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Documentation of Bee Pasturage and their Foraging Behaviour in Tropical Forests

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***Abstract*: Honey bees are a crucial part for functioning of natural ecosystem and crop production. As they do service as pollinator, promotion in all categories of nursery industry where the performance of seed increase plots as well as the importance of pollination in supporting persistent plant communities in tropical areas. A study was conducted to document bee pasturage and the foraging activity of domesticated honey bee, *Apis cerana indica* in tropical forest system at Forest College and Research Institute, Mettupalayam, Tamil Nadu. The bee flora accounted the study location was 38 covers 23 families. Among these, Fabaceae, Bignoniaceae and Caesalpiniaceae contributes a maximum of 5 species (13.15%) followed by Mimosaceae contributing 3 species (5.26%) and Meliaceae 2 species (4.74%). Among all climatic factors, day temperature had significant impact on foraging activity of *A.cerana* by adversely affecting the numbers of worker bees moving out of hive. With increase in minimum temperature and relative humidity, there was an increase in bee activity but the later adversely affected pollen collection efficiency of bees. Rainfall hampered the foraging activity while wind speed was found to have no significant effect.**

***Keywords*: Apis cerana indica, Bee pasturage, Forage behaviuor, Pollen.**

1. Introduction

Honey bees are micromanipulators which harvest pollen and nectar from the flowers, in turn bee helps the flowers in pollination process and both have mutualistic effect (Dalio, 2015; Kumar and Sharma, 2016). Bee pasturage in the location is essential for better management of the hive and improving the yield (Sodre *et al.,* 2007). Tropical regions are credited with high density of flowering plant species and any study on the foraging behaviour of their potential pollinators would probably contribute towards better understanding of plant-pollinator interaction in a particular area. Agricultural producers can increase seed or fruit production with colonies of domesticated honey bees, managed native bees, or by facilitating land to increase populations of native bees. In natural ecosystem, the availability of bee pasturage is enormous for honey bees with different blooming seasons. The floral period can be predicated by maintaining bee colonies in the particular bio diversified ecosystem (Rhoades, 2013). Foraging activity decides the efficiency of bee survival and it directly depends on the colony population. Foraging activity of the worker bees is stimulated by various factors prevailing inside and outside the colony. Factors present inside the colony are workers age, queen presence, strength of the colony, need of food and storage, pest and diseases *etc*., and factors present outside the colony are ambient weather parameters *viz*., temperature, rainfall, relative humidity, wind speed, sunshine hours and foraging floral availability *etc*., During foraging, honey bees are exposed to a broad range of ambient weather parameters which affect their efficiency in forage and alter the time of forage (Kovac and Stabentheiner, 2011). The Indian bee, *Apis cerana indica* Fabricius is an economically important, domesticated native honey bee species in southern part of India (Ianson Price and Gruter, 2015). It has been distributed in China, Japan, India, Bangladesh, Nepal, Papua New Guinea and Malaysia (Egelie *et al.,* 2015; Theisen-Jones and Bienefeld, 2016). Besides the quality and quantity of pollen, the distance of flowering plants from their colony and their attractiveness as enhanced by the crowding of flowers are known to increase the foraging tendencies of honey bees towards such profitable resource (Kaur and Mattu, 2016).

2. Materials and Methods

The study area was the Forest College and Research Institute, Mettupalayam of Tamil Nadu, India, which was located at the latitude of 9°55'25.79" N, longitude of 78°05'27.00" E and altitude of 331 feet mean sea level. The study area was surrounded by Jakanari reserve forest. Indian honey bee, *A. cerana indica* colonies in 10 Marthandam hives were maintained in the above said location. All the colonies were with six frames in brood chamber and six frames in super chamber having approximate of 10000 -14000 bees. The study was conducted during 2019 to 2020. Foraging flora was studied regularly once in a week during the entire study period. Observations were taken from 6.00 to 18.00 hr by recording different flowering plant species on which the bee performs foraging. Bee foraging plants were confirmed by the visit of bees and successful foraging of at least three bees within 10 minutes period of observation as described by Bhalchandra *et al.,* 2014. The identified flora was further grouped into nectar,

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pollen and both nectar and pollen supplying plants. Nectar source was determined by extension of proboscis by the bee into the flower for nectar collection and pollen source was determined by the presence of pollen in the hind legs of bees. The plants were identified by the help of published reports, experts and online services.

A. Observations on foraging activity

Foraging activity of bees was determined by counting the number of worker bees moving out and returning to the hive with and without the pollen loads per five minutes by using hand tally counter and stop watch (Reddy *et al.,* 2015). Bees returning without pollen loads were considered as nectar gatherers. To study the foraging activity variations for the period of 49th to 9th meteorological standard weeks of 2019 - 20, observations were recorded three times a day *viz*., 8.00 a.m., 12.00 noon and 4.00 p.m. for 5 minutes. The mean value of observations at three intervals was taken as the foraging activity of that particular day.

The diurnal patterns study were recorded as weekly observations at hourly interval starting form 6.00 a.m. to 6.00 p.m. for five minutes. Bees activity percentage was calculated by using the formula as Ft/FT*100 where, Ft is average flight activity during a particular time interval and FT is the total flight activity as adopted by Mattu and Verma, 1985.

B. Meteorological parameters recording

The meteorological parameters *viz*., maximum and minimum temperature (°C), relative humidity (%), rainfall (mm) and wind speed (kmph) were recorded from the Automatic Weather Station located in the Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, India, which is located within 700 m radius from the experimental colonies. Foraging data recorded were correlated with the meteorological data of the corresponding days. Analysis of variance (ANOVA) at 5% significance was used to test the significance of mean differences.

3. Results and Discussion

The identified plants of bee forage of 23 families were, Annonaceae, Balsaminaceae, Bignoniaceae, Bombacaceae, Bignoniaceae, Caesalpiniaceae, Erthroxylaceae, Euphorbiaceae, Fabaceae, Hernandiaceae, loganiaceae, Meliaceae, Mimosaceae, Myrtaceae, Proteaceae, Rhamnaceae, Rutaceae, Santalaceae, Sapindaceae, Sapotaceae, Simaroubaceae, Ulmaceae, and Verbenaceae. Among these 23 families Fabaceae, Bignoniaceae and Caesalpiniaceae contributes a maximum of 5 species (12.25%). Fabaceae and Mimosaceae (6.72%) contributing 4 species of bee foraging flora followed by Meliaceae 2 (4.74%) (Table 1). The bee flora accounted in our study location was 38. Majority of them were Bignoniaceae, Caesalpiniaceae, Fabaceae, Mimosaceae and Meliaceae. Similar study was conducted and showed that Fabaceae contributed a maximum of 31 species (12.25%) followed by Asteraceae 6.72% with 17 flora, Caesalpiniaceae (5.53%) and Cucurbitaceae (4.74%) (Hemalatha *et al.,* 2018).

A. Foraging behaviour of honey bees

Foraging activity of honey bees showed significant variations during maximum temperature *A. cerana*. The worker bees have to maintain and regulate their body as well as colony temperature according to the external condition which, in turn, would affect their foraging efficiency. It is clearly evident from the results that maximum temperature had negatively affected (r= - 0.477) the number of bees moving out to forage (Table 3). Maximum temperature during the study period ranged between 28 °C to 36°C and the mean number of bees exited per minute at these temperatures was 65.20 and 20.30, respectively. Maximum temperature also showed significant negative effect on incoming bees, comprising pollen and nectar collectors with r values of - 0.415 and - 0.493 respectively. The mean monthly minimum temperature ranged from 20.5°C in December to 22.50°C in April. Significant effect of the minimum temperature was observed on bee movement. But the minimum temperature showed positive effect on the number of bees exiting the hive (r = 0.552) and those entering with pollen (r = 0.477). However, the number of nectar collectors was not significantly affected by variation in the minimum temperature. Higher temperature and low humidity were reported to adversely affect the flight activity of honey bees. At higher temperatures, the number of pollen collectors and nectar collectors decreases. Similarly, Reddy *et al.,* (2015) reported that the number of worker bees going out to forage came down significantly at temperature beyond 30°C. Contrary to this, the minimum temperature showed a positive impact on outgoing bees and nectar collectors while pollen collectors showed no significant correlation.

The pattern of bee activity varied, not only, over seasons but also at different hours of the day, with maximum during early hours between 6.00 and 11.00 am (Fig.1). The number of bees going out of the hive ranged from 216.00 at 6.00 am to 24.00 at 6.00 pm. In case of pollen collectors, peak was recorded between 7.00 and 10.00 am with 64 and 62 foragers /5 min respectively. Trend was almost similar with nectar collectors. Across the day, it was observed that nectar collectors outnumbered the pollen collectors. The foraging activity declined considerably after 12.00 O' clock and the lean period continued till evening except for a minor peak in the number of nectar collectors at 6.00 pm. The decreased activity during late afternoon hours, coinciding with higher day temperatures, could be attributed to two factors. The first being the requirement is a greater number of bees to maintain the colony temperature, thus the number available for foraging is less. Secondly, the anthesis of a large number of flowers takes place in early morning and hence pollen availability was higher as compared to hot hours. In addition, nectar solidified with increased temperature requiring more time and energy to harvest, prompting bees to make maximum use in morning hours

Table 1
Bee flora flowering season and colour of the flower

S.No.	Common Name	Scientific Name	Family	Flowering Season	Colour of the Flower
1	Jamun	*Syzygium cumini*	Myrtaceae	March -April	Creamy
2	White Kashmir Teak	*Gmelina arborea*	Verbenaceae	Feb-March	Brownish yellow
3	Gurial	*Bauhinia racemosa*	Caesalpinaceae	March -June	White to pale yellow
4	Tree of Heaven	*Ailanthus exclsa*	Simaroubaceae	Jan-march	Greenish yellow
5	Bitter Albizia	*Albizia amara*	Mimosaceae	March-may	Pinkish white
6	Siris	*Albizia lebbeck*	Mimosaceae	Feb-April	Greenish white
7	Margosa	*Azadirachta indica*	Meliaceae	March-April	White
8	Golden shower	*Cassia fisttula*	Caesalpinaceae	March-May	Yellow
9	Kapok tree	*Ceiba pentandra*	Bombacaceae	Jan-April	Whitish yellow
10	Satin wood	*Chloroxlon swietenia*	Rutaceae	March-April	Creamy
11	Thanakku	*Gyrocarpus americanus*	Hernandiaceae	Jan-Feb	Yellow
12	Indian Elm	*Holoptelia integrifolia*	Ulmaceae	Feb-March	Greenish yellow
13	Red cedar	*Erythroxylum monogynum*	Erythroxylaceae	March –May	Greenish white
14	Malabar Neem	*Melia dubia*	Meliaceae	March-April	Greenish white
15	Indian Beech	*Millettia pinnata*	Fabaceae	Feb-June	Pale purple
16	Magizhamaram	*Mimusops elengi*	Sapotaceae	March-April	Creamy
17	Gooseberry	*Phyllanthus emblica*	Euphorbiaceae	March-April	Reddish
18	Karunkottai	*Zizuphus glabrata*	Rhamnaceae	March-May	Greenish
19	Honey Mesquite	*Prosopsis glandulosa*	Mimosaceae	Jan-March	Yellow
20	Soapnut tree	*Sapindus trifoliatus*	Sapindaceae	Feb-April	Creamy
21	Strychnine tree	*Strychnos nus-vomica*	Loganiaceae	March-April	Greenish
22	Paradise tree	*Simarouba glauca*	Simaroubaceae	Jan-March	Greenish
23	Gliricidea	*Gliricidia sepium*	Fabaceae	Feb-April	Pale pink
24	Copper Pod	*Peltophorum pterocarpum*	Caesalpinaceae	March-Sep	Yellow
25	Sausage tree	*Kigelia pinnata*	Bignoniaceae	March-June	Red
26	Siver Oak	*Grevillea robusta*	Proteaceae	Feb-March	Yellow
27	Mast tre	*Polyalthia longifolia*	Annonaceae	March-May	Pale green
28	Siam cassia	*Cassia siamea*	Caesalpinaceae	Jan-May	Yellow
29	Purple Bauhinia	*Bauhinia purpurea*	Caesalpinaceae	Feb-April	Pink to purple
30	Jacaranda	*Jacaranda mimosifolia*	Bignoniaceae	Feb-March	Purple
31	Tree of God	*Tebebuia argentea*	Bignoniaceae	Jan-March	Yellow
32	Rain tree	*Samanea saman*	Mimosaceae	March-Sep	White & Pink
33	Pink poui	*Tebebuia rosea*	Bignoniaceae	Feb-March	Pink
34	African Tulip tree	*Spathodea companulata*	Bignoniaceae	Feb-Aug	Orange
35	Flame of the forest	*Butea monosperma*	Fabaceae	Jan-March	Orange
36	Elephant ear tree	*Enterolobium cyclocarpum*	Fabaceae	Feb-April	Creamy white
37	Indian coral tree	*Erythrina indica*	Fabaceae	Feb-March	Orange
38	Sandal	*Santalum album*	Santalaceae	Feb-May	Maroon

Table 2
Family wise distribution of bee flora in FC&RI, Mettupalayam during 2019 -20

S.No.	Family	No. of species	Percent contribution
1	Myrtaceae	1	2.63
2	Verbenaceae	1	2.63
3	Caesalpinaceae	5	13.15
4	Simaroubaceae	2	5.26
5	Mimosaceae	3	10.52
6	Meliaceae	2	5.26
7	Bombacaceae	1	2.63
8	Rutaceae	1	2.63
9	Hernandiaceae	1	2.63
10	Ulmaceae	1	2.63
11	Erythroxylaceae	1	2.63
12	Fabaceae	5	13.15
13	Sapotaceae	1	2.63
14	Euphorbiaceae	1	2.63
15	Rhamnaceae	1	2.63
16	Sapindaceae	1	2.63
17	Loganiaceae	1	2.63
18	Proteaceae	1	2.63
19	Annonaceae	1	2.63
20	Santalaceae	1	2.63
21	Bignoniaceae	5	13.15
22	Balsaminaceae	1	2.63

Relative humidity plays an important role in brood development. A significant positive relation was recorded between relative humidity and foraging activity, especially the bees going out for foraging (r = 0.465) and nectar collectors (r = 0.42). However, the correlation of pollen collectors with relative humidity, though negative, was non- significant (r = -0.333). Wind, particularly strong current, tends to reduce the ground speed of bees and hence reduces the number of flights per day. The results indicated a negative correlation between wind speed and bee foraging activity, though it was statistically not significant (Table 3). Manoj *et al.,* (2017) reported that the relative humidity had significant and positive correlation with nectar area and honey production. A wind stronger than 12 mph was reported to affect honeybee foraging as they could not carry load upwind at a speed more than 15 mph. However, in the present study, average wind speed during the experimental period varied from 6.30 to 12.25 kmph indicates that the given range of wind speed did not affect the foraging activity of *A cerana* significantly. Significant negative correlation was established between the foraging activity of *A cerana* and rainfall. The r values for outgoing bees, nectar and pollen collectors were -0.588, - 0.775 and - 0.560 respectively. Reduction in number of bees coming could be attributed not only to the lower number of bees moved out but also to the death of foragers caught in heavy rain. Though there was a significant reduction in bee movement during the rainy period, considerable level of activity was observed during light drizzling. Another implication of heavy rainfall will be the washout of pollen and nectar, which adversely affects the foraging as well as pollination efficiency of bees. A study by Pastagia *et al.,* (2014) revealed that the minimum temperature, relative humidity and rainfall exhibited significant and negative correlation with brood area, pollen area and nectar area. While, sunshine hours exhibited significant and positive influence on nectar area and pollen area.

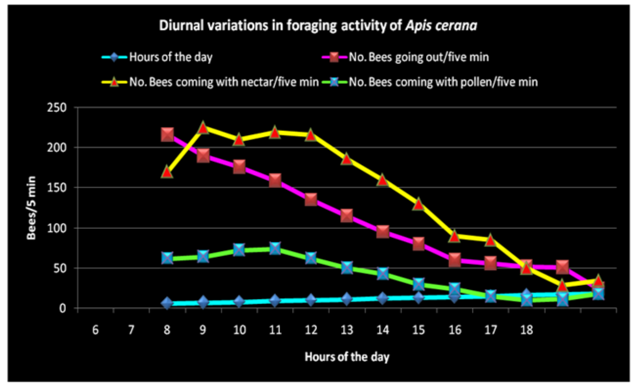

Fig. 1. Diurnal variations in foraging activity of *Apis cerana*

Table 3
Correlation of foraging activity with climatic variables

Factors	Correlation coefficient (r)		
	No. Bees going out/five min	**No. Bees coming with nectar/five min**	**No. Bees coming with pollen/five min**
Maximum temperature (°C)	-0.477**	-0.493**	-0.415**
Minimum temperature (°C)	0.552**	0.591	0.477**
RH %	0.465**	0.42	-0.333**
Rainfall (mm)	-0.371	-0.157	-0.426
Wind speed (kmph)	-0.588**	-0.775**	-0.56**

Table 4
Influence of weather factors on bee activity

Standard week	Max Temp	Min Temp	Max RH	Min RH	Rainfall	Evp (mm)	Wind velocity	Sunshine hours	% Bee activity	Pollen collectors	Nectar Collectors	Outgoing
32	30.7	19.9	84.7	73.1	23.55	2.23	1.6	3.76	4	8.2	26.5	21.2
33	31.6	20.1	83.7	61.4	0	2.5	1.4	3.9	11.5	8.1	25.3	21.5
34	32.9	20.7	83.7	69.9	0	3	1.5	4.5	12	7.2	23.3	26.6
35	32.7	19.9	85.8	72.5	9.8	3	1.6	4.9	11.6	7.6	22.3	23.2
36	32.9	20.7	84.4	74.1	0	2.3	1.4	4.4	10.6	8.9	21.2	20.2
37	34.3	20.5	79.2	68.2	0	2.3	1.4	5.6	10.2	8.2	25.3	21.2
38	33.2	20.6	83.1	71.4	0	2.5	1.8	5.8	13.5	8.6	26.3	20.3
39	32	20.6	76.9	73.9	14.7	1.9	2.3	4.1	5.6	8	22.3	24.2
40	31.8	20.5	77.7	77	19.1	2	2.1	4	5.1	7.2	24.2	26.5
41	30.9	20.5	79.1	76	15.9	1.8	0.8	3.5	5	7.1	26.2	28.9
42	30.9	20.3	78.4	75	30	0.5	1	3.1	3.2	7.5	23.3	29.3
43	30.3	20.1	74.6	60	35	0.9	1.6	3.1	3	7.2	23.1	30.2
44	30.2	19.3	82.6	58.7	10.1	0.9	0.9	2.9	6.2	7.3	25.2	31.2
45	29.9	17.6	90	57	55.8	0.9	0.5	2.4	3	7.6	26.3	32.2
46	30.5	19.4	81.1	60.4	31.7	0.7	0.7	3	3	7.1	28.2	32.8
47	30.6	20.4	81.3	64	0	1.1	0.5	3.2	12.9	6.9	28.3	32.9
48	30	19.8	80.3	63.4	3.6	1.1	0.5	2.8	6	6.5	28.1	32.2
49	30.5	19.6	87.1	46.1	28.8	0.9	0.5	2.6	3.9	7.1	27.3	29.3
50	30.8	19.9	85	49	0	1.3	0.5	3.5	13.2	6	29.2	28.6
51	31.3	19.3	84	47.1	0	1.2	0.5	3.4	12.3	5.9	29.3	29.3
52	29.9	19.8	80.1	48.3	0	1.3	0.5	3.4	12.6	26.5	48.6	49.6
1	29.9	18	68	41	2	1.4	0.5	3	7.2	23.8	48.9	49.8
2	29.4	18.4	74	45	7.2	1.7	0.5	3	6.5	24.6	49.2	51.2
3	28.5	18.7	79	46	0	2.1	0.4	3.9	12.1	24.3	47.2	52.3
4	29.6	18.3	76	41.1	0	2.3	0.6	4	12.9	23.2	47	51.2
5	31.9	19.5	87	50	0	4.8	1	5.1	13.6	24.2	46.5	46.2
6	33.2	19.6	88.7	46.1	0	5.4	1	6	13.2	22.3	43.2	41.2
7	32.9	19.8	88.9	51.1	0	5.9	1.4	7.4	13.1	18.2	30.2	28.2
8	34	20.1	87.4	46.5	0	5.8	1.1	7.9	11.3	14.2	29.2	33.2
9	34.2	20.6	88.7	45.9	2.6	5.1	1.4	7	6	10.3	25.2	35.2
10	35.1	21.5	88.3	44.9	0	6.1	0.8	8.3	12.2	10.1	24.3	36.2

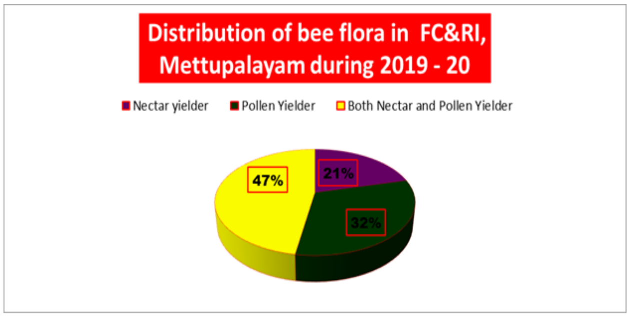

Fig. 2. Distribution on bee flora in FC&RI, Mettupalayam

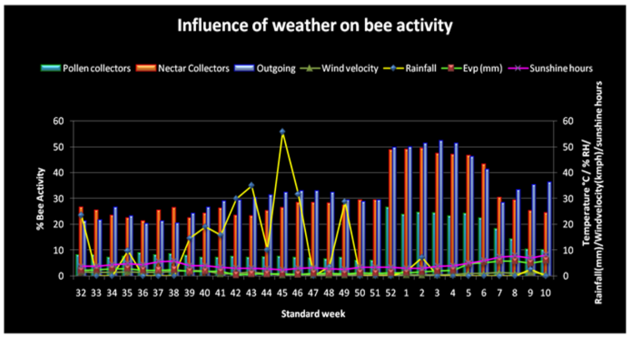

Fig. 3. Influence of weather parameter on bee activity

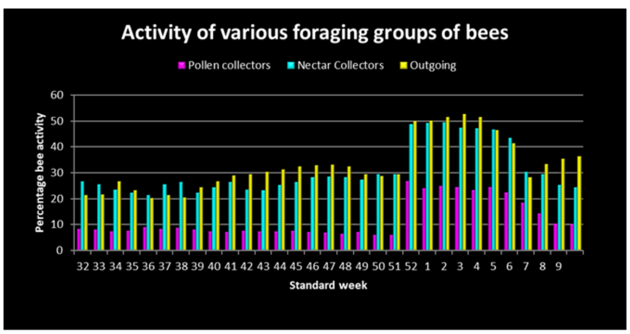

Fig. 4. Activity of various foraging groups of bees

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