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VISITATION TIME OF *APIS CERANA INDICA* ON SOME FLOWERS IN A GORAKHPUR LOCALITY

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ABSTRACT

Foraging activity of honey bees is greatly affected by the region and local conditions with higher foraging rate occurring at afternoon period. Judging the forage worthiness of resource depends on various benefit and cost assessment. The ability to use and learn colour to optimally discriminate profitable food sources from inefficient ones is prerequisite for an efficient foraging strategy. Visitation time of local honeybee *Apis cerana indica* on three flowers types of different colour was recorded in early summer in a Gorakhpur locality in Eastern Uttar Pradesh, India. Longest visitation time was on Mustard flowers with a mean of 23.97±6.99 sec, followed by sweet pea and hibiscus flowers with a mean of 16.60±4.24 sec and 10.22±2.74 sec respectively. The study validates the reported foraging strategies of bees based on colour stimulus, energetic value, handling time, flow rate and flight distance between flower.

KEYWORDS: *Apis*, visitation time, foraging.

INTRODUCTION

Animals have evolved efficient mechanisms to maximize foraging success by being able to judge the quality and availability of foraging resources.[1,2,3,4] Animals like honey bees foraging on resources to which they may make multiple trips has to make a "exploitation vs. Exploration" trade-off. It involves judging the worthiness of foraging resources and choosing whether to return or to quit for search of new resource off.[5,6] Several previous studies have also shown that forager honey bees do respond to energetic returns in adaptive ways.[7] Flower colour plays an important role in foraging response. Bees' visual range extends to UV but less towards red. Thus, UV absorption or reflection from floral parts mixed with other colours form patterns which may help bees to judge the foraging resource.[8,9] Apart from colour, they often chose flowers based on their energetic value, handling time,[10,11] flow rate[12] or flight distance between flowers.[13,14]

Foraging activity can be classified into water, nectar, pollen or resin foraging according to the resource forager bees collect.[15] The type of foraging, whether for pollen or nectar, is considered to be a colony-level trait with a genetic component and is affected by the genotype of bee strain.[16] It has also been found that under shortages of pollen or in conditions of poor pollen quality the honey bee colonies increase the proportion of pollen foragers without increasing foraging rate.[15] The foraging choice between pollen (protein) and nectar (carbohydrate sources) is influenced by insulin receptor substrate (IRS) as demonstrated by Wang et al.[17] It seems that the foraging activities and tasks are under the control of many factors warranting detailed studies.

Honey bees collect pollen and nectar as food for the entire colony and in this process they pollinate plants. Although honey and pollen comprise the main diet of honey bees is, they do collect other liquids and juices from plant and fruit exudates as well. Honey bees have a wide range of nutritional requirements, including vitamins, minerals, lipids, proteins and carbohydrates. Honey bees need these nutrients for taking care of their young ones, the development of young workers and the overall survival of a the colony.[15]

Honey bees are known to initiate foraging activity in early morning and finishes in the evening. Studies have shown that the commencement of foraging activity by honey bee workers can be greatly impacted by the region and local conditions. The honeybee time sense is highly adaptive, allowing bees to synchronize their foraging behavior with the peak time of daily floral nectar rhythms.[18] Alqarni found that, under desert conditions a higher number of foragers left the colonies at 8 am than at 10 am.[19] In general, the foraging activity tends to fluctuate during the day from the morning until the evening. Reyes-Carrillo et al. found higher pollen collection in the early morning than in the afternoon.[20] Pernal and Currie reported a higher foraging rate mean during the afternoon period (36.02 foragers/min) than during the morning period (17.66 foragers/min).[21] Yucel

and Duman found that honey bee workers visited onion flowers from 8.15 to 16.30 h and the peak foraging was between 11.00 to 12.00 h.[22] Foragers even have the ability to remember the time of the day at which the higher food resources are available and such ability may correlate with foraging activity peaks. In general, the normal foraging interval at the same feeding site is less than 5 min and bees spend different times per flower depending on the plant species.

Apis cerana indica, a common honey bee subspecies in this region, is an important pollinator with maximum foraging activities during flowering seasons. The present study aims to determine the flower preference and time spent by these local honey bees on it for collection of nectar and pollen. Since there are no previous reports in this regard from this region of Uttar Pradesh, in India, this study tries to unravel some aspects of bee foraging behavior pertaining to this region.

MATERIAL AND METHODS
Five spots were designated in a field plot randomly in Gorakhpur locality (26.758°N 83.369°E), eastern Uttar Pradesh, India, having abundant flowering plants. Mustard (*Brassica compestris* L.), sweet pea (*Pisum sativum*) and hibiscus (*Hibiscus* sp.) plants were designated for study of bee visit on their flowers. They were chosen for their distinct colour ranging across the visible spectrum and UV. The time spent by the bees visiting these flowers was recorded by digital stopwatch. Only the bees collecting pollen and nectar were considered. The observations were made in the month of March at noons with temperature ranging from 24 to 30ºC and relative humidity of nearly 55±10%. For each spot visitation time of ten foraging bees were noted for each flower.

The data was assessed by One-way ANOVA for differences among visitation time on each flower type in all five plots and to compare differences between the time spent by bees on each flower type. The significance threshold was set at p=.05. The Tukey post hoc test was also conducted to find any statistically significant relationships.

OBSERVATION AND RESULTS
A total of 50 observations were made for each flower type ranging across the five designated spots. Longest time was spent on Mustard flowers by honey bees and it ranged from 11.30 to 49.81sec with a mean ± S.D. of 23.97±6.99 sec, followed by sweet pea and hibiscus flowers ranging from 9.41 to 24.74 seconds with a mean of 16.60±4.24 sec and 5.94 to 17.48 sec with a mean of 10.22±2.74 sec respectively (Table. 1).

One-way analysis of variance (ANOVA) yielded no statistically significant difference on the visitation time spent on five plots for each flower type, namely, Hibiscus ($F_{(4,45)}$= 1.748, p= .156), Mustard ($F_{(4,45)}$= 1.370, p= .259) and Sweet Pea ($F_{(4,45)}$= 1.023, p= .406) (Fig.1). The mean visitation time on these three flower types were also compared with each other for statistically significant relationship using one-way ANOVA. There was a statistically significant difference between the visitation time on the three flower types ($F_{(2,147)}$=95.552, p< .001). A Tukey post hoc test revealed that the visitation time was statistically significantly higher for Mustard flowers (23.97±6.99 sec, p< .001) than Sweet Pea (16.60±4.24 sec, p< .001) and Hibiscus flowers (10.22±2.74 sec, p< .001). There was also statistically significant difference between the visitation time of bees on Sweet Pea and Hibiscus flowers (p< .001).

Table 1: Visitation time of bees on the flowers.

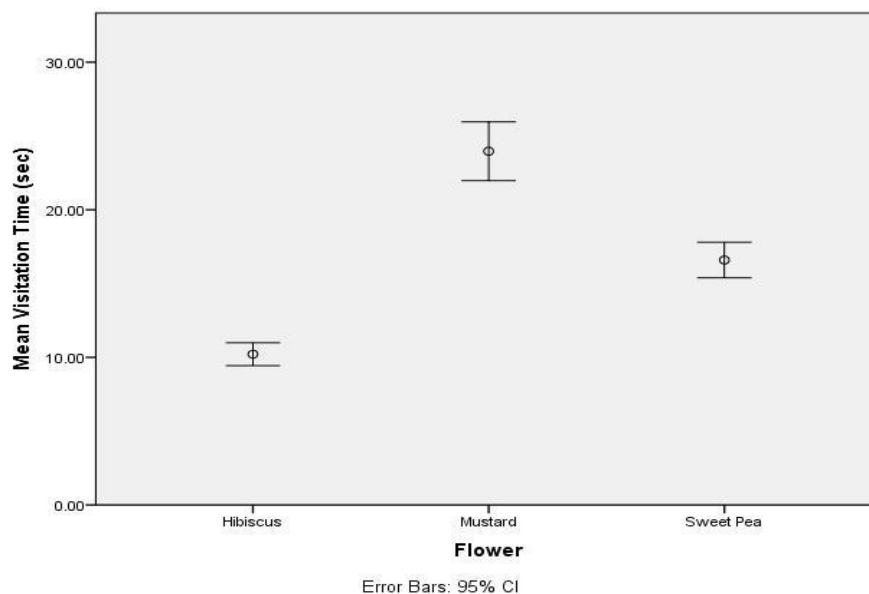| Observation Plots	Mean ±S.D. for time spent on flowers (sec)		
	Hibiscus	**Mustard**	**Sweet Pea**
1	10.29±2.67	27.48±11.14	16.19±3.22
2	10.51±2.59	23.51±6.79	17.34±4.65
3	9.07±2.67	20.61±4.44	18.54±4.01
4	11.87±2.92	23.07±4.22	15.79±4.62
5	9.33±2.42	25.15±5.43	15.12±4.49
Total Mean ± S.D.	10.22±2.74	23.97±6.99	16.60±4.24
$F_{(4,45)}$	1.748	1.370	1.023
Significance (p=.05)	.156	.259	.406

Fig 1: Visitation time of Honeybees on Hibiscus (*Hibiscus* sp.), Mustard (*Brassica compestris* L.) and Sweet Pea (*Pisum sativum*). **Dots are places at the statistical mean and the bars represent the 95% confidence intervals. The three means have statistically significant difference between them (p<.001).**

DISCUSSION AND CONCLUSION

Bees were found to spend significantly more time on mustard followed by pea flower and then Hibiscus (Fig. 1). The flowers with long visitation time must therefore be the most rewarding in terms of foraging resource such as pollen and nectar. Factors such as flower colour, energetic value, accessibility, handling time etc, are important for bees to judge the worthiness of the foraging resource.

The temporal accuracy of visiting time of foraging bees varies more considerably for the foraging groups coming out later in the day. Studies seem to show that individual bees are continuously and accurately aware of the time of day, but are programmed to forage with greater anticipation to late-day food sources.[18] In our experiment, the feeding time varied from bee to bee on a single flower type but not significantly.

Colour plays an important role in the foraging preference of honeybee. Bees have trichromatic colour vision, based on three photoreceptor types maximally sensitive in the ultraviolet (UV), blue and green waveband suggesting that bees are less able to detect red colours.[23,24] Color and response of honeybee to color have long been studied since the discovery that foragers could be trained to visit certain colors and are able to discriminate different color wavelengths.[25,26] Honeybees can become "constant" to certain colors thus making the role of color important in forager decision making.[27] Wells and Wells were able to show "individual constancy", using artificial flowers, as a foraging strategy where individuals visited a single color irrespective of hivemate behavior.[27] This is beneficial for the flowering plant as it reduces the amount of wasted pollen and prevents stigma blockage by heterospecific pollen.[28]

Bees are observed to be attracted to yellow and blue-purple coloured flowers. Most yellow bee-pollinated flowers displayed a pattern with UV-absorbing centres and UV-reflecting peripheries.[8] A statistically significant preference for human-blue coloured flowers has been seen during initial foraging activity. Flower colors that contrast with their background are more important to foraging bees than patterns of colored veins on pale flowers. Recent works suggests that color veins give clues to the location of the nectar. There is little to suggest, however, that bees have an innate preference for striped flowers.[9] Mustard and Sweet pea flowers must therefore be more visually promising than the red Hibiscus.

Flower distribution and density also seem to affect the judgement of bees. Plants with larger inflorescences were visited more often than those with fewer flowers. Seed production in plants also increased with increasing size of inflorescences as bees made few long visits (of more than 60s) than large numbers of short visits (of less than 60s). Therefore, visitation time (duration of foraging) rather than the frequency of visitations (number of visits) was critical for higher fecundity. Hence, plants with larger inflorescences, such as mustard, which provide a conspicuous signal to pollinators and offer greater rewards in terms of nectar, received longer visits by bees.[29]

Bees also judge flower worthiness based on quality and accessibility of pollen and nectar. Studies have shown that the frequency of zygomorphic and vertically arranged corollas is significantly higher in bee-pollinated flowers.[30] Foragers chose shallow-well flowers (short-handling time) with a smaller net harvest rate over deep-

well flowers (long-handling time) with a greater net harvest rate.[10] This implies that short-welled Mustard flower and zygomorphic pea flower is selectively chosen by prospecting and foraging bees over deep-welled hibiscus when all these flowers are present together.

Forager honey bees do respond to energetic returns in adaptive ways.[7] Given choices, apart from colour, they often chose flowers based on their energetic value, handling time,[10,11] flow rate[12] or flight distance between flowers.[13,14] The type of foraging, whether for pollen or nectar, is a colony-level trait with a genetic component, and is affected by the genotype of bee strain. Also, these tasks depend on collective and individual decisions of forager bees. The prior experience at a feeding place plays a role during collective foraging.

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REFERENCES

1. Belovsky GE. Diet optimization in a generalist herbivore: the moose. Theoretical population biology, 1978; 14(1): 105-34.
2. Pyke GH. Optimal foraging: movement patterns of bumblebees between inflorescences. Theoretical population biology, 1978; 13(1): 72-98.
3. Van Nest BN, Moore D. Energetically optimal foraging strategy is emergent property of time-keeping behavior in honey bees. Behavioral Ecology, 2012; 23(3): 649-58.
4. Rivera MD, Donaldson-Matasci M, Dornhaus A. Quitting time: When do honey bee foragers decide to stop foraging on natural resources?. Ballroom Biology: Recent Insights into Honey Bee Waggle Dance Communications, 2016; 6.
5. Krebs JR, Kacelnik A, Taylor P. Test of optimal sampling by foraging great tits. Nature, 1978; 275(5675): 27-31.
6. McNamara JM, Houston AI. Optimal foraging and learning. Journal of Theoretical Biology, 1985; 117(2): 231-49.
7. Grüter C, Moore H, Firmin N, Helanterä H, Ratnieks FL. Flower constancy in honey bee workers (Apis mellifera) depends on ecologically realistic rewards. Journal of Experimental Biology, 2011; 214(8): 1397-402.
8. Papiorek S, Junker RR, Alves-dos-Santos I, Melo GA, Amaral-Neto LP, Sazima M, Wolowski M, Freitas L, Lunau K. Bees, birds and yellow flowers: pollinator-dependent convergent evolution of UV patterns. Plant Biology, 2016; 18(1): 46-55.
9. Whitney HM, Milne G, Rands SA, Vignolini S, Martin C, Glover BJ. The influence of pigmentation patterning on bumblebee foraging from flowers of Antirrhinum majus. Naturwissenschaften, 2013; 100(3): 249-56.

10. Sanderson CE, Orozco BS, Hill PS, Wells H. Honeybee (Apis mellifera ligustica) response to differences in handling time, rewards and flower colours. Ethology, 2006; 112(10): 937-46.
11. Cakmak I, Sanderson C, Blocker TD, Pham LL, Checotah S, Norman AA, Harader-Pate BK, Reidenbaugh RT, Nenchev P, Barthell JF, Wells H. Different solutions by bees to a foraging problem. Animal Behaviour, 2009; 77(5): 1273-80.
12. Greggers U, Menzel R. Memory dynamics and foraging strategies of honeybees. Behavioral Ecology and Sociobiology, 1993; 32(1): 17-29.
13. Marden JH, Waddington KD. Floral choices by honeybees in relation to the relative distances to flowers. Physiological Entomology, 1981; 6(4): 431-5.
14. Hill PS, Hollis J, Wells H. Foraging decisions in nectarivores: unexpected interactions between flower constancy and energetic rewards. Animal Behaviour, 2001; 62(4): 729-37.
15. Abou-Shaara HF. The foraging behaviour of honey bees, Apis mellifera: a review. Veterinarni Medicina, 2014; 59(1).
16. Robinson GE, Page RE. Genetic determination of nectar foraging, pollen foraging and nest-site scouting in honey bee colonies. Behavioral Ecology and Sociobiology, 1989; 24(5): 317-23.
17. Wang Y, Mutti NS, Ihle KE, Siegel A, Dolezal AG, Kaftanoglu O, Amdam GV. Down-regulation of honey bee IRS gene biases behavior toward food rich in protein. PLoS genetics, 2010; 6(4): e1000896.
18. Moore D, Siegfried D, Wilson R, Rankin MA. The influence of time of day on the foraging behavior of the honeybee, Apis mellifera. Journal of Biological Rhythms, 1989; 4(3): 305-25.
19. Alqarni AS. Tolerance of summer temperature in imported and indigenous honeybee, Apis mellifera L. races in Central Saudi Arabia. Saudi Journal of Biological Sciences, 2006; 13(2): 123-7.
20. Reyes-Carrillo JL, Eischen FA, Cano-Rios P, Rodriguez-Martinez R, Nava Camberos U. Pollen collection and honey bee forager distribution in cantaloupe. Acta zoológica Mexicana, 2007; 23(1): 29-36.
21. Currie RW, Pernal SF, Guzmán-Novoa E. Honey bee colony losses in Canada. Journal of Apicultural Research, 2010; 49(1): 104-6.
22. Yucel B, Duman I. Effects of foraging activity of honeybees (Apis mellifera L.) on onion (Allium cepa) seed production and quality. Pakistan J. Biol. Sci, 2005; 8(1): 123-6.
23. Lunau K, Papiorek S, Eltz T, Sazima M. Avoidance of achromatic colours by bees provides a private niche for hummingbirds. Journal of Experimental Biology, 2011; 214(9): 1607-12.
24. Peitsch D, Fietz A, Hertel H, de Souza J, Ventura DF, Menzel R. The spectral input systems of hymenopteran insects and their receptor-based

colour vision. Journal of Comparative Physiology A, 1992; 170(1): 23-40.

25. Von Frisch K. Der farbensinn und formensinn der biene. Zool. Jahrbuch Physiol, 1914; 35: 1-188.

26. Daumer K. Reizmetrische untersuchung des Farbensehens der Bienen. Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology, 1956; 38(5): 413-78.

27. Wells H, Wells PH. Honey bee foraging ecology: optimal diet, minimal uncertainty or individual constancy?. The Journal of Animal Ecology, 1983; 829-36.

28. Waser NM. Competition for pollination and floral character differences among sympatric plant species: a review of evidence. Handbook of experimental pollination biology, 1983; 277-93.

29. Ohara M, Higashi S. Effects of inflorescence size on visits from pollinators and seed set of Corydalis ambigua (Papaveraceae). Oecologia, 1994; 98(1): 25-30.

30. Menzel R, Shmida AV. The ecology of flower colours and the natural colour vision of insect pollinators: the Israeli flora as a study case. Biological Reviews, 1993; 68(1): 81-120.