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Diurnal foraging activity of little bee (*Apis Florea*) in mustard

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ABSTRACT

Daily foraging activity of *Apis florea* was studied in mustard with and without application of jaggery solution (10%). No bee activity was recorded during 6.00-8.00 am. Abundance of *A. florea* was 0.56 bees/m²/5 min during 8.00-10.00 am. It gradually increased and reached its peak during 12.00 – 2.00 pm and thereafter started gradually declined to 1.19 during 4.00-6.00 pm. The pattern was similar in jaggery treated mustard with abundance of 0.22 bees/m²/5 min at 8.00-10.00 am, peak of 11.04 bees/m²/5 min during 12.00-2.00 pm and 2.30 bees/m²/5 min during 4.00-6.00 pm. Foliar application significantly increased bee visitation from a baseline of 3.94 bees/m²/5 min to a peak of 7.78 bees/m²/5 min at 1 day after spraying (1 DAS), compared to 5.83 bees/m²/5 min in untreated control plots. A second application produced a similar short-term boost (5.11 bees/m²/5 min at 1 DA2S) as against 3.17/ bees/m²/5 min in untreated plots on the same day. Overall bee activity was higher in jaggery treated plot (4.78 bees/m²/5 min) than untreated plots (3.73 bees/m²/5 min). Overall, 10% jaggery solution serves as an effective short-term attractant to boost *A. florea* pollination on mustard flowers.

Keywords: *Brassica juncea*, *Apis florea*, Jaggery solution, Foraging activity, Diurnal variation, Bee abundance, Pollination

Introduction

Mustard (*Brassica juncea* L.) is one of the major oilseed crops cultivated in India and is an important source of edible oil. The crop is predominantly self-compatible; however, insect visitation can contribute to effective pollination and improve reproductive performance. The flowers of mustard produce nectar and pollen and attract a wide range of insect visitors, including honey bees, which are considered important pollinators of the crop.

Indian mustard (*Brassica juncea* L.) is one of the important cultivated species of the genus *Brassica*, occupying a major share of the cultivated area. Its seeds are nutritionally and economically important, containing about 28–32% oil and 28–36% protein (Chandrashekhar *et al.*, 2013; Solvance & Pathak, 2016) [1, 2].

As a predominantly cross-pollinated crop, mustard benefits considerably from insect pollination, with honey bees serving as important pollination service providers (Singh *et al.*, 2005; Mohapatra *et al.*, 2010) [4, 3]. Therefore, understanding the abundance and foraging activity of honey bees on mustard is important for assessing their role in pollination and crop productivity. Das *et al.* (2018) [5] recorded *A. florea* among the honey-bee visitors of *Brassica juncea* flowers.

Among honey bees, *Apis florea* is an important wild honey bee species that frequently visits flowering oilseed crops. Its small body size and active foraging behaviour enable it to visit a large number of flowers during the flowering period. Therefore, understanding the diurnal foraging behaviour of *A. florea* and methods for enhancing its visitation may contribute to improved pollination of mustard. Hence, the present study was undertaken to assess the effect of jaggery solution on the foraging activity of *A. florea* on mustard flowers and to study its temporal variation in comparison with an untreated plot.

Materials and Methods

The present investigation was conducted at the experimental Apiary and research farm of the College of Agriculture, Dharashiv, Maharashtra, India during the *rabi* season of 2025-2026. The experimental site is geographically located at latitude 18°16'58" N and longitude 76°04'24" E. The experiment was carried out under natural field conditions to study the foraging of *A. florea*. The experiment was conducted under natural field conditions with three replications. Each plot measured 4.0 × 3.0 m, with a spacing of 50 × 15 cm. Two treatments were studied *viz.* jaggery solution @ 10% and untreated plot. The jaggery solution was applied during the flowering period, and observations were recorded before and after application. Foraging activity of *Apis florea* was assessed by counting bees visiting a 1 m² area of mustard flowers for five minutes (bees/m²/5 min). Observations were taken at two-hour intervals from 6:00 AM to 6:00 PM at 1

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day before spraying (1 DBS) and at 1, 3, 5 and 7 days after spraying (DAS). Similar observations were recorded at 1, 3, 5 and 7 days after the second spray (DA2S). Diurnal activity was assessed during six time intervals, from 6:00 AM to 6:00 PM.

Result and Discussion

Foraging activity of bees on mustard flower after application of jaggery solution

The foraging activity of *A. florea* on mustard flowers following the application of jaggery solution was recorded at different intervals after the first and second sprays, as presented in Table 1 and Fig 1). The observations indicated considerable variation in the foraging population of *A. florea* across different days after application.

At 1 day before spraying (1 DBS), the foraging activity of *A. florea* was relatively low, with a population of 3.94 bees/m²/5 min. Following the application of jaggery solution, the bee population increased markedly and reached 7.78 bees/m²/5 min at 1 day after spraying (1 DAS). Thereafter, the population showed some fluctuation, recording 7.00 bees/m²/5 min at 3 DAS, 5.67 bees/m²/5 min at 5 DAS and

4.22 bees/m²/5 min at 7 DAS. After the second spray, the population was 5.11 bees/m²/5 min at 1 DA2S, followed by 4.28, 3.39 and 1.61 bees/m²/5 min at 3, 5 and 7 DA2S, respectively.

The highest mean population of *A. florea* was therefore recorded at 1 DAS (7.78 bees/m²/5 min), indicating a marked response of the bees during the initial period following application of jaggery solution. After the second spray, the population again showed a relatively higher value at 1 DA2S (5.11 bees/m²/5 min), followed by a gradual decline with increasing days after application. The lowest population was recorded at 7 DA2S (1.61 bees/m²/5 min). This indicates that the effect of jaggery solution on bee visitation was more pronounced during the initial days following application.

A distinct diurnal pattern in foraging activity of *A. florea* was also observed. The maximum activity was recorded during 12:00–2:00 PM,

with a mean population of 11.04 bees/m²/5 min, followed by 2:00–4:00 PM (8.63 bees/m²/5 min) and 10:00 AM–12:00 PM (6.48 bees/m²/5 min). The minimum activity was recorded during 8:00–10:00 AM (0.22 bees/m²/5 min), whereas no foraging activity was observed during 6:00–8:00 AM. Thus, *A. florea* showed maximum foraging activity during the afternoon period, particularly between 12:00 and 2:00 PM.

The present study showed that application of jaggery solution increased the foraging activity of *A. florea* on mustard flowers, particularly during the initial period after spraying. The population increased from 3.94 bees/m²/5 min at 1 DBS to 7.78 bees/m²/5 min at 1 DAS, representing a clear increase following the first application. Although the population declined subsequently, a relatively higher population was again recorded at 1 DA2S (5.11 bees/m²/5 min) after the second application. The lowest population of 1.61 bees/m²/5 min was recorded at 7 DA2S. These observations indicate that the response to jaggery solution was strongest shortly after application and decreased with increasing days after spraying.

The present findings are in similar with Manchare *et al.* (2019) [6]. A 10 per cent jaggery solution was sprayed on the crop as a bee attractant, which increased bee abundance. More *et al.* (2020) [7] and Dorjay *et al.* (2022) [8], who reported increased honey bee foraging activity following application of bee attractants, particularly during the initial period after application. The present study also showed that jaggery solution enhanced bee visitation to mustard flowers during the early period.

A clear diurnal variation was observed in *Apis florea*, with maximum foraging activity during 12:00–2:00 PM (11.04 bees/m²/5 min) and minimum activity during 8:00–10:00 AM (0.22 bees/m²/5 min), while no activity was recorded during 6:00–8:00 AM.

Similar diurnal variation has been reported by Yadav *et al.* (2021) [9] and Manhare *et al.* (2017) [10], who recorded higher bee activity during the late morning to afternoon period. These findings indicate that the foraging activity of *A. florea* on mustard was strongly influenced by the time of day.

Table 1. Effect of jaggery application on foraging activity of *Apis florea* on mustard

Time	Number of bees/m ² /5min									
	First spray					Second spray				
	1DBS	1DAS	3DAS	5DAS	7DAS	1DA2S	3DA2S	5DA2S	7DA2S	Mean
6-8 am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8-10 am	0.00	1.33	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.22
10-12 am	6.33	9.00	7.33	12.00	9.33	10.33	1.00	2.00	1.00	6.48
12-2 pm	7.33	15.00	20.67	9.00	8.00	12.67	11.00	10.33	5.33	11.04
2-4 pm	9.33	13.00	7.67	11.67	4.00	7.67	13.67	7.67	3.00	8.63
4-6 pm	0.67	8.33	6.33	0.67	4.00	0.00	0.00	0.33	0.33	2.30
Mean	3.94	7.78	7.00	5.67	4.22	5.11	4.28	3.39	1.61	4.78

*each value represents mean of 3 replications.

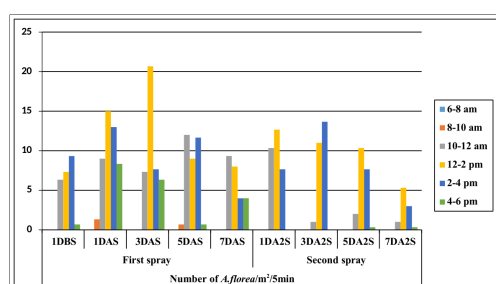


Figure 1. Effect of jaggery application on foraging activity of *Apis florea* on mustard

2. Foraging activity of bees on mustard in untreated plot

The foraging activity of *Apis florea* on mustard flowers in the untreated plot was recorded at different intervals corresponding to the observations made after the first and second spray schedules, as presented in Table 2 (Fig 1). In the absence of attractant application, the

population showed considerable variation among different observation days.

At 1 day before spraying (1 DBS), the foraging activity of *A. florea* was recorded at 4.44 bees/m²/5 min. In the untreated plot, where no attractant was applied, the foraging activity varied naturally throughout the observation period. The highest overall mean activity was recorded at 1 DAS (5.83 bees/m²/5 min), followed by 3 DAS (4.83 bees/m²/5 min) and 5 DAS (4.67 bees/m²/5 min). The activity subsequently declined to 3.50 bees/m²/5 min at 7 DAS, 3.17 bees/m²/5 min at 1 DA2S and 3 DA2S,

2.39 bees/m²/5 min at 5 DA2S, and reached the lowest value of 1.61 bees/m²/5 min at 7 DA2S.

A clear diurnal variation was observed in the foraging activity of *A. florea*. The maximum activity was recorded during 12:00–2:00 PM (9.52 bees/m²/5 min), followed by 10:00–12:00 AM (6.37 bees/m²/5 min) and 2:00–4:00 PM (4.78 bees/m²/5 min). Comparatively lower

activity was recorded during 4:00–6:00 PM (1.19 bees/m²/5 min) and 8:00–10:00 AM (0.56 bees/m²/5 min). No foraging activity was recorded during 6:00–8:00 AM.

The maximum foraging activity of *Apis florea* during 12:00–2:00 PM, with no activity during 6:00–8:00 AM, indicated a distinct midday foraging pattern under untreated conditions. This finding similar with [Prajula et al. \(2024\) \[11\]](#), who recorded peak activity of *A. florea* at 13:00 h on mustard, with 12.44 bees/10 plants/5 min and a maximum foraging rate of 14.49 flowers/5 min. Similarly, [Nagpal et al. \(2019\) \[12\]](#) and [Roy et al. \(2014\) \[13\]](#) reported greater insect visitor activity on mustard during the middle part of the day. [Parida et al. \(2023\) \[14\]](#) observed *A. florea* foraging from 08:00 to 17:00 h on rapeseed, while [Tan et al. \(2004\) \[15\]](#) reported variation in visitation time among sympatric honey bee species. These findings support the present observation of higher

A. florea activity during the midday period.

Table 2. Foraging activity of bees on mustard in untreated plot

Time	Number of bees/m ² /5min									
	First spray					Second spray				
	1DBS	1DAS	3DAS	5DAS	7DAS	1DA2S	3DA2S	5DA2S	7DA2S	Mean
6-8 am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8-10 am	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56
10-12 am	8.67	13.00	10.00	7.00	5.00	0.67	4.00	3.33	5.67	6.37
12-2 pm	6.00	12.00	11.33	15.00	12.00	10.33	8.33	6.67	4.00	9.52
2-4 pm	6.33	7.00	3.67	3.00	4.00	8.00	6.67	4.33	0.00	4.78
4-6 pm	0.67	3.00	4.00	3.00	0.00	0.00	0.00	0.00	0.00	1.19
Mean	4.44	5.83	4.83	4.67	3.50	3.17	3.17	2.39	1.61	3.73

*each value represents mean of 3 replications.

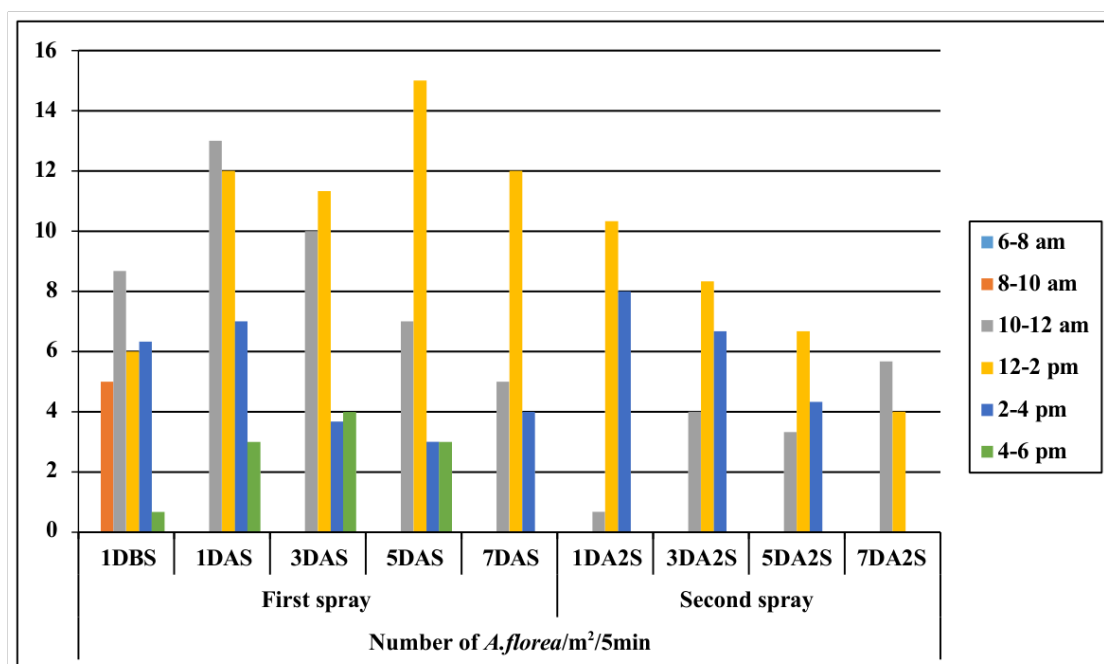


Figure 2. Foraging activity of *Apis florea* on mustard in untreated plot

Overall, the untreated plot recorded an average foraging activity of 3.73 bees/m²/5 min, with the highest activity occurring during 12:00–2:00 PM and the

lowest during 6:00–8:00 AM. The gradual decline in activity during the later observation dates indicates natural variation in *A. florea* visitation in the absence of an attractant. (Fig 3)

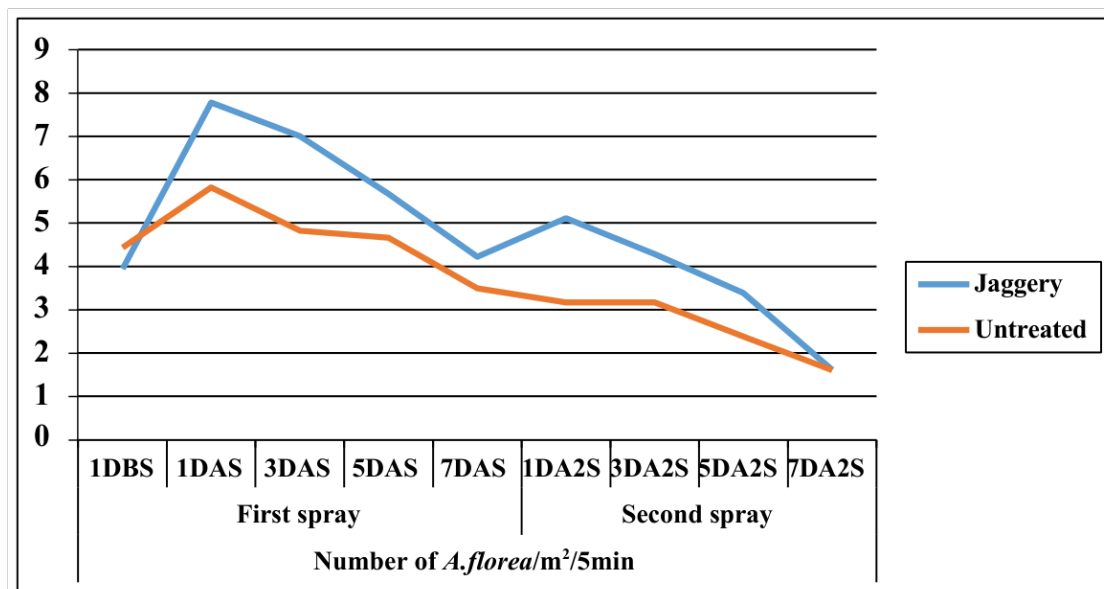


Figure 3. Comparative foraging activity of *Apis florea* on mustard CONCLUSION

The study showed that application of jaggery solution increased the foraging activity of *Apis florea* on mustard flowers, especially during the early days after spraying. The bee population increased from 3.94 bees/m²/5 min before spraying to

7.78 bees/m²/5 min at 1 DAS, after which it gradually decreased with time. Foraging activity also varied with the time of day, with the highest activity recorded during 12:00–2:00 PM, while no activity was observed during 6:00–8:00 AM. The untreated plot recorded a lower overall bee population of 3.73 bees/m²/5 min. These findings suggest that jaggery solution can help increase *A. florea* visitation to mustard flowers, particularly shortly after application, with the highest natural foraging activity occurring around midday.

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