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Pollinator Community of Onion (*Allium cepa* L.) and its Role in Crop Reproductive Success

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Abstract.- Investigations to identify the pollinator community of insects and its role in onion (*Allium cepa* L.) pollination were carried out at the research farm of University College of Agriculture, Bahauddin Zakariya University, Multan, Pakistan. The community of pollinators was composed of two bees (Order: Hymenoptera) and eight true flies (Order Diptera). Among bees, *Apis dorsata* proved to be an abundant pollinator (2.85±1.57 individuals/25 plants) while among true flies *Episyrphus balteatus* (Syrphidae) had the maximum abundance of 14.00±4.61 individuals/25 plants. All the insect pollinator species reached peak activity during 10:00 to 12:00 h. *Eupeodes corollae* (Syrphidae) exhibited the most efficient foraging behavior by visiting 17.14±1.38 flowers in 147.5±8.14 seconds on an umbel. *A. dorsata* was revealed as the most effective pollinator, however, based on seed setting results for visits by single species over 20 minutes and which produced 506 seeds/umbel/20 minute visit.

Key words: *Allium cepa* L., onion, pollination effectiveness, pollinators, seed setting.

INTRODUCTION

The availability of natural insect pollinators is decreasing rapidly due to the continuous use of pesticides and decline of necessary habitat (Richards, 2001). Pollinators provide an essential ecosystem service that contributes to the maintenance of biodiversity and ensures the survival of plant species including crop plants.

Insect pollination is necessary for many cross pollinated crops especially in the case of hybrid seed production e.g. onion (*Allium cepa* L.) (Mayer and Lunden, 2001). The role of managed honey bee (*Apis mellifera* L.) in onion pollination has widely been documented by many authors (Kumar *et al*. 1989; Rao and Suryanarayans, 1989; Ahmed and Abdalla, 1984; Mayer and Lunden, 2001; Tolon and Duman, 2003), but managed bee pollination is not always possible in all environments. Conserving alternate native pollinators can be a good option in areas which are very hot e.g. Southern Punjab, Pakistan where the average temperature in summer is 46ºC (PARC, 1980) or very cold and dry Balochistan province, Pakistan, where stationery bee keeping can not be practiced because of prevailing dry and cold climatic conditions and lack of forage during the large part of the year.

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Consequently, native pollinators should be assessed for their pollination potential, so as to conserve and manage the most efficient native pollinators to produce maximum crop yield. Pollinator species and their composition may vary with geographical area, latitude and time (Ollerton and Louise, 2002). For example, in the mountainous Hindu Kush Himalayan region *Apis mellifera*, *A. dorsata*, *A. cerana* and *A. florea* are the most frequent visitors (Chandal *et al*., 2004), but in the plains of Punjab, Pakistan, *A. mellifera* and *A. cerana* are poorly represented.

Most of the experiments on the onion have been done in caged conditions using different flies and bees *e.g. Calliphora*, *Lucilia* (Diptera: Calliphoridae), *Eristalis* sp. (Diptera: Syrphidae), *Osmia rufa* (Hymenoptera: Megachillidae) (Moffett, 1965; Bohart *et al*., 1970; Currah and Ockendon, 1983; Free, 1993; Schittenhelm *et al*., 1997) but very few studies have been done in open field conditions.

Onion flowers are protandrous and pollen is shed within 2-3 days before the stigma is receptive (Lesley and Ockendon, 1978), therefore, self-pollination within a flower is not possible. In order for pollination to occur, pollen must come from another flower of the same or a different plant (Zdzislaw *et al.*, 2004). Thus, cross-pollination is common in onion (Chandel *et al.*, 2004), which results in early seed set and higher yields. Wind is not a factor of significance in onion pollination (Erickson and Gabelman, 1956) and onion does not produce quality seed if insects do not visit the flowers (Chandel *et al*., 2004). Non-availability of pollinators during the flowering period of onion causes only 17% fruit setting and free availability of pollinators increased fruiting up to 73% (Rao and Sunyanarayana, 1989).

Cross-pollination is obligatory in the fertilization of male-sterile onions used in hybrid seed production (Van der Meer and Van Bennekom, 1968). Onion suffers severe inbreeding depression with drastic decrease in growth bulb size, and seed production after only two cycles of self-pollination within a plant (Jones and Davis, 1944). In onion when the flowering begins, only a few flowers open each day on an umbel, but the number increases until at full bloom where 50 or more florets may be open on a single day (Moll, 1954).

Apart from honeybees, onion flowers are visited by bumblebees, dipterans and butterflies (Jablonski *et al*., 1982). In various regions of India (Chandel *et al*., 2004), syrphids are important contributors in the process of pollination along with the most effective *Apis dorsata* and *A. florea*. The lack of intense attractiveness of onions may cause the bees to neglect the crop (Franklin, 1970), particularly if another highly attractive crop is in flowering nearby.

The objective of this experiment was to study the diversity of most frequent pollinators of the onion and exploring their pollination effectiveness in perspective of conserving and managing the best pollinators for onion pollination.

MATERIALS AND METHODS

Study site

The investigations were carried out at the research farm of the University College of Agriculture, Bahauddin Zakariya University, Multan (30.255º North Latitude and 071.513º East Longitude) during 2007 vegetative season (October-April). The experimental material was onion *(Allium cepa* L.) seedlings of Var. "Dark Red".

Pollinator abundance and population dynamics

The syrphid pollinators were identified to generic level using identification keys (Vockeroth, 1996), with further specialist assistance to reach species level (see acknowledgement).

Pollinator abundance and population dynamics were calculated by randomly observing 25 plants for 60 seconds/plant and counting the number of individuals visiting for each of the different pollinator species. Observations were made in two-hourly intervals from 6:00 to 18:00 h throughout the day and repeated in four-daily intervals during the full flowering period of 36 days.

Foraging behavior of pollinators

Insect foraging behavior was observed by counting the average stay time/umbel/visit and number of flowers visited/umbel/visit in different intervals of the day for different species.

Role of different pollinators in reproductive success

To determine the role of different pollinators in pollination, 50 primary umbels of the same age were randomly selected and veiled with nylon mesh bags before the flowers opened. When 50 percent of the flowers had opened in the middle of peak flowering period, which lasts for 4-10 days (Lesley and Ockendon, 1978), these umbels were unveiled during the peak foraging period of the day, *i.e.* 10:00 to 12:00 h. Only one individual of single pollinator species was allowed to sit on the umbel at a time, for a total of 20 minutes. During this time the number of flowers visited/umble/20 minutes were visually counted, a stop watch being used to time the visit until the insect flew away. The umbel was re-veiled after completion of a 20 minutes visit. These veiled umbels were later counted for seed set and compared with that of open-pollinated and self-pollinated (veiled throughout the flowering duration) umbels.

The data of visiting time/umbel, flowers visited and seed produced/umbel/20minute visit were subjected to the statistical analysis using analysis of variance (ANOVA). Means were separated by LSD test at P= 0.05 using MSTAT-C software (Steel and Torrie, 1980).

For comparison of self-pollinated and open-pollinated yield, 25 umbels of same age were veiled with nylon mesh bags before opening of the flowers and another 25 umbels were tagged for open pollination, respectively.

RESULTS

The community of pollinators was mainly composed of two bee species *i.e.* *A. dorsata* and *A. florea* and eight fly species *i.e.*, *Episyrphus balteatus, Eupeodes corollae*., *Sphaerophoria scripta* (L), *Mesembrius bengalensis*, *Eristalinus aeneus* (all Syrphidae), *Musca domestica* (Muscidae), Calliphoridae sp. and *Sarcophaga* sp. (Sarcophagidae) (Table I). The spectrum of pollinator abundance was composed 87% of dipteran species and remaining 13 % of Hymenoptera species. Among the dipteran species, 72% were composed of syrphid flies and 28% of non-syrphids *i.e. M. domestica*, Calliphoridae sp. and *Sarcophaga* sp. Likewise, among hymenopteran species, 55% were composed of *A. dorsata* and 45% *A. florea*.

Table I.- List of floral visitors of onion (*A. cepa* L.) in Multan, Pakistan

Insect order	Family	Species
Hymenoptera	Apidae	*Apis dorsata*
	Apidae	*Apis florea*
Diptera	Syrphidae	*Episyrphus balteatus*
	Syrphidae	*Eupeodes corollae*
	Syrphidae	*Sphaerophoria scripta*
	Syrphidae	*Mesembrius bengalensis*
	Syrphidae	*Eristalinus aeneus*
	Muscidae	*Musca domestica*
	Calliphoridae	Calliphoridae sp.
	Sarcophagidae	*Sarcophaga* sp.

In bees, *A. florea* was a frequent a pollinator having an average abundance of 3.57±2.57 compared to that of *A. dorsata i.e.*, 2.85±1.57 (Table II). Diurnal abundance dynamics of bees *i.e. A. dorsata* and *A. florea* (Fig. 1) revealed that their activity started early in the morning *i.e.* 6:00 h. With the increase in temperature and decrease in humidity, as the day progressed, their activity increased, peaking between 10:00 h and 12:00 h, with the temperature ranging from 29.9 to 31.0°C. As the temperature rose to 33.0°C at 14:00 h, a sharp decline in activity was observed, which again started increasing at 16:00 h (30°C) and then again decrease to minimum up to 18:00 h (sunset).

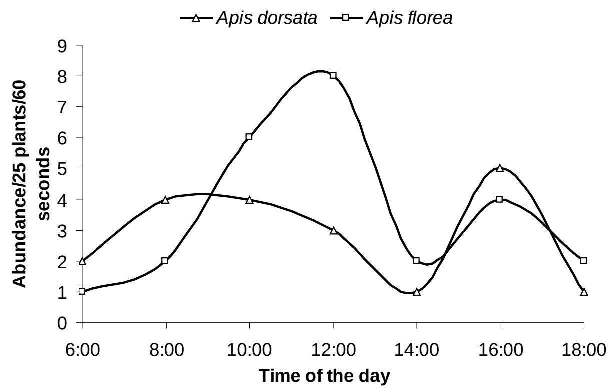

Fig. 1. Diurnal activity pattern of *A. dorsata* and *A. florea* on the flowers of *A. cepa* L. in Multan, Pakistan.

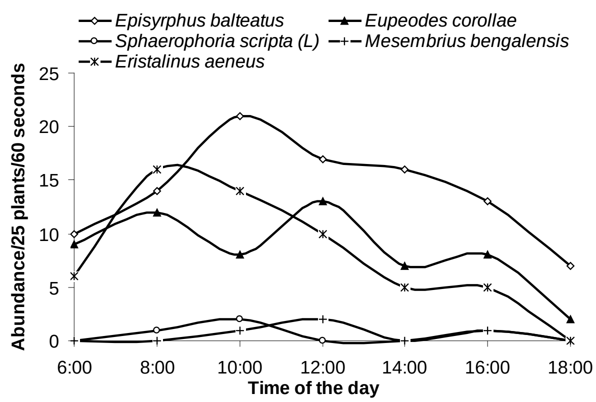

Fig. 2. Abundance of different species of syrphid flies on the flowers of *A. cepa* L. in Multan, Pakistan.

Among the syphids, *E. balteatus* remained the most frequent visitor having an average abundance of 14.00±4.61 followed by *E. corollae* (8.42±3.59) and *E. aeneus* (8.00±5.62). *S. scripta* and *M. bengalensis* remained very low in abundance (Fig. 2). The maximum activity of syrphids was observed between 10:00 to 12:00 h (29.9°C to 32.6°C).

The activity pattern of the other flies (Fig. 3) also exhibited the same pattern as that of bees and syrphids. Maximum visits were made by *M. domestica* having an average abundance of 9.3±6.15

followed by Calliphoridae sp. (2.42±1.90) and *Sarcophaga* sp. (0.57±0.78) (Table II).

Table II.- Foraging behavior (stay time/visit/umbel; Mean±SD; n= 8 for each treatment) and average abundance of different species of insects on flowers of *A. cepa* L. Mean values sharing similar letters in respective columns show non-significant differences (P<0.05) by using LSD test.

Pollinator Species	Stay time/ visit/umbel (seconds)	No. of flower visited/ umbel/visit	Average abundance (Individuals/25 plant)
Apis dorsata	19.5±1.60 h	11.4±1.83 c	2.85± 1.57
Apis florea	56.6±3.30 e	3.5±0.70 g	3.57± 2.57
Episyrphus balteatus	52.4±5.41 f	6.5±1.30 ef	14.00±4.61
Eupeodes corollae	147.5±8.14 a	17.1±1.38 a	8.42±3.59
Sphaerophoria scripta	49.2±2.68 f	4.5±0.75 fg	1.57± 0.78
Mesembrius bengalensis	37.2±3.64 g	7.0±1.20e	0.88±0.78
Eristalinus aeneus	63.7±4.85d	12.7±1.98 b	8.00±5.62
Musca domestica	66.4±1.64 d	3.5±0.84 g	9.3±6.15
Calliphoridae sp.	93.5±4.98b	16.7±1.45 a	2.42±1.90
Sarcophaga sp.	72±4.14 c	9.4±1.83 d	0.57±0.78

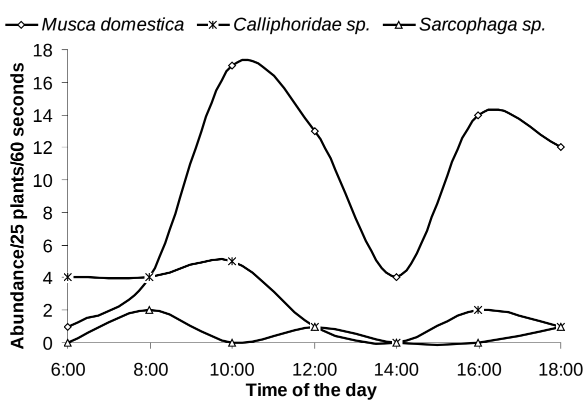

Fig. 3. Abundance of non-syrphid flies on the flowers of *A. cepa* L. in Multan, Pakistan.

There was a significant difference among the foraging behavior (time spent/umbel/visit, F= 562.91; df= 63; p<0.001 and number of flowers visited/umbel/visit, F= 106.13; df= 63; p<0.001) of different pollinators. Foraging behavior revealed (Table II) that among the flies, *E. corollae* stayed on an umbel for maximum time period (147.5±8.14 sec.) and visited maximum numbers of flowers *i.e.*, 17.14±1.38) followed by Calliphoridae sp. (16.7±1.45 flowers in 93.5±4.98 sec.). Contrarily, *M. domestica* spent 37.2 seconds and covered minimum number of flowers (3.5±0.84) on an umbel. *A. dorsata* stayed for minimum time period of 19.5±1.60 seconds/umbel/visit and visited 11.4±1.83 flowers/umbel/visit. *A. florea*, *E. balteatus* and *S. scripta* were relatively lazy foragers with a stay time of 56.6±3.30, 52.4±5.41 and 49.2±2.68 seconds/umbel/visit, respectively and visited only 3.5±070, 6.5±1.30 and 4.5±0.75 flowers/umbel/visit, respectively. Similarly, *M. domestica* and *E. aeneus* also showed similar visitation behavior having a stay time of 66.4±1.64 and 63.7±4.85 seconds/umbel/visit, respectively but *E. aeneus* visited greater number of flowers (12.7±1.98 flowers/umbel/visit) than that of *M. domestica i.e.* 3.5±0.84 flowers/umbel/visit.

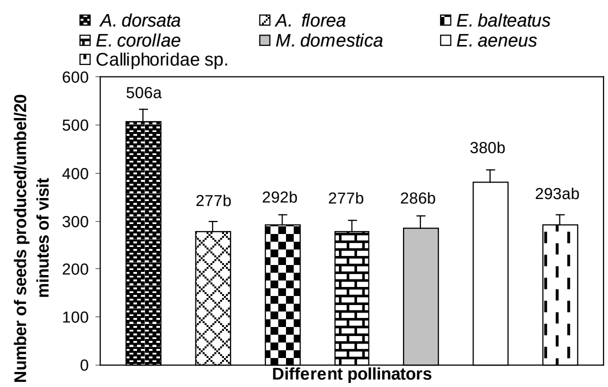

Fig. 4. Number of seeds produced per umbel per 20 minute of visit by different pollinators in *A. cepa* L. Mean values sharing similar letters show non-significant differences (P<0.05) by using LSD test.

Pollinator abundance, dynamics and visitation behavior were not good indicators of an insect being effective pollinator. Therefore, the role of different pollinators in seed setting was measured.

There were significant differences among the insect species in seeds produced as a result of 20 minute visits (F= 67.6; df= 24; p<0.001) (Fig. 4). The number of seeds produced per 20 minute visit revealed that *A. dorsata* resulted in maximum number of seed set (506±27.41 seeds/umbel/20 minute visit) followed by Calliphoridae sp., which produced 292.4±19.81 seeds/umbel/20 minute visit. The other five pollinators *viz. A. florea*, *E. baleatus*, *E. corollae*, *E. aeneus* and *M. domestica* resulted in statistically similar seed settings of approximately 280 seeds/umbel/20 minute visit).

The comparison of yield of self-pollinated (caged throughout the flowering season/no insect visitation) and open-pollinated plants shows (Fig. 5) that an average of 130 seeds/umbel were produced in caged plants whereas open-pollinated plants produced 932 seeds/umbel. This represents 616 % more seed set in open-pollinated plants whose credit solely goes to insect pollinators.

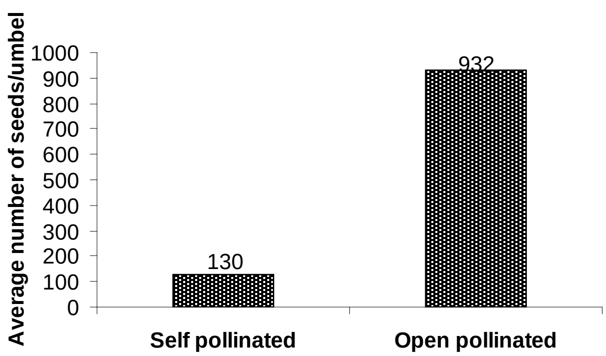

Fig. 5. Average number of seeds produced in open-pollinated and self-pollinated umbels.

DISCUSSION

The pollinator community in our experiment was mainly composed of Hymenoptera and Diptera. Apart from honey bees, onion flowers are visited by bumble bees, dipterans and butterflies (Jablonski *et al.*, 1982). In various parts of India (Chandel *et al.*, 2004) *Apis dorsata*, *A. cerana*, *A. florea* and *A. mellifera* are the most effective pollinators. Also dipterans from the syrphid (Syrphidae) family take part in onion pollination (Bohart *et al*., 1970).

In our studies, only two native species of bee (*A. dorsata* and *A. florea*) were observed, with *A. florea* the most abundant pollinator followed by *A. dorsata*, This is contrary to the results of Chandel *et al*. (2004) in which *A. dorsata* was a more frequent pollinator of onion than *A. florea* and *A. mellifera* in mountainous areas of India. This change in *Apis* species composition and abundance might be in the result of competition for resources between introduced specie *i.e., A. mellifera* and native species. Other factors that may determine species composition and abundance include cropping pattern and land altitude, which need further study. Priti (1998) supports our observations that *A. florea* was the most abundant pollinator of onion followed by *A. mellifera* in lowland conditions.

The foraging activity by bees and flies started at around 6:00 h, which is supported by the findings of Chandel *et al.* (2004). The foraging activity of *A. dorsata*, *A. florea* and all other dipteran pollinators peaked between 10:00-12:00 h, however, peak activity for *A. dorsata* and *A. cerana* was observed between 12:00-14:00 h (Partap and Verma, 1994; Priti, 1998; Chandel *et al.*, 2004). Their findings might be due to difference in climate and latitude. In the present studies, the activity of all pollinators was comparatively low early in the morning and late in the evening. This diurnal pattern of abundance can be useful for scheduling pest control operations.

Foraging behavior and abundance patterens alone are not good indicators of any floral visitor as an effective pollinator. Many other factors also contribute such as body size, shape of an insect, its thurst for nectar or pollen, or the chances to be in contact with the stigma of the flowers and pollen deposition. *A. dorsata* proved to be the most effective pollinator in our study, which is supported by the work of several authors (Kutjatnikova, 1969; Jefimockina, 1971; Martin, 1978; Lazic *et al*., 1985; Kumar *et al*., 1989; Priti, 1998; Chandel *et al*., 2004). On the other hand, from a closely related plant species, Stephen *et al*. (2007) harvested a higher *Allium ampeloprasum* L. seed yield (340.7g/47 umbels) contributed by *Calliphora vicina* as compared from *M. domestica* (70.5g/47 umbels). We also observed Calliphoridae sp. as the second most effective pollinator among all the pollinators and most effective among the Diptera. In our experiment, the comparison of yield obtained from open and self-pollinated crop represents a difference of 616% of the yield in open pollinated crop (Fig. 5). Similar results were also observed by Zdzislaw *et al*. (2004) who found 699% more yield in open pollinated crop than self pollinated crop.

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