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ORIGINAL RESEARCH PAPER in HORTICULTURAL PLANTS

Utilization of Indian Dammar Bee (*Tetragonula iridipennis* Smith) as a Pollinator of Bitter Gourd

Sourabh Bisui [1], Ujjwal Layek [2], Prakash Karmakar [1*]

[1] Department of Botany and Forestry, Vidyasagar University, Midnapore, 721102, India
[2] Department of Botany, Rampurhat College, Birbhum, 731224, India

*To whom correspondence should be addressed. Email: karmakar_p@yahoo.co.in

Abstract

An experiment was conducted to determine the pollination deficit in bitter gourd (*Momordica charantia* L.) and the effect of the use of Indian dammar bee as pollinator on the yield. Diverse native visitors were recorded during the blooming period. Among those honeybees, stingless bee, solitary bees, and butterflies are legitimate visitors; all of them showed a selective preference for male flowers (flower sex type selection index ranged from 0.41 to 0.62). The plant species showed a pollination deficit in nature (coefficient of pollination deficit, D = 0.20), resulting in low fruit set in an open-pollination system. However, the value was significantly increased by the supplementary pollination services of a managed dammar bee colony. Furthermore, the quality of the fruits also improved in hand-pollinated and managed bee-pollinated systems in comparison to an open pollination system. Therefore, it is generally recommended that farmers use Indian dammar bee colonies in their agricultural land to increase the quantity and quality of the yield of bitter gourd.

Keywords

crop yield; legitimate visitors; *Momordica charantia*; pollinators; stingless bee

1. Introduction

Bitter gourd (*Momordica charantia* L.) is widely cultivated in the tropical and subtropical regions of the world, including India, Malaysia, China, Thailand, Japan, Brazil, and Central and South America (Shan et al., 2012; Walters & Decker-Walters, 1988). Since ancient times, fruits have been used as vegetables. Additionally, fruits and seeds have important pharmacological uses, with antidiabetic, antihelminthic, antimalarial, antiulcerogenic and immunomodulatory effects (Ahmed et al., 1998; Matsuda & DeFronzo, 1999; Raza et al., 2000). With the increasing demand for bitter gourd, it is important to optimize its yield through improved agronomic practices and intensive pollination. Fruit quality also depends upon pollinator services (Abrol et al., 2019). Natural pollinators have been drastically reduced by several anthropogenic drivers like habitat fragmentation, use of pesticides, climate change, and introduced pathogens (Goulson et al., 2015; Kovacs-Hostyanszki et al., 2011; Potts et al., 2010). Utilization of managed honey bees is considered as one of the cheapest and most eco-friendly approaches in maximizing the yield of cross-pollinated crops. In tropical climatic conditions, stingless bees are important pollinating agents for many native plant species (Roubik, 1995). Many species of stingless bees contribute to the pollination of commercially important crops (Heard, 1999; Kukutani et al., 1993; Maeta et al., 1992). Stingless bees have certain advantages over other bees. As these bees lack a functional sting, this helps in easy management and makes them less hazardous to humans. The dammar bee, *Tetragonula iridipennis* Smith is the most abundant stingless bee in India including West Bengal. This bee species forages for diverse angiosperm flora with a high degree of floral fidelity (Layek & Karmakar, 2018).

Therefore, utilizing this bee colony to pollinate crops could be very effective. Unfortunately, the management and utilization of this bee species for pollination are minimal. Only a few people have utilized this bee species to pollinate crops like cucumber (Kishan et al., 2017).

The present study was undertaken to evaluate the yield enhancement potential of a managed Indian dammar bee colony on bitter gourd in West Bengal, India.

2. Material and Methods

2.1. Study Area

The study was conducted within the campus of Vidyasagar University (22.4320° N and 87.2979° E) in Paschim Medinipur District of West Bengal, India, from 2016 to 2019. Three neighboring plots (5 m × 5 m) were selected for the cultivation of bitter gourd. These plots were situated side by side, with a 1-m gap between each plot. To provide support for climbing twigs, we used a nylon net hung 1.5 m from ground level.

2.2. Native Floral Visitors

Floral visitors on *M. charantia* were observed at different times of day and night throughout its flowering period. The voucher specimens were sent to entomologists for identification at the Zoological Survey of India (ZSI), Kolkata. The number of each flower visiting species (per 2 m × 2 m field area) was counted during all field observations, and then relative abundance of different visitors was calculated as follows:

$$Relative\ abundance\ (\%) = \frac{No.\ of\ a\ visitor}{Total\ No.\ of\ all\ visitors} \times 100.$$

For each visitor, the type of visit (legitimate or illegitimate) and collected floral reward (nectar, pollen or tissue) were recorded. Furthermore, flower sex type selection index (FSI) for each legitimate visitor was determined using the following method:

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

Based on the FSI value, we placed the visitors within one of seven categories, which are shown inTable 1.

Table 1 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

Fruit set in different systems (pollinator exclusion, hand-pollination, open-pollination, and managed dammar bee pollination with native bees) were recorded. During the peak flowering period, matured female flower buds (n = 100 for each system) were selected and tagged with labels. Plot 1 was set up as hand-pollinated system, and pollinators were excluded by covering selected buds with nylon net. Plot 2 was the open-pollination system and required no additional treatment, while Plot 3 was open to native pollinators and was also serviced by a managed bee colony. Three days after the opening of the last selected bud in the open-pollination system, a managed hive of dammar bee, i.e., Colony G (Bisui et al., 2019) was set up close to Plot 3. The height of the hive was almost at flower level, and orientation of the nest entrance was same to its original orientation. After settling the managed bee colony in Plot 3, we did not further selected flowers from Plot 2, which was in the open pollination system. During that time period, we only recorded the quality and quantity of fruits within Plot 2. Ten days after flower opening, length, girth, and weight of young fruits were recorded (n = 10 for each system except in the pollinator exclusion system). We calculated the yield enhancement in Plot 3 (associated with the managed dammar bee colony in addition to native visitors) in comparison to Plot 2 (open pollination system) using the following equation:

$$Yield\ enhancement\ (\%)\ by\ managed\ bee\ pollination = \frac{a-b}{b},$$

where $a = Fruit\ set\ (\%) \times Average\ weight\ of\ a\ fruit\ in\ Plot\ 3,\ b = Fruit\ set\ (\%) \times Average\ weight\ of\ a\ fruit\ in\ Plot\ 2.$

Using the results of fruit set in the open-pollination and hand-pollinated systems, we measured a coefficient of pollination deficit (D) as follows:

$$D = 1 - \frac{Fruit\ set\ in\ open\ pollination\ system}{Fruit\ set\ in\ hand\ pollination\ system}.$$

According to the value of D, we categorized the plant as one of the following classes: High pollination deficit (D > 0.5), medium pollination deficit (D = 0.3–0.5), low pollination deficit (0.3 > D ≥ 0.1) and negligible pollination deficit (D < 0.1).

2.3. Statistical Analyses

Statistical analyses of the data were conducted to obtain the arithmetic mean and standard deviation. One-way ANOVA followed by Duncan's multiple range test (DMRT) was used to analyze data, and $p \leq 0.05$ was considered statistically significant.

3. Results

3.1. Native Floral Visitors

In the open-pollination system, 22 insect species were observed to visit *M. charantia* flowers (Table 2, Figure 1). Among them, eight were Hymenopterans, seven were Lepidopterans, four were Dipteran, and three were Coleopteran. Among the floral visitors, the most abundant were *Halictus* sp. (relative abundance 15.70%), *Apis dorsata* (relative abundance 10.25%), *Lasioglossum* sp. (relative abundance 9.42%) and *Pelopidas mathias* (relative abundance 6.78%).

In terms of visitor's legitimacy, beetles, flies, and ants were illegitimate ones. Beetles were florivorous, flies acted as pollen thieves, and ants performed as nectar thief. Bees, butterflies, and wasp were legitimate visitors. Bees (honey bees, stingless bee, and solitary bees) collect both nectar and pollen from male flowers and nectar from female flowers, whereas butterflies and wasp visited the flowers to collect only nectar. Male flowers were more attractive than female flowers to all the visitors. In the case of butterflies, their flower sex type selection index (FSI) was >0.5 (except for *Danaus chrysippus*; FSI = 0.48) indicating that they moderately preferred to select male flowers to collect nectar. However, all bees strongly preferred to select male flowers (FSI < 0.5) to collect both nectar and pollen.

3.2. Productivity

Successful pollination in bitter gourd is obligatorily dependent on insect pollinators, as demonstrated in the pollinator exclusion system where fruit set did not take place (Table 3). Pollination service for the crop is performed by several native pollinators (honey bees, stingless bee, solitary bees, butterflies, and wasp). However, all of them showed a selective preference for male flowers over female flowers. As a result, the crop suffered from a pollination deficit (coefficient of pollination deficit; D

Table 2 Floral visitors of *Momordica charantia* in open condition in West Bengal, India.

Floral visitors	Relative abundance	Foraging strategy	Resource	FSI
Coleoptera				
Coccinella sp.	1.65	Fl	Floral parts	-
Cochliomyia hominivorax	1.32	Fl	Floral parts	-
Raphidopalpa foveicollis	1.82	Fl	Floral parts	-
Diptera				
Chrysomya bezziana	0.99	PT	Pollen	-
Episyrphus balteatus	5.29	PT	Pollen	-
Eristalinus tabanoides	2.31	PT	Pollen	-
Ischiodon scuttellaris	0.83	PT	Pollen	-
Hymenoptera				
Apis cerana	3.97	LV	Nectar, pollen	0.42
Apis dorsata	10.25	LV	Nectar, pollen	0.45
Apis florea	1.32	LV	Nectar, pollen	0.48
Camponotus sericeus	1.16	NT	Nectar	-
Halictus sp.	15.70	LV	Nectar, pollen	0.44
Lasioglossum sp.	9.42	LV	Nectar, pollen	0.41
Tetragonula iridipennis	1.49	LV	Nectar, pollen	0.42
Vespa orientalis	5.79	LV	Nectar	0.47
Lepidoptera				
Borbo cinnara	6.12	LV	Nectar	0.51
Cupido comyntas	5.29	LV	Nectar	0.54
Danaus chrysippus	4.30	LV	Nectar	0.48
Eurema hecabe	3.80	LV	Nectar	0.53
Junonia iphita	3.97	LV	Nectar	0.52
Ocybadistes walkari	6.45	LV	Nectar	0.52
Pelopidas mathias	6.78	LV	Nectar	0.62

Fl – florivorous; LV – legitimate visitor; NT – nectar thief; PT – pollen thief; FSI – flower sex type selection index.

= 0.20). The percentage of fruit set of bitter gourd was significantly lower in the open pollination system (75 ± 12.69) in comparison to the maximum potential i.e., fruit set obtained in the hand-pollinated system (94 ± 8.43). When we used a managed Indian dammar bee colony to pollinate the crop, the percentage of fruit set significantly increased in comparison with the open pollination system.

Fruit quality also significantly differed among open-pollination, hand-pollination, and managed bee pollination systems [length: $F(2, 27) = 7.95$, $p < 0.05$; girth: $F(2, 27) = 32.21$, $p < 0.05$; weight: $F(2, 27) = 13.25$, $p < 0.05$]. Length, girth, and weight of fruits were the highest in the hand-pollinated system, followed by the managed bee-pollinated system and the open-pollination system (Table 3).

When both the fruit set and fruit weight were considered, the yield was the highest

Table 3 Effect of pollination treatments on field-grown bitter gourd.

Measure	Pollinator exclusion	Hand pollination	Open pollination	Managed bee colony
Fruit set (%)	0	94 a ± 8.43	75 b ± 12.69	86 a ± 11.74
Fruit quality (after 10 days of flower open)				
Length (mm)	-	122.9 a ± 8.31	108.4 b ± 7.17	115.3 b ± 8.84
Girth (mm)	-	96.7 a ± 5.81	80.3 b ± 2.41	92.6 a ± 5.32
Weight (g)	-	35.45 a ± 3.84	25.90 c ± 2.83	30.91 b ± 5.39

Values given as mean ± standard deviation. Means in the row followed by same letters do not differ significantly by DMRT at 5%.

Figure 1 Floral visitors of *Momordica charantia*. (**A**) *Apis dorsata*, (**B**) *Episyrphus balteatus*, (**C**) *Halictus* sp., (**D**) *Junonia iphita*, (**E**) *Pelopidas mathias*, and (**F**) *Tetragonula iridipennis*. Scale bars = 10 mm.

in the hand-pollinated system, followed by the managed bee-pollinated system, and then the open-pollination system. When a managed dammar bee colony was used in addition to native pollinators, the crop yield of bitter gourd increased by approximately 36.85% in comparison to the open-pollination system.

4. Discussion

A large number of visitors to bitter gourd flowers collect nectar, pollen, and floral tissue. Though, documentation of floral visitors of the plant species were done from other parts of India (Subhakar et al., 2011) and also from outside of country (Deyto & Cervancia, 2009). However, the diversity, species composition, and abundance of pollinating insects vary from region to region, and hence documenting pollinators and their effect on yield in bitter gourd is important. Greater abundance of Indian dammar bee in comparison to other pollinators was reported from Andhra Pradesh (Subhakar et al., 2011). However, dammar bee abundance was significantly lower in the open-pollination system in the area used for this study. The abundance of pollinators on a flowering plant depends on several factors such as quantity and quality of floral rewards, duration of anthesis, weather conditions, and availability of nests of wild bees in the vicinity of the crop field (Free, 1993). All the legitimate visitors showed a selective preference for male flowers over female flowers due to their bright-yellow color and greater available reward (both nectar and pollen grains). This selective preference resulted in a light pollination deficit of the crop.

To overcome this pollination deficit, different measures such as hand-pollination (Klein et al., 2007; Partap & Ya, 2012), pollen sprays (Bahadur et al., 2015), and the use of managed bee hives have been undertaken. Among bee species used for crop pollination, the European honey bee (*Apis mellifera* L.) is the most common, and the use of Indian dammar bee is less so. Kishan et al. (2017) used this bee species for the pollination of greenhouse cucumber in Tamil Nadu. We believe that our experiment will be the pioneered one in relation to the use of Indian dammar bee to pollinate bitter gourd in West Bengal. The present work showed that the use of dammar bee for supplementary pollination was very effective with respect to increasing fruit set as well as improving the quality of fruits.

5. Conclusions

In the open-pollination system, several insect species visited the flowers of the bitter gourd. Among those, few were legitimate visitors. The Indian dammar bee (*T. iridipennis*) was one such legitimate visitor. Despite having diverse floral visitors, the bitter gourd showed a pollination deficit under open pollination conditions, resulting in low yield. Indian dammar bee colonies may be utilized to overcome this shortcoming, as this bee species visits both male and female flowers to collect rewards (nectar and pollen, and only nectar, respectively). Thus, a managed dammar bee colony, working in conjunction with other native pollinators, plays a synergistic role in improving the yield of bitter gourd.

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