

Pollination potential of stingless bee *Tetragonula iridipennis* Smith. (Hymenoptera, Apidae) in pumpkin (*Cucurbita moschata* Duchex Poir)

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ABSTRACT: An experiment was conducted to investigate the pollination potential and effectiveness of the stingless bee (*Tetragonula iridipennis* Smith.) on pumpkin. The abundance and diversity of foragers in male and female pumpkin flowers were assessed by measuring the number of foragers per flower per minute. The pumpkin fruit set and yield were evaluated under three different conditions: open pollination, bee pollination, and pollination exclusion. The foraging rate of bees was higher in male pumpkin flowers (0.22 bees/flower/min) than in female flowers (0.14 bees/flower/min) on the 45th day of flowering. Foraging time was longer on male flowers (40.66 seconds) than on female flowers (35.33 seconds). In terms of yield, the bee-pollinated pumpkin field achieved an average of 3.15 fruits per plant, compared to 3.12 fruits in open-pollinated plots. The bee-pollinated field also produced heavier fruits, with an average fruit weight of 3.45 kg (4.12% increase over open pollination). The total yield in the bee-pollinated plot was 36.1 t ha⁻¹, compared to 34.6 tons in the open-pollination plot. Colony monitoring showed a 1.93 per cent weight gain, from 897 to 924g. Foraging activity at the hive entrance was maximum during the morning hours (07 00–09 00), with on average 10.58 outgoing bees and 8.19 bees at peak nectar forager activity. In contrast, the pollination exclusion condition failed to produce any fruit, emphasizing the positive impact of *T. iridipennis* on pumpkin pollination and yield, particularly during peak flowering periods.

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KEY WORDS: Bee abundance, foraging activity, pollination efficiency, Open pollination, bee pollination, pollination exclusion

INTRODUCTION

Pumpkin (*Cucurbita moschata* Duch. ex Poir.) is an economically and nutritionally significant vegetable cultivated worldwide. It is a rich source of essential nutrients, particularly vitamin A, minerals, and antioxidants, while its seeds contain high levels of protein (40.27%), crude fibre (34.59%), and ash content (44.5%) (Rana, 2014). Archaeological evidence suggests that pumpkins

originated in Mexico and Peru, later spreading to India through South American traders. In India, pumpkins are widely consumed as fresh vegetables, processed products, and livestock feed (Thamburaj and Narendrasingh, 2001). Pollination is crucial for the fruit set and seed development in cucurbits, which largely depend on insect pollinators for successful reproduction (Roubik, 1995). Among pollinators, honey bees (*Apis* spp.), stingless bees (*Meliponini*), and bumble bees (*Bombus* spp.) play

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a vital role in enhancing crop productivity (Free, 1993; Chauhan *et al.*, 2013). Honey bees contribute to approximately 80% of crop pollination, improving yield and quality across various horticultural crops. In tropical regions, stingless bees serve as key pollinators for native flora and cultivated crops (Roubik and Roubik, 1992). Studies highlight their efficiency in pollinating economically valuable crops such as coconut, cotton, mango, strawberries, tomatoes, and sweet peppers (Rindfleisch, 1980; Maeta *et al.*, 1992; Roubik and Roubik 1992; Kakutani *et al.*, 1993; Heard, 1999; Malagodi-Braga and Kleinert, 2004). These bees exhibit flower constancy, ensuring effective pollen transfer and their stingless nature makes them suitable for pollination in managed environments like greenhouses (Robinson and Decker-Walters, 1999; Slaa, 2006).

Despite the well-established role of pollinators in improving agricultural yields, studies specifically evaluating *Tetragonula iridipennis* in pumpkin pollination under open-field conditions remain limited. Most research has primarily focused on *Apis cerana* and *Apis dorsata*, leaving a knowledge gap regarding the effectiveness of stingless bees in pumpkin cultivation. Furthermore, comparative studies on open pollination, bee pollination, and pollinator exclusion in pumpkin fields are scarce. A recent study revealed that *Apis cerana* exhibited the highest foraging rate and pollination efficiency, leading to significant increases in fruit set (77.5%), fruit weight (1.71 kg), and seed count (162), whereas open-pollinated plots had a higher percentage of crooked fruits (Longkumer *et al.*, 2024). This study aims to assess foraging behaviour, and their impact on fruit set and yield under natural field conditions; and to assess the effectiveness of different pollination methods for enhancing pumpkin productivity.

MATERIALS AND METHODS

Evaluation of colony growth parameters: In the pumpkin field at Pollachi, two stingless bees were introduced at the beginning of the flowering stage. Colony growth was evaluated by calculating the initial and final weight of the shifted colony at 15-day intervals. This measurement provides insights

into the changes in the colony's weight and potential growth over time.

Foraging activity at the hive entrance: The foraging activity of *T. iridipennis* at the hive entrance was assessed by counting the number of returning foragers carrying nectar and pollen, as well as the number of outgoing bees, during specific time intervals throughout the day. The observations were conducted for a period of 5 minutes each at the following time slots: 8:00am to 10:00am; 12:00pm to 1:00pm and 4:00pm to 6:00pm. During these time intervals, the number of returning foragers carrying nectar and pollen was recorded. Additionally, the number of outgoing bees from the hive was also counted.

Field experiments: Two field experiments were conducted to evaluate the pollination potential of managed bee pollinators in enhancing the pumpkin yield. It was carried out in a farmer's field in Pollachi (10.757°N; 76.967°E) ensuring that the pumpkin field was located 2 km away from an open-pollination field to avoid interference. The experimental design followed a randomized block structure with three treatments and seven replications for each treatment, with each plot measuring 4m × 10m. The experiments aimed to assess the impact of pollination by managed bee pollinators (stingless bee colonies) compared to pollinator exclusion and open pollination on the yield of pumpkins.

Pollinator exclusion: In this treatment, female flower buds were covered with sleeve net cages before blooming to prevent pollinators from accessing the flowers. Two flowers from five selected plants per replication (70 flowers in total) were covered with cages. After one week of flowering, the cages were removed, and the flowers were tagged for further assessment of fruit set under the caged condition. The crop was grown in an open field without protected conditions, and this treatment ensured that no pollinators, including *T. iridipennis*, contributed to the fruit set, allowing a controlled evaluation of pollination dependency.

Bee pollination: This treatment involved the introduction of managed stingless bee colonies into

the pumpkin fields. Two stingless bee colonies were placed in the field during February 2023. The colonies were introduced when the crop was at (approximately 10%) flowering stage.

Open pollination: This treatment served as a control where the natural process of open pollination by various pollinators was allowed. Observations were recorded on the different pollinators that visited the flowers, and various yield parameters were also recorded.

Number of fruits per plant, weight of each fruit and total yield were recorded in different pollination treatments. The harvested yield in different treatments was scaled up based on the area covered by the plants. ANOVA was used to analyse the data, and AGRES Software are used to carry out all additional calculations.

RESULTS AND DISCUSSION

Abundance of managed bee pollinator *T. iridipennis* in pumpkin flowers:

The study revealed that *T. iridipennis* exhibited higher activity in pumpkin male flowers compared to female flowers. The average number of bees visiting male flowers was recorded at 0.13 bees per flower per minute, while it was slightly lower for female flowers (0.09). Peak bee activity was observed on the 45th day of the flowering period, with an average of 0.22 bees in male flowers and in female flowers it was 0.14 bees per flower per minute. The lowest bee activity was recorded on

the 15th day, with 0.07 bees in male flowers and in female flowers It was 0.04 bees per flower per minute (Table 1)

Regarding foraging behaviour, *T. iridipennis* spent more time collecting rewards from male flowers, with an average of 32.06, compared to 28.92 seconds per female flower. The longest foraging time was recorded on the 45th day, where bees spent 40.66 seconds on male flowers and 35.33 seconds on female flowers (Table 2).

Colony growth parameter of *T. iridipennis*:

Growth of the two *T. iridipennis* colonies introduced into the pumpkin field was monitored, and the colonies showed a slight increase in weight during the study period. The initial weight of the colonies before placement in the field was 897g, which increased to an average of 908g on 15th day (0.78% increase in weight), 915g on 30th day (1.28% increase) and on 45th day 924g with a weight gain of 1.93 per cent, indicating that the colonies experienced growth during their time in the field.

Foraging activity of *T. iridipennis* at the hive entrance:

The foraging activity of *T. iridipennis* was monitored at the hive entrance at various intervals throughout the day. On average, the number of outgoing bees was higher, with a mean of 10.58 bees, and the peak outgoing activity occurred between 07:00 and 09:00 hours. Incoming nectar foragers were more abundant, averaging 6.68 bees,

Table 1. Abundance of *T. iridipennis* in pumpkin flowers. Location: Pollachi, Coimbatore district on 2023

No. of foragers/flower/min $\pm$ S. D						
	15 th day	30 th day	45 th day	60 th day	75 th day	Mean
Male flower	0.07 (0.75)	0.12 (0.78)	0.22 (0.84)	0.16 (0.81)	0.11 (0.78)	0.13(0.79) ^a
Female flower	0.04 (0.73)	0.09 (0.76)	0.14 (0.80)	0.11 (0.78)	0.08(0.75)	0.09(0.76) ^b
Mean*	0.055 (0.74) ^c	0.10 (0.77) ^B	0.18 (0.82) ^A	0.13(0.79) ^A	0.09 (0.76) ^B	
C.D @ 0.05						
Treatment A ^s						0.01
Treatment B ^s						0.01
Treatment A*B ^s						0.03

Note: *Mean of 10 plant observation; figures in parentheses are square root ($X+0.5$) transformed values. In a column, the means followed by a common lower-case alphabet and in a row, the means followed by a common upper-case alphabet are significantly different at $p=0.05$ by LSD.

Table 2. Foraging activity of *T. iridipennis* in pumpkin flowers. Location: Pollachi, Coimbatore district on 2023

Time spent by a forager/flower/min in seconds± S. D						
	15 th day	30 th day	45 th day	60 th day	75 th day	Mean
Male flower	26.33 (5.1)	30.33 (5.5)	40.66 (6.4)	34.66 (5.9)	28.33 (5.3)	32.06 (5.6) ^a
Female flower	24.33 (4.9)	28.66 (5.4)	35.33 (5.9)	30.66 (5.5)	25.66 (5.0)	28.92 (5.4) ^b
Mean*	25.33 (5.1) ^E	29.49 (5.4) ^C	37.99 (6.2) ^A	32.66 (5.7) ^B	26.99 (5.2) ^D	

Note: *Mean of 10 plant observations; figures in parentheses are square root ($X+0.5$) transformed values. In a column, the means followed by a common lower-case alphabet and in a row, the means followed by a common upper-case alphabet are significantly different at $p=0.05$ by LSD

compared to pollen foragers, who averaged 5.43 bees. The highest incoming nectar forager activity was also recorded between 07 00 and 09 00 hours, with an average of 8.19 foragers, followed by 15 00 to 17 00 hours, which saw an average of 7.74 nectar foragers (Table 5). These findings suggest that *T. iridipennis* exhibits higher foraging activity in the morning, particularly for nectar collection, with a second peak in the late afternoon.

Effect of *T. iridipennis* on pollination and yield of pumpkin:

In the field, where two colonies of stingless bees were introduced, the fruit set was recorded at an average of 3.15 fruits per plant, slightly higher than the 3.12 fruits per plant in the open pollination plot. Moreover, the bee-pollinated plot produced heavier fruits, averaging 3.45kg per fruit, compared to 3.37kg fruit in the open pollination plot, representing a 4.12 per cent increase in fruit weight. The yield in the bee-pollinated plot was 36.1 t ha⁻¹, compared to 34.6 t ha⁻¹ in the open pollination plot (Table 3).

No fruit set was observed in the pollinator exclusion treatment, where flowers were sleeve-caged to prevent pollination, confirming the importance of bee pollination in ensuring fruit set and yield. The effect of pollination modes on pumpkin yield was determined through statistical analysis, not just observed data. The results demonstrate that *T. iridipennis* positively influenced both the quantity and quality of pumpkin production compared to open pollination.

Introducing *T. iridipennis* as a managed pollinator in pumpkin fields led to modest improvements in pumpkin yield and colony growth. The fluctuation

in bee activity throughout the flowering period can be attributed to variations in flower availability, as noted in earlier studies (Yogapriya *et al.*, 2019). Similar patterns of abundance were reported by Subhakar *et al.* (2011), where *T. iridipennis* was the most abundant flower visitor in bitter gourd fields. These findings confirm the significance of *T. iridipennis* as an active pollinator, particularly during peak flowering periods.

The effect of *T. iridipennis* on pumpkin pollination and yield was positive but less pronounced compared to other crops. Managed bee pollination resulted in a slight increase in the number of fruits per plant, fruit weight, and overall yield when compared to open-pollinated plots. Specifically, the fruit weight increased (4.12%), and the yield was higher in bee-pollinated plots, indicating that *T. iridipennis* contributed to enhanced productivity. However, studies on other crops such as watermelon and ash gourd have shown greater benefits. Layek *et al.* (2021) reported a 14 per cent increase in watermelon fruit set, with significant improvements in fruit length and yield after the introduction of *T. iridipennis*. Chauhan and Singh, (2021) noted a 27.96 per cent increase in fruit set in ash gourd with *T. iridipennis* pollination. While the present study shows that *T. iridipennis* benefits pumpkin crops, its impact may be more limited than in other cucurbits due to differences in flower structure and pollination requirements. The large, deep, campanulate structure of pumpkin flowers and their high pollen demands limit the foraging efficiency of *T. iridipennis*, as their smaller body size and short proboscis reduce effective pollen transfer, resulting in lower pollination efficiency compared to larger pollinators. The slight increase

Table 3. Effect of different modes of pollination on pumpkin yield

Modes of pollination	No. of female flowers observed	No. of picking /plant	No. of fruits / plants	Fruit weight (kg)	Percent increase in fruit weight	Yield of 10 plants (kg)	Yield (t/ha)	Percent increase in yield (t/ha)
T1 Pollinator exclusion	70	0 (0.71) ^b	0(0.71) ^b	0(0.71) ^b	-	0	0	-
T2 Bee pollination	70	2.63(1.76) ^a	3.15(1.91) ^a	3.45(1.98) ^b	2.31	98.5	36.1	4.12
T3 Open pollinated	70	2.6(1.76) ^a	3.12(1.90) ^a	3.37(1.96) ^b	-	94.9	34.61	-

Note: *Mean of five observations, No. fruit set was observed in pollinator exclusion. Figures in parentheses are the square roots of $(X+0.5)$ transformed values. In columns, means followed by alphabet are highly significant different at 5% level LSD

in colony weight of *T. iridipennis* from 897 to 924 g while foraging on pumpkin flowers suggests that these flowers provide some resources, but they may not be as rich or suitable as those found in other crops, such as mangoes. Walters and Taylor (2006) reported that honey bee pollination significantly enhances fruit size and yield in cucurbits, with honey bees being crucial for maximizing fruit set and seed development. In contrast, studies have shown that different floral resources can lead to varying foraging efficiencies among bee species. For instance, the presence of honey bee hives in pumpkin fields increased their visitation rates, but this did not translate to a proportional increase in native bee visits, indicating a complex interaction between floral resource availability and bee foraging behaviour (Artz *et al.*, 2011). Therefore, while pumpkin flowers do support *T. iridipennis*, the more substantial weight gain observed in mango orchards may reflect a higher quality or quantity of available resources (Saffari *et al.*, 2010).

Finally, foraging activity at the hive entrance revealed a peak in outgoing, nectar, and pollen foragers during the morning hours between 07 00

and 09 00 am, which coincides with pumpkin's peak flowering and anthesis period. This synchronization of foraging activity with floral resources maximizes pollination efficiency, as noted in earlier research (Lintu, 2020). The timing of foraging behaviour aligns with the availability of floral resources, ensuring that *T. iridipennis* can effectively pollinate crops during peak periods. Studies on cucumber crops have shown similar patterns of peak foraging activity, which may vary slightly based on crop type and flowering behaviour. This synchronization plays a critical role in enhancing reproductive success and ensuring efficient resource utilization by stingless bees.

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REFERENCES

Artz D. R., Hsu C. L. and Nault B. A. (2011) Influence of honey bee, *Apis mellifera*, hives and field size on foraging activity of native bee species in

Table 4. Incoming and outgoing of *T. iridipennis* at hive entrance during peak flowering period

Foraging time	Incoming nectar forager	Incoming pollen forager	Outing bees	Mean
07:00- 09:00 h	8.19 (2.86) ^a	7.16 (2.67) ^a	14.42 (3.79) ^a	9.92
11:00- 13:00 h	4.13 (2.03) ^b	3.58 (1.89) ^b	7.42 (2.72) ^c	5.04
15:00-17:00 h	7.74 (2.78) ^a	5.55 (2.35) ^a	9.91 (3.14) ^b	7.73
Mean*	6.68	5.43	10.58	
C.D. (P=0.05)	0.629	0.687	0.595	

Note: * Mean of five observations, figures in parentheses are square root $(X+0.5)$ transformed values. In column means followed by different alphabets are highly significantly different at 5% level LSD

- pumpkin fields. *Environmental Entomology* 40(5): 1144–1158. doi:10.1603/en10218
- Atkins E.L., Mussen E. and Thorp R.W. (1979) Honeybee pollination of cantaloupe, cucumber and watermelon. Division of Agricultural Sciences. University of California. Leaflet 2253. doi:10.3733/ucanr.7224
- Chauhan A. and Singh H.K. (2021) Impact of stingless bee *Tetragonula iridipennis* Smith pollination in watermelon. *Indian Journal of Entomology* 83(3): 321–325. doi:10.5958/0974-8172.2020.00216.3
- Chauhan A., Katna S. and Rana B.S. (2013) Life cycle of bumble bee *Bombus haemorrhoidalis* Smith in Himachal Pradesh. *Insect Environment* 19(3): 183–186.
- Free J.B. (1993) *Insect pollination of crops*, 2nd edn. U.K. Academic Press, London, 544 pp.
- Heard T.A. (1999) The role of stingless bees in crop pollination. *Annual Review of Entomology* 44(1): 183–206. doi:10.1146/annurev.ento.44.1.183.
- Kakutani T., Inoue T., Tezuka T. and Maeta Y. (1993) Pollination of strawberry by the stingless bee, *Trigona minangkabau*, and the honey bee, *Apis mellifera*: an experimental study of fertilization efficiency. *Researches on population ecology* 35: 95–111. doi:10.1007/bf02515648
- Layek U., Kundu A., Bisui S. and Karmakar P. (2021) Impact of managed stingless bee and western honey bee colonies on native pollinators and yield of watermelon: A comparative study. *Annals of Agricultural Sciences* 66(1): 38–45. doi:10.1016/j.aos.2021.02.004
- Lintu V.V. (2020) Foraging behaviour of *Tetragonula iridipennis* (Smith) in cucumber under protected cultivation. *International Journal of Agriculture Sciences* 12(18): 10228–10231.
- Longkumer B., Devi H.S., Chauhan A., Neog P. and Singh M.S. (2024) Studies on impact of different pollinators in pumpkin (*Cucurbita moschata* Duch. ex Poir). *Pharma Innovation* 13(12): 170–174.
- Maeta Y., Tezuka T., Nadano H. and Suzuki K. (1992) Utilization of the Brazilian stingless bee *Nannotrigona testaceicornis* as a pollinator of strawberry. *Honey Bee Science* 13(2): 71–78.
- Malagodi-Braga K.S., and Kleinert A.D.M.P. (2004) Could *Tetragonisca angustula* Latreille (Apinae, Meliponini) be effective as strawberry pollinator in greenhouses? *Australian Journal of Agricultural Research* 55(7): 771–773. doi:10.1071/ar03240.
- McGregor S.E. (1976) *Insect Pollination of Cultivated Crops*. Agricultural Research Services, U.S. Department of Agriculture, Agricultural Handbook, U.S. Government printing office, Washington, D.C, USA. 496pp.
- Rindfleisch (1980) A case for meliponiculture in pollination. *American Bee Journal* 120(6): 468–470.
- Robinson R.W. and Decker-Walters D.S. (1999) *Cucurbits*. CAB International Wallingford, Oxon (GB). 226pp.
- Roubik D.W. (1995) *Pollination of cultivated plants in the tropics*. FAO Agricultural Services Bulletin, Rome, 118: 53.
- Roubik D.W. and Roubik D.W. (1992) *Ecology and natural history of tropical bees*. Cambridge University Press, New York. 311pp.
- Saffari A., Kevan P.G. and Atkinson J. (2010) Consumption of three dry pollen substitutes in commercial apiaries. *Journal of Apicultural Science* 54(1): 13–20.
- Slaa E.J. (2006) Population dynamics of a stingless bee community in the seasonal dry lowlands of Costa Rica. *Insectes Sociaux* 53: 70–79. doi:10.1007/s00040-005-0837-6.
- Subhakar G., Sreedevi K., Manjula K. and Reddy N.P. (2011) Pollinator diversity and abundance in bitter gourd, *Momordica charantia* Linn. *Pest Management in Horticultural Ecosystems* 17(1): 23–27.
- Thamburaj S. and Singh N. (2001) *Textbook of vegetables, tubercrops and spices*. Indian Council of Agricultural Research, New Delhi. 151pp.
- Walters S.A. and Taylor B.H. (2006) Effects of honey bee pollination on pumpkin fruit and seed yield. *Hort Science* 41(2): 370–373. doi:10.21273/hortsci.41.2.370.
- Yogapriya A., Usharani B., Suresh K., Vellaikumar S. and Chinniah C. (2019) Foraging behaviour of major pollinators in bitter gourd. *International Journal of Current Microbiology and Applied Sciences* 8(6): 947–954. doi:10.20546/ijcmas.2019.806.114.