

Original Research Article

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Foraging Behavior of Bumble Bees (*Bombus haemorrhoidalis* Smith) and Honey Bees (*Apis mellifera* L.) on Kiwifruit (*Actinidia deliciosa* Chev.)

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ABSTRACT

Foraging behavior of bumble bees and honey bees with respect to foraging activity, foraging rate, foraging speed, loose pollen grains and abundance were studied by utilization of bumble bees (*B. haemorrhoidalis*) and European honey bees for the pollination of kiwifruit cv. Allison under caged condition at kiwifruit orchard of Dr. YS Parmar University of Horticulture & Forestry, Nauni, Solan (HP) during 2017. The results revealed that high activity of bumble bees in cage with one colony and cage with two colonies were recorded during 1600-1800hr whereas activity of honey bees was maximum during 1200-1400hr. Bumble bees visited more number of flowers per minute than honey bees, however, honey bees took more time for completing a single foraging trip and spent significantly more time per flower than bumble bee. Peak abundance of bumble bees was recorded at 1600-1800hr and it was between 1200-1400hr for honey bees. Pollination index showed that *B. haemorrhoidalis* scored higher than *A. mellifera*. *B. haemorrhoidalis* carried more number of loose pollen grains adhered to its body as compared to *A. mellifera*. Number was almost double than that carried by *A. mellifera*. The present study suggests that bumble bee foragers preferred to visit kiwifruit bloom during morning and evening time than mid-day with more activity, foraging rate and foraging speed during these hours of the day while honey bees preferred mid-day hours with more activity, foraging rate and foraging speed to visit kiwifruit bloom.

Keywords

Foraging behavior,
Bumble bees,
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Introduction

Pollination is one of the major factors responsible for good quality and high productivity of any agricultural and horticultural crop. Insect pollinators like bumble bees, honey bees and solitary bees helps in the process of reproduction of many

field and fruit crops by transferring pollens from flower to flower. They are in commercial use for successful crop production (McGregor, 1976). Bumble bees are the superstars of pollination also known as teddy bear of insects. Bumble bees are most diverse group of pollinators in temperate regions and only 34 species out of the 250

species found in the tropics (Williams, 1998). Frequent crossover appears to facilitate the carryover of viable pollen from pollen-fertile staminate to pollen-sterile pistillate flowers. Pomeroy and Fisher (2002) suggested that bumble bees exhibited a greater degree of crossover between male and female flowers than honey bees, based on an examination of male and female pollen in corbicular loads. The bumble bees are more efficient and reliable pollinators especially under protected conditions (Mackenzie, 2009). Cobert *et al.*, (1991) observed the temperature and pollinating activity of social bees. They suggested that bumble bees are remarkably hardy and will forage in very cold conditions and even when it is raining. Wearing (1983) conducted an experiment on kiwifruit pollination with increasing bumble bee density. He reported that fruit size increased with increasing number of bumble bees. He also observed that 900 viable pollen grains were found on the stigma after a bumble bee visit. Bumble bees collected seven times more viable pollen and the production was higher when population of the bumble bees increased on the flowers. Abak *et al.*, (2000) conducted an experiment on eggplants grown in unheated plastic houses and observed that bumble bee's activity on eggplants was increased between 9:00 and 11:00 a.m., the peak activity was observed between 10:00 and 11:00 a.m. then decreases gradually and they stopped between 13:00 and 14:00 p.m. They started foraging again in the afternoon between 15:00 and 18:00 p.m. Spivak (2000) found that bumble bees are more efficient foragers than honey bees on cranberry flowers because they are capable of buzz-pollination. Bumble bees hang on to the flower and buzz it by vibrating their muscles that control flight. Bumble bees are the most efficient pollinators not only for the wild plants, but also for pollination services, used in both outdoor and greenhouse horticulture and orchards (Wolf and Moritz, 2008).

Materials and Methods

The study was carried out in 5 year old kiwifruit orchard of Dr. YS Parmar University of Horticulture & Forestry located at Nauni, Solan (Himachal Pradesh) during 2017. The vines of Allison cultivar were spaced at 4 x 6 m and trained on standard T-bar trellis system. Four cages, each measuring 36 x 8 x 10 ft., made of insect proof nylon were erected over single male and a female vine before flowering (Plate 1). Laboratory reared bumble bee (*B. haemorrhoidalis*) colonies were utilized for pollination of kiwifruit cv. Allison at the time of 5-10% flowering. In all there were six treatments, one bumble bee colony (10-12 foragers) was placed in middle of first cage, 4-framed *A. mellifera* colony in second cage, third with two bumble bee colonies (16-18 foragers) and fourth cage was without pollinators (control). Other two treatments were hand pollination and open pollination. In hand-pollination, bearing shoots were bagged with muslin cloth after pollination (Plate 1). Bumble bee colonies were fed with 50% sucrose solution and honey bees with sugar solution. Bumble bees were also fed with fresh pollen collected from honey bee colonies for first two days to make them acclimatized to the field environment. Data on various parameters like abundance of bumble bees and honey bees on kiwi flowers, foraging rate, foraging speed and loose pollen grains were recorded on kiwifruit grown inside cage from early morning (0600hr) till late in the evening (1800hr) at two hour interval consecutively for nine days during three bloom stages of kiwifruit viz. early bloom (20-25%), full bloom (75%) and late bloom (90%). Counts of bees visiting the kiwifruit bloom/5 minutes/m² were made during the activity period i.e. 0600hr to 1800 hr. Foraging speed of bees on the bloom was recorded by observing time spent by the forager on each flower using stop watch. Foraging rate was recorded in term of number

of flowers visited by a forager/minute. Number of loose pollen grains adhering to the body of bees was determined by capturing the forager and killing immediately in 5 ml of 70% alcohol in glass vials. From the rinsate an aliquot of 0.02 ml (replicated three times), was taken on a counting dish and the pollen grains were counted under binocular microscope at 100× magnification. Total number of pollen grains in the whole rinsate was then calculated. Pollination efficiency of bumble bees and honey bees was assessed on the basis of their abundance and foraging behavior, such as foraging rate, foraging speed, number of loose pollen grains sticking to their bodies. The data were analysed statistically using randomized block design.

Results and Discussion

Data on abundance and foraging behaviour of bumble bees (*B. haemorrhoidalis*) and honey bees (*A. mellifera*) on kiwi bloom have been summarized as follows:

Foraging activity of bumble bees at nest entrance

B. haemorrhoidalis has long working hours as it started foraging activity on kiwifruit inside cage from early morning (0610 hr) till late in the evening (1750 hr). Foraging activity of bumble bees inside kiwifruit cage with one colony and two colonies were recorded to be peaked i.e. 5.07 bumble bees/5min and 8.09 bumble bees/5min, respectively at 1600-1800 day hours while minimum activity was recorded at 1200-1400hr for both bumble bee treatments (Fig. 1). It was observed that the activity of bumble bees peaked at evening and minimum during noon hours under caged conditions. These findings are in conformity with the report of Chauhan (2011) who reported the activity of bumble bees on cucumber plants grown under green house to be maximum (8.24 bumble bees/5min) during

1800-1900hr while the minimum (4.41 bumble bees/5 min) activity at 1200-1300hr, respectively. Yankit (2016) also reported the maximum activity of bumble bees on tomato grown under protected conditions during 1800-1900hr (8.33 bumble bees/5min) while the minimum at 1200-1300hr (4.67 bumble bees/5min). The foraging activity of honey bees inside kiwi cage was recorded highest at 1200-1400hr (19.02 honey bees/5min) while minimum during 0600-0800hr (12.11 honey bees/5min). These results are in line with the observations of Jay and Jay (1983) who observed the activity of honey bees on the kiwifruit flowers only between 0900 and 1400hr, with peak activity recorded at noon.

Foraging rate

Foraging rate of bumble bee on kiwifruit inside cage with one colony and two colonies was peaked at 1000-1200hr (7.60 flowers/min and 7.84 flowers/min), respectively while minimum foraging rate was recorded during same day hour 1200-1400hr (2.11 flowers/min and 2.29 flowers/min), respectively (Fig. 2). These results are in agreement with the observations of Yankit (2016) who found that foraging rate of bumble bees on tomato under polyhouse was maximum (4.74 flowers/min) during morning (1000-1100hr) and minimum (2.37 flowers/min) at noon (1200-1300hr).

These findings also corroborated by the results of Ahmad *et al.*, (2015) who reported that foraging rate of *B. terrestris* was more in morning time as compared to evening time inside polyhouse on tomato. Honey bees (*A. mellifera*) visited maximum (3.82 flowers/min) number of flowers during noon (1200-1400hr) and minimum (1.60 flowers/min) during evening (1600-1800hr). Bakshi in 2015 found the foraging rate of honey bees (*A. mellifera*) in sweet cherry under caged condition to be maximum during

1000-1200hr (7.00 flowers/min) and minimum at 1500-1600hr (5.67 flowers/min).

Foraging speed

B. haemorrhoidalis was found to spend 7.82 and 8.02 sec per flower (maximum foraging speed) during 0800-1000hr and 3.42 and 3.62 sec/flower during 1200-1400hr (minimum), respectively on kiwifruit inside cage with one colony and two colonies, respectively (Table 1 and 2). Similar results were found by Kashyap (2007) and Yankit (2016) for foraging rate and speed for *B. haemorrhoidalis* on cucumber and tomato, respectively under polyhouse. These findings are also in conformity with Ahmad *et al.*, (2015) who reported that foraging rate of *B. terrestris* was more in morning time as compared to evening time. Foraging speed of honey bees was recorded to be maximum (11.50 sec/flower) during 1000-1200hr and minimum (9.09 sec/flower) during 0600-0800hr. Bakshi (2015) reported average foraging speed of honey bees (*A. mellifera*) on sweet cherry to be maximum at 1000-1100hr (8.9 sec/flower) inside cage.

Loose pollen grains

The data recorded on loose pollen grains on the body of bees revealed that more number of average loose pollen grains were adhered to the body of *B. haemorrhoidalis* during full bloom (4429.00± 137.95), early bloom (3472.67±68.26) and end bloom (3293.67± 57.83) than *A. mellifera* during full bloom (2409.00± 162.20), early bloom (1886.00±68.54) and end bloom (1664.67± 107.62) (Table 3). It is evident from this study that bumble bees carried more number of loose pollen grains on their body than honey bees during all stages of kiwifruit bloom. These results are in agreement with earlier findings of Chauhan (2011) and Yankit (2016) who found that bumble bees carried

more loose pollen grains as compared to *A. mellifera* in cucumber (2179±344; 1730±205) and tomato (1967± 107.10) under polyhouse.

Abundance

The data on abundance (number /m²/5min) of *B. haemorrhoidalis* recorded at two hour interval consecutively for nine days during three bloom stages of kiwifruit viz. early bloom (20-25%), full bloom (75%) and late bloom (90%) revealed that *B. haemorrhoidalis* on kiwifruit inside cage with one colony and two colonies was highest during full bloom and evening hours (6.43 and 8.60, respectively) and minimum during early bloom and at noon hours (4.41 and 6.64, respectively) (Table 4 and 5). The present results are in conformity with observations of Yankit (2016) who found that maximum (11.12 bumble bees/m²/5min) mean abundance of bumble bees was during full bloom and evening hours and minimum (4.88 bumble bees/m²/5min) during early bloom and at noon hours on tomato under protected conditions. The abundance of honey bees was recorded to be highest (18.93) during full bloom and minimum during early bloom (15.01). These results are in conformity with Mehta (2009) who reported that abundance of honey bees on guava was low in the beginning of flowering period, increased with the increase in flowering and decrease till the cessation of flowering. Bumble bee foragers preferred to visit kiwifruit bloom during morning and evening time than mid-day with more activity, foraging rate and foraging speed during these hours of the day while honey bees preferred mid-day hours with more activity, foraging rate and foraging speed to visit kiwifruit bloom.

Pollination index

The data on pollination index showed that *B. haemorrhoidalis* (22.88) scored higher value

than *A. mellifera* (16.98) on kiwifruit bloom (Table 6). No literatures have been found on pollination index in kiwifruit bloom. However, Chauhan (2011) recorded high pollination index for *B. haemorrhoidalis* on

cucumber bloom. On the basis of foraging rate, foraging speed, loose pollen grains and relative abundance of pollinators *B. haemorrhoidalis* is rated as more efficient pollinator than *A. mellifera* in the kiwifruit.

Table.1 Foraging speed of *B. haemorrhoidalis* and *A. mellifera* inside kiwifruit cage during different day hours at kiwi block during April-May 2017

Pollinators	Time spent by foragers/ flower during different day hours (in sec) (Mean)					
	0600-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800
Bumble bee (cage with one colony)	4.67	7.82	6.31	3.42	5.36	5.56
Honey bee	9.09	10.53	11.50	10.57	9.88	9.70
Bumble bee (cage with two colonies)	4.87	8.02	6.36	3.62	5.33	5.76

Table.2 Foraging speed of bumble bees and honey bees inside kiwifruit cages during different flowering stages

Pollinators	Time spent by foragers / flower during different flowering stages (in sec) (Mean)		
	Early bloom	Full bloom	Late bloom
Bumble bee (cage with one colony)	4.89	6.50	5.18
Honey bee	9.56	11.19	9.88
Bumble bee (cage with two colonies)	5.09	6.51	5.38

Table.3 Number of loose pollen grains on bodies of *B. haemorrhoidalis* and *A. mellifera* captured inside kiwifruit cages at kiwi block during April-May 2017

Pollinators	No. of loose pollen grains/forager (Mean±S.E.)		
	Early bloom	Full bloom	Late bloom
Bumble bee	3472.67±68.26	4429.00± 137.95	3293.67± 57.83
Honey bee	1886.00±68.54	2409.00± 162.20	1664.67± 107.62

Table.4 Abundance of *B. haemorrhoidalis* and *A. mellifera* inside kiwifruit cage during different day hours at kiwi block during April-May 2017

Pollinators	Number of foragers /m ² /5min during different day hours (Mean)					
	0600-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800
Bumble bee (cage with one colony)	4.60	5.13	3.69	2.69	7.62	8.31
Honey bee	14.49	18.51	17.49	21.56	18.40	11.44
Bumble bee (cage with two colonies)	6.18	6.78	6.93	3.51	9.71	11.44

Table.5 Abundance of bumble bees and honey bees inside kiwifruit cages during different flowering stages

Pollinators	Number of foragers /m ² /5min during different flowering stages (Mean)		
	Early bloom	Full bloom	Late bloom
Bumble bee (cage with one colony)	4.41	6.43	5.18
Honey bee	15.01	18.93	17.00
Bumble bee (cage with two colonies)	6.64	8.60	7.03

Table.6 Comparative pollination efficiency of *B. haemorrhoidalis* and *A. mellifera* on kiwifruit bloom

Pollinator	Rank assigned on the basis of statistically analysis/efficiency			Average score	Relative abundance (bees/m ² /5min)	Pollination index
	Foraging rate	Foraging speed	Loose pollen grains			
<i>B. haemorrhoidalis</i>	2	2	2	2	11.44	22.88 (2)
<i>A. mellifera</i>	1	1	1	1	16.98	16.98 (1)

Fig.1 Activity of bumble bees and honey bees at nest entrance inside kiwifruit cage

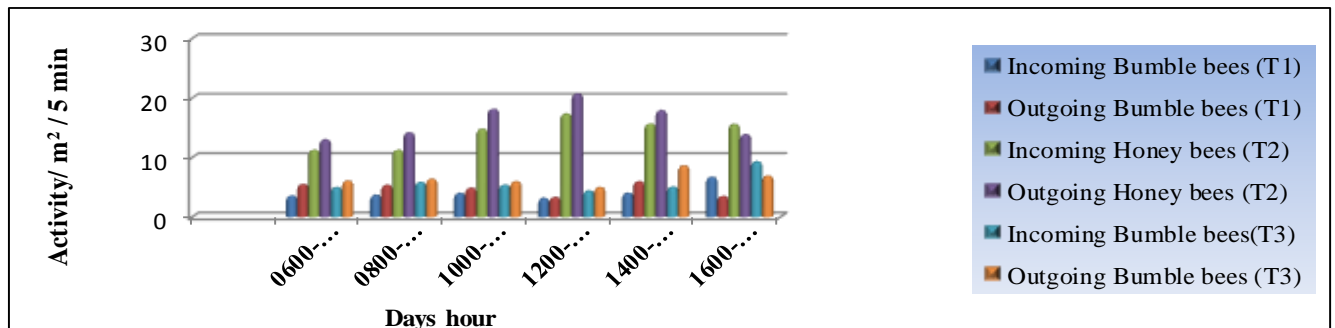


Fig.2 Comparative foraging rate of bumble bees and honey bees on kiwifruit inside cages at kiwi block during April-May 2017

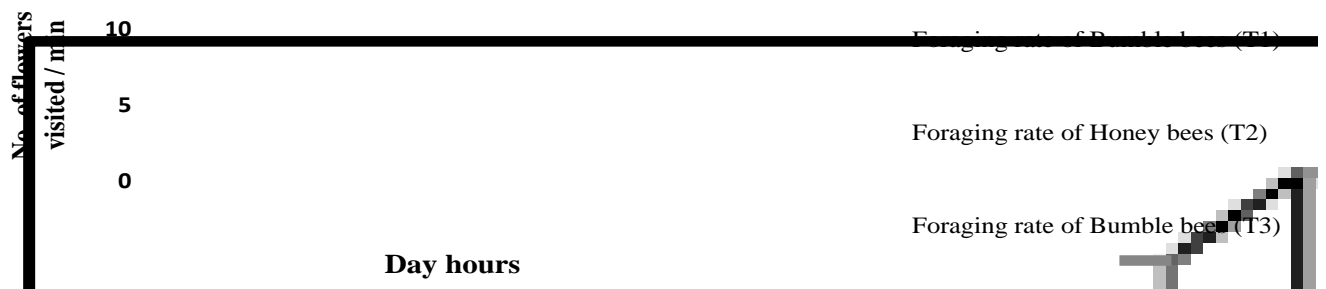


Plate.1 Different treatments of experiment



a) General view of experimental field



b) Cage with one bumble bee colony



c) Cage with two bumble bee colonies



d) Bagging after hand-pollination



e). *B. haemorrhoidalis* foraging on kiwifruit flower

In conclusion, bumble bees as their large size and hairy body allows for the extremely effective collection and deposition of large quantities of pollen than honey bees. The more pollen transferred, the better and effective pollination by bumble bees increases the kiwifruit quality (number of seeds developed, improving fruit size, weight and shape), as well as the quantity (percentage of fruit set, overall number of fruit) and may be the reason of a bountiful crop.

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