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Comparative analysis of foraging activity of *Apis mellifera* on various floral resources

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Abstract
A study entitled "Comparative Analysis of Foraging Activity of Apis mellifera on Various Floral Resources" was conducted at Isabella Thoburn College, Lucknow, Uttar Pradesh, during the months of January and February, 2026. The investigation focused on assessing the incoming and outgoing forager activity of foraging activity of European honeybee, *Apis mellifera, colonies* on beehives. Observations were recorded at regular time intervals during the flowering period to determine the rate of bee visitation and forager movement. Parameters such as the number of incoming and outgoing foragers, peak foraging hours, and preference for different floral resources were analyzed comparatively. The findings indicated significant variation in foraging activity at different times and different floral resources due to differences in nectar and pollen availability, floral morphology, and environmental conditions. The results showed that pollen and nectar foraging peaked at noon, with morning activity being lower. Temperature, humidity, sunshine, and floral diversity all had a major influence on honeybee foraging behavior. The study highlights the necessity of maintaining honeybee colonies and effective pollination services. The importance of floral sources and ideal environmental conditions is emphasized in the study.

Keywords: Foraging**,** corbiculae, pollen basket, incoming forager, outgoing forager, habituation, *Apis mellifera*, pollen collection, nectar collection, pollination, floral diversity, honeybee ecology

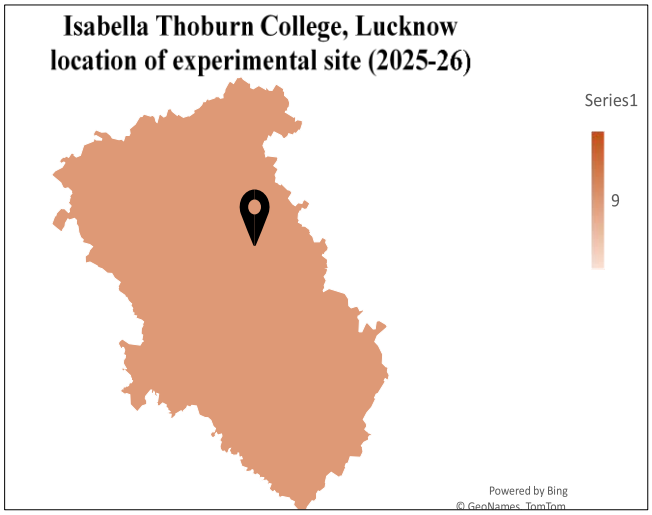
Introduction

The honeybees feed on pollen and nectar, which are the basis of the beekeeping sector. That's why the worker bees in a colony are specialized. Some collect nectar, some collect pollen, and some collect both. (Singh, 1962; Free, 1993) [7, 12]. Pollen is the main source of proteins, lipids, minerals, and vitamins for the bees. In return for pollinating crops, they get nectar, made up of mainly sugars and water in varying proportions. Foraging behavior is the way in which bees collect these from flowers. (Michener, 1974; Gary, 1992) [8, 11]. Asia's climate and abundance of flowers present enormous untapped beekeeping potential. India has invested heavily in increasing agricultural productivity through crop breeding, herbicides, fertilizers, disease-resistant cultivars, improved seeds, and agronomic adjustments. But production has been stagnant for years, so new tactics such as using bee pollination to increase yields are needed. The close relationship between beekeeping and agriculture has not yet been fully understood, so future research should focus on this environmentally beneficial resource. (Crane, 1990 [4]; Verma, 1990) [13]. Access to pollen and nectar for worker bees is influenced by the seasons and the plant blossoming cycles. The availability of fodder during bloom is influenced by temperature, sunshine, and weather. These factors determine how many colonies can survive in an area, and the duration of forage may be as significant as the quantity (Free, 1977; 1993) [6, 7]. The bees that pollinate our food are losing their habitat to cities and huge fields. Diseases ship around the world for trade, and diseases spread quickly. These problems are worse than starved bees worsening faster, which is common in nature. Monocrop fields, however, provide junk food-rich diets, and hives near large farms produce thinner bees, less pollen, less honey, and more losses (but sometimes it's better than cities). (Adam G. Dolezal, Amy L. Toth, 2018) [5]. Honeybee workers forage for nectar as well. Nectar is the source of carbohydrates for the hive, which are used as energy. The other thing they forage for is pollen, which provides 10 important proteins for larvae and queens. They mix pollen with nectar and spit to make "bee bread," which nurse bees eat to make nutrient-rich jelly for the young. Hives eat more carbohydrates, but amino acids are limited by low quality or insufficient pollen, especially at certain seasons. This stunts brood and depletes storage and makes bees eat their own young. (Lau, Bryant; Rangel *et al.,* 2019 [9]*).* Foraging, or food hunting, for honeybees is the link between their hive and the big wide world. All sorts of things mess with it, inside and outside the colony. The research shows the benefits (killer pollination, hive growth) but also the headaches. The honey starts flowing from the foraging farmer's cash in This roundup covers how it's controlled, what influences it, what bees like, differences between bee types, ways to track it, and tricks to manage it. (H.F. Abou-Shaara, 2014) [3].

Honey bees visit flowers to collect pollen by scraping off the loose pollen grains from the anthers with their jaws and front legs. In some plant species, the bees will coat their hairy bodies with pollen by tumbling over the flowers and brushing their sides against the inflorescence. Then, bees will moisten the grains with nectar and saliva, packing them into pasty pellets called pollen loads on their pollen basket (corbicula). (Ujjwal Layek, Siddhartha S. Manna *et al., 2019) [10].* Overlapping generations are a defining feature of advanced insect societies. Offspring, belonging to the "worker" caste, stay in the nest and help their parents, the reproductive caste, reproduce at the expense of their own procreation. (Robert E. Page Jr. & Christine Y.-S. Peng, 2001) [18]

Materials & Methods

The study entitled "Comparative Analysis of Foraging Activity of Apis mellifera on Various Floral Resources" was conducted at Isabella Thoburn College, Lucknow, Uttar Pradesh, situated at 26.87°N, 80.94°E. Foraging activity was conducted in the months of January to February, 2026. Within the study area, the most prominent season was winter (January and February); the temperature ranges from 7 °C to 25.4°C with the low humidity 54.8% to 59.7%.



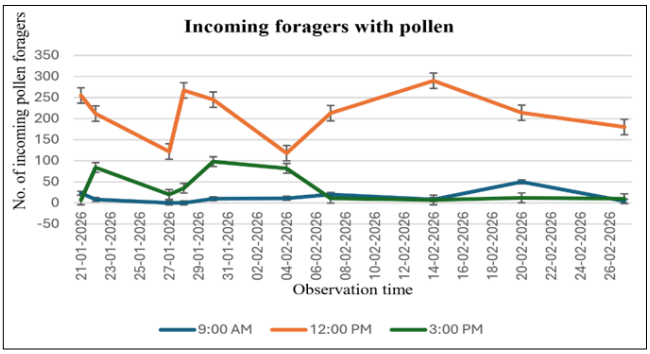
The investigation focused on assessing the incoming and outgoing forager activity of foraging activity of European honeybee, *Apis mellifera, colonies* on beehives. Observations were recorded at regular time intervals during the flowering period to determine the rate of bee visitation and forager movement. Parameters such as the number of incoming and outgoing foragers, peak foraging hours, and preference for different floral resources were analyzed comparatively.

The honeybees (*Apis mellifera)* are plant-eating insects that depend mainly on pollen and nectar from flowers for their food. These resources support their nutrition and help them grow throughout every stage of their life. A honeybee colony includes many worker bees that work together to collect food. Some bees, known as scout foragers, search for food sources and then share information with others about how much food is available, how nutritious it is, and how far away it is. This communication helps the colony gather food efficiently. Bees carrying nectar had a bulging abdomen and no corbiculae burdens, while nectar + pollen collectors had both. Pollen collectors had a pollen basket on their hind legs and were selective in their pollen collection. Using a brush, the foragers removed the pollen pellets from both of their hind legs. The percentage of pollen loads carried by the bees was calculated by weighing the pollen loads with an electric weighing balance after the pollen loads had been taken off the bee body. One bee carries approx. 0.01 mg of pollen.

Foraging activity was measured in terms of the total number of incoming forager bees and outgoing forager bees, which was recorded at fortnightly intervals for five minutes at hourly intervals at 0900, 1200, and 1500 hours. For each time interval, measurements were taken three times a day for at least ten days, and at the end, total values were averaged. We averaged the departing and arriving pollen and nectar foragers.

Table 1: Data represents the number of foragers that come with the pollen.

S. No.	Date	Number of bees visiting in the box with the pollen		
		9:00am	12:00pm	3:00pm
1	21/01/2026	23	255	07
2	22/01/2026	08	212	84
3	27/01/2026	00	122	20
4	28/01/2026	00	267	35
5	30/012026	10	245	58
6	04/02/2026	11	118	82
7	07/02/2026	20	213	11
8	14/02/2026	08	290	07
9	20/02/2026	50	214	12
10	27/02/2026	04	180	10
	Mean ± SE	13.4 ± 4.72	211.6 ± 18.26	32.6 ± 9.78



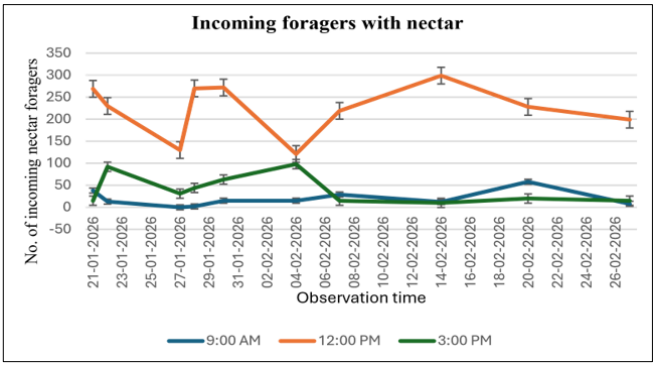
*=Significant at the $p < 0.05$ level.

Graph 1: Graph showing the number of foragers that come with the pollen.

Table 2: Data represents the no. of foragers that come with the nectar

S. No.	Date	Number of bees visit in the box with the nectar		
		9:00 am	12:00 pm	3:00 pm
1	21/01/2026	38	269	15
2	22/01/2026	13	230	92
3	27/01/2026	0	130	31
4	28/01/2026	02	270	44
5	30/012026	15	272	63
6	04/02/2026	15	121	98
7	07/02/2026	29	219	15
8	14/02/2026	12	299	10
9	20/02/2026	58	228	20
10	27/02/2026	8	199	15
	Mean ± SE	19 ± 5.65	223.7 ± 18.92	40.3 ± 10.47

*=Significant at $p < 0.05$ level.

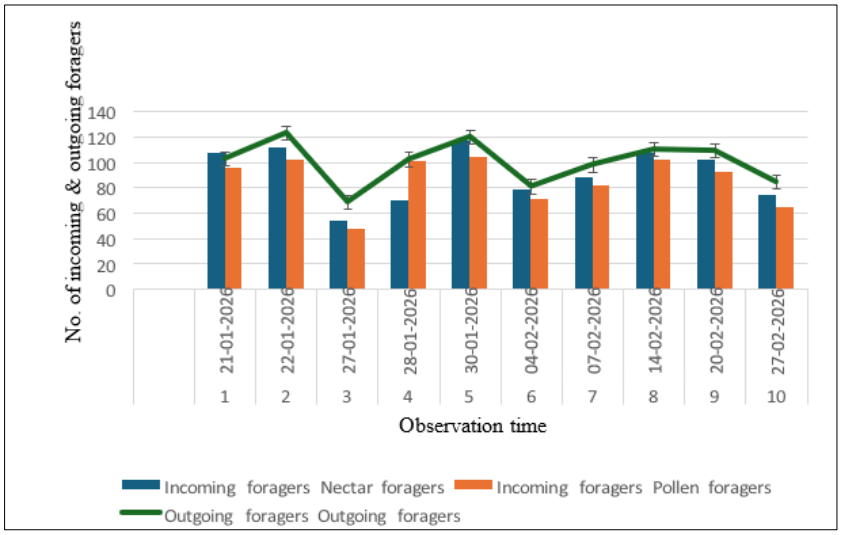


Graph 2: Graph showing the number of foragers that come with the nectar

Table 3: Data represents the incoming and outgoing foragers.

S. No.	Date	Incoming foragers		Outgoing foragers
		Nectar foragers	Pollen foragers	Outgoing foragers
1	21/01/2026	107.33	95	102.67
2	22/01/2026	111.66	101.33	123.09
3	27/01/2026	53.66	47.33	68.22
4	28/01/2026	69.66	100.66	102.09
5	30/01/2026	116.66	104.33	120
6	04/02/2026	78	70.33	80.66
7	07/02/2026	87.66	81.33	97.98
8	14/02/2026	107	101.66	110.01
9	20/02/2026	102	92	109
10	27/02/2026	74	64.66	84.23
	Mean ± SE	90.76 ± 7.1	85.46 ± 6.84	99.40 5.31

* =Significant at the p < 0.05 level



Graph 3: Graph showing the number of incoming and outgoing foragers.

The consumption of pollen, nectar, and honey by honeybees varies according to their developmental stage and specific role within the colony. Young larvae and nurse bees primarily consume pollen due to its high nutrient content essential for growth, whereas older foraging bees depend more on nectar as an energy source. As honeybees age, their pollen intake decreases. This adaptive feeding behaviour enables honeybees to maintain a balanced diet that aligns with their physiological needs and colony responsibilities.

In the surroundings, there are many different flowering plant species, so honeybees visit a wide variety of flowers to collect nectar and pollen. Some of the commonly observed species include Lily (Lilium longiflorum)**,** Pot Marigold (*Calendula officinalis*), Dahlia (Dahlia pinnata), Gulmohar (*Delonix regia*), and Coral vine *(Antigonon leptopus)* & China rose (*Rosa chinensis*). These flowers attract bees because of their bright colors, fragrance, and availability of nectar. As bees move from one flower to another, they not only gather food for their colony but also play a crucial role in pollination, helping plants reproduce and maintain biodiversity.

The diversity of flowering plants in the area ensures a continuous supply of nectar and pollen, which supports healthy colony growth and sustained foraging activity. Different flowers also provide varying nutritional qualities, which contribute to a more balanced diet for the bees.

Pot marigold (*Calendula officinalis*)

Gulmohar (*Delonix regia*)

When conditioned with a sucrose reward, nectar foragers will perform better and retain information longer than pollen foragers. Pollen foragers will perform better when pollen is used as an extra rewarding stimulus. In the second experiment, we used different combinations of sucrose concentrations and sucrose + pollen as habituation and dishabituation stimuli to subject foragers to PER habituation.

When pollen foragers arrive at the food source, it is anticipated they will exhibit less habituation than nectar foragers when exposed to sucrose + pollen as habituated stimuli, and they will exhibit more dishabituation than nectar foragers when pollen participates as dishabituating stimuli (Moreno, E., & Arenas, A. (2024)).

China rose (*Rosa chinensis*)

Lily (Lilium longiflorum)

Dahlia (Dahlia pinnata)

Coral wine (Antigonon leptopus)

When forage is abundant, colonies can modify their selectivity of patches to focus on rich sources, but when forage is scarce, they can distribute their workers across a greater diversity of sources. Back at the nest, foragers assess the colony's rate of nectar intake and pass nectar to receiver bees. The rate of nectar intake by the colonizer is negatively correlated with ease of unloading. Foragers judge the quality of the patch while foraging on nectar in the field. (Núñez JA (1982)**).** When it comes to gathering food, insect foragers are not all alike. (Sampat Ghosh, Hyeijin Jeon & Chuleui Jung, 2020) [19]. The temporal accuracy of foraging trips to experimental feeding times varies significantly throughout the day, becoming less accurate for foraging groups trained later in the day but almost exact for morning-trained groups (Darrell Moore, Dana Siegfried & Mary Ann Rankin, 2001).

Statistical analysis

Statistical analysis of the incoming and outgoing foragers were conducted to obtain the arithmetic mean and standard error. One-way analysis of variance was used for incoming foragers for pollen and nectar, and two-way analysis of variance (ANOVA) was used for comparision of incoming and outgoing foragers to analyze data, and $P \leq 0.01$ was considered statistically significant.

Result

Pollen foraging activity

Table 1 presents data showing a considerable variation in the number of pollen foragers visiting the hive at different times of the day. The highest pollen-foraging activity was recorded at midday (12.00 pm) with an average of 211.6 ± 18.26 bees

visiting with pollen. The average in the morning (9:00 am) was 13.4 ± 4.72 and in the afternoon (3:00 pm) was 32.6 ± 9.78, indicating moderate activity. The largest pollen harvests were recorded at midday on February 14, 2026 (with 290 bees) and on January 28, 2026 (with 267 bees). The least pollen foraging activity occurred on January 27, 2026, in the morning, when no pollen foragers were observed.

The difference observed between three different foraging times in a day ($p < 0.001$) was highly significant with a p-value of 4.89E-12.

Nectar foraging activity

The nectar forager data also showed similar trends (Table 2). Nectar foraging activity was highest at 12:00 pm, with a mean of 223.7 ± 18.92 bees. Morning nectar collecting had the lowest mean of 19 ± 5.65 bees, whereas afternoon observations showed moderate activity with a mean of 40.3 ± 10.47 bees. The most nectar foragers were at noon on February 14, 2026 (299), and the second most were on January 30, 2026 (272). The lowest nectar foraging activity was on 27 January 2026 AM, when no nectar foragers were observed. The results showed that nectar collection was more active during the warmer and brighter hours of the day. The difference observed between three different foraging times in a day ($p < 0.001$) was highly significant, with a p-value of 8.04E-12.

Incoming and Outgoing Foragers

The average number of arriving nectar, incoming pollen, and exiting foragers is shown in Table 3. The average number of arriving pollen foragers was 85.46 ± 6.84 bees, whereas the average number of incoming nectar foragers was 90.76 ± 7.10. With an average of 99.40 ± 5.31 bees, outgoing foragers displayed the highest average activity.

On January 22, 2026, there were 123.09 bee visits, the largest amount of outgoing foraging activity. On January 30, 2026, there were 120 bees. With 68.22 bees, the lowest amount of outgoing activity was noted on January 27, 2026. In a similar vein, entering nectar and pollen foragers also exhibited variations based on flower abundance and weather. The difference observed between three different incoming and outgoing foraging times in a day ($p < 0.001$) was highly significant, with a p-value of 0.00029.

Discussion

This study examined the wintertime (January–February 2026) foraging behaviour of honeybees (*Apis mellifera*) at Isabella Thoburn College in Lucknow. The findings showed distinct differences in nectar and pollen foraging behaviour throughout the day, with noon (12:00 pm) showing the most activity. Numerous researchers have made similar findings and discovered that environmental factors like temperature, humidity, light intensity, and the availability of floral resources have a significant impact on honeybee foraging behaviour (Free, 1993; Gary, 1992; Abou-Shaara, 2014) [3, 7, 8].

In the current study, pollen foraging activity peaked at 12:00 pm (211.6 ± 18.26 bees) and was much lower in the morning (13.4 ± 4.72 bees). Favourable weather conditions, such as higher temperatures and more intense sunlight, which encourage bee flying and flower opening, may be linked to the rise in pollen gathering during noon. Free (1977) [6], who noted that pollen collecting typically increases during warm and sunny hours of the day, reported similar findings. Additionally, Abou-Shaara (2014) [3] observed that bee flight activity and foraging efficiency are strongly influenced by environmental temperature. Similar trends were seen in nectar foraging, with the greatest number of nectar foragers (223.7 ± 18.92 bees) observed at midday.

The increased nectar collecting during midday may be explained by the fact that nectar secretion in flowers is known to increase with temperature and sun radiation. According to Gary (1992) [8], flowers sugar content and nectar availability have a significant impact on nectar foragers. Similarly, according to Seeley (1995) [16], honeybee colonies control nectar gathering based on environmental factors and colony energy requirements. The results of this study also demonstrated that the average activity of outgoing foragers was higher than that of entering nectar and pollen foragers (99.40 ± 5.31 bees). This suggests that worker bees are actively recruiting and communicating. Waggle dance communication is how honeybees tell their nestmates about the location, quality, and distance of food sources (Michener, 1974 [11]; Seeley, 1985). Scout bees play an important role in locating profitable food resources and directing foragers toward them, thereby increasing colony foraging efficiency.

Changes in weather, flower abundance, and nectar secretion patterns may all contribute to variations in foraging activity seen on different dates. The lower activity on January 27, 2026, may have been caused by poor weather, such as low temperatures or less days of sunshine. Verma (1990) and Free (1993) [7, 13], who noted that blooming phenology and environmental conditions directly affect colony survival and production, have found similar seasonal changes in foraging activity.

The study area had variety of flowering plants, such as Pot Marigold *(Calendula officinalis)*, (*Delonix regia)*, Lily (Lilium longiflorum), Dahlia (Dahlia pinnata), Gulmohar (*Delonix regia*), Coral vine *(Antigonon leptopus)* & China rose (*Rosa chinensis*) probably helped to maintain the supply of pollen and nectar. Because nectar offers the carbohydrates needed for energy and pollen delivers proteins, lipids, vitamins, and minerals, honeybees need a variety of floral resources to sustain a balanced diet (Brodschneider & Crailsheim, 2010). Colonies exposed to a variety of floral diets show better immunity, brood growth, and colony strength than colonies reliant on monoculture crops, according to Dolezal and Toth (2018) [5].

The current results corroborate previous research showing that the dietary needs of honeybees differ depending on their age and colony role. While adult foragers eat carbohydrate-rich nectar to maintain flying activity, young nurse bees and larvae need protein-rich pollen for growth and the formation of royal jelly observed by Winston (1987). According to Lau *et al*. (2019) [9], low-quality pollen or insufficient pollen availability might have a detrimental impact on colony health and brood rearing, particularly during times of nutritional stress.

By scraping pollen grains from flower anthers and stacking them into corbiculae pollen burdens on their rear legs, honeybees were able to gather pollen. Bees wet pollen grains with nectar and saliva before storing them in the corbicula, according to Layek and Manna *et al*. (2019) [10], who described similar pollen collection behaviour. Crop pollination is greatly aided by this behaviour, which improves the effectiveness of pollen transfer.

major variations in foraging activity at various times of the day were found using ANOVA statistical analysis ($P < 0.01$), suggesting that temporal and environmental factors have a

major impact on bee behaviour. Moreno and Arenas (2024) revealed similar statistically significant diurnal fluctuations in bee foraging activity and showed that nectar and pollen foragers react differently to reward cues and meal quality.

Conclusion

The present study concluded that the foraging activity foraging activity included nectar and pollen collection were highest at noon time in both incoming and outgoing foragers, and in comparative studies outgoing foragers were much higher than incoming foragers. It is observed that the morning hours the activity of bees was recorded low as compared to noon and after noon however, the highest was recorded during the forenoon because it was the availability of nectar rand pollen in ample quantity.

We conclude that weather has a substantial influence on the outgoing and pollen-gathering foraging activities of honey bees. The foraging of honey bees was found to be variable at different times of day, with high foraging observed at sunrise. The installation of bee hive sheltering honey bee colonies in gardens while having certain measures is suggested for the increased production of nectar and pollen and maintenance of animals and plant biodiversity in an area. The study area had variety of flowering plants, such as Pot Marigold *(Calendula officinalis)*, (*Delonix regia)*, Lily (Lilium longiflorum), Dahlia (Dahlia pinnata), Gulmohar (*Delonix regia*), Coral vine *(Antigonon leptopus)* & China rose (*Rosa chinensis*) helped to maintain the supply of pollen and nectar.

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