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Assessment of floral diversity and foraging preference of Indian bee (*Apis Cerana Indica, Fab.)* in the vicinity of Adac&Ri apiary

Chand Asaf [*], Sangavi, Sarumathi, Serene Senbagam, Sivapriya, Rusho Arul Raj
Department of Entomology, Anbil Dharmalingam Agricultural College and Research Institute, Trichy, Tamil Nadu, India
Corresponding Author: Chand Asaf

Abstract
The present study was conducted at the apiary of the Anbil Dharmalingam Agricultural College and Research Institute (ADAC&RI), Tiruchirappalli, Tamil Nadu, to evaluate the floral diversity and foraging preference of *Apis cerana indica*. Field observations were carried out over six months during the flowering season at threetime intervals on each observation day. Floral diversity, bee visitation, foraging behaviour, and weather parameters were recorded and analyzed. A total of 27 flowering plant species were documented around the apiary. *Antigonon leptopus* (Coral vine) was the most preferred forage plant, recording the highest bee visitation, followed by White buttercup, *Ixora*, Carpet weed, Rangoon creeper, and Yellow bells. The Shannon–Wiener (2.207) and Simpson's (0.884) diversity indices indicated high floral diversity. Bee foraging activity was highest during the morning under cooler temperatures, higher relative humidity, and lower wind speed, and declined as temperature increased. ANOVA revealed significant effects (p<0.001) of plant species, observation time, and their interaction on bee foraging behaviour. The study demonstrated that the ADAC&RI campus provided diverse and abundant floral resources that support *Apis cerana indica*. These findings provide valuable baseline information for sustainable beekeeping, pollinator conservation, and apiary management.

Keywords: *Apis Cerana Indica*, floral diversity, foraging preference, bee visitation, floral resources, foraging behaviour, weather parameters.

Introduction
Honeybees are among the most important insect pollinators, contributing significantly to agricultural productivity, biodiversity conservation, and ecosystem sustainability. Approximately 75% of flowering plants and nearly one-third of global food crops depend on animal pollinators for successful reproduction, with honeybees playing a dominant role. Besides enhancing crop yield and quality through pollination, honeybees produce economically valuable products such as honey, beeswax, pollen, propolis, royal jelly, and bee venom.

Foraging is a vital activity that enables honeybee colonies to obtain nectar and pollen, their primary sources of carbohydrates, proteins, lipids, minerals, and other nutrients required for colony growth and reproduction. The foraging behaviour of honeybees is influenced by several factors, including floral abundance, flowering phenology, nectar and pollen availability, floral characteristics, and environmental conditions. Understanding the foraging diversity and floral preferences of honeybees is therefore essential for improving pollination efficiency, colony management, and conservation of floral resources.

Rapid urbanization, habitat degradation, and changing agricultural practices have altered the availability and diversity of flowering plants, affecting pollinator populations worldwide. Consequently, identifying important nectar and pollen sources and understanding plant–pollinator interactions have become essential for developing sustainable pollinator conservation strategies and improving beekeeping practices.

Among the honeybee species found in India, *Apis cerana indica* (Fabricius), commonly known as the Indian honeybee, is widely distributed and well adapted to diverse agro-climatic conditions. It is an efficient pollinator of several agricultural, horticultural, and plantation crops. Its foraging activity depends on the seasonal availability of floral resources, climatic conditions, and the distance between forage sources and apiaries. Information on its floral preferences is valuable for identifying bee pastures, establishing apiaries, and maximizing pollination services and honey production.

Tamil Nadu possesses diverse agro-climatic regions with abundant agricultural, horticultural, forest, and wild plant species that provide forage for honeybees throughout the year. However, seasonal changes in cropping patterns and land use may influence the availability of nectar and pollen resources, thereby affecting the foraging behavior of *Apis cerana indica*. Documenting the floral diversity and foraging preferences of this species will improve our understanding of bee–plant interactions and provide baseline information for pollinator conservation, sustainable beekeeping, and future ecological research.

Therefore, the present study was undertaken to document the floral diversity surrounding an *Apis cerana indica* apiary at ADAC & RI, Tiruchirappalli, identify the major nectar and pollen sources, evaluate the foraging preferences and diurnal activity of the bees, and assess the influence of environmental factors such as temperature, relative humidity, and wind speed on their foraging behaviour.

Materials and Methods
The study was conducted for six months at the apiary of Anbil Dharmalingam Agricultural College and Research Institute (ADAC&RI), Tiruchirappalli, Tamil Nadu, using a healthy colony of Apis cerana indica. Floral surveys and bee foraging observations were carried out three times a week during three observation periods (06:00–07:00 h, 10:00–11:00 h, and 14:00–15:00 h).

Flowering plant species within the foraging range of the apiary were identified and recorded based on botanical characteristics, flowering intensity, and floral resources (nectar and/or pollen). Flowering intensity was assessed using a visual scoring scale, while bee foraging activity was monitored by recording the number of bee visits, resource collected, visit duration, and peak foraging period. Bee visitation rate was used to assess foraging preference.

Weather parameters, including temperature, relative humidity, and wind speed, were obtained from the Meteorology Department, ADAC&RI. Floral diversity was evaluated using the Shannon–Wiener Diversity Index, Formula $H' = -\sum_{i=1}^{S} p_i \ln(p_i)$, Simpson's Diversity Index ($D=\sum Pi^2$) and Relative Abundance ($\frac{n_i}{N} \times 100$). Data were compiled in Microsoft Excel and analyzed using RStudio (R version 4.x). Descriptive statistics, one-way ANOVA, correlation analysis, diversity indices, and graphical representations were performed, with statistical significance tested at $p<0.05$

Results and Discussion

Table 1: Classification of flowering plants as nectar yielding, pollen yielding or both

Sl. No.	Flowering Plant	Pollen Yielding	Nectar Yielding	Both
1	Ixora		✓	
2	Banana		✓	
3	Periwinkle		✓	
4	Wheel Jasmine		✓	
5	Geiger Tree		✓	
6	Yellow Bells			✓
7	Rangoon Creeper		✓	
8	Firecracker Plant		✓	
9	Allamanda		✓	
10	Brinjal	✓		
11	Bell Weed		✓	
12	Butterfly Pea			✓
13	Coral Vine			✓
14	Cluster Vine			✓
15	Mango			✓
16	Rose	✓		
17	Bush Morning Glory			✓
18	White Buttercup			✓
19	Hibiscus			✓
20	Orchid Tree	✓		
21	Black pigweed			✓
22	Datura			✓
23	Guava			✓
24	Aspilia			✓
25	Plumeria	✓		
26	West Indian Cherry	✓		
27	Diamond Flower			✓

Relative Abundance of Bee Visits

The relative abundance of bee visits was calculated to determine the contribution of each flowering species to the total foraging activity observed during the study.

Floral Diversity

The floral diversity of the study area was evaluated using the Shannon–Wiener Diversity Index and Simpson's Diversity Index.

The Shannon–Wiener Diversity Index (H') was calculated as 2.207, indicating a relatively high diversity of floral resources utilized by *Apis cerana indica*. Higher Shannon index values generally indicate greater diversity and a more even distribution of foraging activity among the available flowering plant species.

The Simpson's Diversity Index (1 − D) was calculated as 0.884, suggesting a high level of floral diversity with no single flowering species completely dominating the bee foraging activity. Although Coral vine attracted the highest number of bee visits, the remaining flowering species also contributed substantially to the overall foraging pattern, resulting in a balanced distribution of bee activity.

Table 2: Relative abundance of selected plants

Plant species	Total bee visits	Relative abundance (%)
Coral vine	1417	17.12
White butter cup	1089	13.15
Ixora	993	11.99
Carpet weed	985	11.90
Rangoon creeper	980	11.84
Yellow bells	847	10.23
Corymb diamond weed	718	8.67
West Indian cherry	585	7.07
Brinjal	517	6.24
Bell weed	148	1.79

The combined values of both diversity indices indicate that the study site provided diverse and suitable floral resources capable of supporting healthy populations of *Apis cerana indica* throughout the observation period.

Table 3: Floral intensity, mean bee visits, mean time per flower, mean flowers per bee of selected plants Observation on the abiotic factors

Plant Species	Floral Intensity	Mean Bee Visits	Mean Time/Flower	Mean Flowers/Bee
Bell weed	1	4.11	1.75	6.78
Brinjal	3	14.36	4.57	8.94
Carpet weed	2	27.36	3.64	6.81
Coral vine	4	39.36	2.54	5.00
Corymb diamond weed	3	19.94	1.97	18.06
Ixora	4	27.58	3.53	7.00
Rangoon creeper	4	27.22	2.61	11.11
West Indian cherry	1	16.25	6.50	3.08
White butter cup	3	30.25	9.14	2.81
Yellow bells	2	23.53	7.67	4.97

Table 4: Observation time, temperature and mean bee visit Temperature (°C)

Observation Time	Temperature (°C)	Mean Bee Visits
6–7 AM	28.08	26.71
10–11 AM	33.42	24.41
2–3 PM	36.75	17.88

The results indicated that bee visitation was highest during the early morning (26.71 visits at 28.08°C) and gradually declined as temperature increased, reaching the lowest value (17.88 visits) during the afternoon (36.75°C). Moderate morning temperatures provided favourable conditions for bee foraging, while higher afternoon temperatures likely reduced bee activity due to heat stress and increased energy requirements for flight. This suggests that temperature plays an important role in determining the foraging behaviour of honeybees.

Table 5: Observation time, wind speed and mean bee visit Wind Speed (km/h)

Observation Time	Wind Speed (km/h)	Mean Bee Visits
6–7 AM	12.9	26.71
10–11 AM	22.58	24.41
2–3 PM	23.29	17.88

Bee visitation decreased with increasing wind speed throughout the observation period. The highest bee activity was recorded at the lowest wind speed (12.9 km h^{-1}) during the morning, whereas the lowest bee visits were observed when wind speed increased to 23.29 km h^{-1} in the afternoon. Higher wind speeds may have hindered bee flight and reduced their ability to forage efficiently, resulting in fewer visits to flowers. This indicates that increasing wind speed has a negative influence on honeybee foraging activity

Table 6: Observation time, relative humidity and mean bee visit Relative Humidity (%)

Observation Time	Relative Humidity (%)	Mean Bee Visits
6–7 AM	72	26.71
10–11 AM	55	24.41
2–3 PM	45	17.88

The results showed that both relative humidity and mean bee visits gradually decreased from morning to afternoon. The highest bee visitation (26.71 visits) was recorded during 6–7 AM when relative humidity was highest (75%), while the lowest bee visitation (17.88 visits) occurred during 2–3 PM when relative humidity declined to 44%. The cooler and more humid morning conditions were more favourable for honeybee foraging, whereas the drier afternoon conditions reduced bee activity. This indicates that moderate to high relative humidity during the morning supports greater flower visitation by honeybees.

Table 7: Mean weather parameters and mean bee visits recorded during the study period Diurnal variation in mean bee visits.

Time	Bee visits
6–7 AM	26.71
10–11 AM	24.41
2–3 PM	17.88

Highest mean bee visits recorded during 6–7 AM (26.71), followed by 10–11 AM (24.41), and the lowest during 2–3 PM (17.88). Bee activity was greatest during the cooler morning hours when environmental conditions were more favourable for foraging. As the day progressed, increasing temperature and reduced relative humidity likely decreased bee activity, resulting in fewer flower visits during the afternoon. These findings indicate that the early morning period is the most favourable time for honeybee foraging and pollination.

Table 8: Plant-wise mean bee visits

Plant	Mean bee visits
Coral vine	39.36
White butter cup	30.25
Ixora	27.58
Carpet weed	27.36
Rangoon creeper	27.22
Yellow bells	23.53
Corymb diamond weed	19.94
West Indian cherry	16.25
Brinjal	14.36
Bell weed	4.11

The results revealed considerable variation in honeybee visitation among the flowering plants observed during the study. Coral vine recorded the highest mean bee visits (39.35), followed by White butter cup (30.25) and Ixora (27.58), indicating their high attractiveness to honeybees. Moderate bee visitation was observed in Carpet weed, Rangoon creeper, yellow bells, and Corymb diamond weed, whereas West Indian cherry, Brinjal, and Bell weed recorded comparatively lower bee visits, with Bell weed showing the least visitation (4.11). The differences in bee visitation may be attributed to variations in floral characteristics such as nectar and pollen availability, flower colour, fragrance, and floral morphology, which influence the foraging preference of honeybees.

Table 9: Mean Avg Time per Flower (s)

Plant Species	Mean Avg Time per Flower (s)
Bell weed	1.75
Brinjal	4.57
Carpet weed	3.64
Coral vine	2.54
Corymb diamond weed	1.97
Ixora	3.53
Rangoon creeper	2.61
West Indian cherry	6.50
White butter cup	9.14
Yellow bells	7.67

The mean average time spent per flower varied considerably among the plant species, indicating differences in floral attractiveness and resource availability. White butter cup recorded the longest average visitation time (9.14 s), followed by yellow bells (7.67 s) and West Indian cherry (6.50 s), suggesting that bees spent more time collecting nectar and pollen from these flowers. In contrast, Ixora (1.97 s) and Bell weed (1.75 s) recorded the shortest visitation times, indicating rapid foraging on these flowers. The variation in handling time among plant species may be attributed to differences in flower morphology, nectar accessibility, and the quantity of floral rewards available to honeybees.

The number of flowers visited per bee varied considerably among the plant species. Corymb diamond weed recorded the highest mean flowers visited per bee (18.06), followed by Rangoon creeper (11.11) and Brinjal (8.94), indicating rapid movement of bees between flowers. In contrast, White butter cup (2.81) and West Indian cherry (3.08) recorded the lowest values, suggesting that bees spent more time on individual flowers before moving to the next. These differences may be attributed to variations in floral architecture, nectar availability, and ease of resource collection.

Table 10: Mean Flowers per Bee

Plant Species	Mean Flowers per Bee
Bell weed	6.78
Brinjal	8.94
Carpet weed	6.81
Coral vine	5.00
Corymb diamond weed	18.06
Ixora	7.00
Rangoon creeper	11.11
West Indian cherry	3.08
White butter cup	2.81
Yellow bells	4.97

ANOVA

Bee Visitation Rate

Source	Df	SS	MS	F	P
Plant species	9	3474.64	386.07	171.59	<0.001
Time of day	2	127.52	63.76	28.34	<0.001
Plant × Time	18	1703.06	94.61	42.05	<0.001
Error	6	13.50	2.25	—	—
Total	35	5318.72	—	—	—

ANOVA table

Interpretation: Bee visitation rate differed significantly among plant species, times of day, and their interaction ($p<0.001$).

Table 11: Average Time per Flower

Source	Df	SS	MS	F	P
Plant species	9	118.52	13.17	31.42	<0.001
Time of day	2	8.61	4.31	10.28	0.011
Plant × Time	18	44.36	2.46	5.88	<0.01
Error	6	2.52	0.42	—	—
Total	35	174.01	—	—	—

Interpretation: The average time spent per flower varied significantly among plant species, observation times, and their interaction.

Table 12: Flowers Visited per Bee

Source	Df	SS	MS	F	P
Plant species	9	286.84	31.87	48.67	<0.001
Time of day	2	21.48	10.74	16.41	0.004
Plant × Time	18	82.63	4.59	7.01	<0.001
Error	6	3.93	0.66	—	—
Total	35	394.88	—	—	—

Interpretation: The number of flowers visited per bee differed significantly among plant species, observation times, and their interaction.

Conclusion

The present investigation revealed that the surroundings of the ADAC & RI apiary possess rich floral diversity, with 27 flowering plant species providing continuous nectar and pollen resources for Apis cerana indica. Coral vine (*Antigonon leptopus*) was the most preferred forage plant, followed by White buttercup, Ixora, Carpet weed, Rangoon creeper and Yellow bells. Early morning (6.00–7.00 AM) was the most favourable period for bee foraging, with maximum mean bee visitation (26.71 visits) under moderate temperature (28.08°C), higher relative humidity (72%) and lower wind speed (12.9 km h^{-1}). Increasing temperature and wind speed, along with decreasing relative humidity, reduced bee activity during the afternoon. The Shannon–Wiener and Simpson's diversity indices confirmed the importance of floral diversity, while significant ANOVA results indicated the influence of flowering plants and environmental conditions on bee visitation and foraging efficiency. Overall, conserving bee-friendly flowering plants, reducing pesticide use during flowering, and maintaining diverse floral resources around apiaries and agricultural fields can support honeybee populations, enhance pollination services and improve agricultural productivity.

Discussion

Floral diversity indices indicated a diversified foraging resource base, with a Shannon–Wiener index of 2.207 and Simpson's index of diversity ($1 - D$) of 0.884. These values suggest that bee foraging was distributed among several flowering species rather than being exclusively dependent on a single floral resource. Such diversity may provide nutritional stability to colonies and reduce dependence on individual forage species during periods of seasonal floral scarcity.

Foraging behaviour also varied considerably among plant species. White buttercup recorded the longest mean handling time per flower (9.14 s), whereas Bell weed showed the shortest (1.75 s). A. cerana indica visited the highest number of flowers per bee on Corymb diamond weed (18.06), followed by Rangoon creeper (11.11). These differences suggest that bees modify their handling time and movement rate according to flower structure and accessibility of floral rewards. Thus, high visitation frequency does not necessarily correspond to longer residence time on individual flowers, reflecting differences in foraging efficiency among plant species.

A clear diurnal pattern was observed in bee activity. The highest mean visitation (26.71 visits) occurred during 06:00–07:00 h, when temperature was 28.08°C, relative humidity was 72% and wind speed was 12.9 km h^{-1}. Bee visitation declined to 24.41 visits during 10:00–11:00 h and further decreased to 17.88 visits during 14:00–15:00 h, when temperature increased to 36.75°C, humidity decreased to 45% and wind speed increased to 23.29 km h^{-1}. Overall, the results indicate that cooler, more humid and less windy conditions were favourable for A. cerana indica foraging, whereas hot and windy afternoon conditions reduced bee activity.

The ANOVA results further demonstrated that bee visitation rate, time spent per flower and number of flowers visited per bee differed significantly among plant species, observation periods and their interactions. The significant plant × time interaction indicates that the influence of time of day varied among plant species, probably due to differences in floral traits and species-specific flowering and nectar secretion patterns. These findings confirm that A. cerana indica foraging behaviour is determined by the combined effects of floral resource characteristics and environmental conditions.

Overall, the study demonstrates that maintaining diverse and attractive flowering plants around apiaries can support sustained foraging by A. cerana indica. Coral vine, White buttercup, Ixora and Rangoon creeper were particularly important forage resources, while early morning was the most favourable period for bee activity. Conservation of diverse bee forage plants and appropriate management of apiary surroundings may therefore contribute to improved honeybee nutrition, pollination services and sustainable beekeeping.

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