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Foraging behavior of stingless bees, *Tetragonula laeviceps* Smith in net house condition

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Abstract
Studies on foraging behaviour of stingless bees, *Tetragonula laeviceps* Smith on muskmelon flowers in net house condition were carried out at Navsari Agricultural University, Navsari during March 2013 to December 2014. The foraging behaviour of stingless bees with respect to number of outgoing foragers, incoming forager with pollen load and without pollen load recorded at hive entrance revealed that the maximum activity of outgoing foragers was recorded at 12 00 h (37.25 foragers 5 minutes^{-1}). The maximum activity of incoming foragers with pollen load was recorded at 13 00 and 15 00 h (7.42 foragers 5 minutes^{-1}) while that of foragers without pollen load was at 15 00 h (36.64 foragers 5 minutes^{-1}).

Keywords: Stingless bees, *Tetragonula laeviceps*, and foraging behavior

Introduction
Stingless bees, *Tetragonula laeviceps* Smith are the highly social insects like honey bees and produce very less amount of honey. The stings of these bees are greatly reduced hence, the name given stingless bees. Stingless bees are living in permanent colonies and their nest found in old walls, logs, crevices and such other concealed places. Stingless bees are belongs to order hymenoptera and super family Apoidea, family Apidae and sub family Meliponinae. The genera *Melipona* and *Trigona* which belong to the tribe *Meliponinae* and *Trigonini*, respectively [10]. *Trigona* is the largest and most widely distributed genus, which includes 130 spp. under ten sub-genera. *Melipona* consists of 50 species and is confined to the neotropics. All Asian and African species of stingless bees belong to the tribe *Trigonini*. The genus *Trigona* is found in the neotropics from Mexico to Argentina and in the Indo Australian regian from India and Srilanka to Taiwan, east to the Caroline Island. The Solomon Islands and south throughout Indonesia and New Guinea to about latitude 34 S in Australia. The various genera in this tribe include *Trigona, Plebeia, Tetragona* and *Nanotrigona* [1]. Until now, it has been reported that *T. irridipenis* is the only species found in India but recent identification stingless bees collected from South Gujarat region revealed the presence of *T. laeviceps* in India [6]. The colonies of stingless bee are perennial and consist of hundreds or thousands of workers [10]. The number of stingless bee found in colonies ranging from a few dozen to 100,000 or more workers and they are highly social bees [5].

Stingless bees, *Tetragonula laeviceps* has an ability to visit a wide range of flowers like, vegetable crops, fruit crops, oil seed crops, pulse crops, forage crops, weed crops and ornamental and flower plants. In the lowland neotropics, 52 species of plants visited by *Melipona* and 108 of the 128 species visited by other stingless bee species [8]. Melendez-Raminez *et al.* recorded the bee visitors of pumpkin (*Cucurbita moschata* Duchesne), cucumber (*Cucumis sativus* L.), melon (*Cucumis melo* L.) and watermelon (*Citrullus lanatus* L.), on 14 sites in Yucatan, Mexico [4]. The maximum foraging activity by bee species (*Apis ceranaindica* Fabricius, *Apisdorsata* Fabricius and *Trigona* sp.) was noticed between 10 00 to 11 00 h of the day except *Apis florea* Fabricius which recorded the maximum activity during 13 00 to 15 00 h. All the above four species collected both nectar and pollen [9].

Considering the importance of stingless bees, *T. laeviceps* as pollinator, a study was carried out to know the foraging behaviour of stingless bees.

Materials and Methods
The study on foraging behaviour of stingless bees, *Tetragonula laeviceps* Smith on muskmelon flowers in net house condition was carried out at Navsari Agricultural University,

Navsari during March 2013 to December 2014. Three colonies of *T. laeviceps* were placed in net house condition after initiation of flowering. The foraging behaviour of bees of these colonies was recorded throughout the flowering period. The studies were made for a two seasons *i.e., kharif* - 2013 and *rabi* – 2014.

The observations on the foraging behaviour of pollen and non-pollen foragers were recorded at hive entrance at weekly interval. The observations were taken at one hour interval starting from 06 00 h to 17 00 h on number of bees out going and bees coming with pollen and without pollen for a period of five minutes. The data obtained were pooled and statistically analysed considering one colony as replication using Completely Randomized Design (CRD).

Results and Discussion

Foraging behaviour of stingless bee

Foraging activity of stingless bee, *Tetragonula laeviceps* Smith was studied for a two seasons *kharif* - 2013 and *rabi* - 2014 on musk melon crop grown in net house condition at Navsari Agricultural University, Navsari. Three stingless bee colonies were placed in net house with initiation of musk melon flowering.

Outgoing foragers

The observation on the mean number of outgoing foragers was recorded at one hour interval for five minutes at the hive entrance form three stingless bee colonies. To find out the fluctuation in foraging efficiency of outgoing foragers during initiation of flowering to completion of flowering period (Six observations) and the seasons, the data are summarized irrespective of time of the day for the *kharif* - 2013 and *rabi* - 2014.

The analysis of data on number of outgoing foragers during different hours of the day recorded during *kharif* - 2013 are presented in Table 1. The analysis of data on number of outgoing foragers recorded at different hours of the day revealed significant variation in activity during different hours of the day.

The activity of outgoing foragers started at 06 00 h (10.28 foragers 5 minutes^{-1}) gradually increased and reached to its peak at 12 00 h (39.06 foragers 5 minutes^{-1}) than after it decreased little bit at 13 00 h (32.39 foragers 5 minutes^{-1}) and again reached to its peak at 14 00 h (35.11 foragers 5 minutes^{-1}). After 14 00 h it started declining gradually and reached to 24.28 foragers 5 minutes^{-1} at 17 00 h.

Mean data on diurnal activity of outgoing foragers at different hours of the day during *rabi* season for the year 2014 are presented in Table 2. The analysis of data on number of outgoing foragers recorded at different hours of the day revealed significant variation in activity during different hours of the day.

In *rabi* season, the activity of outgoing foragers started late as compared to *kharif* season. It started at 08 00 h (5.67 foragers 5 minutes^{-1}) and gradually increased to its peak at 12 00 h (35.44 foragers 5 minutes^{-1}) then after it decreased little bit at 13 00 h (31.06 foragers 5 minutes^{-1}) and again reached at its highest peak at 14 00 h (37.11 foragers 5 minutes^{-1}). The activity of bees declined gradually thereafter and reached 14.72 bees 5 minutes^{-1} at 17 00 h.

Further, to know the diurnal activity pattern of outgoing foragers in different seasons, the data are summarized by splitting the entire day in hours. The average data on the foraging activity were compared between hours in a day. The summarized data on foraging activity recorded at one hour interval for a period of five minutes for the *kharif* - 2013 and *rabi* – 2014 are presented in Table 3.

The statistical analysis of data of two season revealed that the interaction effect of the season with hours of the day was significant indicating the inconsistent performance of bee activity at different hours of the day during different season.

The analysis of pooled data on number of outgoing foragers revealed that the activity of outgoing foragers commenced from 06 00 h (5.14 foragers 5 minutes^{-1}) and found throughout the day. However, the maximum number of outgoing foragers were recorded during 12 00 h (37.25 foragers 5 minutes^{-1}) followed by 14 00 h (36.11 foragers 5 minutes^{-1}) and 11 00 h (33.25 foragers 5 minutes^{-1}). The significantly minimum number of outgoing foragers were recorded during 06 00 h (05.14 foragers 5 minutes^{-1}).

Sethi reported that the maximum foraging activity by bee species (*Apis cerana indica* Fabricius, *Apis dorsata* Fabricius and *Trigona* sp.) was noticed between 10 00 to 11 00 h of the day except *Apis florae* Fabricius which recorded the maximum activity during 13 00 to 15 00 h [9]. Roopa studied seasonal variation in foraging activity of *Trigona iridipennis* Smith at Bangalore. During summer season, there were two peaks of activities *i.e.* first peak between 10 00 to 11 00 h and second between 15 00 to 1600 h while during monsoon, major and minor peaks were observed between 12 00 to 13 00 h and 16 00 to 17 00 h. In winter season, two peaks were observed between 11 00 to 12 00 h and 15 00 to 16 00 h [7]. According to Devanesan *et al.*, foraging activity of *Trigona irridipenis* Smith was started at 07 00 h with a gradual rise in activity reaching its first peak at 12 00 h. A decline in activity was observed at 13 00 h then increased until it reached its second peak at 15 00 h. There was almost no activity at 18 00 h [3]. Danaraddi recorded that foraging activity of *Trigona irridipenis* Smith started at 06 00 h with a gradual rise in activity reaching its first peak at 12 00 h. It declined in activity was recorded at 13 00 h to the end of the day at 18 00 h. The maximum number of outgoing foragers was observed during 10 00 h to 12 00 h. The variations in activity of outgoing foragers in present study and reported by others may be due to species, climatic, geographical variations or due to confined condition of net house [2].

Incoming foragers with pollen load

The observations on the mean number of incoming foragers with pollen load were recorded at one hour interval for five minutes at the hive entrance form three stingless bee colony. To find out the fluctuation in foraging efficiency of pollen foragers during initiation of flowering to completion of flowering period (Six observations) and the seasons the data are summarized hourly irrespective of time of the day for the *kharif* - 2013 and *rabi* – 2014 as well as pooled of both the year.

The analysis of data on number of incoming foragers with pollen load during different hours of the day recorded during *kharif* - 2013 are presented in Table 1. The activity of incoming foragers with pollen load commenced from 09 00 h (5.11 foragers 5 minutes^{-1}) and found throughout the day. However, the maximum number of incoming foragers with pollen load were recorded during 13 00 h (8.72 foragers 5 minutes^{-1}) followed by 14 00 h (8.33 foragers 5 minutes^{-1}) while minimum number of incoming foragers with pollen load were recorded during 17 00 h (2.28 foragers 5 minutes^{-1}).

Mean data on diurnal activity of incoming foragers with

pollen load at different hours of the day during *rabi* season for the year 2014 are presented in Table 2. During *rabi* season, the activity of bees started late, there was no any activity of incoming foragers with pollen load during 06 00, 07 00 and 08 00 h. The activity of incoming foragers with pollen load commenced from 09 00 h (1.89 foragers 5 minutes^{-1}) with a gradual rise in activity reaching its first peak at 12 00 h (7.83 foragers 5 minutes^{-1}) which was followed by 15 00 (6.89 foragers 5 minutes^{-1}). At 17 00 h the activity of incoming foragers with pollen load was recorded to be 1.72 foragers 5 minutes^{-1}).

Further, to know the diurnal activity pattern of incoming foragers with pollen load in different seasons, the data are summarized by splitting the entire day in hours. The average data on the foraging activity were compared between hours in a day. The summarized data on foraging activity recorded at one hour interval for a period of five minutes for the *kharif* - 2013 and *rabi* – 2014 and the pooled are presented in Table 3.

The statistical analysis of pooled data of both season revealed that the interaction effect of season with the hours of the day was significant indicating the inconsistent activity of bees during different hours of the day during both season.

The activity of incoming foragers with pollen load commenced from 09 00 h (3.50 foragers 5 minutes^{-1}) and found throughout the day. However, the maximum number of incoming foragers with pollen load were recorded during 13 00 and 15 00 h (7.42 foragers 5 minutes^{-1}) followed by 12 00 h (7.28 foragers 5 minutes^{-1}) and 14 00 h (7.22 foragers 5 minutes^{-1}). During activity period minimum number of incoming foragers with pollen load were recorded during 17 00 h (2.00 foragers 5 minutes^{-1}). The foraging activity of incoming foragers with pollen load was started at 09 00 h (3.50 foragers 5 minutes^{-1}) with a gradual rise in activity reaching its first peak at 13 00 h (7.42 foragers 5 minutes^{-1}). A decline in activity was observed at 14 00 h (7.22 foragers 5 minutes^{-1}) then increased until it reached its second peak at 15 00 h (7.42 foragers 5 minutes^{-1}).

Roopa studied seasonal variation in incoming foragers with pollen load of *T. iridipennis* Smith at Bangalore. During summer season, the peaks of pollen foragers were recorded between 10 00 to 12 00 h and 14 00 to 15 00 h. During monsoon two distinct peaks of pollen foraging were recorded between 13 00 to 14 00 h and 15 00 to 16 00 h. During winter season, the pollen foragers were recorded between 12 00 to 13 00 h [7]. Devanesan *et al.* observed that in the case of incoming foragers with pollen load of *T. iridipennis* Smith, the maximum numbers of pollen foragers were observed in the morning. The average number of incoming foragers with pollen load were 17.9 foragers 5 minutes^{-1} during the first peak at 12 00 h and the average number of pollen foragers were 13.9 foragers 5 minutes^{-1} during the second peak at 15 00 h [3]. Danaraddi reported that the maximum numbers of incoming foragers with pollen load were observed during 10 00 to 13 00 h. Thus, the present findings are more or less similar with the earlier reports [2].

Incoming foragers without pollen load

The bees returning to hive without pollen pellet were considered as non-pollen foragers and also called incoming foragers without pollen load. The mean data on mean number of incoming foragers without pollen load were recorded at one hour interval for five minutes at the hive entrance form three stingless bee colony. To find out the fluctuation in foraging efficiency of pollen foragers during initiation of flowering to completion of flowering period (Six observation) and the seasons the data are summarized irrespective of time of the day for the *kharif* - 2013 and *rabi* - 2014.

The statistical analysis showed significant differences in bee activities during different hours of the day in *kharif* – 2013, *rabi* – 2014 and pooled.

The analysis of data on number of incoming foragers without pollen load during *kharif* - 2013 at different hours of the day recorded are presented in Table 1. The activity of incoming foragers without pollen load commenced from 06 00 h (7.22 foragers 5 minutes^{-1}) with a gradual rise in activity reaching its first peak at 11 00 h (34.78 foragers 5 minutes^{-1}). The activity of incoming foragers without pollen load found throughout the day. However, the maximum number of incoming foragers without pollen load were recorded during 11 00 h (34.78 foragers 5 minutes^{-1}) followed by 13 00 h (32.06 foragers 5 minutes^{-1}) while minimum number of incoming foragers without pollen load were recorded during 06 00 h (7.22 foragers 5 minutes^{-1}).

Mean data on diurnal activity of incoming foragers without pollen load at different hours of the day during *rabi* season for the year 2014 are presented in Table 2. Data on number of incoming foragers without pollen load during different hours of the day revealed that there was no any activity of incoming foragers without pollen load during 06 00 and 07 00 h. The activity of incoming foragers without pollen load commenced from 08 00 h (4.50 foragers 5 minutes^{-1}) with a gradual rise in activity reaching its first peak at 15 00 h (41.39 foragers 5 minutes^{-1}) which was followed by 14 00 and 16 00 h (39.50 and 38.17 foragers 5 minutes^{-1}, respectively). During activity period significantly minimum number of incoming foragers without pollen load were recorded during 08 00 h (4.50 foragers 5 minutes^{-1}).

Further, to understand the diurnal activity pattern of incoming foragers without pollen load in different seasons, the data are summarized by splitting the entire day in hours. The average data on the foraging activity were compared between hours in a day. The summarized data on foraging activity recorded at one hour interval for a period of five minutes for the *kharif* - 2013 and *rabi* – 2014 and the pooled are presented in Table 3.

The statistical analysis revealed that the interaction effect of season with the hours was significant indicating inconsistent bee activity during different hours of the day during different seasons.

The analysis of two seasons data indicated that the activity of incoming foragers without pollen load commenced from 06 00 h (3.61 foragers 5 minutes^{-1}) and found throughout the day. However, the maximum number of incoming forager without pollen load were recorded during 15 00 h (36.64 foragers 5 minutes^{-1}) followed by 14 00 and 13 00 h (35.33 and 34.33 foragers 5 minutes^{-1}, respectively). During activity period minimum number of incoming foragers without pollen load were recorded during 06 00 h (3.61 foragers 5 minutes^{-1}).

Roopa studied seasonal variation in incoming foragers without pollen load activity of *Trigona iridipennis* Smith at Bangalore. The foragers were active in all the seasons and the foraging activity was found throughout the day during all the months [7]. Danaraddi studied the activity of incoming foragers without pollen load of *Trigona iridipennis* Smith and reported that the maximum number of incoming foragers without pollen load were observed during 12 00 h to 14 00 h [2].

Conclusion

The activity of outgoing foragers commenced from 06 00 h (5.14 foragers 5 minutes^{-1}) and found throughout the day. However, the maximum number of outgoing foragers were recorded during 12 00 h (37.25 foragers 5 minutes^{-1}). The activity of incoming foragers with pollen load commenced from 09 00 h (3.50 foragers 5 minutes^{-1}) and found throughout the day. However, the maximum number of incoming foragers with pollen load was recorded during 13 00 and 15 00 h (7.42 foragers 5 minutes^{-1}). The activity of incoming foragers without pollen load commenced from 06 00 h (3.61 foragers 5 minutes^{-1}) and found throughout the day. However, the maximum number of incoming foragers without pollen load were recorded during 15 00 h (36.64 foragers 5 minutes^{-1}).

Table 1: Foraging activity of stingless bees, *T. laeviceps* in net house condition during *kharif* – 2013

Hours	Mean number of pollen forager per five minutes (Mean of six observations)		
	Out going	Incoming	
		With Pollen	Without Pollen
06 00	3.28 (10.28)	0.71 (0.00)	2.77 (7.22)
07 00	4.60 (20.67)	0.71 (0.00)	4.20 (17.11)
08 00	5.33 (27.94)	0.71 (0.00)	5.47 (29.44)
09 00	5.28 (27.33)	2.37 (5.11)	4.83 (22.83)
10 00	5.33 (27.89)	2.67 (6.61)	5.29 (27.44)
11 00	6.02 (35.72)	2.54 (5.94)	5.94 (34.78)
12 00	6.29 (39.06)	2.69 (6.72)	5.54 (30.22)
13 00	5.73 (32.39)	3.04 (8.72)	5.71 (32.06)
14 00	5.97 (35.11)	2.97 (8.33)	5.63 (31.17)
15 00	5.64 (31.33)	2.91 (7.94)	5.69 (31.89)
16 00	5.19 (26.39)	2.55 (6.00)	5.07 (25.17)
17 00	4.98 (24.28)	1.67 (2.28)	5.06 (25.11)
S. Em. ±	0.04	0.02	0.06
C. D. at 5%	0.12	0.05	0.18
C. V. %	1.32	1.47	2.14
Figure in parentheses are retransformed values, those outside parentheses are SQRT (n+0.5) transformed values			

Table 2: Foraging activity of stingless bees, *T. laeviceps* in net house condition during *rabi* –2014

Hours	Mean number of pollen forager per five minutes (Mean of six observations)		
	Out going	Incoming	
		With Pollen	Without Pollen
06 00	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
07 00	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
08 00	2.48 (5.67)	0.71 (0.00)	2.23 (4.50)
09 00	3.75 (13.56)	1.55 (1.89)	4.18 (17.00)
10 00	5.00 (24.50)	1.93 (3.22)	5.41 (28.72)
11 00	5.59 (30.78)	2.35 (5.00)	5.73 (32.33)
12 00	6.00 (35.44)	2.89 (7.83)	5.90 (34.28)
13 00	5.62 (31.06)	2.57 (6.11)	6.09 (36.61)
14 00	6.13 (37.11)	2.57 (6.11)	6.32 (39.50)
15 00	5.90 (34.28)	2.72 (6.89)	6.47 (41.39)
16 00	5.62 (31.11)	2.43 (5.39)	6.22 (38.17)
17 00	3.90 (14.72)	1.49 (1.72)	4.91 (23.61)
S. Em. ±	0.05	0.02	0.07
C. D. at 5%	0.16	0.05	0.19
C. V. %	2.19	1.84	2.48
Figure in parentheses are retransformed values, those outside parentheses are SQRT (n+0.5) transformed values			

Table 3: Foraging activity of stingless bees, *T. laeviceps* in net house condition (Pooled)

Hours	Mean number of pollen forager per five minutes (Mean of six observations)		
	Out going	Incoming	
		With Pollen	Without Pollen
06 00	2.37 (5.14)	0.71 (0.00)	2.02 (3.61)
07 00	3.29 (10.33)	0.71 (0.00)	3.01 (8.56)
08 00	4.16 (16.81)	0.71 (0.00)	4.18 (16.97)
09 00	4.58 (20.44)	2.00 (3.50)	4.52 (19.92)
10 00	5.17 (26.19)	2.33 (4.92)	5.35 (28.08)
11 00	5.81 (33.25)	2.44 (5.47)	5.84 (33.56)
12 00	6.14 (37.25)	2.79 (7.28)	5.72 (32.25)
13 00	5.68 (31.72)	2.81 (7.42)	5.90 (34.33)
14 00	6.05 (36.11)	2.78 (7.22)	5.99 (35.33)
15 00	5.77 (32.81)	2.81 (7.42)	6.09 (36.64)
16 00	5.41 (28.75)	2.49 (5.69)	5.67 (31.67)

17 00	4.47 (19.50)	1.58 (2.00)	4.99 (24.36)
S. Em. ±	0.04	0.01	0.05
C. D. at 5%	0.11	0.03	0.13
S. Em. ± (P X S)	0.03	0.02	0.07
CD at 5 % (P X S)	0.09	0.05	0.19
C. V. %	1.34	1.41	2.36
Figure in parentheses are retransformed values, those outside parentheses are SQRT (n+0.5) transformed values			

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