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EVALUATION OF POLLINATION EFFICIENCY OF MAJOR INSECT POLLINATORS ON SUMMER SQUASH (*CUCURBITA PEPO* L.)

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ABSTRACT

The pollination efficiency of major insect pollinators of summer squash was evaluated at the Department of Entomology, CCS Haryana Agricultural University, Hisar, during the crop season in 2013-14. The abundance (bees/m^2/5 minutes) of *Apis mellifera* (2.21) was highest followed by *A. cerana* (1.16), *A. dorsata* (1.07) and *A. florea* (0.62). Irrespective of species, the population was maximum (1.45 bees/m^2/5 minutes) at 1000-1200 h of the day. The number of loose pollen grains sticking to the body of *A. dorsata* was registered maximum (av. 165000 pollen grains) followed by *A. mellifera* (97750 pollen grains), *A. cerana* (60,000 pollen grains) and *A. florea* (48750 pollen grains). Based on pollination index of four bee species, *A. mellifera* was found to be the most efficient pollinator of summer squash flowers with pollination index of 216030 followed by *A. dorsata, A. cerana* and *A. florea*, having pollination index 176550, 69600 and 30230, respectively under agro-ecological conditions of Hisar.

Keywords: *A. mellifera*, *A. cerana*, *A. dorsata*, *A. florea*, *C. pepo* and pollination index

INTRODUCTION

Pollination plays an important role in the reproduction and fruit set of flowering plants (Buchmann and Nabhan, 1996**).** Animal pollinators are thought to contribute between 15 and 30 per cent of global food production (Roubik, 1995), and insect pollination accounts for 90 per cent of animal pollination (Richards, 1986; Buchmann and Nabhan, 1996). Bees are the most versatile, active and best-known pollinators. In addition, bees are faithful to one species of flower per trip (floral constancy), which greatly facilitates pollination. The efficiency of an insect to pollinate the flower is called the pollination efficiency of that insect pollinator. An effective pollinator makes sequential visits to the flowers, carries pollens and transfers them to stigma during a visit (Corbet *et al*., 1991). Pollination efficiency depends upon large number of factors such as abundance, foraging behaviour, competing flora, loose pollen grains carrying capacity, multiplicity of bee visits and morphometrical characters, *i.e.*, body size, tongue length, pollen collecting apparatus and hairyness (Atwal, 1970; Kapil and Brar, 1971; Free, 1993). Various workers considered the relative effectiveness of insect pollinators of crops based on their abundance alone (Atwal, 1970; Kapil and Brar, 1971); while most of the workers considered the relative effectiveness of various species to affect pollination in spite of their abundance (Free *et al*., 1975; Anderson *et al*., 1982). Brantjes and Leemans (1976) noticed that the large sized insects were effective in pollination of flowers due to their body contact with anthers and stigmas as compared to small sized insects, which often missed their contact with anthers and stigmas while foraging for floral rewards.

Summer squash is an upright non-trailing bush (in contrast to climbing growth habit of most cucurbits) with 45-75 cm height. Fruits come in diverse forms from oblong or elongate to flattened, but some varieties have a crook-necked fruits. The fruit surface may be smooth, scalloped, ridged, or warty and colour may vary from white or cream to yellow to green but some are variegated or striped. Its fruits develop rapidly after flowering, and thus, they are harvested within few days before the seeds and rind become hard and the flesh becomes fibrous. The plant bears male and female flowers separately on same branch with many more male flowers usually being present. The pollens of cucurbitaceous crops are sticky, thus, cannot be blown by wind. Cross-pollination can thus be accomplished only if the number of insect pollinators working on the flowers is optimum. Cucurbitaceous vegetable crops require insects, such as honeybees, to transfer pollens from staminate (male) to pistillate (female) flowers (Delaplane and Mayer, 2000). Grewal and Sidhu (1978) recorded that *Apis* spp. constituted 70.70 per cent of the total number of bees collected from *Cucurbita pepo* in 1974 and 77.2 per cent in 1975. Among the solitary bees,

Pithitis smaragdula (10.8%) was more abundant in 1974 and *Xylocopa fenestrata* (7.3%) in 1975. The megachilid bees visited flowers of these crops only occasionally.

Baker *et al.* (1971) reported that the frequency of flower visitors, the number of flowers visited per unit time and the amount of pollen grains picked per visit helped to distinguish the pollinators as major and minor ones, however, he admitted that there were inherent differences in the ability of various species to affect pollination in spite of their abundance (Anderson *et al.*, 1982). Therefore, the present study has been planned to test the pollination efficiency of *Apis* spp. on summer squash

MATERIALS AND METHODS

The crop was raised at Research Farm of the Department of Entomology, CCS Haryana Agricultural University, Hisar. The field area (48m x16m) was first divided into 4 equal plots of 8 m width and 24 m length with irrigation channels of 50 cm width and 20 cm depth. Four hybrids of summer squash *viz*., Parikrama, Chandra, Chamatkar and Gold Queen were sown. Before sowing, the seeds of all the four hybrids were treated with Captan @ 3 g/kg of seed. Per hill two seeds were sown on the single side edge of the raised bed keeping a distance of 80 cm between rows and 50 cm between plants. The seeds were sown on 27th November, 2013 and five replications for each hybrid were maintained. All the normal package of practices was followed for raising a healthy crop.

Comparative pollination efficiency of different insect pollinators of summer squash flowers were worked out by different indices such as:

i. Number of loose pollen grains sticking to their body: For estimating the number of loose pollen grains sticking to the body of different insect pollinating species, the insects were captured gently with the help of forceps from the flowers to avoid shaking of body, and the hind legs of these pollinators, which collect the pollen on their hind legs, were amputated. The insects were captured at the time of their peak activity during flowering and were kept in 70 per cent alcohol in vial. The insects were then shaken vigorously to wash out pollen grains from their body. The number of pollen grains was counted with the help of a haemocytometer under the microscope. Twenty individuals of each insect species were captured for counting the number of loose pollen grains.

ii. Abundance: The abundance of different *Apis* spp. were recorded continuously for a period of five minutes at 2- hourly intervals from 06:00 till 18:00 h (6 time intervals) using a hand tally counter between different day hours following the methods given by Free (1993) on calm, clear and sunny days at peak flowering.

iii. Foraging rate: The foraging rate of different *Apis* spp. was recorded in terms of the number of flowers visited per minute.

Based on pollination index (Number of loose pollen grains sticking on the body X relative abundance of a particular pollinator X foraging rate), the pollination efficiency was calculated (Balina *et al*., 2012).

RESULTS AND DISCUSSION

Abundance

Data on abundance of different bee species on summer squash flowers at different hours of the day have been presented in Table (1). Variations in abundance were recorded over time and space. No bee population was observed during 12:00-16:00 h. The mean number of bee species over different day hours on summer squash flowers ranged from 0.62 (*A. florea*) to 2.21 bees/m^2/5 minutes (*A. mellifera*). Irrespective of species, the abundance of bees was lowest at 16:00-18:00 h (1.10 bees/m^2/5 minutes) and highest at 10:00-12:00 h (1.45 bees/m^2/5 minutes). The cumulative mean abundance of important bee species revealed that *A. mellifera* was the most abundant visitor with a mean population of 2.21 bees/m^2/5 minutes followed by *A. cerana* (1.16 bees/m^2/5 minutes), *A. dorsata* (1.07 bees/m^2/5 minutes) and *A. florea* was least frequent (0.78 bees/m^2/5 minutes) visitor of summer squash flowers in the present investigations.

All the bee species started visiting the crop from 06:00 h of the day, but their abundance varied during different intervals of the day. *A. dorsata* and *A. mellifera* were most abundant during 10:00 to 12:00 h of the day (1.63 and 2.50 bees/m^2/5 minutes, respectively); while, *A. florea* was most abundant during 06:00 to 08:00 h (0.83 bees/m2/5 minutes) and *A. cerana* during 16:00 to 18:00 h (1.46 bees/m2/5 minutes) of the day. Atwal (1970) recorded more than 23 species of bees visiting cucurbitaceous flowers at Ludhiana. Of the various bee species, *A. dorsata* was the most abundant species visiting the flowers followed by *A. florea*, *Ceratina binghami* Cockerel, *Xylocopa pubescens* Spinola, *Nomioides* sp. and halictine bees. *Apis* species, especially *A. dorsata* and *A. florea*, constituted 77.20 and 70.70% of the total number of bees collected from *C. pepo* L. in 1974 and 1975, respectively at Ludhiana (Grewal and Sidhu, 1979).

In Hisar, Hanh (2008) observed that *Ceratina sexmaculata*, *Halictus* sp. and *A. dorsata* were the most abundant insect pollinators visiting cucumber flowers with 2.79, 2.69 and 0.78 bees/m^2/5 minutes, respectively.

Pateel and Sattagi (2007) recorded that *A. florea*, *A. cerana* and *A. dorsata* were the most frequent insect pollinators visiting the *Rabi* cucumber flowers in Karnataka with 8.03, 6.03 and 3.43 bees/m^2/5 minutes, respectively. The abundance of bees on flowering crops depends on so many factors such as anthesis, weather parameters, competing flora, nests of wild bees in the vicinity of flowering crops, nectar concentration and its volume (Free, 1993).

Table 1. Abundance of different bee species on flowers of *Cucurbita pepo* during different hours of the day

Bee species	Number of bees/m^2/5 minutes during different day hours				
	06:00-08:00	08:00-10:00	10:00-12:00	16:00-18:00	Mean
Apis dorsata	0.66 (1.28)	1.33 (1.53)	1.63 (1.67)	0.66 (1.28)	1.07 (1.44)
Api mellifera	2.17 (1.76)	2.33 (1.82)	2.5 (1.87)	1.83 (1.66)	2.21 (1.78)
Apis florea	0.83 (1.29)	0.67 (1.35)	0.51 (1.29)	0.46 (1.23)	0.62 (1.29)
Apis cerana	1.16 (1.52)	0.83 (1.47)	1.17 (1.34)	1.46 (1.53)	1.16 (1.47)
Mean	1.21 (1.46)	1.29 (1.54)	1.45 (1.55)	(1.42)	

Each value represents mean of 20 observations; Figures in parentheses are $\sqrt{(x+1)}$ transformed values.

S. Em. C.D. (p= 0.05)		
Bee species	(0.04)	(0.13)
Day hours	(0.04)	(0.15)
Bee species × Day hours	(0.08)	(0.27)

Foraging rate:

The data on number of flowers visited per minute (foraging rate) by different bee species on summer squash flowers have been presented in Table (2). The number of flowers visited by four bee species differed significantly during different times of the day. The mean foraging rate in case of *A. mellifera* varied from 5.20 to 6.07 flowers during different hours of the day. It was 3.13 to 3.33 flowers in case of *A. cerana*, 3.90 to 5.26 flowers in case of *A. dorsata* and 1.97-2.20 flowers for A. *florea*. Among the bee species, the mean foraging rate was highest in *A. mellifera* (5.45 flowers/minute), followed by *A. dorsata* (4.38 flowers/minute) and *A. cerana (*3.21 flowers/minute), and it was lowest in *A. florea* (2.10 flowers/minute). Reports indicate that foraging rate of honey bees per 5 minutes ranged from 2.80 to 7.33 while that of stingless bee ranged from 1-2 (Anonymous, 2013).

Table 2. Foraging rate of different bee species on flowers of *Cucurbita pepo* during different hours of the day

Bee species	Number of flowers visited per minute				
	06:00-08:00	08:00-10:00	10:00-12:00	16:00-18:00	Mean
Apis dorsata	4.27 (2.31)	5.26 (2.24)	4.10 (2.20)	3.90 (2.27)	4.38 (2.26)
Apis mellifera	5.21 (2.21)	6.07 (2.23)	5.31 (2.48)	5.20 (2.47)	5.45 (2.35)
Apis florea	2.20 (1.42)	2.07 (1.48)	2.17 (1.45)	1.97 (1.48)	2.10 (1.46)
Apis cerana	3.20 (2.47)	3.33 (2.51)	3.13 (2.50)	3.17 (2.45)	3.21 (2.49)
Mean	3.72 (2.10)	4.18 (2.11)	3.68 (2.16)	2.18)	

Each value represents 20 observations; Figures in the parentheses are $\sqrt{(x+1)}$ transformed values

	S. Em.	C.D. (p= 0.05)
Bee species	(0.06)	(0.15)
Day hours	(0.07)	(0.16)
Bee species × Day hours	(0.11)	(0.31)

Number of loose pollen grains sticking to the body of a bee

The number of loose pollen grains sticking to the body of bees while foraging on summer squash flowers has been presented in Table (3). Significant differences were found among the number of loose pollen grains sticking to the body of different foragers. *A. dorsata* had the highest loose pollen grains on their body (165000 pollen grains) followed by *A. mellifera* (97750 pollen grains) and *A. cerana* (60,000 pollen grains), and it was lowest in case of *A. florea* (48750 pollen grains). Irrespective of four bee species, the number of loose pollen grains sticking to the body of bee did not differ significantly among different hybrids of summer squash.

It was highest in cultivar Chamatkar (94500 pollen grains), followed by Chandra (93750 pollen grains), Parikrama (92500 pollen grains) and lowest in Gold Queen (90750 pollen grains) hybrid. On cucumber, Hanh (2008) observed that the number of loose pollen grains sticking to the body surface of *A. dorsata* was highest (113690.00) followed by *Halictus* sp. and *C. sexmaculata* with 47040.00 and 43620.00 loose pollen grains per body surface, respectively.

Table 3. Number of loose pollen grains sticking on the body of bee species on flowers of *Cucurbita pepo*

Bee species	Number of loose pollen grains (000"s) sticking on the body of a bee on different hybrids				
	Parikrama	Chandra	Gold Queen	Chamatkar	Mean
Apis dorsata	170.00	165.00	160.00	165.00	165.00
Apis mellifera	100.00	95.00	98.000	98.000	97.75
Apis florea	45.00	55.00	45.00	50.00	48.75
Apis cerana	55.00	60.00	60.00	65.00	60.00
Mean	92.50	93.75	90.75	94.50	

Each value represents mean of 10 observations

	S. Em.	C.D. (p= 0.05)
Bee species	1.23	3.65
Hybrids	1.42	4.12
Bee species × hybrids	2.64	NS

Pollination efficiency

The data on pollination efficiency of different bee species foraging on summer squash flowers presented in Table 4 depict that *A. mellifera* entrapped the maximum number of pollen grains (165000 pollen grains) followed by *A. dorsata* (97750 pollen grains), *A. cerana* (60000 pollen grains) and *A. florea* (av. 48750 pollen grains). The abundance of *A. mellifera* (2.21 bees/m^2/5 minutes) was highest followed by *A. cerana* (1.16 bees/m^2/5 minutes) and *A. dorsata* (1.07 bees/m^2/5 minutes), while the abundance of *A. florea* was least (0.62 bees/m^2/5 minutes) and the foraging rate of *A. mellifera* (5.45 flowers visited/minutes) was highest followed by *A. cerana* (3.21 flowers visited/minutes) and *A. dorsata* (4.38 flowers visited/minutes), while the foraging rate of *A. florea* was least (2.10 flowers visited/minutes) but the pollination index of *A. mellifera* was highest (1177360) followed by *A. dorsata (*773280), *A. cerana* (223420) and *A. florea* (63480). Hence, it was observed that *A. mellifera* was the most efficient pollinator followed by *A. dorsata*, *A. cerana* and *A. florea* on summer squash flowers under agro-ecological conditions of Hisar. The bigger body size and higher density of body hairs made it more efficient pollinator, even though its abundance is somewhat low among the four bee species. However, Hanh (2008) observed that *Halictus* sp. was the most efficient pollinator of cucumber followed by *C. sexmaculata* at Hisar. Stanghellini *et al*. (1997) reported that honey bees were the best pollinators of cucumber and watermelon followed by bumble bees. Rao and Suryanarayana (1988) stated that *Apis cerana* was the main pollinator of watermelon at Vijayarai (Andhra Pradesh).

Table 4. Pollination efficiency of different bee species on flowers of *Cucurbita pepo*

Bee species	Abundance (bees/m^2 /5 minutes)	Number of loose pollen grains sticking on the body of a bee	Foraging rate	Pollination index (abundance × loose pollen grains x foraging rate)	Pollination efficiency (Rank)
Apis dorsata	1.07	165.00	4.38	773.28	2nd
Apis mellifera	2.21	97.75	5.45	1177.36	1st
Apis florea	0.62	48.75	2.10	63.48	4th
Apis cerana	1.16	60.00	3.21	223.42	3rd

Thus from present study it can be concluded that for efficient pollination of cucumber flowers *A. mellifera* and *A. cerana* colonies should be placed near cucumber field and means of conserving wild *Apis* spp. *(A. dorsata* and *A. florae*) should be adopted.

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