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Foraging performance of stingless bee, *Tetragonula iridipennis* Smith (Hymenoptera: Apidae) during winter season in Madurai, Tamil Nadu

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Abstract
A study on foraging activity of stingless bees was conducted at Insectary of Department of Agricultural Entomology, Agricultural College and Research Institute, Madurai, Tamil Nadu, India to study the seasonal foraging activity of stingless bee during winter under the influence of climatic factors viz., temperature, rainfall, relative humidity, wind speed etc. The objective of this study was to investigate the active period of foraging in winter. The foraging activities consist of the total number of outgoing foragers, incoming foragers with pollen load and incoming foragers without pollen load were observed from December 2017 to February 2018. The average bee activity was recorded high during the morning hours between 6.00 am to 12.00 pm with maximum of 66.92 bees/5 min. The total bee activity was recorded highest during the 5th and 8th standard week of 130.63 and 135.35 numbers of bees/5 min, respectively. The maximum pollen gatherer was observed during 5th standard week (18.28 bees/5 min). The study revealed that both maximum temperature and wind speed has positive correlation with foraging behavior of outgoing bees, incoming bees and incoming bees with pollen (r = 0.72, r = 0.73, r = 0.84 respectively). The average weather parameters prevailed during this study period was maximum temperature of 32.05 °C and minimum of 20.07 °C, relative humidity of 64.30%, rainfall of 1.52 mm and wind velocity of 1.30 kmph.

Keywords: Stingless bee, foraging activity, winter, pollen, weather parameters, diurnal variations, seasonal variations

Introduction
The stingless bees (Hymenoptera: Apidae: Meliponini) are eusocial and corbiculate, showing tropical and southern subtropical distribution (Leonhardt *et al*., 2007) [9]. Asiatic stingless bee *Tetragonula iridipennis* is one of the most primitive honeybees found in India. The Indian subcontinent with a tropical Savanna climate, varying physiographic environment, higher altitudes and luxuriant flora offers an abode for the rich and wide distribution of stingless bee (*T. iridipennis*). As in honeybees, their principal resources are pollen and nectar, but they also collect materials such as resin, water, sap, wax, honeydew, extrafloral nectar, mud and fungal spores for nutrition or nest-building materials (Roubik, 1980) [12]. Stingless bee colonies are perennial and usually consist of hundreds or thousands of workers (Wille, 1983) [16]. They are found in colonies ranging from a few dozen to 100,000 or more workers and are highly social bees (Michener, 2000) [10]. Factors present outside the colony are ambient weather parameters *viz*., temperature, rainfall, relative humidity, wind speed, sunshine hours and foraging floral availability *etc*., During foraging, honey bees are exposed to a broad range of ambient weather parameters which affect their efficiency in forage and alter the time of forage (Kovac and Stabentheiner, 2011) [7].
The stingless bees were exposed to the various weather conditions during foraging and such studies were done mainly related to pollen and nectar foraging, studies on foraging activity related to weather conditions was found very few. So the aim of this study to analyse the foraging activity of stingless bee in relation to weather conditions in winter by recording the incoming and outgoing forging bees.

Material and Methods

The study was conducted at insectary of Department of Agricultural Entomology, Agricultural college and Research Institute, Madurai present in the foot hills of Yanaimalai hillock (Latitude 9°55'25.79" N; Longitude 78°05'27.00" E), a small rocky monolithic mountain on the western side, encompasses a geographical area of approximately about 154 hectares with several agricultural, horticultural crops besides and a variety of wild flora the natural vegetation, that has greatly supporting the stingless bee to flourish naturally. Stingless bee colonies maintained at the Insectary of were selected for the study. For observing the effect of ambient weather factors on bees, three colonies having uniform strength were selected. Each colony was considered as a replication.

The meteorological data were recorded from the Automatic Weather Station located in the Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, India, which is located within 700 m radius from the experimental location. The meteorological parameters *viz*., maximum and minimum temperature (°C), relative humidity (%), rainfall (mm) and wind speed (kmph) recorded were used for estimating the systemic and functional relationship of bee foraging *viz*., pollen, nectar and resin gathering activities.

Foraging behavior of stingless bees was observed by recording the number of worker bees going out and coming in with and without pollen loads per five minutes with stop watch and hand tally counter. The bees returning to the hives with pollen load in hind leg were counted as pollen gathers and bee coming into the hives without pollen load were considered as nectar and resin collectors.

To study the foraging activity variations for the period of 49th to 9th meteorological standard weeks of 2017-18, observations were recorded three times a day *viz*., 8.00 a.m., 12.00 noon and 4.00 p.m. for 5 minutes. The mean value of observations at three intervals was taken as the foraging activity of that particular day. The diurnal patterns study was conducted by weekly observations were recorded at hourly interval starting from 6.00 a.m. to 6.00 p.m. for five minutes. Foraging data recorded were correlated with the meteorological data of the corresponding days. Analysis of variance (ANOVA) at 5% significance was used to test the significance of mean differences.

Results and Disussion

The ambient weather conditions depicted varying relationship with stingless bee foragers. The average weather parameters prevailed during this study period was maximum temperature of 32.05°C and minimum temperature of 20.07 °C, relative humidity of 64.30%, rainfall of 1.52 mm and wind velocity of 1.30 kmph. The study revealed that maximum temperature has positive correlation with foraging behavior of outgoing bees, incoming bees and incoming bees with pollen (r = 0.72, r = 0.73, r = 0.84 respectively). The minimum temperature had negative correlation with bees going out (r = -45), bees coming in (r = -0.49) and bees coming in with pollen (r = -0.51) (Table 1).

Among the various abiotic factors, temperature was found crucial with factor affecting bee activities. The maximum temperature showed positive relation and minimum temperature recorded negative relation with bees going out, bees coming in and bees coming in with pollen and therefore temperature should be optimum for effective foraging of bees. The observations in this study revealed that relative humidity and rainfall also had negative correlations, while wind speed had positive correlations with outgoing bees, incoming bees and incoming bees with pollen.

Gebremedhn *et al*. (2014) [4] described that the number of *A. mellifera* bees had a positive association with air temperature (r = 0.67) and negative relationship with relative humidity (r = -0.59) which are comparable in our investigations. We observed that the pollen foraging bee activity was affected during high wing speed with least flight activity. Accordingly a wind stronger than 12 kmph was reported to affect honey bee foraging as they could not carry pollen load upwind at a speed > 15 kmph (Reddy *et al.*, 2015) [11]. During our study period the wind speed was optimum (1.30 kmph) and it had not affected the foraging activity of stingless bee significantly. Similarly bees had not come for foraging during rainfall thus showing a strong negative correlation. Foraging activity of stingless bee was stopped with high wind speed and rainfall which tends to decrease the ground speed of bees which resulted in reduction in the number of flights per day (Kumar *et al.*, 2015) [8]. Relative humidity showed less effect on the flight activities of stingless bee. Maximum temperature gave positive regression coefficient to the pollen collectors (a = +2.80), incoming bees (a = +4.88) and outgoing bees (a = +4.91) and minimum temperature had negative regression coefficient to pollen collectors (b = -0.33) while incoming bees (b = +2.06) and outgoing bees (b = +1.26) showed positive regression coefficient (Table 2).

Maximum temperature prevailed in this study period was 30.40 ºC to 34.0 ºC during this condition pollen collectors population was increased with increase in temperature and decresed with minimum temparature (18.90 ºC to 21.70 ºC). Al Qarni, (2006) [1] added that higher temperature and low humidity were reported to adversely affect the flight activity of honey bees. It may due to more energy involved in colletion of pollen as it involves series of activities, like grooming, packing of the pollen in the pollen basket etc. that may lead to exhaustion at lower temperature.

The observations on the foraging activity revealed that the peak activity was observed from morning 6.00 am to 12.00 pm with average maximum foragers of 66.92 bees/5 min between 9 to 10.00 am and after 12.00 pm the bee activity was gradually declined and recorded the lowest in the evening 5.00 pm and 6.00 pm of 32.4 bees/5 min and 24.11 bees/5 min, respectively. The pollen collectors activity was high during the early morning hours 7.00 to 8.00 am (16.78 bees/5 min) reached peak by 8.00 to 9.00 am (17.11 bees/5min) followed by 9.00 to 10.00 am (14.78 bees/5min), there after the pollen collectors activity was declined in the evening hours with least numbers at 5.00 to 6.00 pm (2.67 bees/5min).

The incoming bees activity was recorded high in the morning hours from 11.00 am to 12.00 pm (68.78 bees/5min) followed by 9.00 to 10.00 am (65.06 bees/5min), 10.00 to 11.00 am (64.06 bees/5min) and the evening hours from 6.00 to 7.00 pm (24.11 bees/5min) recorded lowest incoming bee activity follwed by 5.00 to 6.00 pm (36.78 bees/5min). The diuranal pattern of stingless bee showed the incoming bees were more in the morning session (6.00 am to 12.00 noon) and less in the afternoon hours and again slightly raised in the eveing hours (4.00 to 5.00 pm). Performance of outgoing bees was observed peak in morning 9.00 to 10.00 am (68.77 bees/5min) and gradually declined to minimum in evening 5.00 Pm to 6.00 pm of 28.05 bees/5min (Fig. 1).

Similar observations have been reported by many workers in various ecosystems (Ghazi *et al.*, 2014; Vijayan *et al.*, 2018, and Hemalatha *et al.*, 2018) [5, 15, 6]. Vijayan *et al*. (2018) [15] also observed that the foraging activity of stingless bee was

peak between 7.00 am to 12.00 pm and then a steady decline and abruptly decreased between 5.00 to 7.00 pm. Hemalatha *et al*. (2018) [6] found the highest numbers of Indian honeybees activity in the morning hours, while the least numbers were observed at evening hours. Pollen foraging was observed more in morning hours of the day, which is like the discoveries of Sommeijer *et al.* (1983) and could be upheld by the way that the pollen is inexhaustibly present in early morning hours (Roubik, 1982) [13]. Particular pinnacle of pollen gatherers during morning hours was similar to the findings of Bruijn and Sommeijer (2007) and Devanesan *et al*. (2002) [3].

Stingless bee total foraging activity reached maximum during 5th, 6th, 7th and 8th standard meterological weeks by registering 130.17 bees/ 5 min, 122.61 bees/5 min, 124.25 bees/5 min and 135.35 bees/5 min, respectively. The foraging activity was recorded minimum in the 49th and 50th standard week with total bee activity of 84.21 and 73.53 bees/5 min, respectively (Fig. 2). The incoming foragers increased in 7th (12.11 bees/5 min), 8th standard week (67.17 bees/5 min) and least in 50th standard week (35.78 bees/5 min). The outgoing bees population was high during 5th, 6th and 8th standard week showed 68.87 bees/5 min, 65.63 bees/5 min and 68.18 bees/5 min, respectively and pollen foragers observed during this study was active from 1st standard week (12.11 bees/5 min), recorded peak activity of 18.28 bees/5 min and 17.73 bees/5 min at 5th and 8th standard meterological week and observed minimum in 50th (5.75 bees/5 min) and 49th standard week (6.25 bees/5 min) (Fig. 3).

Vijayan *et al*. (2018) [15] studied the foraging activity of *T. iridipennis* from December 2017 to March 2018 and found that the pollen foraging was increased from January and attained peak gradually in February and March. Foraging activity was common in bees to gather food resources. The changes in weather especially the temperature and sunshine which might be optimum for the foraging activity of stingless bees and surplus availability of floral source from 1st to 8th standard week. Hemalatha *et al*. (2018) [6] also revealed that the foraging activity of *A. cerana indica* was maximum from 3rd to 5th standard week.

Table 1: Correlation of foraging activity with climatic variables during winter, 2017-18

Weather parameters	Correlation coefficient (r)		
	No. Bees going out/5 min	No. Bees coming in /5 min	No. Bees coming with pollen/5 min
Maximum temperature (°C)	0.72*	0.73*	0.84*
Minimum temperature (°C)	-0.45*	-0.49*	-0.51*
Average RH (%)	-0.64*	-0.71*	-0.67*
Rainfall (mm)	-0.35*	-0.39*	-0.39*
Wind speed (kmph)	0.11*	0.12*	0.01

*Significance at 0.05%

Table 2: Multiple Regression equations for the foraging activity with climatic variables during winter, 2017-18

Division of worker bees	Multiple regression equation	R^2 values
Incoming bees with pollen	$Y = -37.59 + 2.80x_1 – 0.33x_2 – 0.50x_3 + 0.11x_4 – 1.48x_5$	0.91
Incoming bees	$Y = -19.08 + 4.88x_1 + 2.06x_2 – 1.98x_3 + 0.55x_4 – 0.33x_5$	0.81
Outgoing bees	$Y = -27.39 + 4.91x_1 + 1.26x_2 – 1.57x_3 + 0.50x_4 – 0.02x_5$	0.72

Where,

x_1 - Maximum temperature; x_2 - Minimum temperature;

x_3 - Relative humidity; x_4 - Rainfall; x_5 - Wind speed

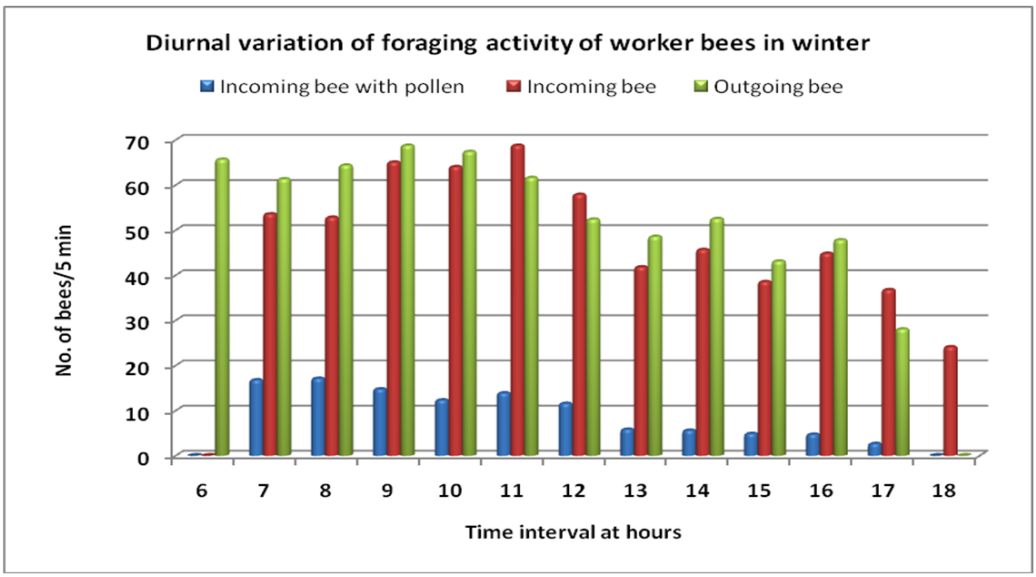

Fig 1: Diurnal variation of foraging activity of worker bees in winter 2017-18

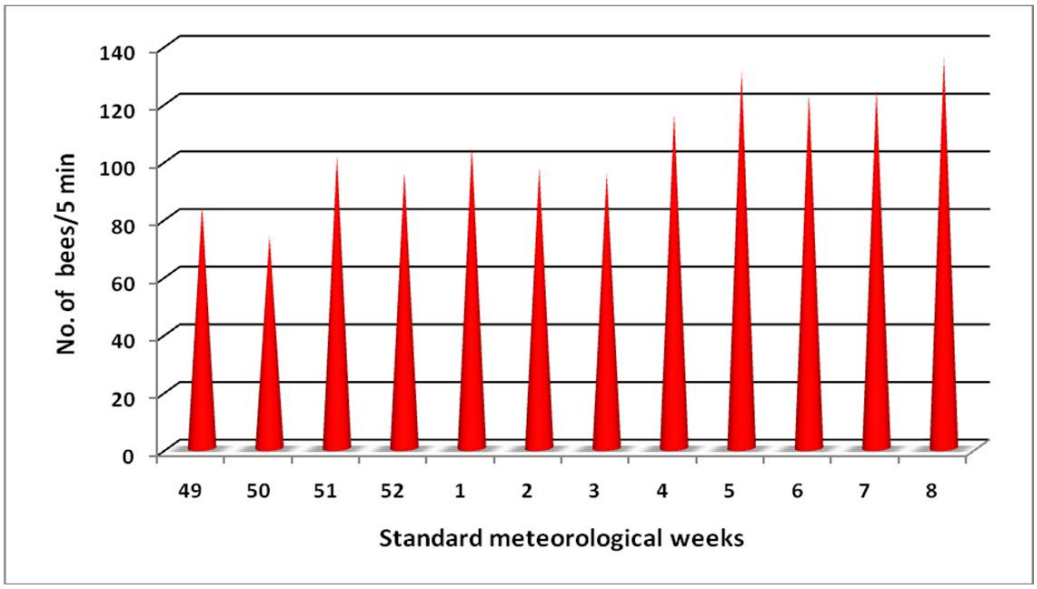

Fig 2: Total foraging activity of bees during winter 2017-18

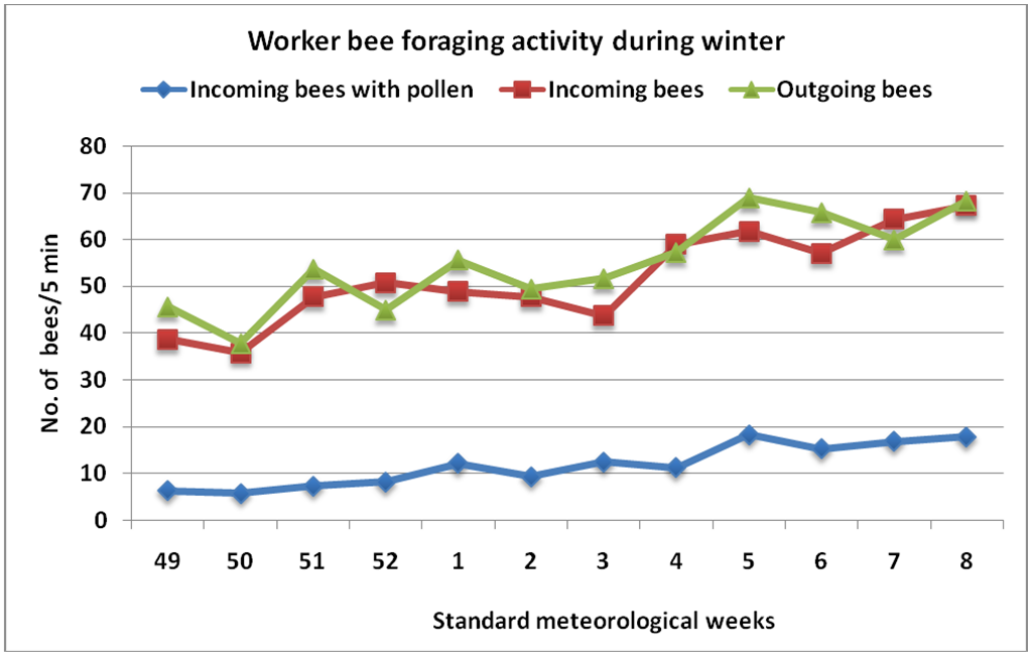

Fig 3: Winter seasonal variation of Stingless bee foraging activity

Conclusion

The present study revealed that the foraging performance of stingless bee was maximum from 9.00 am to 12.00 pm. Peak pollen foraging was observed from 8.00 to 9.00 am (17.11 bees/5 min), the outgoing and incoming bees activity were gradually declined in the evening hours. Stingless bee foraging activity was increased from 4th to 8th standard week during winter season. The ambient weather factors prevailed during this study period should be optimum for effective foraging of the stingless bees. Understanding the flexible behavior of stingless bee in this changing environment could be utilized in colonies conservation and survival by beekeepers and farmers for better meliponiculture.

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