Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2015; 3(3): 203-207

Received: 14-04-2015
Accepted: 17-05-2015

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Foraging behavior of the Himalayan Honeybee, *Apis cerana* (Hymenoptera: Apidae) associated with sunflower *(Helianthus annuus* L.) at Peshawar District of Khyber Pakhtunkhwa (KP)

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Abstract
This paper presents foraging behavior of the Himalayan Honeybee, *Apis cerana* associated with sunflower, *Helianthus annuus* L. The current study was conducted under field conditions at New Developmental Farm (NDF), The University of Agriculture Peshawar, (34.01° N, 71.53° E) Khyber Pakhtunkhwa (KP), Pakistan for two consecutive years i.e. 2012 and 2013. *A. cerana* initiated their foraging activities on floral heads of sunflower early in the morning and ceased in the late/evening hours of the day. Total length of foraging movement comprised of 10 hours. A total of two peaks of feeding activities were recorded. First peak was recorded at 1200 hours, while second peak of foraging was noticed at 1000 hours of the day. From pollination point of view, both peaks were of prime importance. Foraging activities of *A. cerana* were slowly turned down to its minimum level during late hours of the day i.e. 1800 hr.

Keywords: *Apis cerana,* Foraging behavior, Pollination, Sunflower, Peshawar, Pakistan

1. Introduction
Honeybees (*Apis* spp.) are the most important insect visitors of numerous crop species. Their body parts are well adapted to undertake pollination process of various agricultural and horticultural crops. Wide range of host range enables honeybee species to pollinate several types of crops. Honeybees have longest visit time to crops and are less affected by unfavorable climatic conditions as compared to many other insect pollinators. Their close relation to a lot of imperative crops and its foraging behavior makes them successful insect pollinators. Honeybees are reported to have an essential role in enhancing the efficiency level of many crops including most of seed species crops [3, 1, 19]. They also improve quality of seeds per fruit in various vegetable crops. Blossoms of seed species crops are eye-catching in colors and contain high level of nectar, pollens and aroma, which ultimately magnetize large numbers of insect visitors including different species of honeybees. Honeybees, which embraces chief insect visitor as pollinator or foragers on many seed species crops play considerable role in pollination of these crops [10].

Previous studies carried out by Moeller *et al.* and Neupane [12, 14] have shown that honeybee pollination can enhance fruit set by 10 to 25 per cent and fruit yield by 18 to 100 per cent depending upon the cultivar. Sunflower is such a crop that is generally fertilized by wind. Even though, the wind is considered as the chief pollinator for many flowering plants, yet it is not adequate enough for pollination on many kinds of plants including sunflower *(H. annuus* L.) because it is not competent to offer homogenous pollination as well as not being able to carry heavy pollens [5, 16, 6]. *Apis cerana* is the only social honeybee species present at high altitude in the Asian tropics and in northeastern Asia and is considered an important pollinating agent [4]. Worker bees of *A. cerana* forage less number of pollens from different flowers than that of *A. mellifera,* which forage and carry huge pollen loads from flowers. However, *A. cerana* individuals forage heavier pollens during early morning hours [17].

As per report of ICIMOD [7] population density of *A. cerana* in the region is declining because of many reasons i.e. extensive inclusion and promotion of *A. mellifera* species by public and private sector through developmental intrusion, alteration in their habitat and biodiversity, non-judicious use of pesticides, diseases and parasites attack etc. When two or more bee species struggle for the same sources of pollen and nectars, it has been noticed that the more

powerful and aggressive species generally dislodge the weaker species from the floral sources in an area which, severely affecting proportion of crop pollination. Similarly, the existence of *A. mellifera* dislocated and declined the incidence of *A. cerana* individuals from the geographical area [17, 13].

Keeping in view the importance of pollinators, the current investigation was taken up with the objective to study the foraging behavior as well as population density of the Himalayan honeybee *(A. cerana)* in Peshawar District of Khyber Pakhtunkhwa (KP).

2. Materials and methods

Present investigation on foraging activities of the Himalayan honeybee *(A. cerana)* associated with sunflower was carried out the New Developmental Farm (NDF) of the University of Agriculture Peshawar, located 34.01° North latitude and 71.53° East longitude with 306 meters elevation above the sea level. The experiment was conducted during two growing seasons i.e. spring and autumn in 2012 and 2013. Sunflower hybrid Hysun-33 raised as a test crop @ 2.5 kg per hectare during the course of experimentation. Sowing of sunflower seeds was done manually on ridges by dibbling three seeds per hull up to a depth of 3cm to maintain optimum population per plot. Following emergence, thinning was done for getting optimum population of plants. Weekly irrigation and other recommended agronomic and cultural practices were adapted uniformly to all the treatments. The experimental area was kept free from any pesticidal application during the blooming period of the crop. The experiment was laid out in Randomized Complete Block (RCB) design, which was replicated four times. Plot size was kept 3 × 3 m2 with 5 rows that were 60 cm apart from each other. Plant-to-plant distance was maintained 30 cm respectively. The following parameters were studied during the course of experiment:

2.1 Foraging behavior of *Apis cerana*

The Himalayan honeybee *(A. cerana)* exploited sunflower as source of pollen and nectar during its blooming period. Observation on bee visit to sunflower floral heads was started from initiation of 5 per cent flowers on the crop and continued until 35th days after flowering. Observation on bee visitation after a gap of 5 days was recorded at 6 different time intervals i.e. 0800, 1000, 1200, 1400, 1600 and 1800 hrs of the day. Observation were taken on total number of bee visits for a maximum period of 5 minute in an area of 3 m^2 in each replication during different time intervals, thus average relative abundance and foraging behavior was worked out. The experiment was comprised of following 6 treatments.

T1 = 0800 hr, T2 = 1000 hr, T3 = 1200 hr, T4 = 1400 hr, T5 = 1600 hr, T6 = 1800 hr

2.2 Statistical analysis

Collected data were analyzed according to the procedure appropriate for randomized complete blocked design (RCBD) combine over year and season by using statistical software, Gen-Stat third edition. Least significance test was performed for separation of means when the F- test was found significant.

3. Results

3.1 Foraging activity of *Apis cerana* on sunflower Hysun-33 during spring 2012-13

Foraging behavior of bees on crop at different time intervals showed that 5 days after initiation of flowers on the crop, maximum (6.00) incidence of *A. cerana* individuals were recorded during noon at 1200 hr, which was further followed by second peak (5.12) of foraging activities at 1000 hrs. Similarly, mean incidence of *A. cerana* was recorded as 4.37, 4.12 and 3.50 individuals per 3 m^2 area per 5 minutes at 1400, 1600 and 0800 hrs respectively, whereas lowest foraging activity was found at 1800 hrs of the day (Table-1).

After 10 days, 5 per cent blooming on sunflower, *A. cerana* constituted maximum (6.50 and 5.76) strength of bee counts at 1200 and 1000 hrs respectively and was followed by an average number of 5.12 and 4.75 bees at 1400 and 1600 hrs of the day. It was found that lowest (3.12 and 3.87) foraging activities were observed at 1800 and 0800 hrs respectively.

On 15th day after flowering, the foraging activity of *A. cerana* started at 0800 hr with 4.50 bees/3m^2/5 min and increased to its maximum numbers of 7.12 and 6.37 bees at 1200 and 1000 hr. Similarly, mean incidence (5.87 and 5.12) of *A. cerana* individuals was counted at 1400 and 1600 hrs.

Minimum strength was recorded with 3.62 bees at 1800 hrs of the day.

On 20th day of 5 per cent of flowering on the crop, *A. cerana* individuals foraging activities were observed with 5.12 bees per 3 m^2 area for 5 minutes at 0800 hr and it was found that incidence of bees continuously increased to its maximum strength of 8.12 at 1200 noon, which was further followed by a mean counts of 7 bees at 1000 hrs. Further, at 1400 and 1600 hrs the average counts of *A. cerana* individuals were recorded as 6.25 and 5.62, respectively. The foraging activities were declined to least count of 4.12 bees at 1800 hr during evening hours of the day.

On 25th day after flowering, the first peak of foraging activities of *A. cerana* was recorded at 1200 and 1000 hr with 8.62 and 7.75 bees/3m^2/5 minutes. It was noticed that population of bees started declining towards the evening hours with mean count of 6.50 and 6.12 individuals of *A. cerana*. Similarly, the least activity was found at 1800 hr, which recorded only 4.75 bees/3m^2/5min.

On 30th day after crop blooming stage, it was noticed that highest bee visitation was occurred at 1200 noon with average number of 5.37 bees, which was followed by a second peak of 4.87 individuals of *A. cerana* at 1000 hrs of the day. During early hours of the day at 0800 hr, mean number of bees were counted as 3.62. Less foraging activities of bees were observed during late hours and was found that mean number of 4.50 and 4.12 bees were engaged in foraging at 1400 and 1600 hrs respectively, which attained its minimum count of 2.62 bees/3 m^2/5 minutes at 1800 hrs.

Foraging activities of *A. cerana* on sunflower after 35th days of crop flowering stage showed that their incidence declined due to maturity of crop and less availability of pollens and nectar on flowers. However, highest (4.12 and 3.75) mean counts of bee individuals were made at 1200 and 1000 hr respectively. Another peak was noticed with 3.25 bees/3 m^2/ 5 minutes at 1400 hr and was followed by 2.75 and 2.30 bees at 1600 and 0800 hrs of the day. Minimum (1.87) level of bee population was found at 1800 hr of the day.

Table 1: Foraging behavior of *Apis cerana* per 3 m^2 per 5 minutes on Sunflower Hysun-33 during spring 2012-13

Treatments (Hours)	5 DAF	10 DAF	15 DAF	20 DAF	25 DAF	30 DAF	35 DAF
0800 hr	3.50x-zab	3.87u-z	4.50p-v	5.12k-q	5.50h-n	3.62w-za	2.30d-h
1000 hr	5.12k-q	5.76f-l	6.37d-g	7.00c-e	7.75bc	4.87m-s	3.75v-z
1200 hr	6.00f-j	6.50d-f	7.12cd	8.12ab	8.62a	5.37i-o	4.12s-x
1400 hr	4.37q-w	5.12k-q	5.87f-k	6.25e-h	6.50de	4.50p-v	3.25yza-c
1600 hr	4.12s-x	4.75n-t	5.25j-p	5.62g-m	6.12f-i	4.12s-x	2.75b-f
1800 hr	2.87a-e	3.12za-d	3.62w-za	4.12s-x	4.75n-t	2.62c-g	1.87g-i

Means in the columns followed by different letters are significantly different from one another at ($P \leq 0.05$) level of probability

$LSD_{0.05} = 0.86$

DAF = Days after flowering

3.2 Foraging activity of *Apis cerana* on sunflower Hysun-33 during autumn 2012- 13

Data presented in table-2 indicated that on 5th day after 5 per cent of flowering on the crop, the foraging activity of *A. cerana* started at 0800 hr with 2.37 bees/3m^2/5min and attained its highest counts of 4.25 and 3.75 bees/3m^2/5min at 1200 and 1000 hr respectively. Further, an average frequency (3.12 and 2.87) of *A. cerana* individuals were recorded at 1400 and 1600 hrs. Minimum count of bees was recorded with 1.87 bees/3m^2/5 minutes at 1800 hrs of the day.

On 10th day after flowering, *A. cerana* foraging activities were observed with highest count of 4.62 and 4.12 bees per 3 m^2 area for 5 minutes at 1200 and 1000 hrs of the day respectively, which was further followed by a mean population of 3.62 bees at 1400 hr. Further, at 0800 and 1600 hrs the counts of *A. cerana* individuals were recorded as 2.87 and 3.25 respectively. The foraging activities of A. *cerana* individuals were turned down to least incidence of only 2.12 bees at 1800 hr during evening hours of the day.

Data regarding foraging behavior of *A. cerana* on 15 days after blooming stage of the crop revealed that the foraging activity occurred throughout the whole day that was recorded right from 0800 through 1800 hr. First peak of *A. cerana* foraging activity was recorded at 1200 hr of the day with 5.25 bees whereas second peak foraging activity was found at 1000 hr with 4.75 bees and was followed by 4.00 individuals at 1400 hrs of the day. Further, the mean incidence of *A. cerana* was recorded as 3.62 and 3.12 bees/3m^2/5 minutes at 1600 and 0800 hrs of the day. Minimum activity of bees was found at 1800 hrs, which recorded only 2.50 individuals of *A. cerana.*

Foraging activities of Himalayan bees on sunflower after 20th days flowering indicated that their population increased due to more number of nectars and pollens on floral heads of sunflower. Highest (5.87 and 4.12) mean frequency of *A. cerana* individuals were recorded at 1200 and 1000 hr respectively. The next peak foraging was observed with 4.50 bees/3m^2/5 minutes at 1400 hr and was followed by 4.25 bees at 1600 hrs of the day at 0800 hr. An average density of 3.62 bees was recorded during early hours of the day. Significantly, lowest (2.87) population of bees was found at 1800 hr of the day.

Similarly, on 25th day after crop blooming stage, again it was noticed that highest number of bee visitation took place due to more number of plants in blooming. Maximum foraging recorded at 1200 noon with mean number of 6.00 bees, which was followed by a second peak of 5.00 individuals of *A. cerana* at 1400 hrs of the day. Further, at 1000 and 1600 hr, average counts on bee foraging was made as 4.87 and 4.62 bees/3m^2/5 minutes respectively. Mean number of bees at 0800 hr were counted as 3.75 whereas minimum counts with 3.12 bees/3m^2/5 minutes was noticed at 1800 hrs of the day.

On 30th day after flowering, the first peak of foraging activities of *A. cerana* was found at 1200 and 1000 hr with 4.50 and 3.87 bees/3m^2/5minutes. An incidence of 2.50 bees of *A. cerana* was observed at 0800 hr of the day. It was noticed that mean number of bee individuals were started declining during late hours in the evening. Mean counts of 3.12 and 2.87 individuals of *A. cerana* was recorded at 1400 and 1600 hr, whereas an average count on only 2.00 bees recorded at 1800 hr.

On 35th day after crop blooming stage, it was found that significantly more (3.12 and 2.87) number of bee individuals were recorded at 1200 and 1000 hr respectively which was followed by 2.62 bees at 1400 hr. Average count of *A. cerana* was noticed with 2.00 and 1.75 bees/3m^2/5 minutes at 1600 and 0800 hr of the day, whereas minimum (1.37) foraging activity was recorded at 1800 hrs of the day.

Table 2: Foraging behavior of *Apis cerana* per 3 m^2 per 5 minutes on Sunflower Hysun-33 during autumn 2012-13

Treatments (Hours)	5 DAF	10 DAF	15 DAF	20 DAF	25 DAF	30 DAF	35 DAF
0800 hr	2.37d-h	2.87a-e	3.12za-d	3.62w-za	3.75v-z	2.50c-h	1.75hi
1000 hr	3.75v-z	4.12s-x	4.75n-t	5.12k-q	4.87m-s	3.87u-z	2.87a-e
1200 hr	4.25r-x	4.62o-u	5.25j-p	5.87f-k	6.00f-j	4.50p-v	3.12za-d
1400 hr	3.12za-d	3.62w-za	4.00t-y	4.50p-v	5.00l-q	3.12za-d	2.62c-g
1600 hr	2.87a-e	3.25yza-c	3.62w-za	4.25r-x	4.62o-u	2.87a-e	2.00f-i
1800 hr	1.87g-i	2.12e-i	2.50c-h	2.87a-e	3.12za-d	2.00f-i	1.37i

Means in the columns followed by different letters are significantly different from one another at ($P \leq 0.05$) level of probability

$LSD_{0.05} = 0.86$

DAF = Days after flowering

4. Discussion

Apis cerana indica foraging activity was found throughout flowering period of sunflower. Individuals of *A. cerana* generally commenced their foraging activity early in the morning hours, which attained its peak in the noon hours of the day. The foraging activity of *A. cerana* was recorded at their peak at 1000 hr and 1200 hr respectively. The population of the bees was high up to 1600 hr, but in the evening hours, their incidence was declined and minimum foraging was observed during late hours of the day at 1800 hr. During the flowering period, bee activity was highest on 20th and 25th day after initiation of flowers on the crop. The lowest visitation was observed during 30th and 35th days after flowering on the crop due to less pollens availability due to

maturity of the crop. The peak foraging hours of the visit coincide with the number of blooming flowers. According to Singh [19] the peak hours of foraging activity of honeybees are of great importance from the pollination point of view, because by keeping different bee species in the agricultural blooming crops, the total period of peak foraging activity can be increased for timely pollinating the blooming flowers and for intense honey harvest. The present results more or less endorses the previous reports of Panda *et al*. [15] who recorded maximum bee visitation from 1100 to 1200 hr during the flowering days. Similarly, Ahmed and Rehman [2] reported the peak activity of *A. cerana* indica on sunflower at 1100 to 1200 hr. The present findings are also in accordance with the views of Singh *et al.* [19], Verma and Partap [21] and Joshi [8] where they made similar observations on commencement, termination and extent of *A. cerana* foraging activity on *Brassica juncea*.

The time spent by bees for foraging on the flowers depends on the availability of nectar and pollen on the flowers of the crop. It also differs with the type of flower on which they forage and the stage of its development with climatic conditions. In the present study, it was observed that the time spent on the flowers by *A. cerana* was more during early hours than in the afternoon hours of the day. This agree with the earlier observation made by Kopel'kievski [9] who stated that different insect visitors are mostly forage on the flowers between 0900 through 1200 hrs of the day. This may be because nectar flow is numerous in the flowers particularly during early hours of the day, there after the nectar availability little by little reduced Solov'ev [20].

5. Conclusion

From the study, it is concluded that pollination by different honeybee species is the most significant contribution in sunflower seed production. It was also believed not to be confined to sunflower pollination simply with honeybee species, but needs to sustain and conserve other insect visitors, thus strategies to endorse pollination by honeybees may be supportive in enhancing seed yield in sunflower and possibly in many other agricultural crops.

6. Recommendation

Different species of pollinators are encouraged to have easy access to seed crops for getting higher yields. Colonies of honeybees should be placed near the fields during flowering period of the crops, which will eventually improve yield and quality of sunflower. Farmer communities should stay away from broad use of chemical insecticides throughout peak blooming periods of sunflower and other crops in order to protect and conserve natural enemies and other insect visitors.

7. Acknowledgment

The authors thankfully acknowledge the kind collaboration received from Faculty members, Chairman, Department of Entomology, Dean (Faculty of crop Protection Sciences), and Farm Manager, New Developmental Farm (NDF) of The University of Agriculture, Peshawar, Khyber Pakhtunkhwa-Pakistan. The financial assistance provided by the Higher Education Commission (HEC) Islamabad, Government of Pakistan is also highly acknowledged.

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