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Research Article

FORAGING BEHAVIOUR OF *Tetragonula iridipennis* (Smith) IN CUCUMBER UNDER PROTECTED CULTIVATION

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Abstract: Foraging behaviour of *Tetragonula iridipennis* (Smith) on cucumber (*Cucumis sativus* L.) flowers inside the polyhouse was evaluated to determine the effectiveness of using them as pollinators. The mode of foraging and foraging behaviour *viz*; foraging rate, foraging intensity and foraging speed of stingless bees was recorded during the peak flowering stage of the crop. The diurnal variations in colony activity *viz*; total number of returning (pollen and nectar) and outgoing foragers were counted separately for 5 minutes at the entrance of the bee colony. The observations were taken at hourly intervals from 0800-0900 h to 1600-1700 h. Temperature and the relative humidity inside the polyhouse was also recorded. Two modes of alighting were observed viz; side workers (78.00 %) and top workers (22.00 %). The highest foraging rate as 6.80 male flowers 5 min^{-1} was observed during 0800-0900 h, highest foraging intensity as 4.40 bees male flower-1 10 min^{-1} during 1000-1100 h and longest time spent by bee per male flower as 44.30 sec. during 1200-1300 h. The nectar and pollen collection peaks were during 1200-1400 h. There is a significant positive correlation between temperature and number of incoming foragers (r = 0.78) and a significant negative correlation between relative humidity and number of incoming foragers (r = -0.68).

Keywords: *Foraging behaviour, Stingless bee, Diurnal variation, Cucumber, Polyhouse*

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Introduction

Meliponiculture is an art and science of keeping stingless bee in man-made nests, for their pollination services and hive products. It is being popularized because of their potential contribution in sustainable agriculture and for conserving biodiversity [1]. Even though our agricultural fields are blessed with a plethora of pollinators, augmented pollination with domesticated bees are largely exploited in the open field conditions [2]. Evolution in agricultural practices, demand the rise in production and productivity without expanding area. One of the improved production technologies to cope up with adverse climatic condition in many parts of the world is protected cultivation. Greenhouse crop production is now a growing reality throughout the planet with an estimate of 405,000 ha of greenhouses spread over all the continents. There are more than 55 countries now in the world where protected cultivation of crops is undertaken on an advert scale. The total greenhouse area in India is also increasing with a current estimate of 30,000 ha [3]. The expansion of protected cultivation in world agriculture has driven crops traditionally cultivated in open field to greenhouse.

Several species of stingless bees have been proven as good foragers and effective pollinators especially in enclosed conditions, indicating their potential as pollinators of different polyhouse crops [4]. Stingless bee pollination is found superior to open pollination [5], mechanical pollination, and in tropical climates it could be an alternative to the use of highly defensive African-derived *Apis mellifera* Linnaeus or non-native bumble bees (*Bombus* spp.) [6]. Besides, they are efficient than that of hand pollinated ones [7]. In India, *T. laeviceps* Smith [8] and *T. iridipennis* [9] were the only examined stingless bees that effectively adopt in enclosures. In the current investigation, foraging behaviour of *T. iridipennis* on non parthenocarpic cucumber grown in polyhouse was evaluated.

Materials and Methods

Site and agricultural practices

The experiment was conducted from November, 2019 to January, 2020 in a 75 m^2 polyhouse. Seedlings of non-parthenocarpic salad cucumber (*C. sativus*) variety, AAUC-2 were transplanted and raised through organic farming system according to the adhoc package of practices recommendations for organic farming of Kerala Agricultural University [10]. Single colony of *T. iridipennis* was placed at the center of the plot after initiation of flowering (10 % flowering).

Initiation and cessation time of foraging activity

The period of stingless bee foraging activity (visiting the flowers for pollen and nectar) inside the polyhouse was determined from the time of appearance of first forager outside the hive to the time of returning by the last forager. Observations were taken continuously for 10 days.

Mode of alighting of individual foragers visiting the bloom

Mode of alighting of fifty stingless bees on male flowers during the peak period of bee activity was observed. Individual foragers alighting directly on top of stamen were considered as top workers while those alighting on petals as side workers

Foraging behaviour

The foraging behaviour of stingless bees was recorded during the peak flowering stage of the crop. Foraging rate of stingless bees was recorded as the number of male flowers visited by individual bee in 5 minutes. Foraging intensity is the number of individual foragers visited per male flower per ten minutes. Foraging speed was observed in terms of time spent by individual bees on a flower. This is the duration between first alighting on flower and the time at which bee leaves the flower and was recorded with the help of a stop watch. Time spent by pollen foragers on male and nectar foragers on male and female flowers was recorded separately.

These observations were taken at hourly intervals during 0800-0900, 0900-1000, 1000-1100, 1100-1200, 1200-1300, 1300-1400, 1400-1500, 1500-1600 and 1600-1700 h of the day and repeated for a week period [11].

Diurnal variation in colony activity

Total number of returning (pollen and nectar) and outgoing foragers were counted separately for 5 minutes at the entrance of the bee colony. Pollen collectors were identified by the pellets of pollen adhering to their hind legs. Those without pollen pellets were considered as nectar gatherers; often their abdomen bulged with nectar. The number of bees was counted from 0800-1700 h at hourly intervals. Weather parameters such as temperature (°C) and relative humidity (%) inside the polyhouse were measured hourly using a thermohygrometer (data logger).

Statistical analysis

The experiment on foraging behaviour and colony activity were carried out using Completely Randomised Design. Recorded data were subjected to square root transformation wherever necessary. Statistical analysis was carried out using the software WASP version 2.2. Influence of temperature (°C) and relative humidity (%) on foraging behaviour of stingless bees inside the polyhouse were analyzed by correlating them with colony activity. Data were correlated with the aid of OPSTAT and SPSS software.

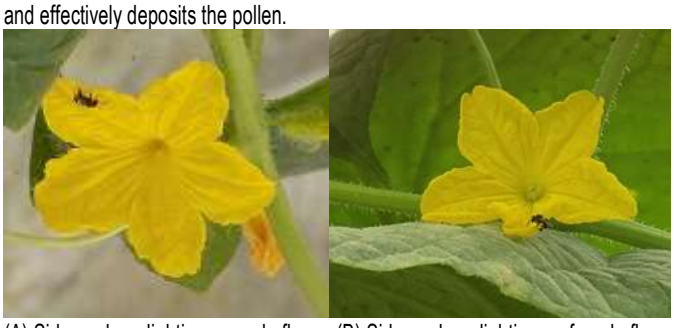
Results and discussion

Initiation and cessation time of foraging activity

The foraging activity of *T. iridipennis* foragers usually begins at 0750 h in the morning immediately after the anthesis of cucumber flowers. It was also observed that total duration of daily flight activity throughout the observation period (November 2019 to February 2020) was around 9 h. The observations were similar to length of the daily flight period of *Trigona carbonaria* Smith that ranged from 3 to 9 h during cooler months of the year [12].

Mode of alighting of individual foragers visiting the bloom

While recording the foraging behaviour, two different modes of alighting of *T. iridipennis* were observed in the present study. Most of the observed bees (78.00 % were side workers) land on the petals and proceed towards the reproductive part (stamen or stigma). The rest of the foragers (22.00 % were top workers), land directly on the top of stamen or stigma [Fig-1]. Same bees were observed to perform both the modes of alighting on same flower during the same visit. In either way, they have their body dusted with adequate amount of sticky pollen grains. Even if a portion of pollen is loaded to corbicula, enough pollen will remain on their body hairs. This is transferred to the stigma unintentionally while they visit pistillate flowers seeking nectar. This is similar to the earlier report of [13] that adequate pollen grains of watermelon flowers were transferred to the body of the stingless bees *Scaptotrigona* sp. regardless of the way of approach. A large proportion of bee body comes in contact with stigma of flowers due to their relatively small size and effectively deposits the pollen.



(A) Side worker alighting on male flower (B) Side worker alighting on female flower

(C) Top worker alighting on male flower (D) Top worker alighting on female flower

Fig-1 Mode of alighting of *Tetragonula iridipennis*

Foraging behaviour

The foraging rate was highest (6.80 male flowers 5 min^{-1}) during the time of initiation of foraging activity (0800 – 0900 h) and was least (3.60 male flowers 5 min^{-1}) during the cessation time of foraging activity (1600-1700 h). But the foraging intensity was minimum during the initiation and cessation time of foraging activity (1.40, 1.20 and 0.80 bees male flower-1 10 min^{-1} recorded during 0800 – 0900, 1500 – 1600 and 1600 – 1700 h respectively). Maximum foraging intensity (4.40 bees male flower-1 10 min^{-1}) was observed during 1000 – 1100 h. Maximum time spent by pollen collectors per male flower was recorded as 44.20 sec. during 1200-1300 h of the day [Table-1]. Similar observation was reported in *Sechium edule* (Jacq.) under caged condition, where *T. iridipennis* spent maximum time during 1200 h [14]. For nectar collection, stingless bee spent more time on female flower compared to that of male flowers. The visit to female flowers was longer during morning hours [15]. Longest time spent by a single bee on female flower was recorded as 323.40 sec [Fig-2].

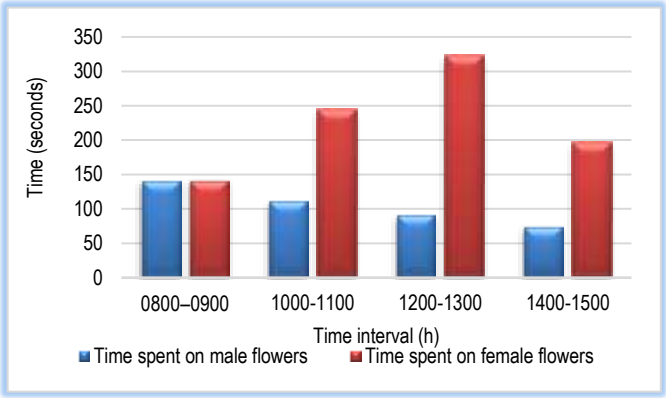


Fig-2 Diurnal variation in time spent by nectar foragers in cucumber flowers

Diurnal variation in colony activity

Stigma of cucumber becomes most receptive during five to six hours after flower opening [16]. The foragers of *T. iridipennis* had their peak activity within the optimal period of stigma receptivity and pollen viability. The total number of incoming and outgoing foragers at the hive entrance increases with the ascent of the day reaches a maximum during 1300-1400 h (67.00 and 58.00 number of incoming and outgoing foragers respectively) and then decreases thereafter.

The pollinators were most active when nectar secretions were abundant [17]. In cucumber, the amount of nectar was highest during 1200 h [18]. In the present study, the number of nectar foragers increases gradually along the day and reached a maximum during 1200-1400 h and then decreased thereafter throughout the three weeks of observations [Fig-3].

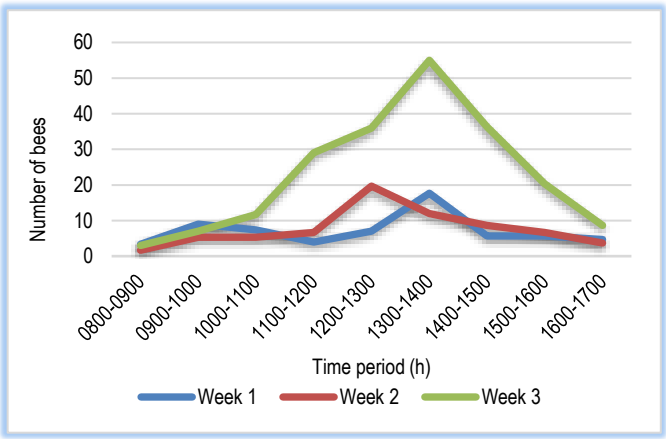


Fig-3 Diurnal variation in foraging activity of nectar collectors during different weeks

There are two activity peaks of *T. iridipennis* pollen foragers, first during 1000-1100 h and the second during 1400-1500 h in February [14]. Two activity peaks were reported for *Nannotrigona testaceicornis* (Lepeletier) during 1000 h and 1300 h [19].

Table-1 *Diurnal variation in foraging behavior of Tetragonula iridipennis in cucumber grown inside polyhouse*

Time period (h)	*Foraging rate Male flowers 5 min^{-1}	* Foraging intensity Bees male flower^{-1} 10 min^{-1}	*Foraging speed (sec.)
0800-0900	6.80(2.69)^{a}	1.40(1.27)^{c}	23.20^{bc}
0900-1000	5.20(2.38)^{bc}	3.00(1.84)^{a}	28.00^{abc}
1000-1100	4.20(2.15)^{cd}	4.40(2.18)^{a}	33.20^{ab}
1100-1200	4.20(2.16)^{cd}	2.80(1.78)^{ab}	41.00^{ab}
1200-1300	4.00(2.11)^{cd}	3.00(1.81)^{a}	44.20^{a}
1300-1400	4.00(2.10)^{d}	2.80(1.80)^{a}	39.40^{ab}
1400-1500	6.00(2.54)^{ab}	2.80(1.79)^{ab}	28.20^{abc}
1500-1600	4.00(2.11)^{cd}	1.20(1.29)^{bc}	23.80^{bc}
1600-1700	3.60(2.01)^{d}	0.80(1.08)^{c}	12.00^{c}
CD (0.05)	(0.278)	(0.503)	18.554

**Mean of 5 observations, Figures in parenthesis are square root transformed value*

The study also revealed that the number of pollen foragers gradually increases at each time intervals up to 1000-1100 h followed by a slight decline during 1100-1200 h and then reached a highest peak at 1200-1300 h (during first and second week) or 1300-1400 h (third week) and declined thereafter [Fig-4]. This may be because of the optimum climatic factors favourable for pollen collection during 1000-1100 h and following decline indicate the shifting of pollen collectors to nectar collectors. The second peak in number of pollen collectors may be due to the increase in total number of bees which were out for foraging. However, the number of nectar collectors was higher than that of pollen collectors.

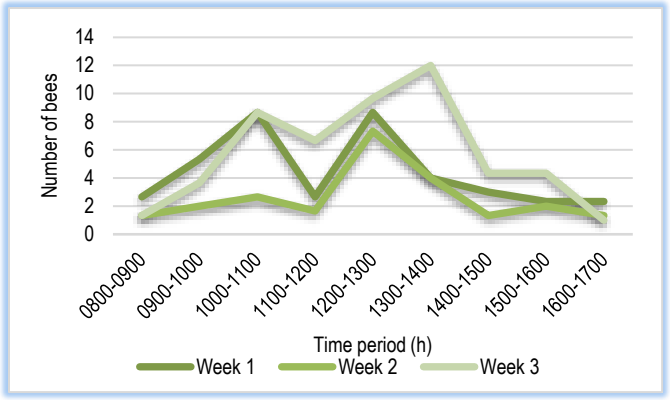


Fig-4 Diurnal variation in foraging activity of pollen collectors during different weeks

Influence of weather parameters on foraging activity of *T. iridipennis*

The maximum bee activity was recorded during maximum temperature (32.86°C) and minimum relative humidity (59.80%) [Fig-5]. With regard to the stingless bee, *Heterotrigona itama* Cockerell the ideal temperature related to foraging behaviour was 29ºC to 32 ºC [20].

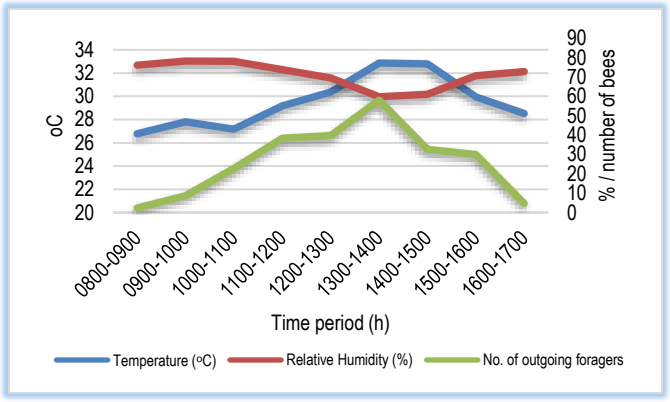


Fig-5 Influence of temperature and relative humidity on flight activity of *Tetragonula iridipennis*

There is a significant positive correlation between temperature and number of incoming foragers (r = 0.78) and a significant negative correlation between relative humidity and number of incoming foragers (r = -0.68). The influence of temperature accounted for 46 percent variation in the number of incoming foragers (R^2 = 0.46) while the relative humidity accounted for 36 percent variation in number of incoming foragers (R^2 = 0.36) [Fig-6, 7].

The present inferences are comparable to the observations of [21], where they recorded significant positive correlation of foraging activity of *Nannotrigona perilampoides* Cresson (number of bees entering the hive and number of bees visiting the flowers) with temperature and negative correlation with relative humidity.

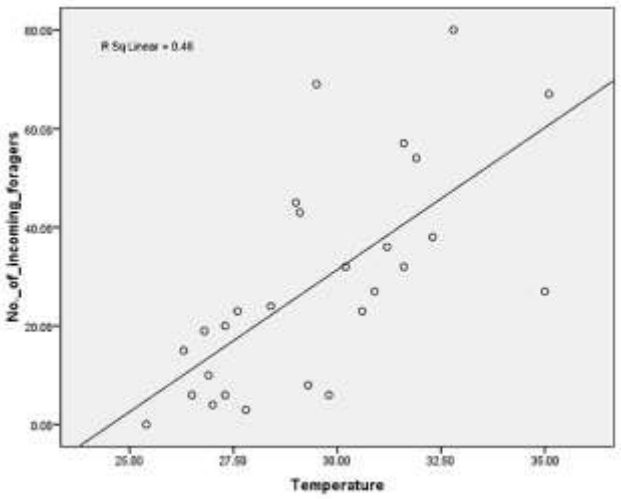


Fig-6 Influence of temperature on foraging activity of *Tetragonula iridipennis*

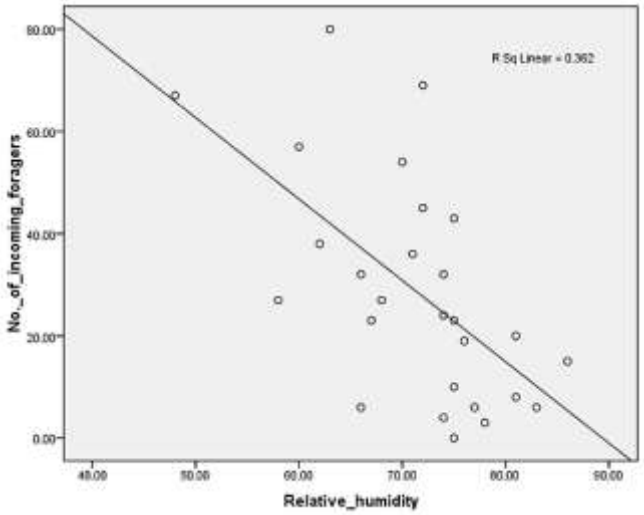


Fig-7 Influence of relative humidity on foraging activity of *Tetragonula iridipennis*

Conclusion

The present study reveals that *T. iridipennis* were active throughout the day with highest foraging rate during 0800-0900 h, highest foraging intensity during 1000-1100 h and longest time spent by bee per male flower during 1200-1300 h. The nectar and pollen collection peaks were highest during 1200-1400 h. The foraging activity is positively correlated with temperature and negatively correlated with relative humidity.

Application of research: To evaluate the foraging behaviour of stingless bee under protected cultivation

Research Category: Foraging behaviour of stingless bee

Abbreviations: R^2-Multiple correlation coefficient, r-Correlation coefficient

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Research project name or number: MSc Thesis

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Cultivar/Variety name: Salad cucumber- AAUC-2

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

References

[1] Devanesan S., Premila K.S., Shailaja K.K. (2017) *Biodiversity for Sustainable Development, Springer, Cham.* 267-272.
[2] Premila K.S., Devanesan S., Shailaja K. K. (2014) *In Proceedings of international symposium on conservation and management of pollinators for sustainable agriculture and ecosystem services, New Delhi.* 297-311.
[3] Reddy P.P. (2016) *Cucumber. In Sustainable Crop Protection under Protected Cultivation. Springer, Singapore*, 297-311.
[4] Slaa E.J., Sánchez L.A., Sandí M., Salazar W. (2000) *Apidologie*, 31(1), 141-142.
[5] Malagodi-Braga K.S. and Kleinert A.D.M.P. (2004) *Australian Journal of Agricultural Research*, 55(7), 771-773.
[6] Cruz D.D.O., Freitas B.M., Silva L.A.D., Silva E.M.S.D., Bomfim I.G.A. (2005) *Pesquisa Agropecuária Brasileira*, 40(12), 1197-1201.
[7] Nunes-Silva P., Hrncir M., da Silva C. I., Roldão, Y.S., Imperatriz-Fonseca, V.L. (2013) *Apidologie*, 44(50), 537-546.
[8] Gadhiya V.C. (2015) *PhD Thesis, Navsari Agricultural University, Navsari, Gujarat* 396450, 101.
[9] Tej K.M., Srinivasan M.R., Rajashree V., Thakur R.K. (2017) *J. Entomol. Zool. Stud.* 5(4), 1729-1733
[10] Alexander D., Rajan S., Rajamony L., Ushakumari K. and Kurien S. (2009) *Organic Farming*, 209.
[11] Thakur M. (2007) *PhD Thesis, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh* 173230, 100.
[12] Heard T.A. and Hendrikz J.K. (1993) *Australian Journal of Zoology*, 41(4), 343-353.
[13] Bomfim I.G.A., de Melo Bezerra A.D., Nunes A.C., de Aragão F.A.S., Freitas B.M. (2015) *Sociobiology*, 61(4),502-509.
[14] Roopa A.N. (2002) *PhD Thesis, University of Agricultural Sciences, Bengaluru, Karnataka 560065*, 202.
[15] Nicodemo D., Malheiros E.B., De Jong D., NogueiraCouto R.H. (2013) *Semina: Ciências Agrárias*, 3625-3633.
[16] Bomfim I.G.A., Breno M.F., Fernando A.S.A., Stuart A.W. (2016) *Handbook of Cucurbits: Growth, Cultural Practices, and Physiology. Florida (US): CRC Press*, 181-200
[17] Cervancia C.R. and Bergonia E.A. (1990) *In VI International Symposium on Pollination* (288), 278-282.
[18] Satheesha H.S. (2010) *PhD Thesis, University of Agricultural Sciences, Bengaluru, Karnataka 560065,* 95.
[19] dos Santos S.A., Roselino A.C., Bego L.R. (2008) *Neotropical Entomology*, 37(5), 506-512.
[20] Jaapar M.F., Jajuli R., Mispan M.R., Ghani I.A. (2018) *In AIP Conference proceedings, AIP Publishing LLC,* 1940(1), 020037.
[21] Palma G., Quezada-Euán J.J.G., Reyes-Oregel V., Meléndez V. and Moo-Valle H. (2008) *Journal of Applied Entomology*, 132(1), 79-85.