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Effects of managed pollination by stingless bee (*Tetragonula iridipennis* Smith) on productivity and fruit quality of sponge gourd (*Luffa cylindrica*)

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ABSTRACT

Pollination is a critical ecosystem service that directly influences fruit set, yield and quality in cucurbit crops. The present study evaluated the pollination efficiency of the stingless bee, *Tetragonula iridipennis* Smith, in sponge gourd (*Luffa cylindrica*) under protected cultivation conditions at the experimental farm of AICRP on Honeybees and Pollinators, Nagaland. Floral biology observations revealed that sponge gourd is monoecious and protandrous, with peak anthesis occurring between 0500 and 0700 h and stigma receptivity lasting up to 9 hours. A diverse assemblage of pollinators was recorded, among which stingless bees were the most dominant visitors. Pollinator abundance was highest during the morning hours, particularly between 0800 and 1000 h, indicating optimal conditions for pollination activity. Managed pollination using *T iridipennis* significantly enhanced fruit yield and quality compared to open pollination and pollinator exclusion treatments. The highest fruit yield (3.68 ± 0.11 kg/plant), fruit length (25.60 ± 0.14 cm), fruit diameter (7.83 ± 0.09 cm) and fruit weight (0.621 ± 0.11 kg) were recorded under stingless bee pollination. This treatment also resulted in the lowest percentage of crooked fruits (9%), highest number of healthy fruits (91%), maximum seed number per fruit (214 ± 21) and highest 100-seed weight (150.14 g). In contrast, pollinator exclusion significantly reduced yield and fruit quality. The findings demonstrate that *T iridipennis* is an efficient and reliable pollinator for sponge gourd under protected conditions and offers a sustainable alternative to manual pollination for improving crop productivity and fruit quality.

Keywords: Sponge gourd; *Luffa cylindrica*; Stingless bee; *Tetragonula iridipennis*; Pollination efficiency; Protected cultivation; Fruit yield; Fruit quality; Seed set

INTRODUCTION

Pollination is a vital biological process responsible for fruit and seed set in plants. Among insects, bees are the most important pollinators of crops grown worldwide for food production. Honeybees, stingless bees and bumble bees play a significant role in pollination, as they depend entirely on flowers for their growth and development. While honeybees and bumble bees have been extensively studied for their pollination efficiency, stingless bees remain relatively underexplored and their pollination potential is not yet fully recognized.

Sponge gourd (*Luffa cylindrica*) is a summer vegetable crop, primarily cultivated during the spring and summer seasons in tropical and subtropical regions. It belongs to Cucurbitaceae family and has diploid chromosome number of 2n = 26 (Gantayat et al 2025).

The plant is monoecious, bearing both male (staminate) and female (pistillate) flowers on the same individual. The large, bright yellow, unisexual flowers are typically borne singly in the leaf axils. Male flowers are more numerous and appear earlier than female flowers, which possess an ovary that develops into fruit after successful pollination. Female flowers are generally receptive for a single day, with stigma receptivity reaching its maximum during the morning hours, coinciding with peak pollinator foraging activity (Ikram et al 2025).

The flowers of sponge gourd produce large, sticky pollen grains that must be transferred from the anthers of male flowers to the stigma of female flowers. This transfer is primarily facilitated by a diverse range of insect pollinators (Free 1970). Stingless bees are small bees belonging to the order Hymenoptera. Nine species of stingless bees have been recorded from the northeastern states of India, of which six species are commonly reported (*Tetragonula iridipennis*, *T laeviceps*, *T gressitti*, *Lepidotrigona ventralis*, *L arcifera*, *Lophotrigona canifrons*) in Nagaland (Chauhan et al 2019). Stingless bees are widely used as pollinators in greenhouse crops in both temperate and tropical regions, as some species act as efficient buzz pollinators, such as *Melipona quadrifasciata* (Del Sarto et al 2005, dos Santos et al 2009).

According to Heard (1999), stingless bee species are effective pollinators of crops like *Cocos nucifera*, *Mangifera indica*, *Sechium edule*, *Averrhoa carambola* and *Macadamia integrifolia*. Stingless bees are considered superior pollinating agents due to several advantageous characteristics: their ability to pollinate small flowers, better adaptation to tropical climates, minimal risk to humans, coexistence with other bee species, suitability for confined spaces such as greenhouses, environmental friendliness, low swarming tendency, reduced susceptibility to pests and diseases and short foraging range. These traits make them highly suitable for pollination under nethouse conditions. Moreover, their use reduces labour requirements and eliminates the tedious process of manual pollination.

Therefore, stingless bees are valuable agents for enhancing cross-pollination in protected cultivation systems (Gadhiya 2015). Considering the dominant presence of stingless bees in Nagaland and their efficiency under greenhouse conditions, the present study was conducted to evaluate their pollination potential in sponge gourd.

MATERIAL and METHODS

The experiment was carried out at the Experimental farm AICRP Honeybees and Pollinators, Department of Entomology, School of Agricultural Sciences (25.75961° N, 93.853698° E) to use stingless bee species for pollination of sponge gourd under protected conditions. All agronomical practices were done as per good agricultural practices for crop raising and kept same in three different conditions. Floral biology was studied as per Chauhan et al (2019). One hive of stingless bee, *T iridipennis* (volume 1,200 cm^3) was shifted in the caged plots at 10 per cent flowering and data were recorded (Fig 1). Impact of stingless bee pollination was evaluated with fruit set. The female flowers per vine were pre-counted. Thirty plants from each treatment viz stingless bee pollinated, control and open pollinated were selected and tagged randomly. Fruit set was recorded for each treatment and total yield was calculated based on fruit set. The number of healthy fruits was also counted.

A sample of thirty fruits was selected to measure fruit length, diameter and weight (10 fruits from each treatment, ie stingless bee-pollinated, control and open-pollinated). Similarly, thirty mature fruits (10 from each treatment) were collected for seed analysis. Seeds were extracted and soaked in water for 24 hours. After washing, the seeds were dried in temperature-controlled chambers for 24 hours and then counted. The 100-seed weight was also recorded. The percentage increase in fruit yield per plant, number of healthy fruits, fruit weight, number of seeds and 100-seed weight were calculated, along with the percentage decrease in deformed fruits. The data were statistically analyzed using an appropriate transformation under a randomized block design (RBD) following Gomez and Gomez (1984). Temperature and relative humidity during the experimental period were also recorded using a digital thermometer and hygrometer.

RESULTS and DISCUSSION

Sponge gourd floral biology revealed monoecious, pentamerous flowers exhibiting protandrous conditions (Fig 2). Maximum anthesis was observed between 0500 and 0700 h, while stigma receptivity commenced 30 minutes prior to anthesis and persisted for up to 9 hours. Various insect visitors were observed visiting the sponge gourd flowers during the flowering period.

The main visitors were *T iridipennis* Smith, *T gressitti* Smith, *Lophotrigona canifrons* (Smith), *Lepidotrigona arcifera* Smith, *Apis mellifera* Linnaeus, *A cerana* Fabricius, *A dorsata* Fabricius, *A florea* Fabricius, *Xylocopa tenuiscapa* Westwood, *Halictus semiaerinus* and *Megachile lanata* Fabricius visiting the crop throughout the day (Table 1). Chauhan et al (2019) reported high population of stingless bees followed by honeybees on ash gourd. Similarly, *A florea,*

Fig 1. Stingless beehive placed for pollination in sponge gourd

Fig 2. Female and male flower in sponge gourd

Table 1. Insect visitors on sponge gourd under open conditions

Scientific name	Order	Family
Tetragonula iridipennis Smith	Hymenoptera	Apidae
Lophotrigona canifrons Smith	Hymenoptera	Apidae
Lepidotrigona arcifera Cockrell	Hymenoptera	Apidae
T gressitti Smith	Hymenoptera	Apidae
Apis mellifera Linnaeus	Hymenoptera	Apidae
A cerana Fabricius	Hymenoptera	Apidae
A dorsata Fabricius	Hymenoptera	Apidae
A florea Fabricius	Hymenoptera	Apidae
Halictus semiaerinus	Hymenoptera	Halictidae
Xylocopa tenuiscapa Westwood	Hymenoptera	Apidae
Episyrphus sp	Diptera	Syrphidae
Musca sp	Diptera	Muscidae
Mylabris pustulata	Coleoptera	Meloidae
Monomorium indicum	Hymenoptera	Formicidae
Megachile sp	Hymenoptera	Megachilidae
Rhinia sp	Diptera	Rhinidae

A mellifera, A dorsata, Halictus sp and *Bombus* sp were reported by Grewal and Sidhu (1978) as main insect visitors of cucurbit crops.

Sajjanar et al (2004) recorded 24 insect species visiting cucumber flowers and reported hymenopterans as the predominant floral visitors. Similarly, Gimhavanekar et al (2025), while studying pollinator interactions in different cucurbits including sponge gourd, cucumber, spine gourd, bitter gourd and ridge gourd, observed that sponge gourd and cucumber were the most preferred flowers among the crops. These crops exhibited the highest pollinator abundance (6.51 bees/5 min), foraging rate (2.20 flowers/min) and flower handling time (31.26 s), highlighting a strong plant-pollinator relationship and emphasizing the crucial role of stingless bees in the pollination of cucurbit crops.

The mean overall pollinator abundance was highest during the early morning hours, particularly between 0800 and 1000 h, suggesting that this period is most favourable for pollination in sponge gourd (Table 2). Similar observations were reported by Chauhan et al (2019), who documented the highest pollinator activity on ash gourd at 1000 h, followed by a gradual decline after 1200 h, with activity ceasing by 1800 h. The temporal variation in pollinator activity may be attributed to fluctuations in floral rewards such as nectar and pollen availability, which differ among crop species and environmental conditions.

Devanesan et al (2002) reported that the foraging activity of *T iridipennis* at Thiruvananthapuram, Kerala, began at 0700 h and gradually increased to reach its first peak at 1200 h. A decline in activity was observed at 1300 h, followed by a second increase peaking at 1500 h, while almost no activity was recorded at 1800 h. Danaraddi (2007) also recorded peak activity of *T iridipennis* between 1000 and 1200 h. Kishan et al (2017) suggested that stingless bees could serve as effective pollinators for crops grown under protected conditions. Similarly, Roopa (2002) observed that during summer, *Trigona iridipennis* exhibited major peaks of pollen and nectar foraging between 1000-1200 h and 1200-1300 h, respectively, with a second peak occurring between 1400-1500 h and 1500-1600 h.

After fruit set, the stingless bee colony was removed from the nethouse and the effects of different pollination treatments on the yield and quality attributes of sponge gourd were evaluated (Table 3). The results clearly demonstrated the positive impact of *T iridipennis* pollination on both fruit yield and quality compared to open pollination and pollinator exclusion.

The highest fruit yield per plant (3.68 ± 0.11 kg) was recorded in the stingless bee-pollinated treatment, followed closely by open pollination (3.44 ± 0.17 kg), whereas, significantly lower yield (0.96 ± 0.33 kg) was observed under pollinator exclusion. Fruit quality parameters were also markedly improved under stingless bee pollination. The longest fruits (25.60 ± 0.14 cm) with the greatest diameter (7.83 ± 0.09 cm) were obtained from plants pollinated by *T iridipennis*, while open-pollinated plants produced slightly shorter fruits (24.33 ± 0.08 cm) with smaller diameter (5.61 ± 0.14 cm). In contrast, fruits from pollinator-excluded plants were significantly smaller, with a length of only 9.33 ± 0.10 cm and diameter of 3.40 ± 0.11 cm. Similarly, fruit weight was significantly higher in the stingless bee-pollinated treatment (0.621 ± 0.11 kg), followed by open pollination (0.590 ± 0.10 kg), whereas, the lowest fruit weight (0.178 ± 0.10 kg) was recorded in the pollinator exclusion treatment. The percentage of crooked fruits was minimum (9%) in stingless bee-pollinated plants, compared to 22 per cent under open pollination, indicating better fruit shape and market quality under managed pollination. Although the pollinator-excluded treatment recorded 12 per cent crooked fruits, the overall fruit development and yield remained substantially inferior. Correspondingly, the highest proportion of healthy fruits (91%) was observed in stingless bee-pollinated plants, followed by pollinator exclusion (88%) and open pollination (78%). Seed parameters also reflected enhanced pollination efficiency. Fruits from stingless bee-pollinated plants contained the highest number of seeds per fruit (214 ± 21), followed by open pollination (188 ± 9), while pollinator-excluded plants produced significantly fewer seeds (69 ± 11). Similarly, the 100-seed weight was highest in the stingless bee-pollinated treatment (150.14 g), closely followed by open pollination (149.60 g), whereas, the lowest 100-seed weight (74.60 g) was recorded under pollinator exclusion.

Overall, the results indicated that managed pollination with *T iridipennis* significantly enhanced fruit yield, improved fruit size and quality and increased seed production in sponge gourd, emphasizing its effectiveness as an efficient pollinator under protected cultivation conditions.

Table 2. Relative abundance of different pollinators on sponge gourd, *Luffa cylindrical*

Time (h)	Honeybees	Stingless bees	Other pollinators	Mean
0600	3.66	16.66	1.00	7.11
0800	10.33	24.33	3.00	12.55
1000	7.66	22.33	3.33	11.11
1200	9.00	15.66	3.33	9.33
1400	3.00	6.33	2.33	3.89
1600	0.33	2.66	1.00	1.33
Mean	5.66	14.66	2.33	

Relative abundance = Number of foragers/5 min/m^2

$CD_{0.05}$	
Time	0.42
Pollinator	0.56
Time × Pollinator	0.97

Table 3. Effect of stingless bee pollination in sponge gourd, *Luffa cylindrical*

Parameter	Pollination treatment		
	Tetragonula iridipennis	Open pollination	Pollinator exclusion
Fruit yield/plant (kg)	3.68 ± 0.11	3.44 ± 0.17	0.96 ± 0.33
Crooked fruits (%)	9	22	12
Healthy fruits (%)	91	78	88
Fruit diameter (cm)	7.83 ± 0.09	5.61 ± 0.14	3.40 ± 0.11
Fruit length (cm)	25.60 ± 0.14	24.33 ± 0.08	9.33 ± 0.10
Fruit weight (kg)	0.621 ± 0.11	0.590 ± 0.10	0.178 ± 0.10
Seeds/fruit	214 ± 21	188 ± 9	69 ± 11
100-seed weight	150.14	149.60	74.60

Delgado-Carrillo et al (2024) reported that in experiments where pollinators were excluded from flowers, watermelon yielded no fruits, while green tomato experienced a 65 per cent reduction in production. Likewise, Shikhalia et al (1990) observed that artificial pollination in spine gourd resulted in 87.67 per cent fruit set compared with 25.67 per cent under natural pollination. Pande et al (2021) reported that higher fruit weight (2.69 kg/plant) was obtained in honeybee pollinated plants compared to self-pollinated plants (2.03 kg/plant). Similarly, Balaji et al (2023) recorded higher fruit set and better fruit quality parameters when bitter gourd crop was pollinated using stingless bee, *Tetragonula* sp over control experiments.

Kumar et al (2012) reported that stingless bees were major contributors to pollination in various cucurbit crops, enhancing both fruit quantity and quality. Similarly, Hodges and Baxendale (1991) observed fewer deformed fruits in bee-pollinated cucumber plants and a higher incidence of deformities under control and open pollination conditions. Chauhan and Thakur (2014) also reported fewer crooked fruits in cucumber when pollinated by bumble bees under protected conditions. Likewise, Chauhan et al (2019) recorded superior quality ash gourd fruits under stingless bee pollination compared to honeybee pollination.

CONCLUSION

The present study confirms the significant role of the stingless bee, *Tetragonula iridipennis*, in improving pollination success, fruit yield and quality in sponge gourd under protected cultivation conditions. Managed pollination with stingless bees resulted in superior fruit set, increased fruit size and weight, reduced deformities and enhanced seed production compared to open pollination and pollinator exclusion treatments. Their small size, non-aggressive behaviour, adaptability to enclosed environments and efficient foraging make stingless bees highly suitable pollinators for nethouse cultivation systems.

The use of *T iridipennis* not only reduces dependence on labour-intensive manual pollination but also provides an environmentally sustainable approach to enhancing productivity in cucurbit cultivation. Promoting stingless bee-based pollination management can, therefore, serve as an effective strategy for improving crop yield and ensuring sustainable protected agriculture.

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