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Study of Evaluation of Foraging Behaviour of Major Insect Pollinators on Summer Squash (*Cucurbita Pepo* L.)

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Abstract
An experiment on the insect pollinators was conducted with four summer squash hybrids viz., Parikrama, Chandra, Chamatkar and Gold Queen at the Research Farm of the Department of Entomology, CCS Haryana Agricultural University, Hisar. Foragers of *A. dorsata*, *A. mellifera*, *A. florea* and *A. cerana* commenced their pollen collection activity at 0600, 0630, 0700 and 0700 h, with peak periods at 0600-0800, 0800-1000, 1000-1200 and 0800-1000 h respectively and all of them ceased their activity between 1700- 1800 h. Out of the total foragers of the day for *A. mellifera*, 47.93 per cent were pollen, 19.01 per cent were nectar collectors and 33.06 per cent were pollen+nectar collectors. *A. mellifera* spent maximum time (10.30 seconds/flower), whereas, *A. florea* spent least time (2.51 seconds/flower) while these values are 7.61 and 5.10 seconds/flower for *A. dorsata* and *A. cerana*. All the four bee species *viz*., *A. mellifera*, *A. cerana*, *A. dorsata* and *A. florea* foraged on summer squash flowers as top workers and they were in well contact with male and female parts of the flowers when collecting nectar and/or pollens. The number of loose pollen grains sticking to the body of *A. dorsata* was registered maximum (av. 165000 pollen grains) followed by *Apis mellifera* (97750 pollen grains), *Apis cerana*a (60,000 pollen grains) and *Apis florea* (48750 pollen grains) under agro-ecological conditions of Hisar (Haryana).

Keywords: foraging, honey bees, hybrids, workers.

Introduction
Pollination plays an important role in the reproduction and fruit set of flowering plants (Buchmann and Nabhan, 1996) [6]. Animal pollinators are thought to contribute 15- 30% of the global food production (Roubik, 1995) [8]. 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 varying in colour, shape and surface. The plant bears male and female flowers separately on same branch, with more male flowers usually, and requiring insect pollination. Both male and female flowers produce nectar but the male flower nectar has a higher sugar concentration. Flowers of both the sexes typically open for only a single day, after which, the male and insufficiently pollinated female flowers are dropped. Female flowers are visited more than the male flowers (Nepi and Pacini, 1993) [9]. There are many native bee species in India with varied foragingbehavbiour in different agroclimatic regions, pollinating these. It is essential to estimate their foraging behavbiour and contribution in pollinating. Also, due to the narrow blooming period this is important. Hence, the present investigation with on the foraging behavbiour of insect pollinators on summer squash is essential as little research has been done in India on these.

Materials and Methods
The summer squash crop was raised at Research Farm of the Department of Entomology, CCS Haryana Agricultural University, Hisar. The field area (48x16 m) 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 viz., Parikrama, Chandra, Chamatkar and Gold Queen were sown, before sowing treated with Captan @ 3 g/kg. Per hill, two seeds were sown on single side edge of the raised bed keeping a distance of 80 cm between rows and 50 cm between plants. Then foraging behaviour of different honeybees were observed.

Foraging behaviour of insect visitors on flowers of summer squash
Different aspects of foraging behaviour of the most frequent insect visitors on summer squash

flowers were recorded as follows.

a. **Foraging rate:** The foraging rate of different types of insect visitors was recorded in terms of the number of flowers visited per minute.
b. **Foraging speed:** The foraging speed of bees was recorded in terms of the time spent by each species on a flower. Twenty flowers were observed and each flower was considered as one replication.
c. **Working behaviour:** Individuals of different insect visitor species was observed for their working behaviour, *i.e.*, whether they are working from top or side. Movement of insect from one flower to another was also observed. Nectar and/or pollen gathering behaviour was also observed.

Results and Discussion

Foraging activity

The data on foraging activity of different bee species on summer squash flowers presented in Table 1 depict that *A. dorsata* initiated foraging activity on summer squash flowers little earlier in the morning and ceased its activity little later in the evening when compared to *A. mellifera*, *A. cerana* and *A. florea*. *A. dorsata* started collecting pollens from 0600 h of the day, *A. mellifera* from 0630 h while *A. cerana* and *A. florea* from 0700 h of the day. Peak activity in pollen collection was observed during 0600-0800 h (*A. dorsata*), 0800-1000 h (*A. mellifera* and *A. cerana*) and 1000-1200 h (*A. florea*) of the day. Foraging activity for nectar by *A. dorsata* initiated from 0630 h of the day while in *A. mellifera* and *A. cerana* it started from 0730 h and in *A. florae* from 0800 h of the day. However, all the four bee species attained their peak nectar foraging activity during 1000-1200 h of the day.

Table 1: Foraging activity of different bee species on flowers of *Cucurbita pepo* during different hours of the day

Bee species	Activity time (h)		
	Initiation	Peak	Cessation
Pollen foraging (number of bees)			
Apis dorsata	0600 (5.0)	0600-0800 (14.0)	1800 (2.0)
Apis mellifera	0630 (7.0)	0800-1000 (21.0)	1730 (4.0)
Apis florea	0700 (3.0)	1000-1200 (8.0)	1700 (1.0)
Apiscerana	0700 (5.0)	0800-1000 (14.0)	1700 (3.0)
Nectar foraging (number of bees)			
Apis dorsata	0630 (2.0)	1000-1200 (8.0)	1800 (4.0)
Apis mellifera	0730 (3.0)	1000-1200 (9.0)	1800 (2.0)
Apis florea	0800 (1.0)	1000-1200 (4.0)	1700 (1.0)
Apis cerana	0730 (1.0)	1000-1200(8.0)	1800 (2.0)

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

Bee species	Time spent per flower (sec)				
	0600-0800	0800-1000	1000-1200	1600-1800	Mean
Apis dorsata	7.77 (2.96)	7.40 (2.89)	7.76 (2.96)	7.50 (2.91)	7.61 (2.93)
Apis mellifera	10.30 (3.36)	10.27 (3.36)	10.40 (3.37)	10.20 (3.35)	10.30 (3.36)
Apis florea	2.70 (1.92)	2.63 (1.91)	2.50 (1.87)	2.20 (1.82)	2.51 (1.88)
Apis cerana	5.07 (2.46)	5.03 (2.46)	5.20 (2.49)	5.10 (2.49)	5.10 (2.48)
Mean	6.46 (2.68)	6.33 (2.65)	6.47 (2.67)	6.25 (2.64)	

Each value represents 20 observations

Figures in the parentheses are √(x+1) transformed values

Foraging speed

The data on foraging speed, *i.e*., time spent by bee species on summer squash flowers during February-March, have been given in Table 2. The time spent per flower by four bee species differed significantly. The mean foraging speed varied from 10.20 to 10.40 seconds in case of *A. mellifera* during different hours of the day, while in case of *A. cerana*, it was 5.03 to 5.20 seconds, while in case of *A. dorsata*, it was 7.40 to 7.77 seconds, and 2.20 to 2.70 seconds in case of *A. florea*. The maximum time (10.3 seconds) per flower was spent by *A. mellifera* followed by *A. dorsata* (7.61 seconds), *A. cerana* (5.10 seconds) and *A. florea* (2.51 seconds). Irrespective of different bee species, the mean time spent during different day hours did not differ significantly. The mean time spent by four bee species during 1000-1200 h of the day (6.47 seconds/flower) was at par with these four bee at other intensities of 0800-1000 h (6.33 seconds/flower), 1600-1800 h (6.25 seconds/flower) and 0600-1000 h (6.46 seconds/flower) of the day.

Nectar and /or pollen collectors of different bee species on flowers of *Cucurbita pepo* during different hours of the day

The data presented in Table 3 on foraging behaviour of bee species on summer squash flowers at different day hours revealed that the total number of *A. mellifera* bees observed was 25, 45, 29 and 14 bees during 0600-0800, 0800-1000, 1000-1200 and 1600-1800 h, respectively. The population was 22 bees (0600-0800 h), 28 bees (0800-1000 h), 13 bees (1000-1200 h) and 12 bees (1600-1800 h) for A. c*erana* while for *A. dorsata*, the total population observed was 23, 33, 4 and 11 bees during 0600-0800, 0800-1000, 1000-1200 and 1600-1800 h of the day. The population was 2 bees (0600-0800 h), 11 bees (0800-1000 h), 1 bee (1000-1200 h) and 1 bee (1600-1800 h) for *A. florea*. Among total foragers of the day, 47.93 per cent were pollen collectors, 19.01 per cent were nectar collectors and 33.06 per cent were pollen and nectar collectors in case of *A. mellifera*. Similarly, in case of *A. cerana* 43.66 per cent were the pollen collectors, 38.03 per cent nectar collectors and 18.31 per cent pollen and nectar collectors, while in case of *A. dorsata*, it was 44.43, 25.39 and 28.17 per cent and in case of *A. florea*, 39.88 per cent were the pollen collectors, 25.95 per cent nectar collectors and 24.67 per cent pollen and nectar collectors. Pollen collectors of *A. mellifera* was highest (19.00 bees) during 0800-1000 h and the population of nectar collectors was registered maximum (9.00 bees) during 0800-1000 h, while pollen and nectar collectors population was observed maximum (17.00 bees) during 0800-1000 h. In case of *A. cerana*, the maximum number of pollen, nectar and pollen + nectar collectors was observed during 0800-1000 h (14.00 bees), 0800-1000 h (8.00 bees) and 0800-1000 h of the day (6.00 bees), respectively. The population of pollen collectors of *A. dorsata* was highest, *i.e*., 15.00 bees during 0600-0800 h, and the maximum nectar collectors were 8.00 bees during 0800-1000 h, and for pollen + nectar collectors, it was highest (15.00 bees) during 0800-1000 h. The population of pollen collectors of *A. florea* was highest, *i.e*., 9.00 bees during 0800-1000 h and maximum nectar collectors were 10.00 bees during 0800-1000 h, and for pollen + nectar collectors, it was highest (11.00 bees) during 0800-1000 h.

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 4. 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). Significant differences were also found in the foraging rate of bee species on summer squash flowers during different hours of the day. Irrespective of different bee species, the mean flowers visited per minute by four bee species were recorded maximum during 0800-1000 h (4.18 flowers/minute), followed by 0600-0800 h (3.72 flowers/minute) and 1000-1200 h of the day (3.68 flowers/minute). It was minimum (3.56 flowers/minute) during 1600-1800 h of the day.

Table 3: Nectar and /or pollen collectors of different bee species on flowers of *Cucurbita pepo* during different hours of the day

Foraging time (h)	Apis dorsata				Apis mellifera				Apis cerana			
	P	N	NP	Total	P	N	NP	Total	P	N	NP	Total
0600-0800	15.00(72.73)	5.00(18.18)	3.00(9.09)	23.00	13.00(51.72)	5.00(20.69)	7.00(27.59)	25.00	11.00(55.56)	8.00(33.33)	3.00(11.11)	22.00
0800-1000	10.00(30.31)	8.00(24.24)	15.00(45.45)	33.00	19.00(43.75)	9.00(18.75)	17.00(37.50)	45.00	14.00(50.00)	8.00(28.57)	6.00(21.43)	28.00
1000-1200	2.00(50.00)	1.00(25.00)	1.00(25.00)	4.00	15.00(50.00)	5.00(18.75)	9.00(31.25)	29.00	4.00(33.33)	6.00(50.00)	3.00(16.67)	13.00
1600-1800	3.00(30.77)	5.00(46.15)	3.00(20.08)	11.00	7.00(50.00)	3.00(16.67)	4.00(33.33)	14.00	3.00(23.08)	7.00(53.84)	2.00(23.08)	12.00
Total	30.00(44.43)	19.00(25.39)	22.00(28.17)	71.00	54.00(47.93)	22.00(19.01)	37.00(33.06)	113.00	32.00(43.66)	29.00(38.03)	14.00(18.31)	75.00

Table 4: 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				
	0600-0800	0800-1000	1000-1200	1600-1800	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)	3.56 (2.18)	

Conclusion

The pollen foragers of *A. mellifera*, *A. cerana*a, *A. dorsata* and *A. florea* commenced their activity at 0700, 0630 and 0600, 0700 h, respectively with peak period at 0800-1000 h and ceased their activity at 1730, 1800, 1700 and 1700 h of the day, while nectar foragers of *A. mellifera*, *A. cerana*, *A. dorsata* and *A. florea* commenced their activity at 0730, 0730, 0630 and 0800 h, respectively with peak period 1000-1200 h of the day. All the four bee species ceased their nectar collection activity at 1800 h during bloom period. Among total foragers of the day, 47.93 per cent were the pollen collectors, 19.01 per cent nectar collectors and 33.06 per cent pollen and nectar collectors in case of *A. mellifera*, 43.66, 38.03 and 18.31 per cent in case of *A. cerana*, 44.43, 25.39 and 28.17 per cent in case of *A. dorsata* and 39.88, 25.95 and 24.67 per cent, respectively in case of *A. florea.* The maximum time (10.3 seconds) per flower was spent by *A. mellifera* followed by *A. dorsata* (7.61 seconds), *A. cerana* (5.10 seconds) and *A. florea* (av. 2.51 seconds). *A. florea* spent least time (2.51 seconds/flower) but visited maximum number flowers (2.10 flowers/minute).

All the four bee species *viz*., *A. mellifera*, *A. cerana*a, *A. dorsata* and *A. florea* foraged on summer squash flowers as top workers and they were in well contact with male and female parts of the flowers when collecting nectar and/or pollens. The number of loose pollen grains sticking to the body of *A. dorsata* was registered maximum (av. 165000 pollen grains) followed by *Apis mellifera* (97750 pollen grains), *Apis cerana*a (60,000 pollen grains) and *Apis florea* (48750 pollen grains)

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