https://www.scirp.org/journal/ns Natural Science, 2026, Vol. 18, (No. 5), pp: 73-89

Giant Honeybee, *Apis dorsata* (Hymenoptera: Apidae) Colony Population during Summer Season amidst Urban Conditions of Mysore, Karnataka, India

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Keywords: Giant Honeybee, *Apis dorsata*, Colony Population, Summer, Mysore

Received: March 20, 2026 **Accepted:** May 24, 2026 **Published:** May 27, 2026

ABSTRACT

The Mysore (12.29′58˚N, 76.63′94˚E) lies at 770 meters above sea level at the base of Chamundi Hills and has several natural lakes such as Kukkarahalli, Karanji, Lingambudhi and known for salubrious climate with good vegetation. All these features have attracted many migratory animals including honeybee, *Apis dorsata* (Hymenoptera: Apidae) during different seasons. Systematic observations were made during summer season to record *A. dorsata* colony population by following random sampling method at diversified habitats from April to June, 2024. Total 164 nest sites were used by *A. dorsata* to establish colonies at man-made structures and tree species. Altogether, 829 *A. dorsata* colonies were recorded at different nesting sites, of which, 604 colonies were recorded on various man-made structures with 13 different coloured surfaces such as white, brown, yellow and grey colours along with glass surface. Total 225 colonies were recorded on different tree species at various heights ranged in between 10 to 110 ft and above the ground level. The colonies were grouped into small, medium, big size and had four shapes namely "U", "V", "irregular" and "dome" shape with different orientations. In Mysore, the prevailed conditions along with foraging source at the vicinity of *A. dorsata* colonies during summer season were good. Of all, Fabaceae family members were predominantly supplied floral source (both nectar and pollen) along with good supply of water from different source. Besides locally prevailed good conditions helped *A. dorsata* to have normal survival during summer season despite experiencing several biological constraints. Being an open nester, *A. dorsata* experiencing different levels of human interference, killing, burning, spraying pesticides on the colonies, hunting and pre-monsoon rainfall was observed during summer season. Despite various interferences, *A. dorsata* showed nest site fidelity to its previously nested site during summer in Mysore. *A. dorsata* is one of the potential pollinators, its hive products are

economically important and *A. dorsata* playing a pivotal role in pollination and poverty alleviation as well. Hence, its investigation during different seasons helps reveal the status under natural conditions that could be used for local biodiversity conservation.

1. INTRODUCTION

Human association existed with honeybees since pre-historic times and it was evidenced by observing the beekeeping activities in ancient Egyptian, Greek and Mesoamerican civilizations [1]. This long-standing relationship underscores the importance of honeybees not only as economic resources [2], but also as cultural, ecological and symbolic organisms. Of all the existing honeybee species, wild honeybee, *Apis dorsata* (Hymenoptera: Apidae) is one of the major pollinator species, and its hive products have good medicinal properties and are useful to mankind across the world [3]. Being a social insect [4, 5], it is an open nester [6-8], building nests on multistoried man-made establishments [9, 10], tall trees [9, 11, 12] and rock cliffs [13-16] to have safe survival, colony stability and help achieve good colony growth, seasonal swarming cycle and migration [8, 17]. Thus, *A. dorsata* inhabits not only in forested area and rural regions, but also was found abundantly in urban and semi-urban regions [18, 19]. Numerous *A. dorsata* colonies are observed in urban areas due to abundantly occurring man-made structures and tall avenue trees [10, 15, 20, 21]. In metropolitan city areas, nests are more likely to be found on buildings due to the increased protection from the sun, wind and rain [22]. However, *A. dorsata* colony population showed seasonal fluctuations, with the greater number of colonies found in winter followed by summer seasons. **Table 1** shows few published reports on *A. dorsata* at different parts of the world. Various researchers have recorded the nesting behavior of *A. dorsata* at different parts of India and other parts of the world including Karnataka [23, 24]. Sixty colonies of *A. dorsata* at south Andaman Island, India was recorded by [25]. *A. dorsata* colonies on 15 trees in Subah, Borneo, Indonesia were recorded by [26]. *A. dorsata* nests elevation at 51 nesting sites by studying 1,434 nests in and around Bangalore, Karnataka was measured by [27]. Few nesting parameters of *A. dorsata* in Raichur, Karnataka were recorded by [28]. Nests distributions of *A. dorsata* at 11 sites in and around Bangalore were reported by [13]. Seasonal migration of *A. dorsata* in protected habitat of Bogor Botanical Garden, West Jawa, Indonesia by monitoring the arrivals and departures of colonies was observed by [29]. Further, migratory behavior of *A. dorsata* was studied by [30]. Nesting behaviour and conservation status of *A. dorsata*, in southern Deccan Peninsula, Karnataka was reported by [31, 32]. Furthermore, nesting behavior, elevation and orientation of *A. dorsata* from 197 colonies at CCS Haryana Agricultural University, Hisar, Haryana was studied by [33]. Similarly, [21, 22] have studied the nesting behaviour of *A. dorsata* in Mysore. [20] has studied the colony density variation in *A. dorsata* during different seasons. [10] has studied biological constraints affecting *A. dorsata* in southern Karnataka. [8] has studied 587 *A. dorsata* colonies from 23 nesting sites in Nepal, India and Bhutan. [18] has recorded 2,407 live colonies of *A. dorsata* on trees, rock cliffs and man-made structures in southern Karnataka. [34] has recorded the nest orientation of *A. dorsata* colonies on different objects at plains of south Karnataka. [16] has recorded more number of *A. dorsata* colonies on man-made buildings and trees in urban regions of Bengaluru, Karnataka.

However, in recent past, honeybee population is seriously threatened by deforestation, agricultural intensification, monoculture farming, extensive pesticide use, destructive honey hunting activities, forest fires, prolonged droughts, increasing temperature and regional/local climate change [35, 36] at different parts of the world. Hence, honeybee population is facing unprecedented threats due to various reasons. Since, honeybees represent a biologically diverse and ecologically indispensable group of insects, whose survival is tightly linked to global food security, biodiversity [2, 37] and ecosystem resilience. Moreover, honeybees (e.g. *A. dorsata*) are potential pollinators, recording that their colony population requires continuous monitoring during different seasons to monitor local/regional biodiversity. However, published reports on *A. dorsata* during summer season amidst urban conditions are incomplete. Therefore, understanding their distribution, colony population and foraging sources during different seasons is essential for developing effective conservation [24, 38, 39] and management strategies. Hence, present study was undertaken during

Table 1. **Few published reports on giant honeybee, *Apis dorsata* in India and other parts of the world.**

Sl. No.	Researched on	Important findings	Place	Source
1.	Nesting behaviour of Indian honeybee	Recorded different nest sites of honeybees	India	Deodikar *et al.* (1977)
2.	Retrieval of visuo-spatial memories by honeybees	Identified the selection of nest sites	-	Collette and Kelber (1988)
3.	Height-dependent nest site selection in *Apis dorsata*	Recorded the height-dependent nesting activities	Bangalore, India	Reddy and Reddy (1989)
4.	Colony migration in the tropical honeybee, *Apis dorsata*	Recorded migratory behaviour	India	Dyer and Seeley (1994)
5.	Arboreal bee forage plants	Identified epiphytes floral source to honeybees	India	Joshi *et al.* (1998)
6.	Status of natural colonies of *Apis dorsata*	Recorded the status	Karnataka, India	Basavarajappa (1998)
7.	Honeybee memory: Navigation by associative grouping and recall of visual stimuli.	Observed the associative grouping and recall of visual stimuli by honeybees	-	Zhang *et al.* (1999)
8.	Nesting site recognition by *A. dorsata*	Identified different nest sites	China	Liu *et al.* (2000)
9.	Defence strategies in *A. dorsata* under natural conditions	Recorded different defence strategies against pests and predators	-	Kastberger *et al.* (2001)
10.	Memory use in insect visual navigation	Recorded how insects use navigation by visual cues	-	Collette and Collette (2002)
11.	Home-site fidelity in migratory honeybees	Recorded the home-site fidelity in honeybees	-	Neumann *et al.* (2000)
12.	Giant honeybees return to their nest sites	Observed the return of honeybees to their previously nested sites	-	Paar *et al.* (2000)
13.	Grouping of visual objects of honeybees	Recorded the objects which are used for nesting	-	Zang *et al.* (2004)
14.	Status of *Apis dorsata*	Recorded the natural status	Karnataka, India	Basavarajappa (2004)
15.	Group decision making in nest-site selection by honeybees	Recorded the group decision making in nest-site selection	-	Seeley and Visscher (2004)
16.	Honeybee memory recorded experimentally	Recorded the honeybee decision making abilities	China	Zang *et al.* (2006)
17.	Nesting behaviour of *Apis dorsata*	Identified different nest sites	North India	Khan *et al.* (2007)

Continued

18.	Old comb for nesting site recognition by *Apis dorsata*?	Recorded how *A. dorsata* identify the previously nested sites	China	Liu *et al.* (2007)
19.	Nesting behaviour of *A. dorsata*	Recorded nesting behaviour	Mysore, India	Manjunath (2008)
20.	Pests of *Apis dorsata*	Identified the pests	Karnataka	Basavarajappa (2009)
21.	Characteristics of trees used as nest sites by *Apis dorsata*	Recorded trees as nest sites of *Apis dorsata*	Nilgiri Biosphere Reserve, India	Thomas *et al.* (2009)
22.	Bee tree of Sahyadri	Recorded 75 *A. dorsata* colonies	Shimogga, India	Basavarajappa (2009)
23.	Honeybees and the uses to mankind	Revealed usefulness of honeybees to ecosystem	India	Basavarajappa (2010)
24.	Anthropogenic interferences on wild honeybees	Recorded various man-made activities impact on wild honeybees	Mysore, India	Basavarajappa (2010)
25.	Nest host trees of *Apis dorsata*	Identified the bee trees in southern Karnataka	India	Basavarajappa (2009)
26.	Conservation of Asian honeybees	Suggested the conservation of honeybees	-	Oldroyd and Nanork (2009)
27.	Colony status of *Apis dorsata*	Identified the colony status	Southern Karnataka	Basavarajappa and Raghunandan (2013)
28.	Greater wax moth, *Galleria mellonella* infestation on *Apis dorsata*	Recorded *G. mellonella* infestation	South-western Karnataka, India	Raghunandan and Basavarajappa (2014)
29.	Floral hosts of *Apis dorsata*	Recorded various flowering plants which provide floral source to *A. dorsata*	Southern Karnataka, India	Raghunandan and Basavarajappa (2014)
30.	Bio-ecology of *Apis dorsata*	Recorded the influence of biological and ecological factors on the survival of *A. dorsata*	Southern Karnataka, India	Raghunandan and Basavarajappa (2014)
31.	Honeybee diversity is precious	Essential to preserve local biodiversity	India	Basavarajappa (2018)
32.	Conservation of honeybees	Essential for human survival is highlighted	India	Basavarajappa (2020)
33.	Nesting ecology of honeybees under managed and natural landscapes	Highlighted the need for conservation of honeybees	India	Basavarajappa (2022)

summer season at Mysore city, India.

2. MATERIALS AND METHODS

Study area: Mysore city is situated in the southern Deccan Plateau, lies at 12.29′58˚N, 76.63′94˚E with an elevation 770 meters above sea level. The city lies at the base of Chamundi Hills and have several natural lakes like Kukkarahalli, Karanji and Lingambudhi [40]. The city covers an area 155 km^2 to 286 km^2 with fertile landscape and possesses a salubrious climate with temperatures ranging from 15˚C (winter) to 35˚C (summer), supporting scrub jungle vegetation in uncultivated areas. March to end of May month's experience summer season and it is followed by the south-west monsoon lasting up to September end. The October and November months are experiencing retreating monsoon. Moreover, the vegetation is thorn-scrubby type along with tropical forest of deciduous type and evergreen type is also noticed in the eastern portion of the district. All these prevailed conditions amidst Mysore district have provided suitable habitat for many migratory insects including different species of honeybees.

Methodology: Observation was made at randomly selected 40 study sites in Mysore city to record the *A. dorsata* colony population during summer season as per [15]. Study sites represented the recreation parks, residential areas, school-college zones, office/administrative areas, commercial areas, religious places, hospital/health care centers, un-used barren fields, protected areas and at these sites, local people were met personally and collected information on *A. dorsata* using pre-tested questionnaire that included more than 15 parameters. Further, study sites were earmarked with identification tags and visited once in a week from morning 8.00 AM to 12.00 Noon and evening 4.00 PM to 7.00 PM for a period of three months *i.e.*, from April to June, 2024 continuously. *A. dorsata* colonies were observed by following an all-out search method, where every spot is critically surveyed and checked to record the *A. dorsata* colonies at various man-made structures, on trees and on rock cliffs using binocular, digital camera and through naked eyes as per [9, 12, 15]. Live or deserted colonies, colony nested place, number of colonies, name of nest host tree, size and shape of the colony, nest orientation, colour of the nested surfaced objects and locally available resources nearby the nest, water source, human interference and nest site fidelity were recorded as per [10, 41-43]. Nesting architecture was studied carefully by opening deserted nests to observe brood cells, pollen chambers, honey chambers and internal nest arrangement as per [9]. Floral source was recorded as per [44]. Collected data was systematically analyzed, compiled using SPSS to find out the deviation and coefficient variation if any between the nest sites and colony parameters as per [45].

3. RESULTS

Nest sites: Total 164 nest sites were recorded at man-made structures and on different tree species during summer season in Mysore (**Table 2**). Of all, 15 sites were preferred on different tree species by *A. dorsata* and remaining 149 sites were recorded on various man-made structures (**Table 2**). Amongst the man-made structures, commercial buildings were more preferred (45 sites) and it was followed by educational buildings (27 sites), residential buildings (22 sites), government offices and water tanks (15 sites each) preferred for nesting by *A. dorsata* during summer season in Mysore. Moreover, other man-made structures included hotels, hospitals, conventional halls, religious and heritage buildings were also preferred for nest establishment by *A. dorsata* and there existed a considerable coefficient variation (CV = 86.58) between them (**Table 2**).

No. of colonies: Total 829 *A. dorsata* colonies were recorded at different nesting sites during summer season in Mysore. Of all, highest (604) colonies were recorded on various man-made structures (**Table 2**) and around 225 colonies were recorded on different tree species and showed considerable coefficient variation (CV = 89.32) between them during summer season. Distribution of *A. dorsata* colonies on different man-made structures including trees are given in **Table 2**.

Nest elevation: *A. dorsata* preferred to nest at various heights from the ground and it was ranged in between 10 to 110 ft and above the ground level during summer season (**Table 2**). Interestingly, 40 - 49 ft elevation was more preferred height, where highest (279) number of colonies were observed and it was

followed by 30 - 39 and 20 - 29 feet height preferred by 242 and 212 colonies respectively (Table 2). However, at 10 - 19, 50 - 59, 60 - 69, 70 - 79, 80 - 89, 90 - 99 and 100 to 110 feet and above height was also preferred by *A. dorsata* for their colonies establishment and exhibited considerable coefficient variation (CV = 84.45) during summer season in Mysore (Table 2).

Table 2. Recorded few nesting parameters of giant honeybee, *Apis dorsata* during summer season in Mysore.

Sl. No.	Name of nest site	No. of nest sites	No. of colonies	Sl. No.	Nest height (in ft)	No. of colonies	Sl. No.	Nesting surface colour	No. of colonies
1.	Educational Buildings	27	120	1.	0 - 9	-	1.	White	205
2.	Hotels	10	33	2.	10 - 19	3	2.	Cream	32
3.	Commercial Buildings	45	136	3.	20 - 29	112	3.	Yellow	73
4.	Government Offices	15	112	4.	30 - 39	242	4.	Orange	16
5.	Religious Buildings	1	4	5.	40 - 49	279	5.	Red	37
6.	Hospitals	9	74	6.	50 - 59	80	6.	R-M	37
7.	Residential Buildings	22	65	7.	60 - 69	47	7.	Pink	7
8.	Conventional Halls	4	6	8.	70 - 79	12	8.	Blue	7
9.	Heritage Buildings	1	6	9.	80 - 89	10	9.	Green	12
10.	Water Tanks	15	48	10.	90 - 99	27	10.	Orange-Green	2
							11.	Brown	78
							12.	Grey	56
11.	Trees	15	225	11.	100 - 110 & above	17	13.	Black	22
							14.	Silver	10
							15.	Glass	10
Total ± SD		164 ± 12.91	829 ± 67.31	Total		829 ± 98.16	Total		604 ± 50.59
CV		86.58	89.32	-		84.45	-		92.13

Note: Each value is total of 12 observations. CV: Coefficient variability.

Colour of nested surface: *A. dorsata* colonies were observed on 13 different coloured surfaces on various man-made structures (Table 2). Amongst all the colours, white colour was most commonly preferred for 205 colonies establishment during summer season by *A. dorsta* (Table 2). The other coloured surface preferred by *A. dorsata* were brown, yellow and grey colours where, 78, 73 and 56 colonies established respectively (Table 2). Moreover, other coloured surfaces on which *A. dorsata* established their colonies are depicted in Table 2. Further, glass surface was also chosen by *A. dorsata* for establishing its colonies and exhibited considerable coefficient variation (CV = 92.13) during summer season at Mysore (Table 2).

Colony conditions: Total 485 live colonies and 344 deserted colonies were recorded and there exhibited little coefficient variation (CV = 24.05) between them during summer season in Mysore (Table 3). The live

colonies were enriched with workers, drones and queen bee. While, deserted colonies were devoid of workers, drones and queen bee. Among the deserted colonies, few were dismantled, many were torn and few were infested with wax moth.

Size of colonies: *A. dorsata* established different sized colonies such as small, medium and big size respectively 180, 418 and 231 colonies during summer season in Mysore (Table 3). Interestingly, there was a moderate coefficient variation (CV = 45.35) existed between colony sizes during summer season.

Table 3. Colony parameters of giant honeybee, *Apis dorsata* during summer season in Mysore.

Sl. No.	Colony condition	No. of colonies	Sl. No.	Size of the colony	No. of colonies	Sl. No.	Shape of the colony	No. of colonies	Sl. No.	Orientation of the colony	No. of colonies
1.	Live	485	1.	Small	180	1.	'U'	673	1.	North-south	295
			2.	Medium	418	2.	'V'	39	2.	East-west	257
2.	Deserted	344	3.	Big	231	3.	Irregular	70	3.	Northeast-southwest	178
						4.	Dome	47	4.	Northwest-southeast	99
Total ± SD		829 ± 99.70	Total		829 ± 125.31	Total		829 ± 310.78	Total		829 ± 87.08
CV		24.05	-		45.35	-		149.95	-		42.02

Note: Each value is a total of 12 observations. CV: Coefficient variability.

Shape of colonies: During the present study, four shaped colonies were observed commonly. They were "U", "V", "irregular" and "dome" shaped colonies and shown highest coefficient variation (CV = 149.95) between them. Of all, "U" shaped colonies were more predominant (673 colonies) compared to others (156 colonies) and representing 81.2 and 18.8% respectively during summer season in Mysore (Table 3).

Orientation: *A. dorsata* usually establish its colonies with different orientations under natural conditions. Being an open nester, perhaps to avail sunlight and to have good navigation path, *A. dorsata* established differently oriented colonies at various man-made structures and on trees during summer season. *A. dorsata* established north-south, east-west, northeast-southwest and northwest-south easterly oriented colonies and exhibited little coefficient variation (CV = 42.02) between the orientations (Table 3). Of all, north-southerly oriented *A. dorsata* colonies were more (295 colonies) compared to other orientations during summer season in Mysore (Table 3).

Further, Table 4 shows few prevailed conditions at the vicinity of *A. dorsata* colonies during summer season in Mysore. Around 604 *A. dorsata* colonies were distributed on various man-made structures and exhibited considerable coefficient variation (CV = 64.65) between the man-made structures and trees. Only, 225 *A. dorsata* colonies were established on seven tree species. The *Ceiba petandra, Ficus benghalensis*, *Albizia saman, Ficus religosa, Pterogyta allata, Peltophorum pterocarpum* and *Palm* species were selected for nesting and shown highest coefficient variation (CV = 102.83) between the nested tree species. Figure 1 shows the per cent occurrence of *A. dorsata* colonies on different tree species. Comparatively, *C. petandra, F. benghalensis* and *A. saman* were more opted by *A. dorsata* during summer season in Mysore. Number of *A. dorsata* colonies established on different tree species are given in Table 4. Further, there was a good vegetation observed nearby 143 *A. dorsata* colonies and source of water was good nearby 155 *A. dorsata* colonies and showed less coefficient variation (CV = 5.69). Figure 2 shows the foraging source to *A. dorsata* during

Table 4. **Prevailed conditions at the vicinity of giant honeybee, *Apis dorsata* colonies during summer season in Mysore.**

Sl. No.	Nests observed on	No. of colonies	Sl. No.	Nest host tree	No. of colonies	Sl. No.	Natural resource prevailed	No. of colonies	Sl. No.	Source of water	No. of colonies
1.	Man-made structures	604	1.	*Ceiba petandra*	78	1.	Vegetation	143	1.	Tap	74
2.	Rocks	-	2.	*Ficus benghalensis*	62				2.	Water leakage from the pipe	42
			3.	*Albizia saman*	58				3.	Stagnant water	21
			4.	*Ficus religosa*	22	2.	Water	155	4.	Water tank	17
3.	Trees	225	5.	*Pterogyta allata*	3						
			6.	*Peltophorum pterocarpum*	1				5.	Pond	1
			7.	*Palm* sp.	1						
Total ± SD		829 ± 267.99		Total	225 ± 33.05		Total	298 ± 8.48		Total	155 ± 28.13
CV		64.65		-	102.83		-	5.69		-	90.74

Note: Each value is a total of 12 observations. CV: Coefficient variability.

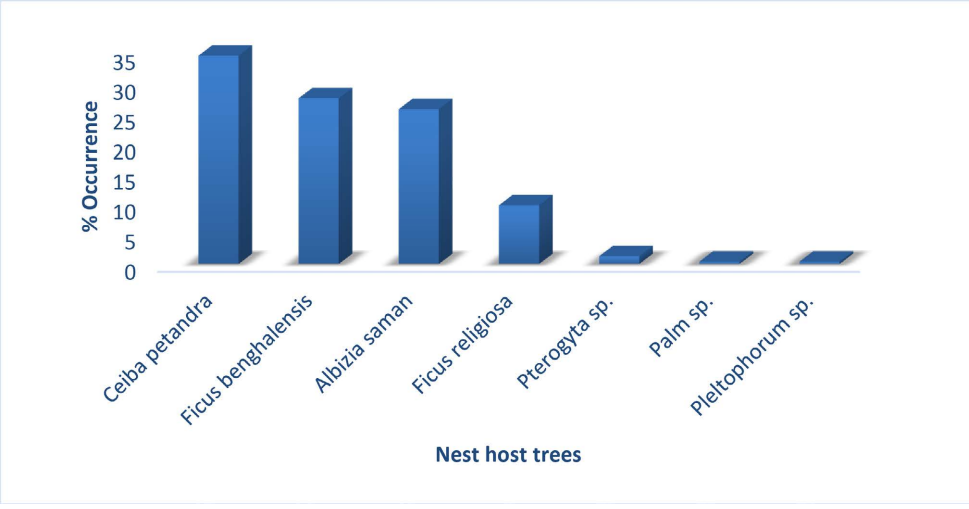

Figure 1. The per cent occurrence of nest host trees offered by *Apis dorsata* during summer season.

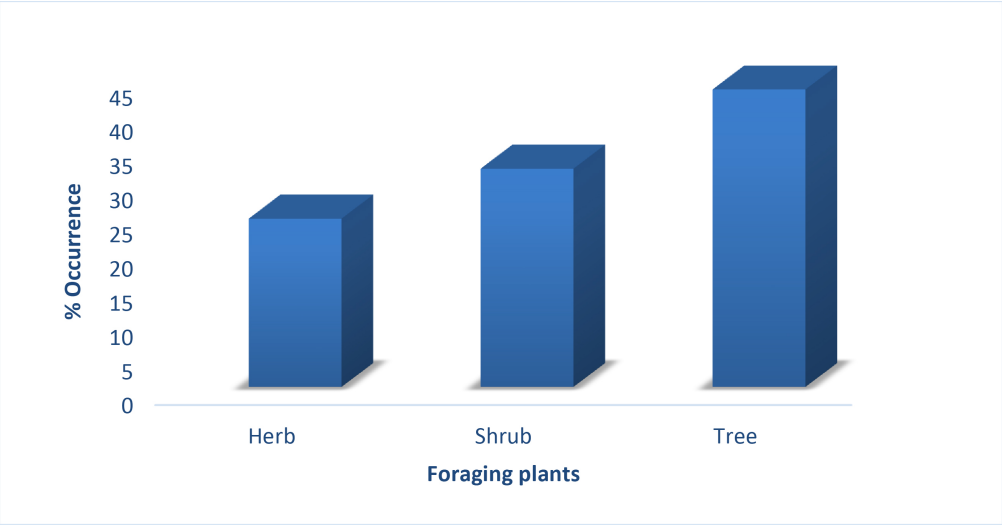

Figure 2. The per cent occurrence of foraging plants to *A. dorsata* during summer season.

summer in Mysore. Comparatively, tree species contributed more foraging source to *A. dorsata* than that of shrubs and herbs. Altogether, 236 *A. dorsata* colonies had good floral source and water source was good at 155 *A. dorsata* colonies during summer season (Table 4). However, for remaining 531 *A. dorsata* colonies suffered due to poor availability of floral sources at their nesting place. Figure 3 shows the foraging source extended to *A. dorsata* by different plant families during summer season in Mysore. Total 27 plant families extended their floral source (pollen and nectar) to *A. dorsata* during summer months *i.e.*, March to June. Of all, Fabaceae family members were predominantly supplied floral source (both nectar and pollen) and it was followed by Apocyanaceae, Asteraceae, Moraceae and Acanthaceae family members. Remaining 18 plant families supplied considerable amount of nectar and pollen source to *A. dorsata* during summer season in Mysore (Figure 3). Furthermore, *A. dorsata* depended for its water requirement from tap water, water leaked from the water supplying pipes, stagnant water, water tanks, ponds/lakes and sewage canals and exhibited considerable coefficient variation (CV = 90.74) during summer season in Mysore (Table 4).

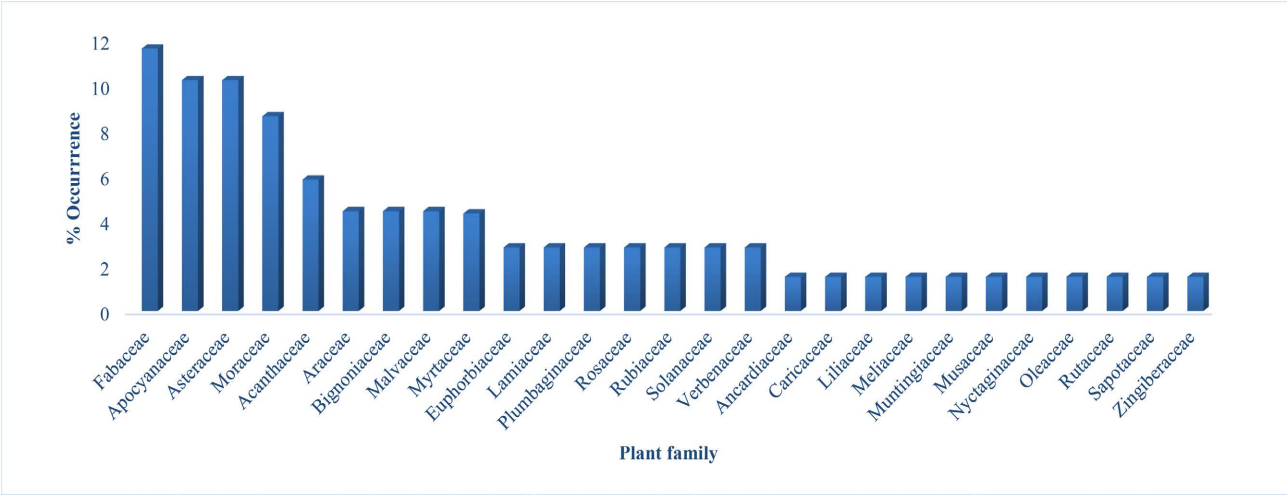

Figure 3. The plant families extended the floral source to *Apis dorsata* population during summer season.

Anthropogenic interferences: *A. dorsata* experienced several biological constraints during summer

season under natural conditions of Mysore. Being an open nester, it is commonly experiencing various interferences at its nesting sites. Amongst the biological constraints, man-made activities intervene with the life of *A. dorsata* midst urban conditions during summer season. The level of human interference was low with 37 *A. dorsata* colonies and it was followed medium level with 50 *A. dorsata* colonies and high level with 77 colonies with a coefficient variation 37.32 (Table 5). Further, killing of *A. dorsata* population, burning of live and deserted colonies, spraying of pesticides on the colonies and hunting of *A. dorsata* colonies were observed at Mysore city during summer season (Table 5). Despite various interferences, *A. dorsta* showed nest site fidelity to its previously nested site in Mysore. Total 84 *A. dorsata* colonies did show site fidelity among 829 *A. dorsata* colonies and that represented 10.1% nest site fidelity to its previously nested site with a coefficient variation 26.90 (Table 5). The fidelity status information was collected by personal interaction with the local residents along with regular observation of nest marks (chemical signature – wax marks of nests) (Table 5).

Table 5. Commonly occurring human interferences at the vicinity of giant honeybee, *Apis dorsata* colonies recorded during summer season in Mysore.

Sl. No.	Level of human interference	No. of colonies	Sl. No.	Nature of interference	No. of incidences	Sl. No.	Nest site Fidelity	No. of colonies
1.	Low	37	1.	Killing	17	1.	By interview	34
2.	Medium	50	2.	Burning	7			
3.	High	77	3.	Pesticide spray	12	2.	Nest marks	22
			4.	Hunting	3			
Total ± SD		164.0 ± 20.40	Total		39.0 ± 6.08	Total		84.0 ± 11.30
CV		37.32	-		62.36	-		26.90

Note: Each value is total of 12 observations. CV: Coefficient variability.

4. DISCUSSION

The giant honeybee, *Apis dorsata* Fabricius (1793) (Hymenoptera: Apidae) [46, 47] is a non-domesticated species [35, 36, 48], live under wild conditions by establishing normally "U" shaped, big sized single comb [5] at higher elevations at the eave of multistoried man-made establishments and tall trees [12, 13, 16, 18, 49]. Being an open nester, it builds colonies based on locally available good source of nectar plants, pollen plants, water source and undisturbed conditions [15, 16, 21, 41, 43, 44], However, during the present investigation, 829 *A. dorsata* colonies were recorded during summer season in Mysore. *A. dorsata* preferred 164 nest sites to establish 604 colonies on man-made structures, which included Commercial buildings (45 sites), Educational buildings (27 sites), Residential buildings (22 sites), Government offices and Water Tanks (15 sites each), Hotels, Hospitals, Conventional Halls, Religious and Heritage buildings to establish colonies during summer season. Similar type of observations was made by [10, 21] in Mysore, [19] in Bangalore. Interestingly, during the present study, only on 15 sites, *A. dorsata* established 225 colonies on seven tree species namely: *Ceiba petandra, Ficus benghalensis, Albizia saman, Ficus religosa, Pterogyta allata, Peltophorum pterocarpum* and *Palm* species. Of all, *C. petandra, F. benghalensis* and *A. saman* were more preferred by *A. dorsata* during summer season in Mysore. Further, *A. dorsata* preferred 10 to 110 feet elevation to establish colonies on these tree species. Perhaps, it is due to their well ramified canopy with broad surfaced tree limbs along with undisturbed navigation path during most of the day in summer season which might have encouraged *A. dorsata* to establish its nests more on the eave of these tree limbs [12]. Interestingly, 40 to 49 feet elevation was more preferred, where 279 *A. dorsata* colonies were observed. Medium height

extended 51 nesting sites and hosted 1,434 nests in and around Bangalore [27]. However, 30 to 39 and 20 to 29 feet elevation was offered by *A. dorsata* to establish 242 and 212 colonies respectively in Mysore. Moreover, *A. dorsata* also nested at 10 to 19, 50 to 59, 60 to 69, 70 to 79, 80 to 89, 90 to 99 and 100 to 110 feet heights. The Mysore is located at an elevation 770 meters above sea level at the vicinity of Chamundi Hills and it is housed with many natural ponds/lakes [40]. Water is available at parks, neatly maintained lawns, sewage canals and other sources, which could help provide required water source to *A. dorsata* colony members during summer season. Moreover, the city possesses a salubrious climate with temperature ranging from 24˚C to 35˚C during summer season [40] and locally prevailed scrubby type vegetation along with tropical deciduous trees which bear abundant flowers during March to end of May months. Further, Mysore is one of the big cities in Karnataka, popularly called "City of Palaces" [40], known for tall buildings, big sized trees with ramified broad limbed long branches. The man-made structures, tall religious /heritage buildings are provided suitable nest sites to *A. dorsata* population [5, 12]. Surprisingly, these man-made structures and few tall trees are monitored and maintained under heritage tag by the local administration in Mysore [40]. As a result, no disturbance was made with many tall trees and their broad limbed branches, which are untrimmed and several heritage/religious buildings/monuments, office buildings are undisturbed. Perhaps, this could be one of the reasons for recording more *A. dorsata* colonies on man-made structures in Mysore during summer. Moreover, several multistoried human inhabited buildings are not accessed easily to mankind. And, these man-made tall structures and few tree species might have supported the *A. dorsata* colonies from the direct sunlight, wind and rainfall [19] and perhaps, reduced human interference [50]. Perhaps, all these locally prevailed conditions might have extended the increased protection to the normal survival of *A. dorsata* during summer season in Mysore. Similar type of observations was made by [5, 8, 9, 12, 13, 16, 18, 19, 21, 34, 43] at Bangalore district in Karnataka, in China, in Niligiri Biosphere Reserve, in southern Karnataka, in Mysore, district and in Subah, Borneo, Indonesia, in Nepal, India and Bhutan. Thus, present reports are on par with the earlier published reports.

Despite, locally prevailed undisturbed conditions at many man-made structures, *A. dorsata* colony population showed fluctuations in its colony size. Since, *A. dorsata* is a migratory species [29, 30, 51, 52] which establish colonies seasonally [29] and migrate from one place to other to complete swarming cycle and in search of good floral source, suitable nesting conditions in the wild [5, 8, 17, 44]. Moreover, locally occurring biological constraints [15] during different seasons interfere with their normal activity and affect the colony survival of *A. dorsata*. So, overall, 485 live colonies and 344 deserted colonies of *A. dorsata* were recorded during summer season in Mysore. So, desertification of a colony occurs due to various man-made interferences or by natural means or due to swarming cycle [29, 30, 51, 52]. Thus, the colony size varied considerably and they were grouped into small (180), medium (418) and big sized (231) colonies. The colonies were "U", "V", "irregular" and "dome" shape in their appearance with different orientations. Interestingly, "U" shaped colonies were more predominant (673) compared to others. Thus, *A. dorsata* established different sized, shaped colonies with north-south, east-west, northeast-southwest and northwest-south easterly orientations on man-made structures and on trees during summer season. Of all, north-southerly oriented colonies [53] were more (295) compared to other orientations during summer season. Being an open nester, perhaps to avail sunlight and to have good navigation path, *A. dorsata* established differently oriented colonies with varied size and shape at various man-made structures and on trees during summer season. Thus, establishing comb with different orientations helped to achieve safety and protection from direct sunlight, wind [23], rainfall and to avail good navigation path [54] for easy movement to conduct hive-out activities by the worker bees [19, 34]. Although, locally prevailed conditions are suitable, *A. dorsata* obviously constructed uniform sized colonies, but the size and shape of many colonies were uneven, perhaps it was influenced by the locally available varied conditions at man-made establishments and on trees. Hence, to avail the good navigation path and to avoid direct sunlight, wind and rainfall on the comb [34], *A. dorsata* established different shaped combs under arboreal conditions. Or, pests or predatory animal's regular interferences [5, 15] might have discouraged to attain big size of the colonies. Or, *A. dorsata* perhaps might have involved in defencing the colony due to various biological constraints (e.g. Wax moth infestation or predators interferences) [15] rather to expand the colony vertically or horizontally to build big sized comb with

specific orientation. Or, perhaps small to medium sized colonies established recently and they were younger and not older.

Floral source was good at the vicinity of 143 *A. dorsata* colonies during summer season in Mysore. The vegetation consists of more tree species than that of shrubs and herbs which belong to 27 families [55] extended floral source to *A. dorsata* colonies. Of all, many Fabaceae family members were more predominant during summer due to high temperature [56] that could help bloom the flowers continuously to supply floral source (both nectar and pollen) to *A. dorsata* population [44]. The Apocyanaceae, Asteraceae, Moraceae and Acanthaceae family members also extended good source of both nectar and pollen to *A. dorsata* population. Perhaps, this might be one of the reasons for big sized colonies due to increased foraging and brood rearing activity [17] at some places in Mysore city. The water source was good at the vicinity of 155 *A. dorsata* colonies and it was gathered from tap water, water from the water supplying pipes leakage, stagnant water, water tanks, ponds/lakes and sewage canals during summer season in Mysore city. Since summer is characterized by high (<36˚C) temperature [40], being a poikilothermic organism [46], *A. dorsata* require more water to cool its brood and maintain comb temperature below 36˚C. Perhaps, to protect the colony and brood from high temperature, majority of the worker bees might have engaged with water collection from faraway places rather than pollen and nectar collection to increase breeding activity and expanding the colony. Perhaps, different sized colonies occurred due to all these reasons during the present study. *A. dorsata* preferred 13 different coloured surfaces on various man-made structures to establish its colonies during summer season. Similar type of observations was made by [10, 26, 57-59] on man-made structures at different parts of the world including India. Surprisingly, white surfaced objects were the most commonly preferred by *A. dorsata* and accordingly more (205) colonies were established on white surfaced objects during summer season. However, brown, yellow and grey colour surfaced objects were also preferred by *A. dorsata* for colony establishment during summer season. *A. dorsata* prefer different coloured surfaces to establish its colony on man-made structures [10]. Excepting red, perhaps, many colours including white colour might help retrieve the visuo-spatial memories [60] using visual navigation [54] while establishing the new colony on previously nested sites [10]. White surfaced objects of various man-made structures have attracted more by the new *A. dorsata* swarm [10] and perhaps that might have provided a visual cue, help recollect the memory of previously nested site [61] by worker bees [42] to decide [41] site for colony establishment. Interestingly, glass surface was also chosen by *A. dorsata* for establishing its colonies during summer season at Mysore. Despite various interferences, *A. dorsta* showed nest site fidelity to its previously nested site [43]. Total 84 *A. dorsata* colonies did show site fidelity among 829 *A. dorsata* colonies and that represented 10.1% nest site fidelity to its previously nested sites [52]. Further, *A. dorsata* leave chemical signature (wax marks) while departing the colony during swarming or desertification [43]. These wax marks are used as landmarks for establishing colonies at previously nested sites [10, 30] and thus *A. dorsata* demonstrated the fidelity to its previous nest sites [52], this behavior varied considerably between different colour surfaced objects [10] and thus *A. dorsata* return to its previous nest sites [30]. Thus, *A. dorsata* exhibited elite nesting strategy [5, 28, 62-67] and revealed site fidelity. Recording nest site fidelity status is very essential to protect previously nested sites to allow new swarm to establish colony [30, 43], thereby it is possible to restore *A. dorsata* population amidst their preferred habitats. Despite all the above mentioned prevailed conditions during summer season under urban ecosystems, *A. dorsata*, being an open nester [8], experienced several biological constraints [15, 16, 35, 36] amidst different nest sites in Mysore. The level of human interference was low with 37 *A. dorsata* colonies, medium level of interferences with 50 *A. dorsata* colonies and high level of interferences with 77 *A. dorsata* colonies. *A. dorsata* population was killed from live colonies by hunting, burning and spraying pesticides at different nest sites during summer season. All these man-made interferences perhaps discouraged the development of colony growth [15] and resulted to occur different sized colonies during summer season at different nest sites in Mysore. This kind of man-made activities are more in recent past, as a result honeybee colony population is seriously threatened by deforestation, agricultural intensification, monoculture farming, extensive pesticide use, destructive honey hunting activities [10, 68], forest fires, prolonged droughts, increasing temperature and regional/local climate change [35, 36] at

different parts of the world. Hence, honeybee population is facing unprecedented threats due to various reasons [15]. Perhaps, this might be one of the reasons for *A. dorsata* colonies population to fluctuate during different seasons [16]. Since, *A. dorsata* represents one of the biologically diverse and ecologically indispensable species, its survival is partly/fully linked to global food security, local/regional biodiversity and ecosystem resilience. Astonishingly, *A. dorsata* is one of the potential pollinators [3], recording its colony population is need of the hour during different seasons to monitor local/regional biodiversity [2, 5, 67]. Surprisingly, human association with honeybee's existed dates back *i.e.*, around thousands of years ago with evidence of beekeeping in ancient Egyptian, Greek and Mesoamerican civilizations [1]. This long-standing relationship underscores the importance of honeybees not only as economic resources but, it could help in poverty alleviation of many people across the world [2, 69]. Therefore, this kind of season specific investigations are essential for developing effective conservation-cum-management strategies [5, 38, 70] and to reap the bee products [69] and pollination role for poverty alleviation as well. Hence, present study help reveal status [71, 72] of wild honeybee, *A. dorsata* population and justified the need to understand the prevailed conditions to protect locally existed pollinators population [38, 70] during summer season amidst urban environmental conditions.

ACKNOWLEDGEMENTS

Authors thankful to the local people of Mysore for their inputs during field investigations. Authors also thankful to the Chairman, DOS in Zoology, University of Mysore, Mysore for the facility.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

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