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Foraging behavior of major insect pollinators on Pumpkin, *Cucurbita moschata* (Duch.ex Lam)

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Abstract: Foraging activity period of different honey bee species on *C. moschata* (C-1076) flowers at different day hours during August-September (2013) revealed that *A. dorsata*, *A. mellifera, A. cerana* and *A. florea* initiated their activity early in the morning at 0530, 0615, 0625 and 0630 h, respectively and stopped their activity at 1030, 1020, 1025 and 1030 h of the day, respectively while on *C. moschata* (C-1106, *A. dorsata*, *A. mellifera, A. cerana* and *A. florea* initiated their activity early in the morning at 0535, 0615, 0620 and 0625 h, respectively and ceased their activity at 1045, 1025, 1015 and 1040 h of the day, respectively. The mean foraging speed (time spent per flower) in seconds on flowers of pumpkin (C-1106) was maximum of *A. florea* (181.72), followed by *A. mellifera* (7.15), *A. cerana* (6.05) and *A. dorsata* spent least time (5.83) and in pumpkin (C-1076), foraging speed was maximum in case of *A. florea* (178.71), followed by *A. mellifera* (7.63), *A. cerana* (6.24) and *A. dorsata* spent least time (6.06). The mean foraging rate (flowers visited per minute) on flowers of pumpkin (C-1106) was maximum in case of *A. dorsata* (5.13), followed by *A. cerana* (4.30), *A. mellifera* (4.16) and *A. florea* visited least flower (0.32) and in pumpkin (C-1076), foraging rate was maximum in case of *A. dorsata* (4.96), followed by *A. cerana* (4.19), *A. mellifera* (4.02) and *A. florea* visited least flower (0.33). Present study advises the farmers that they should not apply the pesticide when the activity of honey bee is on the peak period because pesticides application at the time of bee activity in the field crop causes mortality of bees.

Keywords: Foraging rate, Foraging speed, Honey bee species, Pumpkin

INTRODUCTION

Foraging behavior is one of the distinctive behaviors of honey bee species. This behavior is the link between the honey bee colony and the ambient environment. Foraging behavior of pollinators collecting floral resources on pumpkin flowers was arbitrarily divided into three successive periods, based on the bees' positions on squash flowers (e.g. pre-arrival at the flowers; landing on the petal of the flowers; and lingering near the stigma/ anther of the flowers).

The floral size and architecture of *C. moschata* i.e large size petals with campanulate shape provide suitable landing platform for bees. Slight scented, bright flowers attract the bees, especially under sunny condition, when the scent is dispersed far by solar radiation. Since the flowers are short lived and open only for few hours, this period is very important for pollination of this crops. The size and complexity of floral display used to advertise their location is one of the several factors influencing the behavior of pollinators (Goulson, 1999). The high male to female ratio achieves the production of sufficient amount of pollen deposits, thus aids in effective pollination. Foraging activity of insect visitors showed mostly negative correlation with temperature and positive correlation with relative humidity on cloudy days and sunny days. Rainy days showed negative correlation to temperature both positive, negative correlation with relative humidity in terms of insect activity. Elevated temperatures may affect the plant pollinator interaction and reduce the overall food production that leads to food crisis. Food production could be increased with the help of reducing the global warming (Pandian *et al*., 2012).

MATERIALS AND METHODS

Studies were carried out at the Research farm and Apiculture Laboratory of the Department of Entomology, Chaudhary Charan Singh Haryana Agricultural University, Hisar during June to December, 2013 on two cultivars of pumpkin viz., C-1076 and C-1106. Flowering in pumpkin crop initiated during August-September, 2013.

Determination of working behavior of the pollinators: Initiation and cessation time of different insect visitor's activity were recorded. Observation on the insects pollinator's body contact with the anther and /or stigma, whether working from the top of the flower (top worker, bees that stand on the anther or receptacle and push their tongue and frontal part of their body toward nectaries and touch the stigma and/ or anther) or side of the flower (side worker, bees that

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Fig. 1. *Apis dorsata foraging on pumpkin flower.*

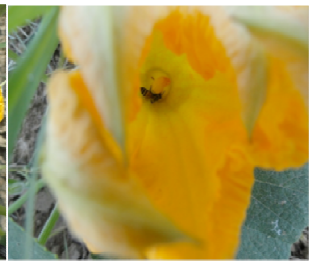

Fig. 2. *Apis florea foraging on pumpkin flower.*

push their tongue for obtaining nectar between the stamen filament having gap while standing on petal with meso and meta-thorasic legs) were also recorded. Ten individuals of each honey bee species were observed. The observations were recorded throughout the flowering period of the crops.

Determination of foraging speed of the insect pollinators: Foraging speed of honey bees were recorded in terms of time (seconds) spent by them on each flower. A total of ten bees of each species were observed for recording time spent (seconds) by them per flower at peak flowering period of the crop. The time spent to inject the proboscis and suck the nectar or brushing/collecting pollen was considered as the time spent per flower and the same was recorded with the help of a chronometer having an accuracy of 0.01 seconds.

Determination of foraging rate of insect pollinators: Foraging rate of four honey bee species was recorded in terms of the number of flowers visited per minute. A total of ten bee of each species were observed for recording the number of flowers visited per minute at peak activity time of particular species at peak flowering period of the crop. The numbers of flowers visited per minute were recorded including the flying time from one flower to another flower. Ten observations were recorded for each honey bee species**.**

RESULTS AND DISCUSSION

Foraging activity: Data pertaining to foraging activity of four honey bee species on *C. moschata* flowers are presented in Table 1. From the observations noted, it was revealed that all the four honey bee species *viz. Apis dorsata, A. mellifera, A. cerana* and *A. florea*, while foraging on pumpkin flowers were found to be top workers. *A. dorsata* initiated foraging activity on pumpkin flowers little earlier in the morning when compared with *A. mellifera, A. cerana* and *A. florea*, and all the four honey bee species ceased their activity till flowers closed (i.e between 1015 to 1045 h). *A. dorsata, A. mellifera, A. cerana* and *A. florea*, started foraging activity at 0530, 0615 h, 0620 and 0620 h of the day, respectively. Data in table 1 also depict that *A. dorsata* ceased foraging activity at 1030 h of the day in C-1076 cultivar. However in C-1106 cultivar, *A. dor-*

Table 1. Initiation and cessation activity time of four honey bee species on *C. moschata* cultivars, (C-1076 and C-1106) during peak flowering (September, 2013).

Honey bee species	Activity time (hours)			
	Cultivar C-1076		Cultivar C-1106	
	Initiation	Cessation*	Initiation	cessation*
Apis dorsata	0530	1030	0535	1045
Apis mellifera	0615	1020	0615	1025
Apis cerana	0620	1025	0620	1015
A. florea	0620	1030	0625	1040

*The cessation time was due to closing of flowers .The honey bees visit the flowers till their closing.

Table 2. Foraging speed of four honey bee species on *C. moschata* cultivar (C-1106) flowers at different hours of the day during September, 2013.

Honey bee species	Time spent per flower (seconds)					
	0530-0630	0630-0730	0730-0830	0830-0930	0930-1030	Mean
Apis dorsata	6.32(2.72)	6.47(2.74)	6.01(2.50)	5.30(2.43)	5.04(2.68)	5.83(2.61)
Apis mellifera	8.28(3.04)	9.50(3.20)	6.17(2.67)	6.01(2.64)	5.79(2.60)	7.15(2.83)
Apis cerana	6.44(2.68)	6.57(2.70)	5.52(2.61)	5.44(2.46)	6.27(2.52)	6.05(2.61)
A. florea	131.22(11.08)	191.67(13.01)	202.87(13.61)	216.71(14.28)	167.50(12.50)	181.72(12.90)
Mean	38.22(4.88)	53.55(5.41)	55.14(5.35)	58.36(5.45)	46.15(5.06)	

Factors	SE(m)	SE(d)	C.D.
Bee species	0.36	0.51	1.01
Day hours	0.40	0.57	N/S
Bee species X day hours	0.81	1.14	N/S

Each value represents mean of 10 observations at each sampling time; Figures in parentheses are √(n+1) transformed value.

Table 3. Foraging speed of four honey bee species on *C. moschata* cultivar (C-1076) flowers at different hours of the day during September, 2013.

Honey bee species	Time spent per flower (seconds)					
	0530-0630	0630-0730	0730-0830	0830-0930	0930-1030	Mean
Apis dorsata	6.48(2.72)	6.54(2.74)	5.45(2.48)	5.58(2.51)	6.27(2.86)	6.06(2.63)
Apis mellifera	8.67(3.10)	9.57(3.21)	7.14(2.85)	6.97(2.82)	5.79(2.60)	7.63(2.91)
Apis cerana	6.74(2.75)	6.75(2.75)	6.30(2.62)	6.35(2.68)	5.04(2.45)	6.24(2.65)
A. florae	129.14(10.91)	191.80(12.84)	196.82(13.38)	208.28(13.71)	167.50(12.50)	178.71(12.67)
Mean	37.76(4.87)	53.66(5.38)	53.93(5.33)	56.80(5.43)	46.15(5.06)	
Factors	**SE(m)**		**SE(d)**		**C.D.**	
Bee species	0.39		0.39		(1.10)	
Day hours	0.43		0.43		(N/S)	
Bee species X day hours	0.87		0.87		(N/S)	

Each value represents mean of 10 observations at each sampling time; Figures in parentheses are √(n+1) transformed value.

Table 4. Foraging rate of four honey bee species on *C. moschata* cultivar (C-1106) flowers at different hours of the day during September, 2013.

Honey bee species	Flowers visited per minute					
	0530-0630 h	0630-0730	0730-0830	0830-0930	0930-1030	Mean
Apis dorsata	5.64(2.56)	4.38(2.24)	6.47(2.25)	4.67(1.60)	4.51(2.31)	5.13(2.19)
Apis mellifera	4.17(2.30)	4.36(2.45)	5.11(1.54)	3.69(2.72)	3.51(2.45)	4.16(2.29)
Apis cerana	4.16(2.03)	5.09(1.49)	3.17(2.37)	4.51(2.16)	4.61(2.33)	4.30(2.08)
A. florea	0.44(1.20)	0.29(1.12)	0.26(1.11)	0.26(1.11)	0.36(1.16)	0.32(1.14)
Mean	3.60(2.06)	3.53(2.04)	3.75(2.08)	3.28(1.99)	3.25(1.99)	
Factors	**SE(m)**		**SE(d)**		**C.D.**	
Bee species	0.03		0.05		(0.10)	
Day hours	0.04		0.05		(N/S)	
Bee species X day hours	0.08		0.11		(0.23)	

Each value represents mean of 10 observations at each sampling time; Figures in parentheses are √(x+1) transformed value

sata started foraging activity at 0535 h of the day, *A. mellifera* at 0615 h, *A. cerana* at 0620 h and *A. florea* at 0625 h. *A. dorsata* ceased foraging activity at 1045 h of the day followed by *A. mellifera*, *A. cerana* and *A. florea*. In both cultivars, honey bee species stopped foraging activity between 1015 to 1045 h at Hisar because flowers of pumpkin closed during this period. In general, foraging activity of diurnal insect pollinators starts with sunrise. The flight activity and visitation rates of pollinators are influenced by anthesis and weather parameters like temperature, relative humidity, wind and rainfall (Fageri and Vander Pijl, 1979; Forbes and Cervancia, 1994; Kearns and Inouye, 1993). In Philippine, Deyto and Cervancia (2009) on bitter gourd reported that honey bee (*A. mellifera* and *A. cerana*) started foraging activity at 0600 h, while *Trigona* sp. (Stingless bees) and *Halicuts* sp. (Solitary bee) exploited the flower at 0630 h and other flower visitor at around 0700 h. When foraging for pollen or nectar, honey bees were on the top stamens in such a way that their bodies were always in contact with the anthers. They would land directly on stamen or on petals and then walk toward top of the anther. Honey bee collecting nectar spent longer time on flower. Bees collected cucumber pollens heavily from 0800 to 1000 h and nectar from 1000 to noon (Amaral *et al.*, 1963). Pernal and Currie (2010) reported a higher foraging rate mean during the afternoon period (36.02 foragers/ min) than during the morn-ing period (17.66 foragers/ min). Yucel and Duman (2005) found that honey bee workers visited onion flowers from 8.15 to 16.30 h and the peak foraging was between 11.00 to 12.00 h. Foragers have the ability to remember the time of the day at which the higher food resources are available as found with *Sysirinchium palmifolium* plants (Silva *et al.*, 2013) and such ability may correlate with foraging activity peaks.

Foraging speed four honey bee species on *C. moschata* cultivar (C-1106) flowers during September, 2013: The data on foraging speed by four honey bee species on *C. moschata* cultivar (C-1106) flowers during September, 2013 are depicted in Table 2. Time spent/flower by four honey bee species differed significantly. The mean foraging speed in case of *A. dorsata* during different hours of the day varied between 5.04 to 6.47 seconds followed by *A. mellifera* (5.79 to 9.50 seconds), *A. cerana* (5.44 to 6.57 seconds) and 167.50 to 216.71 seconds in case of *A. florea*. The maximum mean time (181.72 seconds)/flower were spent by *A. florea* followed by *A. mellifera* (7.15 seconds), *A. cerana* (6.05 seconds) and *A. dorsata* (5.83 seconds). Irrespective of different bee species, the

Table 5. Foraging rate of four honey bee species on *C. moschata* cultivar (C-1076) flowers at different hours of the day during September, 2013**.**

Honey bee species	Flowers visited per minute					
	0530-0630	0630-0730	0730-0830	0830-0930	0930-1030	Mean
Apis dorsata	5.36(2.49)	4.23(2.27)	6.33(2.69)	4.57(2.35)	4.31(2.27)	4.96(2.42)
Apis mellifera	4.03(2.21)	4.26(2.28)	4.91(2.41)	3.55(2.12)	3.37(2.41)	4.02(2.22)
Apis cerana	4.48(2.23)	4.94(2.41)	3.03(1.99)	4.37(2.29)	4.57(2.29)	4.19(2.59)
A. florae	0.47(1.21)	0.30(1.13)	0.27(1.12)	0.25(1.15)	0.35(1.16)	0.33(1.14)
Mean	3.48(2.03)	3.43(2.02)	3.63(2.05)	3.18(1.97)	3.15(1.97)	
Factors	**SE(m)**		**SE(d)**		**C.D.**	
Bee species	0.04		0.05		(0.11)	
Day hours	0.04		0.06		(N/S)	
Bee species X day hours	0.09		0.13		(0.26)	

Each value represents mean of 10 observations at each sampling time; Figures in parentheses are √(x+1) transformed value

mean time spent during different day hours differed at 5% significant level. The mean time spent irrespective of the honey bee species during 0830 to 0930 h of the day (58.36 seconds/flower) was higher than the time spent during 0730 to 0830 h (55.14 seconds/flower), 0630 to 0730 h (53.55 seconds/flower), 0930 to 1030 h (46.15 seconds/flower) and 0530 to 0630 h (38.22 seconds/flower) of the day. These findings are in close proximity with the finding of Collison and Martin (1979) that the average time *A. dorsata* spent on a flower of cucumber was 11.4 seconds per flower to visit 5.3 flowers per minute. Girish (1981) found that *A. cerana* and *A. dorsata* spent 34 and 38 seconds per flower, respectively on *Cucurbita pepo* L., while Foster and Levin (1967) reported that *A. cerana* and *A. dorsata* bees spent about 6.6 and 3.15 seconds per flower on two different strains of muskmelon, respectively.

Foraging speed of four honey bee species on *C. moschata* cultivar (C-1076) flowers during September, 2013: The data on foraging speed, i.e time spent/ flower in seconds by four honey bee species on *C. moschata* cultivar (C-1076) flowers during September, 2013 . differed at 5% significant level significantly (Table 3). The mean foraging speed (time spent/flower in seconds) during different hours of the day in case of *A. dorsata* varied from 5.45 to 6.54 seconds followed by *A. mellifera* (5.79 to 9.57 seconds), *A. cerana* (5.04 to 6.75 seconds) and 167.50 to 208.28 seconds in case of *A. florea*. The maximum time (178.71 seconds)/ flower were spent by *A. florea* followed by *A. mellifera* (7.63 seconds), *A. cerana* (6.24 seconds) and *A. dorsata* (6.06 seconds). Irrespective of different bee species, the mean time spent during different day hours differed significantly at 5% level. In Brazil, Nicodemo *et al*. (2009) found that *A. mellifera* visited pumpkin flowers at 1030h for nectar and pollen collection. It spent 34.5 seconds/flower for collecting pollen and for nectar collection it spent 43.9 and 29.3 seconds on female and male flower, respectively, whereas, *T. spinipes* collected only nectar, during a mean time of 60.5 seconds per pumpkin flower.

Foraging rate: The data on flowers visited/ minute by four honey bee species on *C. moschata* cultivar (C-1106) flowers have been presented in Table 4 revealed that foraging rate of four honey bee species differed significantly at 5% level. Data on foraging rate (number of flowers visited/ minute) of *A. dorsata* varied from 4.38 to 6.47 during different hours of the day. The figure ranged between 3.53 to 5.11 flowers in case of *A. mellifera*, 3.17 to 5.09 flowers in case of *A. cerana* and 0.26 to 0.44 in case of *A. florea.* Among four honey bee species, the mean foraging rate was highest in case of *A. dorsata* (5.13 flowers/minute) followed by *A. cerana*. (4.30 flowers/minute), *A. mellifera (*4.16 flowers/minute) and it was lowest in *A. florea* (0.32 flowers/minute). The mean flowers visited per minute were maximum (3.75 flowers/minute) during 0730-0830 h followed by (3.60 flowers/minute) during 0530-0630 h, (3.53 flowers/minute) during 0630-0730 h and (3.28 flowers/minute) during 0830-0930 h. It was minimum (3.25 flowers/minute) during 0930-1030 h of the day. Foraging rate of forager is influenced by a complex system of factor like temperature and length of corolla tube (Benedek, 1976). Collison and Martin (1979) reported that except in early morning and late afternoon, the average time a bee spent on cucumber flower decreased throughout the day. The average time, 11.4 seconds per flower visit corresponds to a foraging rate of 5.3 flowers per minute in Michigan.

Foraging rate of four honey bee species on *C. moschata* hybrid (C-1076) flowers: The data on flowers visited per minute by four honey bee species on *C. moschata* cultivar (C-1076) flowers are presented in Table 5. The mean foraging rate (flowers visited/ minute) in case of *A. dorsata* varied from 4.31 to 6.33 during different hours of the day. It was 3.55 to 4.91 flowers in case of *A. mellifera*, 3.03 to 4.94 flowers in case of *A. cerana* and 0.25 to 0.47 1n case of *A. florea*. Among four honey bee species, the mean foraging rate was highest in *A. dorsata* (4.96 flowers/minute) followed by *A. cerana*. (4.19 flowers/minute), *A. mellifera* (4.02 flowers/minute) and it was lowest in *A. florea* (0.33 flowers/minute). Irrespective of different

bee species, no significant differences were found in the foraging rate of four honey bee species on pumpkin flowers during different hours of the day. The mean flowers visited/ minute were maximum (3.63 flowers/ minute) during 00730-0830 h followed by (3.48 flowers/minute) during 0530-0630 h followed by (3.43 flowers/minute) during 0630-0730 h and (3.18 flowers/ minute) during 0830-0930 h. It was minimum (3.15 flowers/minute) during 0930-1030 h of the day.

Conclusion

We concluded that the mean foraging speed (time spent per flower) in seconds on flowers of pumpkin (C -1106) was maximum in case of *A. florea* (181.72), followed by *A. mellifera* (7.15), *A. cerana* (6.05) and *A. dorsata* spent least time (5.83) and in pumpkin (C-1076), foraging speed was maximum in case of *A. florea* (178.71), followed by *A. mellifera* (7.63), *A. cerana* (6.24) and *A. dorsata* spent least time (6.06). The size and complexity of floral display used to advertise their location is one of the several factors influencing the behaviour of pollinators. The high male to female ratio achieves the production of sufficient amount of pollen deposites, thus aids in effective pollination. Pumpkin is a cross pollinated crop if bee doec not play role in the transfer of pollen grain from male to female flower, fruit will not set (0%) that's why crucial role of bees as providers of pollination services in developing countries cannot be ignored with farmers having A.mellifera colonies, although this service is mainly feral there. Honeybee pollinators are required for producing up to 30 % of the human food supply directly or indirectly and the farmers rely on managed honeybees throughout the world to provide these services. There are many natural and human made challenges that decline many groups of pollinators. Declines are associated with habitat loss, fragmentation, and deterioration, non target pesticide exposure and invasive species. Human activities concern with the establishment of monocultures, overgrazing, land clearing, irrigation so as to modify their habitat in the area of agriculture affect the population of bee species and their abundance.

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