



RESEARCH ARTICLE

# Diversity and abundance of insect pollinators and visitors of Indian mustard (*Brassica juncea* L.)

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## Abstract

The study was conducted to identify the diversity and abundance of insect pollinators and floral visitors associated with Indian mustard (*Brassica juncea*). A total of 24 insect species were observed and collected in the study, which represented five insect orders, 14 families and 21 genera. The order Hymenoptera was the most dominant, accounting for 45.83 % of the total pollinators/visitors, with 11 species of eight genera, followed by order Diptera, contributing 29.16 % of the total insect assemblage with seven species from seven genera. Among all the insects, three species belonged to the order Lepidoptera from three genera (12.50 %), while Coleoptera, with 8.33 % of abundance, included two species from two genera and a single species of order Neuroptera was recorded with 4.16 %. Among the visitors, eight insect species were recorded as pollinators: *Apis* species, i.e. *A. dorsata* (32.9 %), *A. cerana indica* (22.9 %) and *A. mellifera* (18.7 %), followed by other hymenopteran *Tetragonula iridipennis* (9.4 %), which was most dominant, while the least dominant were Dipteran *Eristalinus arovum* (2.8 %). The pollinators had the peak period of activity between 11.00 am to 1.00 pm, where the mean population was 5.03 and the least activity was observed between 7.00 AM to 9.00 AM and 3.00 PM to 5.00 PM, with a mean population of 0.72 and 0.91 each. The findings reveal the predominance of Hymenopteran species in *B. juncea* along with other species, underscoring the need for pollinators in agroecosystems to affect the reproductive success and productivity of cross-pollinated crops like Indian mustard.

**Keywords:** abundance; *Apis mellifera*; *Brassica juncea*; hymenoptera; pollinators

## Introduction

Indian mustard (*Brassica juncea* L. Czern & Coss) is an important oilseed crop in India, contributing to nearly 30 % of the country's total oilseed production (1). It is primarily cultivated in the northern and central regions of India during the *Rabi* (winter) season, especially in semi-arid regions. Indian mustard is valued for its high oil content, typically ranging from 30 %-40 % and serves as a major source of edible oil, animal feed (oilcake) and green manure (2). The mustard seed contains 8.5 g of moisture, 20 g of protein, 23.8 g of carbohydrates, 39.7 g of fat, 1.8 g of fibre, 490 mg of calcium, 700 mg of phosphorus, 7.9 mg of iron, 541 K cal energy value per 100 g edible portion (3, 4). *B. juncea* is the second-largest oilseed crop in the world, following groundnut. Three major species- *Brassica juncea*, *Brassica campestris* and *Brassica napus* L. are cultivated in the Indian subcontinent. Oilseeds cover approximately 27.5 M ha of total cropped area in India and contribute around 5 % to gross national product, which is 24.72 MT of production and accounts for 10 % of all agricultural commodities (5). In the 2023-24 agricultural year, rapeseed-mustard accounted for 30.3 % of the acreage and 33.2 % of the

production among nine oilseed crops grown in India (1). With the production of 13.2 MT, rapeseed-mustard became the largest oilseed crop in India. Indian mustard is cultivated in most states across India, but the bulk production comes from mainly five states, namely, Rajasthan (45.40 %), Uttar Pradesh (14.24 %), Haryana (10.78 %), Madhya Pradesh (13.28 %) and West Bengal (6 %) during 2023-24 (1).

Pollinators play a vital role in the pollination of crops, primarily bees, flies and moths, being important among all. Insects, particularly bees, play a crucial role as the primary pollinators of Indian mustard (*B. juncea*), significantly boosting its productivity and yield quality (6). Alongside honeybees, other insect species, such as solitary bees (e.g. *Andrena*, *Halictus*), bumblebees (*Bombus* spp.), syrphid flies (hoverflies), butterflies, moths and certain beetles, also contribute to the pollination, each differing in foraging behaviour, floral preference and visitation time (7-9). Over 80 % of the pollination activities are performed by insects and bees contribute nearly 80 % of the total insect pollination (10). Indian mustard, being a cross-pollinated crop, relies hugely on insects; honey bees, such as *Apis mellifera* and *A.*

*cerana*, play a crucial role in maximising seed yield and quality (7, 11). The floral morphology, with bright yellow petals and high volume of sugar-rich nectar and pollen, is highly attractive to a range of insect pollinators, especially honey bees (*A. dorsata*, *A. mellifera* and *A. cerana indica*), bumblebees and various solitary bees (12-15). The insects visit the mustard flowers for nectar and pollen and, in the process, transfer pollen from one flower to another, facilitating fertilisation. The nectar and pollen of mustard attract various insect pollinators and visitors (16).

In Indian mustard farming, insect pollinators contribute to higher yield with improved oil content and consistent seed maturation. The mustard plots visited by pollinators exhibit higher seed set, better pod formation and improved seed weight compared to plots isolated from insect visits (17, 18). Managed pollination using honey bee colonies has significantly boosted crop performance in mustard farming systems (19, 20). Besides increases in effective cross-pollination and increased yield, species diversity also ensures pollination resilience against declines in specific species. The presence of a diverse pollinator enhances pollination quality with improved pod set, seed weight and oil content in mustard (21). However, modern farming practices with indiscriminate pesticide usage and habitat destruction have threatened their existence and ecological role. It has also been documented that the low seed yield in *Brassica* has been associated with a major issue due to inadequate pollination in open pollination conditions (22). During 2020-21, domestic edible oil production was 9.5 MT, while domestic oil consumption was 22.5 MMT/year, with a gap of 13 MT, which might be the result of a decline in effective pollinators and their efficiency (23). Under the scenario of climate change, there is a change in the diversity and abundance of insect pollinators. Climate change affects both the plants and pollinators, thus ultimately affecting plant-pollinator interactions (24). Though some studies had already been carried out with respect to pollinator diversity and abundance in India, there is an urgent need to assess the pollinator diversity and abundance under the scenario of current climate change (25). This may aid in initiating proper pollinator conservation practices in order to conserve biodiversity.

## Materials and Methods

The field experiment was conducted at the Agricultural Research Farm, BHU, Varanasi, on Indian mustard with variety Giriraj (DRMRIJ-31) in a 10 × 10 m<sup>2</sup> plot size (25°25'62.12" N and 82°99'20.28" E). The seed was uniformly sown on 7<sup>th</sup> November 2023 with a seed rate of 3.5 kg/ha. All agronomic practices were meticulously followed as required to ensure the healthy growth of the crop.

The insect pollinators/visitors were recorded from December 2023 to February 2024, with the commencement of flowering. The diurnal abundance of insect pollinators visiting the crop was determined at regular intervals throughout the day, where the insects were observed, collected and recorded throughout the flowering season of the crops. The observation was made every two hours from 7:00 AM to 5:00 AM. The visitor's record was made in an area of one square meter within the plot. The insects visiting were also recorded for their nature and behaviour, the visitors or the pollinators. The specimens thus collected were appropriately labelled and preserved in an insect

collection box. The collected insect specimens were identified with the help of available literature and the keys to the morphological characteristics of the specimens. Online software and tools such as Google Lens, Moth and Butterfly of India and iNaturalist were used to identify some species.

The following observation and data analysis were made for the pollinators and visitors in the mustard field.

### Relative abundance (%)

Relative abundance is the percent composition of an organism of a particular kind relative to the total number of organisms in the area.

$$\text{Relative abundance (\%)} = \frac{n}{N} \times 100 \quad (\text{Eqn. 1})$$

Where, n= Number of each individual, N= Total number of individuals.

### Species richness

Species richness is the number of different species present in a specific area or an ecological community. The more the number of species, the richer the area with diversity of species (24).

$$\text{Species richness} = \sum_{i=1}^R 1 \quad (\text{Eqn. 2})$$

Where R is the total number of species, each species is counted once.

### Shannon-wiener diversity index (H) and Shannon's E index (Evenness index)

The diversity of pollinator insect species was calculated using the Shannon-Wiener diversity index (H). The index, which considers both species richness and evenness, was originally proposed by Shannon (26). The diversity of pollinator insect species was calculated using the Shannon-Wiener diversity index (H).

$$H = -\sum p_i \times \ln(p_i) \quad (\text{Eqn. 3})$$

Where,  $p_i = n_i / N$ ,  $n_i$  is the number of individuals of the species and  $N = \sum n_i$ .  $\ln$  = the natural log,  $\sum$  = the summation of calculations.

### Evenness index (E)

Species evenness index refers to how close in numbers each species is in the environment, which is also known as Pielou's evenness index (27). The value ranges from 0 to 1.

$$E = \frac{H}{H_{\max}} \quad (\text{Eqn. 4})$$

Where,  $H_{\max} = \ln(S)$ , S is the total species richness.

### Simpson's diversity index (D)

Simpson developed an index of diversity, which is a measure of the probability of less diversity; the greater the probability that two randomly selected individuals will be of the same species (28).

$$D = 1 - \left( \frac{\sum n(n-1)}{N(N-1)} \right) \quad (\text{Eqn. 5})$$

Where, n = number of individual species, N = total number of species.

## Effective number of species

The ENS is the number of equally abundant species that would yield the same Shannon index value as the observed community. A higher ENS indicates a more diverse community (29).

Effective number of species

$$ENS = \exp(H') \quad (\text{Eqn. 6})$$

Where  $H'$  = Shannon-Wiener diversity index and is calculated by taking its exponential.

## Results

Diversity of insect pollinators and visitors on Indian mustard (*B. juncea*). The diversity of insect pollinators and floral visitors observed on Indian mustard (*B. juncea*) highlights a rich assemblage of species, predominantly the order Hymenoptera, followed by orders Diptera and Lepidoptera. This study, conducted during the *Rabi* season 2023-24, reveals that honey bees (*A. dorsata*, *A. mellifera* and *A. cerana indica*) were the most frequent and effective pollinators. Additionally, *T. iridipennis* and *X. fenestrata* were also frequently recorded hovering and pollinating the crop. Syrphid flies (hoverflies) were also significant visitors, particularly notable during day hours, contributing to pollination by transferring pollen while foraging for nectar. In addition to the primary pollinator, butterflies like *Junonia almana* and various beetle species were recorded visiting Indian mustard.

A total of 24 specimens belonging to 21 genera, 14 families and five orders were collected from the field (Table 1). Among all species collected, the Hymenoptera order was the predominant one with 11 species, followed by Diptera with seven species, Lepidoptera with three species and Coleoptera with two species, while the Neuroptera order with only one species. Among the total genera, eight genera belong to the order Hymenoptera, seven genera belong to Diptera, three genera belong to Lepidoptera, two genera belong to Coleoptera and one genus belongs to the Neuroptera order (Table 2 and Fig.

1). However, order-wide species abundance data indicated that the Hymenoptera order accounts for 45.83 % of pollinators/visitor's diversity, followed by Diptera with 29.16 % abundance, Lepidoptera was 12.50 %, Coleoptera was 8.33 % and Neuroptera was 4.16 % (Table 2 and Fig. 2). The most prevalent family among the pollinators/visitors was Apidae with six species, followed by Syrphidae (four species), Halictidae and Coccinellidae (two-two species) and other families had only one species (Table 2 and Fig. 2). Among all the pollinators, *Apis* species (*A. dorsata*, *A. mellifera*, *A. cerana indica* and *A. florea*) were the major pollinators of Indian mustard (*B. juncea*) (Fig. 3).

## Diurnal abundance of the pollinators

The present study reported that the honey bees were the most dominant pollinators among others. The pollinators' activity was observed to be maximum between 11.00 AM–1.00 PM, the abundance of the pollinators was recorded to be 5.03 pollinators/m<sup>2</sup>, which was followed by 4.05 pollinators/m<sup>2</sup> recorded during the morning hours between 9.00 AM–11.00 AM (Table 3). Whereas the pollinator abundance was observed least in the early morning between 7.00 AM – 9.00 AM and in late afternoon between 3.00 PM–5.00 PM, with an abundance of 0.72 and 0.91 pollinators/m<sup>2</sup>, respectively. Amongst the pollinators, *A. florea* activity was not observed between 7.00 AM – 9.00 AM, while *Eristalinus arovum* activity was not observed during the evening hours between 3.00 PM – 5.00 PM. Out of the eight pollinators *A. dorsata* was the most predominant species with highest abundance between 9.00 AM – 11.00 AM which was recorded to be 12.03 bees/m<sup>2</sup> while they were 11.3 bees/m<sup>2</sup> during the day between 11.00 AM – 1.00 PM, whereas their activity was least during early morning and late afternoon which was 2.27 and 2.83 bees/m<sup>2</sup> respectively. *A. dorsata* is followed by *Apis cerana indica* in diurnal activity where these bees were most active during the day between 1.00 PM–3.00 PM with the abundance of 10.2 bees/m<sup>2</sup>. The diurnal activity of *A. mellifera* was recorded as maximum between 11.00 AM–1.00 PM with 8.93 bees/m<sup>2</sup>, while the activity was least with 0.8 bees/m<sup>2</sup> during the late afternoon between 3.00 PM – 5.00 PM. Among the bees from

**Table 1.** Diversity of insect pollinators and visitors on Indian mustard (*B. juncea*)

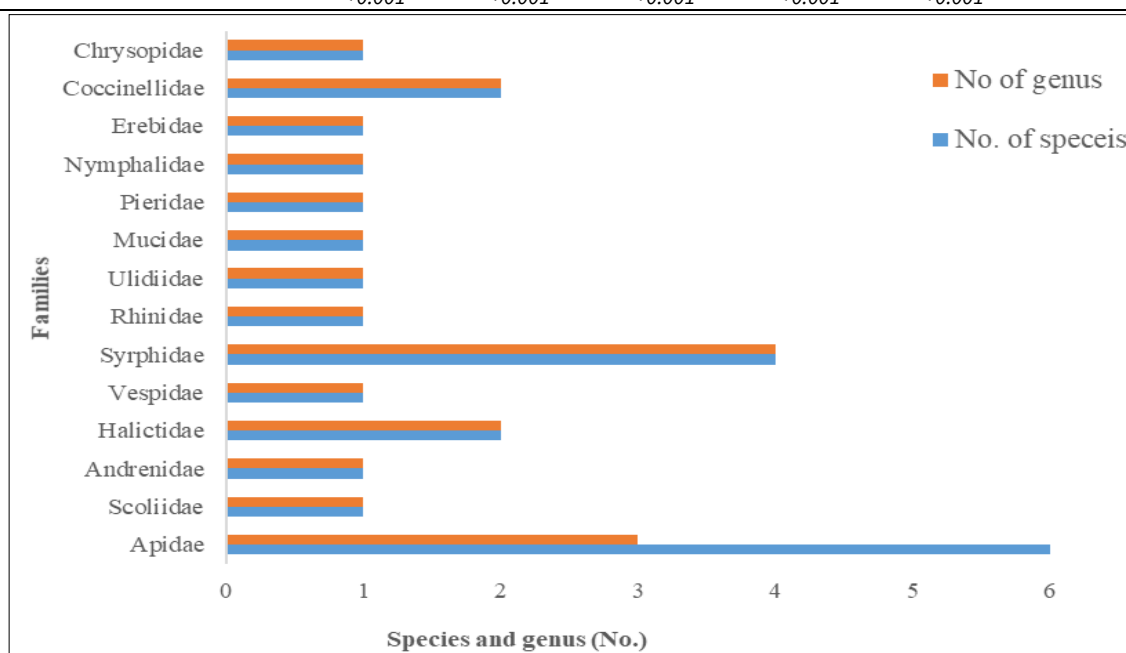
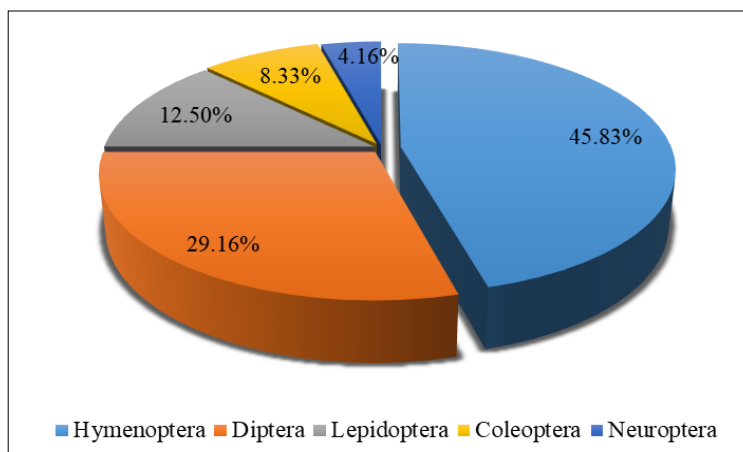
Order	Family	Scientific names of pollinators/visitors	Common names of pollinators/visitors	Author
Hymenoptera	Apidae	<i>Apis dorsata</i>	Rock bee	Fabricius, 1793
		<i>Apis mellifera</i>	European honey bee	Linnaeus, 1758
		<i>Apis cerana indica</i>	Indian honey bee	Fabricius, 1798
		<i>Apis florea</i>	Little bee	Fabricius, 1787
	Halictidae	<i>Tetragonula iridipennis</i>	Indian stingless bee	Smith, 1854
		<i>Xylocopa fenestrata</i>	Carpenter bee	Fabricius, 1798
		<i>Lasioglossum serenum</i>	Sweat bee	Cameron, 1897
		<i>Steganomus nodicornis</i>	Nodulated-horn bee	Smith, 1875
		<i>Campsomeriella collaris</i>	Scoliid wasp	Fabricius, 1775
		<i>Andrena pilipes</i>	Black mining bee	Fabricius, 1781
		<i>Vespa orientalis</i>	Oriental hornet	Linnaeus, 1771
Syrphidae	<i>Eristalinus arovum</i>	Field hoverfly	Fabricius, 1787	
	<i>Episyrphus balteatus</i>	Marmalade hoverfly	De Geer, 1776	
	<i>Ischiodon scutellaris</i>	Yellow-shouldered hoverfly	Fabricius, 1805	
	<i>Sphaerophoria Indiana</i>	Globetail (Hoverfly)	Bigot, 1884	
	<i>Stomorhina discolor</i>	Blow fly	Fabricius, 1794	
Diptera	Ulidiidae	<i>Physiphora alceae</i>	Picture-winged fly	Preyssler, 1791
	Muscidae	<i>Musca domestica</i>	Housefly	Linnaeus, 1758
Lepidoptera	Pieridae	<i>Delias eucharis</i>	Common jezebel	Drury, 1773
	Nymphalidae	<i>Junonia almana</i>	Peacock pansy	Linnaeus, 1758
	Erebidae	<i>Eublemma anachoresis</i>	Banner moth	Wallengren, 1863
Coleoptera	Coccinellidae	<i>Coccinella septempunctata</i>	Seven-spotted ladybug	Linnaeus, 1758
		<i>Cheilomenes sexmaculatus</i>	Zigzag ladybird beetle	Fabricius, 1781
Neuroptera	Chrysopidae	<i>Chrysoperla carnea</i>	Common green lacewing	Stephens, 1836

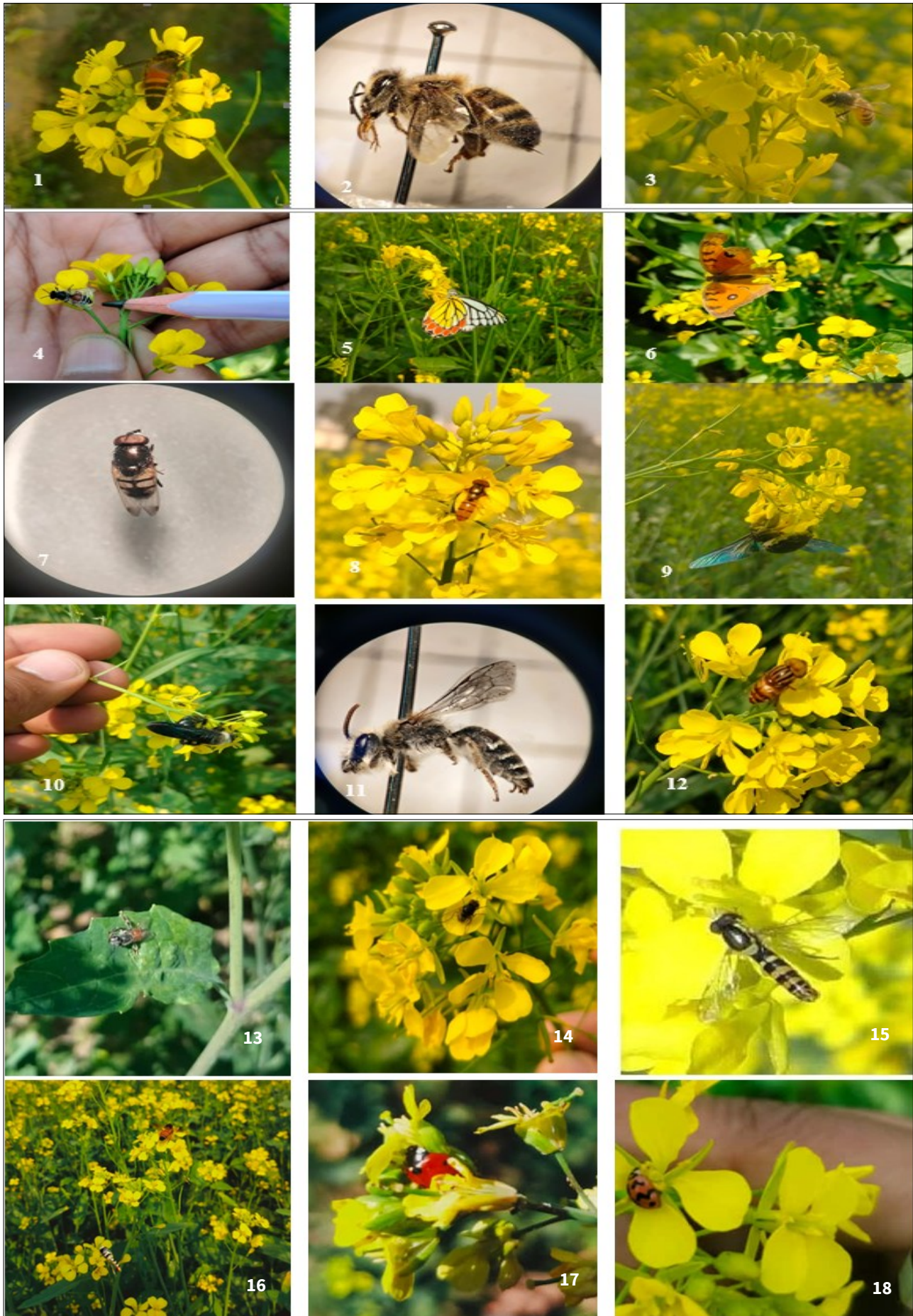
**Table 2.** Order and family-wise summary of insect pollinators and visitors on Indian mustard

Order	Family	No. of species	No. of genera	Total no. of species/order	Pollinators/visitors (%)
Hymenoptera	Apidae	6	3	11	45.83
	Scoliidae	1	1		
	Andrenidae	1	1		
	Halictidae	2	2		
	Vespidae	1	1		
Diptera	Syrphidae	4	4	7	29.16
	Rhinidae	1	1		
	Ulidiidae	1	1		
	Mucidae	1	1		
	Pieridae	1	1		
Lepidoptera	Nymphalidae	1	1	3	12.50
	Erebidae	1	1		
Coleoptera	Coccinellidae	2	2	2	8.33
Neuroptera	Chrysopidae	1	1	1	4.16

**Table 3.** Diurnal abundance of the pollinators on Indian mustard at different hours of the day

Pollinator/ visitors	Order	7.00 AM – 9.00 AM	9.00 AM – 11.00 AM	11.00 AM – 1.00 AM	1.00 AM – 3.00 AM	3.00 AM – 5.00 AM	Mean	RA
<i>Apis dorsata</i>	Hymenoptera	2.27	12.03	11.3	7.93	2.83	7.27	32.90
<i>Apis mellifera</i>	Hymenoptera	0.97	6.96	8.93	4.25	0.80	4.38	18.76
<i>Apis cerana indica</i>	Hymenoptera	0.23	4.90	8.13	10.2	1.87	5.07	22.92
<i>Apis florea</i>	Hymenoptera	0.00	1.40	2.23	1.33	0.50	1.09	3.13
<i>Tetragonula iridipennis</i>	Hymenoptera	0.90	2.77	4.17	2.00	0.67	2.10	9.41
<i>Eristalinus arovum</i>	Diptera	0.29	1.02	1.25	0.53	0.00	0.62	2.83
<i>Stomorhina discolor</i>	Diptera	0.71	2.04	2.79	1.29	0.42	1.45	6.69
<i>Episyrphus balteatus</i>	Diptera	0.37	1.25	1.42	0.71	0.17	0.78	3.31
Mean	-	0.72	4.05	5.03	3.53	0.91	-	-
CD	-	0.421	1.76	1.264	1.19	0.859	-	-
<i>p</i> value	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	-	-

**Fig. 1.** Family and genus-wise distribution of insect pollinators and visitors richness on Indian mustard at Varanasi during *Rabi* season 2023-24.**Fig. 2.** Pie diagram showing the percentage of insect pollinators and visitors belonging to different orders.



**Fig. 3.** Images of pollinators/visitors in the Indian mustard field during December 2023 to February 2024. 1. *Apis dorsata*; 2. *A. mellifera*; 3. *A. cerana indica*; 4. *A. florea*; 5. *Delias eucharis*; 6. *Junonia almanac*; 7. *Stomorhina discolor*; 8. *Episyrrhus balteatus*; 9. *Xylocopa fenestrata*; 10. *Campsomeriella collaris*; 11. *Lasioglossum serenum*; 12. *Eristalinus arozum*; 13. *Tetragonula iripennis*; 14. *Musca domestica*; 15. *Sphaerophoria indiana*; 16. *Ischiodon scutellaris*; 17. *Coccinella septempunctata*; 18. *Cheilomenes sexmaculatus*.

the Apidae family, *A. florea* had the least floral activity. The floral activity of the little bees was recorded at its highest during the day between 1.00 PM - 3.00 PM, with the floral abundance of 1.33 bees/m<sup>2</sup>. In contrast to this, the abundance of the *Eristalinus arovum* was least among the 8 pollinators, which was found most active during the day between 11.00 AM – 1.00 PM, with an abundance of 1.23 flies/m<sup>2</sup>. Among the three Dipteran *Stomorhina discolor* was dominant and had more foraging activity. The flies were most active during the day between 11.00 AM – 1.00 PM, with their abundance of 2.83 flies/m<sup>2</sup>, while they were observed in mere numbers at late afternoon with their population of 0.42 flies/m<sup>2</sup>.

### Species richness and diversity indices of pollinators

The pollinator richness in mustard was observed to be only seven (seven pollinators) in the morning between 7.00 AM and 9.00 AM and in the evening between 3.00 PM – 5.00 PM, whereas the species richness of eight (eight pollinators) was recorded between 9.00 AM – 3.00 PM. Shannon diversity index (H) of insect pollinators of mustard ranged from 1.59 to 1.72, which indicated moderate diversity of the pollinators in mustard field, with the Species evenness (E) index was 0.76 to 0.86, inclined near the highest value 1 representing inequality in distribution of the pollinators within the community (Table 4). The effective number of species during the busiest hour of the pollinator was 5.61, which simply implies the importance and distribution of the equally abundant number of species in the area at that period, regardless of the actual species composition and their abundances. The Simpson value 0.79 indicates that the period between 11.00 AM – 1.00 PM has a 79 % higher chance that in every two species recorded are different, which indicates diversity in species. The Simpson D Index here ranges between 0.76 and 0.79, where the value indicates the chance of diversity between 76 % to 79 % in the community.

### Discussion

The diversity of insect pollinators and floral visitors on Indian mustard reflects the crop's ecological resilience and its dependence on insect species for effective pollination. Honey bees, particularly *A. dorsata*, *A. cerana indica* and *A. mellifera*, dominated the pollinator assemblage, demonstrating their vital role in the pollination of mustard and the increase of yield. Apis species visited mustard bloom for pollen and nectar; while moving from one plant to another, it carried out pollen grains through its plumose hair distributed throughout its body, thus aiding in pollination service (30). Additionally, the presence of other pollinators such as *A. florea*, syrphid flies, butterflies and beetles suggests that mustard flowers attract both specialist and generalist foragers, which may contribute to pollination under variable environmental conditions. The dominant insect order in the mustard during the flowering seasons was Hymenoptera (45.83 %), followed by Diptera (29.16 %), Lepidoptera (12.50 %)

and Coleoptera (8.16 %) and Neuroptera (4.16 %), with the peak foraging activity during the daytime from 11.00 AM – 1.00 PM (47.41 pollinators/m<sup>2</sup>). The findings of the present study are consistent with previous research on the importance of a diverse insect community in mustard pollination and productivity (31). The Hymenopterans, particularly the family Apidae, *A. dorsata*, *A. mellifera*, *T. iridipennis*, were the major floral visitors with the maximum insect abundance found in the afternoon (3.00 PM – 4.00 PM with 31.5 pollinators/plant/5min). *A. dorsata* was the dominant among others, with maximum activity in the afternoon (32). The findings of the present study are consistent with previous research that reported 30 insect species from 4 orders and 10 families, with Hymenoptera being the most dominant group. He further highlighted the dominance of four species: *A. cerana indica*, *A. florea*, *A. mellifera* and *A. dorsata* (25). Apis species were the major pollinators in the mustard ecosystem, with their abundance varying according to the geographical region (33). Previously similar result was reported with 17 insect visitors in mustard and Hymenopterans were dominant among all, with 9 species, followed by 3 Dipterans, 4 Lepidopterans and 1 Coleopteran (34). Another researcher reported 36 species from 8 insect orders, with consistent dominance of Hymenoptera: primarily *Apis* species as key floral visitors of Indian mustard (9). The *A. cerana* was predominant, with maximal foraging activity at 11.00 AM. While *A. dorsata* and *A. florea* were present at 2.00 PM at lower densities (35). The occurrence of 19 insect visitors/pollinators and Hymenoptera (59.38 %) was the dominant one with 21.08 population/m<sup>2</sup>/5 min followed by Diptera (23.88 % and 8.49/m<sup>2</sup>/5 min), Lepidoptera (9.40 % and 3.34/m<sup>2</sup>/5 min), Coleoptera (4.33 % and 1.54/m<sup>2</sup>/5 min) with the peak period of activity during 11.00 AM to 1.00 PM as recorded in our study as well (36).

A total of 24 species of insect pollinators from 4 orders, 13 families and 19 genera, with Hymenoptera being the dominant order, while Coleoptera had the least presence on mustard. The Indian honeybee (*A. cerana indica*) was the most frequently observed visitor, highlighting its significant role in pollination, which is similar to the present study (37). Research indicates that 13 insect visitors belonging to the order Hymenoptera (6 species viz. *A. dorsata*, *A. mellifera*, *A. cerana indica*, *A. florea*, *Ceratina* sp. and *Halictus* sp.), Diptera (5 species viz. *Episyrphus* sp., *Eristalinus tabanoides*, *Musca domestica*, *Chrysomya* sp. and *Sarcophaga* sp.) and Lepidoptera (2 species viz. *Amata bicincta* and *Pieris* sp.) in Indian mustard. Honeybees (*Apis* spp.) were observed at maximum, representing 74.52 % of the total pollinators, where *A. mellifera* (35.18 %) was dominant sequentially, followed by *A. cerana indica* (23.11 %), *A. dorsata* (12.00 %) and *A. florea* (4.23 %) (38). Numerous studies on the diversity and abundance of the visitors and pollinators on Indian mustard emphasise the significance of Hymenopterans as key pollinators, which is followed by Dipterans, Lepidopterans and many others, as this study demonstrates. These pollinators are crucial for environmental resilience and for improved crop yield.

**Table 4.** Species richness and diversity indices of pollinators

Pollinator	7.00 AM – 9.00 AM	9.00 AM – 11.00 AM	11.00 AM – 1.00 PM	1.00 PM – 3.00 PM	3.00 PM – 5.00 PM
Species richness (S)	7	8	8	8	7
Shannon's H index	1.68	1.59	1.72	1.65	1.62
Evenness index	0.86	0.76	0.82	0.79	0.83
Effective number of species	5.37	4.92	5.61	5.22	5.05
Simpson D index	0.78	0.77	0.79	0.76	0.76

## Conclusion

The Indian mustard flower attracts a diverse array of insect visitors, reflecting the richness of pollinators' diversity associated with the crop. This diversity plays a pivotal role in increasing pollination efficiency and ultimately the crop yield, improved seed quality and greater oil content. Among the many insect pollinators, the most prominent pollinators include honey bees such as *A. mellifera*, *A. cerana indica*, *A. dorsata* and *A. florea*. Additionally, the insects *Tetragonula* and *Xylocopa fenestrata* are also frequent dweller of the mustard plant, exceedingly attracted to mustard flowers for their sweet nectar and pollen resources. In addition to honeybees, other insect species such as syrphid flies (hoverflies), butterflies, moths and certain beetles also contributed to the pollination, each exhibiting different foraging behaviour and floral preferences. The insect visitors and pollinators are active throughout the day, with the peak foraging activity occurring between 11.00 AM– 1.00 PM. *Apis dorsata* was the dominant pollinator, most active between 9.00 AM – 1.00 PM, after which the floral activity of the bee tends to decline. Since insects play a vital role in maintaining the ecological balance, it is essential to conserve the diversity of pollinators through eco-friendly agricultural practices. Pollinators, in particular insect pollinators, are unable to acclimate themselves to a changing climate because of their high sensitivity to climatic factors. Loss of diversity of pollinators may lead to loss of biodiversity as many of the wild as well as cultivated plant depends on pollinators for fertilisation and fruit set. So, there is a need to develop strategies for protecting the pollinators from the harmful effects of a warmer climate. Emphasis should be put on the conservation of pollinators as well as pollinating plants. Otherwise, there may be severe disturbance of plant-pollinator interactions, which may harm global food production and nutritional security.

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## Authors' contributions

RN and GSG were involved in data collection and manuscript preparation. RK, AKS and SVSR contributed to the study's conception and design. VS and SN carried out the identification, documentation and assisted in manuscript preparation. KS and AK were responsible for reviewing and editing the manuscript. All authors reviewed and approved the final version of the manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interest to declare.

**Ethical issues:** None

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