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Diversity and abundance of insect pollinators on *Allium cepa* L.

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Abstract
Field experiment was conducted at CCS Haryana Agricultural University, Hisar during 2009-10 to investigate the diversity and abundance of insect pollinators on *Allium cepa* L. and correlate their incidence in relation to the abiotic environmental factors. Hymenopterans were found to be the most abundant (60%) followed by Lepidoptera, Diptera and Coleoptera. Variation in abundance was recorded over time and space. Irrespective of different day hours, significantly maximum number of *Apis dorsata* was recorded from onion umbels (5.24 bees/m^2/5 min.) followed by *A. mellifera* (4.05 bees/m^2/5 min.), *A. cerana* (2.93 bees/m^2/5 min.) and *A. florea* (1.79 bees/m^2/5 min.) (CD=0.51; p=0.05). Fluctuation in visits of insect pollinators on different days was observed. The visits were low at the time of commencement and cessation of flowering but remained high during mid-flowering period. The study revealed that among abiotic factors, maximum and minimum temperature and relative humidity play a significant role in the foraging population on onion umbels.

Keywords: *Allium cepa* L., Hymenopterans, insect pollinators, diversity, abundance.

1. Introduction
Onion (*Allium cepa* L.) is an important vegetable crop worldwide and has been used in various forms of food as salads, as a raw or cooked vegetable and as a condiment. A global review of major vegetables shows that onion ranks second after tomato in area. Approximately, 36 million tonnes onion are produced on 2-5 million ha globally. India, second in world onion production, grows onion in approximately 8, 00,000 ha with an average productivity of 10 tones/ha (FAO, 2008). Vegetable and fruit crops depend upon insect pollination for yield and fruit quality. Colour, shape and odour of flowers are well-known attractants to pollinators. Besides these physical features, the other source of variation for differential attraction between genotypes is the caloric reward *viz*,, nectar and pollen provided by the flowers. The nectar provided by the flowers has been found to be a significant parameter that shapes the behaviour of pollinators in relation to their energetic needs [1]. The absence of natural pollinators on onion seed plantations poses a serious problem for breeders all over the world. In case of onion, wind pollination has a little effect because of the presence of sticky pollen. According to [3], the pollination activity of wind was 10 %, other pollinators were 3% and honey bees were 87% in onion pollination. Hand pollination is cumbersome job but an important method of pollen transfer in plant breeding. The onion umbel is a roughly spherical inflorescence composed of numerous open, dish shaped flowers with easily accessible nectar, which attracts many short tongued insects. Besides physical features of flowers such as colour, shape and odour, environmental factors such as temperature, humidity, light, solar radiation, time of the day and nectar flow affect the behaviour of pollinating insects thereby influencing the cross-pollination and the production of the crop (Corbet *et al*., 1993). Thus, it was decided to investigate the diversity and abundance of insect pollinators on *Allium cepa* L. and correlate their incidence in relation to the abiotic environmental factors.

2. Material and Methods
Field experiment was conducted at research farm of the Department of Vegetable Sciences, Chaudhary Charan Singh Haryana Agricultural University, Hisar and Apiculture Laboratory of the Department of Entomology. The crop was raised under field conditions following standard agronomical practices. The bulbs of onion variety HS-2 were planted on November 13, 2009 with eight replications. The observations were recorded from March to April, 2010. The crop was harvested in mid April, 2010. To determine the spectrum of different insects visiting the blossoms of onion, these were collected by a cone type hand net with 40 cm ring diameter.

Sweepings were made by insect net throughout the blooming period at weekly intervals during March to May at hourly intervals from morning to evening i.e. 0600-0800, 0800-1000, 1000-1200, 1400-1600 and 1600-1800 h. The collected insects were kept in insect killing bottle which was used to kill the insect visitors and pollinators on onion umbels with the help of chloroform. These were pinned with the help of insect pin (number 9) in wooden insect box and preserved as dry specimen. Collected insects included both insect visitors and pollinators on onion umbels. These were identified as per available literature.

Abundance of different insect visitors/pollinators of onion crop mentioned above was recorded from the commencement (first week of March) till the end of the blooming season (second week of April). For this purpose, ten umbels of uniform size of HS-2 were randomly selected per meter row length and the total number of insect pollinators of each species was recorded by visual counting at the beginning of each hour for five minutes from 0600–1800h on all the days of observation. The mean of these observations constituted a reading for each hour. Observations were recorded daily, using a hand tally counter and chronometer (stopwatch) following the method given by Free (1993). Chronometer with an accuracy of 0.01 second was used to record the time spent per umbel and the number of umbels visit per unit time by different insects on variety of *Allium cepa*. These observations were continued during whole blooming period. To record the relative abundance of various pollinators, abundance as per the method described above was recorded per square meter per minute for whole day on all days of observations.

Behaviour of pollinating insects in relation to some meteorological variables was studied. Data on the meteorological variables *viz.* temperature (maximum and minimum), relative humidity (morning and evening), sunshine hours, wind speed (km/h) and average evaporation pressure, were obtained from Department of Meteorology, CCSHAU, Hisar.

The statistical significance of data was assessed through two factorial analysis of variance (ANOVA) using OPSTAT software and means were then compared using Duncan's multiple range test (p= 0.05). Correlation matrix was worked out to study the influence of meteorological variables on abundance of pollinators.

Table 1: List of insect visitors/ pollinators of onion (*Allium cepa* L.) umbels at Hisar

Sr. No.	Scientific name	Family	Order
1.	*Apis cerana* Fab.	Apidae	Hymenoptera
2.	*Apis dorsata* Fab.	Apidae	Hymenoptera
3.	*Apis florea* Fab.	Apidae	Hymenoptera
4.	*Apis mellifera* L.	Apidae	Hymenoptera
5.	*Coccinella* sp.	Coccinellidae	Coleoptera
6.	*Danais chrysippus* (L.)	Danaidae	Lepidoptera
7.	*Diaphania indica* (Saunders)	Pyralidae	Lepidoptera
8.	Dung Beetle	Scarabaeidae	Coleoptera
9.	*Eristalis* sp.	Syrphidae	Diptera
10.	*Megachile* sp.	Megachilidae	Hymenoptera
11.	*Musca domestica* L.	Muscidae	Diptera
12.	*Nomia* sp. 1	Apidae	Hymenoptera
13.	*Nomia* sp. 2	Apidae	Hymenoptera
14.	*Pieris rapae* L.	Pieridae	Lepidoptera
15.	*Polistis hebraeus* Fab.	Vespidae	Hymenoptera
16.	*Sarcophaga* sp.	Sarcophagidae	Diptera
17.	*Spodoptera exigua* (Hübner)	Noctuidae	Lepidoptera
18.	*Spodoptera litura* (Fabricius)	Noctuidae	Lepidoptera
19.	*Stizus* sp.	Sphecidae	Hymenoptera
20.	*Trigona iridepennis* Smith	Apidae	Hymenoptera
21.	*Vespa orientalis* L.	Vespidae	Hymenoptera
22.	Wasp (thin waisted)-1		Hymenoptera
23.	Wasp (thin waisted)-2		Hymenoptera
24.	*Xylocopa* sp.	Apidae	Hymenoptera
25.	Yellow wasp with black lines		Hymenoptera

3. Results and Discussion

3.1 Diversity and abundance of insect pollinators

The pollinators recorded in the present investigation have been listed in Table 1. As far as per cent frequency of occurrence in terms of pollination activity is concerned, Hymenopterans were most abundant (60%) followed by Lepidoptera, Diptera and Coleoptera. (Fig.1). All the four *Apis* species *viz. A. dorsata, A. cerana, A. mellifera* and *A. florea* were recorded as top workers on onion umbels as pollen and nectar gatherers. Of all the insect visitors, *A. dorsata* and *A. mellifera* were the most frequent visitors. In earlier studies also, insect fauna belonging to Diptera, Hymenoptera and butterflies has been reported to visit and pollinate the onion field [4, 16, 18]. The onion flowers are attractive to these insects because they feed upon the nectar, pollen, or both [4]. The nectaries are shallow, and, unless the nectar is rapidly removed by insects, it can be easily seen glistening in the sunlight like a tiny jewel. In general, diversity of pollinating insects varies from region to region and locality to locality. According to Saeed *et al.* (2008) [18], the community of pollinators on onion was composed of four bee species and twelve true fly species, whereas Shafqat and Masood (2008) [21] reported two Hymenopteran bees and eight true flies of Diptera as pollinators of onion crop. In consonance with our findings, the predominance of honey bees constituting 68.4% (Kumar *et al.*, 1985) and 82.3% [6] pollinators was recorded in onion crop.

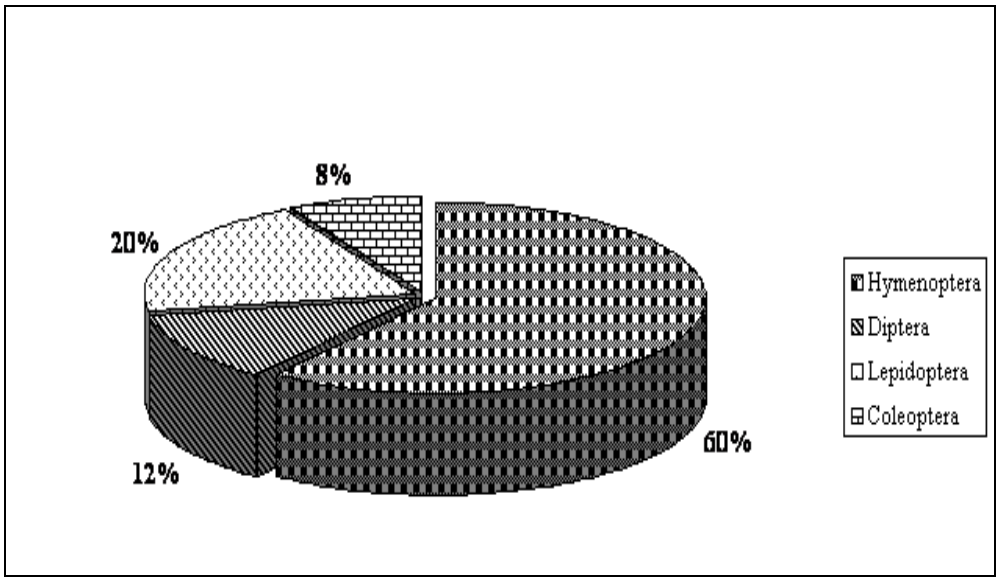

Fig 1: Abundance of different insect pollinators on onion (*A. cepa*) umbels

Table 2: Abundance of bee pollinators on *A. cepa* umbels at different hours of the day during March-April 2010 at Hisar

Bee species	Number of bees /m^2/5 min during different day hours*					Mean
	0600-0800	0800-1000	1000-1200	1400-1600	1600-1800	
Apis dorsata	4.32	6.88	4.28	5.00	5.72	**5.24**
A. mellifera	3.88	4.28	3.56	3.72	4.84	**4.05**
A. cerana	1.84	2.88	3.68	3.56	2.72	**2.93**
A. florea	1.84	1.52	1.72	2.28	1.60	**1.79**
Mean	**2.97**	**3.89**	**3.31**	**3.64**	**3.72**	-

* Figures are means of 50 observations
CD (p=0.05) for bee species = 0.51; SE(m)= 0.18
CD (p=0.05) for duration = 0.57; SE(m)= 0.20
CD (p=0.05) for bee species× duration = 1.14; SE(m)= 0.41

Data on abundance of bee pollinators on *A. cepa* umbels at different hours of the day is presented in Table 2. Variation in abundance was recorded over time and space. Irrespective of different day hours, significantly maximum number of *Apis dorsata* was recorded from onion umbels (5.24 bees/m^2/5 min.) followed by *A. mellifera* (4.05 bees/m^2/5 min.) and *A. cerana* (2.93 bees/m^2/5 min.) (CD=0.51; p=0.05). Significantly minimum population of *A. florea* (1.79 bees/m^2/5 min.) was observed on onion umbels. Wind is not a factor of significance in onion pollination (Erickson and Gabelman, 1956). Insects are the primary factors. Honey bees are effective pollinators of open-pollinated onions because both pollen and nectar are available on all umbels. Beekeepers occasionally obtain honey with a characteristic onion flavor that disappears after a few weeks. In this study, honey bees were dominant fauna visiting onion umbels as all the four honey bee species, *A. dorsata, A. mellifera, A. florea* and *A. cerana* were found to visit the onion variety HS-2. The relative abundance of *A. dorsata* and *A. florea* was observed as 45 and 37 per cent on onion florets by Chaudhary (2004) [6]. While studying the role of pollinator community in onion, Shafqat and Masood (2008) [21] reported the abundance of *A. dorsata, Episyrphus balteatus* (Syrphidae) as 2.85± 1.57 and 14± 4.61 individuals/ 25 plants, respectively.

Table 3: Relative Abundance of bee pollinators on *A. cepa* umbels during March-April 2010 at Hisar

Date of observation	Number of bees//m^2/ minute*				
	Apis dorsata	*Apis mellifera*	*Apis cerana*	*Apis florea*	Mean
08.03.2010	7.90	5.50	4.80	3.50	**5.42**
13.03.2010	8.60	6.40	5.10	3.70	**5.95**
21.03.2010	8.80	6.40	5.50	4.00	**6.17**
02.04.2010	9.60	4.90	4.50	3.40	**5.60**
0.6.04.2010	6.70	4.20	3.60	3.10	**4.40**
Mean	**8.32**	**5.48**	**4.70**	**3.54**	

* Figures are mean of 50 observations
CD (p=0.05) for bee species = 0.23; SE(m)= 0.11
CD (p=0.05) for date of observation = 0.67; SE(m)= 0.19
CD (p=0.05) for bee species× date of observation = 1.04; SE(m)= 0.21

Data on relative abundance of four *Apis* species on different dates of observations is presented in Table 3. The results clearly showed that at the initiation of flowering period (initial date of observation), irrespective of bee species, number of bees was significantly less (5.42 bees/m^2/min) during the day (CD = 0.23; p= 0.05). As the flowering period increased, it showed corresponding significant increase in number of bees to 5.95 bees/m^2/min on 13.03.2010, and which increased to maximum (6.17 bees/m^2/min) during full bloom (21.03.2010). Afterwards, the number of bees declined significantly. Irrespective of dates of observations, relative abundance of *A. dorsata* was maximum (8.32 bees/m^2/min) followed by *A. mellifera* (5.48 bees/m^2/min), *A. cerana* (4.70 bees/m^2/min) and *A. florea* (3.54 bees/m^2/min) (CD = 0.67; p = 0.05). Pollination process is more efficient when there are more flowers on a plant. At peak flowering, the availability of flowers is more than commencement and cessation and large numbers of insects visit the crops during this period to help maximize the pollination process. In the present investigation, fluctuation in visits of insect pollinators on different days on onion crop was observed. The visits were low at the time of commencement and cessation of flowering but these remained high during mid flowering period. This difference may be due to variation in the floral density during the span of blooming on the crops. Kendell and Smith (1975) [14], Willson and Price (1977) [23], Schaffer and Schaffer (1979) [19], Schemske (1980) [20] and Dhaliwal and Atwal (1985) [7] also stated that at the peak flowering, number of flowers was more/maximum and these were visited by larger number of pollinators and helped maximization of pollination in different crops. Choudhary (2004) also recorded maximum number of *A. dorsata* during full bloom period in onion. The maximum pollinator activity was observed from 12 to 24 days after opening of the flowers [17].

Table 4: Correlation coefficient matrix exhibiting interrelations of different environmental factors influencing pollination activity of bees visiting onion umbels

	No. of *A. dorsata*	**No. of *A. mellifera***	**No. of *A. cerana***	**No. of *A. florea***	**Max temp (º C)**	**Min temp (º C)**	**RH (M) (%)**	**RH(E)(%)**	**SS (h)**	**WS (Km/h)**	**AVP (mm)**
No. of *A. dorsata*	1										
No. of *A. mellifera*	0.957*	1									
No. of *A. cerana*	0.886*	0.872*	1								
No. of *A. florea*	0.921*	0.926*	0.961*	1							
Max temp (º C)	0.619*	0.707*	0.609*	0.662*	1						
Min temp (º C)	0.727*	0.674*	0.702*	0.739*	0.925*	1					
RH (M) (%)	-0.435	-0.543	-0.406	-0.459	-0.708*	-0.777*	1				
RH (E) (%)	-0.702*	-0.736*	-0.662*	-0.644*	-0.975*	-0.827*	0.639*	1			
SS (h)	0.591	0.708*	0.626*	0.511	-0.357	-0.351	0.824*	0.328	1		
WS (Km/h)	0.094	-0.026	-0.232	0.086	-0.435	-0.634*	0.158	0.325	-0.408	1	
AVP(mm)	-0.369	-0.313	-0.470	-0.254	0.813*	0.828*	-0.301	-0.735*	0.148	-0.742*	1

* Significant at 5% level

3.2 Relationship of foraging population with environmental factors

To find the relationship between biotic i.e. honey bees and environmental factors, correlation matrix was calculated and presented in Table 4. Variation of *A. dorsata* abundance was significantly positively correlated with variation in *A. cerana* (r=0.886), *A. mellifera* (r=0.957) and *A. florea* (r=0.921) abundance. The study revealed that among abiotic factors, maximum and minimum temperature and relative humidity play a significant role in the foraging population of all the four *Apis* species on onion umbels. The number of *A. dorsata* foragers on *A. cepa* umbels was correlated positively and significantly with the maximum (r= 0.619) and minimum (r= 0.727) temperature within the maximum temperature range of 26.6° to 40.5 °C and minimum temperature range of 7.5° to 19.2 °C.

A significant negative correlation between *A. dorsata* forager population and evening relative humidity (r=-0.702) was recorded. A non-significant relationship was obtained between average evaporation pressure and population of *A. dorsata.* Due to inequitable distribution of average evaporation pressure in different sampling dates, no significant relationship was recorded. Similarly, no significant relation between evening relative humidity, sun shine hours, wind speed and *A. dorsata* forager population was recorded in the present investigation. Similar results were obtained for the interaction between *A. florea* and abiotic factors (Table 4). The correlation coefficient matrix (Table 4) between *A. mellifera* activity and environmental factors indicated that foraging populations of *A. mellifera* correlated significantly and positively with sunshine hours (r=0.708) and negatively with evening relative humidity.

Each bee species has a specific ecological threshold for commencement and cessation of flight activities. The results are in accordance with Kapil and Kumar (1974) [13] who reported 15–18 ˚C as the minimum threshold temperature for commencement of field activities in honey bees. Ewies and El-Sahhar (1977) [9] reported 30-32 ^{0}C temperature as most favourable because maximum number of bees foraged at this temperature in onion. Kapil and Jain (1980) [12] reported that air temperature appeared to be a key factor influencing the initiation of bee activity but cessation was independent of air temperature. The suitability of atmospheric temperature coupled with relative humidity and light intensity not only favoured the initiation but also led to maximum of bee activity. In the evening, relative humidity remained favourable but cessation of bee activity occurred due to decline in the light intensity. Burill and Dietz (1981) [5] found that in honey bees, foraging activity increased with increasing air temperature but was not correlated with changes in atmospheric pressure and relative humidity. Bee activity was found to be uniformly positively and significantly correlated with the ambient temperature and nectar sugar concentration, and negatively and significantly with the relative humidity in all the three honey bee species and on all the cultivars of oilseed crops (Sihag and Khatkar, 1999) [22]. According to Abrol (2006) [2], the ecological threshold for commencement and cessation of flight activity of each honey bee species varied from one another. Path analysis revealed that in general, 15.5 -18.5 ˚C temperature, 600 -1700 lx light intensity, and 9 -20 mW/cm^2 solar radiation appeared to be the minimum ecological conditions for commencement of flight activity in *Apis* species. Cessation of activities in all the honey bee species was controlled mainly by decline in values of light intensity and solar radiation irrespective of other factors.

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