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Rabiul Islam
Senior Scientific Officer, Oilseed Research Centre, Bangladesh Agricultural Research, Institute, Gazipur, Bangladesh

Md. Ariful Islam
Scientific Officer, Oilseed Research Centre, Bangladesh Agricultural Research, Institute, Gazipur, Bangladesh

Krisna Chandra Saha
Scientific Officer, Oilseed Research Centre, Bangladesh Agricultural Research, Institute, Gazipur, Bangladesh

Hosna Kohinoor
Senior Scientific Officer, Oilseed Research Centre, Bangladesh Agricultural Research, Institute, Gazipur, Bangladesh

Nazneen Ara Sultana
Senior Scientific Officer, Oilseed Research Centre, Bangladesh Agricultural Research, Institute, Gazipur, Bangladesh

Saleh Adnan
Department of Primary Industries, Horticulture Entomologist, NSW Australia

Corresponding Author:
Rabiul Islam
Senior Scientific Officer, Oilseed Research Centre, Bangladesh Agricultural Research, Institute, Gazipur, Bangladesh

Foraging behaviour of native honeybee *Apis dorsata* on *Brassica napus*

Rabiul Islam, Md. Ariful Islam, Krisna Chandra Saha, Hosna Kohinoor, Nazneen Ara Sultana and Saleh Adnan

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Abstract
The study was carried out at the Oilseed Research Centre of the Bangladesh Agricultural Research Institute, Gazipur, to monitor the foraging behaviour of native honeybee *Apis dorsata* in order to improve pollination of *Brassica napus* variety BARI Sarisha 8. *A. dorsata* was shown to have a greater foraging rate (18.91 flowers/minute) in the study. *A. dorsata* on *B. napus* was shown to have a faster foraging speed (bee time/flower, 2.91 seconds). The hours of 10.00 h to 12.00 h were found to be the peak foraging times. The present study aims to support the management of a sustainable and economically viable seed production programme for *B. napus*.

Keywords: Pollinators, pollination, foraging behavior, *Apis mellifera*, *Apis dorsata*

Introduction
Honeybees are particularly drawn to the flowers of rapeseed because they are significant sources of both pollen and nectar. They are important rapeseed (*Brassica campestris* L. var. toria) pollinators (Dhakal, 2003) [3]. Around 80% of all pollination activities are carried out by insects, and bees do roughly 80% of all insect pollination, making them the best pollinators (Robinson and Morse, 1989) [12]. Fruits, vegetable seeds, spices, oilseeds, and forage crops all benefit from bee pollination in terms of yield and quality (Partap and Partap, 1997; Dhakal, 2003; NARC, 2008) [10, 3, 16]. So, it is not unexpected that research on bees has contributed much to our understanding of entomophilous pollination of crops. Because honeybee colonies may easily be employed for crop pollination and hybrid seed production programs, this understanding is very important. Bee pollination of crops is the most efficient and affordable way to boost crop productivity and the creation of hybrid seeds. All honeybee species, however, are not always the most effective pollinators of all the crops.
Rapeseed is the second-largest source of protein meal and the third-largest source of vegetable oil worldwide. All honeybee species are effective pollinators in general (Fairhurst *et al.*, 2021) [5] and bees are thought to be responsible for about 90% of the pollination done by insects. So, it is not unexpected that research on bees has contributed much to our understanding of insect pollination of crops. Because honeybee colonies may easily be employed for crop pollination and seed production programs, this understanding is very important. Pollination of the crops by the bees are the most economical and efficient way to increase agricultural productivity and the creation of hybrid seeds. All honeybee species, however, are not always the most effective pollinators of all the crops. Foraging rate (the number of flowers visited per minute) or foraging speed (the amount of time spent on each flower) are important factors to consider when comparing the pollinating effectiveness of various *Apis* species (*A. mellifera* and *A. dorsata*) because more flowers visited per unit time increases the likelihood of pollination because more flowers can be pollinated in a shorter amount of time. According to Hoy *et al.*, 2019 [7], foraging frequency is influenced by a variety of variables, such as insect instinctive foraging behavior, the length of the proboscis, the depth of the corolla, the type of floral rewards, and the density of flowers on a specific cultivar of the crop in question. Foraging efficiency is a trade-off between the nectar or pollen yield anticipated from a flower and the time necessary to gather it. More time will be spent on each bloom if there is more nectar or pollen available. The size and structure of the flower, as well as its parts, such as the petals, stamens, anthers, nectarines, etc., and their placement, have an

impact on the pollination insect's rate of foraging. *B. napus* has slower foraging speed because its flowers are larger and contain more nectar per flower. In general, the likelihood of pollination increases with foraging speed. Hence, it can be concluded that *B. campestris* may benefit more from bee pollination than *B. napus*. Compared to *B. napus*, *B. campestris'* inflorescence has significantly smaller and more closely-spaced flowers. Hence, bees forage more quickly on smaller flowers. On *B. napus*, the bees spend more time per bloom than they do on *B. campestris*. In general, greater is the foraging speed, more are the chances of pollination. The foraging rate is impacted by environmental or climatic elements such as temperature, relative humidity, light intensity, chilly winds, heavy dew, etc. (Calovi *et al.*, 2021) [1]. These variables change during the day, therefore the foraging pace is also influenced by the time of day. Consequently, the objective of this study was to count the number of flowers visited by *A. mellifera* and *A. dorsata* species per minute on *B. napus* and assess how effectively they pollinate to advance our understanding of seed production, pollination, and bee management technologies.

Materials and methods

Study region and crop

For foraging behavior of bees was observed at Oilseed Research Centre experimental field in Bangladesh Agricultural Research Institute, Gazipur (24.3688° N, 88.6618° E). To study of foraging behavior of *A. dorsata* on *B. napus* we used BARI Sarisha 8 as a variety.

Foraging speed and foraging rate

Foraging speed and foraging rate of *A dorsata* was recorded two hours interval (10 am to 4pm) at different weeks during blooming period. In *B. napus* data was collected on January 13, 20, 27 and 3, 10 February. The design was RCBD with three replications. There was no bee population observed before 10 h and after 16h may be due to foggy and cold weather in the cropping season. Data on the following parameters were collected:

Foraging speed of *A. dorsata* on *B. napus*

The foraging speed was calculated time spend by bees per flower throughout the day at two hours interval in three replications in different sunny days (no cloud in the sky) using stop watch.

Foraging rate of *A. dorsata* on *B. napus*

It was calculated by counting number of flowers visited by bees per minute throughout the observation day at every two hour intervals in three replications. The observations were recorded using stop watch in different sunny days (no cloud in the sky).

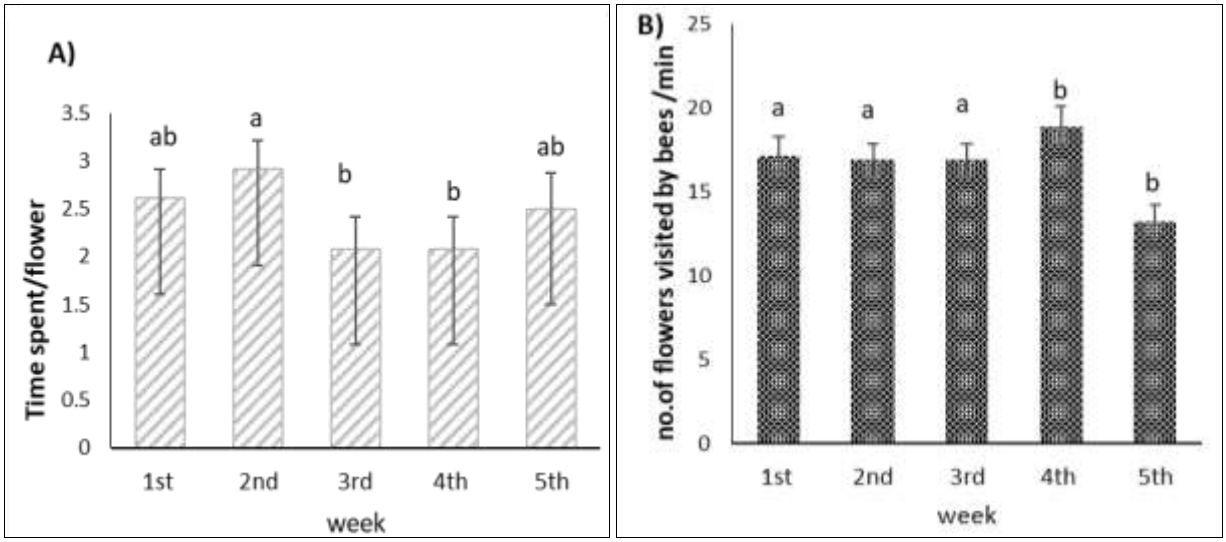
Data analysis

To assess the foraging behavior we used the package R version 3.5.1 (R Core Team 2018) [18]. The data of pollinators behaviour were subjected to statistical analysis using analysis of variance (ANOVA), followed by means comparison with Least Significant Difference (LSD) at P = 0.05.

Results

Foraging speed of *A. dorsata* on *B. napus* over week was observed during 2020-21 cropping season presented in figure 1 A. The foraging speed over the times exposed that the speed varied 1.00 to 3.66 seconds/flower (Figure 1 C). The highest foraging speed (2.91 seconds/flower) of *A. dorsata* was observed at 2nd week which was statistically similar with the results of 1st, 3rd, 4th and 5th week and lowest (2.08 seconds/flower) was observed at 3rd and 4th week of the cropping season (F=2.28, df=4, p>0.07). In case of different times (Figure 1C.) of the day the maximum foraging speed was observed at 10 h (3.33 second/flower) followed by 12 h (3.20 seconds/flower) and lowest was found at 16 h of the day (1.33 seconds/flower). There was statistically difference among the mean value of bees of different times of the day of different weeks (F=20.32, df=3, $p<0.0005$).

The mean data on foraging rate of *A. dorsata* on *B. napus* over week was observed during 2020-21 cropping season presented in Figure 1 B. The foraging rate over the times revealed that the rate varied 10.66 to 21.10 flowers/minute (Figure 1D). There was a statistically significant difference among the values of different weeks of the cropping season (F=8.29, df=4, $p<0.0004$). The highest foraging rate (18.91 flowers/minute) of *A. dorsata* was observed at 4th week and lowest (13.25 flowers/minute) was observed at 5th week of the cropping season. In case of different times of the day the maximum foraging rate was observed at 12 h (18.33 flowers/minute) followed by 10 h (18.26 flowers/minute) which was statistically similar. The lowest was found at 16 h of the day (12.13 flowers/minute). There was statistically difference among the mean value of bees of different times of the day (F=23.21, df=3, $p<0.0005$).



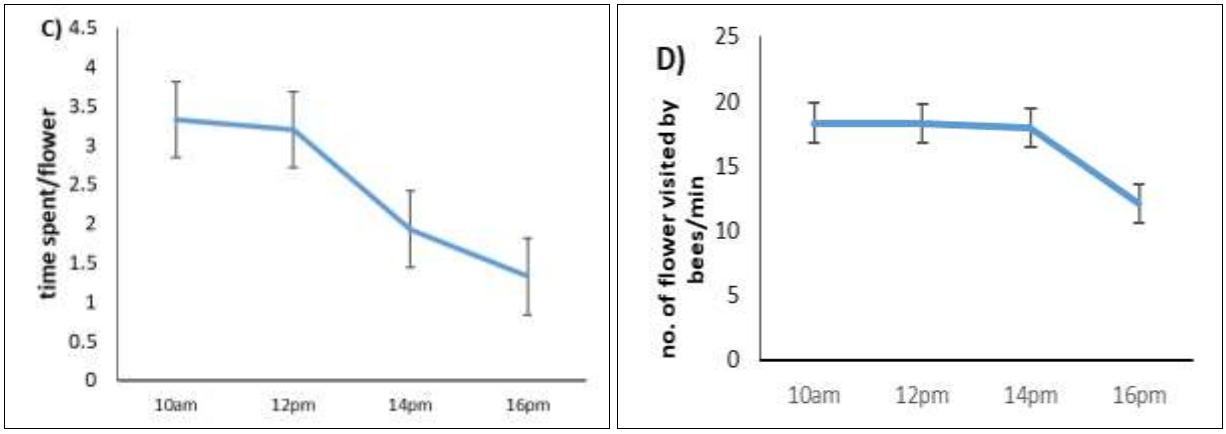


Fig 1: Mean foraging speed and rate over week and time. Error bars are (mean ± S.E). Bars within each figure with the same letter are not significantly different at the 5% significance level

Discussions

The overall mean foraging speed was higher in *A. dorsata* (2.45 seconds/flower) on *B. napus* (2.50 seconds/flower). These results are similar with the findings of Nagpal *et al.*, 2020 who found that the foraging speed was of *A. dorsata* 3.41 second /flower in *B. juncea* at different time of the day of the cropping season. Present results also similar with the results of Srivastava *et al.*, (2017) [14] who stated that *A. dorsata* had the higher foraging speed (5.20 second/flower) in *Brassica oleracea* in India during different date and times. Current result is also match with the results of Inouye (1980) [8]; Murrell and Nash (1981) [15], Devi *et al.*, (2011) [4]. The peak mean foraging speed of *A. dorsata* on *B. napus* it was 3.33, seconds/flower observed at 10-12 h of the day. Present results are matched with the results of Devi *et al., (*2011) [4], who observed that maximum (2.20-2.80 second/flower) foraging speed of *A. dorsata* was found at 12 h of the day and minimum foraging speed was found at 16 h of the day on mustard.

The overall mean foraging rate was found *A. dorsata* on *B. napus*, it was 16.33 flowers/minute. These findings are also match with the results of Dalio (2018) [2]. The findings are also similar with Pudasaini *et al.* 2014, who observed higher number of flowers visited by *A. dorsata* (9.33 and 15.83 flowers) at 10 am and 12 pm, respectively on rapeseed flowers. The higher foraging rate was observed at the 10-12 h of the day by *A. dorsata* on *B. napus*, (18.26, flowers/minute). This finding is also similar with the results of Uma and Verma (1994) [16], Singh *et al.*, (2005) [13] who found that the peak foraging rate of *A. dorsata* was observed at 12h of the day and least was observed at 16 h of the day in *B. juncea.*

It was observed different foraging speed of *A. dorsata* in different *Brassica* sp may be due to the different body morphological size i.e., proboscis length of *A. dorsata* bees, because time taken by a bee to on a flower and remove nectar from it depends on proboscis lengths (Waddington, 1987) [20] and the floral biology and morphology of the *Brassica* sp. and availability of nectar and pollen. It also can vary by the influences of the climatic conditions of the particular growing season of the experimental area. Here it was observed that the *A. dorsata* was spending more time per flower this may be due to their high requirements of pollen and nectar, and larger body size of *A. dorsata*. So the pollen and nectar requirement may be also high in *A. dorsata.* Further detailed research should be taken in this area for better pollination service for yield improvement of rapeseed and mustard.

Conclusion

Foraging rate and foraging speed is important factors for determining of pollination efficiency of any bee species. The highest foraging speed and foraging rate of *Apis dosata* was observed at 10.00 h-12.00 h of the day. Since bee pollination of crops is the most efficient and affordable way to increase crop productivity and improve the production seeds, this study will offer instructions for seed production, pollination, and honeybee management technologies.

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