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Original Research Article

Pollination Efficiency of Different Bee Species on Cucumber (*Cucumis sativus*) in Tarai Region of Uttarakhand

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A B S T R A C T

Pollination Efficiency of different bee species on Cucumber (*Cucumis sativus*) was studied in Tarai region of Uttarakhand. The region has a great diversity of flowering plants and has good potential for commercial beekeeping. The area fall under Foothills of Himalayas in Uttarakhand state. This region was selected for maximum utilization of flora by beekeepers and recognizes the major pollen and nectar source to honeybees. The present study was conducted at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar-263145, District Udham Singh Nagar (Uttarakhand) India, during the period 2011-2013. The present study revealed that the honeybees and *Xylocopa* spp. are the major pollinators on *Cucumis sativus*. The pollination index was maximum (512565.7) in *Apis mellifera*, followed by *Apis dorsata* (428160.2) and *Apis cerana* (320718.5), The *Ceratina sexmaculata* was (0202632), *Nomia melanderi* (199008.1), *Megachile bicolor* (195700.5), *Megachile disjuncta* (191452.8), *Apis florea* (183055.4), *Megachile hera* (0182405), *Xylocopa iridipennis* (127223.5), *Xylocopa aestuans* (124426.7), *Xylocopa amethystine* (97416.25), *Xylocopa latipes* (0096685) and lowest pollination index (074232.9) was found in *Xylocopa verticalis*.

Keywords

Pollination Index, Pollinators

Introduction

Cucumber (*Cucumis sativus*) is a widely cultivated plant in the gourd family, Cucurbitaceae. The crop is grown worldwide in tropical and subtropical parts of the world. The cucurbit 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. The pollen grains being large and sticky, need an external agent for transfer of pollen grains between flowers (Sedgley and Scholefield 1980). Pollination indices calculation on the basis of relative abundance, foraging behaviour (foraging

speed, rate, amount of loose pollen carried on the body has been found as an alternate parameter to evaluate the pollination efficiency (Sharma, 1990). Fruits, vegetables or seed production from 87 of the 115 leading global food crops depends upon animal pollination Klein *et al.,* (2007). The value of insect pollination for worldwide agricultural production is estimated to be 153 billion, which represents 9.5% of the value of the world agricultural production used for human food in 2005 Gallai *et al.,* (2009).

The *Xylocopa* species are also the major insect pollinators of Cucurbitaceous crop. *Xylocopa* species belong to the family Anthophoridae and subfamily Xylocopinae. A pollen grain is a marvelous product evolved by flowering plants to continue their generation. Honeybees and flowering plants have been considered as an example for co-evolution and mutualism. Bees pollinate flowers, which mean they transfer the pollen from the flower of one plant to the flower of another plant. When pollen from one flower is carried to the stigma of another, this is called cross-pollination.

Pollination efficiency of different insect pollinators has been evaluated on the basis of number of characteristics. However, it is recognized that there are inherent differences in the ability of various species to effect pollination inspite of their abundance. Therefore, efficiency of an insect species as pollinator has also been attributed to its foraging behaviour and the amount of loose pollen grains adhered to its body (Bohart and Nye, 1960; Free, 1993). The behaviour of pollinator is very important aspect in bid to promote the pollination and pollinators. The behaviour of pollinators, their relative abundances and foraging speed is indeed helpful for determining the extent of contribution in ecosystem and agricultural production.

Study sites

Geographically Pantnagar is located in the sub-tropical zone at 29^0N latitude and 79.3^0E longitude and at an altitude of 243.8 m above the mean sea level in the "tarai" region of Uttarakhand in Northern India (Fig. 1 and 2).

The location has sub-humid tropical climate and is situated in the foot hills of "Shivalik" range of the Himalayas. The meteorological data indicate that the humid climate here is characterized by hot dry summer and cold winter.

The temperature rises up to 40^0C in summer, while it falls to 2-10^0C in winter. Approximately, 1400 mm mean rainfall has been recorded and relative humidity fluctuates around 90 ± 5 per cent during rainy season.

Materials and Methods

Abundance of insect pollinators of different cross- pollinated crops

Abundance of different insect pollinators on *Cucumis sativus* crop was studied during their peak blooming periods. The total numbers of different insect pollinators were recorded randomly selected per meter row length for five minutes of crop at different time intervals such as 0600-0800h, 0800-1000h, 1000-1200h and1600-1800h for 7 days, using a stop watch. These observations were started when 50 percent of the plants came in to bloom.

Estimation of pollen grains

The loose pollen grains sticking to the body of different bee species were estimated. The3 bees were captured on their peak activity during peak flowering. The bees were kept in 70 percent alcohol in glass vial after

amputating the hind pair of legs very gently. The bees were shaken vigorously to wash out the pollen grains from their body. Total volume of the rinsate was made to 5 ml before pollen count.

An aliquot, 0.01 ml (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.

Neubauer Haemocytometer- Neubauer haemocytometer was used to count the number of loose pollen grains sticking on bee body in aliquot following the method suggested by Traynor (1981).

$$\text{Number of pollen grains} = \frac{\text{Pollen grain count} \times \text{dilution}}{\text{Number of squares } (1\text{mm}^2) \text{ counted}}$$

Microscope

A microscope was used to magnify and count the number of loose pollen grains on neubauer haemocytometer.

Pollination efficiency

Pollination efficiency of different bee species were assessed based on their relative abundance and foraging behaviour parameter such as foraging speed and the amount of loose pollen grains sticking to their bodies. The pollination index was calculated by number of loose pollen grains sticking on the body of the bee x abundance of different insect pollinators on flowers of different crops.

Based on pollination index (number of loose pollen grains sticking to their body x abundance), the pollination efficiency calculated.

Pollen efficiency index

The data on comparative pollination efficiency of different bee species were assessed based on their relative abundance on *Cucumis sativus* and the amount of loose pollen grains sticking their bodies at Pantnagar during August to September.

Statistical analysis

In order to find out the abundance of insect pollinators on *Cucumis sativus*, the data was statistically analyzed in to two factorial randomized block design.

Results and Discussion

Abundance of different bee species on Cucumber (*Cucumis sativus*) flowers at different hours of the day during August-September 2013 at (Vegetable Research Centre) Pantnagar

The average abundance of different bee species on *Cucumis sativus* flowers at different hours of the day presented in table 1 revealed that mean abundance of different bee species over different day hours on *Cucumis sativus* flower ranged from 3.82 in *Megachile hera* to 6.25 in *Xylocopa amethystine*. Among 6 species of carpenter bees the *Xylocopa aestuans* exhibited higher abundance 8.14, 6.14, 6.00 and 4.42 bees/m^2/5 minutes throughout different day hours at 0800-1000 h, 0600-0800 h, 1000-1200 h and 1600-1800 h respectively with higher abundance at 0800-1000 h. *Xylocopa verticalis* was highest (6.42 bees/m^2/5 minutes) at 0800-1000 h, (5.28 bees/m^2/5 minutes) at 0600-0800, (5.14 bees/m^2/5 minutes) at 1000-1200 h. The lowest abundance (4.14 bees/m^2/5 minutes) was observed at 1600-1800 h. The abundance of *Xylocopa iridipennis* observed maximum (7.00 bees/m^2/5 minutes) at 0800-1000 h,

followed by 6.85 bees/m^2/5 minutes at 0800-1000h, 5.71 bees/m^2/5 minutes at 1000-1200 h and 5.14 bees/m^2/5 minutes at 1600-1800 h. In case of *Xylocopa amethystine* the maximum abundance (7.28 bees/m2/5 minutes was observed at 0800-1000 h followed by 6.57 bees/m2/5 minutes at 0600-0800 h, 6.14 bees/m2/5 minutes and lowest (5.00 bees/m2/5 minutes) at 1600-1800 h. *X. latipes* exhibited higher abundance 7.85, 6.71, 5.42 and 4.42 bees/m^2/5 minutes throughout different day hours at 0800-1000 h, 0600-0800 h, 1000-1200 h and 1600-1800 h respectively with higher abundance at 0800-1000 h. *Ceratina sexmaculata* observed maximum (6.14 bees/m^2/5 minutes) at 0800-1000 h, followed by 5.57 bees/m^2/5 minutes at 0600-0800 h, 4.14 bees/m^2/5 minutes at 1600-1800 and lowest abundance (4.14 bees/m^2/5 minutes) was recorded at 1200-1600 h. In Karnataka Pateel and Sattagi (2007) found that *Apis florea*, *Apis cerana* and *Apis dorsata* were the most frequent pollinators on Rabi Cucumber with 8.03, 6.03 and 3.43 bees/m^2/5 minutes. Several insect species visit cultivated crops to collect pollen and nectar. A few are considered very good pollinators. Abundance, foraging mode, loose pollen grains adhered to the body, foraging rate and morphological characters help in determining the efficiency of the pollinators (Free 1993).

Among 4 *Apis* bee species, the *Apis dorsata* observed maximum abundance (5.14 bees/m^2/5 minutes) at 0800-1000h, followed by 5.00 bees/ m^2/5 minutes at 0600-0800 h, 4.14 bees/ m^2 /5 minutes at 1000-1200 h and lowest abundance observed at 1600-1800 h. Another species of honey bee *i.e. Apis mellifera* was observed maximum abundance (6.57 bees/m^2/5 minutes) at 0800-1000 h, followed by 6.28 bees/m^2/5 minutes at 0600-0800 h, 5.00 bees/m^2/5 minutes at 1200-1600 and lowest abundance (4.85 bees/m2/5 minutes) was observed at 1600-1800 h. In *Apis cerana* maximum abundance (5.14 bees/m^2/5 minutes) was recorded at 0800-1000 h, followed by 4.71 bees/m^2/5 minutes at 0600-0800 h, 4.57 bees/ m^2/5 minutes at 1200-1600 h and lowest abundance (4.42 bees/ m^2/5 minutes recorded at 1600-1800 h. *Apis florea* exhibited maximum abundance 4.71, 4.14, 3.57 and 3.42 bees/ m^2/5 minutes at 0800-1000 h, 0600-0800 h, 1000-1200 h and 1600-1800 h respectively. *Nomia melanderi* was observed maximum abundance (5.85 bees/ m^2/5 minutes) followed by 5.57 bees/ m^2/5 minutes), 4.85 bees/ m^2/5 minutes at 1200-1600 and lowest abundance (4.71 bees/ m^2/5 minutes recorded at 1600-1800 h. Among leaf cutter bees, *Megachile hera* exhibited maximum abundance (5.00 bees/ m^2/5 minutes) at 0800-1000 followed by 3.57 bees/ m^2/5 minutes at 0800-1000 h, 3.42 bees/ m^2/5 minutes at 1000-1200 h and lowest (3.28 bees/ m^2/5 minutes) at 1600-1800 h. *Megachile disjuncta* recorded maximum abundance (4.71 bees/ m^2/5 minutes) at 0800-1000 h, followed by 4.28 bees/ m^2/5 minutes, 3.71 bees/ m^2/5 minutes and lowest abundance (3.52 bees/ m^2/5 minutes) observed at 1600-1800 h. *Megachile bicolor* exhibited higher abundance 5.42, 5.00, 4.28 and 4.14 bees/ m^2/5 minutes at 0800-1000, 0600-0800, 1000-1200 and 1600-1800 h respectively with higher abundance at 0800-1000 h. The cumulative mean abundance of different bee species revealed that the *Xylocopa amethystine* (6.25 bees/m^2/5 minutes) most abundant forager followed by *Xylocopa aestuans* (6.17 bees/m^2/5 minutes), *Xylocopa iridipennis* (6.17 bees/m^2/5 minutes), *Xylocopa latipes* (6.10 bees/m^2/5 minutes), *Apis mellifera* (5.67 bees/m^2/5 minutes), *Xylocopa verticalis* (5.25 bees/m^2/5 minutes), *Nomia melanderi* (5.25 bees/m^2/5 minutes), *Ceratina sexmaculata* (5.03 bees/m^2/5 minutes), *Apis cerana* (4.71 bees/m^2/5 minutes), *Megachile bicolor* (4.71 bees/m^2/5 minutes), *Apis dorsata* (4.53 bees/m^2/5

minutes), *Megachile disjuncta* (4.07 bees/m^2/5 minutes), *Megachile hera* (3.82 bees/m^2/5 minutes) and *Apis florea* (3.96 bees/m^2/5 minutes). Irrespective abundance of bee species was highest at 0800-1000 h (6.10 bees/m^2/5 minutes) and lowest (4.26 bees/m^2/5 minutes) at 1600-1800 h. In Hisar, Hanh (2008) observed that *Ceratina sexmaculata*, *Halictus* sp. and *Apis dorsata* were the most abundant insect pollinators visiting cucumber flowers with 2.79, 2.69 and 0.78 bees/m2/5 minutes, respectively.

Fig. 1

Fig. 2

Table.1 Abundance of different bee species on Cucumber (*Cucumis sativus*) flowers at different hours of the day during August- September 2013 at (Vegetable Research Centre) Pantnagar.

Bee species	No. of bees/m^2/5 minutes				
	0600-0800	0800-1000	1000-1200	1600-1800	Mean
Xylocopa aestuans	6.14	8.14	6.00	4.42	6.17
Xylocopa verticalis	5.28	6.42	5.14	4.14	5.25
Xylocopa iridipennis	6.85	7.00	5.71	5.14	6.17
Xylocopa amethystine	6.57	7.28	6.14	5.00	6.25
Xylocopa latipes	6.71	7.85	5.42	4.42	6.10
Ceratina sexmaculata	5.57	6.14	4.14	4.28	5.03
Apis dorsata	5.00	5.14	4.14	3.85	4.53
Apis mellifera	6.28	6.57	5.00	4.85	5.67
Apis cerana	4.71	5.14	4.57	4.42	4.71
Apis florea	4.14	4.71	3.57	3.42	3.96
Nomia melandri	5.57	5.85	4.85	4.71	5.25
Megachile hera	3.57	5.00	3.42	3.28	3.82
Megachile disjuncta	4.28	4.71	3.71	3.57	4.07
Megachile bicolor	5.00	5.42	4.28	4.14	4.71
Mean	5.40	6.10	4.72	4.26	5.12
				SE(m)	**C.D. (p=0.05)**
Bee species				0.20	0.55
Day hours				0.10	0.29
Bee species x day hours				0.40	1.11
CV				20.65	

Table.2 Pollination efficiency of different bee species on cucumber (*Cucumis sativus*) flowers during August- September 2013 at (Vegetable Research Centre) Pantnagar

Bee species	Abundance (bees/m^2/5 minutes)	Number of loose pollen grains sticking on the body of a bee	Pollination index (Abundance X loose pollen grains)
Xylocopa aestuans	6.17	20166.4	124426.7
Xylocopa verticalis	5.25	14139.6	074232.9
Xylocopa iridipennis	6.17	20619.7	127223.5
Xylocopa amethystine	6.25	15586.6	97416.25
Xylocopa latipes	6.10	015850	0096685
Ceratina sexmaculata	5.03	40284.7	0202632
Apis dorsata	4.53	94516.6	428160.2
Apis mellifera	5.67	90399.6	512565.7
Apis cerana	4.71	68093.1	320718.5
Apis florea	3.96	46226.1	183055.4
Nomia melanderi	5.25	37906.3	199008.1
Megachile hera	3.82	047750	0182405
Megachile disjuncta	4.07	047040	191452.8
Megachile bicolor	4.71	041550	195700.5

Number of loose pollen grains sticking to the bee body

The number of loose pollen grains sticking to the body of bees presented in table 2. Significant differences were found among the number of loose pollen grains sticking to the body of different bee species. *Apis dorsata had* the highest loose pollen grains on their body (avg. 94516.6 pollen grains), followed by *Apis mellifera* (90399.6 pollen grains), *Apis cerana* (68093.1 pollen grains), *Apis florea* (46226.1 pollen grains), *Megachile hera* (47750 pollen grains), *Megachile disjuncta* (47040 pollen grains), *Megachile bicolor* (41550 pollen grains), *Ceratina sexmaculata* (40284.7 pollen grains), *Nomia melanderi* (37906.3 pollen grains), *Xylocopa iridipennis* (20619.7 pollen grains), *Xylocopa aestuans* (20166.4 pollen grains), *Xylocopa latipes* (15850 pollen grains), *Xylocopa amethystine* (15586.6 pollen grains) and in case of *Xylocopa verticalis* it was lowest (14139.6 pollen grains).

Pollination efficiency (Pollination Index)

The pollination efficiency of different bee species on *Cucumis sativus* presented in table 2. Significant differences were found among the pollination efficiency of different bee species. The present study revealed that the pollination index maximum (512565.7) in *Apis mellifera*, followed by *Apis dorsata* (428160.2) and *Apis cerana* (320718.5), Connor and Martin 1969 also observed that the honeybees are the major insect pollinators on cucumber. The *Ceratina sexmaculata* it was (0202632), *Nomia melanderi* (199008.1), *Megachile bicolor* (195700.5), *Megachile disjuncta* (191452.8), *Apis florea* (183055.4), *Megachile hera* (0182405), *Xylocopa iridipennis* (127223.5), *Xylocopa aestuans* (124426.7), *Xylocopa amethystine* (97416.25), *Xylocopa latipes* (0096685) and lowest pollination index (074232.9) was found in *Xylocopa verticalis*. Pollination efficiencies are different for different insect species on different crops (Schemske and Hortivitz, 1984). An effective pollinator makes sequential visits to the flowers, carries pollen grains and transfer them to stigma during a visit and cause pollination (Corbet *et al.,* 1991). Pollination efficiency depends upon large number of factors such as abundance, foraging behaviour, loose pollen carrying capacity, competing flora, multiplicity of bee visits and morphological characters of, *i.e.*, body size, tongue length, pollen collecting apparatus and hairiness (Atwal, 1970; Kapil and Brar, 1971; Free, 1993). Lukoschus (1957) reported that the number of loose pollen grains sticking on the bodies varied with bee species and the plant variety on which the bees were working. Stanghellini *et al.,* (1997) also cited the honeybees were the best pollinators of cucumber and watermelon followed by bumble bees.

Thus this study indicates that the number of loose pollen grains found on the body of different pollinators, *Apis dorsata* had the highest loose pollen grains on their body, followed by *Apis mellifera* due to their foraging legs and hairs on the body. The carpenter bees *Xylocopa verticalis*, *Xylocopa latipes*, *Xylocopa iridipennis* were found to be important contributor of pollination in various crops. On the basis of pollination index in various crops it may be concluded that the most efficient pollinator is *Apis mellifera* ((512565.7), followed by *Apis dorsata* (428160.2), *Apis cerana* (320718.5), however poor efficiency was observed in *Xylocopa verticalis* (14139.6 pollen grains).

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