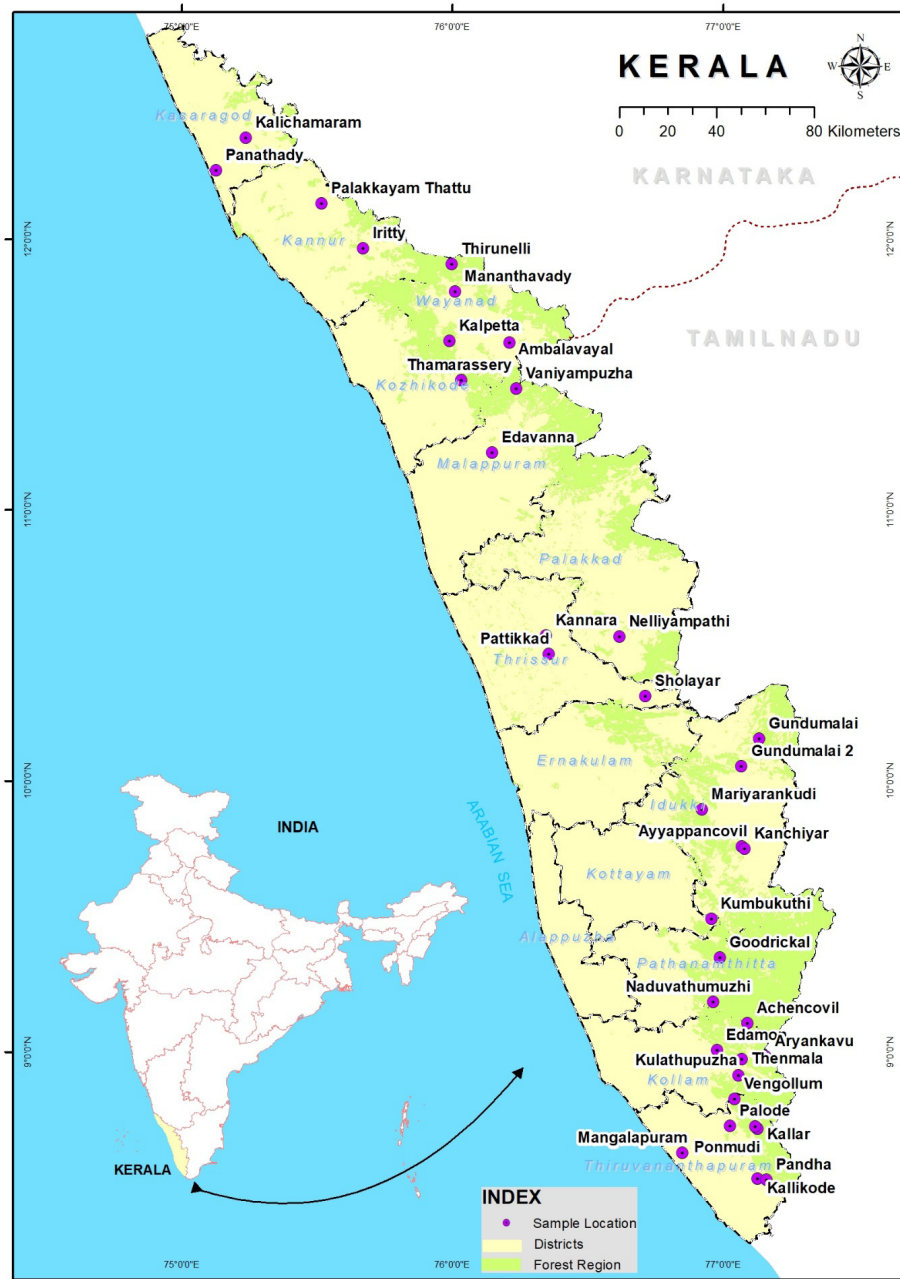


Fig. 1. Survey locations of cavity nesting honey bee colonies in Kerala

tion revealed that the arrangement of combs in plains showed a slight positive correlation ($r = 0.26$) wherein the proportion of parallel arrangement of combs to the direction of nest entrance was high (0.83). In the hilly regions, a very slight positive correlation ($r = 0.03$) was observed with higher proportion of comb arrangement at right angles to the direction of entrance (0.88) (Table 3).

Discussion

Primary forests, disturbed or agricultural land as well as undisturbed lands

were found to be the nesting habitats of cavity nesting bees in Kerala. Seeley *et al.* (1982) observed the existence of cavity nesting bee, *A. cerana* in almost all habitats, including primary forests. Otis (1996), Hadisoesilo (1997) and Phiancharoen *et al.* (2011) reported that the bees prefer to nest in secondary forest, agricultural or disturbed areas. Honey bee habitat is closely associated to the availability of flowering plants as food source and water availability. As the primary forests provide diverse flora, the existence of honey bees in primary forests in Kerala is very common.

Among the nesting sites, tree hollows were the prevalent nesting sites of cavity nesting bees in Kerala. Cavities in the trees are used for housing multiple combs, as a shelter from predators and unfavourable weather conditions. Also, a cavity is appropriate for nesting if it can be inhabited by a

colony of bees for a comparatively longer period of time (Jasmi *et al.*, 2014). A wide range of tree species were exploited as the nesting sites of bees in Kerala. The tree species utilized by honey bees as nesting sites primarily depends on the diversity of tree species available in that locality. *Tectona grandis* was the most predominant tree species utilized as nesting site of bees in Kerala because of the relative abundance of the trees in those areas.

In our study, we also observed non-tree locations used by cavity nesting bees as nesting sites such as rock crevices, mud walls, termite mound and letter box. The selection of a new nest site is ecologically critical for an insect colony (Visscher, 2007). Potential nesting sites were detected by individual scout bees and they integrate multiple properties of these sites into assessments of their quality. The diversity and abundance of early successional flowering



a) Tree hollow



b) Rock crevice



c) Mud wall



d) Termite mound

Plate 1. Nesting sites of feral colonies of cavity nesting bees in Kerala

plants also determine cavity sites selected by honey bees, as reported by Coulson *et al.* (2005).

The cavity nesting bees tend to nest at relatively low heights (0-600 cm) with an average nest height of 129 cm. Supportive statements were provided by Seeley *et al.* (1982) and Karlsson (1990) wherein they observed an average nest height of 2 m and the maximum nest height varied between two to ten meters (Inoue, 1990; Karlsson, 1990; Kuntadi, 1989; Seeley, 1983). Also, only in a few colonies, nest entrances were observed at the ground level (2 out of 35). It is unidentified whether this difference is due to peculiar nesting behaviour in Kerala, or whether the nest height data might be generally biased due to the difficulty of finding nests at large heights. Furthermore, no significant differences were observed in the nest height of honey bee colonies in the hill and plain regions in Kerala.

Ruttner (1988) and Inoue (1990) reported that the number of *A. cerana* combs varied from three to fourteen with an average of 6.4 in Bangladesh (Karlsson, 1990), 5.6 in Thailand (Seeley, 1982) and 7.9 in Indonesia (Inoue, 1990). In Kerala, similar results were observed wherein the number of combs varied from five to twelve.

In addition, no significant differences were observed in the number of combs in the honey bee

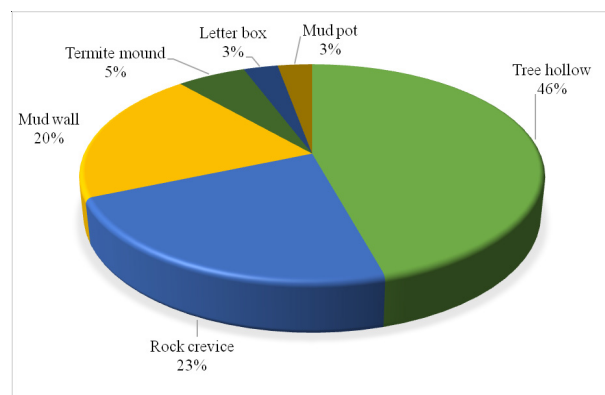


Fig. 2. Percentage of nesting sites of cavity nesting bees in Kerala

Table 3. Arrangement of combs of cavity nesting honey bees to the direction of nest entrance in the hilly and plain regions of Kerala'

Arrangement of combs	Proportion of each category		Correlation matrix (r)
	Parallel	Right angle	
Hill	0.12	0.88	0.03
Plain	0.83	.017	0.26

colonies in the hilly and plain regions in Kerala. Investigation by Jasmi *et al.* (2014), revealed that the number of combs in a colony depended on the cavity size *i.e.*, larger cavities allowed a colony to establish more combs.

The arrangement of combs to the direction of entrance showed distinct variations between plain and high altitude colonies, wherein combs were arranged parallel to the direction of nest entrance in plains and at right angles in higher altitudes. Similar reports were given by David and Kumaraswami (1975) wherein the combs being arranged at right angles to the entrance in cold regions (Hill) and parallel to the direction of entrance in the plains wherein the temperature is relatively warmer.

The present study showed a preliminary effort to identify the nesting habitat, nesting sites, nest height, and nest characteristics of cavity nesting honey bees in Kerala. Identification of the nesting

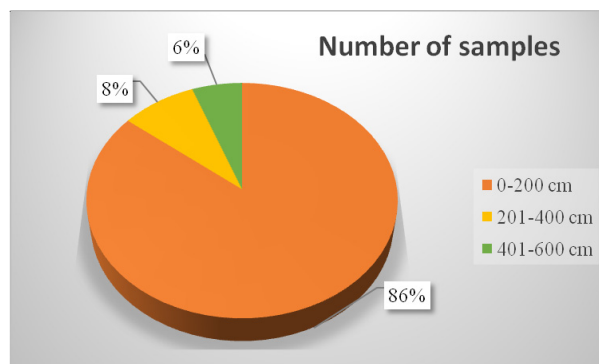


Fig. 3. Percentage of nest height of honey bee colonies from ground level

Table 2. The variations in the number of combs and nest height of cavity nesting bees inhabiting hilly and plain regions of Kerala

Colony characteristics	Conditions	Mean value	t-stat	P value
Number of Combs	Hills	7.12	-1.65	0.11
	Plains	8.22		
Nest Height	Hills	127.76	-0.03	0.97
	Plains	129.33		

habitat and nesting sites were advantageous in the conservation of honey bees in their natural ecosystems. More investigation on the feral colonies of cavity nesting bees may reveal unidentified nesting sites of bees in Kerala.

Acknowledgement

Authors immensely thank Department of Entomology, College of Agriculture, Vellayani for providing all the facilities. This work was supported by student contingency grant (H/A '202-21-2014-232), Kerala Agricultural University, Thrissur.

Conflicts of interest

The authors declare that they have no potential conflict of interest in relation to the study in this paper. The authors have no relevant financial or non-financial interests to disclose.

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