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Foraging Ecology of Bumblebee, *Bombus haemorrhoidalis* on Brinjal *Solanum melongena* Flowers in Relation to Fruit Production

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ABSTRACT

Foraging activity of bumblebee, *B. haemorrhoidalis* was studied on brinjal flowers *Solanum melongena* during September 2016 at different hours of the day at Udheywalla, Jammu 285 m above sea level. The maximum foraging density of *B. haemorrhoidalis* was recorded between 10.00 to 12.00 hrs with 6.2 /5 plants/10 min. Maximum mean number of bumblebee/5plants/10 min (21.4) were recorded on 1st day of observation followed by 4th day of observation (19.2) on bloom of brinjal crop. The maximum number of flowers was visited by *B. haemorrhoidalis* between 10.00 to 12.00 hrs on different observation dates. The mean time spent by bumblebee/sec/bout was found to be maximum (7.53) on 3rd day of observation and minimum (6.77) was on 1st day of observation. In case of bumblebee pollination, fruit set was significantly higher (78.43 %) followed by open pollination (69.61%) and hand pollination (48.71 %). All these treatments were superior over self pollination where fruit set was only 33.69 %. The percentage increase over control was much higher in bumblebee pollination (232.76%) as compare to open pollination (206.58%) and hand pollination (144.58%).

Keywords *Bombus haemorrhoidalis*, Brinjal flowers, Pollination, Fruit production.

INTRODUCTION

Insect pollinators enhance fruit set of many vegetable and fruit crops (Klein *et al.* 2007). Eggplant is among the crops that benefits from insect pollination (Amoako and Yeboah-Gyan 1991, Free 1993). Eggplant pollen is dispersed through vibration of the anthers by wind or insect pollination. Few visitors are attracted to eggplant flowers, because the flowers do not produce nectar. Furthermore, many bees are inefficient at eggplant pollination, although honey bees and several wild bee species are known to increase yield (Levin 1989, Free 1993, Gemmill-Herren and Ochieng 2008). Several species of bumble bees are used for commercial pollination of Solanaceous crops (Velthius and van Doorn 2006) and bumble bees are one of the few pollinators in the United States that effectively buzz pollinate eggplant flowers. Studies report up to a 22% increase in eggplant fruit set by adding bumble bees to greenhouses (Abak *et al.* 1995, Abak *et al.* 2000). While pollination efficiency has been measured in several Solanaceous crops (Free 1993), no study has yet quantified the effect of visitation frequency on eggplant fruit characteristics. In the eastern and central United States, eggplant flowers are primarily visited by *B. impatiens* Cresson 1863, a common, generalist bumble bee (Matteson and Langellotto 2009). The inability of other polli-

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Fig. 1. *B. haemorrhoidalis* on *Solanum melongena* in plain areas of Jammu.

nators in our study system to buzz pollinate prevents suitable vibration of eggplant anthers by species not in the genus Bombus. Reported declines in certain bumblebee species (Cameron *et al.* 2011) will make each individual pollinator visit especially crucial in outdoor areas where few bumble bees are present. We investigated eggplant fruit and seed set from sequential bumblebee visits to individual flowers until the occurrence of the 12th visitor. We hypothesized that a greater number of visits to an eggplant flower would lead to a heavier and seedier fruit. As bees visited flowers, we recorded the cumulative duration of each visit, as this may reflect the amount of pollen transfer in other Solanaceous crops (Jarlan *et al.* 1997, Palma *et al.* 2008) as well as fruit characteristics in other crops (Gingras *et al.* 1999). Information about bumble bees' contribution to pollination will be useful to greenhouse and outdoor growers who are considering supplementing mechanical or self-pollination with insect pollinators. Bumblebees are perfect to release the pollen from the another efficiently. Brinjal flowers do not produce nectar. So bumblebees can be use with honeybees for brinjal pollination. The bumblebee pollinated eggplants gives higher yield (25%), fruit size (14% in weight and 7% in length) and four times higher number of seeds per fruit than vibration under unheated plastic houses (Abak *et al.* 2000). Al-Abbadi (2009) reported that the fruit set percentages for eggplant were 66, 59, 52 and 30%, for the two honeybees nuclei, one honeybees nuclei, bumblebees and control treatments, respectively. He found that *Bombus terrestris* L. perform as good pollinator after *Apis mellifera* L. in the fruit set, fruit weight and length parameters of brinjal.

MATERIALS AND METHODS

The present investigation was carried out in the experimental farm of the farmers at Udheywalla which was located 20 kms from Sher-e- Kashmir University of Agricultural Sciences and Technology, Main campus Chatha, Jammu. The study was made on crop raised in the month of September 2016. The crop variety Kashmiri Brinjal local was raised in a plot size of 5 × 5 m following package of practices. Visual observations on randomly selected plants were made in different locations as per the method described by Abrol (2010) with some modifications.

Table 1. Foraging activity of bumblebee, *B. haemorrhoidalis* on Brinjal flowers on different days of observation during different times of the day at Udheywalla in Jammu plains.

Observation date	Observation hours						Mean bumblebees/ 5 plants/ 10 min
	B. haemorrhoidalis /5 plants /10min						
	6.00-8.00	8.00-10.00	10.00-12.00	12.00-2.00	2.00-4.00	4.00-6.00	
23.10.2016	1.0	5.8	6.2	5.4	2.6	0.4	21.4
06.11.2016	0.4	5.2	4.4	4.6	2.6	0.0	17.2
20.11.2016	0.2	4.2	6.8	2.8	2.0	0.2	16.2
04.12.2016	0.2	5.6	7.2	3.6	2.4	0.2	19.2

Marked flowers were monitored regularly at peak flowering period between 6:00-8:00, 8:00-10:00, 10:00-12:00, 12:00-2:00, 2:00-4:00 and 4:00-6:00 hrs for ten minutes in each square meter area from five plants during peak flowering period.

The observation on the selected plants were made at hourly intervals and the number of bumblebee species visiting / 1 m^2 area for 10 minutes from each side of the plot were recorded by visual observation. Mean of such 5 observations were constitute reading for each hour. Time spent by bumblebee in seconds were also observed during the different time intervals.

During the observations behavior of the bumblebees as nectar collectors, pollen collectors or both were recorded. Rate of flower visitation were also recorded using chronometer (stop watch) to determine the foraging efficiency of bumblebees. Foraging behavior of insects was also monitored keenly to work out plant pollinator interaction.

Role of insect pollination on quantity of fruit production

To determine, the impact of pollinators on quantity of fruit production, the studies were made under open pollination, hand pollination, bee pollination and self pollination. The experiment was carried out in RBD with four treatments replicated thrice. All the treatments were imposed at 10% flowering of the crop. In open pollination (T_1), pollinators had unrestrained access on flowers, whereas in hand pollination pollen from flowers was emasculated on other flowers (T_2). In bumblebee pollination (T_3), naturally pollinated flowers were tagged, and bagged with envelop having minutes holes for aeration and in self pollination, flowers were caged with synthetic nylon netting to exclude nectarivorous insects (T_4). The cage was removed after completion of flowering. After maturity, the crop was harvested and compared for different treatments.

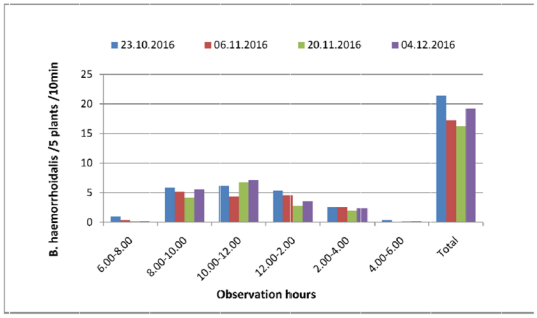

Fig. 2. Foraging of bumblebee, *B. haemorrhoidalis* / 5 plants / 10 minutes on brinjal flowers.

The fruit set in all the treatments was estimated by counting the number of fruit set out of female flowers. The mean fruit set was expressed as given below :

$$\text{Rate of fruit set (\%)} = \frac{\text{Number of fruit set}}{\text{Total number of female flower}} \times 100$$

RESULTS

Foraging ecology of bumblebee, *B. haemorrhoidalis* on brinjal flowers

During the present study one dominant bumblebee species viz., *B. haemorrhoidalis* which is widely prevalent in plain area of Udheywalla was selected to

Table 2. Time spent by *Bombus haemorrhoidalis* during foraging on brinjal flowers per bout.

Observation date	Observation hours Time spent in seconds by *B. haemorrhoidalis* /bout						
	6.00-8.00	8.00-10.00	10.00-12.00	12.00-2.00	2.00-4.00	4.00-6.00	Mean time spent/sec/bout
23.10.2016	5.8	9.4	7.8	8.0	9.4	0.2	6.77
06.11.2016	7.0	7.0	10.6	9.8	8.4	0.0	7.13
20.11.2016	9.0	8.0	9.8	10.2	8.2	0.0	7.53
04.12.2016	8.8	7.8	9.2	8.6	7.2	0.4	7.00

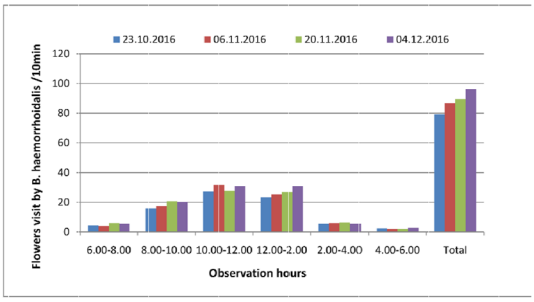

Fig. 3. Number of brinjal flowers visited by *B. haemorrhoidalis* /10min on different day and time.

study foraging behavior on brinjal (Fig. 1). Foraging activity of bumblebee, *B. haemorrhoidalis* on brinjal flowers on different days during different times of the day was conducted at Udheywalla in Jammu plains. Four different observations at forth nightly intervals were recorded for the bumblebee foraging and their role in enhancing the yields of brinjal crop. The foraging activity of *B. haemorrhoidalis* on 23.10.2016 revealed that the number of bumblebee foraging during different times on the day ranged between 0.2 and 7.2/5plants/10 min (Table 1, Fig. 2). The maximum *B.haemorrhoidalis* foraging density was recorded between10.00 to12.00 hrs with 6.2 /5 plants/10 min. Except second observation dated 06.11.2016, similar findings were recorded on 3rd and 4th observation with 6.8 and 7.2 bumblebee/5plants/10 min. The table showed that although they had started foraging early (6.00–8.00 hrs) in the morning, their density and number was quite low. Their visitation was declining gradually after 2.0 hrs and recorded minimum foraging during 4.00 to 6.00 hrs during the day. Mean number of bumblebee/5plants/10 min were recorded to be maximum (21.4) on 1st observation and 4th date of observation (19.2) on bloom of brinjal crop.

Number of flowers visited by *B.haemorrhoidalis*/10min was depicted in Table 2 which showed that the maximum number of flowers was visited by *B. haemorrhoidalis* between 10.00 to 12.00 hrs on different observation dates. *B. haemorrhoidalis* visited 27.4 on 1st, 31.6 on 2nd, 27.8 on 3rd and 31.0 flowers/10 min on 4th day observations. Again, the minimum number of flowers visited was recorded between 4.00 to 6.00 hrs. The flowers visitation rates ranged from 1.8 to 31.6 flowers/10 min (Fig. 3). The mean no. of flowers visited by bumblebee/10 min was recorded maximum (16.03) during 4th day observation.

The amount of time bees take to forage on flower is an important component determining foraging behavior. The time spent by *B. haemorrhoidalis* on flower ranged between spent 0.2 and 10.6 sec/flower. The mean time spent by bumblebee/sec/bout was found maximum (7.53) on 3rd day of observation and minimum (6.77) was on 1st day of observation (Table 2, Fig. 3).

The data presented in Table 3 revealed that percentage fruit set varied in different treatments. In case of bumblebee pollination, fruit set was significantly higher (78.43 %) followed by open pollination (69.61%) and hand pollination (48.71 %). All these treatments were superior over self pollination where fruit set was only 33.69 %. The data clearly shows that bumblebee pollination resulted in higher fruit set followed by open pollination and hand pollination as compare to self pollination. Similarly, the percentage increase over control was much higher in bumblebee pollination (232.76%) as compare to other treatments. In general, the overall effectiveness of treatments was in the order : Bumblebee pollination (232.76%) > open pollination (206.58%) > hand pollination (144.58%) > self pollination.

DISCUSSION

Insect foraging behavior is an important area which has been getting momentum in recent years due to

Table 3. Impact of *B. haemorrhoidalis* pollination treatments on quantity of fruit set on brinjal.

Sl. No.	Treatments	Percent fruit set	Per cent increases over control (Self pollination)
1	Hand pollination	48.71	144.58
2	Self pollination (caged/ control)	33.69	–
3	Bumblebee pollination	78.43	232.76
4	Open pollination (tagged)	69.61	206.58

drastic decline in pollinators' fauna worldwide. Keeping in mind, the fascination of bumblebee among society, availability and huge potential of wild in nature, much of the research has focused on domestication of bumblebee for vital ecosystem services, their importation in various countries for pollination, in green house commercial crops pollination. There are a number of reasons which enables bumblebees to be excellent organisms for studies of foraging behavior. Rather the bees, bumblebee forage ceaselessly, even under cool and cloudy conditions when other insects are inactive.

The maximum *B. haemorrhoidalis* foraging density was recorded between 10.00 to 12.00 hrs with 6.2 /5 plants/10 min. Mean number of bumblebee/5plants/10 min were recorded to be maximum (21.4) on 1st observation and 4th date of observation (19.2) on bloom of brinjal crop. The maximum number of flowers was visited by *B. haemorrhoidalis* between 10.00 to 12.00 hrs on different observation dates. The mean time spent by bumblebee/sec/bout was found maximum (7.53) on 3rd day of observation and minimum (6.77) was on 1st day of observation. In case of bumblebee pollination, fruit set was significantly higher (78.43%) followed by open pollination (69.61%) and hand pollination (48.71 %). All these treatments were superior over self pollination where fruit set was only 33.69%. The percentage increase over control was much higher in bumblebee pollination (232.76%) as compare to open pollination (206.58%) and hand pollination (144.58%). The present results are in the line of Buchmann and Nabhan (1996) who highlighted the important guild of pollinators playing a central role in the ecological functioning of all terrestrial ecosystems. They guarantee the survival of wild plant species and thereby contributing to the maintenance of ecological communities (Kearns and Inouye 1997). Moreover, the productivity of many food crops relies on pollinators that provide an economically important ecosystem service to agriculture (Klein *et al.* 2007). Foraging range is the pre-requisite of bumblebee ecology which determines the area of the habitat, food resources and nesting sites for colony survival and distribution (Nakamura and Toquenaga 2002, Williams and Kremen 2007). Gemmill-Herren and Ochieng (2008) studied the efficiency of different pollination ways on two eggplant varieties. For both of them, a positive influence of bumblebee pollination on the quality of eggplant fruits was confirmed. Fruits with significantly larger seed number were achieved in plants where flowers were pollinated by insects as compared to those set due to self-pollination or inflorescence vibrating. Bumblebees have extensively been used for pollination in cages for several crops like *Brassica oleracea, B. napus, Trifloium pratense*, *Raphanus sativus, Solanum esculentum*. They have been reported to just double the seed yield from 110 kg/ha to 210 kg/ha in red clover at differing bumblebee densities.

CONCLUSION

Bumblebees are excellent pollinators of many fruit and vegetable crops and have ability to pollinate flowers under inclement low temperature conditions. Qualitative fruits are produced by bumblebees pollinated crops because they are able to transfer pollen grains in sufficient amount and quickly. In addition, bumblebees are able to do buzz pollination that helpful for solanaceaus crops because these crops require vibration for pollination. During last few decades, the population of bumblebees and other pollinators are decreasing due to use of toxic agrochemicals, loss of natural habitats and climate change at worldwide. There is a need to improve the health of bumblebees and other pollinators by use of nontoxic chemicals and *in situ* conservation of natural habitats.

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