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Working behavioural studies of different *Apis* spp. on Indian mustard (*Brassica juncea*)

Kanika Nagpal, Sunita Yadav, Yogesh Kumar and Robin Singh

Abstract
The working behavior of different *Apis* spp. while foraging on Indian mustard (*B. juncea*) variety RH-0749 was studied. The maximum nectar foraging was recorded in *A. dorsata* (37.25%) followed by *A. florea* (36.08%) bees. The maximum proportion of pollen gatherers were recorded in case of *A. dorsata* (26.00%) followed by *A. mellifera* (25.44%). Foraging for both nectar and pollen was the maximum in case of *A. cerana indica* (48.50%) followed by *A. florea* (43.50%), *A. mellifera* (42.94%) and *A. dorsata* (36.75%). The maximum percentage of nectar and pollen foraging by *Apis* spp. at different day hours was recorded at 1200-1400 h (47.75%) and 0800-1000 h (44.86%) respectively. The maximum proportion of top workers were in *A. dorsata* (100%) followed by *A. cerana indica* (90.25%), *A. mellifera* (82.94%) and *A. florea* (59.50%).

Keywords: *Apis*, foraging, Indian mustard, nectar, pollen, top foraging, side foraging

Introduction
Rapeseed (sarson and toria) and mustard (rai) are prominent oil producing crops being grown in India as well as in 52 other countries throughout the world. India is one of the largest rapeseed- mustard growing country in the world, occupying the first position in area and second position in production after China (Khavse *et al*., 2014) [1]. Rapeseed comprises five different crops namely, *Brassica rapa* var. brown sarson, *B. rapa* var. yellow sarson, *B. rapa* var. toria, *B. napus* and *Eruca sativa*, whereas, *B. juncea* and *B. carinata* comes under mustard (Kumar *et al.,* 2014) [2]. *Brassica* spp. contributes 28.6 per cent in the total production of oilseeds and ranks second after groundnut sharing 27.8 per cent in Indian oilseed economy (Shekhawat *et al.,* 2012) [3]. Rapeseed-mustard is widely and extensively grown for its seeds which yield an essential oil and condiment. Because of the lowest amount of harmful saturated fatty acids, rapeseed-mustard oil is considered the best quality oil for human consumption as compared to other edible oils (Porter and Crompton, 2008) [4]. During 2016-17, rapeseed and mustard were grown over an area of 26.18 million ha in India with production and productivity of 31.28 million tons and 1195 kg/ha, respectively (Anonymous, 2018) [5]. In Haryana, during 2016-17 rapeseed and mustard were grown on 0.53 million ha area with production and productivity of 0.96 million tons and 1832 kg/ha, respectively (Anonymous, 2018) [5].
Among rapeseed-mustard, Indian mustard, *B. juncea* (L.) Czernj. & Cosson is predominantly cultivated in Haryana and adjoining states. It is known as *rai*, *raya* or *laha*. 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) [6]. The bowl shaped flower of mustard is a suitable place for the landing of insect pollinators, especially honey bees (Roubik, 1989) [7]. Population of natural pollinators differ from location to location depending upon the availability of suitable natural habitat such as forestry and weed flora, which serve as alternate source of nectar and pollen. In case of lack of natural pollinators, it is possible to utilise honeybees as they can be reared and their population can be manipulated according to the need of hour. Bees are considered the best pollinators (Robinson and Morse, 1989) [8] due to their suitable body size, hairiness, thoroughness, steadfastness, floral constancy, and manageable populations. Being polytrophic in nature and more flower-constant, they effectively pollinate a large number of crops. Bees feed exclusively on pollen and nectar (Masierowska, 2003) [9] and deliberately visit a great number of flowers in order to satisfy the colony needs (Corbet *et al*., 1991) [10]. Different workers have studied the working behaviour of honey bees as nectar and pollen gatherers (Verma and Partap, 1994, Abrol, 2007, Roy *et al.*, 2014 and Kamel *et al.*, 2015) [11-14].

Materials and Methods

The study was carried out during 2015-2016 Rabi Season with Indian mustard variety RH 0749 (recently developed and recommended by CCS HAU, Hisar) at Research Area of Oilseeds Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana located at 29.15º N latitude and 75.70º E longitude.

Raising of crop

The crop was raised under field conditions at Research Area of Oilseeds Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar 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.

The experiment was started when about 10% flowering had taken place. The observations were recorded throughout the blooming period of the crop, weekly at two hour interval starting from 0600 to 1800 h. Twenty observations were made for each pollinator for recording the foraging mode.

Different aspects of working behaviour of *Apis* spp. on Indian mustard flowers were recorded as follows:

i. **Nectar gatherer or pollen gatherer:** The bees carrying pollen on their corbiculae were considered as pollen gatherers and others, which inserted their proboscis in the flower but would not be carrying corbicular pollen load, were considered as nectar gatherers.
ii. **Both nectar and pollen gatherer:** Bees carrying both corbicular pollen load and also inserting their proboscis in the flower to collect nectar were counted as foraging simultaneously for both pollen and nectar.
iii. **Top worker/side worker:** Individuals of different insect visitors were observed for their working behaviour, i.e., whether they are working from top or side.

Data obtained was tabulated and subjected to statistical analysis as per requirement with angular transformation.

Results and Discussion

Nectar and/or pollen collectors of different bee species on *B. juncea* variety RH-0749 flowers

The proportion of nectar or pollen and nectar plus pollen foraging of *A. mellifera* on *B. juncea* flowers during different weeks of the flowering are presented in Figure 1. The percentage of nectar gatherers was observed maximum (33.75%) during 4th and 5th week of flowering. The weekly mean proportion of pollen gatherers of *A. mellifera* ranged between 20.00 to 28.75 per cent. Minimum percentage of pollen gatherers (20.00%) were observed during the 1st week, it gradually increased with subsequent weeks up to the 4th week (28.75%) and it again decreased in 5th week (22.50%) corresponding to the flowering in the crop. Whereas, the maximum percentage of both nectar and pollen gatherers (46.67%) was observed during the 1st week, it gradually decreased with subsequent weeks up to the 4th week (37.50%) and it again increased in 5th week (43.75%).

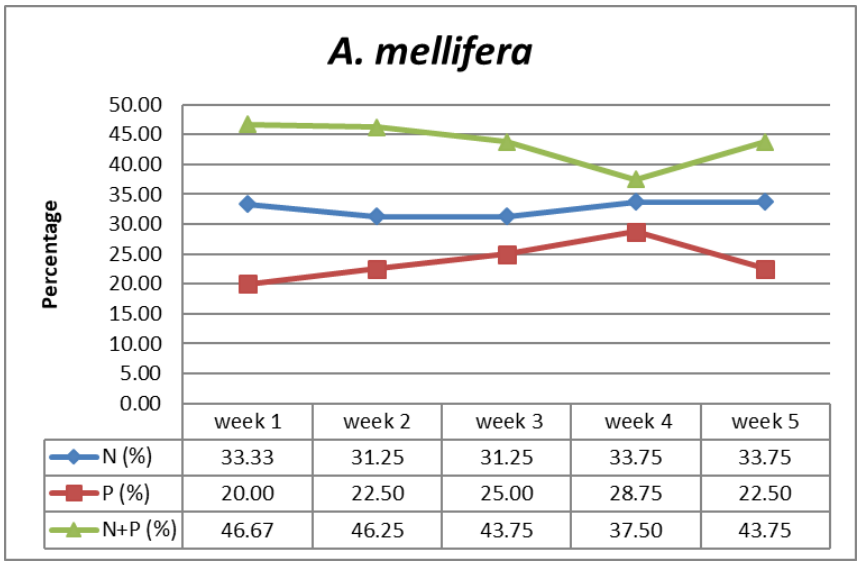
The data on the proportion of nectar, pollen and nectar plus pollen foraging of *A. cerana indica* on *B. juncea* flowers during different weeks of the flowering are presented in Figure 2 and it was revealed that the weekly mean proportion of nectar gatherers of *A. cerana indica* ranged between 28.75 to 37.50 per cent. The percentage of nectar gatherers was observed maximum (37.50%) during 4th and 5th week of flowering. While percentage of pollen gatherers of *A. cerana indica* was minimum during the 2nd week (15.00%) and there was equal proportion of pollen gatherers (20.00%) during the 3rd, 4th and 5th week. Whereas, the maximum percentage of both nectar and pollen gatherers (53.75%) was observed during the 1st week, it gradually decreased with subsequent weeks up to the 4th week (42.50%) and was observed similar in the 5th week of flowering (42.50%).

The proportion of nectar, pollen and nectar plus pollen foraging of *A. dorsata* on *B. juncea* flowers during different weeks of the flowering are presented in Figure 3. It was depicted that the weekly mean proportion of nectar gatherers of *A. dorsata* ranged between 33.75 to 42.50 per cent. The maximum percentage of nectar gatherers was observed maximum (42.50%) during 4th week of flowering. While, minimum percentage of pollen gatherers (21.25%) was observed during the 1st week, it gradually increased with subsequent weeks up to the 4th week (28.75%) and it again decreased in 5th week (27.50%) corresponding to the flowering in the crop. Thus, the maximum pollen foraging was observed in 4th week of the flowering. Whereas, both nectar and pollen gatherers followed an opposite trend as the maximum percentage of both nectar and pollen gatherers was observed during the 1st week (43.75%), it gradually decreased with subsequent weeks up to the 4th week (28.75%) and it again increased in the 5th week of flowering (32.50%).

The data on proportion of nectar or pollen and nectar plus pollen foraging of *A. florea* on *B. juncea* flowers during different weeks of the flowering are presented in Figure 4 and it was revealed that the maximum nectar foraging (41.25%) was observed during 4th week of the flowering as it was the peak period of flowering and the minimum (35.00%) was observed in the initiation of the flowering i.e. in the 1st week. While, maximum percentage of pollen gatherers (20.00%) was observed during the 1st and 2nd week which decreased subsequently during different weeks of flowering and minimum percentage of pollen gatherers (16.25%) was observed during the 5th week. Whereas, in case of both nectar and pollen gatherers, the weekly mean proportion ranged between 40.00 to 47.50 per cent. The maximum proportion of dual foraging for both nectar and pollen (47.50%) was observed during the 5th week and minimum (40.00%) was observed in the 4th week.

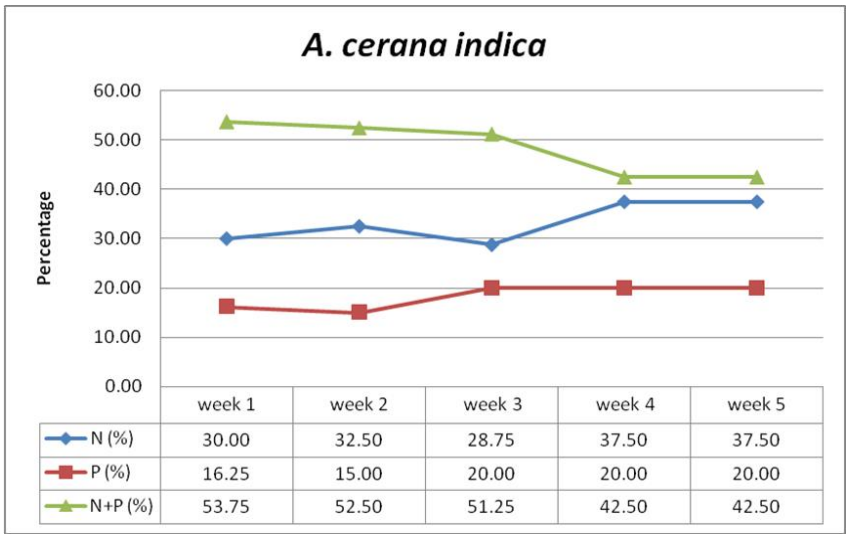
Nectar gatherers of different bee species on *B. juncea* flowers

The proportion of nectar foraging of different bee species on the flowers of *B. juncea* has been presented in Table 1. In the present investigation, maximum nectar foraging was recorded in case of *A. dorsata* (37.25%) followed by *A. florea* (36.08%), *A. cerana indica* (33.25%) and *A. mellifera* (31.63%) bees on *B. juncea*. Similar results were also documented by Mohr and Jay (1988) [15] and Rana *et al.* (1997) [16] that in *A. cerana indica*, higher proportion of foragers were collecting nectar than that of *A. mellifera* on *B. campestris* bloom.



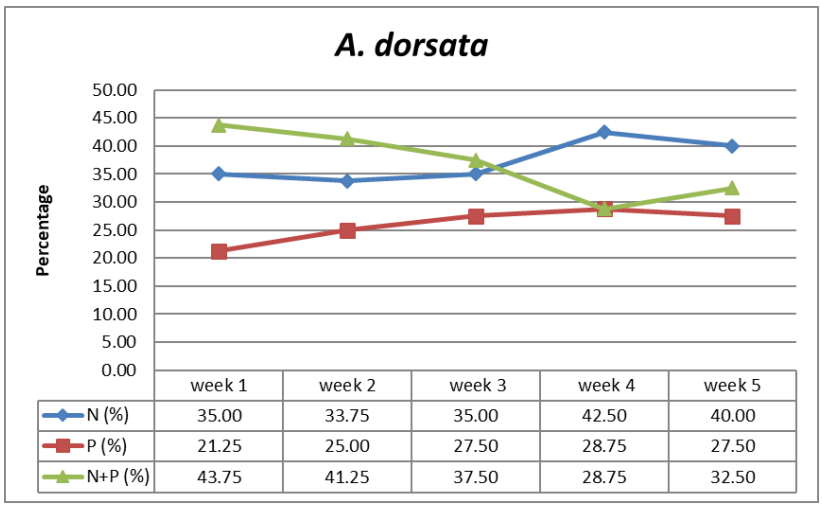
	week 1	week 2	week 3	week 4	week 5
N (%)	33.33	31.25	31.25	33.75	33.75
P (%)	20.00	22.50	25.00	28.75	22.50
N+P (%)	46.67	46.25	43.75	37.50	43.75

Fig 1: Percentage of nectar and/or pollen gatherers of *A. mellifera* on flowers of *Brassica juncea* variety RH-0749 over different weeks of flowering during the year 2015-2016



	week 1	week 2	week 3	week 4	week 5
N (%)	30.00	32.50	28.75	37.50	37.50
P (%)	16.25	15.00	20.00	20.00	20.00
N+P (%)	53.75	52.50	51.25	42.50	42.50

Fig 2: Percentage of nectar and/or pollen gatherers of *A. cerana indica* on flowers of *Brassica juncea* variety RH-0749 over different weeks of flowering during the year 2015-2016



	week 1	week 2	week 3	week 4	week 5
N (%)	35.00	33.75	35.00	42.50	40.00
P (%)	21.25	25.00	27.50	28.75	27.50
N+P (%)	43.75	41.25	37.50	28.75	32.50

Fig 3: Percentage of nectar and/or pollen gatherers of *A. dorsata* on flowers of *Brassica juncea* variety RH-0749 over different weeks of flowering during the year 2015-2016

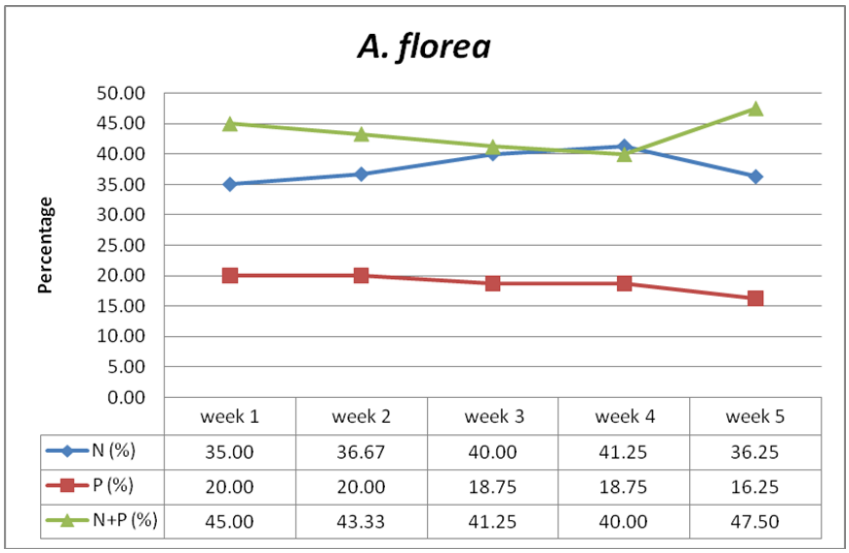


Fig 4: Percentage of nectar and/or pollen gatherers of *A. florea* on flowers of *Brassica juncea* variety RH-0749 over different weeks of flowering during the year 2015-2016

Table 1: Percentage of nectar gatherers of different bee species on the flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

Foraging time (h)	*A. mellifera*	*A. cerana indica*	*A. dorsata*	*A. florea*	Mean
0800-1000	12.50 (20.62)	16.00 (23.53)	20.00 (26.49)	18.33 (25.31)	16.71 (23.99)
1000-1200	33.00 (34.89)	34.00 (35.58)	42.00 (40.36)	39.00 (38.58)	37.00 (37.35)
1200-1400	46.00 (42.68)	47.00 (43.26)	49.00 (44.41)	49.00 (44.41)	47.75 (43.69)
1400-1600	35.00 (36.24)	36.00 (36.80)	38.00 (38.03)	38.00 (37.91)	36.75 (37.24)
Mean	31.63 (33.61)	33.25 (34.79)	37.25 (37.32)	36.08 (36.55)	

Figures in parentheses represent angular transformed values
There was no honey bee activity at 0600-0800 h and 1600-1800 h

	SE(m)	CD (p= 0.05)
Bee species	(0.64)	(1.81)
Time	(0.64)	(1.81)
Bee species × Time	(1.27)	(N.S.)

The data revealed that the mean proportion of all the bees foraging for nectar during different day hours varied between 16.71 to 47.75 per cent. The mean proportion of nectar gatherers was low in the early morning, 0800-1000 h (16.71%) but rapidly increased throughout the afternoon and reached to an average of 47.75 per cent at 1200-1400 h which differed significantly with other times of the day. Nectar in the flowers became more concentrated in the afternoon. The percentage of nectar gatherers observed at 1000- 1200 h (37.00%) were statistically at par with that observed at 1400-1600 h (36.75%).

The findings of the present study are strongly supported by the findings of Murrell and Nash (1981) [17] who reported that nectar foragers were low (16%) in morning (0900 h) but rapidly increased throughout the afternoon to an average of over 40 per cent in *B. campestris*. The present findings are also in line with the findings of Verma (1983) [18] who reported peak period of nectar collection by *A. cerana indica* between 1200 to 1400 h. Many workers have reported nectar collection by *A. mellifera* and *A. cerana indica* during the later part of the day due to more concentration of sugar at that time on *Brassica* crops (Free, 1970, Mohr and Jay, 1988[]) [19, 15]. Similar results were documented by Rana *et al.* (1997) [16] that the highest percentage of nectar gatherers of *A. cerana indica* and *A. mellifera* were recorded at 1500 h and the lowest at 0900 h on *B. campestris* bloom.

In contrast to the present findings, Thakur *et al.* (1982) [20] reported more nectar collection by *A. mellifera* and *A. cerana indica* between 0700 and 1000 h on *Brassica* species. This may be due to variations in the plant spp. and climatic conditions.

Pollen gatherers of different bee species on *B. juncea* flowers

The proportion of pollen gatherers of different bee species on the flowers of *B. juncea* has been presented in Table 2. In the current study, maximum pollen foraging was recorded in case of *A. dorsata* (26.00%) followed by *A. mellifera* (25.44%), *A. florea* (20.42%) and *A. cerana indica* (18.25%) on *B. juncea*. The present study is strongly supported by findings of Mohr and Jay (1988) [15] who reported that 48 per cent of the honey bees actively collected pollen from *B. napus*. Similar findings were reported by Murrell and Nash (1981) [17] on *B. campestris* that *A. cerana indica* foragers carrying pollen pellets shortly after anthesis, when 40 per cent of the bees were carrying pollen load.

Table 2: Percentage of pollen gatherers of different bee species on the flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

Foraging time (h)	*A. mellifera*	*A. cerana indica*	*A. dorsata*	*A. florea*	Mean
0800-1000	53.75 (47.15)	35.00 (36.22)	54.00 (47.28)	36.67 (37.25)	44.86 (41.97)
1000-1200	23.00 (28.43)	20.00 (26.49)	23.00 (28.57)	21.00 (26.92)	21.75 (27.60)
1200-1400	15.00 (22.78)	11.00 (19.30)	16.00 (23.53)	14.00 (21.79)	14.00 (21.85)
1400-1600	10.00 (18.20	7.00 (15.12)	11.00 (19.30)	10.00 (18.20)	9.50 (17.70)
Mean	25.44 (29.14)	18.25 (24.28)	26.00 (29.67)	20.42 (26.04)	

Figures in parentheses represent angular transformed values
There was no honey bee activity at 0600-0800 h and 1600-1800 h

	SE(m)	CD (p= 0.05)
Bee species	(0.83)	(2.35)
Time	(0.83)	(2.35)
Bee species × Time	(1.66)	(4.71)

The mean proportion of pollen gatherers was maximum (44.86%) at 0800-1000 h which decreased subsequently during the course of the day and reached to minimum (9.50%) at 1400-1600 h. Pollen collection by bees was more in the morning hours because anthesis occurred in the morning and thus the flowers produced huge amount of pollen. However the pollen dried up over the course of the day, so that little of it was available to the bees in the afternoon.

The present study is strongly supported by the findings of Thakur *et al.* (1982) [20] who revealed peak pollen collection by *A. mellifera* and *A. cerana indica* between 0700 and 1000 h due to anthesis of the crop in the morning hours on *B. campestris*. The present findings are also in line with the information given by Mohr and Jay (1988) [15] that the proportion of pollen gatherers of *A. mellifera* and *A. cerana indica* was the highest at 0900 h and the lowest at 1500 h in *B. napus*. Similar results were documented by Murrell and Nash (1981) [17], Raj and Rana (1993) [21], Rana *et al.* (1997) [16] who recorded that the proportion of pollen gatherers of *A. mellifera* and *A. cerana indica* was the highest at 0900 h and the lowest at 1500 h in *B. campestris.*

Both nectar and pollen gatherers of different bee species on *B. juncea* flowers

The proportion of both nectar and pollen gatherers of different bee species on the flowers of *B. juncea* has been presented in Table 3. Foraging for both nectar and pollen was the maximum in case of of *A. cerana indica* (48.50%) followed by *A. florea* (43.50%), *A. mellifera* (42.94%) and *A. dorsata* (36.75%) on *B. juncea*. Present results are corroborated by the findings of Brar *et al.* (2008a, b) [22, 23] who reported dual foraging simultaneously for both nectar and pollen in *A. mellifera* ranged from 59.20 to 74.20 per cent, whereas in *A. cerana indica* dual foraging simultaneously for both nectar and pollen was 84.10 per cent. Similar results were documented by Mohr and Jay (1988) [15] who reported that most workers collected either pollen or nectar, but 4-7 per cent collected both nectar and pollen during the same foraging trip on *B. napus*.

Table 3: Percentage of both nectar and pollen gatherers of different bee species on the flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

Foraging time (h)	*A. mellifera*	*A. cerana indica*	*A. dorsata*	*A. florea*	Mean
0800-1000	33.75 (35.41)	49.00 (44.41)	26.00 (29.99)	45.00 (42.11)	38.44 (37.98)
1000-1200	44.00 (41.52)	46.00 (42.66)	35.00 (36.06)	40.00 (39.10)	41.25 (39.83)
1200-1400	39.00 (38.61)	42.00 (40.34)	35.00 (36.19)	37.00 (37.44)	38.25 (38.15)
1400-1600	55.00 (47.86)	57.00 (49.03)	51.00 (45.56)	52.00 (46.15)	53.75 (47.15)
Mean	42.94 (40.85)	48.50 (44.11)	36.75 (36.95)	43.50 (41.20)	

Figures in parentheses represent angular transformed values
There was no honey bee activity at 0600-0800 h and 1600-1800 h

	SE(m)	CD (p= 0.05)
Bee species	(0.89)	(2.52)
Time	(0.89)	(2.52)
Bee species × Time	(1.78)	(5.04)

Both pollen and nectar gatherers of *Apis* spp. were recorded maximum at 1400-1600 h (53.75%), while the minimum were recorded at 1200-1400 h (38.25%) in *B. juncea*. The present results are in agreement of the findings of Brar *et al.* (2008a, b) [22, 23] who reported that *A. mellifera* foraging simultaneously for both nectar and pollen was higher in the morning at 1000 h and again in the evening at 1600 h. Whereas, *A. cerana indica* foraging simultaneously for both nectar and pollen was highest at 1600 h. However, in contrary to the present results, Mohr and Jay (1988) [15] reported that nectar- pollen gatherers of both the species were at their peak at 1200 h on *B. napus* and *B. campestris*. Similarly, findings of Raj and Rana (1993) [21] and Rana *et al.* (1997) [16] also confront the present results as they reported that *A. mellifera* and *A. cerana indica* showed more nectar plus pollen collection at 1200 and 1500 h than at 0900 h on *B. campestris* bloom.

Top or side workers of different bee species on *B. juncea* variety RH-0749 flowers

The proportion of top and side workers of different *Apis* spp. on *B. juncea* flowers during different weeks of the flowering are presented in Figure 5. It was depicted that the weekly mean proportion of top workers of *A. mellifera, A. cerana indica* and *A. florea* ranged between 78.75 to 86.25, 87.50 to 95.00 and 55.00 to 60.00 per cent, respectively. The maximum percentage of top workers was recorded from 4th week of flowering in *A. mellifera* (86.25%) and *A. florea*

(60.00%), while, the maximum percentage of top workers in *A. cerana indica* (95.00%) was recorded from 3rd week of flowering. Whereas, all *A. dorsata* bees (100.00%) were working as top foragers throughout the period of investigation.

The weekly mean proportion of side workers of *A. mellifera*, *A. cerana indica* and *A. florea* ranged between 13.75 to 21.25, 5.00 to 12.50 and 40.00 to 45.00 per cent, respectively. The maximum percentage of side workers was recorded from 2nd week of flowering in *A. mellifera* (21.25%), 1st and 2nd week of flowering in *A. cerana indica* (12.50%) and 1st week of flowering in *A. florea* (45.00%). The minimum percentage of side workers was recorded from 4th week of flowering in *A. mellifera* (13.75%) and *A. florea* (40.00%), while the minimum percentage of side workers in *A. cerana indica* (5.00%) was recorded from 3rd week of flowering.

Top workers of different bee species on *B. juncea* flowers

The proportion of top workers of different bee species on the flowers of *B. juncea* has been presented in Table 4. The data revealed that the mean proportion of all the bees working as top foragers during different day hours ranged between 69.67 to 84.92 per cent. The maximum top workers (84.92%) were recorded at 0800-1000 h which differed significantly with different times of the day, while the minimum (69.67%) were recorded at 1400-1600 h. The mean proportion of top workers recorded at 1000- 1200 h (79.33%) was statistically at par with that at 1200-1400 h (76.33%).

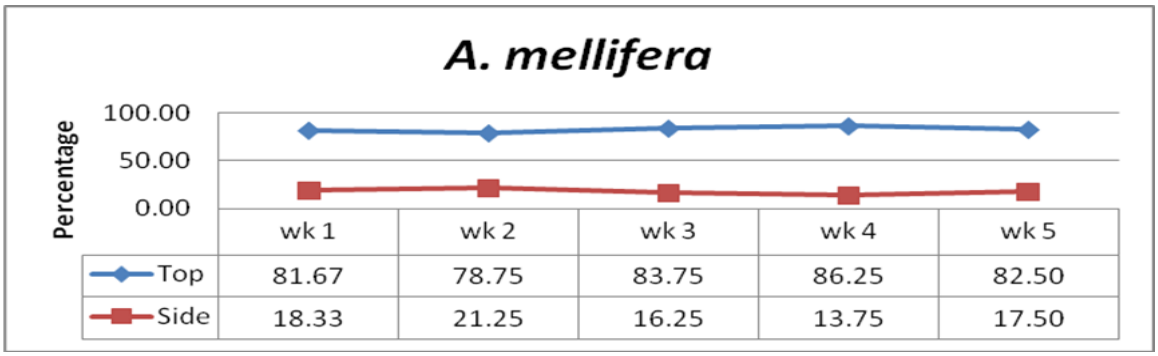
Table 4: Percentage of top workers of different bee species on the flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

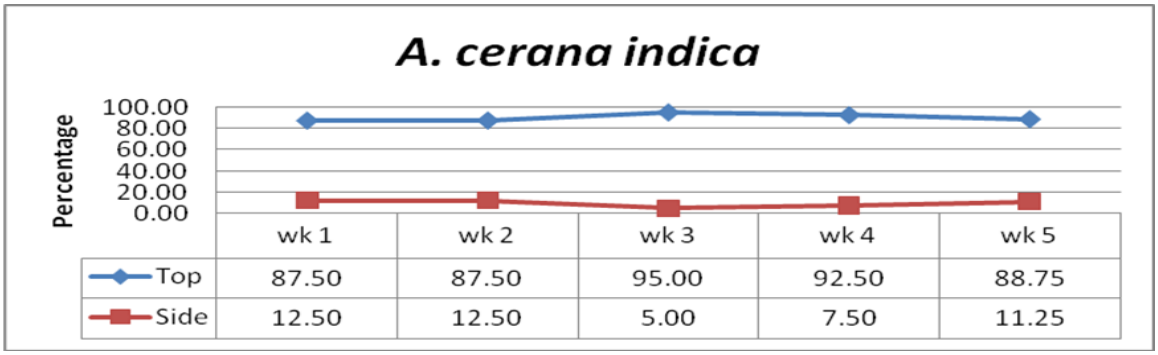
Foraging time (h)	*A. mellifera*	*A. cerana indica*	*A. florea*	Mean
0800-1000	88.75 (70.78)	96.00 (80.88)	70.00 (56.80)	84.92 (69.49)
1000-1200	87.00 (69.04)	89.00 (70.89)	62.00 (51.98)	79.33 (63.97)
1200-1400	80.00 (63.55)	91.00 (72.87)	58.00 (49.61)	76.33 (62.01)
1400-1600	76.00 (60.71)	85.00 (67.30)	48.00 (43.84)	69.67 (57.28)
Mean	82.94 (66.02)	90.25 (72.99)	59.50 (50.56)	

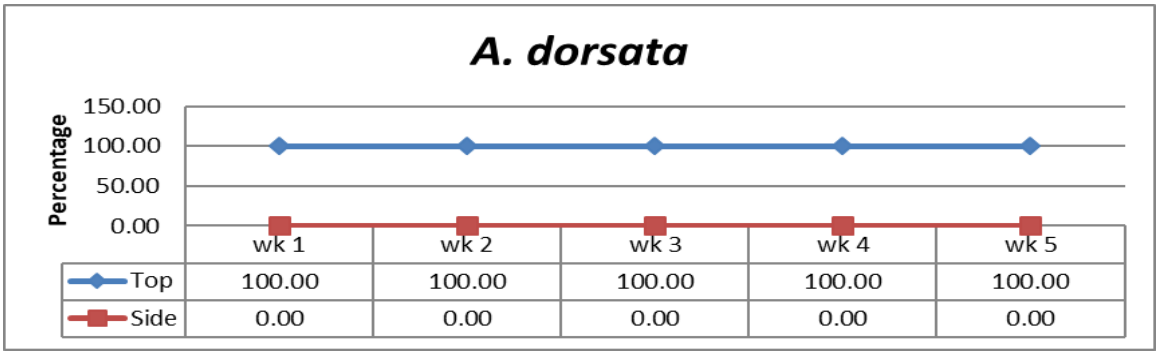
Figures in parentheses represent angular transformed values

There was no honey bee activity at 0600-0800 h and 1600-1800 h

	SE(m)	CD (p= 0.05)
Bee species	0.87	2.48
Time	1.00	2.87
Bee species × Time	1.74	N.S.







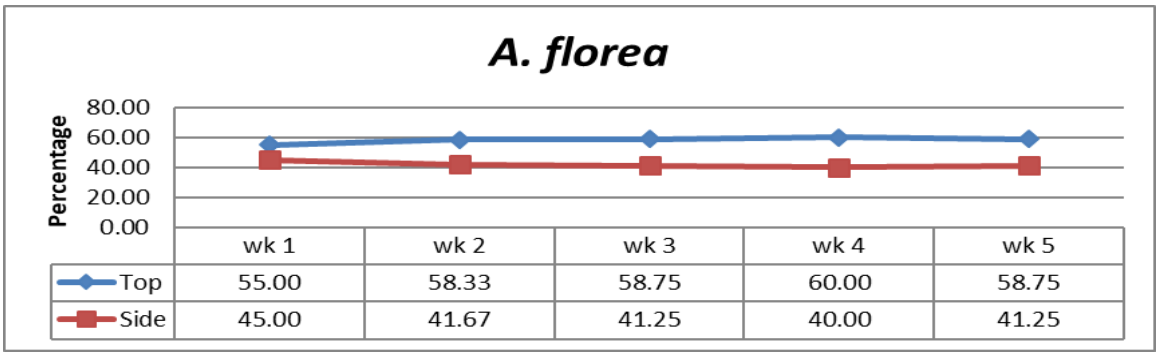


Fig 5: Percentage of top or side workers of different bee species on flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

Side workers of different bee species on *B. juncea* flowers

The proportion of side workers of different bee species on the flowers of *B. juncea* has been presented in Table 5. The data revealed that the maximum side workers (30.33%) were recorded at 1400-1600 h which differed significantly with other times of the day, while the minimum (15.08%) were recorded at 0800-1000 h. The mean proportion of side workers recorded at 1000-1200 h (20.67%) was statistically at par with that at 1200-1400 h (23.67%).

Table 5: Percentage of side workers of different bee species on the flowers of *Brassica juncea* variety RH-0749 during the year 2015-2016

Foraging time (h)	*A. mellifera*	*A. cerana indica*	*A. florea*	Mean
0800-1000	11.25 (19.18)	4.00 (8.85)	30.00 (33.18)	15.08 (20.40)
1000-1200	13.00 (20.92)	11.00 (19.06)	38.00 (37.98)	20.67 (25.99)
1200-1400	20.00 (26.42)	9.00 (17.09)	42.00 (40.36)	23.67 (27.96)
1400-1600	24.00 (29.26)	15.00 (22.66)	52.00 (46.13)	30.33 (32.68)
Mean	17.06 (23.94)	9.75 (16.92)	40.50 (39.41)	

Figures in parentheses represent angular transformed values
There was no honey bee activity at 0600-0800 h and 1600-1800 h

	SE(m)	CD (p= 0.05)
Bee species	0.88	2.51
Time	1.02	2.90
Bee species × Time	1.76	N.S.

In the present study, the maximum proportion of top workers was observed in *A. cerana indica* (90.25%) followed by *A. mellifera* (82.94%) and the minimum proportion was observed in *A. florea* (59.50%). Whereas, *A. florea* (40.50%) had the maximum side foragers followed by *A. mellifera* (17.06%) and *A. cerana indica* (9.75%). Thus, there was very less population of *A. mellifera* and *A. cerana indica* who were side foragers. All the bees of *A. dorsata* were working as top foragers on *B. juncea*. *A. mellifera*, *A. cerana indica*, *A. dorsata* and *A. florea* were most active between 1200-1400 h. Top foraging by *A. mellifera*, *A. cerana indica*, *A. dorsata* and *A. florea* was the maximum between 0800-1000 h (84.92%), while the maximum side foraging was recorded between 1400-1600 h (30.33%) on *B. juncea*.

Results of the present study are strongly supported by the findings of Delbrassinne and Rasmont (1988) [24] who reported that *A. mellifera* showed both types of foraging mode that is top foragers and nectar robbing as side foragers on *B. napus*. Similar results were reported by Sihag (1988) [25] in cruciferous crops, that *A. mellifera* showed both the top and side foraging behavior in Hisar. In contrast to the present findings, Free and Fergusson (1983) [26] reported on *B. napus*, that all *A. mellifera* bees worked as top foragers. Similar results were reported by Sharma *et al.* (2001) [27] that all the bees foraged as top workers on *B. campestris* var. sarson except *A. florea* which foraged as side worker on *Brassica* flowers at Chaudhary Charan Singh Haryana Agricultural University, Hisar.

4. Conclusion

From the findings of research conducted, it was observed that the nectar foraging and pollen gathering was maximum in *A. dorsata* bees. Whereas, foraging for both nectar and pollen was the maximum in case of *A. cerana indica* and minimum in case of *A. dorsata* bees. The nectar and pollen foraging by *Apis* spp. also depends on the different day hours, as the maximum nectar and pollen foraging was recorded at 1200-1400 h and 0800-1000 h respectively. All the bees of *A. dorsata* were found to be working as top workers. Whereas, the maximum proportion of side workers were observed in *A. florea*, followed by *A. mellifera* and *A. cerana indica*.

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