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## Foraging behaviour of stingless bee, *Tetragonula iridipennis* Smith on gherkin

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**Abstract**

Stingless bees play an important ecological role and identified as the ideal pollinators for crop pollination under protected cultivation. The present study was carried out to know the activity of stingless bee, *Tetragonula iridipennis* in pollination of gherkin crop cultivated under greenhouses located in seed farm, Ranebennur taluk, Haveri district, Karnataka of southern India during two seasons, *rabi* (2020-2021) and *kharif* (2022). At the time of flower initiation five stingless bee colonies were introduced inside the greenhouse. The activity of outgoing foragers started at 07:00 AM and continued up to 06:00 PM with peak activity at 11.00 AM to 12.00 PM (100.40 foragers 5 min<sup>-1</sup>) during *rabi*. In *kharif*, activity of bees started from 08:00 AM till 06:00 PM with peak activity at 11:00 AM to 12:00 PM (92.80 foragers 5 min<sup>-1</sup>). Among the incoming foragers, pollen foragers commenced from 09:00 AM with maximum activity at 10:00 AM to 11:00 AM (36.80 foragers 5 min<sup>-1</sup> in *rabi* and 27.20 foragers 5 min<sup>-1</sup> in *kharif*). Whereas, nectar foragers initiated from 07.00 AM and 08.00 AM during *rabi* and *kharif* season, respectively with peak at 11.00 AM to 12.00 PM (85.00 foragers 5 min<sup>-1</sup> in *rabi* and 75.20 foragers 5 min<sup>-1</sup> in *kharif*). Nectar foragers found throughout the day up to 06.00 PM. The flower sex type selection index of stingless bee was 0.479 indicates strong preference to male flower. Thus, stingless bee, *T. iridipennis* Smith are the prominent foragers of greenhouse cro0070.

**Keywords:** Stingless bee, gherkin, foragers, activity, nectar, pollen, flower

**Introduction**

Pollinators are essential biotic factors in enhancing the crop production and productivity. The efficient pollinators are belongs to super family Apoidea, among these most promising one seems to be stingless bees belongs to family Apidae and sub family meliponinae, since they have vestigial sting that makes them safe for farm workers to carryout daily cultural practices (Chauhan *et al.*, 2019) [3]. Stingless bees forage at different distances depends on the size of the individuals; however, many species can occupy a much smaller effective foraging range of less than 0.5 km. Stingless bees are potential pollinators for open and protected cultivation. Several stingless bees species have been determined to provide adequate pollination services to many different crops grown under protected cultivation, such as strawberry, eggplant (*Solanum melongena* L.), sweet pepper (*Capsicum annuum* L.), tomato (*Lycopersicon esculentum* Mill.) and cucumber (*Cucumis sativus* L.) (Nunes *et al.*, 2013; Nicodemo *et al.*, 2013) [9, 8]. In fact, most research on stingless bees from the Indian subcontinent has focused on their role as crop and native flora pollinators (Raju *et al.*, 2009) [10]. Cucumber is wildy grown crop in greenhouses and flower phenology of cucurbits ensures better cross-pollination for higher fruit set and yield (Roubik, 1995; Santos *et al.*, 2008) [13, 14]. Gherkin fruits are similar to cucumber in form and nutrition value, exported as preserved gherkins. Nearly one lakh farmers involved in gherkin cultivation and Karnataka produced 2.65 tons in 50000 acres (Reddy, 2019) [11]. Cucurbits require efficient transfer of pollen to the stigmas so, it becomes necessary to introduce hives to attain good yields (Nicodemo *et al.*, 2013) [8] in confined condition. The generalist feeding habits and floral constancy suggest the profitable use of stingless bee species in field and greenhouse crops, as a promising option for pollination efficiency. Keeping in view the enhanced use of stingless bees in pollination of different crops, present study evaluates the foraging behaviour of stingless bee, *Tetragonula iridipennis* Smith in gherkin that aids in good pollination services under protected cultivation.

**Materials and Methods**

The present investigations carried out in Devar seed farm located in Ranebennur taluk, Haveri district of Karnataka (14.7951° N, 75.3991° E, 571 m above MSL).

Gherkin crop was raised inside the 500 m<sup>2</sup> area of greenhouse. All agronomic practices except plant protection measures were carried out with the crop sown in *rabi* season of the year 2020-21 and *kharif* 2022. After 15 days of transplanting crop came to bloom. After that, five stingless bee colonies were introduced inside the greenhouse at five per cent flowering of crop. The following observations were recorded to find out role of stingless bee in applied pollination of gherkin under protected cultivation. Activity of outgoing foragers (bees going out of the colony), incoming foragers (bees moving inside the colony) with pollen (pollen foragers) and without pollen (nectar foragers) from 06:00 AM to 06:00 PM were recorded. Each hour colonies were observed for five minutes and number of bees moving outside and inside were counted for five days in weekly interval during peak flowering period of the crop. The number of female flower and male flower within the randomly selected area were counted and number of female flowers and male flowers visited by the bee in that area were also recorded for further calculation of flower sex type selection index (FSI). Flower sex type selection index (FSI) is determined using the following method:

$$FSI = \frac{\text{No. of visited female flowers}}{\text{No. of visited male flowers}} \div \frac{\text{No. of female flowers within the area}}{\text{No. of male flowers within the area}}$$

Based on the FSI value, the stingless bees were placed within one of seven categories, which are shown below.

Categories of floral visitors based on flower sex type selection index (FSI) value

Category	Value of FSI
Strong preference to female flower	>1.5
Moderate preference to female flower	1.2–1.5
Slightly preference to female flower	1 < FSI < 1.2
Neutral to flower sex type	1
Slightly preference to female flower	0.8 < FSI < 1
Moderate preference to male flower	0.5–0.8
Strong preference to male flower	< 0.5

## Results and Discussions

The activity of outgoing foragers during *rabi* 2020-21, initiated at 07:00 AM (3.20 foragers 5 min<sup>-1</sup>) then, gradually increased and maximum outgoing foragers were observed between 10:00 AM to 01:00 PM *i.e.* 86.40 foragers 5 min<sup>-1</sup> between 10:00 to 11:00 AM and peak was observed between 11:00 AM to 12:00 PM (100.40 foragers 5 min<sup>-1</sup>). After 01:00 PM activity started declining slowly and reached to 16.80 foragers 5 min<sup>-1</sup> at 05:00 PM. No foragers were found going outside after 05:00 PM (Table 1). In *kharif* season (Table 2), the activity of outgoing foragers started late as compared to *rabi* season. The activity started at 08:00 AM (3.40 foragers 5 min<sup>-1</sup>) then, increased exponentially from 09:00 AM (32.20 foragers 5 min<sup>-1</sup>) and reached to its peak between 11:00 AM to 12:00 PM (92.80 foragers 5 min<sup>-1</sup>) followed by 12:00 PM to 01:00 PM (81.60 foragers 5 min<sup>-1</sup>). In afternoon, activity of outgoing foragers gradually declined from 70.80 foragers 5 min<sup>-1</sup> (01:00 to 02:00 PM) to 13.20 foragers 5 min<sup>-1</sup> (05:00 to 06:00 PM).

The activity of incoming pollen foragers in *rabi* commenced from 09:00 AM (31.00 foragers 5 min<sup>-1</sup>) and found only mid part of the day. However maximum number of incoming foragers with pollen load were recorded during 10:00 AM to 11:00 AM (36.80 foragers 5 min<sup>-1</sup>) followed by 11:00 AM to 12:00 PM (31.00 foragers 5 min<sup>-1</sup>) while minimum number of

incoming pollen foragers were recorded during 03:00 PM (1.80 foragers 5 min<sup>-1</sup>). The activity of incoming bees with pollen load started late, there was no activity of incoming foragers with pollen load in the early morning from 06:00 AM to 09:00 AM (Table 1). In *kharif* 2022, the activity of incoming pollen foragers initiated from 09:00 AM (18.40 foragers 5 min<sup>-1</sup>) and maximum number of incoming foragers with pollen load were recorded during 10:00 AM to 11:00 AM (27.20 foragers 5 min<sup>-1</sup>) followed by 11:00 AM to 12:00 PM (19.60 foragers 5 min<sup>-1</sup>). Later, activity of incoming pollen foragers decreased, while minimum number of incoming pollen foragers were recorded between 03:00 PM to 04:00 PM (1.80 foragers 5 min<sup>-1</sup>) (Table 2).

The bees returning to hive without pollen pellet were considered as non-pollen foragers or nectar foragers. The foraging activity of incoming nectar foragers initiated from 07:00 AM (1.80 foragers 5 min<sup>-1</sup>) with a gradual rise in activity reaching maximum at 11:00 AM to 12:00 PM (85.00 foragers 5 min<sup>-1</sup>) followed by 12:00 PM to 01:00 PM (83.00 foragers 5 min<sup>-1</sup>) (Table 1). In *kharif* 2022, the incoming nectar foragers activity initiated from 08:00 AM (1.20 foragers 5 min<sup>-1</sup>) with a gradual rise in number *i.e.* 23.20 foragers 5 min<sup>-1</sup> (09:00 to 10:00 AM) and 48.80 foragers 5 min<sup>-1</sup> (10:00 to 11:00 AM) reaching maximum at 11:00 AM to 12:00 PM (75.20 foragers 5 min<sup>-1</sup>) followed by 12:00 PM to 01:00 PM (62.20 foragers 5 min<sup>-1</sup>) (Table 2). The activity of incoming foragers without pollen load (nectar foragers) found throughout the day. The moderate decline in the activity was observed in the afternoon hours.

The activity of outgoing foragers, incoming foragers with pollen and incoming foragers without pollen during two seasons, *rabi* 2020-21 and *kharif* 2022 varied significantly with different hours of the day but, trend of the activity was remarkably similar in both the seasons (Fig.1). In *rabi*, higher number of outgoing foragers, incoming foragers with and without pollen was recorded compare to *kharif* season. This is due to weather condition outside the greenhouse that influenced the activity of foragers inside the greenhouse. Stingless bees require high temperature for its activity and bees come out only when there is a bright sunshine outside. Most cucurbit flower stigmas are receptive during anthesis from about 06:00 AM to 02:00 PM (Delaplane and Mayer, 2000) [6]. These results are in lined with Danaraddi (2007) [5] revealed that, the peak activity of outgoing bees, pollen foragers and incoming bees without pollen occurred at 12:00 PM and was higher in October, November and February (*rabi*) compare to July and August (*kharif*) due to high rainfall. Similarly, Roopa (2002) [12] reported major and minor peak of outgoing foragers between 10:00 AM to 12:00 PM and 12:00 PM to 01:00 PM, respectively whereas, second peak of nectar foragers recorded between 02:00 PM to 03:00 PM. Santos *et al.* (2008) [14] outlined that, the maximum collecting activity of stingless bees was observed at 12:00 PM. Malerbo-Souza *et al.* (2020) [7] stated that, bees prefer to visit gherkin flowers from 08:00 AM to 03:00 PM and they visit both male and female flowers to collect nectar and pollen, characterizing them as effective pollinators. In confirmation with our findings, Bomfim *et al.* (2016) [2] found that, in cucumber flower, stigma becomes more receptive during five to six hours after flower opening so, maximum activity of foragers were observed during 11:00 AM to 01:00 PM. The variations in some findings are preferably due to difference in climatic factors, availability of foraging resources and colony conditions.

In order to calculate flower sex type selection index of stingless bees on gherkin crop, number of female flowers and male flowers per square meter area were counted. Then, number of female flower and male flowers visited by bee were recorded during *rabi* 2020-21 and *kharif* 2022 (Table 3). During *rabi* 2020-21, the calculated flower sex type selection index (FSI) of stingless bees on gherkin flower was 0.477. During *kharif* 2022, calculated flower sex type selection index (FSI) of stingless bees on gherkin flower was 0.481. The pooled data of *rabi* 2020-21 and *kharif* 2022 depicted that

flower sex type selection index of stingless bees on gherkin flower was 0.479 indicating that preference of stingless bees was more to male flower compare to female flower during foraging. This result in agreement with Bisui *et al.* (2020)<sup>[1]</sup> reported that stingless bees are legitimate visitors of bitter gourd flowers and they showed a selective preference for male flowers (FSI of 0.42). Female flowers produce higher volume of nectar compare to male flowers but sugar concentration is more in male flowers of cucumber (Collison, 2007)<sup>[4]</sup>.

**Table 1:** Activity of outgoing and incoming foragers in gherkin during *rabi* 2020-21

Time period	No. of bees/5 min		
	Outgoing foragers (Mean $\pm$ SD)	Incoming foragers with pollen (Mean $\pm$ SD)	Incoming foragers without pollen (Mean $\pm$ SD)
6 AM - 7 AM	0.00	0.00	0.00
7 AM - 8 AM	3.20 $\pm$ 1.17	0.00	1.80 $\pm$ 0.75
8 AM - 9 AM	10.80 $\pm$ 2.93	0.00	6.20 $\pm$ 2.14
9 AM - 10 AM	53.20 $\pm$ 9.33	23.00 $\pm$ 6.42	39.40 $\pm$ 8.96
10 AM - 11 AM	86.40 $\pm$ 16.91	36.80 $\pm$ 11.69	79.80 $\pm$ 14.47
11 AM- 12 PM	100.40 $\pm$ 15.32	31.00 $\pm$ 8.88	85.00 $\pm$ 8.29
12 PM- 1 PM	83.60 $\pm$ 6.68	8.80 $\pm$ 2.79	83.00 $\pm$ 10.28
1 PM - 2 PM	79.60 $\pm$ 5.50	3.80 $\pm$ 3.25	74.20 $\pm$ 5.84
2 PM - 3 PM	69.00 $\pm$ 7.54	1.80 $\pm$ 1.60	66.40 $\pm$ 6.47
3 PM - 4 PM	59.80 $\pm$ 9.02	0.00	64.60 $\pm$ 12.63
4 PM - 5 PM	16.80 $\pm$ 6.49	0.00	45.40 $\pm$ 14.19
5 PM - 6 PM	0.00	0.00	11.20 $\pm$ 4.45

\*Mean of 5 observations \*SD- Standard deviation

**Table 2:** Activity of outgoing and incoming foragers in gherkin during *kharif* 2022

Time period	No. of bees/5 min		
	Outgoing foragers (Mean $\pm$ SD)	Incoming foragers with pollen (Mean $\pm$ SD)	Incoming foragers without pollen (Mean $\pm$ SD)
6 AM - 7 AM	0.00	0.00	0.00
7 AM - 8 AM	0.00	0.00	0.00
8 AM - 9 AM	3.40 $\pm$ 3.07	0.00	1.20 $\pm$ 1.17
9 AM - 10 AM	32.20 $\pm$ 11.63	18.40 $\pm$ 5.31	23.20 $\pm$ 9.28
10 AM - 11 AM	68.60 $\pm$ 10.21	27.20 $\pm$ 5.91	48.80 $\pm$ 12.45
11 AM- 12 PM	92.80 $\pm$ 7.98	19.60 $\pm$ 5.16	75.20 $\pm$ 8.21
12 PM- 1 PM	81.60 $\pm$ 10.84	7.20 $\pm$ 1.72	62.20 $\pm$ 9.11
1 PM - 2 PM	70.80 $\pm$ 14.46	3.60 $\pm$ 1.85	55.60 $\pm$ 10.46
2 PM - 3 PM	60.80 $\pm$ 11.96	1.40 $\pm$ 1.50	44.20 $\pm$ 11.69
3 PM - 4 PM	45.40 $\pm$ 11.72	0.40 $\pm$ 0.80	37.00 $\pm$ 13.40
4 PM - 5 PM	13.20 $\pm$ 5.15	0.00	19.40 $\pm$ 9.35
5 PM - 6 PM	0.00	0.00	10.40 $\pm$ 4.80

\*Mean of 5 observations \*SD- Standard deviation

**Table 3:** Flower sex type selection index (FSI) of stingless bees on gherkin flower

Season	No. of female flowers/ m <sup>2</sup>	No. of male flowers/ m <sup>2</sup>	No. of female flowers visited by bee/ m <sup>2</sup>	No. of male flowers visited by bee/ m <sup>2</sup>	FSI
<i>rabi</i> 2020-21	41.50 $\pm$ 13.93	15.80 $\pm$ 3.61	14.90 $\pm$ 3.35	11.90 $\pm$ 4.18	0.477
<i>kharif</i> 2022	38.70 $\pm$ 10.33	16.20 $\pm$ 5.59	11.60 $\pm$ 3.95	10.10 $\pm$ 4.53	0.481
Pooled	40.10 $\pm$ 9.39	16.00 $\pm$ 2.47	13.25 $\pm$ 2.25	11.00 $\pm$ 2.61	0.479

\*Mean of 10 observations SD- Standard deviation

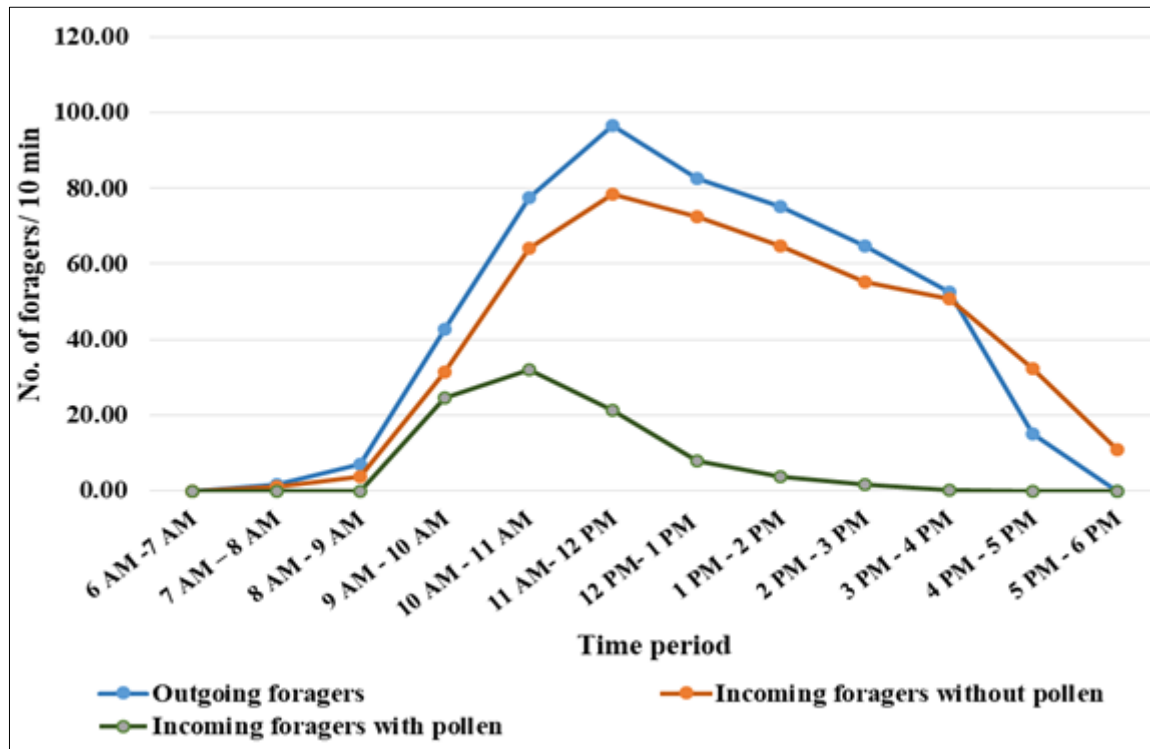


Fig 1: Activity of stingless bee foragers in gherkin under protected cultivation

The foraging activity of stingless bees commence slowly in the morning hours; gradually raise with sunshine and reaches the top at late morning hours then, pollinating visits declines at the end of the day. Bees can be successfully reared if the availability of flora is sufficient even at a relatively high temperature (>30 °C) and humidity, suggesting that they are potential pollinator of crops under greenhouse. In search of high quality food source bee visitation was more on male flowers even though they are in less number compare to female flowers. Stingless bees tend to prefer pollen as a food to honey and collect mainly the pollen that indicate they are very good pollinator.

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