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## Foraging behaviour of Carpenter bee (*Xylocopa fenestrata*) on Ridge gourd (*Luffa acutangula*) flowers

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**Abstract**

The foraging behaviour of Carpenter bee (*Xylocopa fenestrata* Fab.) was studied in ridge gourd, *Luffa acutangula* under field condition at University Apiary, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur (Bihar) during the year of 2016-17 in *Kharif* season. The results on foraging behaviour of *Xylocopa fenestrata* revealed that the bees started visiting ridge gourd flowers in early morning and ceased their activity later in the evening. It remained active throughout the flowering period. The minimum foraging rate of *X. fenestrata* was 3.9 flowers/minute in the morning hours (0700-h) and 3.2 flowers/minute in evening hours (1700-h) however, maximum was 7.3 flowers/minute during the mid day hours (1300-h). The maximum foraging speed was 17.6 sec. in morning hours (0700-h) and 23.5 sec. in evening hours (1700-h) while minimum 11.1 sec. in mid day hours (1300-h) and there was inverse relation between foraging rate and foraging speed. The heaviest pollen load carried by the *Xylocopa* was 28.54 mg in the evening hour (1700-h) while lightest pollen load was carried 9.75 mg in mid day hour (1300-h) which indicated that more pollen was collected by *Xylocopa* during morning and evening hours from ridge gourd flowers.

**Keywords:** Foraging behavior, *Xylocopa fenestrata*, ridge gourd

**1. Introduction**

The ridge gourd [*Luffa acutangula* (Roxb.) L.] is an important cucurbitaceous vegetable and being predominantly monoecious and cross pollinated crop [5]. It is a climbing herb and found in tropical and subtropical regions [5]. Carpenter bees (*Xylocopa fenestrata*) are effective pollinators of cucurbitaceous crops, and largely distributed in tropical and subtropical habitats around the world, and occasionally in temperate areas [4]. It tolerates high ambient temperatures during foraging, and most species are inactive at low temperatures. These traits make them attractive pollinators for agricultural pollination in hot climates, particularly in greenhouses, and of night-blooming crops [6]. Current challenges to commercialization of these attempts lie in the difficulties of mass rearing of carpenter bees to ensure pollination of crops [6]. Carpenter bees possess several advantages as potential crop pollinators compared to other non *Apis* bees. Many solitary bees have a short activity season and/or are specialist foragers, and therefore, do not provide a broad alternative to honey bee pollination [6]. Carpenter bees, on the other hand, have long activity seasons and feed on a wide range of plant species. In addition, they are capable of buzz pollination. This makes them potentially more versatile as agricultural pollinators [6]. There is lack of comprehensive information on extends of dependence of ridge gourd on *X. fenestrata* Fab. for pollination. Therefore, the present investigation was undertaken to utilize *X. fenestrata* as input to this crop for enhancing the yield.

**2. Materials and Methods**

The present experiment was conducted on ridge gourd (*Luffa acutangula*) which was grown with recommended agronomic package and practices at University Apiary, Dr. Rajendra Prasad Central Agricultural University Pusa, Samastipur (Bihar) during the year of 2016-17 in *Kharif* season to know the foraging behavior of Carpenter bee (*X. fenestrata*) on ridge gourd flower. The crop was grown in RBD with three replications. The important materials were used to assess the foraging activity of *X. fenestrata* i.e. Stop watch, Insect net, forceps, Hand tally counter, fine brush, electronic balance, etc. The foraging pattern of *Xylocopa fenestrata* on ridge gourd bloom was assessed.

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The observations were recorded on duration of foraging, foraging rate, foraging speed and pollen load per trip per bee (mg).

### 2.1. Duration of foraging

With a view to find out the foraging period of *Xylocopa* on ridge gourd 10 observations were taken on different dates between 17/09/2016 to 22/10/2016 at 3-days intervals in morning and evening hours. The morning hours when *Xylocopa* started visiting ridge gourd flower was recorded as initiation time. Similarly, the time when there were no *Xylocopa* bees on the flower in the evening then it was considered as cessation time. Duration of foraging (in minutes) was calculated as follows:

**Duration of foraging = Initiation time – Cessation time.**

### 2.2. Foraging Rate

Foraging rate (the number of flowers visited by *Xylocopa* per minute) was observed visually, i.e. the number of ridge gourd flowers were visited by *Xylocopa fenestrata* in a unit time. These observations were recorded for consecutive visits in a minute on 0700-h, 0900-h, 1100-h, 1300-h, 1500-h and 1700-hour of the day at 3-days intervals during the flowering period.

### 2.3. Foraging Speed

Foraging speed (the time spent in second by carpenter bee on a flower) was recorded with the help of stop watch. For this as soon as the *Xylocopa fenestrata* arrived at an individual flower, the stop watch was switched on and the watch was switched off, just after their leaving the flower. The observations were recorded at 0700-h, 0900-h, 1100-h, 1300-h, 1500-h and 1700-hour of the day at 3 days interval.

### 2.4. Pollen load per trip/bee (mg)

The pollen load carried out by carpenter bee from the flower of ridge gourd were recorded at 0500-h, 0600-h, 0700-h, 0800-h, 0900-h, 1000-h, 1100-h, 1200-h, 1300-h, 1400-h, 1500-h, 1600-h, 1700-h and 1800 hour of the day at weekly intervals on different dates by capturing the returning foraging bees from field to bamboo nest. The pollens were dislodged from the bee body (Scopa) with help of a fine brush. The collected pollens were weighed on the electronic precision balance to an accuracy of 0.001 mg. The recorded data is mean of 3 observations on five dates.

## 3. Results and Discussion

### 3.1. Duration of foraging

Duration of foraging was the period between initiation and cessation time of foragers. The data recorded on duration of foraging by *Xylocopa* on ridge gourd is presented in Table 1 and Fig. 1. The data revealed that *Xylocopa* bees started their visit earlier during the initiation of flowering in ridge gourd and ceased their activity quiet later. As the flowering progressed and simultaneously day length decreased the activity of *X. fenestrata* ceased and thereby exhibiting decrease in duration of foraging hours. The duration of foraging was maximum on 17-09-2016 being 13.10 h, while minimum duration of foraging was recorded on 22-10-2016 being 10.50 hr. The duration of foraging of *X. fenestrata* decreased as the flowering progressed towards maturity.

The earlier workers also reported similar trends and present results are in conformity to the earlier findings. [8] reported that the foraging activity of *Xylocopa fenestrata* and *X.*

*leucotorax* on ridge gourd persisted from 5.00 to 19.00 hr and the highest number of visits occurred from 5.00 to 6.00 hr. [2] observed that *Apis cerana* began foraging on summer squash at 0600 hr, whereas *A. dorsata* and *A. florea* at about two hours later and all species ceased foraging at about 1200 hr during February. [9] also reported that *Apis dorsata* started foraging activity on cucumber flowers around 0600 hr, whereas, other insect visitors started activity by 0800 hr. The bees were also affected with sun light which determines initiation and cessation of foraging activity affecting the duration of foraging of insect pollinators.

### 3.2. Foraging rate

The result revealed that the *X. fenestrata* had differential foraging rate on different dates and hours of the day. The data recorded have been depicted in Table 2 and Fig. 2. The foraging rate of *X. fenestrata* was minimum in the morning hours (0700-0900 h) being 3.9-4.0 flowers/min. and at evening hours (1500-1700 h) being 3.8-3.2 flowers/min. The maximum foraging rate was observed during mid day being 7.3 flowers/min. at 1300 h followed by 1100 h being 6.1 flower/min. *Xylocopa* visited more number of flowers during mid day hours which might be due to higher temperature and less availability of available floral rewards particularly nectar. So, less time was spent by bees to gather forage from a flower and more flowers were visited by a *Xylocopa* to collect required amount of food. The maximum mean value of foraging rate was observed 5.2 flowers/min. on 02-10-2016 near crop maturity showing that less floral rewards were available to bees and thus required more flowers to fulfill their food requirement. The factors date and time and their interactions were found significant.

These findings were in close proximity with the earlier reports in which foraging rate has been reported to be dependent upon weather parameters and floral availability. When less reward was available the insect pollinators visited more number of flowers showing higher foraging rate and vice-versa. [1] reported that the higher foraging rate of the bees during mid-day hours. [3] also worked on *Xylocopa fenestrata* pollination on ridge gourd and they observed that highest frequency of flower visit per min/bee was 7.1 at 1700-1800 h followed by 5.9 at 1500-1600-h and it was lowest of 3.4 at 0600-0700-hr.

### 3.3. Foraging speed

The data on foraging speed, i.e. time spent by *Xylocopa* bees on ridge gourd flowers have been presented in Table 3 and Fig. 3. The time spent per flower for collecting floral rewards from ridge gourd flower by *Xylocopa fenestrata* differed significantly. The maximum foraging speed was recorded 18.4 sec. on during mid flowering period while the minimum time spent was recorded 15.3 sec. during end of flowering season. The average time spent/flower was significantly highest during 1700-h (23.5 sec/flower) followed by 1500-h (18.3 sec.), 0700-h (17.6 sec.), 0900-h (16.5 sec.), 1100-h (14.0 sec.) and lowest at 1300-h (11.1 sec./flower). This may be attributed to the fact that more number of flowers were opened with higher flower density, *Xylocopa* bee spent more time to getting more floral rewards. Whereas, the minimum foraging speed was noticed to be 9.3 sec. at 1300-h as there might be less number of opened flower with flower density. Both factors date and time and their interaction was found significant reflecting that date and time have significant impact on foraging speed of *Xylocopa* foragers.

The present finding is more or less similar as previous results

of earlier workers. The foraging speed of bees is directly influenced by availability of floral rewards. When there are more floral rewards available the bees spent more time in collecting rewards. [7] reported that foraging speed of *A. mellifera* on cucumber flowers was the highest during 0900-1000-hr followed by 1000-1100-hr and it was the lowest during 1300-1400-hr of the day during *Rabi* cucumber under polyhouse condition. [3] reported that the maximum time spent per flower were 25.60, 20.8 and 19 sec. at 1600-1700-h, 1800-1900-h and 0400-0500-hr, respectively, while the minimum was recorded to be 14.7 sec. at 0700-0800-hr. Therefore, the result indicated that the availability of floral rewards significantly influence the foraging speed of *Xylocopa*.

**3.4. Pollen load per trip/bee (mg)**

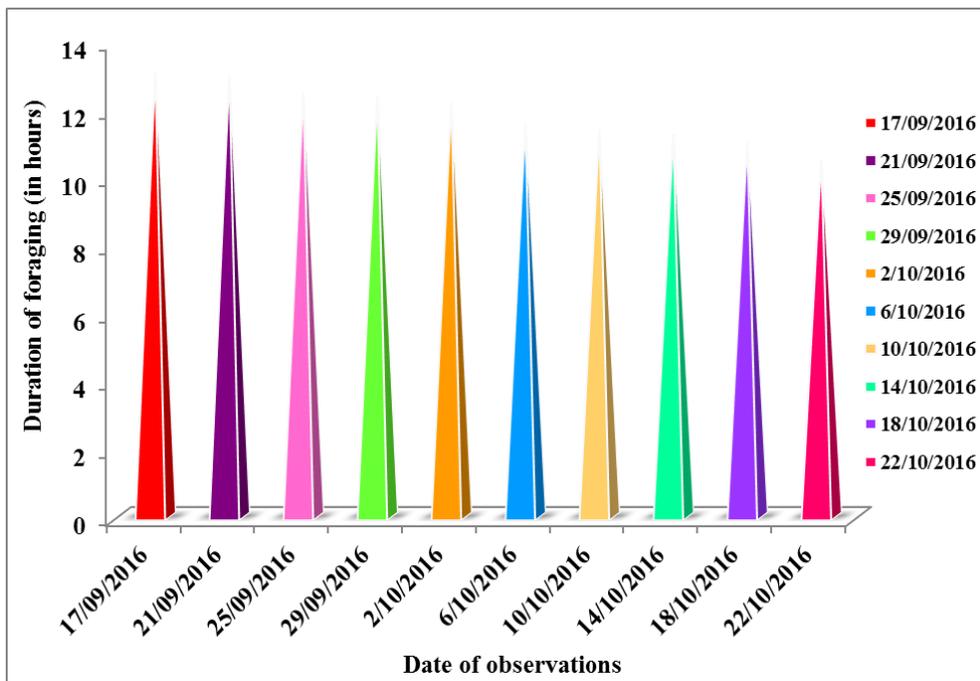
The data recorded during the foraging or carrying pollen by *X.fenestrata* from the flower of ridge gourd is presented in Table 4 and Fig. 4. The results showed significant difference in pollen load carried out by *Xylocopa fenestrata* in different trips. The heaviest weight of pollen was observed (28.54 mg) at 1700 hour of the day and lightest weight of pollen was observed (9.75 mg) at 1300 hour of the day. It might be due to fact that more floral rewards were available at 1700-h, as compared to mid day hours. Therefore, bees collected less

amount of pollen in the mid day which reflected in observation recorded at different hours on pollen load carried by bees to their nest.

Similar observations was also made by [3] who reported that the maximum pollen load (mg) carried out by *Xylocopa fenestrata* was being (28.8 mg) at 1600-1700-hr and it was minimum (16.67 mg) at 0700-0800-hr.

**Table 1:** Initiation and cessation time of *Xylocopa fenestrata* visiting flowers of ridge gourd.

Date of observations	<i>Xylocopa fenestrata</i>		
	Initiation time (I)	Cessation time (C)	Foraging period (P)
17-09-2016	5:00	6:10	13:10
21-09-2016	5:05	6:05	13:00
25-09-2016	5:10	6:00	12:50
29-09-2016	5:15	5:55	12:40
02-10-2016	5:25	5:45	12:20
06-10-2016	5:35	5:30	11:55
10-10-2016	5:45	5:25	11:40
14-10-2016	5:55	5:20	11:25
18-10-2016	6:10	5:15	11:05
22-10-2016	6:20	5:10	10:50
Mean	5:42	5:51	11:90



**Fig 1:** Foraging period of *Xylocopa fenestrata* visiting flowers on ridge gourd.

**Table 2:** Foraging rate of *Xylocopa fenestrata* visiting ridge gourd bloom at different hours of the day.

Date of observations	Mean number of flowers visited/minute						Mean
	700-h	900-h	1100-h	1300-h	1500-h	1700-h	
17-09-2016	3.9	3.6	6.1	7.3	3.8	3.2	4.6
21-09-2016	3.8	3.4	5.9	7.2	3.7	3.1	4.5
25-09-2016	3.7	3.3	5.8	7.1	3.4	3.0	4.3
29-09-2016	4.1	4.2	6.3	7.4	3.9	3.3	4.8
02-10-2016	4.2	5.5	6.4	7.6	4.1	3.4	5.2
Mean	3.9	4.0	6.1	7.3	3.8	3.2	4.6

Factors	S Em (±)	CD (P=0.05)	CV (%)
Date	0.14	0.41	10.12 %
Time	0.11	0.34	
Date × Time	0.13	0.39	

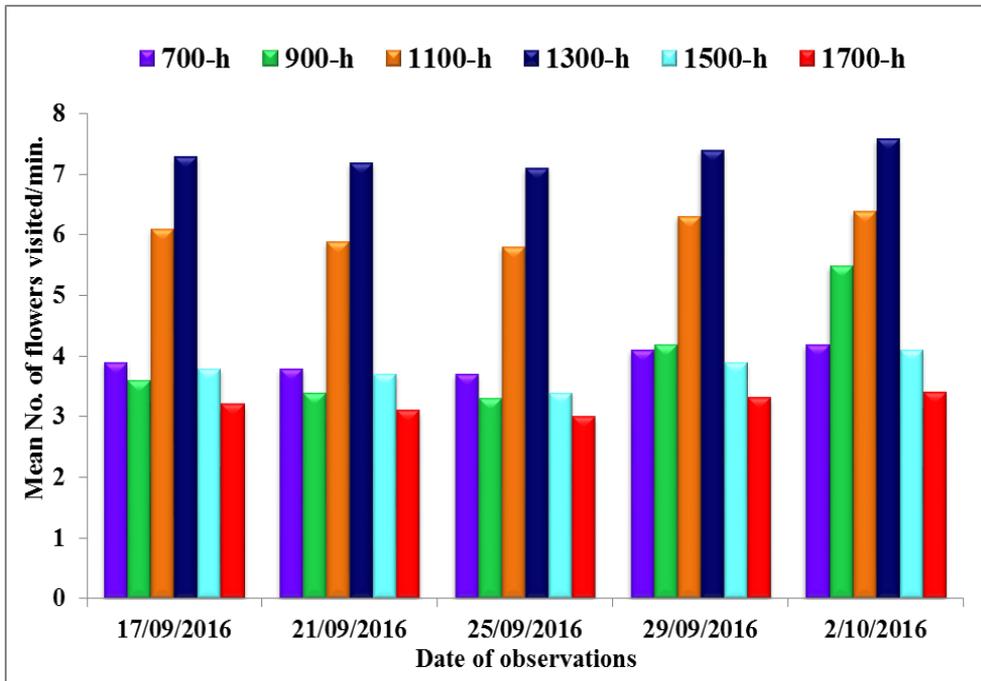


Fig 2: Foraging rate of *Xylocopa fenestrata* visiting ridge gourd bloom.

Table 3: Foraging speed (the time spent in second on a flower) of *Xylocopa fenestrata* visiting ridge gourd bloom.

Date of observations	Time spent on flowers (in sec.)						Mean
	700-h	900-h	1100-h	1300-h	1500-h	1700-h	
17-09-2016	17.5	16.3	13.7	11.2	18.3	23.2	16.7
21-09-2016	18.4	17.2	14.6	11.7	18.7	24.7	17.5
25-09-2016	19.3	17.6	15.8	12.9	19.8	25.4	18.4
29-09-2016	16.7	15.8	13.2	10.6	17.8	22.6	16.1
02-10-2016	16.2	15.4	12.6	9.3	16.8	21.8	15.3
Mean	17.6	16.5	14.0	11.1	18.3	23.5	16.8

Factors	S Em (±)	CD (P=0.05)	CV (%)
Date	0.59	1.72	11.23 %
Time	0.56	1.63	
Date × Time	0.52	1.51	

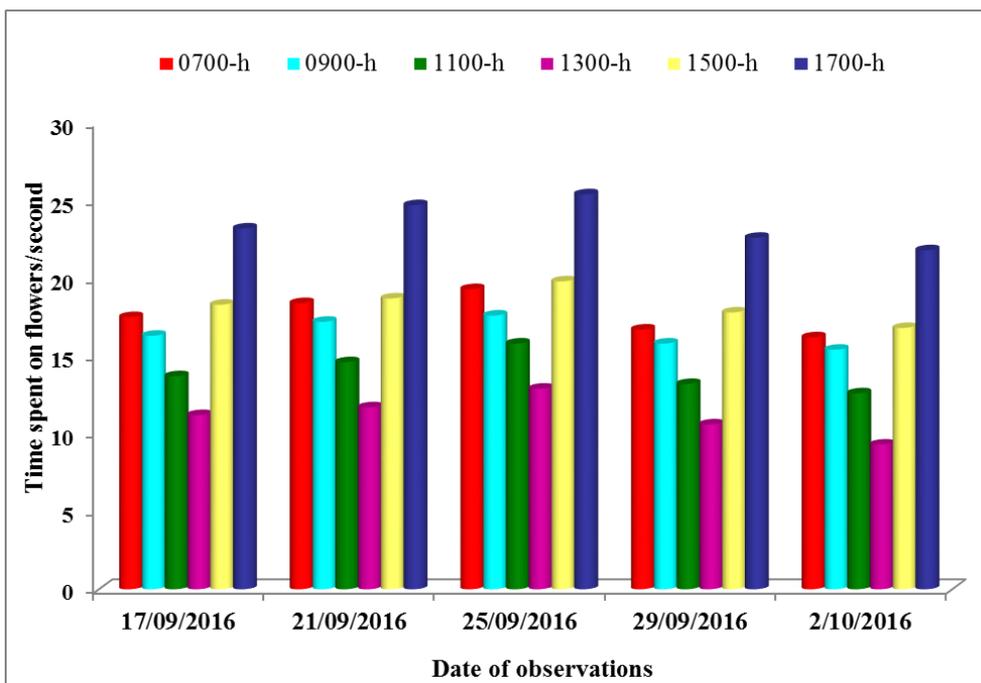
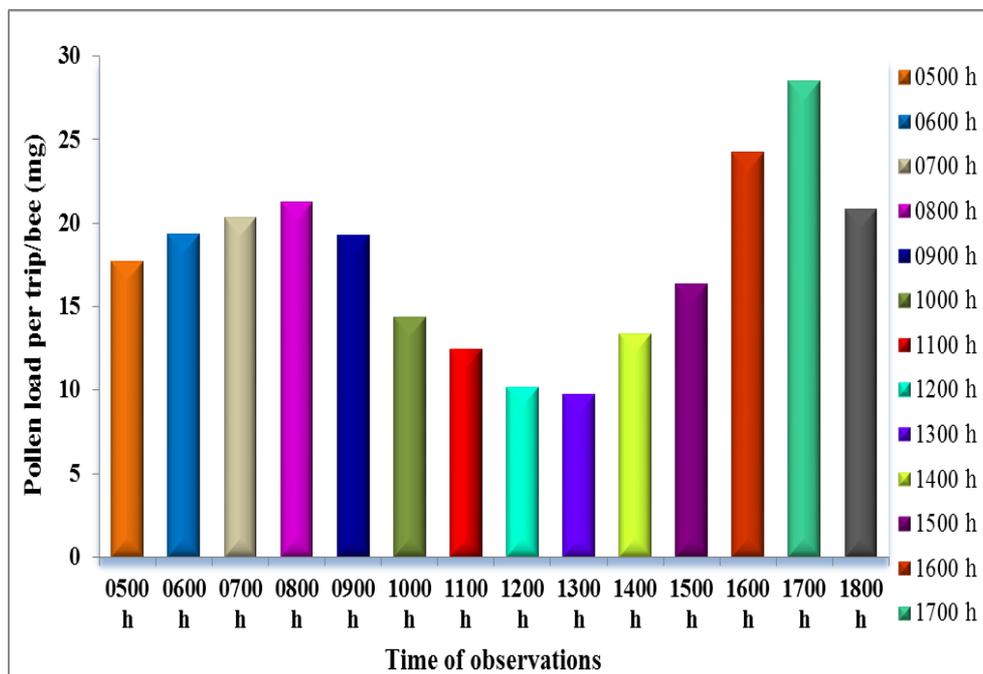


Fig 3: Foraging speed of *Xylocopa fenestrata* visiting ridge gourd bloom.

**Table 4:** Pollen load carried out by *Xylocopa fenestrata* from the flower of ridge gourd.

Time of observations	Pollen load per trip/bee (mg)
0500	17.67
0600	19.36
0700	20.35
0800	21.23
0900	19.24
1000	14.37
1100	12.42
1200	10.15
1300	9.75
1400	13.35
1500	16.34
1600	24.25
1700	28.54
1800	20.84
Mean	17.70
CD	3.27
S Em ( $\pm$ )	1.12

Data is mean of 3 observations on five dates

**Fig 4:** Pollen load carried out by *Xylocopa fenestrata* from the flowers of ridge gourd

#### 4. Conclusion

The present study concluded that the *Xylocopa fenestrata* started their visit earlier during initiation of flowering in ridge gourd and ceased their activity quiet later. As the flowering progressed and simultaneously day length decreased. The duration of foraging of *X. fenestrata* decreased as the flowering progressed towards maturity. The foraging rate of *X. fenestrata* was maximum 7.3 flowers/minute and foraging speed was minimum 11.1 flower/sec during the mid day hour. The inverse relation was observed between foraging rate and foraging speed of *X. fenestrata*. The heaviest weight of pollen load was observed in the evening while lightest weight of pollen load was observed in the noon.

#### 5. Acknowledgement

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