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Studies on Nest Shapes and Comb Architecture of *Apis dorsata* Fab. in Southeast Karnataka, India

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ABSTRACT: *Apis dorsata* is characterized by the construction of large, single-comb nests suspended from arboreal branches and man-made structures. Studies on nest shapes, comb and cell dimensions of 718 nests of *A. dorsata* were conducted across Kolar, Chikkaballapur, and Bengaluru Rural districts of Karnataka, India. Results indicate that semicircular nests predominated (40.80%), primarily on banyan (15.59%) and peepal trees (11.83%), whereas curved U-shaped nests (23.11%) were common on rock cliffs (14.48%) and buildings (8.63%). Irregular nests (12.95%) were found on Terminalia trees (5.98%), horizontally semicircular nests (20.33%) on banyan (3.20%) and eucalyptus trees (4.73%) and vertically semi-circular nests (13.37 %) on rock cliffs (7.10%). Cell measurements confirmed that the worker brood cells were smaller than honey cells, and drone cells. The nest shape distribution was significantly different (χ^2 = 241.7, df = 4, p < 0.001), between the nesting structures (χ^2 = 410.3, df = 18, p < 0.001). ANOVA confirmed significant differences in comb area allocation between brood, honey, and pollen area (p < 0.01). The observations confirmed significant associations between nesting structures and nest shapes (χ^2 test, p < 0.05). These findings provide insights into the ecological plasticity and adaptive strategies of *A. dorsata* in plains of south east Karnataka, India.

Keywords: *Apis dorsata*, comb area, nest shapes, brood area, pollen area, honey area.

INTRODUCTION

Apis dorsata is one of the ecologically and economically significant wild bee species distributed widely across South and Southeast Asia (Huang *et al*., 2022; Ruttner, 2013). Distinguished by its large, single-comb nests suspended from tall trees, rock cliffs, and man-made structures, *A. dorsata* plays a vital role in honey production and pollination services in tropical and subtropical ecosystems (Nagaraja *et al*., 2023). The nests of *A. dorsata* ensures colony survival, thermoregulation and efficient resource storage (Tan, 2007; Buawangpong *et al*., 2014). Typically, brood cells occupy the central portion of the comb, while honey and pollen are stored in peripheral regions. Differentiation honey, worker brood, and drone cells in the combs reflects adaptive strategies for resource allocation and colony growth (Bader *et al*., 2022; Deng *et al*., 2023). Although several studies have documented the nest dimensions and colony densities of honeybee species (Deodikar *et al*., 1977; Reddy, 1983; Kumar and Reddy 2003), the comparative analyses of nest shape and comb architecture have been challenging due to variations in nest size and environmental conditions. Honeybees establish their nests in these hollow spaces, and harvesting is done by carefully opening these natural hives (Divakar and Vijaykumar 2023).

Woyke *et al*. (2016) reported shape indices of *A. dorsata* such as the Nest Shape Index (NSI) and Inclination Index (II), to describe nest geometry. Findings suggest that nest shape was influenced by factors such as substrate availability, microclimate, and predator pressures. *A. dorsata* exhibits ecological plasticity by constructing nests on diverse tree substrates such as banyan (*Ficus benghalensis*), peepal (*Ficus religiosa*), *Terminalia* spp., and increasingly on man-made structures in urban landscapes (Raghunandan and Basavarajappa 2014). This shift underscores the species' adaptability to human-modified environments, but also signals challenges arising from habitat loss and disturbance (Oldroyd and Wongsiri 2009). Understanding the relationship between nest shape, substrate preference, and comb organization is therefore essential for the conservation of these species. The studies on nest architecture of *A. dorsata* remain limited in southern India, particularly in semi-arid agro-ecosystems of Karnataka. The present study investigates nest shapes, substrate associations, and comb architecture of *A. dorsata* nests across Kolar, Chikkaballapur, and Bengaluru Rural districts.

MATERIALS AND METHODS

Study area: The studies on nest-shapes and comb dimensions of *A. dorsata* were conducted across three districts of southern Karnataka, India such as Kolar (13.07°N, 78.7°E), Chikkaballapur (13.33°N, 77.52°E) and Bengaluru rural (12.15°N, 77.59°E). These districts are characterized by semi-arid agroecosystems interspersed with fragmented forest patches and extensive human modified landscapes. Vegetation in these regions comprises *Ficus* spp., *Terminalia* spp., *Eucalyptus* and *Mangifera indica*, which serve as potential nesting substrates for *A. dorsata*. The climate was marked by hot summers, moderate rainfall during the southwest monsoon, and mild winters, conditions that influence colony distribution and nest site selection (Raghunandan and Basavarajappa 2014). A through field survey was made on a total of 718 nests and nine abandoned combs and were categorized according to their shapes as semi-circular, horizontally semi-circular, vertically semi-circular, curved U-shaped and irregular. The nesting supports were also documented on trees, rock cliffs, and buildings.

Fig. 1. Nest shapes of *Apis dorsata* on different nesting structurers.: (a) Horizontal U shape, (b) curved U shape, (c) vertical U shape, (d) irregular shape.

Comb dimensions: Comb architecture of *A. dorsata* was analysed from nine recently abandoned combs across the study sites. Each comb was measured for perimeter using ruler scale, total area of brood, honey and pollen regions were measured using the ImageJ software (Buawangangpong *et al*., 2014; Bader *et al*., 2022).

Cell dimensions: The dimensions of comb cells such as cell diameter and depth were recorded by measuring a series of 10 consecutive cells in ImageJ software by setting scale. Similarly, the individual measurements were also recorded using an ocular micrometre scale with compound microscope. The cell depth was assessed by using ruler scale after sectioning combs along the sagittal plane (Tan, 2007; Buawangpong *et al*., 2013: Deng *et al*., 2023).

Statistical Analysis: A chi-square (χ^2) test was used to assess the relationship between the nest shape and substrate type, while a chi-square goodness-of-fit test was used for the deviation of nest shape distribution from uniformity. The analysis of variance (ANOVA) was employed to compare comb with brood, honey, and pollen area. The Pearson correlation coefficients were used to examine relationships between comb area, drone and worker brood area.

RESULTS AND DISCUSSION

A total of 718 active *A. dorsata* nests were recorded from the study districts, with distinct variation in nest shapes and substrate associations. Among the recorded nests, semi-circular nests predominated (40.8%), followed by curved U-shaped nests (23.11%), irregular nests (12.95%), horizontally semi-circular nests (13.37%), and vertically semi-circular nests (20.33%) (Table 1). A chi-square test confirmed that distribution of nest shapes deviated significantly from uniformity ($\chi^2 = 241.7$, df = 4, $p < 0.001$), indicating that certain nest shapes were preferred by *A. dorsata*. The predominance of semi-circular nests confers both structural stability and efficient use of space (Woyke *et al*., 2016). Results shows that the strong associations between nest shape and nesting support. Semicircular nests were most frequently attached to banyan (*Ficus benghalensis*) and peepal (*Ficus religiosa*) trees, while curved U-shaped nests were observed greater in number on rock cliffs and buildings. Irregular nests were concentrated on *Terminalia* spp., whereas horizontally semicircular nests were mainly found on banyan and eucalyptus trees (Fig. 1). Similarly, vertically semicircular nests occurred primarily on rock cliffs. A chi-square test of independence confirmed significant dependence of nest shape on substrate type ($\chi^2 = 410.3$, df = 18, $p < 0.001$). These results suggest that *A. dorsata* selects nest shapes adaptively depending on substrate availability and structural constraints. Similar observations were reported by Kumar and Reddy (2003) and Oldroyd and Wongsiri (2009), who emphasized the role of substrate orientation and environmental conditions in shaping nest geometry. The occurrence of irregular nests on *Terminalia* spp. highlights how irregular branching patterns can influence comb construction, while the large number of nests on man-made structures demonstrates the ecological plasticity of *A. dorsata* (Nagaraja and Rajagopal 2009; Raghunandan and Basavarajappa 2014). Such adaptability underscores resilience to human-modified habitats but also raises concerns about habitat loss and potential conflict with people.

Table 1: Distribution pattern of different shaped nests of *A. dorsata* on trees, buildings and rock cliffs.

	Percentage of nest shapes on different substrates				
Substrates	**Semicircle**	**Horizontal Semicircle**	**Vertical Semicircle**	**Curved U shaped**	**Irregular**
Peepal tree	11.83	00.27	03.2	-	01.94
Terminalia	05.29	01.53	00.91	-	05.98
Eucalyptus	02.22	04.73	00.13	-	02.22
Mango tree	01.11	00.41	00.13	-	00.13
Banyan tree	15.59	06.40	03.20	-	01.81
Buildings	03.76	-	05.57	08.63	-
Rock cliffs	00.97	-	07.10	14.48	-
Total Nest shapes (%)	**40.80**	**13.37**	**20.33**	**23.11**	**12.95**

Table 2: Comb measurements and Resource Areas.

Comb No.	Perimeter (cm)	Comb area (cm²)	Honey area (cm²)	Brood Area (cm²)	Pollen area (cm²)
1	106.50	673.90	122.70	495.40	55.60
2	111.00	732.10	129.90	564.50	37.50
3	154.00	1409.10	290.90	1034.00	84.10
4	129.50	996.40	180.00	700.20	116.10
5	215.00	2746.60	410.10	2067.70	268.80
6	186.50	2066.70	387.80	1536.50	142.30
7	156.50	1455.30	224.10	1138.00	93.00
8	111.00	732.10	184.60	542.50	4.80
9	106.00	667.60	140.50	465.90	60.00

Analysis of nine *A. dorsata* combs revealed considerable variation in comb size and resource partitioning (Fig. 2). The measurements showed that, the comb perimeter was ranged from 106 cm to 215 cm, while comb area was varied from 667.6 cm² to 2746.6 cm². Brood area was consistently the largest component of the comb, followed by honey and pollen regions (Table 2). ANOVA showed significant differences among brood, honey, and pollen areas ($F = 18.3–24.5$, $p < 0.001$). The predominance of brood area reflects the colony's investment in reproduction and workforce maintenance Buawangpong *et al*. (2014). Larger brood and honey regions in semicircular nests suggest that this shape provides structural advantages for resource allocation.

Measurements of honey, worker brood, and drone cells revealed clear differentiation among cell types (Table 3). Drone cells were the largest followed by honey cells and worker cells, and one-way ANOVA confirmed significant differences among the comb cells ($F = 75–112$, $p < 0.001$). Such specialization reflects functional demands and supports earlier findings by Deng *et al*. (2023). The high variability in honey cells compared to brood cells suggests colonies adjust storage structures in response to fluctuating nectar inflows, while brood cells remain standardized for uniform larval development.

Cell shape analysis revealed that maximum of attachment zone cells was hexagonal, with occasional irregular polygons in the U-shaped periperal regions (Table 4). These comb shapes, significantly different from uniform hexagonal patterns ($\chi^2 = 12.6$, $p = 0.002$), which represents structural adjustments during comb construction and patterns of honeycomb geometry (Seeley, 2009, Nagaraja, 2012).

Table 3: Measurements of worker, drone and honey cells of *Apis dorsata.*

Cell Type	Diameter (mm)
Honey cell	4.6 ± 0.15
Worker brood cell	5.4 ± 0.20
Drone cell	5.6 ± 0.10

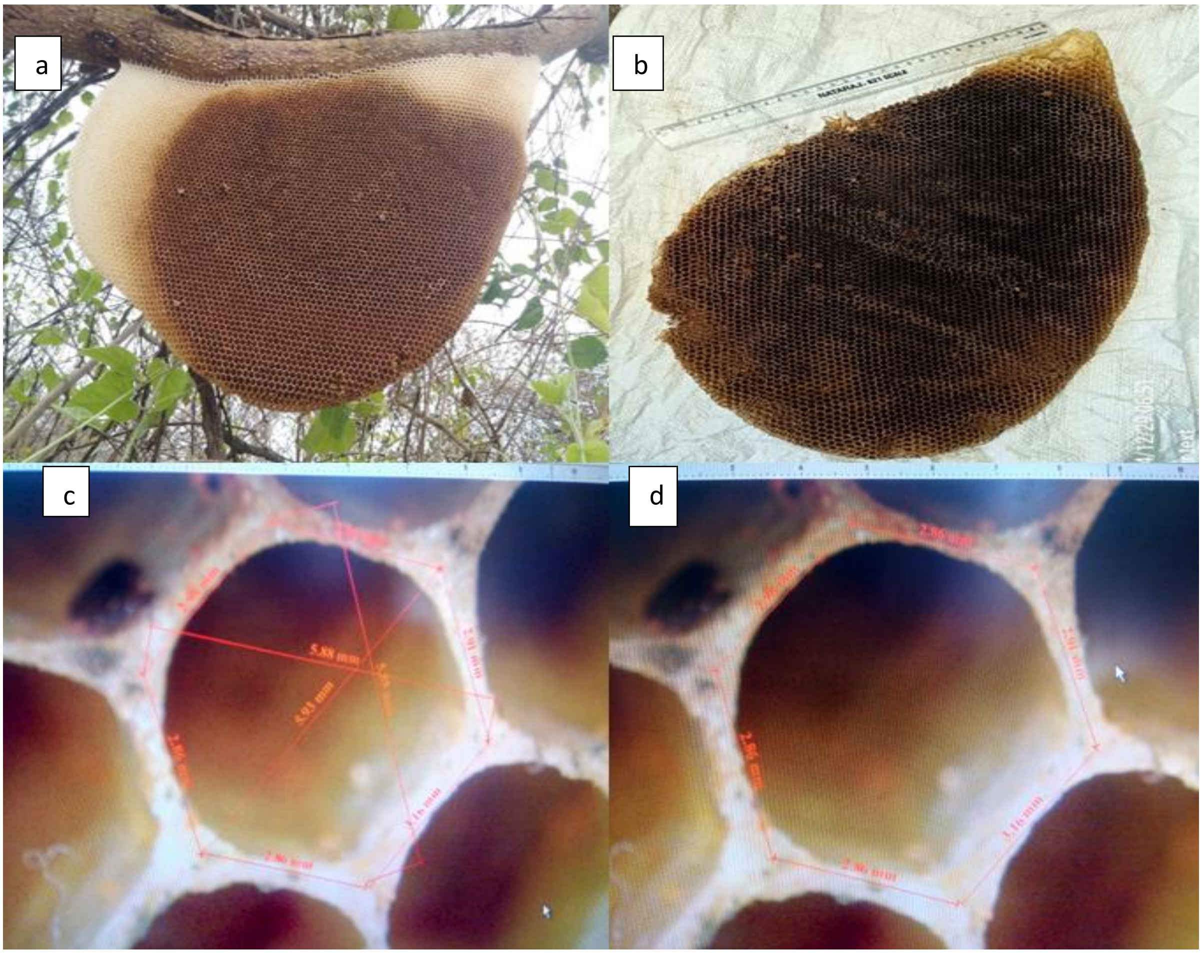

Fig. 2. Measurements of comb parameters of *Apis dorsata*: (a) abandoned comb, (b) measuring comb width (c) & (d) measuring cell diameter.

Table 4. Cell number and shapes of attaching comb portion and peripheral portion.

Region	Cell Count Range	Predominant Cell Shape	Irregular Shapes Present
Attachment zone (to branch)	160±20	Hexagonal	polygons
U-shaped peripheral portion	250±50	Hexagonal	Pentagonal

Honey cells were consistently deeper and thicker than worker brood cells ($p < 0.01$ (Tables 5). Variability was greater in honey storage regions than brood regions, reflecting adaptive flexibility in nectar storage versus the structural consistency required for larval development.

The persistence of consistent architectural patterns in abandoned nests signifies that *A. dorsata* follows intrinsic construction rules shaped by evolutionary and ecological pressures. The dependence of nests on Banyan and peepal trees as preferred nesting sites highlights the importance of conserving such keystone species as hosting surfaces, while the increasing occurrence of nests on buildings and rock-cliffs reflects adaptability but also potential conflict with the humans. The conservation and management approaches must therefore focus on protecting natural nesting substrates while promoting coexistence strategies in human-modified landscapes (Raghunandan and Basavarajappa 2014). Nonetheless, the nest shapes and comb architecture in *A. dorsata* represent adaptive designs optimised for stability, resource storage, and brood survival, demonstrating the species' resilience in diverse habitats.

Table 5: Cell depth and comb thickness of honey and worker brood cells of *Apis dorsata.*

Comb parameters	Honey Storage	Brood Rearing	Significance
Cell depth (cm)	2.21 ± 0.52	1.72 ± 0.08	($p<0.01$)
Comb thickness (cm)	4.70 ± 1.10	3.67 ± 0.19	($p<0.01$)

CONCLUSIONS

The findings of the study deepen understanding the conservation of natural nesting substrates and comb design of *A. dorsata* to ensure the persistence of ecologically and economically *A. dorsata* colonies.

FUTURE SCOPE

The future studies may explore the influence of seasonal variation, microclimatic factors, and landscape changes, altitudinal changes on *A. dorsata* nest architecture. The Advanced imaging, computational modelling can further clarify structural adaptations, while long-term monitoring would helpful to assess impacts of urbanization, ensuring effective conservation and sustainable coexistence strategies.

Conflict of interest: none.

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