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Comparative Evaluation of Bee Abundance and Foraging Behaviour among Major Bee Pollinators on Mustard

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A B S T R A C T

The present study was conducted to evaluate the abundance and foraging behaviour of major bee pollinators on mustard (*Brassica juncea* L.). Five bee species, namely *Tetragonula iridipennis*, *Apis florea*, *Apis mellifera*, *Apis cerana indica* and *Apis dorsata*, were monitored during different hours of the day. Bee activity was assessed in terms of abundance, foraging rate and foraging speed at 08:00, 10:00, 12:00, 14:00, 16:00 and 18:00 h. The results revealed marked differences in abundance and foraging activity among the bee species and observation hours. *T. iridipennis* recorded the highest overall mean abundance (21.07 bees/m²/5 min), followed by *A. florea* (17.05), *A. mellifera* (14.26), *A. cerana indica* (13.24) and *A. dorsata* (11.64 bees/m²/5 min). Overall bee abundance was highest at 12:00 h (25.43 bees/m²/5 min), followed by 14:00 h (23.57 bees/m²/5 min). In terms of foraging rate, *A. mellifera* recorded the highest overall mean (14.60 visits/min), followed by *A. cerana indica* (11.64), *A. dorsata* (9.76), *A. florea* (7.40) and *T. iridipennis* (4.43 visits/min). The overall foraging rate was highest at 12:00 h (15.51 visits/min). Foraging speed, expressed as time spent per flower, varied considerably among species, with *A. mellifera* recording the shortest duration (3.57 s/flower), indicating the fastest flower handling, whereas *T. iridipennis* required the longest duration (15.71 s/flower). The minimum mean flower-handling time was observed at 12:00 h (6.53 s/flower), indicating greater foraging efficiency around midday. The study demonstrated distinct species-specific differences in bee abundance and foraging behaviour, with midday representing the period of peak pollinator activity on mustard flowers.

Introduction

Mustard (*Brassica juncea* L.) is an important oilseed crop in which insect-mediated pollination contributes to reproductive success and seed production. Its flowers attract several bee species, with considerable variation in their abundance and activity. Kunjwal *et al.,* (2014) recorded diverse flower-visiting insects on *B. juncea*, while Bijarniya *et al.,* (2024) reported marked differences in the abundance of major honeybee visitors. Bee foraging is influenced by environmental conditions and floral resource availability. Maity *et al.,* (2014)

reported that temperature, sunshine and other weather factors influenced honeybee activity on mustard. Similarly, Kumari *et al.,* (2020) observed variation in honeybee activity with flowering stage and time of day, indicating distinct daily patterns of visitation. Bee abundance does not necessarily reflect foraging efficiency, as species differ in their rate of flower visitation. Bhatnagar *et al.,* (2011) reported differences in the foraging rate of major *Apis* species on *B. juncea*. Such interspecific variation indicates that bee species may contribute differently to floral resource exploitation. Foraging speed is another important behavioural attribute because the time spent on individual flowers influences the number of flowers visited during a foraging bout. Nagpal *et al.,* (2020) observed significant differences in flower-handling time among *Apis* species on mustard, demonstrating species-specific foraging strategies. Differences among bee species are also evident in their resource-collection behaviour. Nagpal *et al.,* (2019) reported variation in nectar and pollen collection among *Apis* species on Indian mustard.

These differences, together with variation in abundance and visitation rate, may influence their relative contribution to pollination. Bee activity also varies throughout the day with changes in environmental conditions and floral resources. Kumari *et al.,* (2020) and Nagpal *et al.,* (2019) reported distinct temporal patterns in honeybee activity on mustard. Therefore, observations at different hours are important for understanding species-specific foraging patterns. Despite several studies on mustard pollinators, comparative information integrating bee abundance, foraging rate and foraging speed among major bee species remains limited. Therefore, the present study was undertaken to compare these foraging attributes of *Apis mellifera*, *A. cerana indica*, *A. dorsata*, *A. florea* and *Tetragonula iridipennis* on mustard (*B. juncea* L.) at different times of the day.

Materials and Methods

The study was conducted during the *rabi* season of 2025–26 at the Department of Entomology, College of Agriculture, Parbhani, Maharashtra. Mustard (*Brassica juncea* L.) cv. was grown under open pollination and unsprayed field conditions to facilitate natural bee visitation. Colonies of *Apis cerana indica* and *Apis mellifera* were maintained in the experimental field, while *Apis florea*, *Apis dorsata* and *Tetragonula iridipennis* occurred naturally in the study area. These five bee species were selected for comparative assessment of their abundance and foraging behaviour on mustard flowers.

Bee abundance

Bee abundance was recorded by direct visual observation during the flowering period, starting from 10 % flowering and continuing at weekly intervals until completion of flowering. Bees visiting flowers within a 1m² area were counted for five minutes at 08:00, 10:00, 12:00, 14:00, 16:00 and 18:00 h. The observations were expressed as mean number of bees/m²/5 min

Foraging rate

Foraging rate was determined by recording the number of mustard flowers visited by individual worker bees in one minute. Observations were made at two-hour intervals from 08:00 to 18:00 h using direct visual observation, a manual counter and stopwatch. The results were expressed as mean no of flower visits/min

Foraging speed

Foraging speed was determined by recording the time taken by individual bees to visit and handle a single mustard flower using a stopwatch. Observations were made at two-hour intervals from 08:00 to 18:00 h and expressed as mean time spent in seconds/flower.

Results and Discussion

Comparative visitation pattern and bee abundance of different bee species on mustard flowers during *Rabi* 2025–26

The visitation pattern of the five major bee species on mustard flowers showed considerable variation with time of day during *rabi* 2025–26 (Table 1; Fig. 1). No bee visitation was recorded at 08:00 h, while activity commenced at 10:00 h with an overall mean abundance of 17.89 bees/5 min. Bee abundance increased to a maximum of 25.43 bees/5 min at 12:00 h, followed by 23.57 bees/5 min at 14:00 h, 17.29 bees/5 min at 16:00 h, and 8.54 bees/5 min at 18:00 h. Thus, bee activity was concentrated mainly during the middle hours of the day, with a progressive decline during the evening.

Among the bee species, *Tetragonula iridipennis*

consistently recorded the highest visitation at most observation hours (Table 1; Fig. 1). Its abundance increased from 23.86 bees/5 min at 10:00 h to 33.43 bees/5 min at 12:00 h, followed by 30.29, 23.00 and 15.86 bees/5 min at 14:00, 16:00 and 18:00 h, respectively. *Apis florea* showed a similar pattern, with its abundance increasing from 20.86 bees/5 min at 10:00 h to 28.43 bees/5 min at 12:00 h, followed by a decline to 9.29 bees/5 min at 18:00 h. *A. mellifera*, *A. cerana indica* and *A. dorsata* also attained their maximum abundance at 12:00 h, recording 23.71, 22.29 and 19.29 bees/5 min, respectively.

Considering the overall mean, *T. iridipennis* recorded the highest abundance (21.07 bees/5 min), contributing 27.27 per cent of the total bee visitation, followed by *A. florea* (17.05 bees/5 min; 22.07%), *A. mellifera* (14.26 bees/5 min; 18.46%), *A. cerana indica* (13.24 bees/5 min; 17.13%) and *A. dorsata* (11.64 bees/5 min; 15.07%). The overall mean abundance of the five bee species was 15.45 bees/5 min. Hence, *T. iridipennis* was the most abundant visitor, whereas *A. dorsata* recorded the lowest overall abundance, while 12:00 h emerged as the peak period of bee visitation on mustard flowers (Table 1; Fig. 1).

The present study showed a clear diurnal variation in bee abundance on mustard, with visitation increasing from 17.89 bees/5 min at 10:00 h to a maximum of 25.43 bees/5 min at 12:00 h, followed by a gradual decline towards evening. This midday peak was comparable with Young *et al.,* (2021), who reported distinct daily foraging patterns among *Apis* species. Gayen and Patra (2023) also recorded peak activity of *A. dorsata* and *A. florea* around the midday period on mustard. In the present study, *T. iridipennis* was the most abundant visitor (21.07 bees/5 min), whereas *A. dorsata* recorded the lowest abundance (11.64 bees/5 min). In contrast, Poonam *et al.,* (2022) reported *A. florea* as the most abundant pollinator in rapeseed-mustard. Adlin Prajula *et al.,* (2024) similarly observed peak *A. florea* activity around 13:00 h. Thus, the present findings support the occurrence of higher bee activity during the midday period, while differences in dominant species may reflect variation in location and environmental conditions.

Comparative foraging speed of different bee species n mustard flowers during *Rabi* 2025–26

The foraging speed of the five major bee species on mustard flowers showed considerable variation with respect to time of day during *rabi* 2025–26 (Table 2; Fig. 2). No foraging activity was recorded at 08:00 h. The overall mean time spent per flower was 8.08 sec/flower at 10:00 h, which decreased to the minimum of 6.53 sec/flower at 12:00 h. Thereafter, the time spent per flower increased to 7.31, 8.93 and 9.36 sec/flower at 14:00, 16:00 and 18:00 h, respectively. Thus, the shortest overall flower-handling time was observed at 12:00 h, indicating comparatively faster foraging activity during the midday period.

Among the bee species, *Apis mellifera* recorded the shortest overall mean flower-handling time (3.57 sec/flower), followed by *A. cerana indica* (3.86 sec/flower) and *A. dorsata* (4.35 sec/flower). *Apis florea* showed a comparatively longer mean duration of 6.03 sec/flower, whereas *Tetragonula iridipennis* recorded the longest duration of 15.71 sec/flower. At 10:00 h, the time spent per flower was 5.04, 4.16, 4.24, 7.49 and 19.49 sec for *A. dorsata*, *A. cerana indica*, *A. mellifera*, *A. florea* and *T. iridipennis*, respectively. At 12:00 h, the corresponding values decreased to 4.16, 3.89, 3.87, 6.04 and 14.70 sec/flower, respectively, representing the lowest handling time for most of the species. A progressive increase in flower-handling time was observed during the later hours of the day (Table 2; Fig. 2). At 14:00 h, *A. mellifera* and *A. cerana indica* recorded 4.10 sec/flower each, while *A. dorsata*, *A. florea* and *T. iridipennis* recorded 4.59, 6.23 and 17.52 sec/flower, respectively. At 16:00 h, the values increased to 5.95, 5.19, 4.53, 7.99 and 20.97 sec/flower, respectively. The highest duration was recorded at 18:00 h, when *T. iridipennis* required 21.56 sec/flower, followed by *A. florea* (8.42), *A. dorsata* (6.34), *A. cerana indica* (5.79) and *A. mellifera* (4.69 sec/flower).

Considering the overall mean across all observation hours, the five bee species showed clear differences in flower-handling time (Table 2; Fig. 2). *A. mellifera* recorded the shortest overall mean of 3.57 sec/flower, indicating the fastest flower handling, followed by *A. cerana indica* (3.86 sec/flower) and *A. dorsata* (4.35 sec/flower). *A. florea* recorded an overall mean of 6.03 sec/flower, whereas *T. iridipennis* required the longest time (15.71 sec/flower). The overall mean for all five bee species was 6.70 sec/flower. Therefore, *A. mellifera* exhibited the fastest foraging speed, while *T. iridipennis* showed the slowest flower-handling speed, with the overall shortest handling time occurring at 12:00 h.

Table.1 Comparative visitation pattern and bee abundance of different bee species on mustard flowers during Rabi 2025–26 (Mean no. of bees observed/5 mins)

Foraging time(Hours of the day)	*Tetragonula iridipennis*	*Apis florea*	*Apis mellifera*	*Apis cerana indica*	*Apis dorsata*	Mean
8:00	0.00	0.00	0.00	0.00	0.00	**0.00**
10:00	23.86	20.86	17.86	14.71	12.14	**17.89**
12:00	33.43	28.43	23.71	22.29	19.29	**25.43**
14:00	30.29	25.57	22.00	21.14	18.86	**23.57**
16:00	23.00	18.14	16.14	15.14	14.00	**17.29**
18:00	15.86	9.29	5.86	6.14	5.57	**8.54**
Mean	**21.07**	**17.05**	**14.26**	**13.24**	**11.64**	**15.45**
Percentage	**27.27**	**22.07**	**18.46**	**17.13**	**15.07**	

Table.2 Comparative foraging speed of different bee species on mustard flowers during *Rabi* 2025–26 (Mean time spent in seconds/flower)

Foraging time (Hours of the day)	*Apis dorsata*	*Apis cerana indica*	*Apis mellifera*	*Apis florea*	*Tetragonula iridipennis*	Mean
8:00	0.00	0.00	0.00	0.00	0.00	**0.00**
10:00	5.04	4.16	4.24	7.49	19.49	**8.08**
12:00	4.16	3.89	3.87	6.04	14.70	**6.53**
14:00	4.59	4.10	4.10	6.23	17.52	**7.31**
16:00	5.95	5.19	4.53	7.99	20.97	**8.93**
18:00	6.34	5.79	4.69	8.42	21.56	**9.36**
Mean	**4.35**	**3.86**	**3.57**	**6.03**	**15.71**	**6.70**

Table.3 Comparative foraging rate of different bee species on mustard flowers during *Rabi* 2025–26 (No.of flowers visited by individual bee/minute)

Foraging time (Hours of the day)	*Apis mellifera*	*Apis cerana indica*	*Apis dorsata*	*Apis florea*	*Tetragonula iridipennis*	Mean
8:00	0.00	0.00	0.00	0.00	0.00	**0.00**
10:00	18.57	14.86	11.86	9.29	5.57	**12.03**
12:00	21.71	18.86	16.57	12.57	7.86	**15.51**
14:00	19.57	16.57	13.71	10.14	6.14	**13.23**
16:00	16.29	11.57	9.71	8.71	4.71	**10.20**
18:00	11.43	8.00	6.71	3.71	2.29	**6.43**
Mean	**14.60**	**11.64**	**9.76**	**7.40**	**4.43**	**9.57**

Fig.1 Comparative visitation pattern and bee abundance of different bee species on mustard flowers during *Rabi* 2025–26 (Mean no. of bees observed/5 mins)

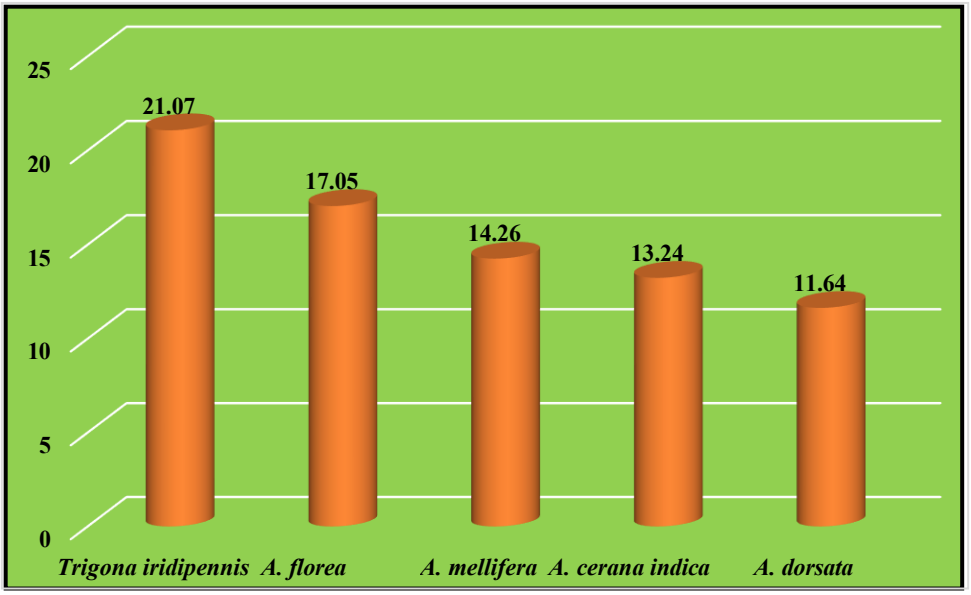


Fig.2 Comparative foraging speed of different bee species on mustard flowers during *Rabi* 2025–26 (Mean time spent in seconds/flower)

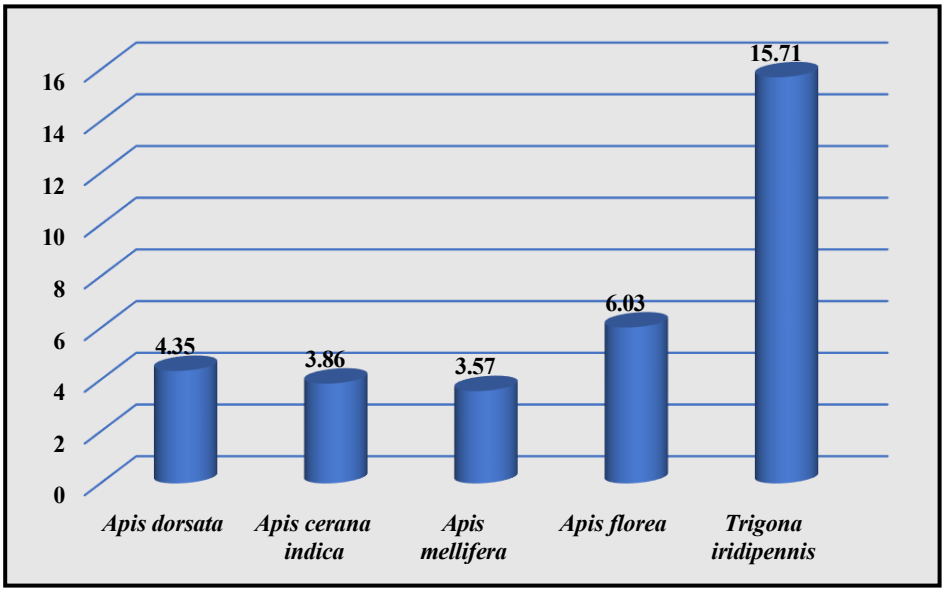
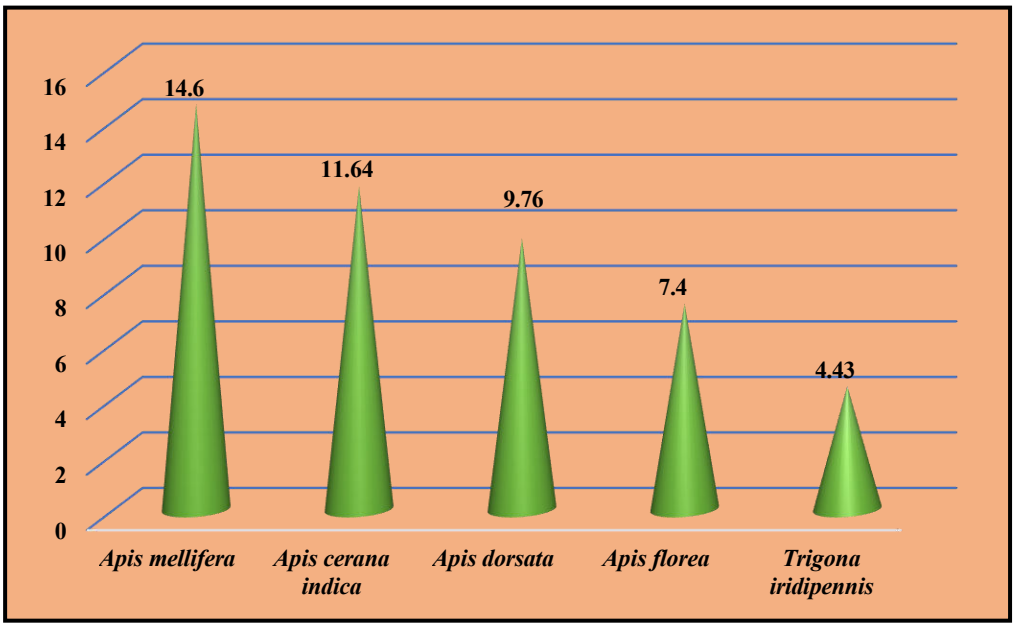


Fig.3 Comparative foraging rate of different bee species on mustard flowers during *Rabi* 2025–26 (No.of flowers visited by individual bee/minute)



The present study showed clear species-wise variation in foraging speed, with *Apis mellifera* recording the shortest flower-handling time (3.57 sec/flower) and *Tetragonula iridipennis* the longest (15.71 sec/flower). *A. cerana indica* (3.86 sec) and *A. dorsata* (4.35 sec) also showed relatively rapid handling, while *A. florea* required 6.03 sec/flower. Nagpal *et al.,* (2020) similarly recorded the shortest handling times for *A. cerana indica* (2.33 sec), *A. mellifera* (2.60 sec) and *A. dorsata* (3.41 sec), whereas *A. florea* required the longest time (6.08 sec). Kaur *et al.,* (2022) also reported *A. mellifera* as a rapid forager on mustard, with 4.42 sec/flower. Thus, the present results agree with earlier studies in showing faster flower handling by *Apis* species, although *T. iridipennis* exhibited substantially longer handling time in the present study.

Comparative foraging rate of different bee species on mustard flowers during *Rabi* 2025–26

The foraging rate of the five major bee species showed a distinct diurnal pattern during *rabi* 2025–26 (Table 3; Fig. 3). No flower visitation was recorded at 08:00 h. *Apis mellifera* recorded 18.57 flowers/min at 10:00 h, which increased to the maximum of 21.71 flowers/min at 12:00 h and subsequently declined to 19.57, 16.29 and 11.43 flowers/min at 14:00, 16:00 and 18:00 h, respectively. *Apis cerana indica* showed a similar pattern, with the rate increasing from 14.86 flowers/min at 10:00 h to 18.86 flowers/min at 12:00 h, followed by a decline to 16.57, 11.57 and 8.00 flowers/min, respectively.

Apis dorsata recorded 11.86 flowers/min at 10:00 h, which increased to 16.57 flowers/min at 12:00 h and then decreased to 13.71, 9.71 and 6.71 flowers/min at 14:00, 16:00 and 18:00 h, respectively. Similarly, *Apis florea* showed a foraging rate of 9.29 flowers/min at 10:00 h, reaching 12.57 flowers/min at 12:00 h, followed by 10.14, 8.71 and 3.71 flowers/min at 14:00, 16:00 and 18:00 h, respectively. *Tetragonula iridipennis* exhibited the lowest foraging rate throughout the observation period, increasing from 5.57 flowers/min at 10:00 h to 7.86 flowers/min at 12:00 h, and thereafter declining to 6.14, 4.71 and 2.29 flowers/min at 14:00, 16:00 and 18:00 h, respectively.

Considering the overall mean, *A. mellifera* exhibited the highest foraging rate (14.60 flowers/min), followed by *A. cerana indica* (11.64 flowers/min) and *A. dorsata* (9.76 flowers/min). *Apis florea* recorded a mean foraging rate of 7.40 flowers/min, while *T. iridipennis* showed the lowest value of 4.43 flowers/min. The overall mean foraging rate of all five bee species was 9.57 flowers/min. Thus, *A. mellifera* was the most active flower-visiting species, whereas *T. iridipennis* showed

the lowest flower visitation rate. The results indicate distinct species-specific differences in foraging efficiency, with 12:00 h representing the peak period of flower visitation on mustard flowers. The present study showed clear species-wise differences in foraging rate, with *Apis mellifera* recording the highest rate (14.60 flowers/min), followed by *A. cerana indica* (11.64) and *A. dorsata* (9.76 flowers/min), while *Tetragonula iridipennis* recorded the lowest rate (4.43 flowers/min). Bhatnagar *et al.,* (2011) similarly reported higher foraging rates of *A. mellifera* than other *Apis* species on mustard. Nagpal *et al.,* (2020) also observed comparatively higher flower visitation by *A. mellifera*, supporting the present finding. The peak foraging rate at 12:00 h was consistent with the greater midday bee activity reported by Kumari *et al.,* (2020). Thus, *A. mellifera* was the most efficient forager, whereas *T. iridipennis* showed the lowest foraging rate.

The study revealed clear differences in the abundance and foraging behaviour of the five major bee species visiting mustard (*Brassica juncea* L.). 12:00 h was the most favourable period for bee activity, recording the highest overall bee abundance and fastest flower handling. Among the species, *Tetragonula iridipennis* recorded the highest abundance (21.07 bees/5 min), whereas *Apis dorsata* recorded the lowest abundance (11.64 bees/5 min). For foraging efficiency, *Apis mellifera* recorded the highest foraging rate (14.60 flowers/min) and the fastest foraging speed (3.57 sec/flower), while *T. iridipennis* recorded the lowest foraging rate (4.43 flowers/min) and slowest foraging speed (15.71 sec/flower). Overall, the results confirmed that bee abundance and foraging efficiency varied among species, with *T. iridipennis* being the most abundant visitor but *A. mellifera* being the most efficient forager on mustard flowers.

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Authors' Contribution

Sriram K. conducted the research and was involved in the experimental work, observations, and data recording. P. S. Neharkar and M. M. Sonkamble provided guidance throughout the research process. F. S. Khan carried out the critical review of the manuscript. Leela Prasanna and Nilavazhagan L. assisted in field observations and experimental activities. All authors read and approved the final manuscript.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

References

Adlin Prajula, J. G., Acharya, V. S., & Syed Mohamed Ibrahim, S. (2024). Insect pollinators of mustard and their foraging behaviour. *Indian Journal of Entomology, 86*(4), 1338– 1341. https://doi.org/10.55446/IJE.2023.1096

Bhatnagar, P., Sharma, H. K., & Gupta, J. K. (2011). Foraging behaviour of honeybees (*Apis* spp.) on Indian mustard (*Brassica juncea* L.). *Journal of Oilseeds Research, 28*(1), 29– 32.

Bijarniya, S., Sharma, H. K., & Kumar, R. (2024). Studies on insect pollinator fauna and abundance of honeybees in Indian mustard (*Brassica juncea* L.). *Journal of Entomological Research, 48*(2), 215–221.

Gayen, A. K., & Patra, S. (2023). Comparative study on foraging activity of two wild honeybee *Apis dorsata* F. and *Apis florea* F. on flowers of mustard plant (*Brassica juncea*, family Brassicaceae), at North 24 Parganas district of West Bengal, India. In *International Seminar on*

Recent Developmental Trends in Biological Research (p. 30).

Kaur, H., Sharma, S. K., & Mehta, V. (2022). Activity of honeybees on *Brassica* crops in Himachal Pradesh. *Indian Journal of Entomology, 84*(2), 470–472. https://doi.org/10.55446/IJE.2021.378

Kumari, S., Chhuneja, P. K., Singh, J., & Choudhary, A. (2020). Relative foraging intensity of various honey bee species on *Brassica juncea* (L.) Czern & Coss. *Agricultural Research Journal, 57*(5), 730–737. https://doi.org/10.5958/2395-146X.2020.00107.6

Kunjwal, N., Kumar, A., & Srivastava, P. (2014). Foraging behaviour and diversity of insect pollinators on mustard (*Brassica juncea* L.). *Indian Journal of Agricultural Sciences, 84*(11), 1378–1382.

Maity, A., Chakrabarty, S. K., & Yadav, J. B. (2014). Foraging behaviour of honeybees (*Apis* spp.) (Hymenoptera: Apidae) in hybrid seed production of Indian mustard (*Brassica juncea*). *The Indian Journal of Agricultural Sciences, 84*(11), 1374–1377. https://doi.org/10.56093/ijas.v84i11.44646

Nagpal, K., Yadav, S., & Singh, R. (2019). Foraging behaviour and resource collection by different *Apis* species on Indian mustard (*Brassica juncea* L.). *Journal of Entomology and Zoology Studies, 7*(6), 1024–1028.

Nagpal, K., Yadav, S., & Singh, R. (2020). Foraging speed of different *Apis* spp. on Indian mustard (*Brassica juncea*) flowers. *Journal of Entomology and Zoology Studies, 8*(2), 628–632.

Poonam, Yadav, S., Jat, M. K., Yadav, S. S., & Kumar, H. (2022). Diversity, abundance and foraging behaviour of pollinators in early sown rapeseed-mustard genotypes. *Journal of Agriculture and Ecology, 14*, 104–112. https://doi.org/10.58628/JAE-2214-215

Young, A. M., Kohl, P. L., Rutschmann, B., Steffan-Dewenter, I., Brockmann, A., & Dyer, F. C. (2021). Temporal and spatial foraging patterns of three Asian honey bee species in Bangalore, India. *Apidologie, 52*, 503–523. https://doi.org/10.1007/s13592-020-00839-1

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