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Major insect pollinators, relative abundance, and their foraging behaviour on *Brassica napus* L. (mustard)

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Abstract
Mustard *(Brassica napus* L.) is an economically important oilseed crop. It is a self-incompatible crop and needs biological agents, including different insects for cross-pollination. Cross-pollination increases the seed yield and seed quality of mustard. This work was carried out during the winter (rabi) season of 2024-2025 in a field located in the Mushahri block of the Muzaffarpur region. The major insect pollinators' relative abundance, foraging rate, and foraging speed were studied. Observations were taken three times in a day between 10:00-11:00 hrs, 13:00-14:00 hrs and 16:00-17:00 hrs during the full bloom of mustard, and the number of insects of each species visiting the flowers was recorded for 5 minutes. The study revealed that the floral visitors of mustard were seven species belonging to two insect orders, Hymenoptera and Diptera, among which the Hymenopteran order was the major floral visitors. *Apis dorsata* (16.06 flower/min) exhibited high foraging rates and *Episyrphus balteatus* (36.53 sec/flower) exhibited high foraging speed during the present study. The abundance of *Apis mellifera* (6.46 insects/$m^{2/}$5min) was highest during the study.

Keywords: Mustard, insect pollinators, foraging rate, foraging speed, *Apis mellifera*

Introduction

Insects are one of the major groups of pollinators as their association with flowers are well established. As per the FAO report released on May 19, 2023, cross-pollination plays a crucial role in supporting biodiversity and sustaining a healthy ecosystem, which are essential for both agriculture and human well-being. Insect pollinators are responsible for 35% of global crop production, assisting in the pollination of 87 out of 115 major crops worldwide, thereby impacting the stability, diversity, and functioning of both natural and agricultural plant ecosystems. Pollination improves the quality of entomophilous crops such as fruits (Garratt *et al*., 2013) [11], field crops such as oilseed (Bommarco, Marini & Vaissiere, 2012) [7] and vegetables and fruits (Anderson, Rundlof & Smith, 2012). Insect pollinators are very effective in pollinating crops, and there is a positive association between the fruit production and insect visits to the field (Garibaldi *et al*., 2013) [10]. Different insects exhibit different foraging behaviour on diverse flora (Bashir *et al*., 2018; Khan *et al*., 2021) [16]. Hymenoptera, Lepidoptera and Diptera are three major orders of insects taking part in pollination (Jadhav *et al*., 2018) [13] and among Hymenopterans, bees are the top of pollinators (Bashir *et al*., 2018). Insects are responsible for 80% of pollination among which 80% is contributed by bees (Thapa, 2006) [24]. Bumble bees exhibit efficient pollination as compared to honey bees (Wahengbam *et al*., 2019) [25]. Das and Jha (2018) [8] found Hymenopteran insects (*A. mellifera, A. dorsata, A. florea, A. cerana indica, Halictus spp* and *Ceratina spp.),* Dipteran insects (*Eristalinus tabanoides, Episyrphus spp, Chrysoma spp., Musca domestica Linnaeus* and *Sarcophaga spp.)* and Lepidopterans (*Pieris spp.* and *Amata bicincta Kollar*). *Brassica napus* (L), commonly called mustard, is the leading oilseed crop grown in India.

Being a self-incompatible crop their flowers cannot utilize their pollen, and require biological agents like different insect species to transfer the pollen from anther to stigma (Roy *et al*., 2014). Honeybees are the major pollinators of mustard and they have been utilized to carry out managed pollination in the mustard fields (Sharma *et al*., 2004 & Klein *et al*., 2007) [17]. The efficiency of pollination depends upon pollinator diversity, their abundance and foraging behaviour. The present study was undertaken to gather information about major insect pollinators, their relative abundance, foraging rate and foraging speed on *Brassica napus* (L).

Materials and methods

This work was carried out during the winter season from 14 December 2024 to 19 January 2025 at a seven-day interval in a field located in the Mushahri block of Muzaffarpur region. Observations were recorded between 10:00-11:00hrs, 13:00-14:00hrs, 16:00-17:00hrs during the full bloom of mustard. Each observation is replicated three times.

Pollinator diversity

Insect visitors were collected from the field using a 30 cm diameter sweep net. Sweeping was done at one-hour intervals between 10:00 to 17:00 hrs. The collected insects were killed in a glass bottle with 70% ethanol, dried, and preserved in insect cabinets for the purpose of identification. The identification of preserved insects were done using taxonomic keys and available literature.

Relative abundance

The number of insects visiting the flowers of each species was recorded for 5 minutes. Observations were done between 10:00-11:00 hrs, 13:00-14:00 hrs and 16:00-17:00 hrs.

Foraging rate

Foraging rate was recorded as the rate of flowers visit per minute by each type of insect. Observations were recorded between 10:00-11:00hrs, 13:00-14:00hrs and 16:00-17:00hrs during full bloom of mustard.

Foraging speed

Foraging speed was measured by the time spent by each insect species, in seconds per flower. Stopwatch was used for recording the foraging speed. Observations were recorded between 10:00-11:00 hrs, 13:00-14:00 hrs and 16:00-17:00 hrs.

Results and discussion

Pollinator diversity

The results shown in Table 1 indicated that seven species of insects visiting mustard flowers were recorded. The insects belonged to 3 families of 2 orders, namely Hymenoptera and Diptera. The Hymenopteran order was major floral visitors with 5 species belonging to 2 families, namely Apidae and Halictidae. The pollinators of the Apidae family were *Apis mellifera, Apis florea, Apis cerana and Apis dorsata,* while the family Halictidae comprised of *Halictus spp*. The Dipteran order included 2 species of 1 family, Syrphidae. The pollinators of family Syrphidae were *Eristalis spp*. and *Episyrphus balteatus*. Giri *et al*., (2018) [12] recorded the Hymenopterans (*A. mellifera, A. dorsata, and Trigona irridipennis Smith*) as the primary floral visitors on mustard, in which *A. mellifera* and *A. dorsata* were the most prominent. thirteen insect species were observed by Das and Jha (2018) [8] on Indian mustard among which six were from the order Hymenoptera (*A. mellifera*, *A. florea*, *A. dorsata*, *A. cerana indica*, *Halictus spp*. & *Ceratina spp*.) five species from the order Diptera (*Eristalinus tabanoides*, *Musca domestica Linnaeus*, *Episyrphus spp.*, *Sarcophaga spp. & Chrysoma spp.)* and two species from the order Lepidoptera (*Pieris spp. & Amata bicincta Kollar*). Fifteen species of insects which belonged to 4 orders and 7 families were recorded by Abrol & Bajiya (2017) on the mustard bloom. The Hymenopterans were the most abundant order. Nagpal (2016) observed sixteen species which belonged to nine families of four orders. Poonam *et al*. (2022) documented 17 insect pollinator species of mustard which belonged to nine families of four orders. Thirty-one species were observed by Adlin *et al*. (2023) which belonged to sixteen families of six orders. Bijarniya *et al*. (2024) accounted for 36 species which belonged to twenty different families of eight orders that visited mustard bloom. According to Wahid *et al*., (2025) [26] twenty-seven different insect species visited mustard flowers, which belonged to seventeen families of five orders.

Table 1: Major insect pollinators on Brassica napus (L).

Major Insect pollinator on sarson			
S. No	**Name of Insect**	**Order**	**Family**
1	*Apis dorsata*	Hymenoptera	Apidae
2	*Apis cerana*		Apidae
3	*Apis florea*		Apidae
4	*Apis mellifera*		Apidae
5	*Halictus sp.*		Halictidae
6	*Eristalis sp.*	Diptera	Syrphidae
7	*Episyrphus balteatus*		Syrphidae

Relative abundance

The highest mean of abundance was exhibited by *Apis mellifera* (6.46 bees per square meter per 5 minutes), and then *Halictus spp*. (2.5 bees per square meter per 5 minutes), *Apis dorsata* (1.86 bees per square meter per 5 minutes), *Apis cerana* (1.66 bees per square meter per 5 minutes), *Apis florea* (1.6 bees per square meter per 5 minutes), *Episyrphus balteatus* (0.93 bees per square meter per 5 minutes) and *Eristalis spp*. (0.4 bees per square meter per 5 minutes) respectively (Table 2). The findings concur with the results of research work by Abrol & Bajiya (2017) & Puddasini *et al*., (2015), who also found *Apis mellifera* to be highest abundant, however, Giri *et al*., (2018) [12] & Nagpal *et al*., (2016) found *Apis dorsata* as the most abundant pollinator.

Table 2: Relative abundance (Number of bees per square meter per 5 minutes) of pollinators on Sarson

S. No	Names of Insects	Time of observations			Grand mean
		In hours			
		10:00-11:00	13:00-14:00	16:00-17:00	
1	*Apis mellifera*	1.2	9	9.2	6.46
2	*Apis florea*	2.4	1.2	1.2	1.6
3	*Apis cerana*	2.6	1.3	1.1	1.66
4	*Apis dorsata*	3.6	0.5	1.5	1.86
5	*Halictus sp.*	2.2	3.1	2.2	2.5
6	*Eristalis sp.*	0.6	0.2	0.4	0.4
7	*Episyrphus balteatus*	0.6	1.4	0.8	0.93
	Mean	1.88	2.38	2.34	2.2

Foraging rate

In the present study, *Apis dorsata* (16.06 flowers/minute) exhibited the highest mean of foraging rate followed by *Apis cerana* (15.73 flowers/minute), *Apis mellifera* (13.73 flowers/minute), *Eristalis spp*. (11.8 flower/min), *Halictus spp*. (9.4 flower/minute), *Apis florea* (3.2 flower/minute) and *Episyrphus balteatus* (1.8 flower/minute) (Table 3). Similarly, Srivastava *et al*., (2017) [23] & Kakar *et al*., (1981) [15] also recorded the highest mean of foraging rate exhibited by *Apis dorsata*. However, the findings differ with the results of research work by Wahid *et al*., (2025) [26] & Kunjwal *et al*., (2014) [18/], who accounted *Apis mellifera* to exhibit the peak average foraging rate, whereas Poonam *et al*., (2022) reported the maximum mean of foraging rate by *Apis cerana.*

Table 3: Foraging rate (Number of flowers visited per minute) by a foraging insect on Sarson.

S. No	Name of Insects	Time of observations			Grand mean
		In hours			
		10:00-11:00	13:00-14:00	16:00-17:00	
1	*Apis mellifera*	14.6	12.4	14.2	13.73
2	*Apis florea*	2.8	2.9	3.9	3.2
3	*Apis cerana*	18.6	14.4	14.2	15.73
4	*Apis dorsata*	19.8	13.8	14.6	16.06
5	*Halictus sp.*	7.2	11.2	9.8	9.4
6	*Eristalis sp.*	13.4	9.2	12.8	11.8
7	*Episyrphus balteatus*	1.8	1.8	1.8	1.8
	Mean	11.17	9.38	10.18	10.24

Foraging speed

Episyrphus balteatus (36.53 sec/flower) exhibited the highest mean of foraging speed, which was followed by *Apis florea* (26.33 sec/flower), *Apis cerana* (8.0 sec/flower), *Eristalis spp*. (4.6 sec/flower), *Halictus spp.* (4.26 sec/flower), *Apis dorsata* (2.6 sec/flower) and *Apis mellifera* (1.86 sec/flower) (Table 4). The findings differ with the results of Pandey & Tripathi (2003), Jat *et al*., (2013) [14], Devi *et al*., (2016) [9] & Nagpal *et al*., (2016), who recorded that *Apis florea* exhibited the highest foraging speed. However, Kunjwal *et al*., (2014) [18] & Ahmad *et al*., (2017) accounted for the maximum foraging speed of *Apis mellifera.*

Table 4: Foraging speed (Time spent in seconds per flower) by a foraging insect on Sarson.

S. No	Name of Insects	Time of observations			Grand mean
		In hours			
		10:00-11:00	13:00-14:00	16:00-17:00	
1	*Apis mellifera*	1.6	2.4	1.6	1.86
2	*Apis florea*	18.6	16.4	44	26.33
3	*Apis cerana*	6.6	10.2	7.2	8
4	*Apis dorsata*	2.4	4	1.4	2.6
5	*Halictus sp.*	3.6	2.6	6.6	4.26
6	*Eristalis sp.*	2.2	2	9.6	4.6
7	*Episyrphus balteatus*	39.4	28.2	42	36.53
	Mean	10.62	9.4	16.05	12.02

Conclusion

The results of the study concluded that Hymenopterans were the primary flower visitors of mustard. *Apis mellifera* (6.46 bees per square meter per 5 minutes) exhibited highest mean of abundance, and *Eristalis spp*. (0.4 bees per square meter per 5 minutes) exhibited lowest mean of abundance. *Apis dorsata* (16.06 flowers per minute) showed the highest mean of foraging rate, and *Episyrphus balteatus* (1.8 flowers per minute) showed the lowest mean of foraging rates. The highest mean of foraging speed was exhibited by *Episyrphus balteatus* (36.53 sec per flower), while the lowest mean of foraging speed was exhibited by *Apis mellifera* (1.86 sec per flower).

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Author contribution statement

BKPS: designed the experiment; FW helped AS in the data collection; AS: statistical analysis and manuscript writing; BKPS: reviewed and edited the manuscript.

Conflict of interest

No conflict of interests.

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