*Mysore J. Agric. Sci., 58 (2) : 191-202 (2024)*

# Influence of Weather Parameters on Foraging Activity of Stingless Bee, *Tetragonula iridipennis* Smith during Winter in Bengaluru, Karnataka

Padmini K. Gaddi, G. Eswarappa, K. S. Jagadish and K. T. Vijayakumar
Department of Apiculture, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : pkgaddi2099@gmail.com

**Authors Contribution**

Padmini K. Gaddi : Conceptualized, carried out experiment and analyzed data;

G. Eswarappa : Provided technical support and inputs;

K. S. Jagadish & K. T. Vijayakumar : Guidance and supervision

***Corresponding Author :***

Padmini K. Gaddi

*Received* : December 2023
*Accepted* : February 2024

**Abstract**

Foraging activity of stingless bees are influenced by unpredictable environmental variables. The study on Influence of weather parameters on foraging activity of stingless bee, *Tetragonula iridipennis* Smith during winter was conducted from October, 2022 to January, 2023. Irrespective of winter months, peak activity of outgoing bees was observed from 1100-1600 hr, nectar carrying bees from 1100-1500 hr, pollen carrying bees from 1200-1400 hr and resin carrying bees from 1200-1500 hr. Hourly temperature and wind speed had positive correlation with foraging activity, whereas, the hourly relative humidity and precipitation negatively affected the foraging activity of *T. iridipennis*. Among forage carrying bees, the number of nectar carrying bees were maximum, followed by pollen and resin carrying bees (N>P >R) during winter.

*Keywords* : Stingless bee, Foraging activity, Weather parameters

Stingless bee (Hymenoptera: Apidae) belonging to the sub-family Meliponinae*,* exhibit eusocial and corbiculate traits and are honey producing insects. These unique bees are primarily found in tropical and southern subtropical regions (Leonhardt *et al.,* 2007). *Tetragonula iridipennis* Smith stands out as one of the most widespread stingless bee species in India. The Indian subcontinent with its diverse physiographic environment and abundant flora provides an ideal habitat for *T. iridipennis.* Despite their small size, they play a significant role in pollination of many tropical plant species, depending on their services. Stingless bee colonies are perennial and usually consist of hundreds to thousands of workers (Wille, 1983). Stingless bees are found worldwide with over 500 described species. In South India, *Tetragonula iridipennis* Smith is the most common species (Michener, 2013). These social insects establish their colonies in concealed places such as old walls of dilapated buildings, tree trunks and cavities.

Foraging activities of the worker bees in social insects is significantly influenced by unpredictable environmental variables, including the timing and location of food sources. The foraging behaviors of bees are governed by a combination of internal and external factors. Internal factors includes, individual memory and threshold responses to foraging stimuli, while external factors are temperature, rainfall, relative humidity, wind speed and sunshine hours which encompass the overall functioning of the colony. The external factors and floral availability affect the efficiency of foraging of bees and timing of their foraging. Honeybee and stingless bee colonies have the ability to allocate more foragers to collect nectar and pollen, based on the availability of food resources (Biesmeijer and de Vries, 2001).

## Material and Methods

### Study Area

The study was conducted at University of Agricultural Sciences, Gandhi Krishi Vignana

Kendra, Bengaluru, Karnataka (12°58 N; 77°35 E), at an altitude of 924m. The campus is spread over 526 ha and receives a mean annual rainfall of 915.8 mm. The experimental area comes under the eastern dry zone of Karnataka and it has diverse vegetation including cultivated crops, plantation crops, medicinal plants, wild trees, shrubs, ornamentals and weeds that may serve as nectar, pollen and resin sources for stingless bees.

**Selection of Colonies**

Four randomly selected stingless bee colonies, with a nearly uniform strength maintained in the hives of size 30×10×10 cm at the Apiary of Department of Apiculture were selected for recording observations and each colony was considered as a replication.

**Foraging Activity of *Tetragonula iridipennis* Smith during Winter, 2022-23**

Ad-libitum sampling of foraging behaviour was done by recording number of outgoing bees, number of returning bees with pollen, nectar and resin at the hive entrance for a period of five minutes per hour at fortnightly intervals from 0700-1900 hr during winter from October, 2022 to January, 2023. The bees coming out from the colony were considered as outgoing bees and those bees entering the hive with pollen load in their corbicula were considered as pollen carrying bees and the bees without pollen load were considered as nectar and resin carrying bees (Bharath *et al.,* 2019). The observations on foraging activity at fortnightly intervals for three days during winter months such as October ($13^{th}$ to $15^{th}$ and $28^{th}$ to $30^{th}$), November ($13^{th}$ to $15^{th}$ and $26^{th}$ to $28^{th}$), December ($13^{th}$ to $15^{th}$ and $28^{th}$ to $30^{th}$), January ($13^{th}$ to $15^{th}$ and $28^{th}$ to $30^{th}$) was recorded and correlated the prevailing weather parameters.

**Meteorological Data of Experimental Site at GKVK during Winter Months**

The hourly mean temperature ($23.88^0$C), relative humidity (84.42 %) and precipitation (7.47mm) during first fortnight were higher than that of second fortnight ($23.48^0$C,. 81.57% and 0.66 mm) of October. The hourly mean wind speed during first fortnight (0.29 kmph) was lesser than that of second fortnight (0.55 kmph) of October.

The hourly mean temperature during first fortnight ($22.85^0$C) was lesser than that of second fortnight ($23.99^0$C). The hourly mean relative humidity during first fortnight (82.93%) was higher than that of second fortnight (77.61%) of November. The hourly mean wind speed (0.34 kmph) was similar in both fortnights of November. The hourly mean precipitation during first fortnight was 3.58 mm and there was no precipitation during second fortnight of November.

The hourly mean temperature during first fortnight ($22.38^0$C) was lesser than that of second fortnight ($24.33^0$C). The hourly mean relative humidity (79.84%), wind speed (0.59 kmph) & precipitation (0.55mm) during first fortnight was higher than that of second fortnight (63.14%, 0.50 kmph & 0.14mm) of December.

The hourly mean temperature during first fortnight ($25.47^0$C) was higher than that of second fortnight ($25.13^0$C). The hourly mean relative humidity during first fortnight (44.53%) was lesser than that of second fortnight (58.45%). The hourly mean wind speed during second fortnight (0.20 kmph) was higher than that of first fortnight (0.07 kmph). There was no precipitation recorded in the month of January.

## Results and Discussion

**Foraging Activity of *Tetragonula iridipennis* Smith during October, 2022**

The number of outgoing bees, pollen, nectar and resin carrying bees of *T. iridipennis* varied significantly between different hours of the day during first and second fortnight of October, 2022 (Table 1).

The bees started going out at 0700-0800 hr (2.03 and 2.66 bees/5 min.) and continued up to 1800-1900 hr (0.68 and 8.87 bees /5min.) during first and second fortnight of October. The maximum number of

TABLE 1

Foraging activity of *Tetragonula iridipennis* Smith during October, 2022

| Time (hr) | October, 2022 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st Fortnight (Mean from 13-10-22 to 15-10-22) | | | | 1st Fortnight (Mean from 13-10-22 to 15-10-22) | | | |
| | O | P | N | R | O | P | N | R |
| 0700-0800 | 2.03 (1.73) | 0.00 (1.00) | 0.68 (1.29) | 0.06 (1.03) | 2.66 (1.91) | 0.00 (1.00) | 1.00 | 0.00 (1.00) |
| 0800-0900 | 3.21 (2.04) | 0.46 (1.20) | 1.53 1.58) | 0.00 (1.00) | 13.00 (3.73) | 0.87 (1.36) | 4.81 | 0.00 (1.00) |
| 0900-1000 | 4.06 (2.24) | 1.94 (1.71) | 1.46 (1.56) | 0.00 (1.00) | 17.93 (4.35) | 4.68 (2.38) | 6.75 | 0.00 (1.00) |
| 1000-1100 | 10.56 (3.41) | 4.18 (2.27) | 2.21 (1.79) | 0.75 (1.31) | 21.06 (4.69) | 7.56 (2.94) | 9.49 | 0.00 (1.00) |
| 1100-1200 | 31.54 (5.70) | 4.46 (2.33) | 11.5 (3.55) | 1.12 (1.45) | 23.50 (4.94) | 10.37 (3.37) | 14.26 | 1.11 (1.43) |
| 1200-1300 | 24.59 (5.05) | 5.46 (2.54) | 22.90 (4.86) | 1.00 (1.41) | 28.68 (5.44) | 16.74 (3.83) | 13.43 | 0.45 (1.20) |
| 1300-1400 | 26.73 (4.91) | 3.68 (2.15) | 9.71 (3.27) | 1.50 (1.57) | 29.06 (5.48) | 13.62 (3.82) | 12.93 | 0.45 (1.20) |
| 1400-1500 | 13.90 (3.86) | 3.16 (2.04) | 17.10 (4.25) | 1.54 (1.59) | 32.25 (5.76) | 14.12 (3.88) | 13.62 | 1.60 (1.61) |
| 1500-1600 | 23.11 (5.26) | 3.43 (2.10) | 15.51 (4.06) | 1.53 (1.59) | 33.33 (5.85) | 14.18 (3.89) | 12.81 | 1.50 (1.58) |
| 1600-1700 | 12.63 (3.69) | 0.93 (1.39) | 9.40 (3.22) | 0.00 (1.00) | 32.18 (5.73) | 13.68 (4.21) | 12.32 | 0.00 (1.00) |
| 1700-1800 | 5.13 (2.47) | 0.90 (1.37) | 2.18 (1.78) | 0.00 (1.00) | 35.74 (6.03) | 12.31 (3.64) | 18.73 | 0.00 (1.00) |
| 1800-1900 | 0.68 (1.29) | 1.62 (1.52) | 1.28 (1.50) | 0.00 (1.00) | 0.00 (1.00) | 2.00 (1.72) | 1.78 | 0.00 (1.00) |
| Mean | 13.18 | 2.52 | 7.96 | 0.06 | 23.19 | 9.22 | 10.16 | 0.42 |
| CD at 5% | 0.11 | 0.30 | 0.27 | 0.11 | 5,38 | 0.13 | 1.98 | 0.12 |
| CV(%) | 2.29 | 11.81 | 6.98 | 6.56 | 16.06 | 3.10 | 13.53 | 7.18 |

O: Outgoing bees, P: Pollen carrying bees, N: Nectar carrying bees, R: Resin carrying bees

outgoing bee was recorded during 1100-1200 hr (31.54 bees/5 min.) and the lowest was recorded at 1800-1900 hr (0.68 bees/5min.) during first fortnight, whereas the lowest number of outgoing bees recorded was at 0700-0800 hr (2.66 bees/5 min.) and maximum was during 1500-1600 hr (33.33 bees /5 min.) in the second fortnight. The mean number of outgoing bees were maximum (23.19 bees/5 min.) during second fortnight compared to the (13.18 bees/5 min.) first fortnight.

The pollen carrying bees started coming back to the nest by 0800-0900 hr (0.46 bees/5 min.) during first fortnight and at 0700-0800 hr (0.87 bees/5 min.) during second fortnight. The pollen carrying activity continued up to 1800-1900 hr (1.62 and 2.00 bees/5 min.) in both fortnights of October. The lowest number of pollen carrying bees was recorded during 0800-0900 hr (0.46 bees/5 min.) during first fortnight and at 0700-0800 hr (0.87 bees/5 min.) during second fortnight. The maximum was recorded at 1200-1300



The Mysore Journal of Agricultural Sciences

hr (5.46 and 16.74 bees /5 min.) in both fortnights. The mean number of pollen carrying bees were maximum during second fortnight (9.22 bees/5 min.) compared to the first fortnight (2.52 bees/5 min.) of October.

Incoming bees without pollen loads were considered as nectar carriers. The nectar carrying bees started returning at 0700-0800 hr (0.68 and 1.00 bees/5 min.) and continued up to 1800-1900 hr (1.28 and 1.78 bees/ 5 min.) during first and second fortnight of October. The lowest number of nectar carrying bees was recorded at 0700-0800 hr. (0.68 and 1 bees/5 min.) during first and second fortnights, respectively. The maximum numbers of nectar carrying bees were recorded during 1200-1300 hr (22.90 bees /5 min.) and at 1600 to 1700 hr (18.73 bees/5min.) during first and second fortnight. The mean number of nectar carrying bees were maximum during second fortnight (10.16 bees/5 min.) compared to the first (7.96 bees/ 5 min.) fortnight of October.

The resin carrying bees were observed at 1100-1200 hr (1.12 and 1.11 bees /5min.) and continued upto 1500-1600 hr (1.53 and 1.50 bees /5 min.) in both the fortnights of October. The resin carrying bees ranged from 1300-1400 hr (1.50 bees /5 min.) to 1400-1500 hr (1.54 bees /5 min.) and 1200-1400 hr (0.45 bees / 5 min.) to 1400-1500 hr (1.60 bees /5 min.) during first and second fortnight. There was no resin foraging activity from 0700-1100 hr and 1600-1900 hr in both the fortnights of October (Table 1).

**Foraging Activity of *Tetragonula iridipennis* Smith during November, 2022**

The number of outgoing bees, pollen, nectar and resin carrying bees of *T. iridipennis* varied significantly between different hours of the day during first and second fortnight of November, 2022 (Table 2).

The bees started going out at 0800-0900 hr (0.84 bees / 5 min.) and continued upto 1800-1900 hr (0.40 /5min.) during first fortnight, whereas, in second fortnight it started at 0700-0800 hr (1.25 bees / 5 min.) and continued upto 1700-1800 (26.00 bees / 5 min.) during second fortnight of November. The maximum number of outgoing bee was recorded at 1300-1400 hr (26.23 and 58.00 bees / 5 min.) in both fortnights and the lowest number of outgoing bees was recorded at 1800-1900 hr (0.40 bees / 5 min.) during first fortnight and at 0700-0800 hr (1.25 bees / 5 min.) during second fortnight. The mean numbers of outgoing bees were maximum during second fortnight (27.73 bees / 5 min.) as compared to the first fortnight (12.74 bees / 5 min.) of November.

The pollen carrying bees was started returning to hive at 0900-1000 hr (6.84 and 8.00 bees / 5 min.) in both fortnights and continued up to 1600-1700 hr (4.59 bees /5 min.) during first of fortnight and at 1700-1800 hr (1.00 bees / 5 min.) during second fortnight. The maximum number of pollen carrying bees was recorded at 1300-1400 hr (14.74 and 17.00 bees / 5 min.) in both fortnights and the lowest number of pollen carrying bees was recorded at 1600-1700 hr (4.59 bees/5 min.) during first fortnight and at 1700-1800 hr (1.00 bees/5 min.) during second fortnight. The mean numbers of pollen carrying bees were maximum during second fortnight (8.37 bees/5 min.) as compared to that of first fortnight (6.54 bees/5 min.) of November.

The nectar carrying bees started appearing at 0900-1000 hr (21.11 bees / 5 min.) and continued upto 1600-1700 hr (4.61 bees /5 min.) during first fortnight. Whereas, in the second fortnight, nectar carrying bees started arriving at 0800-0900 hr (1.25 bees/5 min.) and continued up at 1700-1800 hr (17.25 bees / 5 min.). The maximum number of nectar carrying bees was recorded at 1300-1400 hr (30.84 and 45.00 bees / 5 min.) in both fortnights and the lowest number of nectar carrying bees was recorded at 1600-1700 hr (4.61 bees/5 min.) during first fortnight and at 0800-0900 hr (1.25 bees/5 min.) during second fortnight. The mean numbers of nectar carrying bees were maximum during second fortnight (22.91 bees /5 min.) as compared to that of first fortnight (14.41bees/5 min.) of November.

The resin carrying bees were observed at 0800-0900 hr (0.03 bees / 5 min.) and they continued their activity up to 1800-1900 hr (0.14 bees/5 min.) during first fortnight of November, whereas, in second fortnight they started at 0900-1000 hr (0.90 bees / 5 min.) and

TABLE 2

Foraging activity of *Tetragonula iridipennis* Smith during November, 2022

| Time (hr) | November, 2022 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st Fortnight (Mean from 13-11-22 to 15-11-22) | | | | 2nd Fortnight (Mean from 26-11-22 to 28-11-22) | | | |
| | O | P | N | R | O | P | N | R |
| 0700-0800 | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 1.25 (1.43) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) |
| 0800-0900 | 0.84 (1.31) | 0.00 (1.00) | 0.00 (1.00) | 0.03 (1.01) | 7.50 (2.49) | 0.00 (1.00) | 1.25 (1.36) | 0.00 (1.00) |
| 0900-1000 | 8.45 (2.84) | 6.84 (2.60) | 21.11 (4.29) | 0.61 (1.24) | 19.50 (3.94) | 8.00 (2.74) | 20.25 (4.21) | 0.90 (1.36) |
| 1000-1100 | 20.71 (4.64) | 10.34 (3.36) | 21.29 (4.70) | 0.80 (1.30) | 35.25 (5.94) | 12.50 (3.66) | 30.75 (5.58) | 1.30 (1.48) |
| 1100-1200 | 22.98 (4.87) | 10.16 (3.33) | 28.52 (5.33) | 1.06 (1.38) | 43.00 (6.48) | 14.25 (3.83) | 39.50 (6.25) | 1.68 (1.60) |
| 1200-1300 | 22.86 (4.86) | 11.47 (3.51) | 30.36 (5.55) | 1.08 (1.39) | 49.00 (6.86) | 12.25 (3.63) | 44.50 (6.64) | 1.61 (1.58) |
| 1300-1400 | 26.23 (5.20) | 14.74 (3.94) | 30.84 (5.63) | 1.15 (1.40) | 58.00 (7.44) | 17.00 (4.24) | 45.00 (6.68) | 1.76 (1.62) |
| 1400-1500 | 22.26 (4.80) | 11.54 (3.51) | 23.82 (4.96) | 1.13 (1.40) | 36.00 (6.03) | 16.5 (4.13) | 35.50 (5.95) | 1.38 (1.51) |
| 1500-1600 | 17.61 (4.28) | 8.86 (3.04) | 12.37 (3.65) | 0.62 (1.24) | 32.00 (5.67) | 13.00 (3.72) | 24.50 (4.85) | 0.50 (1.21) |
| 1600-1700 | 9.90 (3.24) | 4.59 (2.25) | 4.61 (2.24) | 0.21 (1.09) | 25.25 (4.99) | 6.00 (2.64) | 16.50 (3.61) | 0.00 (1.00) |
| 1700-1800 | 0.58 (1.20) | 0.00 (1.00) | 0.00 (1.00) | 0.20 (1.08) | 26.00 (4.139) | 1.00 (1.30) | 17.25 (2.84) | 0.00 (1.00) |
| 1800-1900 | 0.40 (1.15) | 0.00 (1.00) | 0.00 (1.00) | 0.14 (1.06) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) |
| Mean | 12.74 | 6.54 | 14.41 | 0.59 | 27.73 | 8.37 | 22.91 | 0.76 |
| CD at 5% | 0.66 | 0.6 | 1.08 | 0.28 | 1.41 | 0.77 | 1.83 | 0.26 |
| CV (%) | 14.09 | 19.46 | 22.35 | 16.21 | 20.78 | 19.55 | 30.46 | 4.19 |

O: Outgoing bees, P: Pollen carrying bees, N: Nectar carrying bees, R: Resin carrying bees

continued up at 1500-1600 hr (0.50 bees / 5 min.). The lowest number of resin carrying bees was recorded at 0800-0900 hr (0.03 bees /5 min.) and the maximum was at 1300-1400 hr (1.15 bees / 5 min.) during first fortnight. The lowest number of resin carrying bees was recorded at 1500-1600 hr (0.50 bees / 5 min.) and the maximum was at 1300-1400 hr (1.76 bees/5 min.) during second fortnight. There was no resin foraging activity from 0700-0800 hr during first fortnight and from 0700-0900 hr and 1600-1900 hr, during second fortnight. The mean numbers of resin carrying bees were maximum during second fortnight (0.76 bees/5 min.) as compared to that of first fortnight (0.59 bees/5 min.) of November (Table 2).

**Correlation between the Outgoing and Forage Carrying Bees of *Tetragonula iridipennis* Smith with Prevailing Weather Parameters during October and November, 2022**

*October, 2022:* The mean number of outgoing bees, nectar and resin carrying bees during first fortnight of October exhibited highly significant positive correlation with hourly temperature (r=0.83 r= 0.77 and r= 0.89), wind speed (r=0.75, r=0.75 and r=0.81) and they had a non-significant negative correlation with hourly precipitation (r=-0.42, r= -0.38 and r=-0.34) whereas, outgoing bees and nectar carrying bees had significant negative correlation with hourly relative humidity (r=-0.59 and r=-0.59) and the resin carrying bees had a highly non-significant negative correlation with relative humidity (r=-0.83). The mean number of pollen carrying bees had a significant positive correlation with hourly temperature (r=0.84) and negative correlation with hourly precipitation (r=-0.54), whereas, they had a highly significant positive correlation with hourly wind speed (r=0.77) and negative correlation with hourly relative humidity (r=-0.53).

The mean number of outgoing bees, pollen and nectar carrying bees during second fortnight of October had exhibited a significant positive correlation with hourly temperature (r=0.57, r=0.59 and r=0.61), negative correlation with hourly relative humidity (r=-0.56, r=-0.60 and r=-0.57) and non-significant positive correlation with wind speed (r=0.04, r=0.01 and r=0.13), whereas, outgoing bees' had a significant negative correlation with hourly precipitation (r=-0.60), pollen and nectar carrying bees had non-significant negative correlation with precipitation (r=-0.47 and r=-0.52). The mean number of resin carrying bees had a non-significant positive correlation with hourly temperature (r=0.47), hourly wind speed (r=0.22) and negative correlation with hourly precipitation (r=-0.21), but had a significant negative correlation with hourly relative (r=-0.57) humidity (Table 3).

*November, 2022* : The mean number of outgoing bees during first fortnight of November exhibited a highly

TABLE 3

Correlation between the outgoing bees, pollen, nectar and resin carrying bees of *Tetragonula iridipennis* Smith with prevailing weather parameters during winter months of October and November, 2022

| Weather parameters | October, 2022 | | | | | | | | November, 2022 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st Fortnight | | | | 2nd Fortnight | | | | 1st Fortnight | | | | 2nd Fortnight | | | |
| | O | P | N | R | O | P | N | R | O | P | N | R | O | P | N | R |
| Temp (°C) | 0.83 ** | 0.84 * | 0.77 ** | 0.89 ** | 0.57 * | 0.59 * | 0.61 * | 0.47 (NS) | 0.79 ** | 0.76 ** | 0.63 * | 0.72 ** | 0.83 ** | 0.80 ** | 0.80 ** | 0.58 * |
| RH (%) | -0.59 * | -0.53 (NS) | -0.59 * | -0.83 ** | -0.56 * | -0.60 * | -0.57 * | -0.57 * | -0.73 ** | -0.69 ** | -0.52 (NS) | -0.61 * | -0.76 ** | -0.72 ** | -0.73 ** | -0.47 |
| WS (nautical miles/hr) | 0.75 ** | 0.77 ** | 0.75 ** | 0.81 ** | 0.04 (NS) | 0.01 (NS) | 0.13 (NS) | 0.22 (NS) | 0.56 * (NS) | 0.48 | 0.58 * | 0.61 * | 0.84 ** | 0.91 ** | 0.89 ** | 0.94 * |
| P (mm) | -0.42 (NS) | -0.54 * | -0.38 (NS) | -0.34 (NS) | -0.60 * | -0.47 (NS) | -0.52 (NS) | -0.21 (NS) | -0.55 * | -0.56 * | -0.52 (NS) | -0.58 * | - | - | - | - |

Weather parameters (Temp=Temperature, RH=Relative Humidity WS=Wind Speed and P= Precipitation) are the mean of three days during first and second fortnight of October and November

significant positive correlation with hourly temperature (r=0.79) and negative correlation with hourly relative humidity (r=-0.73), whereas, they had a significant positive correlation with hourly wind speed (r=0.56) and negative correlation with precipitation (r=-0.55). The mean number of pollen carrying bees had a highly significant positive correlation with hourly temperature (r=0.76) and negative correlation with hourly relative humidity (r=-0.69) but had a significant negative correlation with hourly precipitation (r=-0.56) and non-significant correlation with hourly wind speed (r=0.48).

The mean number of nectar carrying bees had significant positive correlation with hourly temperature (r=0.63) and hourly wind speed (r=0.58), but had a non-significant negative correlation with hourly relative humidity (r=-0.52) and precipitation (r=-0.52).The mean number of resin carrying bees had a highly significant positive correlation with hourly temperature (r=0.72) but had a significant positive correlation with hourly wind speed (r=0.61), negative correlation with relative humidity (r=-61) and hourly precipitation (r=-0.58) (Table 3).

**Foraging Activity of *Tetragonula iridipennis* Smith during December, 2022**

The number of outgoing bees, pollen, nectar and resin carrying bees of *Tetragonula iridipennis* were varied significantly among the different hours of the day during first and second fortnight of December, 2022 (Table 4).

The bees started going out at 0800-0900 hr (1.00 and 1.09 bees / 5 min.) and continued upto 1800-1900 hr (0.82 and 1.50 bees /5min.) during first and second fortnight of December. The maximum numbers of outgoing bees were recorded during 1200-1300 hr (32.20 and 37.49 bees./5 min.) in both fortnights and the lowest was recorded at 1800-1900 hr (0.82 bees/ 5min.) during first fortnight and at 0800-0900 hr (1.09 bees/5 min.) during second fortnight. The mean number of outgoing bees was maximum during second fortnight (14.13 bees/5 min.) as compared to the first fortnight (13.68 bees/5 min.) of December.

The pollen carrying bees started coming back to the nest at 0900-1000 hr (0.25 and 0.50 bees/5 min.) and continued upto 1700-1800 hr (2.71 and 3.20 bees / 5 min.) in both fortnights of December. The lowest number of pollen carrying bees was recorded during 0900-1000 hr (0.25 and 0.50 bees/5 min.) and the maximum was recorded at 1300-1400 hr (12.23 and 11.74 bees / 5 min.) in both fortnights. No pollen carrying bees were observed during 0700-0900 hr and 1800-1900 hr in both fortnights. The mean number of pollen carrying bees was maximum during second fortnight (5.23 bees/5 min.) as compared to the first fortnight (5.00 bees/5 min.) of December (Table 4).

The nectar carrying bees started coming back to hive at 0900-1000 hr (0.29 and 0.5 bees/5 min.) and continued upto 1700-1800 hr (7.93 and 7.68 bees / 5 min.) in both fortnights. The lowest number of nectar carrying bees was recorded at 0900-1000 hr (0.29 and 0.5 bees / 5 min.) during first and second fortnights. The maximum number of nectar carrying bees was recorded during 1200-1300 hr (24.70 and 33.19 bees / 5 min.) in both fortnights. There was no nectar carrying bee observed from 0700-0900 hr and 1800-1900 hr in both fortnights. The mean number of nectar carrying bees was maximum during second fortnight (11.63 bees/5 min.) as compared to that in first fortnight (10.60 bees/5 min.) of December.

The resin carrying bees were first observed at 0800-0900 hr (0.18 bees / 5 min.) which continued upto 1600-1700 hr (0.18 bees/5 min.) during first and second fortnight of December. The maximum number of resin carrying bees was recorded during 1200-1300 hr (1.07 and 1.60 bees / 5 min.) in both fortnights, whereas, the lowest was recorded at 0800-0900 hr and 1600-1700 (0.18 bees /5 min.). No resin carrying bee was observed from 0700-0800 hr and 1700-1900 hr in both fortnights. The mean number of resin carrying bees was maximum during second fortnight (0.49 bees/5 min.) as compared to that of first fortnight (0.39 bees/5 min.) of December (Table 4).

TABLE 4

Foraging activity of *Tertragonula iridipennis* Smith during December, 2022

| Time (hr) | December, 2022 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st Fortnight (Mean from 13-12-22 to 15-12-22) | | | | 2nd Fortnight (Mean from 28-12-22 to 30-12-22) | | | |
| | O | P | N | R | O | P | N | R |
| 0700-0800 | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) |
| 0800-0900 | 1.00 (1.30) | 0.00 (1.00) | 0.00 (1.00) | 0.18 (1.08) | 1.09 (1.39) | 0.00 (1.00) | 0.00 (1.00) | 0.18 (1.08) |
| 0900-1000 | 1.06 (1.38) | 0.25 (1.10) | 0.29 (1.11) | 0.34 (1.13) | 1.53 (1.54) | 0.50 (1.18) | 0.50 (1.18) | 0.34 (1.13) |
| 1000-1100 | 6.53 (2.54) | 1.81 (1.63) | 5.33 (2.46) | 0.78 (1.29) | 10.31 (3.24) | 4.06 (2.19) | 8.68 (3.02) | 0.59 (1.20) |
| 1100-1200 | 18.18 (4.35) | 5.35 (2.45) | 17.59 (4.12) | 0.79 (1.31) | 20.46 (4.61) | 6.91 (2.76) | 19.96 (4.48) | 1.04 (1.41) |
| 1200-1300 | 32.20 (5.74) | 11.30 (3.45) | 24.70 (5.02) | 1.07 (1.40) | 37.49 (6.17) | 10.34 (3.32) | 33.19 (5.81) | 1.60 (1.59) |
| 1300-1400 | 30.79 (5.61) | 12.23 (3.61) | 21.21 (4.67) | 0.56 (1.23) | 27.31 (5.27) | 11.74 (3.51) | 23.23 (4.88) | 1.44 (1.56) |
| 1400-1500 | 29.68 (5.47) | 11.46 (3.45) | 19.55 (4.43) | 0.51 (1.21) | 28.29 (5.36) | 11.30 (3.47) | 20.24 (4.55) | 0.34 (1.13) |
| 1500-1600 | 23.20 (4.80) | 8.95 (3.08) | 18.56 (4.37) | 0.27 (1.12) | 20.68 (4.58) | 7.78 (2.93) | 15.91 (4.10) | 0.18 (1.08) |
| 1600-1700 | 13.60 (3.46) | 5.96 (2.49) | 12.04 (3.18) | 0.18 (1.08) | 13.04 (3.61) | 6.93 (2.80) | 10.18 (3.30) | 0.18 (1.08) |
| 1700-1800 | 7.08 (2.51) | 2.71 (1.82) | 7.93 (2.60) | 0.00 (1.00) | 7.93 (2.86) | 3.20 (2.00) | 7.68 (2.81) | 0 (1.00) |
| 1800-1900 | 0.82 (1.26) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 1.50 (1.41) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) |
| Mean | 13.68 | 5.00 | 10.60 | 0.39 | 14.13 | 5.23 | 11.63 | 0.49 |
| CD at 5% | 1.14 | 0.68 | 1.14 | 0.19 | 1.00 | 0.59 | 0.71 | 0.19 |
| CV (%) | 23.99 | 21.90 | 27.05 | 11.80 | 20.30 | 18.28 | 16.01 | 11.41 |

O: Outgoing bees, P: Pollen carrying bees, N: Nectar carrying bees, R: Resin carrying bees

**Foraging Activity of *Tetragonula iridipennis* Smith during January, 2023**

The number of outgoing bees, pollen, nectar, and resin carrying bees of *Tetragonula iridipennis* were varied significantly among the different hours of the day during first and second fortnight of January, 2022 (Table 5).

In January, the outgoing bees started their activity at 0900-1000 hr (15.93 bees/5 min.) during first fortnight and at 0700-0800 hr (4.50 bees/5 min.) during second fortnight and continued upto 1700-1800 hr (17.74 / 5 min.) during first fortnight and at 1800-1900 hr (1.91 bees/5 min) during second fortnight of January. The maximum number of outgoing bees were recorded at 1300-1400 hr (54.33 bees / 5 min.) and the lowest number of outgoing bees were recorded at 0900-1000 hr (15.93 bees / 5 min.) during first fortnight, whereas, in second fortnight the lowest number of outgoing bees was recorded at 1800-1900

TABLE 5

Foraging activity of *Tetragonula iridipennis* Smith during winter months of January, 2023

| Time (hr) | January, 2023 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st Fortnight (Mean from 13-01-23 to 15-01-23) | | | | 2nd Fortnight (Mean from 28-01-23 to 30-01-23) | | | |
| | O | P | N | R | O | P | N | R |
| 0700-0800 | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 4.50 | 1.18 (1.45) | 1.56 | 0.07 (1.03) |
| 0800-0900 | 0.00 (1.08) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 12.45 | 2.32 (1.76) | 12.09 | 0.22 (1.10) |
| 0900-1000 | 15.93 (4.11) | 3.81 (2.19) | 6.81 (2.79) | 0.06 (1.03) | 27.41 | 4.07 (2.24) | 21.98 | 0.59 (1.26) |
| 1000-1100 | 23.71 (4.96) | 4.29 (2.27) | 11.81 (3.58) | 0.33 (1.15) | 25.20 | 6.45 (2.72) | 67.59 | 1.02 (1.42) |
| 1100-1200 | 26.96 (5.28) | 6.06 (2.62) | 20.80 (4.61) | 0.45 (1.20) | 26.41 | 9.93 (3.30) | 67.31 | 1.04 (1.43) |
| 1200-1300 | 35.81 (6.06) | 10.05 (3.27) | 42.03 (6.56) | 0.54 (1.24) | 31.94 | 10.56 (3.38) | 72.84 | 1.32 (1.52) |
| 1300-1400 | 54.33 (7.43) | 8.05 (3.00) | 45.54 (6.81) | 0.54 (1.22) | 62.19 | 6.92 (2.81) | 79.46 | 1.04 (1.41) |
| 1400-1500 | 41.30 (6.48) | 10.41 (3.37) | 47.08 (6.93) | 0.63 (1.25) | 66.70 | 7.42 (2.88) | 61.87 | 1.14 (1.44) |
| 1500-1600 | 35.44 (6.02) | 7.70 (2.95) | 45.34 (6.80) | 0.32 (1.14) | 50.29 | 5.57 (2.55) | 33.45 | 0.59 (1.25) |
| 1600-1700 | 29.11 (5.48) | 5.71 (2.59) | 30.19 (5.53) | 0.15 (1.06) | 28.93 | 4.32 (2.30) | 19.05 | 0.48 (1.21) |
| 1700-1800 | 17.74 (4.33) | 7.73 (2.95) | 16.86 (4.22) | 0.06 (1.03) | 17.09 | 5.57 (2.55) | 14.41 | 0.17 (1.08) |
| 1800-1900 | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 1.91 | 0.00 (1.00) | 11.44 | 0.00 (1.00) |
| Mean | 23.36 | 5.32 | 22.20 | 0.25 | 29.58 | 5.36 | 38.59 | 0.64 |
| CD at 5% | 0.36 | 0.35 | 0.47 | 0.14 | 6.70 | 0.39 | 21.65 | 0.17 |
| CV (%) | 5.71 | 10.55 | 7.79 | 8.68 | 15.67 | 11.33 | 38.83 | 9.50 |

O: Outgoing bees, P: Pollen carrying bees, N: Nectar carrying bees, R: Resin carrying bees

hr (1.91 bees/5 min.) and maximum was recorded at 1400-1500 hr (66.70 bees/5 min.). No outgoing bees were observed from 0700-0900 and1800-1900 hr during first fortnights. The mean numbers of outgoing bees were maximum during second fortnight (29.58 bees/5 min.) as compared to that of first fortnight (23.36 bees/5 min.).

The pollen carrying bees started their activity at 0900-1000 hr (3.81 bees / 5 min.) during first fortnight and at 0700-0800 hr (1.18 bees / 5 min.) during second fortnight and continued upto 1700-1800 hr (7.73 and 5.57 bees /5 min.) in both fortnights. The maximum number of pollen carrying bees was recorded at 1200-1300 hr (10.05 and 10.56 bees / 5 min.) in both fortnights and the lowest number of pollen carrying bees was recorded at 0900-1000 hr (3.81 bees/5 min.) during first fortnight and at 0700-0800 hr (1.18 bees/ 5 min.) during second fortnight. There were no pollen carrying bees observed from 0700-0900 hr during first fortnight and at 1800-1900 hr in both fortnights. The



The Mysore Journal of Agricultural Sciences

mean number of pollens carrying bees were maximum during second fortnight (5.36 bees/5 min.) compared to that of first fortnight (5.32 bees/5 min.) of January.

The nectar carrying bees were noticed at 0900-1000 hr (6.81 bees / 5 min.) and continued upto 1700-1800 hr (16.86 bees/5 min.) during first fortnight whereas, in second fortnight nectar carrying bee activity was observed during started at 0700-0800 hr (1.56 bees/ 5 min.) and it continued upto 1800-1900 hr (11.44 bees/5 min.). The maximum number of nectar carrying bees were recorded at 1400-1500 hr (47.08 bees/ 5 min.) and the lowest was recorded at 0900-1000 hr (6.81 bees/5 min.) during first fortnight, whereas, in second fortnight the lowest number of nectar carrying bees were recorded at 0700-0800 hr (1.56 bees/5 min.) and maximum was recorded at 1300-1400 hr (79.46 bees/5 min.). No nectar carrying bees were observed from 0700-0900 hr and 1800-1900 hr during first fortnight. The mean number of nectar carrying bees was maximum during second fortnight (38.59 bees/ 5 min.) as compared to that of first fortnight (22.20 bees/5 min.) in January.

The resin carrying bee activity was started coming at 0900-1000 hr (0.06 bees/5 min.) during first fortnight and at 0700-0800 hr (0.07 bees / 5 min.) during second fortnight and continued upto 1700-1800 hr (0.06 and 0.17 bees /5 min.) in both the fortnights. The maximum number of resin carrying bees were recorded at 1400-1500 hr (0.63 bees/5 min.) and the lowest was recorded at 0900-1000 and1700-1800 hr (0.06 bees / 5 min.) during first fortnight, whereas, in second fortnight maximum number of resin carrying bees were recorded at 1200-1300 hr (1.32 bees/5 min.) and the lowest was recorded at 0700-0800 hr (0.07 bees / 5 min.). No resin carrying bees were observed from 0700-0900 hr during first fortnight and 1800-1900 hr in both the fortnights. The mean numbers of resins carrying bees were maximum during second fortnight (0.64 bees/5 min.) as compared to the first fortnight (0.25 bees/5 min.) of January (Table 5).

**Correlation between the Outgoing and Forage Carrying Bees of *Tetragonula iridipennis* Smith with Prevailing Weather Parameters during December, 2022 and January, 2023**

*December,2022* : The mean number of outgoing bees, pollen and nectar carrying bees during first fortnight of December exhibited a highly significant positive correlation with hourly temperature (r=0.89, r=0.88 and r=0.89) and negative correlation with relative humidity (r=-0.89, r=-0.90 and r=-0.91), whereas, they had non-significant positive correlation with hourly wind speed (r=0.49, r=0.43 and r=0.45) and non-significant negative correlation with hourly precipitation (r=-0.33, r=-0.32 and r=-0.35). The mean number of resin carrying bees had a significant positive correlation with hourly temperature (r=0.70), but had a highly significant positive correlation with hourly wind speed (r=0.74), whereas, they had a non-significant negative correlation with hourly relative humidity (r=-0.53) and hourly (r=-0.34) precipitation.

The mean number of outgoing bees, pollen and nectar carrying bees during second fortnight of December exhibited a highly significant positive correlation with hourly temperature (r=0.76, r=0.82 and r=0.73), wind speed (r=0.81, r=0.80 and r=0.82), precipitation (r=0.82, r=0.87 and r=0.80) and negative correlation with relative humidity (r=-0.85, r=-0.91 and r=-0.83). The mean number of resin carrying bees had a non-significant positive correlation with hourly temperature (r=0.46) and negative correlation with hourly relative humidity (r=- 0.50), whereas, highly significant positive correlation with hourly wind speed (r=0.84) and significant positive correlation with hourly (r=0.60) precipitation (Table 6).

*January, 2023* : The mean number of outgoing bees, pollen and nectar carrying bees during first fortnight of January exhibited a highly significant positive correlation with hourly temperature (r=0.77, r=0.81 and r=0.81), negative correlation with relative humidity (r=-0.71, r=-0.76 and r=-0.75) and non-significant positive correlation with wind speed

TABLE 6

Correlation between the outgoing bees, pollen, nectar and resin carrying bees of *Tetragonula iridipennis* Smith with prevailing weather parameters during winter months of December, 2022 and January, 2023

| Weather parameters | December, 2022 | | | | | | | | January, 2023 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st Fortnight | | | | 2nd Fortnight | | | | 1st Fortnight | | | | 2nd Fortnight | | | |
| | O | P | N | R | O | P | N | R | O | P | N | R | O | P | N | R |
| Temp (°C) | 0.89 ** | 0.88 ** | 0.89 ** | 0.70 | 0.76 ** | 0.82 ** | 0.73 ** | 0.46 (NS) | 0.77 ** | 0.81 ** | 0.81 ** | 0.60 * | 0.65 * | 0.67 * | 0.61 * | 0.59 * |
| RH (%) | -0.89 ** | -0.90 ** | -0.91 ** | -0.53 (NS) | -0.85 ** | -0.91 ** | -0.83 ** | -0.50 (NS) | -0.71 ** | -0.76 ** | -0.75 ** | -0.59* | -0.63 * | -0.69 * | -0.63 * | -0.61 * |
| WS (nautical miles/hr) | 0.49 (NS) | 0.43 (NS) | 0.45 (NS) | 0.74 ** | 0.81 ** | 0.80 ** | 0.82 ** | 0.84 ** | 0.43 (NS) | 0.26 (NS) | 0.38 (NS) | 0.30 (NS) | 0.37 (NS) | 0.09 (NS) | 0.19 (NS) | 0.08 (NS) |
| P (mm) | -0.33 (NS) | -0.32 (NS) | -0.35 (NS) | -0.34 (NS) | 0.82 ** | 0.87 ** | 0.80 ** | 0.60 * | - | - | - | - | - | - | - | - |

Weather parameters (Temp=Temperature, RH=Relative Humidity WS=Wind Speed and P= Precipitation) are the mean of three days during first and second fortnight of October and November

(r=0.43, r=0.26 and r=0.38). The mean number of resin carrying bees had a significant positive correlation with hourly temperature (r=0.60), negative correlation with hourly relative humidity (r=-0.59) and had a non-significant positive correlation with hourly wind speed (r=0.30) and there was no precipitation during first fortnight of January.

The mean number of outgoing bees, pollen, nectar and resin carrying bees during second fortnight of January had exhibited a significant positive correlation with hourly temperature (r=0.65, 0.67, 0.61 and 0.59), negative correlation with relative humidity (r=-0.63, r=-0.69, r=-0.63 and r=-.61), but they had a non-significant positive correlation with hourly wind speed (r=0.37, r=0.09, r=0.19 and r=0.08) and there was no precipitation during second fortnight of January (Table 6).

## Overall Foraging Activity of *Tetragonula iridipennis* Smith during Winter Months of 2022-2023

Irrespective of winter months, peak outgoing bees was recorded between 1100-1600 hr, peak nectar carrying bee activity was between 1100-1500 hr, peak pollen carrying bee activity was between 1200-1400 hr and resin carrying bee activity was between 1200-1500 hr. These findings on the resin carrying bees were in accordance with the findings of Roopa (2002) who recorded peak resin foraging activity at 1100-1600 hr during winter. However, the lowest number of outgoing bees, pollen, nectar and resin carrying bees was recorded during early morning (0700-0900 hr) and late evening hours (1700-1900 hr). The variation in the foraging activity might be due to variation in prevailing meteorological parameters and difference in the availability of floral rewards. Among forage carrying bees during winter months, the number of nectar carrying bees were maximum, followed by pollen and resin carrying bees (N>P >R), this might be due to resource requirement of the colony. These findings in the present investigation are more or less similar with the findings of Mythri *et al.* (2023) who recorded significantly maximum number of outgoing bees between 1200-1400 hr, followed by 1000-1200 hrs. The number of pollen and nectar collecting bees

was significantly maximum during 1000-1200 hr, followed by 1200-1400 hr. The number of outgoing bees, pollen and nectar collector bees were significantly lowest in early morning (0600-0800 hr) and late evening hours (1600-1800 hr) during winter months from October, 2022 to January, 2023.

**Overall Correlation between the Outgoing and Forage Carrying Bees of *Tetragonula iridipennis* Smith with Prevailing Weather Parameters during Winter Months of 2022-2023**

Irrespective of the winter months, the number of outgoing bees, pollen, nectar and resin carrying bees had either highly significant positive correlation or significantly positive correlation with hourly temperature except the resin foragers during second fortnight of October and December, which had non-significant positive correlation with temperature. However, they had either highly significant negative correlation or significantly negative correlation with hourly relative humidity, except nectar foragers during first fortnight of November and resin foragers during first and second fortnight of December, which had a non-significant negative correlation with relative humidity.

The number of outgoing bees, pollen, nectar and resin carrying bees had either highly significant positive correlation or significantly positive correlation or non-significant positive correlation with hourly wind speed. However, they had both significant negative correlation and non-significant negative correlation with hourly precipitation except outgoing bees, pollen, and nectar carrying bees during second fortnight of December, which had highly significant positive correlation, while, the resin carrying bees had significant positive correlation with hourly precipitation. This might be due to scattered / less precipitation. As a whole, during winter season, the hourly temperature and wind speed had positive correlation with foraging activity, whereas the hourly relative humidity and precipitation affected the foraging activity of *Tetragunula iridipennis* Smith. These findings are supported by Bharath *et al.* (2020) who stated that the average maximum temperature (32.05°C) and wind speed (1.30 kmph) had a positive correlation with foraging behaviour of outgoing bees (r=0.72), incoming bees (r=0.73) and incoming bees with pollen (r=0.84) and the rainfall had a strong negative correlation with flight activities of stingless bee at Tamil Nadu during winter season.

## References

Bharath, M. P., Chinniah, C., Jayaraj, J., Suresh, K., Balamohan, T. N. and Vellaikumar, S., 2020, Foraging performance of stingless bee*, Tetragonula irridipennis* Smith (Hymenoptera: Apidae) during winter season in Madurai, Tamil Nadu. *Int. J. Chem. Stud*., **7** (6) : 360 - 364.

Biesmeijer, J. C. and De Vries, H., 2001, Exploration and exploitation of food sources by social insect colonies: a revision of the scout-recruit concept. *Behav. Ecol. Sociobiol.*, **49** : 89 - 99.

Leonhardt, S. D., Dworschak, K., Eltz, T. and Blüthgen, N., 2007, Foraging loads of stingless bees and utilisation of stored nectar for pollen harvesting. *Apidologie,* **38** (2) : 125 - 135.

Michener, C. D., 2013, The meliponini. In-pot honey. *Springer*, New York. pp. : 3 - 17.

Mythri, R. N., Kencharaddi, S., Venukumar, L., Hanumantharaya, M., Shivaprasad, G. N. and Hosagoudar, 2023, Foraging behaviour of stingless bee, *Tetragonula iridipennis* (Smith). *J. Exp. Zool. India,* **26** : 461 - 466.

Roopa, A. N., 2002, Bioecology of stingless bees, *Trigona iridipennis* Smith, *M.Sc. (Agri.) Thesis,* University of Agricultural Sciences, Bangalore.

Wille, A., 1983, Biology of the stingless bees. *Annu. Rev. Entomol.,* **28** (1) : 41 - 64.