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Flower-visiting insect pollinators of mustard (*Brassica napus*) in Jammu Region

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Abstract
The present studies on Flower-Visiting Insect Pollinators of Mustard (*Brassica napus*) in Jammu region, India were conducted at Entomological Research farm, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. The blooming crop of the Mustard was visited by 15 species of insects belonging to 4 orders and 7 families of class insects. Hymenopterans were the most dominant visitors constituting (87.48, 88.18) per cent of the insect pollinators, followed by other insect pollinators (12.52, 11.82%) in 2014-15 and 2015-16 respectively. Among the hymenopterans species, *Apis mellifera* L. was highest in number (28.09, 28.31%) of the visitors of mustard flowers, followed by *Apis cerana* F. (25.10, 25.48%), *Apis dorsata* F. (18.00, 18.09%), *Apis florea* F. (8.53, 7.90%), *Xylocopa fenestrata* (5.55, 5.71 %) and other insect pollinators (12.52, 11.82%). of the total flower visiting insect pollinators in 2014-15 and 2015-16 respectively. The foraging activity of honeybees increased with temperature and sunshine and decreased with relative humidity, wind speed and rainfall. However, the species differences in the population dynamics of bees were evident as of all the honey bees *Apis mellifera* was most abundant followed by *A. cerana >A. dorsata >A. florae >X. fenestrata*. The foraging population of *Apis mellifera* was highly significant and positively correlated with maximum temperature and sunshine hours and negatively with relative humidity in the evening but was non-significant with minimum temperature, relative humidity in the morning, rainfall and wind speed. Same trend was observed for *Apis florea* However, the foraging population of *Apis cerana* was significant and positively correlated with maximum temperature and minimum temperature but was non-significant with relative humidity in the morning and evening, rainfall, sunshine hours and wind speed. Same trend was observed for *Apis dorsata* and other pollinator but other pollinator was highly significant and positively correlated with sunshine hours. In case of *Xylocopa fenestrate* was non-significant with all-weather parameters. This clearly reveals that all the four species of honeybees and other pollinators varied in their response to climatic conditions prevailing at a unit time.

Keywords: Mustard, insect pollinators, *Apis* spp., Weather condition

Introduction
Agricultural production forms one of the most important economic sectors (FAOSTATS, 2013) [8] where the quality of most crop species is increased by pollination (Klein *et al*., 2007; Gallai *et al*., 2009) [15, 10]. Pollination is an important process in maintaining healthy and bio diverse ecosystems. Insects constitute one among the primary groups of pollinating agents, as the association between insects and flowers are well established. Insect pollination is important to the reproduction and persistence of many wild plants (Ollerton *et al*., 2011) [24]. Various insect groups, which are of prime significance in pollination of different agricultural, horticultural and medicinal herbal crops mainly belong to the orders Hymenoptera, Diptera, Coleoptera, Lepidoptera, Thysanoptera, Hemiptera and Neuroptera (Free, 1993; Kearns *et al*., 1998; Mitra and Parui, 2002; Mitra *et al*., 2008) [9, 13, 19, 20]. *Brassica napus* is a self-incompatible crop due to which flowers cannot utilize their own pollen which needs biological agents like different insect groups for transfer of the pollen from male flowers to female flowers (Roy *et al*., 2014) [27]. Selfing in the absence of cross pollination generally reduces seed yield, seed size and yield in subsequent generation (Delaplane and Mayer, 2000) [7]. So far, honeybees alone are considered as significant pollinators on *Brassica* crop, however a number of other insects also visit on this crop during flowering period as reported by various workers from different parts of the country (Thakur *et al*., 1982; Bhalla, *et al*., 1983; Mishra *et al*., 1988; Prasad *et al*., 1989; Chaudhary 2001; Singh *et al*., 2004) [32, 3, 18, 25]. Insect pollination in sarson, increase the seed yield, caused formation of well-shaped, larger grain, and more viable seed (Khan and Chaudhary, 1995) [6].

Therefore, keeping in view the economic importance of the crop, the present study was conducted to study Flower-Visiting Insect Pollinators of Mustard (*Brassica napus*) in Jammu Region

Materials and Methods

The experimental trial was laid at Entomological Research Farm, Sher-e-Kashmir University of Agriculture Sciences and Technology of Jammu,during Rabi 2014-15 and 2015-16. The numbers of insect pollinators of each species visiting mustard were recorded at 10 per cent flowering till its complete cessation. The relative abundance of pollinators (number of flowers visited by pollinators) were studied randomly on selected five plants during different times of the day (08.00, 09.00, 10.00, 11.00, 12.00, 13.00, 14.00, 15.00, 16.00, 17.00 and 18.00 hrs) at alternate days interval during the blooming period were counted. The observations on foraging behaviour viz. initiation and cessation time of pollinators activity on bloom, number of flowers (No. of pollinators/m2/min) visited by insect pollinators at different hours of the day, foraging rate of pollinators (Mean number of flowers visited/min) were recorded by using electronic stopwatch at different crop blooming stage. The weather data like temperature, relative humidity and wind speed were also recorded during the flowering period of *Brassica napus* in the growing season of study.

The data were analyzed by SPSS 24 computer package. The statistical tests applied were Pearson's correlation coefficient Sokal and Rholf (1981). Pearson's correlation coefficients between weather parameter namely maximum and minimum temperature (X_1, X_2), relative humidity morning and evening (X_3, X_4), rainfall (X_5), sunshine hours (X_6) and wind speed (X_7) with insect pollinators on mustard crop *Apis mellifera* (Y_1), *Apis cerana* (Y_2), *Apis dorsata* (Y_3), *Apis florea* (Y_4), *Xylocopa fenestrata* (Y_5) and other pollinators (Y_6) were calculated. The Pearson's correlation co-efficient formula is given here under:

$$r_{xy} = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{(N\Sigma X^2 - (\Sigma X)^2)(N\Sigma Y^2 - (\Sigma Y)^2)}}$$

Where,
r = Coefficient of correlation between weather parameters and insect pollinators on mustard crop
X_1, X_2, X_3, X_4, X_5, X_6, and X_7 were the weather parameters
Y_1, Y_2, Y_3, Y_4, Y_5, and Y_6 were the insect pollinators

Results and Discussion

2014-15 Studies

Diversity of insect pollinators on Mustard bloom

The data presented in Table 1 and Figure 1 showed that mustard flowers attracted wide variety of insects belonging to 4 orders, 7 families, 9 genera and 15 species. Of all these insect pollinators, honey bees *A. mellifera*, *A. cerana*, *A. dorsata*, *A. florea* and *Xylocopa fenestrate* were the dominant flower visitors and comprised of 85.27 % of the total flower visiting insect pollinators. Their abundance was in the order: *A. mellifera >A. cerana >A. dorsata >A. florae >Xylocopa fenestrata*. The other important insect pollinators frequenting mustard flowers were *Andrena* spp., *Pieris rapae, Danaus plexippus*, *Musca* spp. and *Syrphus* spp., the latter group of insects mostly collected nectar and frequented at interrupted hours and were not considered as dependable pollinators. The detailed investigations were, therefore, carried out on honeybees which frequented mustard flowers in large numbers throughout the day and were anatomically suited for pollen collection.

Table 1: Insect visitors and their percentage proportion on mustard bloom during 2014-15

Order	Family	Species	Percentage composition	Total
Hymenoptera	Apidae	*Apis mellifera*	28.09	85.27
		A. cerana	25.10	
		A. dorsata	18.00	
		A. florea	8.53	
		Xylocopa fenestrata	5.55	
	Andrenidae	*Andrena leaena*	1.66	2.21
		A.ilerda	0.55	
Lepidoptera	Pieridae	*Pieris rapae*	1.36	1.36
	Danaidae	*Danaus plexippus*	1.87	1.87
Diptera	Muscidae	*Musca* spp.	3.02	3.02
	Syrphidae	*Eristalis* spp.	0.99	3.76
		Episyrphus balteatus	1.30	
		Metasyrphus corollae	1.47	
Coleoptera	Coccinellidae	*Coccinella septumpunctata*	0.87	2.51
		C. sexmaculata	1.64	

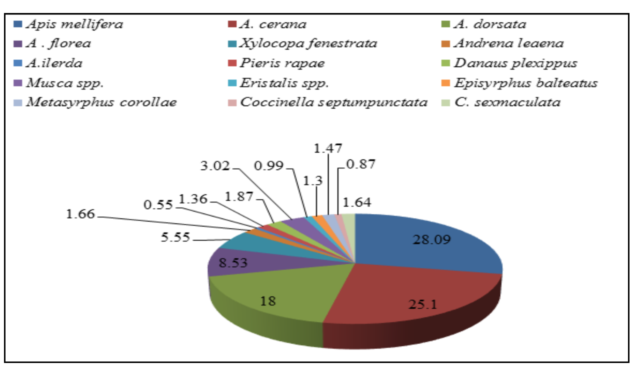
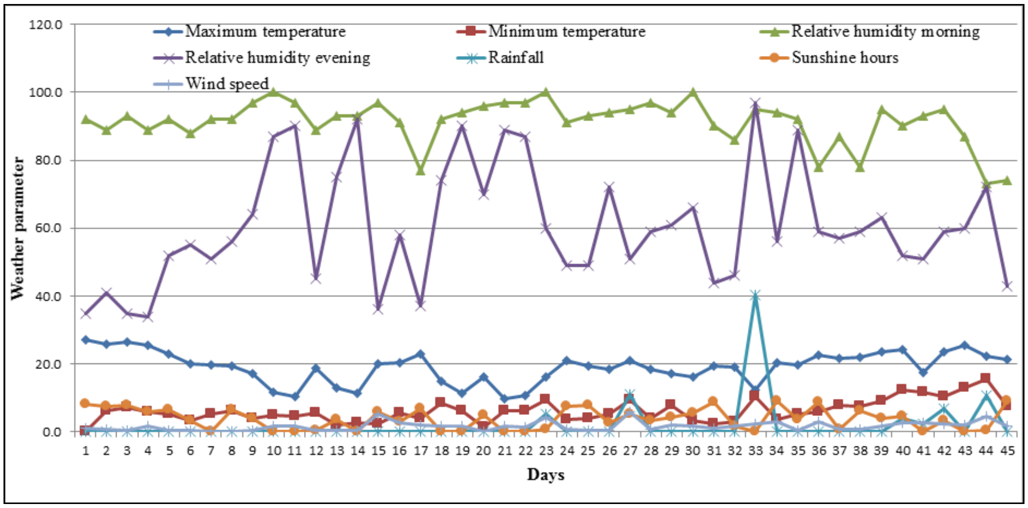


Fig 1: Percentage proportion of insect pollinators complex visiting mustard bloom during 2014-15

Seasonal abundance of pollinators on mustard bloom

The data presented in Figure 2 and 3 showed the seasonal abundance pattern of honey bees *Apis mellifera*, *Apis cerana*, *Apis dorsata*, *Apis florea*, *Xylocopa fenestrate* and other insect pollinators in relation to abiotic factors such as maximum temperature, minimum temperature, morning and evening relative humidity, rainfall, sunshine hours and wind speed. The observations were made at alternative days during the entire flowering periods commencing from 0800 to 1800 hours at hourly intervals. The data recorded during different hours was pooled to obtain observation for alternative day. The data in general revealed that activity of honey bees increased with temperature and sunshine and decreased with relative humidity, wind speed, and rainfall. However, the species differences in the population dynamics of bees were evident as of all the honey bees *A. mellifera* was most abundant followed by >*A. cerana* >*A. dorsata* >*A. florae* >*X. fenestrata.* The influence on the population dynamics of bees as maximum population of all the bee species were observed after 50% of flowering.



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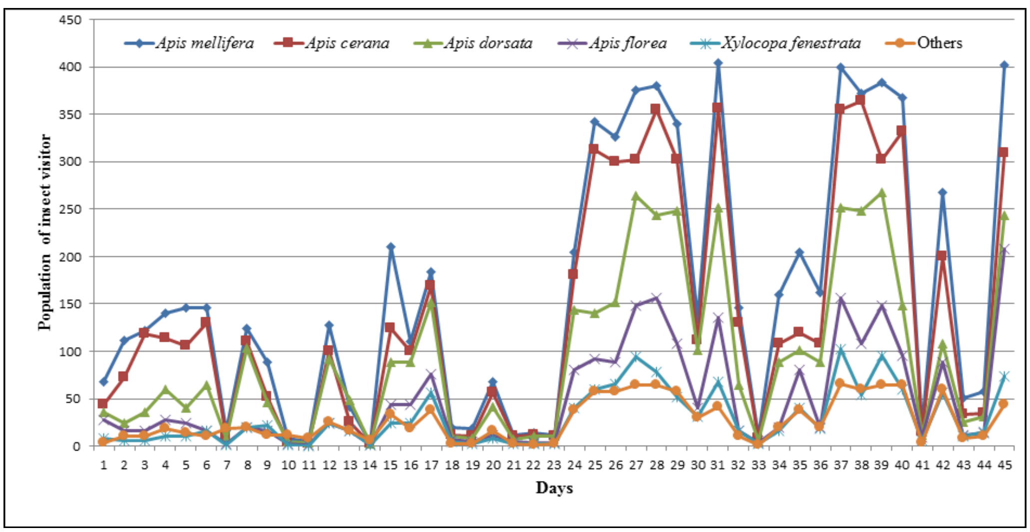


(3)

Fig 2-3: Seasonal incidence of different Pollinators on mustard in relation to weather Parameters

Correlation coefficient (r) between bee activity and weather parameters

The data presented in Table 2 showed that foraging population of *Apis mellifera* was highly significant and positively correlated with maximum temperature and minimum temperature and sunshine hours and negatively with relative humidity in the morning and evening but was non-significant with rainfall and wind speed. However, the foraging population of *Apis cerana* was significant and positively correlated with maximum temperature and minimum temperature and negatively with relative humidity in the morning but was non-significant with relative humidity in the evening, rainfall, sunshine hours and wind speed. Same trend was observed for *Apis florae* but significant and positively correlated with sunshine hours. Similarly, population of *Apis dorsata* was significant and positively correlated with maximum and minimum temperature and sunshine hours, wind speed and negatively with relative humidity in the morning but was non-significant with relative humidity in the evening, rainfall. Same trend was observed for other pollinator. In case of *Xylocopa fenestrata*, the population was significant and positively correlated with minimum temperature and wind speed. Whereas non significant with maximum temperature, relative humidity in the morning and evening, rainfall and sunshine hours. This clearly reveals that all the four species of honeybees and other pollinators varied in their response to climatic conditions prevailing at a unit time.

Table 2: Correlation coefficient matrix between bee pollinators and weather parameters during 2014-15

Name of the parameters	Correlation coefficient (r) with					
	A. mellifera	*A. cerana*	*A. dorsata*	*A. florea*	*Xylocopa fenestrata*	Other pollinators
Maximum temperature	0.535**	0.438**	0.347*	0.388**	0.282	0.380*
Minimum temperature	0.461**	0.427**	0.461**	0.411**	0.483**	0.496**
Relative humidity morning	-0.434**	-0.354*	-0.376*	-0.389**	-0.285	-0.312*
Relative humidity evening	-0.307*	-0.228	-0.083	-0.154	-0.024	-0.060
Rainfall	0.057	0.062	0.165	0.147	0.232	0.130
Sunshine hours	0.210**	0.196	0.089*	0.190**	-0.021	0.050*
Wind speed	0.258	0.237	0.302*	0.253	0.301*	0.294*

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

2015-16 Studies

Diversity of insect pollinators on Mustard bloom

The data presented in Table 3 and Figure 4 showed that mustard flowers attracted wide variety of insects belonging to 4 orders, 7 families, 9 genera and 15 species. Of all these insect pollinators, honey bees *A. mellifera, A. cerana, A. dorsata, A. florea* and *Xylocopa fenestrate* were the dominant flower visitors and comprised of 85.49 % of the total flower visiting insect pollinators. Their abundance was in the order: *A. mellifera >A. cerana >A. dorsata >A. florae >Xylocopa fenestrata*. The other important insects frequenting mustard flowers were *Andrena* spp., *Pieris rapae, Danaus plexippus, Musca* spp. and *Syrphus* spp., the latter group of insects mostly collected nectar and frequented at interrupted hours and were not considered as dependable pollinators. The detailed investigations were, therefore, carried out on honeybees which frequented mustard flowers in large numbers throughout the day and were anatomically suited for pollen collection.

Table 3: Insect visitors and their percentage proportion on mustard bloom during 2015-16

Order	Family	Species	Percentage composition	Total
Hymenoptera	Apidae	*Apis mellifera*	28.31	85.49
		A. cerana	25.48	
		A. dorsata	18.09	
		A. florea	7.90	
		Xylocopa fenestrata	5.71	
	Andrenidae	*Andrena leaena*	1.90	2.69
		A.ilerda	0.79	
Lepidoptera	Pieridae	*Pieris rapae*	1.54	1.54
	Danaidae	*Danaus plexippus*	1.84	1.84
Diptera	Muscidae	*Musca* spp.	1.93	1.93
	Syrphidae	*Eristalis* spp.	1.41	4.08
		Episyrphus balteatus	1.25	
		Metasyrphus corollae	1.42	
Coleoptera	Coccinellidae	*Coccinella septumpunctata*	0.88	2.43
		C. sexmaculata	1.55	

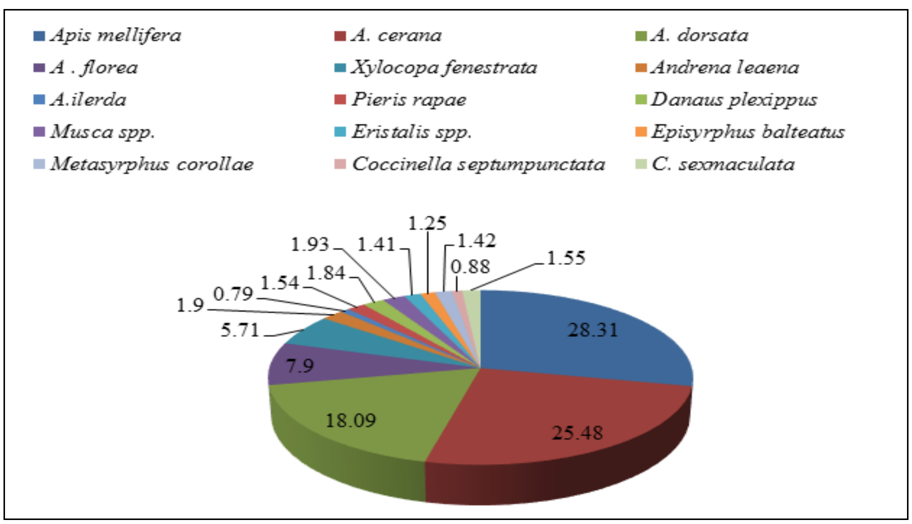
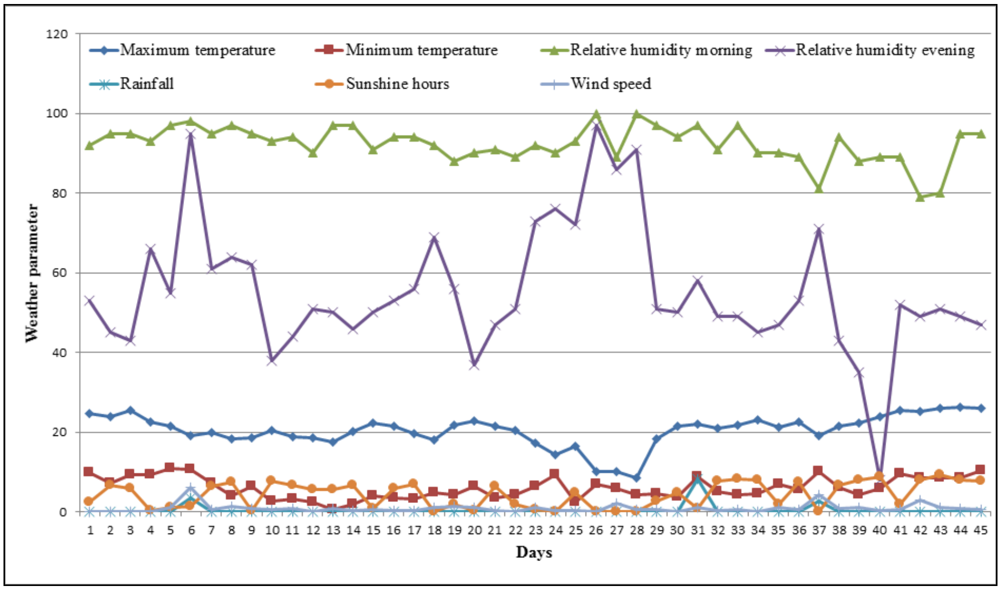


Fig 4: Percentage proportion of insect pollinators complex visiting mustard bloom during 2015-16

Seasonal abundance of pollinators on mustard bloom

The data presented in Figure 5 and 6 showed the seasonal abundance pattern of honey bees *Apis mellifera*, *Apis cerana*, *Apis dorsata*, *Apis florea*, *Xylocopa fenestrate* and other flower visitors in relation to abiotic factors such as maximum temperature, minimum temperature, morning and evening relative humidity, rainfall, sunshine hours and wind speed. The observations were made at alternative days intervals during the entire flowering periods commencing from 0800 to 1800 hours at hourly intervals. The data recorded during different hours was pooled to obtain observation for alternative day. The data in general revealed that activity of honey bees increased with temperature and sunshine and decreased with relative humidity, wind speed, and rainfall. However, the species differences in the population dynamics of bees were evident as of all the honey bees *Apis mellifera* was most abundant followed by *>Apis cerana >Apis dorsata >Apis florae >Xylocopa fenestrata.* The influence on the population dynamics of bees as maximum population of all the bee species were observed after 50% of flowering.



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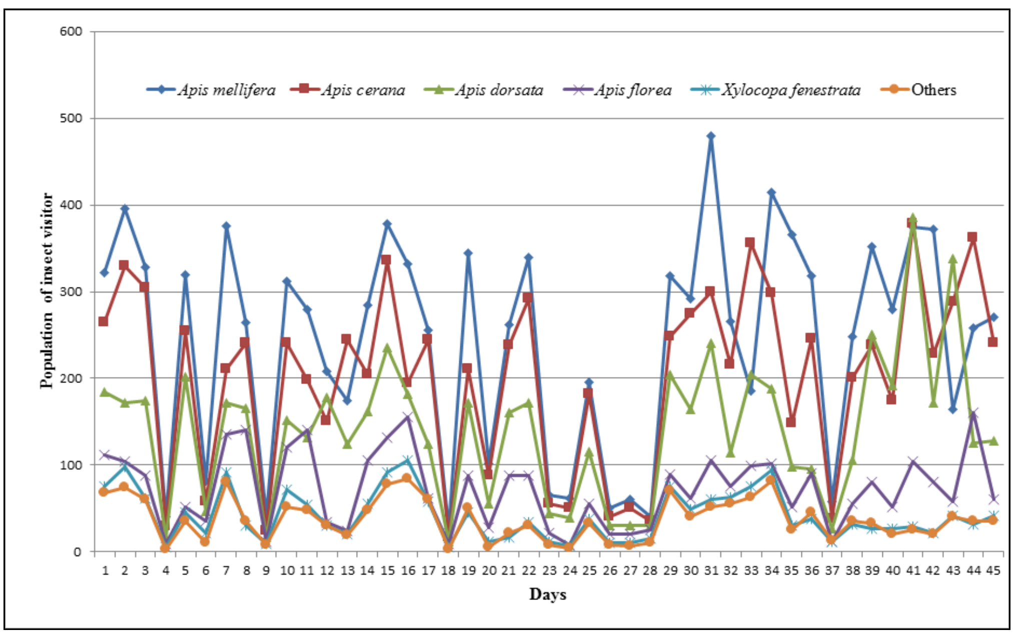

(6)

Fig 5–6: Seasonal incidence of different Pollinators on mustard in relation to weather Parameters

Correlation coefficient (r) between bee activity and weather parameters

The data presented in Table 4showedthat foraging population of *Apis mellifera* was highly significant and positively correlated with maximum temperature and sunshine hours and negatively with relative humidity in the evening but was non-significant with minimum temperature, relative humidity in the morning, rainfall and wind speed. Same trend was observed for *Apis florea* However, the foraging population of *Apis cerana* was significant and positively correlated with maximum temperature and minimum temperature but was non-significant with relative humidity in the morning and evening, rainfall, sunshine hours and wind speed. Same trend was observed for *Apis dorsata* and other pollinator but other pollinator was highly significant and positively correlated with sunshine hours. In case of *Xylocopa fenestrate* was non-significant with all-weather parameters. This clearly reveals that all the four species of honeybees and other pollinators varied in their response to climatic conditions prevailing at a unit time.

Table 4: Correlation coefficient matrix between bee pollinators and weather parameters during 2015-16

Name of the parameters	Correlation coefficient (r) with					
	A. mellifera	*A. cerana*	*A. dorsata*	*A. florea*	*Xylocopa fenestrata*	Other pollinators
Maximum temperature	0.729**	0.588**	0.502**	0.509**	0.256	0.605**
Minimum temperature	0.111	0.346*	0.314*	-0.02	0.042	0.440**
Relative humidity morning	-0.23	-0.276	-0.042	-0.240	0.200	-0.245
Relative humidity evening	-0.615**	-0.242	-0.281	-0.341*	-0.104	-0.265
Rainfall	0.156	0.166	0.189	0.024	0.104	0.251
Sunshine hours	0.165*	0.079	-0.041	0.299*	-0.020	0.041**
Wind speed	-0.158	0.002	0.096	-0.137	-0.040	0.118

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

In earlier studies also, honeybees have been reported as significant pollinators on *Brassica* crop, however a number of other insects also visit on this crop during flowering period as reported by various workers from different parts of the country (Thakur *et al.*, 1982; Bhalla, *et al.*, 1983; Mishra *et al.*, 1988; Prasad *et al.*, 1989; Kakar, 1981; Priti and Gupta, 1992; Kumar *et al.*, 1994; Singh, 1994; Sinha *et al.*, 1983; Chaudhary 2001; Singh *et al.*, 2004) [32, 3, 18, 25, 6]. Floral morphology is well known to affect the efficiency of pollen removal and deposition during pollinator visits (Campbell, 1989; Murcia, 1990; Young and Stanton, 1990; Nishihiro *et al.*, 2000; Yang *et al.*, 2002; Kudo, 2003) [5, 21, 34, 22, 33, 16] and to have the potential to increase or decrease seed production in both self-fertilizing and out crossing plants.

Similar studies have earlier been conducted by Atmowidi *et al.*, (2007) [2] who analysed the diversity of pollinator insects and its effect to seed set of mustard (*Brassica rapa*) planted in agricultural ecosystem in West Java. At least 19 species of insects pollinated the mustard, and three species, i.e. *Apis cerana*, *Ceratina* sp., and *Apis dorsata* showed a high abundance. The higher abundance and species richness of pollinators occurred at 08.30-10.30 am and the diversity was related to the number of flowering plants.

In general, each bee pollinator has specific ecological threshold for foraging activity which differ inter and intra specifically depending upon the level of adaptation of a given species in an environment (Burill and Dietz, 1981; Abrol and Kapil, 1986) [4, 1]. The bee activity increased with temperature but was not affected by relative humidity and vapour pressure. Nunez (1977) [23] found that in case of *Apis mellifera*, morning activity was related to nectar flow and in the evening it was correlated with the photoperiod. Iwama (1977) [11] found that the interaction between temperature and light intensity was responsible for the flight activity of *Tetragonisca angustica*. Abrol and Kapil (1986) [1] found that light intensity and solar radiations were important factors controlling flight activity of *Megachilelanata*

Conclusion

The studies revealed that mustard flowers attracted a wide variety of insects. Of all the insect pollinators, honey bees *A. mellifera, A. cerana, Apis dorsata, A. florae* and *Xylocopa fenestrata* were the dominant flower visitors and comprised of 85.27 and 85.49 % of the total flower visiting insect pollinators. Their abundance was in the order: *A. mellifera >A. cerana >A. dorsata >A. florae >Xylocopa fenestrata*. The other important insects frequenting mustard flowers were *Andrena* spp., *Danaus plexippus, Pieris brassicae, Musca* spp. and *Syrphus* spp. The data on seasonal abundance revealed that activity of honey bees increased with temperature and sunshine and decreased with relative humidity, wind speed and rainfall. However, the species differences in the population dynamics of bees were evident as of all the honey bees *Apis mellifera* was most abundant followed by *Apis cerana >Apis dorsata >Apis florae >Xylocopa fenestrata*. Analysis of data revealed that foraging population of *Apis mellifera* was highly significant and positively correlated with maximum temperature and minimum temperature and sunshine hours and negatively with relative humidity in the morning and evening but was non-significant with rainfall and wind speed. However, the foraging population of *Apis cerana* was significant and positively correlated with maximum temperature and minimum temperature and negatively with relative humidity in the morning but was non-significant with relative humidity in the evening, rainfall, sunshine hours and wind speed. Same trend was observed for *Apis florae* but significant and positively correlated with sunshine hours similarly, population of *Apis dorsata* was significant and positively correlated with maximum and minimum temperature and sunshine hours, wind speed and negatively with relative humidity in the morning but was non-significant with relative humidity in the evening, rainfall. Same trend was observed for other pollinator. In case of *Xylocopa fenestrata*, the population was significant and positively correlated with minimum temperature and wind speed. Whereas non significant with maximum temperature, relative humidity in the morning and evening, rainfall and sunshine hours. This clearly reveals that all the four species of honeybees and other pollinators varied in their response to climatic conditions prevailing at a unit time.

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