International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 08-08-2023, Accepted: 23-08-2023, Published: 09-09-2023
Volume 8, Issue 9, 2023, Page No. 33-36

Foraging rate of different *Apis* species in oilseed *Brassica* ecosystem

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Abstract
The present investigation was undertaken to gather the information of honey bee pollinators for their foraging rate while visiting the flower of different, *Brassica* species. The experiment was done on Indian at Norman E. Borlaug Crop Research Centre in Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) during the rabi season 2020-21 to investigate the foraging rate of *Apis* species on different cultivar of oilseed *Brassica.* Number of flowers visited per minute by a particular bee was counted with the help of a stop watch. During the blooming stage of oilseed *Brassica* spp. The findings indicate that among the selected crops, *A. mellifera* exhibited a higher flower visitation rate per minute compared to other *Apis* species, with *A. dorsata* displaying the lowest rate. Additionally, within the *Brassica* species, the highest flower visitation rate per minute was recorded for *B. napus var.* GSC-6. The majority of *Apis* species were observed foraging more actively between 1000-1200 hours compared to 1400-1600 hours. This behavior can be attributed to their specialized anatomical structures, foraging tendencies, distinct morphological characteristics such as hair density, and variations in the size of body parts and pollen presentation patterns on the flowers.

Keywords: Flower, behaviour, bees, *Apis* spp, *brassica* spp, foraging

Introduction
The Brassicaceae family encompasses approximately 350 genera and 3500 species, solidifying its position as one of the ten most economically significant plant families [1]. Its distinction lies in the presence of conduplicate cotyledons, which are cotyledons that fold longitudinally around the radical, as well as two-segmented fruits (siliquae) housing seeds in one or both segments. Notably, the oilseed *Brassica* serves as an exceptional research crop for investigating variations in pollinator behavior. This is due to the fact that many *Brassica* species, such as *B. campestris* var. toria, *B. napus*, and *Eruca sativa*, rely on insect pollination, benefiting from the swift life cycle of these plants [2].
Brassica crops stand to derive substantial advantages from cross-pollination, a process in which insects assume a pivotal role. The floral architecture of *Brassica* flowers is notably adapted to accommodate interactions with generalist insect pollinators. This adaptation is characterized
by the presence of vibrant and pigmented petals, the emission of olfactory cues, and the copious production of pollen and nectar throughout the entirety of the flowering phase. These intricate features collectively act as a potent attractant, effectively drawing a diverse spectrum of insect species to engage in feeding behaviors [3]. In addition to bees, various other insects are commonly observed visiting the blossoms of these *Brassica* crops. However, as a general observation, these insects often lack the requisite density of body hair and corresponding behavioral patterns necessary for the efficient conveyance of pollen from the anthers to the stigma of the flower. Those visitors who intentionally or inadvertently facilitate the movement of pollen are characterized as pollinators [4]. The majority of insect pollinators associated with *Brassica* crops predominantly belong to the *Apis* species. Evaluating the pollination efficiency of different bee species significantly on their foraging rates. Generally, a higher frequency of foraging corresponds to an increased potential for successful pollination. The rate at which a bee species visits flowers per minute is influenced by various factors, including instinctual foraging behavior, the length of the proboscis [5], the structure of the flower [3], specifically the depth of the corolla [6], the type and quantity of floral rewards [7, 8], the density of flowers on a specific cultivar of the crop, and the time of day. This study presents a comparative analysis of the foraging rates exhibited by different honeybee species on different variety of *Brassica* species, observed at different time intervals throughout the day.

Material and method
The research was conducted at the Norman E. Borlaug Crop Research Centre within Govind Ballabh Pant University of Agriculture and Technology, located in Pantnagar, Uttarakhand. This investigation took place during the winter cropping season of 2020-21. The cultivation of the crop began in October 2020. Foraging rate of bee species was counted with help of stopwatch. The study focused on the foraging behaviors of *Apis* species and other insects that visited flower of oilseed *Brassica* spp. during their blooming phase. These observations were made during different time intervals within the day: 10:00 AM to 12:00 PM and 2:00 PM to 4:00 PM. This was done over six sunny days, with a total of 64 observations each day, encompassing eight species of oilseed *Brassica* flowers. The collected data was compiled, organized into tables, transformed (n+1 transformation), and subjected to statistical analysis known as Analysis of Variance (ANOVA). The statistical significance was assessed at a confidence level of 5 percent.

Result and discussion

Foraging rate of Apis species in different oilseed Brassica: Number of flowers visited per minute by various bee species on different variety of *Brassica* species is shown in Table 1. Highest foraging rate in cultivar *B. compestris* var. BSH-1 among different *Apis* species was recorded on *A. florea* (9.33 flowers/min) and *A. cerana* (9.25 flowers/min) which were statistically similar. In cultivar *B. rapa* var. YST-1 Highest foraging rate was found by *A. mellifera* (9.92 flowers/min) and *A. cerana* (9.42 flowers/min) which were statistically similar. Among different *Apis* species, highest and lowest foraging rate in cultivar *B. juncea* var. Varuna was observed by *A. mellifera* (10.75 flowers/min) and *A. cerana* (5.25 flowers/min), respectively. In *B. juncea* var. PM-31, *A. mellifera* had highest foraging rate (12 flowers/min) followed by *A. cerana* (10.95 flowers/min) and *A. dorsata* (4.33 flowers/min). There were significant variations among different *Apis* species. In cultivar *B. alba* highest foraging rate was found by *A. dorsata* (11.5 flowers/min) which was significantly at par with *A. mellifera* (11.25 flowers/min) and *A. cerana* (11.25 flowers/min. Highest foraging rate in cultivar *B. nigra among different Apis species* was recorded on *A. mellifera* (13.5 flowers/min) followed by *A. cerana* (11.25 flowers/min), *A. florea* (5.75 flowers/min). In *B. napus var. GSC-6 A. florea* had highest foraging rate (12.25 flowers/min) followed by *A. mellifera* (11.75 flowers/min) which was at par with *A. dorsata* (11.5 flowers/min). Whereas in *B. carinata* only highest and lowest foraging rate in cultivar observed by *A. mellifera* (12.17 flowers/min) and *A. florea* (11.25 flowers/min), respectively which were significantly different

Table 1: Foraging rate of *Apis* species irrespective of time

***Brassica* species**	**Foraging rate (flowers visited/min) of different *Apis* species**				
	A.mellifera	***A.cerana***	***A.dorsata***	***A.florea***	**Mean**
B. compestris (var. BSH-1)	8.75 (3.11)	9.25 (3.18)	0.00 (1.00)	9.33 (3.18)	6.83 (2.62)
B. rapa (var. YST-151)	9.92 (3.30)	9.42 (3.22)	0.00 (1.00)	0.00 (1.00)	4.83 (2.13)
B. juncea (var. Varuna)	10.75 (3.42)	5.25 (2.19)	6.00 (2.30)	6.42 (2.36)	7.10 (2.57)
B. juncea (var.PM-31)	12.00 (3.60)	10.92 (3.44)	4.33 2.03	0.00 (1.00)	6.81 (2.52)
B. alba	11.25 (3.30)	11.25 (3.48)	6.42 (2.39)	11.50 3.53	10.10 (3.22)
B. nigra	13.50 (3.79)	11.25 (3.45)	4.92 (2.15)	5.75 (2.27)	8.88 (2.91)
B. napus (var. GSC-6)	11.75 (3.55)	10.42 (3.37)	11.50 (3.53)	12.25 (3.59)	11.48 (3.51)
B. carinata	12.17 (3.62)	0.00 (1.00)	0.00 (1.00)	11.25 (3.49)	5.85 (2.28)
Mean	11.27 (3.49)	8.469 (2.92)	4.15 (1.92)	7.06 (2.55)	

Similar type of conclusion was drawn by Kunjwal *et al.* (2014) [9] who reported that *A.mellifera* had highest foraging rate (10.68 flowers/minute) among *Apis* species. In a study by Sihag and Khatkar (1999) [10], it was also noted that the most significant foraging behavior of *A. mellifera* and *A. florea* occurred on *Brassica compestris* Var. Brown sarson Cv. BSH-1

Table 2: Foraging rate of *Apis* species irrespective of different oilseed *Brassica*

Time	***A.mellifera***	***A.cerana***	***A.dorsata***	***A.florea***	**Mean**
1000-1200	10.69 (3.40)	8.04 (2.80)	6.92 (2.53)	8.35 (2.85)	8.50 (2.89)
1400-1600	11.85 (3.57)	8.90 (3.04)	1.38 (1.31)	5.77 (2.26)	6.97 (2.54)

On an average (Table 2) *Apis* species visited 8.50 and 6.97 flowers per minute at 1000 to 1200hr and 1400 to 1600hr, respectively. Foraging rate was significantly more at 1000 to 1200hr. Among the *Apis* species, *A.mellifera* maintained its dominance during both time intervals, while *A.dorsata* exhibited a pronounced and significant preference for elevated foraging rates throughout. Numerous researchers have also documented that the highest foraging rate occurs between 12:00 PM and 1:00 PM on *Brassica* crops [11-13]. Thakur *et al.* (1982) [14] investigated the foraging habits of *A. cerana indica* and *A. mellifera*. They observed that these bees were most active in the morning (*A. cerana indica* – 9:00 AM and *A. mellifera* - 10:00 AM), reaching their peak around 10:30 AM, followed by a subsequent decline in foraging activity. A resurgence in activity was noted between 3:00 PM and 3:30 PM, followed by a gradual decrease. The researchers identified three peaks: a major one at 12:00 PM and minor ones at 2:00 PM and 3:00 PM. Similarly, Sinha and Chakravarty (1983) [15] documented the foraging patterns of pollinators during the time span of 12:00 PM to 2:00 PM.

Table 3: Foraging rate of bees in different var. of oilseed *Brassica* irrespective of different *Apis* species

***Brassica* species**	***Apis* species**	
	1000-1200	**1400-1600**
B. compestris (var. BSH-1)	6.08 (2.50)	7.58 (2.74)
B. rapa (var. YST-151)	4.75 (2.12)	4.92 (2.14)
B. juncea (var. Varuna)	8.75 (2.91)	5.46 (2.22)
B. juncea (var.PM-31)	8.63 (2.88)	5.00 (2.16)
B. alba	11.25 (3.49)	8.96 (2.94)
B. nigra	11.5 (3.51)	6.25 (2.32)
B. napus (var. GSC-6)	11.58 (3.54)	11.38 (3.49)
B. carinata	5.46 (2.22)	6.25 (2.33)
Mean	8.50 (2.89)	6.97 (2.54)

On an average (Table 3) foraging rate on *Brassica* species was significantly more at 1000-1200hr (8.50flowers/min) than 1400-1600hr (6.97 flowers/min.). *Apis* species showed maximum foraging rate on *B. napus* (var.GSC-6). Among individual oilseed *Brassica* species, *B. juncea* var. Varuna (8.75, 5.46 flowers/min) *B. juncea* var. PM-31 (8.63, 5 flowers/min) *B. nigra* (11.5, 6.25

flowers/min) *B. alba* (11.25, 8.96 flowers/min) had significantly higher foraging rate during 10.00-12.00h, than 14.00-16.00h, respectively. Whereas foraging rate in *B.compestris* var. BSH-1 (6.08, 7.58 flowers/min) and *B. carinata* (5.46, 6.25 flowers/min) was significantly lower during 10.00-12.00h than 14.00-16.00h, respectively. On the other hand *B. rapa* var. YST-151 (4.75, 4.92 flowers/min) and *B. napus* var. GSC-6 (11.58, 11.38 flowers/min) showed non-significant interaction between 10.00-12.00h and 14.00-16.00h respectively. This type of variation during time period also discussed by Sihag and Khatkar (1999) [10], who investigated the foraging behaviors of *A. dorsata*, *A. mellifera*, and *A. florea* on *Brassica compestris* Var. Brown sarson Cv. BSH-1. They observed that *A. dorsata* initiated foraging on Cv BSH-1 at 9:00 AM with a smaller number (0.07 ± 0.28 bees/m2), and by 12:00 PM, the population peaked (10.03 ± 0.33 bees/m2), followed by a decrease afterward. However, *A. florea* and *A. mellifera* began foraging at 10:00 AM with counts of 0.50 ± 0.13 and 0.90 ± 0.33 bees/m2, respectively, reaching their peak populations at 1:00 PM (3.97 ± 0.37 bees/m^2 for *A. florea* and 5.03 ± 0.47 bees/m^2 for *A. mellifera*).

Foraging rate of Apis species on different Brassica species during different time hour: Foraging rate of various bee species at different day hours, on different variety of *Brassica* species is shown in Table 4. The interaction between both time periods of foraging rate in *Brassica* species revealed that, the foraging rate of *A. mellifera* stood out as significantly higher (14.33 flowers per minute) when visiting *B. nigra* plants during the time of 1400 to 1600 hours followed by *A.florea* (13.67 flower/min) during 1200-1600hr. No sign of foraging activity of *A. dorsata* and *A. florea* was seen on *B.rapa* (var YST-151). These results are in line with finding of Chakravarty (2000) [16], who observed that the foraging activity of pollinators was maximum at 12.00hr to 14.00h. Depending on insect foraging habits and the types of flowers on the crop, insects forage at different rates [6]. This foraging rate not only differs among different Brassica cultivars but also varies among various species of honeybees. This variation could be attributed to the distinct floral rewards provided by different cultivars and the differing needs among honeybee species [17].

Table 4: Foraging rate of *Apis* species on different *Brassica* species during different time hour

***Brassica* species**	**Number of flowers visited by *Apis* species**									
	10.00-12.00hr					**14.00-16.00 hr**				
	A.mellifera	***A.cerana***	***A.dorsata***	***A.florea***	**Mean***	***A.mellifera***	***A.cerana***	***A.dorsata***	***A.florea***	**Mean***
B. compestris (var.BSH-1)	8.00 (2.99)	8.50 (3.07)	0.00 (1.00)	7.83 (2.92)	6.08 (2.50)	9.50 (3.23)	10.00(3.29)	0.00 (1.00)	10.83(3.43)	7.58 (2.74)
B. rapa (var.YST-151)	9.33 (3.21)	9.67 (3.25)	0.00 (1.00)	0.00 (1.00)	4.75 (2.12)	10.50(3.38)	9.17 (3.18)	0.00 (1.00)	0.00 (1.00)	4.92 (2.14)
B. juncea (var. Varuna)	10.17 (3.34)	0.00 (1.00)	12.00(3.60)	12.83(3.79)	8.75 (2.91)	11.33(3.50)	10.50(3.39)	0.00 (1.00)	0.00 (1.00)	5.46 (2.22)
B. juncea (var.PM-31)	13.67 (3.83)	12.17(3.62)	8.67 (3.05)	0.00 (1.00)	8.63 (2.88)	10.33(3.37)	9.67 (3.26)	0.00 (1.00)	0.00 (1.00)	5.00 (2.16)
B. alba	10.33 (3.37)	11.17(3.47)	12.83(3.72)	10.67(3.41)	11.25(3.49)	12.17(3.63)	11.33(3.49)	0.00 (1.00)	12.33(3.65)	8.96 (2.94)
B. nigra	12.83 (3.71)	11.83(3.49)	9.83 (3.29)	11.5 (3.53)	11.5 (3.51)	14.33(3.87)	10.67(3.41)	0.00 (1.00)	0.00 (1.00)	6.25 (2.32)
B. napus (var. GSC-6)	9.67 (3.26)	11.00(3.46)	12.00(3.60)	13.67(3.83)	11.58(3.54)	13.83(3.85)	9.83 (3.28)	11.00(3.45)	10.83(3.36)	11.38 (3.49)
B. carinata	11.50 (3.53)	0.00 (1.00)	0.00 (1.00)	10.33(3.36)	5.46 (2.22)	12.83(3.71)	0.00 (1.00)	0.00(1.00)	12.17(3.63)	6.25 (2.33)
Mean **	10.69 (3.40)	8.04 (2.80)	6.92 (2.53)	8.35 (2.85)	8.50 (2.89)	11.85(3.57)	8.90 (3.04)	1.38(1.31)	5.77 (2.26)	6.97 (2.54)

Figures in the () parentheses are angular transformed values
Mean**=mean foraging rate of bee species during 10.00-12.00hr and 14.00-16.00hr.

Mean*=mean foraging rate of bee species in individual *Brassica* species during 10.00-12.00hr and 14.00-16.00h.

Factors	**C.D.**	**SE(d)**	**SE(m)**
Factor (Time)	0.284 (0.053)	0.144 (0.027)	0.102 (0.019)
Factor (Bee species)	0.402 (0.075)	0.203 (0.038)	0.144 (0.027)
Interaction (Time X Bee species)	0.569 (0.107)	0.287 (0.054)	0.203 (0.038)
Factor (*Brassica* species)	0.569 (0.107)	0.287 (0.054)	0.203 (0.038)
Interaction (Time X *Brassica* species)	0.804 (0.151)	0.406 (0.076)	0.287 (0.054)
Interaction (Bee species X *Brassica* species)	1.137 (0.213)	0.575 (0.108)	0.406 (0.076)
Interaction (Time X Bee species X *Brassica* species)	1.608 (0.302)	0.813 (0.153)	0.575 (0.108)

Conclusion

The assessment of foraging rate holds significance in understanding the behavior and effectiveness of pollination for various bee species. Based on this research, it can be deduced that *A. mellifera* demonstrates a statistically superior foraging rate when compared to other *Apis* species during both time period while *A. dorsata* and *A. florea* show no foraging activity at both time period (1000-1200hr and 1400-1600hr) on *B. rapa* var. YST-151. *A. dorsata* significantly show least foraging activity among bee species. Foraging rate varied according to hours of the day and it was observed to be maximum at 1000-1200hr. Among the eight *Brassica* species, *B. napus* (var. GSC-6) and *B. rapa* cultivars exhibit the highest levels of foraging activity. This underscores that The foraging behavior of bees in a crop is influenced by both the specific characteristics of individual bee species and the morphological attributes of different *Brassica* flower species.

Acknowledgement

The authors are highly thankful to the head and technical staff of Department of Entomology, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) for providing necessary facilities. Supervision provided by Office In-charge, Plant Pathology Section, College of Forestry, Ranichauri cannot be neglected as without their continuous motivation and support this work could not be accomplished.

Reference

1. Warwick SI, Francis A, Shehbaz AI. Brassicaceae: species checklist and database on CD-Rom. Plant Systematics and Evolution,2006:259:249-258.
2. Stewart AV. Review of Brassica species, cross- pollination and implications for pure seed production in New Zealand. Agronomy New Zealand,2002:32:63-81.
3. Free JB. Insect pollination of crop plants. Academic Press, London and New York.197.
4. Sihag RC. Characterization of the pollinators of cultivated cruciferous and leguminous crops of sub-tropical Hissar, Indian Bee Wld 69,1988:(3):153-158.
5. Inouye. The effect of proboscis and corolla tube lengths on patterns and rates of flower visitation by bumble bees. Oecologia,1980:45:197-201.
6. Gilbert FS. Flower visiting by hoverflies (syrphidae). Annual Revision of Ecological System,1980:6:139-170.

7. Rao GM, Suryanarayana MC. Studies on the foraging behavior of honeybees and its effect on the seed yield in niger. Indian Bee Journal,1990:52:31-33.
8. Rao GM. Studies on the floral biology and pollination requirements of scented methi (*Trigonella corniculata* Linn.) Indian Bee Journal,1991:53:39-43.
9. Kunjawal Neha, Kumar Y, Khan MS. Flower visiting insect pollinators of Brown mustard *Brassica Juncea* (L) Czern and cross and their foraging behaviour under caged and open pollination. African Journal of Agriculture Research,2014:9(16):1278-1286.
10. Sihag RC, Khatkar S. Foraging pattern of three honeybee species on eight cultivars of oil seed crop. International Journal of Tropical Agriculture,1999:17(1-4):245-252
11. Dhaliwal HS, Bhalla OP. The foraging ecology of Apis cerana indica. Proceedings of the 2nd International Conference Apiculture in Tropical Climate, New Delhi, 1980:513-527.
12. Desh Raj, Rana VK. Time spent by Apis mellifera L. and Apis cerana indica F. foragers on rapeseed bloom. Journal of Entomology Research,1994:18:335-339.
13. Anonymous. Annual report, All India coordinated Project on honeybee Research and Training. C.C.S, HAU Hissar,1999:16-20.
14. Thakur AK, Sharma OP, Garg R, Dogra GS. Comparative studies on foraging behaviour of Apis mellifera and A. cerana indica on mustard. Indian Bee Journal,1992:44(4):91-92.
15. Sinha SN, Chakrabarty AK. Bee pollination and its impact on cauliflower seed production. In: Proc. Second International Conference on Agriculture in Tropical Climates, New Delhi, 29th Feb. to 4thMarch,1983:649-655.
16. Chakravarty MK. Foraging behaviour and pollination efficiency of hive bees in hybrid seed production of Brassica napus L. Thesis (Ph.D. Entomology) submitted to G.B.P.U.A. & T. Pantnagar-263145, (U.S. Nagar), U.P. India: 2000.
17. Kumar M, Singh R. Foraging behavior of Apis mellifera visiting mustard (Brassica juncea L.). Shaspa,2003:10(2):123-126.