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Pollination Efficiency of Native Bee Pollinators of Cucumber (*Cucumis sativus* L.) in India

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Abstract

An experiment was conducted at the Plant Pathology research farm, CCS Haryana Agricultural University, Hisar, India, during the summer season of 2012. Observations pertaining to various aspects were taken throughout the blooming period (April to August). Twenty- four insect species visited cucumber flowers at Hisar, which constituted 12 Hymenopterans, 6 Lepidopterans, 3 Dipterans, 2 Hemipterans and 1 Coleopteran. Among these, *Halictus* sp., *Ceratina sexmaculata* and *Apis dorsata* were dominant. Abundance of *C. sexmaculata* (2.79 bees/m^2/5 minutes) was highest followed by *Halictus* sp. (2.69 bees/m^2/5 minutes) and *A. dorsata* (0.78 bees/m^2/5 minutes) on cucumber flowers. The population irrespective of their species was observed maximum at 08.00~10.00 h of the day. Based on pollination index (Number of loose pollen grains sticking on the body of bee x abundance x foraging rate), *Halictus* sp. was the most efficient pollinator of *C. sativus* followed by *C. sexmaculata* and *A. dorsata* under ecological conditions of Hisar (Haryana).

Key words: Cucumber, Diversity, Abundance, Pollinator, Pollination index

INTRODUCTION

Pollination plays an important role in the reproduction and fruit set of flowering plants (Corbet *et al*., 1991; Buchmann and Nabhan, 1996) since the flower ovary for its development needs stimulus in the form of auxin, which is synthesized by the endosperms of the ovules after fertilization. After pollination and fertilization, the ovary of a flower develops into a fruit and the ovules into seeds. However, in the absence of pollination, the ovary is abscised, meaning that the pollination supplies necessary stimulus for the development of ovary, hence, pollination is prerequisite for setting fruits in all the cross-pollinated crops. It was estimated that in nature, only 5 per cent of the flowers are self-pollinated and 95per cent are cross-pollinated, of which, 10 per cent depend upon wind and 85per cent on animals (Tewari and Singh, 1983). Animal pollinators are thought to contribute 15~30% of the global food production (Roubik, 1995). Cucumber is a member of Cucurbitaceae family comprising of 90 genera and 750 species. It is an important summer vegetable crop grown for its tender fruits, used as salad, in pickles and also cooked as vegetable. Seeds are used in sweets and its oil serves as a tonic for brain (Choudhury, 1987). It is normally monoecious, having both male and female flowers on the same plant at separate nodes. Male flowers occur in clusters with each flower on a slender stem and having three stamens. Female flowers are borne singly and are distinguishable by the presence of a large ovary at the flower base. The ovary has three chambers with several

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rows of ovules and is connected to a short thick style with three stigma lobes. Flowers have yellow wrinkled petals. Both male and female flowers produce nectar, and most bee visitors collect this nectar (Collison, 1973). The flowers are short lived, and the stigma remains receptive throughout the day, being most receptive in early morning. If they are not pollinated during that time, the flowers abort and drop from the vine (Meléndez-Ramirez *et al*., 2002). Cucumber pollen grains are large and sticky, therefore, well suited to pollination by honeybees than by wind. The importance of insects as main agents for the transfer of pollen grains from male flower to female flower is well known (Free, 1993). Fruit abortion can reach 100 per cent in flowers bagged to exclude insect visitors (Stanghellini *et al*., 1997) but self-pollination rates of 30-36 per cent have been documented in the absence of insects and a small rate of parthenocarpy is known to exist at Canada (Gingras *et al*., 1999). However, the foraging behaviour of different species of honeybees on cucumber has been studied in India and abroad but the foraging behaviour in relation to pollination efficiency has not been studied. Hence, the present investigation was carried out to record the diversity and abundance of insect pollinators and to evaluate the pollination efficiency of native bee pollinators on cucumber flowers at Hisar (India).

MATERIALS AND METHODS

Study sites and climate

Pollination studies in cucumber hybrids, *viz*. Evergreen, NBH-Manu, Damini and Rani, was conducted at research farm of the Department of Plant Pathology and Apiculture Laboratory of the Department of Entomology, CCS Haryana Agricultural University, Hisar (India) during the rainy season, *i.e*., April to August 2012. The experimental site is situated at 29°10¡ North latitude and 75°46' East longitude at an altitude of 215.2 meter above mean sea level. The climate of Hisar region is semi-arid and is characterized by hot and dry winds during summer months and dry and severe cold conditions during winter months. The maximum and minimum temperature shows wide range of fluctuations during summer, while the temperature below freezing point accompanied by frost may also be recorded during winter months (December-January), which is very common feature of this region. The rainfall is confined mainly to the monsoon months from July to September but light showers cyclonic rains also occur sometimes during winter and spring months.

Soils status and fertilization

The soil of the field was sandy-loam with moderate fertility and pH 8.0, indicating slightly alkaline nature of the soil. Based on soil analysis, the soil of the experimental field was low in nitrogen, medium in organic carbon (0.33%), available phosphorus (8kg/ha) and rich in potassium (480kg/ha). Well-decomposed two years old farmyard manure was incorporated into the soil @ 10 t/ha at the time of field preparation. The field was prepared up to fine tilth by giving repeated ploughings with disc harrow followed by planking. The field was first divided into plots of 10m width and 40m length in which the channels of 40cm width and 20cm depth were opened manually with the help of spade at a distance of one meter.

Crop husbandry

For raising a healthy crop, 50kg nitrogen, 25kg phosphorus and 25kg potash fertilizers were applied per hectare at the time of last ploughing. The seeds of four varieties before sowing were treated with Captan @ 3g/kg of seed and soaked in water over night to hasten germination. Thereafter, the seeds were dried in shade before sowing. The seeds were sown in plots on 25th March 2011. Per hill, two seeds were sown on the edges of the raised beds keeping a distance of 2m between rows and 50cm between plants. The first irrigation was applied soon after sowing and subsequent irrigations were applied in furrows at an interval of 5~6 days. During vegetative phase, the crop was protected from the attack of red pumpkin beetle by spraying the vines with 0.2% carbryl 50 WP.

Diversity of bee pollinators

A cone type of hand net (30cm) was used to collect insects on the cucumber flowers throughout the blooming period. Sweepings were made at weekly intervals during April to August at two hourly intervals from morning to evening. The collected insects were preserved as dry specimen and got them identified from Insect Identification Service, Division of Entomology, I.A.R.I., New Delhi.

Abundance of insect visitors

Abundance of different insect visitors of cucumber crop was studied during their blooming period. The total number of different insect visiting on the cucumber flowers of two randomly selected per meter row for five minutes of each hybrid was recorded following the method given by Free (1993). These observations were started when 50% of the plants came into bloom.

Foraging rate

Foraging rate of bees was recorded in terms the number of flowers visited per minute following the method given by Free (1993). The total of ten bees of each species were observed for recording time spent by them on flowers of each variety of cucumber and number of flowers visited per minute at two hours interval from 0600 to 1800 h at weekly interval on calm, clear and sunny day during flowering time were counted for 8 days. The number of flowers visited per minute was recorded including the flying time from one flower to another flower.

Loose pollen grains sticking to the body a of bee

The loose pollen grains sticking to the body of different bee species were estimated. The bees were captured gently by forceps to avoid shaking of its body from the flowers and its hind legs were amputated following the method given by Kumar (1990). The bees were captured on their peak activity during peak flowering and kept in 70 per cent alcohol in glass vial (9 × 3cm) after amputating the hind pair of legs very gently. The bees were shaken vigorously to wash out the pollen grains from their body. The total volume of the rinsate was made to 5ml before pollen count. An aliquot, 0.01ml (replicated 5 times) was taken and with the help of a haemocytometer and binocular microscope (15 × 10 magnification), the number of pollen grains were counted. The total number of pollen grains in the whole rinsate was calculated. Identity of the cucumber pollen grains were accomplished with standard pollen slides. The ten individuals of each bee species were captured for counting the number of loose pollen grains. For the study of pollen grains, insects were captured between 1000 and 1200 h of the day.

Pollination efficiency

Comparative pollination efficiency of different bee species were assessed on the basis of their relative abundance, foraging behaviour parameters such as foraging rate and the amount of loose pollen grains sticking to their bodies. The pollination index was calculated by the following the method suggested by Kumar *et al*. (2012).

Statistical analysis

The data pertaining to relative abundance, foraging rate and loose pollen grains were statistically analyzed by using factorial complete randomized design (CRD). Comparative pollination efficiency of different bee species was assessed based on the relative abundance and foraging behaviour.

RESULTS AND DISCUSSION

Twenty-four insect species belonging to eleven families were recorded from the cucumber flowers. The hymenopterans were the major floral visitors comprising of twelve different species from three families (Table 1). *Apis dorsata* Fab., *Ceratina sexmaculata* Smith, *Halictus* sp., *Apis mellifera* L., *Megachile cephalotes* Smith, *Apis cerana* Fabricius, *Megachile bicolor* Fabricius (Family-Apidae), *Vespa auraria* Smith, *Vespa orientalis* Linnaeus, *Polistes hebraeus* Fabricius (Family-Vespidae), and *Eumenes petiolata* Fabricius, *Eumenes dimidiatipennis* Sauss (Family-Eumenidae). Among these insect visitors,

Table 1. List of frequent hymenopteran insect visitors/pollinators of cucumber flowers at Hisar

Family	Species
Apidae	*Apis dorsata* Fab.
	Ceratina sexmaculata Smith
	Halictus sp.
	Apis mellifera Linnaeus
	Megachile cephalotes Smith
	Apis cerana Fabricius
	Megachile bicolor Fabricius
Vespidae	*Vespa auraria* Smith
	Vespa orientalis Linnaeus
	Polistes hebraeus Fabricius
Eumenidae	*Eumenes petiolata* Fabricius
	Eumenes dimidiatipennis Sauss

Table 2. Abundance of native bees (Number of bees /m^2/5 minutes) on cucumber flowers at different hours of the day at Hisar

Species	Time in a day*						
	0700	0900	1100	1300	1500	1700	Mean
Halictus sp.	0.63**	4.20	3.98	1.88	2.50	2.95	2.69
Ceratina sexmaculata	0.75	4.83	4.50	2.38	1.23	3.08	2.79
Apis dorsata	0.60	0.78	1.43	0.23	0.60	1.30	0.78
Mean	0.66	3.27	3.30	1.49	1.44	2.35	
	Species	Day hours		Bee species X Day hours			
SE (m)	0.01	0.02		0.05			
C.D. (p= 0.05)	0.03	0.03		0.08			

*Time ranged ± 1 hr

** Each value represents mean of 20 observations at each sampling time

Table 3. Number of flowers visited by different native bees on cucumber flowers at different hours of the day at Hisar

Species	Time in a day*						
	0700	0900	1100	1300	1500	1700	Mean
Halictus sp.	4.60	5.20	5.50	4.05	3.23	3.70	4.38
Ceratina sexmaculata	5.10	6.28	6.08	4.50	3.75	4.50	5.03
Apis dorsata	15.18	14.95	13.60	0.85	0	7.18	8.63
Mean	8.29 (2.95)	8.81 (3.06)	8.39 (3.01)	3.13 (1.96)	2.33 (1.74)	5.13 (2.46)	
	Species	Time		Species X time			
SE (m)	0.03	0.04		0.08			
C.D. (p= 0.05)	0.09	0.14		0.23			

Each value represents mean of 20 observations at each sampling time.

A. dorsata, *C. sexmaculata* and *Halictus* sp. were the most frequent visitors. The mean bee species population over different day hours on cucumber flowers ranged from 0.78 (*A. dorsata*) to 2.79 bees/m^2/5 minutes (*C. sexmaculata*), and it was maximum at 1000-1200 h (3.30 bees/m^2/5 minutes) followed by 0800-1000 h (3.27 bees/m^2/5 minutes). During early morning and noon hours, their population was lowest at 0600-0800 h (0.66 bees/m^2/5

Table 4. Number of loose pollen grains (x1000) sticking on body of different insect pollinators on cucumber flowers at Hisar

Species	Variety of cucumber				
	Evergreen	NBH-Manu	Damini	Rani	Mean
Halictus sp.	48.27	51.08	46.01	42.79	47.04
Ceratina sexmaculata	39.06	44.02	47.53	43.87	43.62
Apis dorsata	125.00	126.00	104.64	99.11	113.69
Mean	70.78	73.70	66.06	61.92	
	Species			Variety	
SE (m)	5.55			6.41	
C.D. (p= 0.05)	13.82			NS	

Each value represents mean of 10 observations.

Table 5. Pollination efficiency of different native bees on cucumber flowers at Hisar

Bee species	Abundance	No. of loose pollen grains	Pollination index	Pollination efficiency rank
Halictus sp.	2.69	47040	126537.60	1st
C. sexmaculata	2.79	43620	121699.80	2nd
A. dorsata	0.78	113690	88678.20	3rd

minutes) followed by 1400-1600 h (1.44 bees/m^2/5 minutes). The cumulative mean abundance of important bee species revealed that *C. sexmaculata* was the most abundant visitor with a mean population of 2.79 bees/m^2/5 minutes followed by *Halictus* sp. (2.69 bees/m^2/5 minutes), and *A. dorsata* was least frequent (0.78 bees/m^2/5 minutes).

Flowers visited per minute by different bee species on *C. sativus* flowers was presented in Table 3. Number of flowers visited by three bee species differed significantly. The mean foraging rate (flowers visited per minute) in case of *Halictus* sp. varied from 3.23 to 5.50 flowers during different hours of the day. It was 3.75 to 6.28 flowers in case of *C. sexmaculata* and it varied from 0.00 to 15.18 flowers in case of *A. dorsata*. The mean foraging rate irrespective of different day hours was highest in *A. dorsata* (8.63 flowers/min.) followed by *C. sexmaculata* (5.03 flowers/min.), and it was lowest in *Halictus* sp. (4.38 flowers/min.).

Significant differences were found among the number of loose pollen grains sticking to the body of different foragers of three bee species (Table 4). *Apis dorsata* had the highest loose pollen grains on their body (113690 pollen grains) followed by *Halictus* sp. (47040 pollen grains) and it was lowest in case of *C. sexmaculata* (43620 pollen grains). Irrespective of three bee species, the number of loose pollen grains sticking to the body of bees did not differ significantly among different hybrids of cucumber.

Computation of pollination index

The abundance of *C. sexmaculata* (2.79 bees/m^2/5 minutes) was highest followed (Table 2) by *Halictus* sp. (2.69 bees/m^2/5 minutes), while *A. dorsata* was least abundance (0.78 bees/m^2/5 minutes). *Apis dorsata* entrapped maximum number of pollen grains (av. 113690.00 pollen grains) followed by *Halictus* sp. (av. 47040.00 pollen grains) and *C. sexmaculata* (av. 43620.00 pollen grains), but the pollination index of *Halictus* sp. was highest (126537.60) followed by *C. sexmaculata* (121699.80) and *A. dorsata* (88678.20). Hence, it was observed that *Halictus* sp. was the most efficient pollinator followed by *C. sexmaculata* and *A. dorsata* on *C. sativus* flowers under ecological conditions of Hisar (Haryana).

Large number of insects visits the cucumber flowers during the peak flowering period. Free (1993) reported that plants with many flowers attract more floral visitors than those with fewer flowers. In the present investigation, a fluctuation in visits of insect pollinators on different days on cucumber flowers was observed. The visits were low at

the time of commencement and cessation of the flowering but these remained high during mid flowering period. This difference might be due to variation in the floral density during the span of blooming on the crop. Kendell and Smith (1975), Schemske (1980) and Dhaliwal and Atwal (1985) also stated that the number of flowers was more at the peak flowering and these were visited by larger number of pollinators and helped maximization of pollination in different crops. Cucumber flowers at Hisar (Haryana) were visited by 12 Hymenopterans, *viz*. *Apis dorsata* Fab., *Ceratina sexmaculata* Smith, *Halictus* sp., *Apis mellifera*, *Megachile cephalotes* Smith, *Apis cerana* Fabricius, *Megachile bicolor* Fabricius, *Vespa auraria* Smith, *Vespa orientalis* Linnaeus, *Polistes hebraeus* Fabricius, *Eumenes petiolata* Fabricius, *Eumenes dimidiatipennis* Sauss, 6 Lepidopterans, *viz*. *Utethesia pulchella* Moore, *Lampides boeticus* Linnaeus, *Parnara* sp., *Anosia plexippus* Linnaeus and two unidentified, 3 Dipterans, *viz*. *Musca* sp., *Chrysomyia* sp. and *Eristalis* sp., 2 Hemipterans, *viz*. *Nezara graminea* Fabricius and *Dolycoris indicus* Stal and 1 Coleopteran, *viz*. *Epilachna dodecastigma* Wiedemar. Among these insects, *Halictus* sp., *C*. *sexmaculata* and *A*. *dorsata* were the most frequent visitors. In general, diversity of pollinating insects varies from region to region and locality to locality. McGregor in 1976 stated that insects of many species visited the cucumber flowers and pollinated them. These include bees, wasps, moths, butterflies, beetles, thrips and midges. However, bees were the most efficient and the only dependable pollinators. Kauffeld *et al*. (1978) listed 37 species, frequenting cucumber blossom in Louisiana (USA). Cervancia and Bergonia (1991) observed that the most common flower visitors of cucumber were *Xylocopa chlorine* (Cockerell), *X*. *philippinensis* Smith, *Megachile atrata* Smith and *Apis dorsata* Fabricius in Philippines. Total 24 species of insects were found visiting the cucumber flowers, predominantly Hymenopteran, and among bees, *Apis dorsata* was the most frequent visitor (Sajjanar *et al*., 2004). The results of the present investigations and almost similar to those reported by earlier workers (McGregor, 1976; Kauffeld *et al*., 1978; Cervancia and Bergonia; 1991 and Sajjanar *et al*., 2004). In the present study, the pollination efficiency of *Halictus* sp. and *C*. *sexmaculata* was much more than the efficiency of *A*. *dorsata* on *C*. *sativus* bloom under ecological conditions of Hisar (Haryana). This was due to the higher abundance of these bees. However, Stanghellini *et al*. (1997) observed that honey bees were the best pollinators of cucumber and watermelon followed by bumble bees. Kumar (2002) reported that *Melissodes* sp. was considered the best pollinator of cucumber followed by *Sarcophaga* sp. at Hisar.

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LITERATURE CITED

Buchmann, L.S. and Nabhan, P.G. 1996. The Forgotten Pollinators. Island Press, Washington DC, USA, 292pp.

Cervancia, C.R. and Bergonia, E.A. 1991. Insect pollination of cucumber (*Cucumis sativus* L.) in the Philippines. The Sixth International Symposium on Pollination, Tilburg, Netherlands, 27-31 August 1990, pp. 278-282.

Choudhury, B. 1987. *Vegetables*. National Book Trust, Delhi, India.

Collison, C.H. 1973. Nectar secretion and how it affects the activity of honey bees in the pollination of hybrid pickling cucumbers, *Cucumis sativus* L. M.Sc. Thesis, Michigan State University, East Lansing, USA.

Corbet S.A., Williams, I.H. and Osborne, J.L. 1991. Bees and the pollination of crops and wild flowers in the European community. Bee World 72(2): 47-59.

Dhaliwal, J.S. and Atwal, A.S. 1985. Effect of age of crop, plant spacing, soil moisture and phosphatic fertilizers on bee activity on *Brassica* crop. In: Pollination Biology: An Analysis (Ed. R.P. Kapil). Inter India Publication, pp. 91-101.

Free, J.B. 1993. Insect pollination of Crops (2nd edn.). Academic Press, London, U.K., 684 pp.

Gingras, D., Gingras, J. and De-oliveira, D. 1999. Visits of honey bees (Hymenoptera: Apidae) and their effects on cucumbers yields in the field. J. econ. Ent. 92: 435-438.

Kauffeld, N.M., Hernandez, T., Wright, J. and Misaraca, S., 1978. Insects collected from cucumber plants during a pollination study. J. Georgia Ent. Soc. 13(1): 67-71.

Kendell, D.A. and Smith, B.D. 1975. The foraging behaviour of honey bees on ornamental Malus spp. used as pollinizers in apple orchards. J. Appl. Ecol. 12: 465-471.

Kumar, P.B., Sharma, S.K., Rana, M.K. 2012. Diversity, abundance and pollination efficiency of native bee pollinators of bitter gourd (*Momordica charantia* L.) in India. Journal of Apiculture Research, 15(3): 227-231.

Kumar, S. 1990. Studies on insect pollination in Ber (*Zizyphus mauritiana* Lamk.). M.Sc. Thesis, Haryana Agricultural University, Hisar, Haryana, India.

Kumar, S. 2002. Studies on the activities of insect pollinators of cucurbit crops. M.Sc. Thesis, Haryana Agricultural University, Hisar.

Meléndez-ramirez, V., Magaña-rueda, S., Parra-tabla, V., Ayala, R. and Navarro, J. 2002. Diversity of native bee visitors of cucurbit crops (Cucurbitaceae) in Yucatán, México. Journal of Insect Conservation 6: 135-147.

Mcgregor, S.E. 1976. Insect pollination of cultivated crop plants. Agriculture Handbook. US Department of Agriculture, No. 496: viii+411p.

Roubik, D.W. 1995. Pollination of Cultivated Plants in the Tropics. FAO Agriculture Service Bulletine 18, Rome, Italy, 118pp.

Sajjanar, S.M., Kuberappa, G.C. and Prabhuswamy, H.P. 2004. Insect visitors of cucumber (*Cucumis sativus* L.) and the role of honey bee, *Apis cerana* F. in its pollination. Pest Mgt. Eco. Zool. 12(1): 23-31.

Schemske, D.W. 1980. Floral ecology and humming bird pollination of combretum farinosum in Costa Rica. Biotropica, 12: 169-181.

Stanghellini, M.S., Ambrose J.T. and Schultheis, J.R. 1997. The effects of honeybee and bumblebee pollination on fruit set and abortion of cucumber and watermelon. Am. Bee J. 137: 386-391.

Tewari, G.N. and Singh, K. 1983. Role of pollinators in vegetable seed production. Indian Bee Journal 45: 51-56.