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Foraging Attributes of Insect Pollinators on Tulsi (*Ocimum basilicum*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Pollination is an intricate relationship between plants and pollinators; this interaction is the best example of mutualism where pollinators utilize floral rewards while pollination accomplished on plants. Pollination ecology of tulsi (*Ocimum basilicum*) is poorly understood. Foraging attributes:

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foraging rate, foraging speed and transit time of pollinators are key performance indicator to determine their pollination efficiency. Foraging speed and foraging rate were recorded during blooming period with the help of stopwatch and transit time was calculated from foraging rate and foraging speed. The performance of seven pollinators; *Apis florea, Amegilla cingulata, Megachile femoratella, Megachile* sp., *Apis cerana, Apis dorsata* and *Apis mellifera* were evaluated on the basis of foraging attributes. Foraging rate, foraging speed and transit time varied during the blooming period week to week and pollinator species to species. The maximum foraging rate was observed with *A. mellifera,* maximum foraging speed was observed with *A. florea* and minimum transit time as well as wasted minimum time was calculated with *A. mellifera.* The maximum foraging rate, foraging speed and minimum transit time were observed with all the pollinators at the peak of blooming period. Based on foraging attributes *A. mellifera* performance was better than other pollinators on Tulsi.

Keywords: Pollinator; foraging rate; foraging speed; transit time; Ocimum basilicum.

1. INTRODUCTION

Tulsi is known as Queen of herbs due to its utmost medicinal properties [1]. In Ayurveda, it is used as home remedy for treating various diseases. Presence of compounds like camphene, eugenol, and cineole in tulsi cures viral, bacterial, and fungal infections of the respiratory system. Tulsi has antibacterial properties that are used against dental cavities and bad breath. This plant has Eu-medicinal properties viz. Anti-stress [2], anti-inflammatory [3], anti-fungal and anti-bacterial [4], anti-plasmodial [5], anti-diarrhea ohorrea, anticoagulant (Singh et al., 2001), hepatoprotective activity, immune-modulatory [6]. Its oil is used on swollen area helps to reduce swelling and pain. Tulsi oil is also extracted from the seed, and it is propagated by seeds. In angiosperms, pollination is essential for seeds/fruits setting. Pollination is crucial mechanisms of angiosperms for reproduction to produce seed and fruits and maintain the diversity of plant species.

Insect pollinators endow critical ecosystem service as pollination. Pollination is an intricate relationship between plants and pollinators. The plant-pollinator interaction is the best example of mutualism where pollinators utilize the floral rewards while pollination accomplished on plants. The visitation rate of insect pollinators is crucial factor of their efficiency. Stebbins [7] emphasized visit frequency is a key component of pollinators' performance. Sahli and Conner [8] observed that the foraging rates attribute is important than the performance/visit on flowers. During foraging, various anthophiles show variable foraging attributes and strategies. Vazquez et al. [9] indicated the importance of visitation frequency as a proxy for successful pollination using meta-analysis. The visitation rates of Insect pollinators vary during foraging [10,11]. The genera Megachile and Xylocopa are the key insect pollinators of pigeonpea [12,13]. The *O. basilicum* is important medicinal plant and its pollination ecology is poorly understood. The foraging attributes and relative abundance of insect pollinators are important to determine their pollination efficiency. However, it was observed that transit time of insect pollinators was missing in earlier studies. Hence, the present study was envisaged to substantiate based on relative abundance, foraging speed and rate along with transit time between two flowers of *O. basilicum* in order to determine the pollinators' efficiency.

2. MATERIALS AND METHODS

The data were recorded consecutively for two cropping seasons (39th to 48th standard week) during 2022 and 2023 at Agriculture Experimental farm, Banda University of Agricultural & Technology, Banda. This farm is in Bundelkhand region of Uttar Pradesh, between latitudes 24^{o} 53' and 25^{o} 55' N and longitude 80^{o} 07' and 81^{o} 34' E. The temperature at this reason is considerably high during summers, reaches up to 49 ^{o}C during hot summers and reaches as low as 8 ^{o}C winter. The foraging speed and foraging rate were recorded from commencement to cessation of blooms once in a week. The foraging speed was recorded as foragers time spent flower/second while the foraging rate was recorded as number of flowers visited/minute. The notable times were recorded with the help of stopwatch. The data was recorded once in a week at hourly interval from 0801 to 1600 h from every side across the field. The pollinators were caught at blooming stage by sweeping method and identified to species level; when identity could not be determined at the time of observation, these were denoted according to size and body colour for the time being until their identity was confirmed later. The collected specimens were identified by the Insect Identification Service, Division of Entomology, IARI, New Delhi.

The transit time is a key performance indicator of foragers' efficiency. Transit time is the time which was taken by foragers between visits in a pair of flowers during foraging on blooms to reach from one flower to another flower and search for a suitable flower. Transit time was computed from the time taken between visits in a pair of flowers during foraging to reach from one flower to another, in search of a suitable one. It was calculated from foraging rate and foraging speed of the forager in a certain time bout. Singh, 2018 reported formula is given below,

$$\text{Transit time between a pair of flowers} = \frac{(\text{Tb} - \text{Fr} \times \text{Fs})}{(\text{Fr} - 1)}$$

Where, Tb = Time bout (1 minute = 60 seconds)
Fr= Foraging rate (number of flowers visited/time bout)
Fs = Foraging speed (time spent in seconds/flower)

3. RESULTS AND DISCUSSION

3.1 Foraging Rate and Foraging Speed

Foraging rate and foraging speed are noteworthy attributes to compare the pollinator's efficiency. Foraging rate varied during the blooming period and pollinator to pollinator. In the year 2022, the maximum foraging rate (6.94 flower/ min) was observed with *A. mellifera* followed by *A. dorsata, A. cerana, M. femoratella, Megachile* sp. *A. cingulata* and minimum foraging rate (4.46 flower/ min) was observed with *A. florea*. The maximum foraging rate was recorded with all the pollinators at the peak of blooming period (44th std. week) and the lowest at commencement (39th std. week) and cessation (48th std. week) of blooming period. The similar result trends were observed during 2023.

The foraging rate variation might be due to foraging gesture of insect pollinators. This result is corroborated with Singh, 2018. The variation of foraging rate between weeks might be due to flower density. This result corroborates with fact that the greater number of anthesised flowers in a raceme and the greater number of flowering racemes on a plant enhanced the visit of bumble bee [14]. The pollinator's preferential visits influenced due to higher floral reward and abundance is known [15]. Each insect species has its specific weather threshold and beyond that range, activity does not occur [16].

Foraging speed varied during the blooming period and pollinator to pollinator. In the year 2022, the maximum foraging speed (4.32 sec/ flower) was observed with *A. florea* followed by *A. dorsata, A. mellifera, A. cerana, A. cingulata, Megachile* sp. and minimum foraging speed (1.64 sec/ flower) was observed with *M. femoratella*. The maximum foraging speed was recorded with all the pollinators at the peak of blooming period (44th std. week) and the lowest at commencement (39th std. week) and cessation (48th std. week) of blooming period. The similar result trends were observed during 2023.

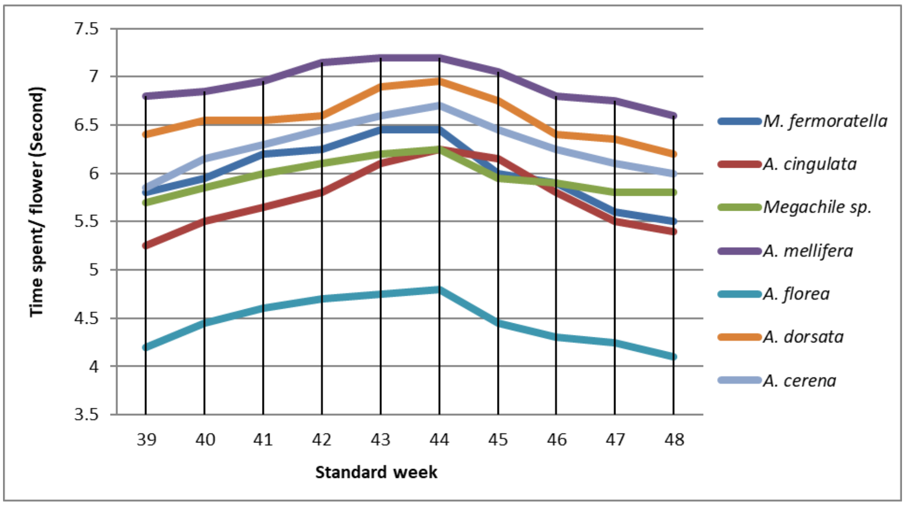

Fig. 1. Foraging rate of insect pollinators during 2022

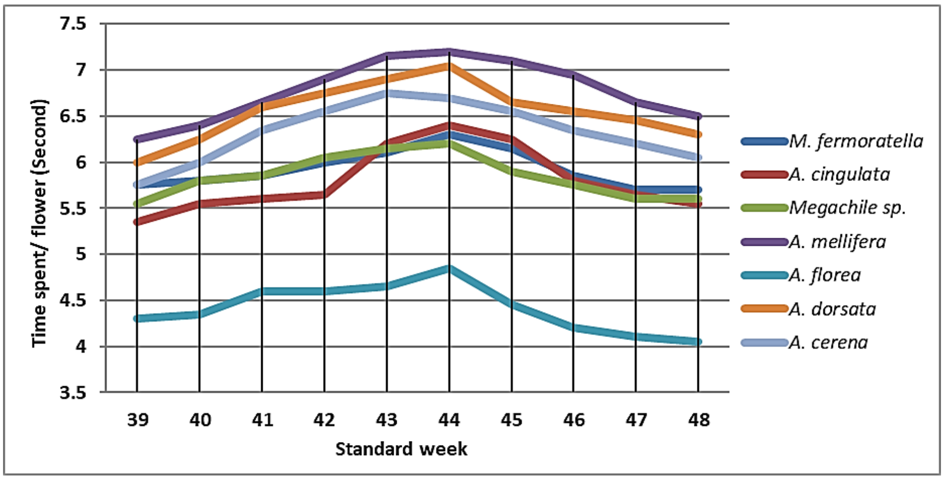

Fig. 2. Foraging rate of insect pollinators during 2023

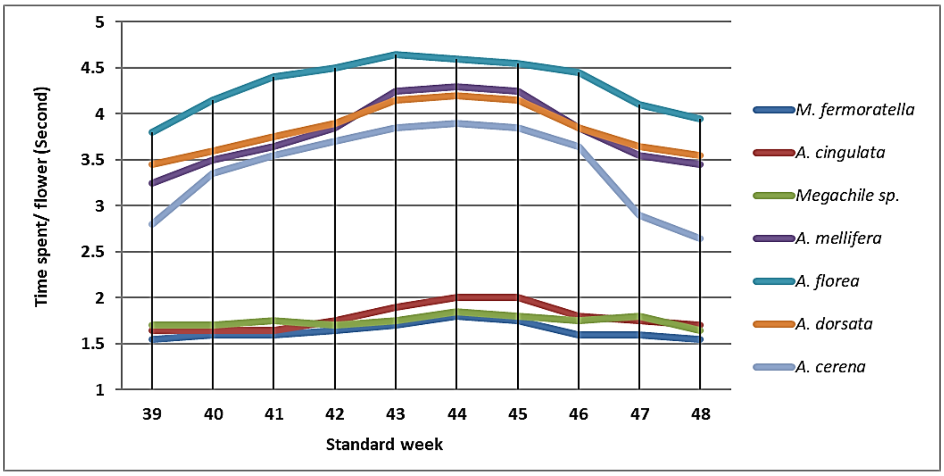

Fig. 3. Foraging speed of insect pollinators during 2022

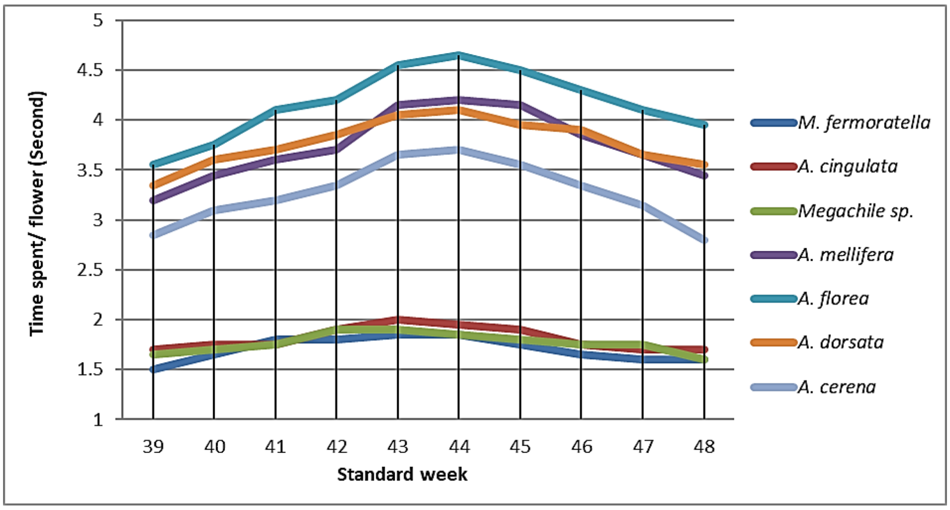

Fig. 4. Foraging speed of insect pollinators during 2023

Table 1. Transit time of insect pollinators on Tulsi (*O. basilicum*) blooms during foraging

Transit time of pollinators between flowers of tulsi															
	2022							2023							
Std week	***Megachile Fermoratella***	***Amegilla Cingulata***	**Megachile sp.**	***A. mellifera***	***A. florea***	***A. dorsata***	***A. cerana***	***Megachile Fermoratella***	***Amegilla Cingulata***	**Megachile sp.**	***A. mellifera***	***A. florea***	***A. dorsata***	***A. cerana***
39th	10.63	12.08	10.70	6.53	13.76	7.02	8.99	10.82	11.70	11.17	7.62	13.56	7.98	9.18
40th	10.20	11.32	10.32	6.16	12.04	6.56	7.65	10.51	11.05	10.45	7.02	13.04	7.14	8.28
41st	9.63	10.90	9.90	5.76	11.04	6.39	7.10	10.20	10.91	10.26	6.38	11.43	6.35	7.42
42nd	9.46	10.39	9.73	5.28	10.50	6.12	6.63	9.84	10.59	9.60	5.84	11.30	5.92	6.86
43th	9.00	9.49	9.45	4.74	10.11	5.32	6.18	9.55	9.15	9.38	4.93	10.64	5.43	6.15
44th	8.88	9.05	9.23	4.68	9.98	5.18	5.94	9.12	8.80	9.33	4.80	9.73	5.14	6.18
45th	9.90	9.26	9.96	4.96	11.52	5.56	6.45	9.56	9.17	10.08	5.01	11.59	5.97	6.62
46th	10.32	10.33	10.14	5.83	12.38	6.55	7.08	10.38	10.39	10.51	5.59	13.11	6.21	7.24
47th	11.10	11.19	10.33	6.27	13.10	6.88	8.30	10.83	10.84	10.91	6.32	13.93	6.69	7.78
48th	11.44	11.55	10.51	6.65	14.13	7.31	8.82	10.83	11.11	11.10	6.83	14.43	7.10	8.53
Mean	10.05	10.56	10.03	5.69	11.86	6.29	7.31	10.16	10.37	10.28	6.03	12.27	6.39	7.42

Similarly, the time spent/flower varies during foraging in various crops [10,11,12]. During foraging, *A. florea* loses most of its time trying to insert their labium up to nectary gland whereas other big size bees have long labium and easily reach up to nectary gland and thereby collect nectar within minimum time. This result corroborates with lowest foraging speed reported with long labium bees [13].

3.2 Transit Time

The transit time is a significant attribute to analyse pollinator's efficiency. Transit time of the insect pollinators was varied during the blooming period and varied from pollinator to pollinator. In the year 2022, the maximum transit time (11.86 sec) was observed with *A. florea* followed by *Amegilla cingulata, Megachile femoratella, Megachile* sp., *A. cerana, A. dorsata* and minimum transit time (5.69 sec) was observed with *A. mellifera*. It was also observed minimum transit time of all the pollinators at the peak of blooming period and the maximum transit time at commencement and cessation of blooming period. The almost similar result trend was observed during 2023 except *M. femoratella,* and *Megachile* sp., and again, minimum transit time of all the pollinators was observed at the peak of blooming period and the maximum at commencement and cessation of blooming period. These data show *A. mellifera* wasted minimum time whereas wasted *A. florea* maximum during foraging. All the pollinators were wasted minimum time at the peak of blooming period whereas maximum during commencement and cessation of blooming period.

During peak of the blooming period, more dens flower was available, and flowers were available at the shorter distances. Therefore, pollinators might be visited maximum number of flowers per time bout. This result corroborates with observation that the number of flowers visited/foraging bouts. Foraging attributes vary among the pollinator's species [17,18]. This result is corroborated with the Singh, [19-25].

4. CONCLUSION

This is concluded that amongst key pollinators of tulsi, *Apis* spp. dominated over others. During blooming period of tulsi, foraging rate, foraging speed and transit time varied week to week and species to species. The maximum foraging rate and minimum transit time were observed with *A. mellifera* and maximum foraging speed was observed with *A. florea*. The maximum foraging rate and minimum transit time were observed with all the pollinators at the peak of bloom. Based on foraging attributes *A. mellifera* performance was better than other pollinators.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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