**Original article**

**Insect pollinators diversity and abundance in *Eruca sativa* Mill. (Arugula) and *Brassica rapa* L. (Field mustard) crops**

Muhammad Shakeel a, Hussain Ali b, Sajjad Ahmad a, Fazal Said c, Khalid Ali Khan d,e, Muhammad Amjad Bashir f, Syed Ishtiaq Anjum b, Waqar Islam h,i, Hamed A. Ghramh d,e,j, Mohammad Javed Ansari j,k, Habib Ali k

a Department of Entomology, Faculty of Crop Protection Sciences, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan  
 b Entomology Section, Agricultural Research Institute (ARI), Tarnab, Peshawar, Khyber Pakhtunkhwa, Pakistan  
 c Department of Agriculture, Abdul Wali Khan University, Mardan, Khyber Pakhtunkhwa, Pakistan  
 d Department of Plant Protection, Faculty of Agriculture Sciences, Ghazi University, Dera Ghazi Khan 32200, Punjab, Pakistan  
 e Department of Zoology, Kohat University of Science and Technology, Kohat 26000, Khyber Pakhtunkhwa, Pakistan  
 f College of Plant Protection, Faculty of Agriculture Sciences, King Saud University, PO Box 2460, Riyadh 11451, Saudi Arabia  
 g Research Center for Advanced Materials Science (RCAMS), King Khalid University, P.O. Box 9004, Abha 61413, Saudi Arabia  
 h Bee Research Chair, Plant Protection Department, College of Food and Agriculture Sciences, King Saud University, PO Box 2460, Riyadh 11451, Saudi Arabia  
 j Unit of Bee Research and Honey Production, Faculty of Science, King Khalid University, P.O. Box 9004, Abha 61413, Saudi Arabia  
 k Biology Department, Faculty of Science, King Khalid University, P.O. Box 9004, Abha 61413, Saudi Arabia

**A B S T R A C T**

Studies on the insect pollinators diversity and their relative abundance in *Eruca sativa* Mill. (Arugula) and *Brassica rapa* L. (field mustard) was carried out during spring season from February to April consecutively during all the three years of 2016–18. Insect pollinators observed belonged to four orders i.e. Hymenoptera, Diptera, Lepidoptera, and Coleoptera. A total of 20 major species of insect pollinators were recorded. The highest abundance of pollinator species belonged to Hymenoptera. The most prominent insect pollinator species were *Apis mellifera* followed by other three honey bee species of *A. cerana*, *A. florea*, and *A. dorsata* respectively. Some species of solitary bees were also recorded. From Diptera, four species of syrphid fly and one species from Muscidae family were also recorded. Insect pollinators recorded from order Lepidoptera were *Pieris brassicae*, *Vanessa cardui*, and *Papilio demoleus*. Lady bird beetle *Coccinella septempunctata* was recorded from Coleoptera order as occasional visitor. It was noticed that *E. sativa* attracted more insect pollinators than *B. rapa* which may be attributed to different amount and chemical properties of nectar, with number of pollen grains, and flower canopy of both crops. Further studies are needed to confirm the reasons for higher pollinator visitation to *E. sativa* than *B. rapa* through chemical analysis of nectar, amount of pollens, flower physiology and phenology of both crops.

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1. Introduction

*Brassica rapa* (Field mustard) belongs to family Brassicaceae. This crop is economically important because of seed oil contents and some other plant parts like leaves which are edible and can be used as fodder crop. The oil extracted from their seeds is consumed by humans from centuries in the Asian continent. Seeds after oil extraction are changed to the shape of cake which is very nutritious and used to feed animals (Ramachandran et al., 2007). *Eruca sativa* (Arugula) also belongs to family Brassicaceae. Local name of *E. sativa* is Taramira. This crop has medicinal and economic value and can be consumed as salad and vegetable by humans. It can also be used as green fodder for feeding animals (Ghazali et al., 2014).

Insects help in pollination of these crops. Crops belonging to family Brassicaceae are predominantly dependent on insect pollination (Entomophilous). Increase in seed quality and quantity is

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possible through pollination (Abrol, 2007; Shakeel and Inayatullah, 2013; Shakeel and Mian Inayatullah, 2015). The role of cross-pollination between cruciferous crops is majorly played by honey bees. Absence of cross-pollination generally reduces seeds number, seeds size, and viability of seeds that can lead to decrease in yield (Delaplane et al., 2000). Pollination by insect not only increase crop yield but also improve physiochemical properties of the fruits (Bashir et al., 2018). Crops of family Brassicaceae are very attractive for insect pollinators for a good source of pollens and nectar (Masirowska, 2003).

The crops with higher number of flowers have generally larger number of insect pollinators (Westphal et al., 2003). The service of pollination provided by pollinators is endangered due to losses in pollinator abundance and diversity (Daily, 1997). Studies on insect pollinators is endangered due to losses in pollinator abundance and diversity between cruciferous crops is majorly played by honey bees. Absence of cross-pollination generally reduces seeds number, seeds size, and viability of seeds that can lead to decrease in yield (Delaplane et al., 2000). Pollination by insect not only increase crop yield but also improve physiochemical properties of the fruits (Bashir et al., 2018). Crops of family Brassicaceae are very attractive for insect pollinators for a good source of pollens and nectar (Masirowska, 2003).

2. Materials and methods

2.1. Experiment location

The experiment was conducted at the model research farm of the university of agriculture during the months of February-April of 2016–18 consecutively.

2.2. Preparation of plots

E. sativa and B. rapa seeds were sown on two separate plots in the month of November 2016, 2017, and 2018. The dimensions of each plot were approximately 18 × 15 m². All the standard agronomic practices were followed for sowing the crops. No pesticide was sprayed on the crops during the whole experiment.

2.3. Diversity of crop visiting insect pollinators

At flowering stage of the crops the insect pollinators visiting the flowers were observed visually and were collected through aerial net throughout the month of February to April of all 3 years. The flower morphology depth of flower, length of petals, distance between the petals were measured with help of simple inch/cm ruler. The height of plants was also measured. Insect pollinators were killed in the killing jar having drops of ethyl acetate. Collection of insect pollinators was carried out throughout the flowering season of the crops. All the collected specimens were labelled and kept in insect collection box. The unidentified specimens were identified through relevant insect identification keys of Ascher and Rasmussen (2010) and Mahmood et al. (2012). All the voucher specimens were deposited to the entomology museum of the department of entomology, faculty of crop protection sciences, the University of Agriculture Peshawar.

2.4. Abundance of pollinators visiting the crop

Abundance of the insect pollinators was recorded on Eruca sativa Mill. (Arugula) and Brassica rapa L. crops. The data were recorded on weekly basis, data were collected in morning timing from 10:00–12:00 am and afternoon time from 2:00–4:00 pm. The data were recorded on the methodology used by Shakeel and Mian Inayatullah (2015). Four-meter square area was selected randomly in the field and insect pollinators visiting the flowers of both crop species were counted by hand counter clicker. The data on the abundance of pollinators were recorded from the start of flowering season till the end. The collected data were statistically analyzed with ANOVA using SPSS® version 15.0 for Windows®. Fishер’s least significant difference (LSD) tests were used for the statistical comparisons of means for evaluating frequency of visitation and relative abundance of pollinators between the two crop species.

3. Results

3.1. Eruca sativa and Brassica rapa flowers and insect pollinators diversity

The flowers of both plants is presented in Fig. 1. Both plants have different flower morphology. The flower colors are also different. B. rapa color is yellow while E. sativa color is whitish. The petals of B. rapa is very close to each other, while in E. sativa the petals are apart from each other. In cross section the depth is shorter in B. rapa compare to E. sativa (Fig. 1). The height is also different in both plants, E. sativa height is lower than B. rapa (Fig. 1).

The insect pollinators collected from the both crop species included four Apis species of honey bees. A. mellifera was the dominant pollinators followed by A. cerana, A. florea, and A. cerana respectively. Other pollinators from the order Hymenoptera were the large carpenter bees of species Xylocopa fenestrata, X. pubescens, Megachile sp., Lasioglossum sp., Polistes olivaceus, and Andrena pilipes.

Insect pollinators from the order Diptera were Episyrphus balteatus, Eristalis tenax, and Eristalis aeneus. Pollinators from order Lepidoptera were Vanessa cardui, Pieris brassicae, and Papilio demoleus. Insect visiting flowers from order Coleoptera observed was Coccinella septempunctata. They mainly visited the flowers of both plants for nectar and pollen collection (Table 1). Lepidopteran were mainly visited for nectar purpose while hymenoptera and Diptera were for both. Coleoptera mainly visited for pollen collection. In Hymenoptera mostly pollinators were from family Apidae. Insects having pollen on their legs and body were marked as pollen collectors.

3.2. Percent relative abundance of insect pollinators

The percent relative abundance of pollinators on E. sativa is presented in Fig. 2. The recorded Hymenoptera order relative abundance was (72%) significantly higher than Diptera (12%) and Lepidoptera (9%). However, the lowest relative abundance was recorded for Coleoptera. Fig. 3 shows the relative abundance of different insect pollinator orders on B. rapa. The percent relative...
abundance of Hymenoptera was (45%) followed by Diptera (23%) and Lepidoptera (17%). Order Coleoptera relative abundance was lower than other three orders on B. rapa.

On E. sativa hymenoptera percent relative abundance was (72%) significantly higher than on B. rapa (45%). On other hand Diptera, Lepidoptera, and Coleoptera relative abundance was higher on B. rapa than E. sativa. This showed that E. sativa attracted more hymenopterans than other orders (Figs. 2 and 3).

3.3. Percent relative abundance on E. sativa and B. rapa at different timings

Abundance of hymenopterans during different day times on E. sativa and B. rapa is presented in Fig. 4. Their abundance was lower in the morning time on both plants. However, their abundance increased in the afternoon on both flowering plants.

Regarding dipteran pollinators similar observation was recoded. Lower abundance was recorded in the morning while highest abundance was recorded in afternoon timing on E. sativa and B. rapa (Fig. 5).

The abundance of lepidopteran pollinators is presented in Fig. 6. It shows that the abundance was low on E. sativa and B. rapa in the morning. During the afternoon their abundance was high comparatively.

4. Discussion

The color of flower has great impact on the attraction of pollinators. E. sativa mainly attracted higher no of Hymenoptera than B. rapa. Other orders of insect pollinator were greatly attracted to B. rapa.

Table 1
Diversity of insect pollinators on Eruca sativa and Brassica rapa.

| Order            | Family       | Pollinator species | Foraging purpose |
|------------------|--------------|--------------------|------------------|
| Hymenoptera      | Apidae       | Apis mellifera     | Nectar and Pollen|
|                  |              | Apis cerana        |                  |
|                  |              | Apis florea        |                  |
|                  |              | Apis dorsata       |                  |
|                  |              | Xylocopa fenestra  |                  |
|                  |              | Xylocopa pubescens |                  |
|                  |              | Ceratina smaragdula|                  |
|                  | Megachilidae | Megachile sp.      |                  |
|                  | Halictidae   | Lasiolissum sp.    |                  |
|                  | Vespidae     | Polistes olivaceus |                  |
|                  | Andrenidae   | Andrena pilipes    |                  |
| Diptera          | Syrphidae    | Episyphus halitus  | Nectar and Pollen|
|                  |              | Eristalis tenax    |                  |
|                  |              | Eristalmus aeneus  |                  |
|                  |              | Syrophyx ribesii   |                  |
|                  |              | Musca sp.          |                  |
| Muscidae         |              |                    |                  |
| Lepidoptera      | Pieridae     | Pieris brassicae   | Nectar           |
|                  | Nymphalidae  | Vanessa cardui     |                  |
|                  | Papilionidae | Papilio demoleus   |                  |
|                  | Pieridae     | Colias erate       |                  |
| Coleoptera       | Coccinellidae| Coccinella septempunctata | Pollen |
**rapa** than *E. sativa*. The reasons could be the colors of flowers. Earlier studies reported that color has great impact on the attraction of insect pollinators. Lepidopterans insects are more attracted towards bright color and this may be the reason of high number of Lepidoptera on *B. rapa* as its color is bright than *E. sativa*. 

Reverté et al. (2016) reported that pollinators have color preferences. Further, they reported that it is not important that similar color should attract similar pollinators. The sugar content and flower morphology also play an important role in attracting different pollinators. Hymenoptera were mainly attracted to *E. sativa* than *B. rapa*. The reason could be high amount of nectar secretion. The other reason could be the depth of flowers, which is more in *E. sativa* than *B. rapa*. More depth of *E. sativa* makes them more feasible for hymenoptera order which having larger proboscis. Silva and Dean (2000) reported that high nectar concentrations of flower attract more honey bees compare with less nectar concentration.

In the current study, among *Apis* species *A. mellifera* abundance was higher than three species. Similar results were also reported by Shakeel and Mian Inayatullah (2015). They reported abundance and diversity of honey bee species of *A. mellifera*, *A. cerana*, *A. dorsata*, and *A. florea* on canola (*B. napus*) at Peshawar region. The highest abundant species was *A. mellifera* followed by *A. cerana*, *A. dorsata*, and *A. florea* respectively. Studies by Kunjwal et al. (2014) on brown mustard *B. juncea* have also reported these four species of honey bees as pollinators in Indian region of Patnagar; other pollinators observed were *Xylocopa* sp., *Ceratina sexmaculata*, *Andrena* sp., and *Megachile* sp. Devi et al. (2017) reported different insect pollinators on *Brassica juncea* from Solan District of northern region of India mainly including four honey species i.e. *A. mellifera*,

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**Fig. 4.** Abundance of pollinators from Hymenoptera on *Eruca sativa* and *Brassica rapa* in different timings of the day during year 2016–2018. *Apis mellifera* (LSD = 1.04, P = 0.003), *Apis florea* (LSD = 1.31, P = 0.006), *Apis dorsata* (LSD = 0.87, P = 0.008), *Apis cerana* (LSD = 0.721, P = 0.004), *Xylocopa fenestrata* (LSD = 0.65, P = 0.04), *Xylocopa pubescens* (LSD = 0.76, P = 0.005), *Lasioglossum sp.* (LSD = 0.17, P = 0.45), *Polistes olivaceus* (LSD = 0.04, P = 0.007), *Ceratina smaragdula* (LSD = 0.72, P = 0.003), *Andrena pilipes* (LSD = 0.76, P = 0.005), *Megachile sp.* (LSD = 0.65, P = 0.04).

**Fig. 5.** Abundance of pollinators from Diptera on *Eruca sativa* and *Brassica rapa* in different timings of the day during year 2016–2018. *Episyrphus balteatus* (LSD = 1.04, P = 0.003), *Eristalis tenax* (LSD = 1.31, P = 0.006), *Eristalis aeneus* (LSD = 0.87, P = 0.008), *Syrphus ribesii* (LSD = 0.721, P = 0.004).
A. cerana, A. dorsata, and A. florea other wild bees included Xylocopa sp. Halictus sp. the dipterous pollinators included Eristalis sp. Episyrphus balteatus, the lepidopteran pollinators included Pieris brassicae and Colias electo. Mishra et al. (1988) reported pollinators of Brassica campestris var. Sarson from India. The major pollinators recorded were honey bee species of A. cerana indica, A. mellifera and pollinators from order Diptera i.e. Episyrphus balteatus, Eristalis spp., Musca sp. etc. Coccinella septempunctata (Coleoptera) was recorded on both plants. Although it has nothing to do with pollination of these crops but may be it feed on pollen grains of the crops. Earlier some research reported that pollen was available in the guts of these species (Triltsch, 1999).

High temperature in the afternoon increases the secretion of nectar which attracts more insect pollinators. Higher abundance of pollinators was also recorded in afternoon in earlier studies on sunflower (Ali et al., 2015). The observed abundance of pollinators on E. sativa and B. rapa was less in the morning while it increased in the afternoon. This may be due to the increase of temperature in afternoon timing or the amount of nectar secretion. Flowers nectar secretion has great relation with temperature.

5. Conclusion

Eruca sativa and Brassica rapa were visited by almost 20 types of insect pollinators. Among the orders hymenoptera abundance was higher than Diptera, Lepidoptera and Coleoptera. Among all pollinators Apis species was most prominent. A. mellifera abundance was higher followed by other 3 honey bee species of A. cerana, A. florea, and A. dorsata respectively. The relative abundance of all insects on both crops were higher in afternoon compare to the morning.

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