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**REVIEW**
**FORAGING BEHAVIOUR OF VARIOUS SPECIES OF HONEY BEES**
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**Abstract:** Foraging behavior is the behavior of honey bees it consists of several behavioral components that include search of food, identification and memorization of food source location, carrying and storing of food and interaction and communication. During the foraging task, honey bees of the same colony share information and communicate each other through a typical dance called waggle dance or tail wagging dance ( food source more than 100 meters from the hive) and round dance ( food source within about 100 meter away from the hive) of honey bees that looks like the numerical figure eight. This waggle dance was first translated by Karl Von Frisch and won the Noble prize in 1973 for his incredible effort toward investigating the sensory perception in honey bee.

**Keywords:** Foraging behavior, Honey bees, *Apis mellifera*, *Apis dorsata*, *Apis cerana indica*, *Apis florea*, *Trigona*

**INTRODUCTION**

Foraging behavior is one of the distinctive behaviors of honey bees, which connects the bee colony with the ambient environment. It is greatly impacted by various, in-colony and out-colony factors. The behavior has immense importance not only for the colony sustenance, but also for the food security and ecosystem sustainability through the means of pollination.

The forager bees are workers bees over 21 days of age when they begin to perform out-colony tasks viz., nectar, pollen or both water or resin collection. The in-colony factors include the genotype of bee strain colony strength and brood rearing activity; queen presence and case (virgin or mated) types of bee hive and the hygienic status of foraging bees. The out-colony factors include availability of plant resources and other environmental factors mainly temperature, humidity and light intensity and time/season of the year. Additionally, natural enemies, insecticides, presence of other species etc. also influence. However, the shifting of nurse bees to foragers are impacted by elevated levels of the foraging gene (Amfor) or the variations in the abundance of mRNA in the worker's brain (Whitfield *et al.* 2003).

Foragers of two categories; scout bees, who first search for the best food resource and reticent bees conducting the task based on information from the scout bees, disseminated by dancing. In general, reticent bees range from 40–90% of the total foragers (Nest and Moore 2012). According to the collection of resources, they can be classified into nectar,

pollen, water or resin foragers and rarely, they can also collect wax from scale insects, *Ceroplastes* sp. The recruitment and change in the proportion of different forager types is related to the colony conditions, such as under pollen shortage or pollen dearth conditions, colonies increase the proportion of pollen foragers without increasing foraging rate (Pernal and Currie 2010).

Foragers prefer the collection of nectar, pollen, water or resin from some resources over others and they exploit the single sources until exhausted (i.e., floral constancy) which make them superior pollinators. They prefer to forage during day hours that tend to fluctuate with time intervals. Their foraging distance varies simultaneously and can be explained by both energy and optical flow hypotheses (Esch and Burns 1996).

**FORAGING DISTANCE**

Foraging distance refer the distance that honey bees travel from their hive to find and collect the nectar, pollen or both and water typically ranging from 1.0 to 1.5 km. If the hive is near the food source then the collection of pollen, nectar or both will be collected higher quantity for good colony strength. Various research worker had worked on foraging distances- Foraging behavior of *Apis cerana indica* on cauliflower and barberry flowers at different distances from the hive, during April 1970 and 1971. The maximum foraging distance on cauliflower was 900 m and on barberry 1100 m. There were 75 per cent of the foragers counted within 400 m of the hive on cauliflower and within 600-700 m on barberry. The pattern of forager distribution on the large continuous area of cauliflower was more regular than

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on the scattered areas of wild barberry Dhaliwal and Sharma (1973)

*Apis cerana indica* bee was trained to visit dishes containing scented sugar syrup at sites which entailed flying up or down hill slopes with different gradients. It was found that practically all the foraging bees collected syrup up to about 650 m from the hive along gentle gradients (below 10 deg ), and up to 250-300 m along steep gradients (above 20 deg ). Taking 75 per cent of the total foragers as the major foraging force of a colony, the economic foraging range was estimated to be not more than 800 m over gentle slopes in a hilly terrain under the temperate and climatic conditions of the western Himalayas, and about half this distance over the steep slopes. The maximum range recorded for a single forager was 1423 m along a gently slope, and 809 m along a steep slope, Dhaliwal and Sharma (1974).

Around an apiary at distances up to 1.6 km from the hives; 44 species were listed, with flowering periods, and whether a major or minor pollen and/or nectar source. Colonies were most active from January to mid-March when pollen and nectar were abundant; surplus honey was stored up to the end of April, the main source being *Nephelium litchi*, Naim and Phadke (1976).

#### FORAGING FOR CAGED BEES

Inside a cage the foraging bees primarily utilized their senses of smell (pheromone) and touch (antennae) to navigate and communicate relying the waggle dance and other movements to share information for food sources.

Foraging behavior of caged honey bees, *Apis mellifera* L. used to pollinate white clover, *Trifolium repens* L. particularly when a large number of controlled crosses are needed. A hive with opening on opposite sides was placed in one end of a screen cage so honey bees would be free to travel into or outside the cage. Clover clones with genetic leaf markings were used as indicator plants to determine if pollen was brought into the cage from outside sources, Harville and Lockett (1978).

#### FORAGING TRIPS

Honey bee foraging trips are essential for colony survival, as forager collect pollen, nectar or both and water etc the primary food sources that sustain the colony's growth, development and reproduction. Some workers worked on the foraging trips -

Collected mixed pollen on all foraging trips on the same day or on each of the 5 days observed. Pollen availability decreased from morning to afternoon and some pollen foragers of both species then changed to nectar collection, but they resumed collection of the original pollen next morning. Two species showed similar behaviour in pollen foraging, with minor differences, Jhaji and Goyal (1979).

Foraging behavior of *Apis cerana* F. and *Apis mellifera* L. (Apidae: Hymenoptera) in Majajay,

Laguna (Philippines). The flight activity of *Apis cerana* was longer than that of *A. mellifera*. However, it had more frequent and shorter duration of foraging trips. Pollen gatherers did not collect nectar during any single foraging trip, however, they shifted from pollen to nectar and nectar to pollen gathering at different trips. A total of 7 and 11 plant species provided the pollen requirements of *A. cerana* and *A. mellifera*, respectively, Forbes and Cervancia (1994)

The *Apis cerana indica* was the main forager on niger and constituted 50.2 to 84.2 per cent of the total bee visits at Bhubneswar, Orissa Panda (1987).

#### FORAGING TIME

Foraging times in honeybees typically starts early in the morning and continue in the evening with peak often occurring at the forenoon of *Apis mellifera* and *Apis cerana indica* but observed *Apis dorsata* during afternoon, influenced by the abiotic parameters and the availability of food sources.

Foraging activities of honeybees and other insects daily, from 0700 to 2000hrs, during the flowering period. Honeybees were constituted 51.4 per cent of the total pollinators on pear (*Pyrus serotina*), 83.1 per cent on apple (*Malus pumila*), and were also the commonest visitors to sesame (*Sesamum indicum*), sunflower (*Helianthus annuus*) and *Robinia pseudoacacia*. Yields of Welsh onion, sesame, and sunflower plants open to insect pollination were 5.61, 1.16, 1.74 and 23.19 times, respectively, Lee *et al.* (1988) and Dash *et al.* (1988) on cashu.

The *Apis cerana indica* was main forager and constituted 35.3 to 42.3 per cent of the total bee visits on niger. *Apis cerana indica* and *Apis dorsata* were active in the forenoon whereas *Apis florea* was active in afternoon, Patel (1988).

Cauliflower (*Brassica oleracea* var. botrytis) grown as a late season seed crop in Himachal Pradesh. *A. cerana* started foraging at about 0800hrs, an hour earlier than *A. mellifera*, and ceased between 1600 and 1800hrs, an hour later than *A. mellifera*. *A. cerana* activity reached its peak at 1400hrs, whereas numbers of *A. mellifera*, although lower, remained fairly constant from 1200hrs until 1500hrs, Kapoor and Dhaliwal (1989).

The foraging activity of *Apis cerana indica* was found higher on niger flowers in first week of November 2011 and 2nd week of December 2012 (33.83 bees/5min/m<sup>2</sup>). Its maximum visitation was found at 1100hrs (66.06 bees/5min/m<sup>2</sup>). The maximum foraging activity of *Apis dorsata* was observed at 1100hrs (11.75 bees/5min/m<sup>2</sup>) whereas, the lowest was observed at 1700hrs (0.50 bee/5min/m<sup>2</sup>). The higher foraging activity of *Apis florea* was noticed at 1300hrs (4.00 bees/5min/m<sup>2</sup>) and was found least at 0900hrs (0.56 bee/5min/m<sup>2</sup>) (Painkra and Shaw, 2016. Painkra (2021) and Manhare *et al.* 2017 on buckwheat flowers.

Foraging activity of *Apis dorsata* on lajwanti grass (*Mimosa pudica*) and found that the maximum activity of *Apis dorsata* was at 1000-1100hrs and the lowest was at 1600-1700hrs and followed by at 0800-0900hrs. In different hours of the day low average population was recorded at 0800-0900hrs (52.44 bees/5min/m<sup>2</sup>) and reached its peak population at 1000-1100hrs (140.33bees/5min/m<sup>2</sup>) and found decreased lowest at 1600-1700hrs (16.22 bees/5min/m<sup>2</sup>) Painkra 2016, Yadav and Painkra 2020) and on *Ageatum conyzoides* by (Painkra, 2018).

Maize tassels (*Zea mays* L.) produce large amounts of pollen, which were visited by several bee species. The objective to evaluate the factors affecting the foraging behavior of bees in maize. The frequency of visitations of bees to collect pollen was obtained by counting in the first five minutes each time, from 8:00 am to 5:00 pm. We had found the prevalence of Italian honey bees (*Apis mellifera*) visiting the maize tassels preferably between 8:00 am and 5:00 pm exclusively for pollen collection (Painkra *et al.* 2021, (Paikara *et al.* 2020). The foraging behavior of European honey bee, *Apis mellifera* was observed in Litchi (orchard) flowers during 27 February 2021-02April 2021. The maximum foraging activity of honey bee was observed third week of March 2021 (32.76 bees/5min/plant) followed by second week of March 2021 (25.38 bees/5min/plant) and fourth week of March 2021 (122.45 bees/5min/plant) however the lowest population was recorded during first week of April 2021 (6.61 bees/5min/plant, Painkra and Jaiswal 2022) and Painkra, 2019 on broccoli flowers, Painkra, 2020 on unmanaged French marigold red cherry (Genda) flowers.

Foraging activity of stingless bee on broccoli flowers at five spots, five minutes per square meter at different hours of the day from 8AM to 5PM. The foraging activity was recorded highest in between 10-11AM (7.82 bee/5min/m<sup>2</sup>/day) followed by in between 11-12 (4.91 bee/5min/m<sup>2</sup>/day) noon and between 9-10 AM (4.00 bee/5min/m<sup>2</sup>/day) and decreased in between 1-2PM (1.88 bee/5min/m<sup>2</sup>/day), 2-3 PM (1.42 bee/5min/m<sup>2</sup>/day) and increased between 3-4 PM (2.22 bee/5min/m<sup>2</sup>/day). However, the lowest activity was recorded in between 4-5 PM (1.00 bee/5min/m<sup>2</sup>/day) (Painkra, 2019) and (Painkra and Kumaranag, 2019 on sunflower).

Various pollinators/visitors on peach bloom *i.e.* *Tetragonula iridipennis*, *Apis mellifera*, *Apis cerana*, *Apis dorsata*, *Musca domestica*, *Pantala flavescens* and *Eurema brigitta* were observed and the *Apis mellifera* was found dominant bee species. Stingless bee (*Tetragonula iridipennis*) recorded higher at 12.00 - 1.00 P.M. noon (1.88 bees/5min/15cm twig) followed by at 3.00 A.M. - 4.00 A.M. (1.25 bees/5min/15cm twig). However the lowest population was recorded at 5.00 - 6.00 P.M. (1.00 bees/5min/15cm twig). Italian bee (*Apis mellifera*)

population was recorded maximum at 12.00 - 1.00 P.M. noon (3.13 bees/5min/15cm twig) followed by (2.38 (Dalpat *et al.*, 2024).

### IMPACT OF FORAGING ACTIVITY ON YIELD

The foraging activity of honeybees significantly impact on crop yield by facilitating crop pollination, leading to increase fruit and seed production and improve quality. It also increase seed weight and germination rate, uniformity maturity and early harvest, economics benefits, increase fruit set and kernel yield etc.

The foraging behavior of honeybees and its effect on the seed yield in niger. Honeybees constituted 91.3 per cent of insect visitors observed on plots of flowering *Guizotia abyssinica* at Pune. *Apis dorsata*, *A. cerana* and *A. florea* contributed 29.5 per cent, 10.3 per cent and 51.5 per cent of the total, respectively. Other insects recorded were butterflies, flies, solitary bees and beetles; only a few *Trigona iridipennis* visited the crop and worked rather slowly on it. The foraging pattern of the 3 *Apis* species were reported; although *A. florea* was the most common species, the other two were also efficient pollinators. On open pollinated plots, seed set was 73 per cent, but on plots caged to exclude insects the seed set was only 3 per cent and seed yield by weight was 4 times higher. On plots caged with *A. cerana*, the yield was 3 times higher than on plots without insects, Rao and Suryanarayana (1990) and Chagnon *et al.* (1991) on raspberry.

### FORAGING ACTIVITY AND ABIOTIC FACTORS

Abiotic factors like temperature, humidity, rainfall, wind speed, number of rainy days, sunshine hours may positively or negatively affect the foraging activity of honeybees. Flight activity in *Apis mellifera* was significantly influenced by the temperature, relative humidity and sunshine hours. Reduced activity of pollinators due to low temperature during flowering contributed to the formation of 5.44 per cent parthenocarpic seedless fruit in mango (Thimmappaiah and Singh, 1983).

The foraging behaviour of honey bees (*viz.*, *Apis dorsata* F., *Apis florea* F. and *Apis cerana indica* F.) on sunflower sown on different dates in Bhubaneswar. Among the three species, *A. c. indica* was main forager. *A. dorsata* and *A. c. indica* were found to be more active in the forenoon while *A. florea* was active in afternoon. *A. florea* was also found to arrive on the flowers later than other two species. Maximum visits of *A. dorsata* and *A. c. indica* were observed during 16-23 Jan., 1988 (average temp. 23.7<sup>o</sup>C), whereas maximum visits of *A. florea* were during 14-21 Dec., 1987 at the average temperature of 25<sup>o</sup>C, Panda *et al.* (1991) and Abrol (1992) on peach flowers.

The foraging behaviour of *Apis mellifera* L. and *Apis cerana indica* F. on rapeseed, *Brassica campestris*. The highest number of forager of both the species entering hive was recorded at 1200hrs of the day. Both species found highest percentage of incoming bee to carry species followed by nectar + pollen, water and pollen collection. Pollen collection in both the species was highest at 0900hrs and was lowest at 1500hrs. No difference in the percentage of nectar gatherers at 1200 and 1500hrs in both species. Both species showed more nectar + pollen collection at 1200 and 1500hrs than 0900hrs. The water collection in both the spp. was highest at 0900hrs, Raj and Rana (1993).

The foraging behavior of three honey bee species on five varieties of niger revealed that *Apis cerana indica* was the main forager. *Apis dorsata* and *A. cerana indica* were relatively more active in the forenoon while *A. florea* were active in the afternoon. The latter also spent more time on florets than *A. cerana indica* and *A. dorsata*, Panda *et al.* (1993).

The behaviour of honey bees, two crops and one wild plant in Himachal Pradesh. In an almond orchard (*Prunus amygdalus*), the number of foragers/m superscript 2 decreased with increasing distance from the hive. Bees preferred the variety Non-pareil to Merced. The percentage of pollen collectors was nearly 58 per cent and it increased to almost 74 per cent on the day after *A. mellifera* colonies were fed with sugar. On cauliflower plots (*Brassica oleracea* var. botrytis) caged with an *A. cerana* colony, foraging activity was higher than for *A. cerana* on open plots. Both *Apis* species foraged on paduana bushes (*Spermatidictyon suaveolens*) where *A. cerana* was the more frequent visitor, Goyal and Rana (1994) and Kumar *et al.* (1994) on sunflower.

Foraging behavior of insect visitors on onion (*Allium cepa* L.) flowers. The dwarf honey bee, *Apis florea* L. was the most abundant flower visitor and comprised more than 94 per cent of the total visitors. The foraging population correlated significantly and positively with air temperature, light intensity, solar radiation and nectar-sugar concentration and negatively with relative humidity. On average *A. florea* visited 1.33±0.26 and 6.17±0.58 umbles and flowers/min, during different hours of the day. The insect pollinated plots produced significantly more seeds with heavier weights than those isolated from insect visits, Abrol (2010).

#### TIME SPENT

The time spent for collection of pollen by *Apis cerana* and *Apis florea* was gradually increased with peak at 1400 h with time spent of 5.01 and 4.22 sec/flower, respectively. Thereafter as the day progressed, the time spent for pollen collection gradually decreased. The mean time spent by *Apis cerana* and *Apis florea* for collection of pollen was 2.72 and 1.82 sec/flower, respectively. Similarly,

time spent for nectar collection gradually increased with peak at 1400 and 1100 h in *A. cerana* and *A. florea* (3.01 and 4.31 sec/flower, respectively). Nectar foraging continued up to end of the day with the mean time spent for nectar collection was 1.74 and 1.48 sec/flower, respectively (Sowmya *et al.* 2014).

Raj and Rana (1994) Studied on time spent per flower by *Apis mellifera* L. and *Apis cerana indica* F. on rape seed *Brassica campestris* var. brown sarson. The two species did not exhibit significant differences in the mean time spent per flower. Also, both the species did not show significant difference at 0900, 1200 and 1500hrs of the day in relation to time spent per flower.

Panda *et al.* (1995) recorded six bee species on plots of niger (*Guizotia abyssinica*). Among these species *Apis florea* was most common, followed by *A. cerana* then *A. dorsata*. Wild bees, which were abundant and identified as *Trigona iridipennis*, *Bombus tunicatus* and *Halictus sp.* Bees were present on the flowers throughout the hours of observation (0900-1600hrs), with a peak from 1100hrs to noon. Abundance and foraging behavior, *A. florea* was the most efficient pollinators of the *Apis* species.

Sinha and Atwal (1996) studied on foraging behavior of honeybee on parental lines of 4 sunflower hybrids (*Helianthus annuus*) at Karnal. Honey bee species and their pollen/nectar collecting behavior influenced bee visit. Time of observation (1000 and 1400 hrs) did not show significant effect on bee visit. Hybrid LSH3 was more attractive to honeybees than other hybrids. *A. mellifera* was most abundant of all 3 species of honeybee. The number of pollen gatherers was 50 per cent higher than the number of nectar collectors. Rock bees (*A. dorsata*) collected only pollen whereas others spp. i.e. *A. mellifera* and *A. florea* worked for both pollen and nectar.

Collins *et al.* (1997) observed the foraging behavior of honey bees (Hymenoptera: Apidae) on *Brassica nigra* and *B. rapa* were grown under simulated ambient and enhanced UV-B radiation in the greenhouse and exposed to honeybees as pollinators. Total duration of the foraging trip, number of flowers visited, foraging time per flower, search time per flower, total amount of pollen collected, and pollen collected per flower were measured.

#### COMPARATIVE FORAGING ACTIVITY

Comparative foraging activity in bees highlights differences between social and solitary bees, with social bees foraging farther and more frequently, while solitary bees have more limited foraging ranges. Foraging activity also differ on various species to species like, *Apis dorsata*, *Apis cerana indica*, *Apis florea*, *Apis mellifera* etc. they are more active from each other.

The comparative foraging activity of *Apis mellifera* L. and *Apis cerana indica* F. on rapeseed bloom revealed that population of *A.c.indica*

( $1.90 \pm 0.35/m^2/2$  minutes) was much higher than *A. mellifera* ( $0.54 \pm 0.08/m^2/2$  minutes). In both the species maximum activity of bees was observed at 1200hrs, but there were no significant differences in the number of foragers between 1200 and 1500hrs in both the species, Rana *et al.* (1997).

#### FORAGING RATE AND SPEED

Honeybees have varying foraging rate and speeds depending on the species and environmental condition. Some bee species visiting more flowers per minutes and having faster foraging speeds than others. Small bee, *Apis florea* was the most abundant of the 18 species of insect pollinators that visited onion bloom in Haryana and recorded peak of abundance of all pollinators during mid-day. Bees had more loose pollen grains sticking to their bodies than flies. Pollen gatherers had more loose pollen grains and foraging rates than pollen and nectar forager, Priti (1998).

Abundance and foraging behaviour of insect pollinators of raya crop and role of *Apis mellifera* in its pollination. *Apis dorsata* Fab., *A. mellifera* L., *A. florea* Fab. and *Andrena sp.* constituted 51.43, 23.77, 20 and 4.80 per cent of total bees caught on this crop. *Apis dorsata* was more active between 1000-1600hrs while *A. mellifera* and *A. florea* were active between 1100-1600hrs. On an average, *A. mellifera*, *A. dorsata*, and *A. florea* visited 14.06, 11.36 and 5.81 flowers/minute. One, two and five bee visits/flower by *A. mellifera* resulted in 65.5, 82.5 and 88.4 per cent pod setting. Intensive pollination of raya by *A. mellifera* increased the number of seeds pod<sup>-1</sup> by 12.22 per cent, seed germination by 7.15 per cent and oil content by 8.31 per cent over natural pollination, Mahindru *et al.* (1998).

#### FORAGING PATTERN

Honeybees utilize various foraging patterns, including honeybees using dance communication to share information about food sources. Various workers worked on these foraging patterns are following-

Sihag *et al.* (1999) observed the foraging pattern of *Apis dorsata*, *A. florea*, and *A. mellifera* in Haryana, in relation to the flowering/ anthesis pattern of 5 oilseed crops i.e. *Helianthus annuus*, *Brassica campestris* var. toria, raya (*Brassica juncea*), taramira (*Eruca sativa*) and *B. campestris* var. sarson. Honeybees started their foraging activities on the crop about a week after the commencement of flowering on it and left the crop about a week before its cessation. Both foraging in honeybees and anthesis in flowers seemed to be regulated by the ambient temperature. The foraging speed and rate on litchi flowers (*Litchi chinensis*) of different species of honeybees prevalent in the area. Foraging speed (time spent in one panicle) was found to be 2.71, 3.40, 5.06 and 1.70 seconds for *Apis cerana indica*,

*A. mellifera*, *A. dorsata* and *A. florea*, respectively. Slower foraging was observed in the early morning and evening. Foraging rate (number of flowers visited/min), was 19.25, 18.80, 16.53 and 21.45 flower/min for *A. c. indica*, *A. mellifera*, *A. dorsata* and *A. florea*, respectively Chaudhary *et al.* (2000). Floral biology, foraging behaviour and honeybee pollination in cardamom (*E. cardamomum*) which were conducted at Kadasikadavu, Kerala. Apidae were the predominant flower visitors (more than 99 per cent of all visitors), the Indian hive bee (*Apis cerana indica*) being the major visitor (95.8 per cent) followed by *Trigona iridipennis* (2.2 per cent). *A. cerana indica* foraging for nectar and pollen was at peak from 0700 to 900hrs and 0800 to 0900hrs, respectively whereas with no bee record after 1300hrs. *A. cerana indica* spent more time collecting nectar (12.4 seconds) than pollen (7.4 seconds) and the proportion of nectar foragers was more (101.7/day) than pollen gatherers (61.6/day). The number of flower visits was minimum (6.6/min) at 0600hrs which increased progressively to 14.9 min at 1100hrs. The number of capsules/10 panicles, number of seeds, number of seeds/capsule, seed weight and 1000-seed weight were higher in open pollination than without insect pollination. Bee pollination resulted in better quality capsules of uniform shape and bigger size, Chaudhary and Kumar (2000).

#### FORAGING BEES

Foraging bees refers the process of worker bees leaving the hive to collect resources nectar, pollen or both, water, resins etc to feed the colony. Worker bees are foraging bees they are responsible for foraging the food materials for collect from different sources. Various workers worked on are as follows- Raw (2000) observed on the foraging behavior of wild bees at hot pepper flowers (*Capsicum annuum*) and its possible influence on cross pollination. Flowers of three cultivars visited from 16 spp. of bees in eight genera: *Hylaeus* (Colletidae), *Dialictus*, *Halictus*, *Augochlora*, *Augochloropsis* and *Ceratalictus* (Halictidae), *Exomalopsis* and *Bombus* (Apidae). No other insects were observed to visit the flowers. Individual bees gathered a full pollen load from 18 to 47 flowers and visited one to eight plants on a single foraging trip.

Kumar and Singh (2001) concluded that the two species of honey bee *A. cerana indica* started foraging earlier (0930hrs) than the *A. mellifera* (0946hrs) and ceased her activities first i.e. 3.37 PM as compared to *A. mellifera*, on sunflower which continued foraging up to 1609hrs and spent more time (1839hrs) for gathering a load of pollen or nectar or both as compared to *A.c.indica* (1806hrs) in a day during the month of December 1999 and January 2000.

Selvakumar *et al.* (2001) studied the foraging behavior of honeybee on parental lines of hybrid

cauliflower Pusa hybrid-2 and revealed that honeybees were predominant pollinators and constituted 85.23 per cent. Among honeybees, *Apis dorsata* F., *Apis mellifera* L. *Apis cerana indica* F. and *Apis florea* F. constituted 28.23 per cent, 26.32 per cent, 24.20 per cent and 21.23 per cent, respectively. The number of pollen gatherers reached to its peak at 1400hrs, while nectar collectors remained constant throughout the day.

Thiyagesan *et al.* (2001) studied in worker honey bees, *Apis cerana indica*, using artificial flowers. Effects of two factors of central place foraging (distance of the food source from the hive and density of flowers) on the bees' nectar collection were studied, in the summer of 1997, using bees from a hive maintained in A V C College campus in India. Results showed that honey bees responded to both the above variations more or less in the same way. Bees significantly decreased their crop load, flower handling time and inter-flower flight time for both an increase in flower-patch distance and inter-flower distance. Significant change in net energy gain (gain-cost/time) with reference to increase in inter-flower distance only and significant increase in energetic efficiency (gain-cost/cost) for both an increase in inter-flower distance and flower patch distance. Bees didn't maximize their net rate of energetic intake while foraging, but increased their energetic efficiency in response to an increase in distances of nectar source from the hives and flower densities. The evidence from this and related studies suggests that the energetic efficiency is a guiding principle underlying the strategy of nectar collection in honey bees.

Kannan (2002) studied that the *Apis mellifera* started their foraging activity at about 0700 hrs and ceased their activity at 1730hrs on blossoms period of mustard at Jabalpur. He further concluded that their peak activity was at 0900 to 1100hrs of the day.

Kumar *et al.* (2002a) conducted an experiment in Bihar, to study the alternative plants competing with sunflowers for foraging of honey bees (*Apis cerana indica* and *Apis mellifera*). Observations were made at 2hrs intervals from 1000 to 1600hrs and at 5-day intervals from 15 December to 15 January. Among 5 other crops, Indian mustard was the most competitive species with sunflower, with an overall average of 6.21 bee visits/ minute/m<sup>2</sup>, while the least preferred plant was maize (0.66 bee visits /minute/ m<sup>2</sup>), compared with the value for sunflower of 9.8 bee visits /minute/ m<sup>2</sup>. Bees were most active at midday, with the maximum number of bee visits averaged over all crops of 5.87/minute in a one square meter area at 1200 hrs, while the least number of bee visits was 3.44/minute at 1600hrs.

Kumar *et al.* (2002b) studied the foraging activities of *A. cerana indica* and *A. mellifera* on sunflower cv. Modern, in Pusa, Bihar. The bees were recorded foraging for nectar, pollen or both at 5-day intervals from 18 December 1999 to 9 January 2000. The

number of bees present were recorded on 5 capitula over the course of a minute, every 2 hrs between 1000 and 1600hrs. More bees were visited the capitula during the early flowering stage of the crop, before maturity. The highest number of bees were recorded visiting capitula at 1200hrs (overall mean of both species on all dates of 10.85 bees/min per 5 capitula) followed by 1400hrs, while the lowest (6.19 bees/min per 5 capitula) was at 1000hrs, followed by 1600hrs. Honey bees numbers were affected by temperature and relative humidity, with higher numbers recorded under the highest mean temperature (18.30 °C) and at low humidity (60 per cent).

Three honey bee species viz. *Apis florea*, *A. dorsata* and *A. cerana indica* for their foraging on litchi flowers. *A. dorsata* was most dominant (44.48 per cent) followed by *A. cerana indica* (41.86 per cent) and *A. florea* (4.59 per cent) amongst honey bee species. Honey bee species alone constituted 90.93 per cent share over total visitors. The population of foragers was found floral density-dependent rather environmental parameters, Chaudhary *et al.* (2002).

Choudhary (2002) reported that the foraging activity of honey bees, *A. mellifera* and *A. c. indica* was highest at 1100hrs followed by 0900hrs, 1300hrs and 1500hrs. Between the two species, *A. c. indica* started foraging earlier (0721hrs) as compared to *A. mellifera* (0733hrs) and ceased her activity later (1642hrs) than *A. mellifera* (1626hrs). Thus, the foraging period was maximum in case of *A.c. indica* (0921 hrs) as compared to *A. mellifera* (0853 hrs). The foraging rate (no. of flowers visited by a bee/min.) of *A.c. indica* was more (11.30) than *A. mellifera* (9.36) and it was highest at 1200hrs followed by 1500hrs and 0900hrs. The foraging speed (time in sec. spent/ bee/ capitulum of *A. mellifera* was more (4.29) than *A.c. indica* (2.86) and it was recorded highest at 0900hrs followed by 1500hrs and 1200hrs.

Nagaraja (2002) determined the foraging activity, load carrying capacity and foraging trip frequency of *A. mellifera*, showed similar diurnal pattern in respect of number of pollen forager, pollen load size and number of pollen foraging trips on one hand and number of nectar forager, nectar load size and nectar forager trips on the other hand, but minimum forager index was observed on mid-day.

Singh *et al.* (2002) determined the foraging activity of bee visitors on litchi flower in Pusa, Bihar. The maximum number of bee foragers minute<sup>-1</sup> panicle<sup>-1</sup> was recorded in *Apis mellifera* (46.51 per cent), followed by *A. cerana indica* (40.28 per cent), *A. dorsata* (9.05 per cent) and *A. florea* (4.16 per cent). The foraging rate (the number of flowers visited by bees per minute) was maximum in *A. mellifera* (10.74), followed by *A. cerana indica* (9.30), *A. dorsata* (2.09) and *A. florea* (0.96). During the day, the maximum number of bee foragers minute<sup>-1</sup> panicle<sup>-1</sup> was recorded at 1030-1130hrs, followed by

1130-1230hrs, while the least number of bee foragers  $\text{minute}^{-1} \text{ panicle}^{-1}$  was recorded at 1530-1630hrs.

Bhowmick *et al.* (2003) reported the maximum pollen collection by *Apis mellifera* at 1000 hrs on niger bloom. No significant difference was observed on maximum pollen collection hours (1000hrs) during 50 per cent and full blooming period at Jabalpur (M.P.). Pandey and Tripathi (2003) conducted an experiment to determine the foraging activity of honey bees (*Apis spp.*) in Indian mustard. *A. cerana indica* showed the highest frequency of visits followed by *A. dorsata*, *A. mellifera* and *A. florea*. The honey bees preferred the flowers containing nectar sugar. The time spent by workers (from the different species) on flowers was also observed. *A. dorsata* workers took the least time (31.4 seconds) followed by *A. mellifera* (31.7 seconds), *A. cerana indica* (33.3 seconds) and *A. florea* (43.9 seconds).

Rajagopal *et al.* (2003) observed that the population of honeybees, viz., *A. dorsata* (2.97 bees/ flower/5 min), *A. cerana* (2.24 bees/ flower/5min), *A. florea* (2.10 bees/ flower/5min.), *A. mellifera* (2.51 bees/flower/5min.) and other pollinators (2.40 bees/ flower/5min.) were maximum on the niger flowers as compared to sunflower and sesamum.

Nidagundi and Sattagi (2005) observed the pollinator fauna and foraging activity of honey bees in bitter gourd during 2003-04. As many as 10 species of pollinators were recorded during the study. Of these, 8 species belong to Hymenoptera and 2 species to Lepidoptera. Among the total pollinators visit was recorded from bitter gourd field, *A. florea* was the most predominant species constituting 43.00 per cent followed by *A. cerana* (26.00 per cent), *A. dorsata* (13.00 per cent) and others (18.00 per cent). The foraging activity of bees on bitter gourd was observed from 0800 hrs to 1800hrs of the day, during 10 per cent flowering. *A. dorsata* and *A. florea* foraging activity was observed from 0800 to 1800hrs of the day, with highest foraging activity at 1200hrs with 6.68 and 15.44 bees/ $\text{m}^2/5\text{min}$ , respectively. But, *A. cerana* and other pollinators foraging activity was maximum at 1000hrs with 12.51bees/ $\text{m}^2/5\text{min}$  and 6.39 pollinators/ $\text{m}^2/5\text{min}$ . Prasad and Patnaik (2005) studied on the foraging activity of *Trigona irridipennis* revealed that irrespective of hives, the number of incoming pollen forager ranged from 0.07 to 2.92/minute while, that of non-pollen forager varied from 0.34 to 6.94/ minute foraging by bees irrespective of hives at peak (2.09 to 12.49 bees /minute) frequently between 17<sup>th</sup> and 35<sup>th</sup> standard week (i.e. last week of April to last week of August). Murugan (2006) worked on the foraging behavior of honey bees, *Apis florea*, *Apis cerana indica* and *Apis dorsata* in western ghats of Coimbatore (Tamil Nadu) on *Eucalyptus teriticornis*, *Tecoma stans* and *Tridax procumbens*. *Apis florea* found to visit on *E. teriticornis* and *A. dorsata* visited only on *T. stans*, but *A. c. indica* visited *E. teriticornis*, *T. stans* and *T.*

*procumbens*. Commencing of foraging of *Apis florea* started at 0630hrs and cessated at 1900hrs, with peak time of foraging was noted from 0830hrs to 0930hrs. Bee population was higher during morning than in the noon and evening. More honey bees were active in the morning hour on the male parent plants as compared to those in the female parent plants on sunflower crop. A positive relationship was observed between nectar production and foraging behavior of honey bee, Chakrabarty and Sharma (2007).

Hogendoorn *et al.* (2007) studied the foraging behavior of blue banded bee, *Amegilla chlorocyanea* under greenhouse conditions results showed that female *Amegilla* was active foragers that make on average 9 pollen foraging flights per day. Flower visitation, estimated that the number of actively nesting females bees needed for adequate pollination in a commercial greenhouse as 282 per hectare.

Gogoi *et al.* (2007) studied on the foraging activity and effect of honey bee (*A. cerana*) pollination on fruit set and yield of Assam lemon. Bee visited the flower right from 0700 to 1600 hrs, although the peak period of their foraging activity was in between 1000-1100hrs with  $9.42 \pm 0.53$  per minute and frequency of flower visit was  $13.26 \pm 0.62$  per minute. It showed that the maximum yield of Assam lemon was obtained in bee pollination treatment ( $48.38 \text{ tonnes ha}^{-1}$ ) against  $32.89 \text{ tonnes ha}^{-1}$  in without bee pollination and  $44.05 \text{ tonnes ha}^{-1}$  in open pollination treatment.

Thakur (2007) concluded that *Syzigium cumini* visited by *A. dorsata* and *A. cerana indica*. *A. dorsata* continued 58.33 per cent. The visit of *A. dorsata* was found to be positively correlated with temperature. In *Trifolium alexandrium*, *A. mellifera* was found to be major *Apis* visitor. *A. cerana indica* visited the crop only at 1200 hrs. *A. florea* was not found at any hour throughout the day.

#### FORAGING FOR BEE FLORA

Worker honey bees visit the different flora for collection of nectar, pollen or both, water, propolis etc for their colony to sustain their life. They collect the pollen through their pollen bag and nectar collect through mouth and bring them into the colony. For the collection of food materials they visit various crops like cereals, pulses, oilseeds, fruit crops, vegetable crops, ornamentals, medicinal etc. Various workers had reported as a honeybee flora they frequently visit them.

Various honeybee foraging activities for identification of potential bee plants in Riyadh. The results revealed that the *Ocimum basilicum*, *Borago officinalis*, *Portulaca spp.*, *Eruca sativa*, *Helianthus annus*, *Pansia spp.* and *Eucalyptus rostrata* for spring season, *Ocimum basilicum*, *Portulaca spp.*, *Helianthus annus* and *Cucumis spp.* for summer season; *Portulaca spp.*, *Ocimum basilicum*, *Helianthus annus*, *Leucaena leucocephala* and *Cynodon dactylon* for autumn season; and *Brassica*

*juncea*, *Helianthus annuus*, *Eruca sativa*, *Acacia farnesiana* and *Acacia salicina* for winter season were the most promising bee plants during their flowering periods. Average honeybee activities reached the maximum at 0900-1100hrs during spring, 0700-0900hrs during summer, 0700-1100hrs during autumn and 1100-1500hrs during winter Al-Ghamdi (2007).

Shaw *et al.* (2008) studied on Indian bee *A. cerana indica* and Italian bee *A. mellifera*, introduced in the agro-climate region of Surguja. The foraging activity of Indian bee was recorded in 39 flora belonging to 23 families from October to March whereas the foraging activity of Italian bee was recorded in 23 flora belonging to 18 families from January to March. The activity of rock bee was also recorded in 9 flora belonging to 7 families from October to March. Indian bee preferred buckwheat, *Fagopyrum esculantum* among crop flora and *Paspalum pospalode* among weed flora, whereas, Italian bee preference was more for faba bean, *Vicia faba* among crop flora, Litchi, *Litchi chinensis* among tree flora and *Ageratum conyzoides* and *Striga* sp. among weed flora. The rock bee preference was more for tree flora like Sisoo, *Dalbergia sisoo*, *Litchi chinensis*, *Eucalyptus* and Pear.

Foraging behaviour of Himalayan honey bee (*A. cerana*) on flowers of buck wheat (*Fagopyrum esculentum*) in November 2001 to 2002 and another on its impact on the grain quality and yield increment of crop at Kirtipur, Kathmandu. *A. cerana* bees started their foraging activities early in the morning ( $06.14 \pm 0.004$ ) and ceased late in the evening ( $17.28 \pm 0.011$ ). Two peaks of foraging activities were observed between 0830 to 1030hrs (peak I) and 1130 to 1330hrs (peak II). It revealed that *A.c.* bee pollination increased grain set in terms of the total number of grains plant<sup>-1</sup> ( $169.76 \pm 4.10$ ), grain weight ( $33.03 \pm 0.26$ g) and grain yield ( $4.40 \pm 0.12$ g) Singh (2008a) and Singh (2008b) worked on *Brassica napus*.

Dhurve (2008) studied the activity of bee species on niger among them, *A. dorsata* visit was noticed from 0800 to 1600hrs with activity at 1600hrs (45.56 bees/m<sup>2</sup>/5min). Bee activity declined in the afternoon reaching lowest at 1800hrs (18.96 bees/m<sup>2</sup>/5min). *A. florea* visitation was noticed from 0800 to 1800hrs with peak activity at 1400 and 1600hrs which recorded 34.80 and 36.93 bees/m<sup>2</sup>/5min, respectively. Bee activity decreased in the afternoon. *A. cerana indica* activity increased in the afternoon from 1200 to 1600hrs which ranged between 20.53 to 23.52 bees/m<sup>2</sup>/5min.

The relative abundance of honey bee foragers on safflower (*Carthamus tinctorius* L.) bloom at Samastipur, Bihar revealed that among the four species of honey bees visiting the bloom, *Apis mellifera* L. was the predominant species followed by *A. cerana indica* F., *A. dorsata* F. and *A. florea* F. During both the seasons, the peak forager bee

activity was recorded at 1100hrs and the least at 1500hrs. The activity of all the species of honey bees in the field was correlated positively and significantly with ambient temperature and negatively with relative humidity. The nectar-sugar concentration of safflower bloom varied from 30.33 to 31.26 per cent in the two seasons, being the least during the morning hours (27.86 and 27.26 per cent in the respective crop season) and maximum (32.86 and 34.46 per cent in the respective season) at 1500hrs, Kumar and Singh (2008).

Joshi and Joshi (2010) observed the foraging behavior on apple flower, time spent per flower and number of flowers visited per minute by two spp. of honey bees viz. *Apis cerana* and *A. mellifera* were made and a significant and nonlinear relationship was found. The number of flowers visited by *A. cerana* was higher than *A. mellifera*. The foraging activity of *A. cerana* was observed at a peak between 1100 to 1300hrs and then declined abruptly between 1700 to 1800hrs. However, in case of *A. mellifera*, the increase was steady and reached its peak between 1300 to 1500hrs.

Chandran and Viraktamath (2010) studied on *Apis dorsata*, *A. cerana* and *A. florea* and they were the major flower visitors on three elite genotypes of niger namely, DNC-4, RCR-18 and NO-71. The mean visit of *A. dorsata* and *A. cerana* was significantly different with higher number of bees on RCR-18 (3.29 and 2.34 bees) and No. 71 (2.73 and 3.40 bees) followed by DNC-4. *A. florea* visitation did not differ among the genotypes. *A. dorsata* visitation was higher on 11th, 15th and 17th day after flowering and *A. cerana* was more on 11th and 17th day. *A. florea* visitation was more only on 11th day after flowering. Similarly mean visit of *Apis* bees was more on 11th day.

Heard (2010) observed the behavior and pollinator efficiency of stingless bees, *Trigona carbonaria* and honeybees, *Apis mellifera* on *Macadamia integrifolia* flowers. Stingless bees mainly collected pollen and resulted in intimate contact with the stigma. Honeybees mainly collected nectar and came into contact with the stigma often. Honey bees visited flowers more quickly than stingless bees. Both bee species responded to racemes rich in pollen and nectar by remaining longer at those racemes and visiting more flowers on them.

Verma and Pratap (2010) studied the foraging behavior of *Apis cerana* on cauliflower and cabbage and its impact on seed production. *Apis cerana* colonies were caged individually with plants of the target crops. Bees started foraging on cauliflower and cabbage at 0700hrs and 0630hrs, respectively, and ceased flight activity at 1800hrs and 1830hrs, respectively. Foraging on cauliflower started at ambient temperatures of 7°C Peak foraging activity was between 1100hrs and 1300hrs for each crop. The duration of individual foraging trips was 26.9 min for cauliflower and 23.9 min for cabbage. Visits to

individual flowers lasted from 4.3 to 6.7 during the day in both crops, bees visited 5-8 flowers/ min. On each crop bees collected either pollen or nectar but never both during the same foraging trip. Fruit set on cauliflower plants pollinated by *A. cerana* was 57 per cent higher than on control plants (pollinators excluded) and 20 per cent higher than on open pollinated plants. Fruit set on cabbage plants following bee pollination was 27 per cent higher than on open pollinated plants whereas control plants did not set fruit.

Chambo *et al.* (2011) evaluated the foraging behavior of Africanized *Apis mellifera* L. (Hymenoptera, Apidae) and its efficiency of pollination on seed yield of sunflower genotypes (open pollination and restricted pollination). There were peaks of visits by *A. mellifera* for nectar collection on the 2<sup>nd</sup> and 3<sup>rd</sup> flowering days between 0700hrs and 0830hrs. The average density of *A. mellifera* during increased visitation ranged from 2.27 to 2.94 bees per capitulum. Nectar collecting bees were more frequent (2.28 bees per capitulum) than pollen collecting (0.40 bees per capitulum).

Das *et al.* (2011) studied the foraging behaviour of honeybees and syrphids during the bloom period of different apple cultivars in relation to prevailing weather conditions. Observations were revealed that synchronization of blooming period among different apple cultivars and their suitable pollinizers which ranged from 25 March to 17 April. Honeybee (*Apis cerana indica* Fabr.) was very efficient in foraging in terms of higher numbers of working bees visiting/m flowering branch/5 min. (12.22 and 14.32 in 2007 and 2008, respectively) during the peak foraging hours (0800hrs-1400hrs). Moreover, during morning (0600-0800hrs) and evening (1400-1700hours) at very low temperature, *A. cerana indica* Fabr. showed a better foraging efficiency than *A. mellifera* L.

Evans *et al.* (2011) studied the honeybee (*Apis mellifera*) distribution and behaviour on hybrid radish (*Raphanus sativus* L.) crops in New Zealand. Honey bees were observed even distribution across the parent lines, although individual bees largely maintained fidelity to the particular line on which they foraged. The bees observed on male-fertile flowers 72 per cent did not switch to the other line. When plants from the different lines were manipulated so that they appeared to be a single plant, 69.5 per cent of honey bees remained constant to the line visited.

Lal (2011) recorded the Italian honey bee, *Apis mellifera* was dominant insect pollinator in five crops out of eight selected crops, followed by *A. cerana indica* and *A. florea*. The maximum activity of all the

species of honey bees was observed in between 0700hrs to 0900 hrs time. The peak foraging activity of *Apis cerana indica* on apple flowers was in between 0900 to 1130hrs when temperature ranged between 15.5 and 21<sup>o</sup>C and 1100 to 1330hrs for *Apis mellifera* when the temperature was 21 to 25<sup>o</sup>c at north-west Himalayas. Mattu *et al.* (2012) observed the foraging behavior on Indian hive bee *A. cerana indica* and European bee *A. mellifera* by placing two colonies of each spp. in apple orchard. The results revealed that *A. cerana* foraged for significantly longer time, reached its peak activity, visited more flowers per minute and took greater time for completing a single foraging trip on apple bloom than *A. mellifera*. However, *A. mellifera* carried significantly heavier pollen loads, greater number of pollen grains and carried significantly more unifloral pollen loads as compared to *A. cerana* in all the three experimental orchards. Verma and Dutta (2011)

Bee flora and to develop the floral calendar for honey bee based on the interview with the beekeepers and visual observations, some important plant species were identified as a major source of flora for honey bee. Spring season (March to June) autumn season (July to October) identified as critical dearth period with a few flowering plants. Winter season (November to February) identified as honey flow period having a number of floral plants viz. *Guizotia abyssinica*, *Brassica spp.*, *Citrus spp.*, *Cajanus cajan*, *Eucalyptus*, Mango, Shisham, Semal, Pea, ornamental plants-Popy, Calendula, Nastertium, Holyhock, *Justicia*, *Berbina*, weed flora *Ageratum conyzoides*, *Bidens pilosa*, and medicinal plants like *Adusa*, *Bhring raj*, *Justicia*, *aswagandha*, *karanj* were the major bee flora. This season was identified as the most suitable for initiation and promotion of beekeeping practices (Painkra *et al.*2015).

## CONCLUSION

Foraging activity is the crucial for both the colony's survival and plant pollination. Foraging activity of honeybees is very important for any colony survival, pollination in colony factors, out colony factors, foraging preferences and communication (honeybees use waggle dance to inform other bees about the location and quality of food sources). Foraging activity support colony growth, reproduction and food storage as well as pollination, which is vital for agriculture and ecosystem. Due to over foraging can lead to the depletion of resources and some foraging activity negatively impact on plants or other insects.

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