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Foraging speed of different *Apis* spp. on Indian mustard (*Brassica juncea*) flowers

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Abstract

The present investigation was undertaken to gather the information pertaining to honey bee pollinators for their foraging speed while visiting the Indian mustard, *Brassica juncea* flowers. The experiment was done on Indian mustard (*Brassica juncea*) variety RH-0749 at Research Area of Oilseeds Section, CCSHAU, Hisar during 2015-2016 Rabi season, which revealed that the mean time spent per flower was maximum in case of *Apis florea* (6.08 sec) followed by *A. dorsata* (3.41 sec), *A. mellifera* (2.60 sec) and *A. cerana indica* (2.33 sec). The mean time spent per flower of different *Apis* spp. over different day hours ranged from 3.25 to 4.20 seconds. The minimum time spent per flower by *A. mellifera*, *A. cerana indica* and *A. dorsata* was 2.38 seconds, 2.02 seconds, 2.97 seconds simultaneously recorded at 1200-1400 h but *A. florea* spent least time per flower (4.23 sec) at 0800-1000 h on *Brassica juncea*.

Keywords: *Apis*, *Brassica*, flower, foraging speed, Indian mustard, time spent

Introduction

The Brassicaceae, which contains about 338 genera and 3,709 species currently recognised (Warwick *et al.*, 2006) [1], is one among the most economically important plant families. *Brassica juncea* is the dominant species grown for oilseed usage in India (Kunjwal *et al.*, 2014) [2]. Indian mustard (*B. juncea*) is a naturally autogamous species, yet in this crop frequent out-crossing occurs which varies from 5 to 30 per cent depending upon the environmental conditions and random variation of pollinating insects (Kumar *et al.*, 2013) [3]. The inflorescence of *B. juncea* is an elongated corymbose raceme, borne terminally on the main stem and branches, carrying bright yellow flower (Langer *et al.*, 1991 [4] and Pua and Douglas, 2004) [5]. Plants of the genus *Brassica*, as with many other crucifers, are known to be very attractive to insect pollinators, serve mainly as a source of nectar and pollen. The bowl shaped flower of mustard is a suitable place for the landing of insect pollinators, especially honey bees (Roubik, 1989) [6].

Bees are the important components of agro-ecosystem as they provide free ecosystem services in the form of pollination which not only enhance the productivity of agricultural crops but also help in conservation of biological diversity. The number of flowers visited per minute by any bee species depends upon the number of factors including instinctive foraging behaviour, length of proboscis (Inouye, 1980) [7], floral structure (Free, 1970) [8] particularly the corolla depth (Gilbert, 1980) [9] type and quantity of floral rewards (Rao and Suryanarayana, 1983 [10]; Rao, 1991) [11] density of flowers on particular cultivar of the crop concerned and hours of the day. Dhaliwal (1980) [12] observed that the average time spent per flower by *A. cerana indica* as pollen and nectar foragers was 4.65 seconds and 6.71 seconds, respectively on *Brassica* seed crop. Murrell and Nash (1981) [13] reported that *A. florea*, *A. cerana* and *A. dorsata* spent 6.45, 3.0 and 4.5 seconds per flower, respectively on *B. campestris* cv. toria. Langridge and Goodman (1982) [14] reported that bees worked readily on rapeseed flower. A single bee worked on as many as 90 flowers in 47 inflorescence in 7 min 12 sec. The average time spent by single bee on one inflorescence was 8.8 sec. Thakur *et al.* (1982) [15] demonstrated that the foraging activity of *A. mellifera* and *A. cerana indica* on mustard was at its peak at 1200 h. There were smaller peaks at 1400 and 1500 h. However, there was a marginal increase between 1500 to 1530 h, followed by a gradual decline.

Tanda (1984) [16] observed that *A. florea* started foraging later and spent more time (5.9-6.4 sec) on *B. juncea* flower as compared to *A. mellifera* (3.0-3.2 sec) and *A. dorsata* (2.2-3.0 sec). Sharma (1987) [17] observed that the pollen gatherers of *A. mellifera* and *A. cerana indica* spent 2.83 and 3.02 seconds per flower, respectively whereas nectar gatherers spent 4.96 and 5.28

seconds per flower, respectively on mustard bloom. Kumar *et al.* (1994) [18] observed that the foraging speed of pollen gatherers of *A. mellifera* was higher than the nectar gatherers. Nectar gatherer of *A. mellifera* spent 3.64 seconds per flower whereas pollen gatherers spent 3.37 seconds per flower on 'toria'. Singh *et al.* (2000) [19] observed that *A. cerana* has foraging speed of 6.37 seconds per flower on *B. napus*. Sharma *et al.* (2001) [20] observed the foraging speed of *Apis* spp. on the flowers of *B. campestris* var. sarson at Hisar during November and found that *A. florea* spent maximum time per flower (3.54 sec.). However, *A. mellifera* spent least time (1.64 sec) per flower/head followed by *A. dorsata* which spent 2.18 seconds per flower. Pandey and Tripathi (2003) [21] noted that *A. florea* worker spent maximum time per flower (43.9 sec) followed by *A. cerana indica* (33.3 sec), *A. mellifera* (31.7 sec) and *A. dorsata* (31.4 sec). Rosa *et al.* (2010) [22] reported that the time of permanence on one flower by *A. mellifera* varied from 1 to 43 seconds ($x = 3.29$; $sd = 2.36$) in Southern Brazil on *B. napus*. The foraging activity of *A. mellifera* L. was studied on mustard under coastal conditions of Orissa and found that maximum time spent by the bee during 1200 h was 2.20 to 2.80 seconds and minimum time spent by bee per flower was during 1600 h (Devi *et al.*, 2011) [23]. The present investigation was undertaken to gather the information pertaining to honey bee pollinators and their foraging speed while visiting the Indian mustard, *B. juncea* flowers.



Plate 1: *Apis mellifera* visiting the flower of *Brassica juncea*

Results and Discussions

Foraging speed of different bee species on Indian mustard flowers

Foraging speed (time spent/ flower) of different bee species on *B. juncea* variety RH-0749 flowers was recorded during different weeks of 2015-16 during different day hours. *Apis* spp. was not foraging during 0600-0800 h due to low temperature in morning hours throughout the investigation period. During evening hours also, very negligible activity of *Apis* spp. was observed between 1600-1800 h due to low temperature during December, 2015 and January, 2016. Therefore, the data on foraging speed of *Apis* spp. was recorded from 0800-1600 h.

1. Foraging speed of *A. mellifera* on *B. juncea* variety RH-0749 flowers

The data on time spent per flower by *A. mellifera* on *B. juncea* flowers have been presented in Table 1. Foraging speed of *A. mellifera* on *B. juncea* flowers recorded during different

Materials and Methods

The experiment was conducted with Indian mustard variety RH 0749 (recently developed and recommended by CCS HAU, Hisar) during 2015-2016 in the Research Area of Oilseed Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana (29°10'N, 75°46'E, 215.2 AMSL), CCS HAU, Hisar, Haryana. The crop was raised under field conditions as per the practices recommended in Package of Practices of CCS HAU, Hisar. The sowing of the crop was done in 1st week of October, 2015 with five replications. All the normal package of practices were followed for raising a healthy crop.

Foraging speed: Foraging speed of *Apis* spp. viz, *A. mellifera*, *A. cerana indica*, *A. dorsata*, *A. florea*, was recorded in terms of the time spent by each species on a flower i.e. time spent/flower. Observations were recorded throughout blooming period (starting from 10 per cent flowering) of the crop weekly at two hour interval starting from 0600 to 1800 h. Twenty observations were made for each pollinator. Chronometer was used for recording the foraging speed.

Chronometer (stopwatch): Stopwatch with an accuracy of 0.01 second was used to record the time spent per flower by different insects on the flowers of Indian mustard.

weeks over the times revealed that the mean weekly foraging speed ranged between 2.37 to 2.80 seconds corresponding to 4th and 2nd week of the blooming period, respectively. The maximum time spent per flower by *A. mellifera* (2.80 sec) was in 2nd week followed by 5th week (2.70 sec), 3rd week (2.61 sec), 1st week (2.53 sec) and 4th week (2.37 sec). Least time spent by *A. mellifera* (1.98 sec) was recorded at 1200-1400 h during 4th week of the observation and highest (3.93 sec) at 1400-1600 h during 1st week of the observation. As far as times of the day were concerned, significantly the maximum time spent per flower (3.09 sec) was recorded at 1400-1600 h followed by that at 1000-1200 h (2.51 sec), 0800-1000 h (2.41 sec) and 1200-1400 h (2.38 sec). The mean foraging speed of *A. mellifera* bees over different day hours ranged from 2.38 to 3.09 seconds. Least time spent at 1200-1400 h (2.38 sec) was statistically at par with that at 0800-1000 h (2.41 sec) and it varies significantly with 1000-1200 h (2.51 sec) and 1400-1600 h (3.09 sec).

Table 1: Foraging speed of *Apis mellifera* on the flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

Time (h)	Mean time spent per flower (sec)					
	15-12-2015	23-12-2015	29-12-2015	05-01-2016	14-01-2016	Mean
0800-1000	0.00 (1.00)	3.17 (2.03)	3.09 (2.01)	2.76 (1.92)	3.05 (1.99)	2.41 (1.79)
1000-1200	3.17 (2.03)	2.55 (1.86)	2.25 (1.79)	2.14 (1.76)	2.47 (1.85)	2.51 (1.86)
1200-1400	3.02 (1.99)	2.42 (1.83)	2.14 (1.76)	1.98 (1.72)	2.36 (1.82)	2.38 (1.82)
1400-1600	3.93 (2.21)	3.04 (1.99)	2.96 (1.98)	2.61 (1.88)	2.91 (1.96)	3.09 (2.01)
Mean	2.53 (1.81)	2.80 (1.93)	2.61 (1.89)	2.37 (1.82)	2.70 (1.91)	2.60 (1.87)

- Each value represents mean of 20 observations
- Figures in parentheses are the means of $\sqrt{n+1}$ transformation
- There was no honey bee activity at 0600-0800 h and 1600-1800 h

	SE(m)	CD (p= 0.05)
Time	(0.02)	(0.06)
Week	(0.03)	(0.07)
Time × Week	(0.05)	(0.14)

2. Foraging speed of *A. cerana indica* on *B. juncea* variety RH-0749 flowers

The data on time spent per flower by *A. cerana indica* on *B. juncea* flowers have been presented in Table 2. Mean weekly foraging speed of *A. cerana indica* during different weeks ranged between 1.72 to 2.71 seconds corresponding to 4th and 1st week of the blooming period, respectively. The maximum time per flower by *A. cerana indica* (2.71 sec) was in 1st week followed by 2nd week (2.64 sec), 5th week (2.46 sec), 3rd week (2.11 sec) and 4th week (1.72 sec).

Least time spent by *A. cerana indica* (1.38 sec) was recorded at 1200-1400 h during 4th week of the observation and

highest (3.28 sec) at 1400-1600 h during 1st week of the observation.

As far as times of the day were concerned, significantly the maximum time spent per flower (2.68 sec) was recorded at 1400-1600 h followed by that at 0800-1000 h (2.50 sec), 1000-1200 h (2.10 sec) and 1200-1400 h (2.02 sec). The mean foraging speed of *A. cerana indica* bees over different day hours ranged from 2.02 to 2.68 seconds. Least time spent at 1200-1400 h (2.02 sec) was statistically at par with that at 1000-1200 h (2.10 sec) but varies significantly with 0800-1000 h (2.50 sec) and 1400-1600 h (2.68 sec).

Table 2: Foraging speed of *Apis cerana indica* on the flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

Time (h)	Mean time spent per flower (sec)					
	15-12-2015	23-12-2015	29-12-2015	05-01-2016	14-01-2016	Mean
0800-1000	2.22 (1.72)	3.04 (1.99)	2.51 (1.85)	2.07 (1.74)	2.68 (1.90)	2.50 (1.84)
1000-1200	2.76 (1.92)	2.35 (1.81)	1.82 (1.67)	1.46 (1.55)	2.13 (1.75)	2.10 (1.74)
1200-1400	2.59 (1.88)	2.20 (1.78)	1.73 (1.64)	1.38 (1.53)	2.22 (1.78)	2.02 (1.72)
1400-1600	3.28 (2.05)	2.98 (1.97)	2.37 (1.81)	1.96 (1.70)	2.80 (1.93)	2.68 (1.89)
Mean	2.71 (1.89)	2.64 (1.89)	2.11 (1.75)	1.72 (1.63)	2.46 (1.84)	2.33 (1.80)

- Each value represents mean of 20 observations
- Figures in parentheses are the means of $\sqrt{n+1}$ transformation
- There was no honey bee activity at 0600-0800 h and 1600-1800 h

	SE(m)	CD (p= 0.05)
Time	(0.03)	(0.08)
Week	(0.03)	(0.08)
Time × Week	(0.06)	(0.17)

3. Foraging speed of *A. dorsata* on *B. juncea* variety RH-0749 flowers

The data on time spent per flower by *A. dorsata* on *B. juncea* flowers have been presented in Table 3. Foraging speed of *A. dorsata* during different weeks ranged between 3.02 to 3.72 seconds corresponding to 4th and 1st week of the blooming period, respectively. The maximum time per flower by *A. dorsata* (3.72 sec) was in 1st week followed by 2nd week (3.68 sec), 5th week (3.41 sec), 3rd week (3.21 sec) and 4th week (3.02 sec).

Least time spent by *A. dorsata* (2.65 sec) was recorded at

1200-1400 h during 4th week of the observation and highest (4.19 sec) at 0800-1000 h during 1st week of the observation.

As far as times of the day were concerned, significantly the maximum time spent per flower (3.85 sec) was recorded at 0800-1000 h followed by that recorded at 1400-1600 h (3.67 sec), 1000-1200 h (3.14 sec) and 1200-1400 h (2.97 sec). The mean foraging speed of *A. dorsata* bees over different day hours ranged from 2.97 to 3.85 seconds. Least time spent at 1200-1400 h (2.97 sec) was statistically at par with that at 1000-1200 h (3.14 sec) but varies significantly with 0800-1000 h (3.85 sec) and 1400-1600 h (3.67 sec).

Table 3: Foraging speed of *Apis dorsata* on the flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

Time (h)	Mean time spent per flower (sec)					
	15-12-2015	23-12-2015	29-12-2015	05-01-2016	14-01-2016	Mean
0800-1000	4.19 (2.26)	4.12 (2.25)	3.64 (2.15)	3.41 (2.09)	3.87 (2.20)	3.85 (2.19)
1000-1200	3.46 (2.10)	3.49 (2.11)	2.94 (1.97)	2.74 (1.93)	3.05 (2.00)	3.14 (2.02)
1200-1400	3.35 (2.08)	3.13 (2.02)	2.78 (1.94)	2.65 (1.90)	2.96 (1.98)	2.97 (1.98)
1400-1600	3.87 (2.15)	3.96 (2.22)	3.47 (2.10)	3.28 (2.05)	3.76 (2.17)	3.67 (2.14)
Mean	3.72 (2.14)	3.68 (2.15)	3.21 (2.04)	3.02 (1.99)	3.41 (2.09)	3.41 (2.08)

- Each value represents mean of 20 observations
- Figures in parentheses are the means of $\sqrt{n+1}$ transformation
- There was no honey bee activity at 0600-0800 h and 1600-100 h

	SE(m)	CD (p= 0.05)
Time	(0.02)	(0.07)
Week	(0.03)	(0.07)
Time × Week	(0.05)	(N.S.)

4. Foraging speed of *A. florea* on *B. juncea* variety RH-0749 flowers

The data on time spent per flower by *A. florea* on *B. juncea* flowers have been presented in Table 4. Mean foraging speed of *A. florea* during different weeks ranged between 5.53 to

6.63 seconds corresponding to 2nd and 5th week of the blooming period, respectively. The maximum time per flower was spent by *A. florea* (6.63 sec) was in 5th week followed by that in 3rd week (6.36 sec), 4th week (6.11 sec), 1st week (5.78 sec) and 2nd week (5.53 sec).

Table 4: Foraging speed of *Apis florea* on the flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

Time (h)	Mean time spent per flower (sec)					
	15-12-2015	23-12-2015	29-12-2015	05-01-2016	14-01-2016	Mean
0800-1000	0.00 (1.00)	0.00 (1.00)	7.05 (2.83)	6.87 (2.80)	7.23 (2.86)	4.23 (2.10)
1000-1200	7.47 (2.91)	7.07 (2.83)	5.95 (2.63)	5.64 (2.57)	6.24 (2.68)	6.47 (2.72)
1200-1400	7.28 (2.87)	6.95 (2.81)	5.74 (2.59)	5.35 (2.51)	6.08 (2.66)	6.28 (2.69)
1400-1600	8.39 (3.06)	8.09 (3.01)	6.71 (2.77)	6.58 (2.75)	6.98 (2.81)	7.35 (2.88)
Mean	5.78 (2.46)	5.53 (2.41)	6.36 (2.70)	6.11 (2.66)	6.63 (2.75)	6.08 (2.60)

- Each value represents mean of 20 observations
- Figures in parentheses are the means of $\sqrt{n+1}$ transformation
- There was no honey bee activity at 0600-0800 h and 1600-1800 h

	SE(m)	CD (p= 0.05)
Time	(0.02)	(0.06)
Week	(0.02)	(0.06)
Time × Week	(0.05)	(0.13)

Least time spent by *A. florea* (5.35 sec) was recorded at 1200-1400 h during 4th week of the observation and highest (8.39 sec) at 1400-1600 h during 1st week of the observation.

As far as times of the day were concerned, significantly the maximum time spent per flower (7.35 sec) was recorded at 1400-1600 h followed by that recorded at 1000-1200 h (6.47 sec), 1200-1400 h (6.28 sec) and 0800-1000 h (4.23 sec). The mean foraging speed of *A. florea* bees during different day hours ranged from 4.23 to 7.35 seconds. Least time spent

(4.23 sec) at 0800-1000 h varies significantly with 1000-1200 h (6.47 sec), 1200-1400 h (6.28 sec) and 1400-1600 h (7.35 sec).

5. Comparative foraging speed of different bee species on *B. juncea* variety RH-0749 flowers

Data on the comparative foraging rate of different bee species on *B. juncea* flowers at different hours of the day have been presented in Table 5.

Table 5: Comparative foraging speed of different bee species on the flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

Foraging time (h)	Mean time spent per flower (sec)				
	<i>A. mellifera</i>	<i>A. cerana indica</i>	<i>A. dorsata</i>	<i>A. florea</i>	Mean
0800-1000	2.41 (1.79)	2.50 (1.84)	3.85 (2.19)	4.23 (2.10)	3.25 (1.98)
1000-1200	2.51 (1.86)	2.10 (1.74)	3.14 (2.02)	6.47 (2.72)	3.56 (2.09)
1200-1400	2.38 (1.82)	2.02 (1.72)	2.97 (1.98)	6.28 (2.69)	3.41 (2.05)
1400-1600	3.09 (2.01)	2.68 (1.89)	3.67 (2.14)	7.35 (2.88)	4.20 (2.23)
Mean	2.60 (1.87)	2.33 (1.80)	3.41 (2.08)	6.08 (2.60)	

- Figures in parentheses are the means of $\sqrt{n+1}$ transformation

	SE (m)	CD (p= 0.05)
Bee species	(0.01)	(0.03)
Time	(0.01)	(0.03)
Bee species × Time	(0.02)	(0.07)

The data on foraging speed (time spent per flower) of different honey bee species on *B. juncea* flowers during 2015-16 revealed that the time spent per flower by four bee species differed significantly. The mean foraging speed during different hours of the day varied from 2.38 to 3.09 seconds for *A. mellifera*, 2.02 to 2.68 seconds for *A. cerana indica*, 2.97 to 3.85 seconds for *A. dorsata* and 4.23 to 7.35 seconds for *A. florea*. The maximum time (6.08 sec) per flower was spent by *A. florea* followed by *A. dorsata* (3.41 sec), *A. mellifera* (2.60 sec) and *A. cerana indica* (2.33 sec).

The present study is strongly supported by the findings of Sharma *et al.* (2001) [20] from Hisar who observed that *A. florea* spent maximum time per flower (3.54 sec) on the flowers of *B. campestris* var. sarson followed by *A. dorsata* which spent 2.18 seconds per flower and *A. mellifera* which spent 1.64 seconds per flower. The present findings are also in agreement with the findings of Inouye (1980) [7] who observed different foraging speed with different length of proboscis in bees and found that *A. florea* is relatively slower forager due

to its tongue length. Murrell and Nash (1981) [13] observed that foraging speed of *A. florea* and *A. dorsata* was 6.45 and 4.5 seconds/flower, respectively on *B. campestris* var. toria. Langridge and Goodman (1982) [14] also reported that bees worked readily on rapeseed flower. The average time spent by single bee on one inflorescence was 8.8 sec. Similar results were recorded by Tanda (1984) [16] who observed that *A. florea* started foraging later and spent more time (5.9-6.4 sec) on *B. juncea* flower as compared to *A. mellifera* (3.0-3.2 sec) and *A. dorsata* (2.2-3.0 sec). Singh *et al.* (2000) [19] also observed that *A. cerana indica* has foraging speed of 6.37 s per flower on *B. napus*. Rosa *et al.* (2010) [22] also reported that the time spent on one flower by *A. mellifera* varied from 1 to 43 seconds on *B. napus*. However in contrary to the present findings, Pandey and Tripathi (2003) [21] noted that *A. dorsata* worker spent least time per flower (31.4 sec) followed by *A. mellifera* (31.7 sec), *A. cerana indica* (33.3 sec) and *A. florea* (43.9 sec) on mustard.

The present findings also revealed that the minimum time spent per flower by *A. mellifera*, *A. cerana indica* and *A. dorsata* was 2.38 seconds, 2.02 seconds, 2.97 seconds simultaneously recorded at 1200-1400 h but *A. florea* spent least time per flower (4.23 sec) at 0800-1000 h on *B. juncea*. Contrary to the present findings, Devi *et al.* (2011) [23] from Orissa recorded that the maximum time spent per flower by *A. mellifera* during 1200 h was 2.20 to 2.80 seconds and minimum time spent per flower by *A. mellifera* was during 1600 h on mustard.

Conclusion

The present experiment conducted on Indian mustard variety RH-0749 at Research Area of Oilseeds Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during 2015-2016 to study the foraging speed of different *Apis* spp. revealed that the mean time spent per flower was maximum in case of *A. florea* (6.08 sec) followed by *A. dorsata* (3.41 sec), *A. mellifera* (2.60 sec) and *A. cerana indica* (2.33 sec). Maximum time spent per flower was observed during the initiation of the flowering (1st week), it gradually decreased with subsequent weeks up to the peak period of the flowering (4th week) and it again increased towards cessation of the flowering (5th week). The mean time spent per flower of different *Apis* spp. over different day hours ranged from 3.25 to 4.20 seconds. The maximum time spent per flower (4.20 sec) was recorded at 1400-1600 h followed by that recorded at 1000-1200 h (3.56 sec), 1200-1400 h (3.41 sec) and 0800-1000 h (3.25 sec). This concludes that *A. florea* is relatively slower forager may be due to its tongue length, while *A. cerana indica* is found to be the fastest among all the *Apis* spp.

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