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Studies on the Role of Insect Pollination on Cucumber Yield

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ABSTRACT

Foraging activities of insect visitors were studied during summer 2007 on inbred lines of cucumber hybrid KH-1. The insect visitors in decreasing order of abundance were *Formica* sp. > *Apis mellifera* > *Bombus haemorrhoidalis* >*Halictus* sp. > other insects > *Apis cerana* > syrphids. The activity of insects peaked between 09:00 and 10:00 followed by 12:00-13:00 and 15:00-16:00. The foraging behaviour of *A. mellifera*, *B. haemorrhoidalis* and *Halictus* sp. was studied. The foraging speed and foraging rate were maximum in *B. haemorrhoidalis* followed by *A. mellifera* and *Halictus* sp. The bees spent significantly more time per flower during morning hours (15.92 sec/flower) and foraged significantly fewer flowers (5.48 flowers/min) compared to evening hours. There were significantly more nectar foragers (5.71/m²/10 min) than pollen foragers (4.84/m²/10 min). Most pollen foragers were observed during morning hours (6.27/m²/10 min) whereas nectar foragers were most active during noon hours (6.31/m²/10 min). There was no significant difference in the number of bees shifting from one line to another or *vice versa*. The effect of honey bee pollination, open pollination and hand pollination on quantity and quality of cucumber was also studied. Significant increase in fruit set was observed; highest being in hand pollination (75.68%) followed by honey bee (74.96%) and open (62.09%) pollination. Percentage of misshapen fruits was maximum in open pollination (20.05) followed by hand (14.1%) and honey bee (8.05%) pollination. Honey bee pollination resulted in significantly highest percentage of healthy fruits (92.22%) as compared to hand (85.85%) and open pollination (79.64%). Similarly weight of fruits (1184.5 g), number of seeds per fruit (472.8), fruit size (28.8 cm) and weight of 1000-seeds (29.14 g) was highest in honey bee pollination as compared to other modes of pollination.

Keywords: *Apis mellifera*, *Bombus haemorrhoidalis*, foraging behaviour, honey bee pollination

INTRODUCTION

Cucumber, *Cucumis sativus* belonging to family Cucurbitaceae, is an important commercial crop grown world-wide in tropical and subtropical parts of the world. The plants are monoecious producing both male and female flowers separately on the same plant. Cucumber flowers are attractive, colourful and visited by a number of insects. In general, the foraging rate (number of flowers visited/min) and foraging speed (time spent/flower) of any bee species determines its pollination efficiency. Moreover, the greater the foraging rate and foraging speed of a bee, the greater are the chances of pollination. Foraging activity of an insect visitor depends upon many factors, including instinctive foraging behaviour and floral structure (Free 1970), particularly the corolla depth, type and quantity of floral rewards (Rao 1991; Dashad *et al*. 1992). Hours of the day also affect the foraging frequency of insects.

Cucumber is grown for tender fruits which are mainly consumed as salad and for preparing pickles and curries. Economic success of cucumbers depends upon large yields of good quality fruits. One of the most important factors which influence the yield and quality of cucumber crop is successful pollination. Due to the presence of male and female flowers separately on the same plant, the flowers are not wind or self-pollinated. Insects, mainly honeybees are the major pollinators of cucumber (Connor and Martin 1969). The pollen grains being large and sticky, need an external agent for transfer of pollen between flowers (Sedgley and Scholefield 1980). Adequate pollination usually assures uniform and perfectly formed fruits with even maturity (McGregor 1976), while incomplete pollination results in improperly formed fruits (Hodges and Baxendale 1991) which are small and misshapen, thus leading to low yield of marketable fruits.

Therefore keeping in view the pollination requirements of cucumber, the present investigations were carried out to study the various insect visitors, their abundance and the foraging behaviour of the most abundant bee species at selected hours of the day and the effect of different modes of pollination, on the yield and quality of cucumber fruits.

MATERIALS AND METHODS

Inbred lines of cucumber (*Cucumis sativus* L.) hybrid KH-1 viz. 2870G (gynoecious) and K-90 (monoecious) were used in this study. The experiment was laid out in a Randomized Block Design (RBD) comprising of a planting ratio of 3: 1 (gynoecious line: monoecious line) during 2007 in three replications as per the technique advocated by Sharma *et al*. (2005). Planting was done in a plot size of 7 × 4 m at a spacing of 1 × 1 m. Two plants per hill were sown which were later thinned out to one per hill. In order to synchronize the flowering period of both the lines staggered sowing of the seed parents was done 15 days later to the monoecious line.

Experiment 1 – Study of foraging behaviour of insects

Insect visitors on cucumber flowers were collected by a usual cone type hand net. Sweeps were made throughout the blooming of cucumber at 09:00-10:00, 12:00-13:00 and 15:00-16:00 hours of the day. For relative abundance of insect visitors, plants were selected randomly in three different plots and observations were started 2-3 days after flowering in the cucumber lines in 1 m^2 bloom area per 10 min. Foraging behaviour, *viz*. he number of flowers visited per minute and time spent per flower by main insect bee visitors (*Apis mellifera*, *Bombus haemorrhoidalis* and *Halictus* sp.) associated with pollination of cucumber was recorded with the help of a stop clock. The proportion of pollen or nectar foragers of *A. mellifera*

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Table 1 Insect visitors of cucumber bloom with their frequency of occurrence.

Scientific name	Common name	Order	Family
Apis cerana F.**	Indian Honey bee	Hymenoptera	Apidae
A. dorsata F.*	Rock bee	Hymenoptera	Apidae
A. mellifera L.***	Italian Honey bee	Hymenoptera	Apidae
Bombus haemorrhoidalis Smith***	Bumble bee	Hymenoptera	Apidae
Formica sp.***	Ants	Hymenoptera	Formicidae
Halictus sp.***	Solitary bee	Hymenoptera	Halictidae
Episyrphus balteatus (DeGeer)**	Syrphid fly	Diptera	Syrphidae
Scaeva pyrastri (L.)*	Syrphid fly	Diptera	Syrphidae
Aulacophora foveicollis L.*	Red pumpkin beetle	Coleoptera	Chrysomelidae
Diabrotica undecimpunctata Mann**	Spotted cucumber beetle	Coleoptera	Chrysomelidae
Coccinella septempunctata (L.)*	Ladybird beetle	Coleoptera	Coccinellidae
Mylabris pustulata T.*	Blister beetle	Coleoptera	Meloidae

* = Less frequent visitors
** = Frequent visitor
*** = Most frequent visitors

bees and bees shifting from monoecious to gynoecious lines (per m²/10 min) and *vice versa* was recorded randomly in three different plots. Five bees of each species were observed at select hours of the day (09:00-10:00, 12:00-13:00 and 15:00-16:00).

Experiment 2 – Effect of different modes of pollination

Pollination was carried out in different modes viz. honey bee pollination, open pollination and hand pollination. In each mode of pollination 3 plots of cucumber each of 7 × 4 m were maintained.

Honey bee pollination (BP): Plants were caged in 40 mesh nylon net and a nucleus beehive of *Apis mellifera* was kept inside the cage for bee pollination.

Open pollination (OP): Plants were kept open for the access of pollination under natural conditions.

Hand pollination (HP): The male and female flowers of were bagged with butter paper bag one day prior to anthesis. Afterwards, when anthesis took place, butter paper bags were opened pollen from bagged male flowers was dusted over the female flowers by gently rubbing the anthers on the stigma; then again the flowers were bagged for 2-3 days to avoid any contamination by foreign pollen. After 3-4 days of pollination, bags were removed.

Sampling technique

The observations were made on percentage fruit set, yield, fruit weight, fruit size, number of seeds per fruit and test weight of seeds.

Statistical analysis

The data of experimental observation were statistically analysed by using factorial RBD (Gomez and Gomez 1986) at 0.05% probability level and the software used was AGRIS.

Table 2 Relative abundance of insect visitors per 10 min/m² cucumber bloom at different hours of the day.

Species \ Day hours	09:00-10:00	12:00-13:00	15:00-16:00	Mean
Apis cerana	1.29	1.24	0.71	1.08
A. mellifera	3.57	2.81	1.95	2.78
Bombus haemorrhoidalis	3.43	2.33	2.00	2.59
Formica sp.	15.05	13.71	10.05	12.94
Halictus sp.	1.81	1.67	1.05	1.51
Syrphids	0.67	0.62	0.62	0.64
Others	1.38	1.19	0.77	1.11
Mean	3.88	3.37	2.45	3.24
$CD_{0.05}$				
Day hours	0.35			
Species	0.54			
Day hours x Species	0.93			

Table 3 Foraging speed (sec/flower) of bee pollinators at different hours of the day.

Species \ Day hours	09:00-10:00	12:00-13:00	15:00-16:00	Mean
A. mellifera	11.69	8.58	7.34	9.20
Bombus haemorrhoidalis	5.27	4.37	3.67	4.44
Halictus sp.	30.79	22.56	18.75	24.03
Mean	15.92	11.83	9.92	
$CD_{0.05}$				
Species	0.56			
Day hours	0.56			
Day hours x Species	0.97			

RESULTS AND DISCUSSION

Experiment 1

In total 12 insect species belonging to 10 genera under 7 families were recorded visiting the cucumber bloom. Out of these 6 species belonged to hymenoptera, 4 to Coleoptera and 2 to Diptera (**Table 1**). Sajjanar *et al*. (2004) recorded 24 insects visiting cucumber crop in which Hymenoptera predominated.

The data on the abundance of insect visitors (**Table 2**) showed that *Formica* sp. was most abundant (12.94 ants/m²/10 min) followed by *A. mellifera* (2.78 bees/m²/10 min) and *B. haemorrhoidalis* (2.59 bees/m²/10 min) which were statistically equal followed by *Halictus* sp. (1.51 bees/m²/10 min). Syrphids were least abundant (0.64 flies/m²/10 min) but were statistically equal with *A. cerana* (1.08 bees/m²/10 min) and other insects (1.11 insects/m²/10 min). In contrast to Rana *et al*. (2005), *M. pustulata*, *C. septempunctata*, *A. foveicollis* and *D. undecimpunctata* in the present studies are new records from this area. Free (1993) and Malerbo *et al*. (1999) reported ants, beetles, flies and solitary bees as the abundant pollinators of cucurbits. The activity of insect visitors was significantly higher during 09:00-10:00, (3.88 insects/m²/10 min) followed by 12:00-13:00 (3.37 insects/ m²/10 min) and 15:00-16:00 (2.45 insects/ m²/10 min). Cervancia and Bergonia (1991), Chen (1996) and Sajjanar *et al*. (2004) also observed that insect visitors were most active during morning hours synchronizing well with flower opening.

On the basis of average time spent per flower irrespective of day hours (**Table 3**) the different bee species in decreasing order of foraging speed was as follows: *B. haemorrhoidalis* (4.44 sec/flower) > *A. mellifera* (9.2 sec/flower) > *Halictus* sp. (24.03 sec/flower). The average time spent/ flower was significantly highest during 09:00-10:00 (15.92 sec/flower) followed by 12:00-13:00 (11.83 sec/flower) and 15:00-16:00 (9.92 sec/flower). This might be attributed to the presence of more nectar sugar in each flower during morning hours due to which bees took more time to collect the forage during this period. Girish (1981) and Rana *et al*.

Table 4 Foraging rate (flowers visited/min) of bee pollinators at different hours of the day.

Species \ Day hours	09:00-10:00	12:00-13:00	15:00-16:00	Mean
A. mellifera	4.31	6.07	6.64	5.67
Bombus haemorrhoidalis	9.01	10.50	10.95	10.15
Halictus sp.	3.12	3.88	4.14	3.71
Mean	5.48	6.82	7.25	
$CD_{0.05}$				
Species	0.19			
Day hours	0.19			
Day hours x Species	0.33			

Table 5 Proportion of *Apis mellifera* bees foraging for pollen or nectar per 10 min/m^2 cucumber bloom at different hours of the day.

Day hours	Pollen foragers	Nectar foragers	Mean
09:00-10:00	6.27 (4.63 ± 6.93)	5.30 (4.17 ± 6.33)	5.78
12:00-13:00	4.56 (3.77 ± 5.8)	6.31 (4.87 ± 6.33)	5.43
15:00-16:00	3.68 (2.33 ± 4.93)	5.53 (4.9 ± 6.1)	4.63
Mean	4.84	5.71	
$CD_{0.05}$			
Foragers	0.32		
Day hours	0.39		
Day hours x Foragers	0.56		

Table 6 Number of bees shifted from gynoecious to monoecious line (per 10 min/m^2) and *vice-versa*.

	№ of bees present		№ of bees shifted	
	Gynoecious line	Monoecious line	Monoecious line	Gynoecious line
Mean	6.3	7.5	3.4	4.1
$CD_{0.05}$	0.89		0.81	

(2005) also observed that the pollinators' visits were of longer duration during morning hours and thereafter the time spent per flower tended to decrease throughout the day.

Average foraging rate irrespective of the species (**Table 4**) was significantly highest during 15:00-16:00 (7.25 flowers/min) followed by 12:00-13:00 (6.82 flowers/min) and 09:00-10:00 (5.48 flowers/min). Comparatively higher foraging rate during 15:00-16:00 might be due to the fact that the supply of available floral rewards particularly nectar, declined in flowers in the afternoon. So, less time was needed to gather forage from a flower and more flowers were therefore visited by a bee to collect a required load of pollen or nectar. The mean foraging rate was significantly higher in case of *B. haemorrhoidalis* (10.15 flowers/min) followed by *A. mellifera* (5.67 flowers/min) and *Halictus* sp. (3.71 flowers/min). Stanghellini *et al*. (2002) also observed that *B. haemorrhoidalis* foraged higher number of cucumber flowers than honey bees.

The data in **Table 5** reveals that irrespective of the day hours, there were a significantly higher number of nectar foragers (5.71 bees/m²/10 min) than pollen foragers (4.84 bees/m²/10 min). Similar results have also been observed by several other workers (Kauffeld and Williams 1972; Collison and Martin 1975; Collision and Martin 1979). The average numbers of pollen foragers were significantly higher during 09:00-10:00 (6.27 bees/m²/10 min) whereas there were significantly more nectar foragers during 12:00-13:00 (6.31 bees/m²/10 min). Sajjanar *et al*. (2004), Bhambure (1958) and Rao and Suryanarayana (1988) also reported the pollen foraging to be maximum during morning hours and nectar foraging to be maximum during afternoon in cucurbit flowers. The average numbers of nectar or pollen foragers were significantly higher during 09:00-10:00 (5.78 bees/m²/10 min) and 12:00-13:00 (5.43 bees/m²/10 min) followed by 15:00-16:00 (4.63 bees/m²/10 min). This might be correlated with the abundance of insect visitors which was higher during morning hours.

The data on bees shift is presented in **Table 6**. The average numbers of bees shifting to gynoecious lines from monoecious line (4.1 bees/m^2/10 min) were significantly higher than the numbers of bees shifting to monoecious line from gynoecious line (3.4 bees/m^2/10 min) but the differ-ence was non-significant. The slight difference in the shift of bees more to a gynoecious line might be due to the fact that the gynoecious line bears predominantly pistillate flowers which contain more nectar sugar (Collision 1973; Kauffeld and Williams 1972) and were also more richer in sugars and proteins than that of male flower and therefore comparatively more attractive to bees (Nepi *et al*. 1996).

Experiment 2

Among different modes of pollination the fruit set (**Table 7**) was observed to be significantly higher in HP (75.68%) and BP (74.96%), as compared to OP (62.09%). This may be due to the reason that in hand pollination pollen is applied generously to whole stigmatic surface. Mouzin *et al*. (1980), Lemasson (1987), Cervancia and Bergonia (1991) and Rafiq (1992) also obtained higher percentage of fruit set in BP as compared to OP. The fruits obtained from HP and BP were also found to be better with respect to shape since the percentage of misshapen fruits was highest in OP (20.05%). Therefore, the percentage of well formed healthy fruits was highest in BP (92.22%) followed by HP (85.85%) and OP (79.64%), in accordance with the results of Cervancia and Bergonia (1991), Hernandez *et al*. (1999), and Kato and Couto (2002), which might be attributed to sufficient amount of pollen being received by the flowers in BP treat-ment.

The fruit characteristics such as fruit weight (1184.5 g), number of seeds per fruit (472.8), fruit diameter (29.9 cm) and fruit length (28.8 cm) was found to be significantly higher in honey bee pollinated plants as compared to hand and open pollinated plants (**Tables 8, 9**). Brewer (1974), Garcia *et al*. (1998) and Prakash *et al*. (2004) had also ob-tained similar results. The number of seeds per fruit and larger fruit size in bee pollinated plants might be attributed to the sufficient number of pollen grains received by the flowers which were best provided by honey bees in caged conditions as compared to OP and HP. The weight of 1000-seeds was also maximum in honey bee pollination (29.14 g) as compared to other modes of pollination (**Table 9**). This also might be due to the adequate pol-

Table 7 Effect of different modes of pollination on percent fruit set, crooked and healthy fruits.

Mode of pollination	Fruit set (%)	Misshapen fruits (%)	Healthy fruits (%)
Honeybee	74.96 (60.06)	8.05 (16.27)	92.22
Open	62.09 (52.18)	20.05 (26.54)	79.64
Hand	75.68 (60.96)	14.1 (21.98)	85.85
$CD_{0.05}$	0.81	0.58	0.64

Figures in parentheses are arc sine transformed values

Table 8 Effect of different modes of pollination on fruit weight and number of seeds/fruit at the time of seed harvesting

Mode of Pollination	Weight of fruit (g)	№ of seed/fruit
Honeybee	1184.5	472.8
Open	982.6	400.0
Hand	990.2	425.2
$CD_{0.05}$	46.29	26.63

Table 9 Effect of different modes of pollination on fruit size (cm) and 1000-seed weight.

Mode of pollination	Fruit diameter (cm)	Fruit length (cm)	1000-seed weight (g)
Honeybee	29.9	28.8	29.14
Open	27.4	25.7	27.73
Hand	26.9	26.5	28.64
$CD_{0.05}$	0.85	1.05	0.41

lination done by honey bees inside the cage.

These studies therefore, indicated that *B. haemorrhoidalis* was the most efficient pollinator. Hours of the day played an important role in foraging activities of insect visitors and the insects were most abundant during 09:00-10:00. There was more number of nectar foragers as compared to pollen foragers. Honey bees resulted in higher yield, fruit weight, number of seeds per fruit and weight of 1000-seeds. It is therefore concluded that BP gives best results and hence should be exploited to enhance the yield and quality of fruits.

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