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

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ABSTRACT

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.

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 (Masierowska, 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 a hot debate globally among researchers due to losses in population of pollinators due to different stresses like climate change, unavailability of floral resources. The diversity and abundance of pollinators is negatively affected by habitat destruction and fragmentation (Ghazoul, 2005a, 2005b; Kremen et al., 2002; Steffan-Dewenter et al., 2002). The impact of pollinator scarcity on the yield of crops should be evaluated precisely for assessing importance of pollinators decline due to different environmental stresses (Knight et al., 2006). Decreased population of pollinators may lead to decline of plant species diversity (Biesmeijer et al., 2006). Winter crops of family Brassicaceae provide large quantities of pollen and nectar to pollinators for their population stability (Klein et al., 2007). Different kinds of pollinators visit crops belonging to family Brassicaceae (Howlett et al., 2009a, 2009b, 2011; Shakeel and Mian Inayatullah, 2015).

Social bees like honey bees have been reported as major pollinators of Brassica plants (Donovan, 1980; Goodell and Thomson, 2007; Shakeel and Mian Inayatullah, 2015). Other pollinators belong to different insect orders like Diptera, Lepidoptera, and Coleoptera have been reported from Brassica crops (Brunel et al., 1992; Chaudhary, 2001; Chifflet et al., 2011; Howlett et al., 2009a, 2009b; Rader et al., 2009; Walker et al., 2009). The present study was conducted to evaluate the difference of pollinators diversity and abundance between *E. sativa* (Arugula) and *B. rapa* (Field mustard) crops.

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 m^2. 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®. Fisher'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

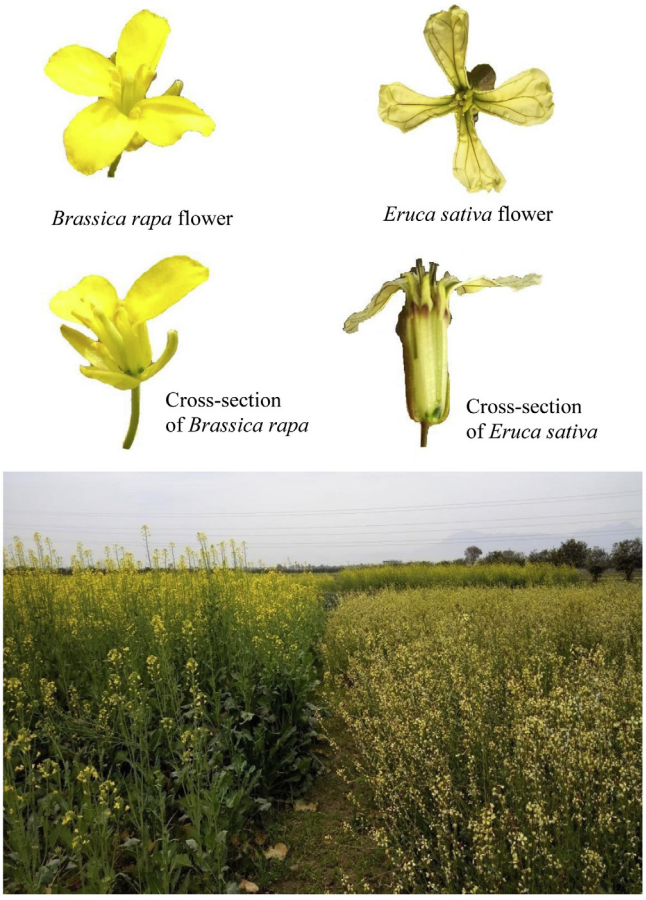

Fig. 1. Flowers, cross sections, and field of *Eruca sativa and Brassica rapa*.

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 fenestrata	
		Xylocopa pubescens	
		Ceratina smaragdula	
	Megachilidae	*Megachile* sp.	
	Halictidae	*Lasioglossum* sp.	
	Vespidae	*Polistes olivaceus*	
	Andrenidae	*Andrena pilipes*	
Diptera	Syrphidae	*Episyrphus balteatus*	Nectar and Pollen
		Eristalis tenax	
		Eristalinus aeneus	
		Syrphus ribesii	
	Muscidae	*Musca* sp.	
Lepidoptera	Pieridae	*Pieris brassicae*	Nectar
	Nymphalidae	*Vanessa cardui*	
	Papilionidae	*Papilio demoleus*	
	Pieridae	*Colias erate*	
Coleoptera	Coccinellidae	*Coccinella septempunctata*	Pollen

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).

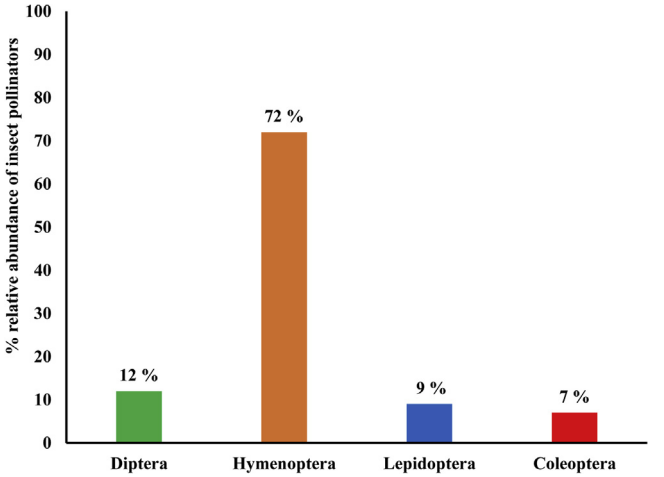

Fig. 2. Percent relative abundance of pollinators on *Eruca sativa* at Peshawar, Pakistan.

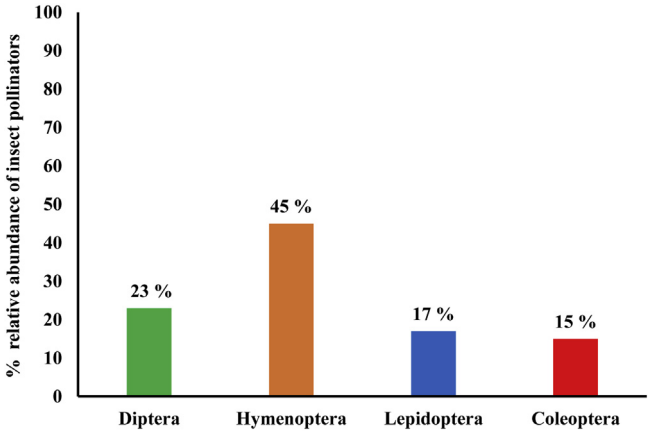

Fig. 3. Percent relative abundance of pollinators on *Brassica rapa* at Peshawar Pakistan.

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 time 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 timing 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.*

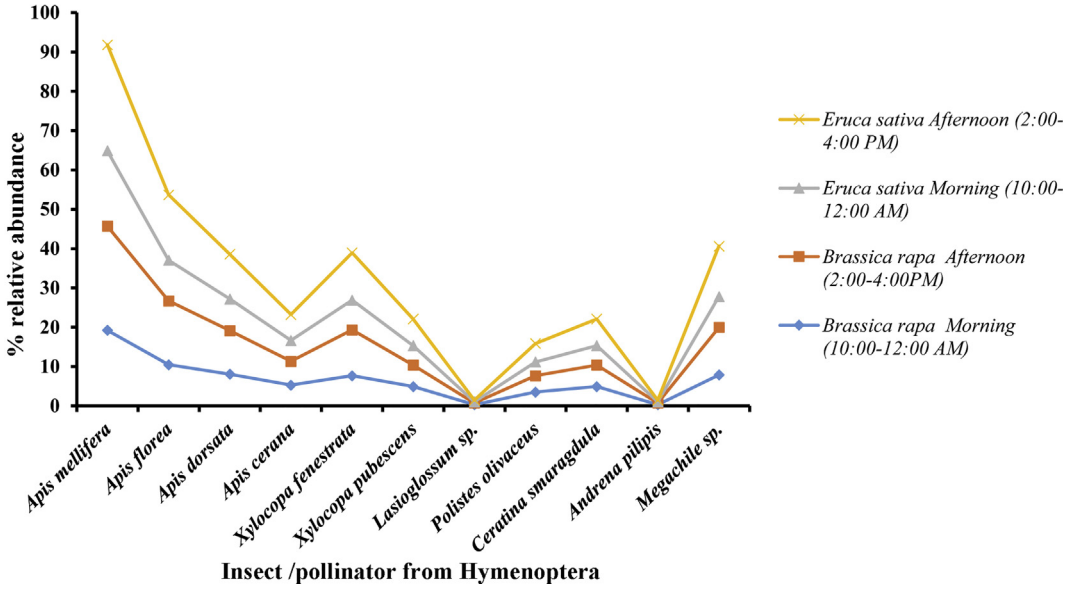

Fig. 4. Abundance of pollinators from Hymenoptera on *Eruca sativa* and *Brassica rapa* in different timings of the day during year 2016–2018. *Apis mellifera* (LSD = 1.04, P = 0.003), *Apis florea* (LSD = 1.31, P = 0.006), *Apis dorsata* (LSD = 0.87, P = 0.008), *Apis cerana* (LSD = 0.721, P = 0.004),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

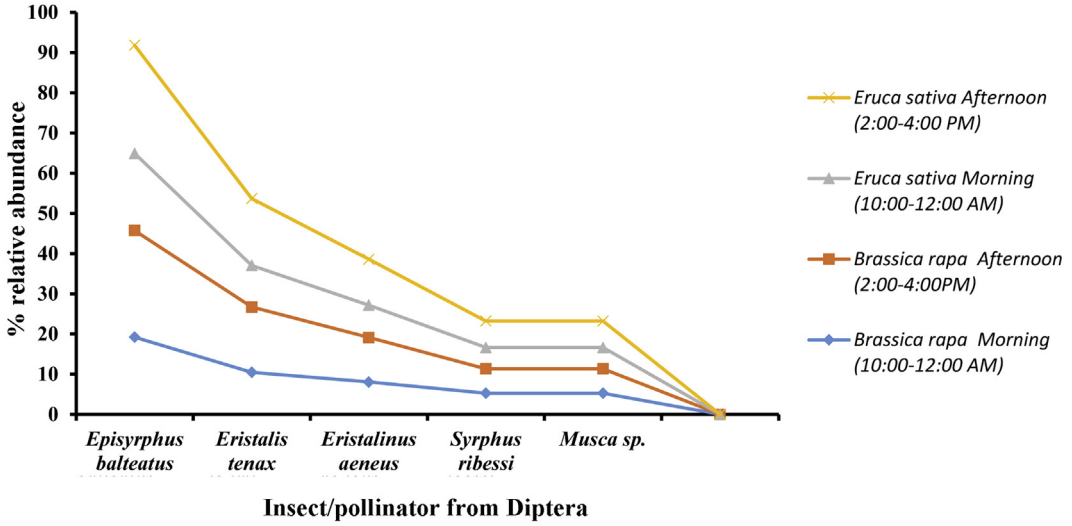

Fig. 5. Abundance of pollinators from Diptera on *Eruca sativa* and *Brassica rapa* in different timings of the day during year 2016–2018. *Episyrphus balteatus* (LSD = 1.04, P = 0.003), *Eristalis tenax* (LSD = 1.31, P = 0.006), *Eristalis aeneus* (LSD = 0.87, P = 0.008), *Syrphus ribessi* (LSD = 0.721, P = 0.004).

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 plays an important role in attracting different pollinators. Hymenopteran were mainly attracted to *E. sativa* than *B. rapa*. The reason could be high amount of nectar secretion. The other reason could the depth of flowers, which is more in *E. sativa* than *B. rapa*. More depth of *E. sativa* make 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*,

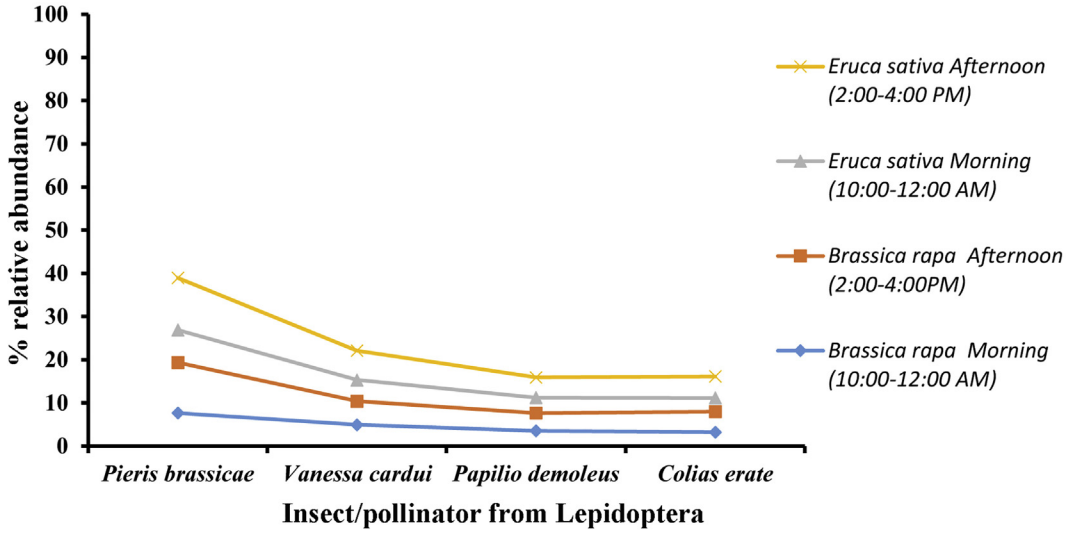

Fig. 6. Abundance of pollinators from Lepidoptera on *Eruca sativa* and *Brassica rapa* in different timings of the day during year 2016–2018. *Pieris brassicae* (LSD = 0.65, P = 0.04), *Vanessa cardui* (LSD = 0.76, P = 0.005), *Papilio demoleus* (LSD = 0.04, P = 0.007), *Colias erate* (LSD 0.041, P = 0.007).

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* (Coloeptera) was recorded on both plants. Although it has nothing to do with pollination of theses crops but may be it feed on pollen grains of the crops. Earlier some research reported that pollen was available in the guts of *C. septempunctata* (Triltsch, 1999).

High temperature in the afternoon increases the secretion of nectar which attracts more insect pollinators. Higher abundance of pollinators was also recoded 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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