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STINGLESS BEE *TETRAGONULA IRIDIPENNIS* AND HONEY BEE *APIS CERANA* POLLINATION IN CUCUMBER

Avinash Chauhan* and H K Singh

Department of Entomology, School of Agricultural Sciences and Rural Development
Nagaland University, Medziphema 797106, Nagaland, India
*Email: avi_shimla@hotmail.com (corresponding author)

ABSTRACT

Pollination in cucumber (*Cucumis sativus* L.) was studied using stingless bees, *Tetragonula iridipennis* Smith and honey bee, *Apis cerana* F. Data on the resource partitioning revealed the foraging activity of pollinators. Pollination efficiency index was observed to be maximum with *A. cerana* (24) followed by *T. iridipennis* (14), and significantly maximum fruit set (81.66 and 78.97%) was obtained with their pollination. An increase of 87.48% in fruit set, 46.47% in healthy fruits and 275.23% in seed numbers was noticed, with longer (17.85 and 17.22 cm) and heavier (0.415 and 0.411 kg) fruits in the *A. cerana* and *T. iridipennis* pollinated plots. Maximum number of healthy fruits was achieved with bee pollination as compared to open pollination and control, and *A. cerana* showed more mortality as compared to *T. iridipennis*.

Key words: *Tetragonula iridipennis*, *Apis cerana*, cucumber, pollination index, pollination impact, fruit set, fruit size, healthy fruits, seed number, seed weight

Honey bees, stingless bees and bumble bees are important pollinators often used for meeting the pollination requirements in different crops (Chauhan et al., 2013; Free, 1993; Mussen and Thorpe, 1995). The effectiveness of pollinator is ascertained by its pollination efficiency index (P.E.I.) (Chauhan et al., 2019) and most efficient pollinator carries and deposits plenty of pollen on stigmas as it moves from flower to flower (Kearns and Inuoye, 1997; Spears, 1983; Inouye and Pyke, 1988; Stubbs and Drummond, 1999; Dag and Kammer, 2001). All the cucurbit vegetables require pollinators for fruit set (Roubik, 1995). Cucumber is cultivated in all states of India, from temperate to tropical regions, and it is widely grown in all North Eastern states. The varieties grown are mainly monoecious and require pollination for better fruit yield and quality (Santos et al., 2008). Honey bees (*A. mellifera* and *A. cerana*) are used for managed pollination of crops in open conditions. These, when utilized under protected conditions, the results are not promising due to inability to orient in a small space and susceptibility to high temperatures sometimes resulting in loss of bee colonies. The stingless bees on the other hand have short flight range, easily orient on flowers under high temperature and do not sting workers. Recent studies have revealed that stingless bees are effective alternatives to honey bees for the pollination of many greenhouse crops. Keeping in view the enhanced use of stingless bees in pollination of different crops, present study evaluates the pollination potential of *T. iridipennis* in cucumber under protected conditions.

MATERIALS AND METHODS

The experiment was carried out on cucumber at the Experimental farm, AICRP Honey Bees and Pollinators, Department of Entomology, School of Agricultural Sciences and Rural Development (25.75961°N, 93.853698°E). All agronomical practices were done as per good agricultural practices with the crop sown in the last week of February 2019 at a spacing of 60 x 90 cm. The crop germinated and came to bloom in the first week of April, 2019. After that, two colonies of stingless bee, *T. iridipennis* were shifted in the caged plots at 5% flowering. Similarly, one colony of *A. cerana* having six frames was added to the other treatment. In control, the crop was not exposed to any pollination service. Resource partitioning (relative abundance) and foraging activity of stingless bees, honey bees and other pollinators (xylocopa, solitary bees, flies, beetles) was observed under open field conditions from early morning hours (0500 hr) till late evening (1700 hr) at 2 hr interval for ten days consecutively. The foraging activity (foraging rate/ speed and loose pollen grains) were observed as per the method adopted by Chauhan and Thakur (2014). Pollination Efficiency Index was worked out for each pollinator, using the formula given by Bohart and Nye (1960). To know the impact of different pollination treatments, the female flowers/ vine were precounted. Ten plants from each treatment viz., stingless bee pollinated, *A. cerana* pollinated, control and open pollinated were selected and tagged randomly. The fruit set on these plants were then recorded and total yield was calculated on fruit set basis. The % healthy fruits and deformed fruits were computes from the data on fruit set. Ten representative fruit samples from each treatment were taken for calculating the fruit length, diameter, fruit weight, seed number/ fruit, weight of 1000 seeds. All these parameters were measured with the scale, digital Vernier caliper and digital weighing balance. Increase in production and quality parameters was also calculated along with decrease in deformed fruits.

RESULTS AND DISCUSSION

The main visitors of cucumber flowers were *A. cerana*, *A. dorsata*, *A. florea*, *T. iridipennis*, *T. laeviceps*, *Lophotrigona canifrons*, *Lepidotrigona ventralis*, *Halictus semiaerinus*, *Xylocopa tenuiscapa*, *Amagiella zonata*, *Megachile umbripennis* and *M. lanata* (Table 1). Honey bees are known as frequent visitors of cucumber flowers besides halictids and Xylocopinae (Thakur and Rana, 2008; Santos et al., 2008; Samoskorn et al., 2010; Chauhan and Thakur, 2014; Sawatthum et al., 2017). Grewal and Sidhu (1978) reported *A. florea, A. mellifera, A. dorsata* and *Bombus* sp. as main insect visitors of cucurbit crops. A total of 24 insect visitors were reported by Sajjanar et al. (2004) in cucumber with hymenopterans as major visitors. In ash gourd stingless bees and honey bees were the predominant pollinators in Nagaland (Chauhan et al., 2019). Resource partitioning studies revealed stingless and honey bees, and other pollinators like halictids, xylocopa bees, flies, beetles and butterflies as the major beneficiaries from cucumber pollen and nectar. All these insect visitors share the resources (pollen and nectar) for their development. Similar observations had been made by McGregor (1976); Kauffeld et al. (1978); Cervancia and Bergonia (1991); Stanghellini et al. (1997); Sajjanar et al. (2004); Hanh et al. (2014); Azmi et al. (2015); Sawatthum et al. (2017). These reveal that bees are the most frequent and beneficial visitors sharing the rewards with other insects from cucumber flowers (Table 1, 2).

Table 1. Insect visitors of cucumber flowers under open conditions

S. No.	Species visiting	N/ P/ N&P	Frequency of Occurrence
1	*Apis cerana*	N&P	M.F.V.*
2	*Apis dorsata*	N&P	M.F.V.*
3	*Apis florea*	N&P	F.V.
4	*Tetragonula iridipennis*	N&P	M.F.V.*
5	*Lophotrigona canifrons*	N&P	M.F.V.*
6	*Lepidotrigona ventralis*	N&P	F.V.
7	*Tetragonula laviceps*	N&P	M.F.V.*
8	*Episyrphus balteatus*	N	F.V.
9	*Mylabris pustulata*	P	F.V.
10	*Raphidopalpa foveicolis*	P	F.V.
11	*Halictus semiaerinus*	N&P	F.V.
12	*Musca sp.*	EFE	L.F.V.
13	*Xylocopa tenuiscapa*	N&P	M.F.V.
14	*Megachile lanata*	N&P	F.V.
15	*Megachile umbripennis*	N&P	F.V.
16	*Icaria guttatipennis*	N	F.V.
17	*Monomorium indicum*	N	M.F.V.
18	*Amagiella zonata*	N&P	M.F.V.

N- Nectar, P- Pollen, EFE- Extra flower exudation, MFV- Most frequent visitor, LFV- Less frequent visitor, FV- Frequent visitor

The activity of pollinators was more in the morning from 0500- 1100 hr which decreased in the noon. The relative abundance of *A. cerana* (11.58 bees/ 5 min) and *T. iridipennis* (10.92 bees/ 5 min) was found statistically at par in comparison to each other irrespective of time. The relative abundance of pollinators in morning time revealed higher nectar and pollen availability between 0700-1000 hr. Maximum activity of pollinators in ash gourd was between 0800-1000 hr (Chauhan et al., 2019), and in cucumber at 1000-1200 hr (Kishan et al., 2017). Similarly, Roopa (2002) observed the major peak of pollen and nectar foragers between 1000 to 1200 hr. Danaraddi (2007) observed the peak activity of *T. iridipennis* at 1000-1200 hr. The activities of stingless bee, *Scaptotrigona aff. deplis* and *Nannotrigona testaceicornis* was more on cucumber flowers in Brazil (Santos et al., 2008). Similarly, Singh and Chauhan (2020) observed stingless bees as the important pollinators of cucumber, and maximum activity of *T. iridipennis* was observed during morning and evening time in Kerala (Devanesan et al., 2002). However, it was observed that maximum numbers of flowers for pollen were visited in the morning time (Fidalgo and Kleinert, 2007). Foraging activity disclosed that honey bees have more pollination efficiency index (24.00) as compared to stingless bees (14.00) and other pollinators (3.00) (Table 2).

Significantly maximum fruit set (81.66 and 78.97%) was obtained with *A. cerana* and *T. iridipennis*) pollinated plots which is at par to each other, followed by open pollinated crop (72.00%) and pollinator excluded crop (42.12%), signifying the role of pollination in cucumber. Amano (2005) obtained maximum fruit set in cucumber using stingless bees, and it was found that honey bees are less efficient. Similarly, weight (0.415 and 0.411 kg) of fruits was observed significantly at par in the honey bee stingless bee pollination; and this is higher as compared to weight (0.386 kg) of fruits obtained in open pollination conditions and in control pollination (0.262 kg). The fruit

Table 2. Activity and pollination efficiency of pollinators in cucumber

Time (h)	Honey bees				Stingless bees				Other pollinators			
	*Relative abundance	Foraging rate	Foraging speed	Loose pollen grains	Relative abundance	Foraging rate	Foraging speed	Loose pollen grains	Relative abundance	Foraging rate	Foraging speed	Loose Pollen grains
0500	9.66 (3.11)	7.25	4.33	1720± 43	10.50 (3.24)	8.25	5.66	1290± 68	2.08 (1.44)	4.66	9.91	465± 71
0700	16.33 (4.04)	8.41	4.55		16.14 (4.02)	9.50	5.66		4.18 (2.04)	7.00	9.00	
0900	17.54 (4.19)	7.66	5.11		16.58 (4.07)	8.33	4.58		7.22 (2.69)	6.16	7.08	
1100	13.42 (3.66)	6.00	4.11		11.74 (3.43)	5.91	4.41		7.81 (2.79)	3.50	5.58	
1300	12.18 (3.49)	5.33	4.00		11.46 (3.39)	6.08	3.25		4.33 (2.08)	4.83	7.33	
1500	9.21 (3.03)	5.91	3.44		8.62 (2.94)	6.16	5.00		2.00 (1.41)	4.41	7.91	
1700	2.72 (1.65)	2.66	2.22		1.41 (1.19)	3.00	1.75		1.11 (1.05)	1.58	3.25	
Mean	11.58 (3.40)	6.17	3.97		10.92 (3.30)	6.75	4.33		4.10 (2.03)	4.59	7.15	
CD (p=0.05)	0.45	0.23	0.051		0.45	0.23	0.051		0.45	0.23	0.051	
Pollination Efficiency Index	24				14				3			

*Relative abundance= number of foragers/ 5 min/ m^2; Foraging rate= Number of flowers visited/ 5 min; Foraging speed= time spent/ flower (in seconds)

Table 3. Impact of modes of pollination on fruit quality and production in cucumber

Treatment	Fruit set (%)	Fruit diameter (cm)	Fruit weight (kg)	Fruit length (cm)	Healthy fruit (%)	Deformed fruits (%)	Number of seeds/ fruit	Weight of 1000 seeds (g)
***Apis cerana* pollination	81.66	10.11	0.415	17.85	81.12	18.88	402	32.08
**Tetragonula iridipennis* pollination	78.97	9.82	0.411	17.22	87.21	12.49	394	32.42
Open pollination	72.00	9.14	0.386	15.43	72.40	27.60	371	27.54
Pollinator exclusion (control)	42.12	6.64	0.262	8.68	59.54	40.46	105	16.64
CD (p=0.05)	4.54	1.12	0.29	0.95	6.66	2.61	6.94	0.18

* Stingless bee **honey bee

length was also found to follow the same trend. Azmi et al. (2017) in Malaysia and Tej et al. (2017) reported more fruit set, fruit length and fruit diameter in crop pollinated by stingless bees. Similar results were reported by Nicodemo et al. (2013) in cucumber crop pollinated by stingless bees. It is also observed that quality of fruits is increased by pollination using stingless bees (Heard, 1999). Singh and Chauhan (2020) also reported stingless bees as important pollinators of cucurbits. Similar results were reported in sweet pepper (Cruz et al., 2005) and in cucumber (Santos et al., 2008); stingless bee pollination gave significantly more healthy fruits (87.21%) and less deformed fruits (12.49%) were obtained followed by honey bee pollination (81.12 and 18.88%) and open pollination (72.40 and 27.60%). Significantly more deformed fruits (40.46%) were observed from pollination excluded plots (Table 3). Chauhan et al. (2019) reported less deformed fruits in stingless bee pollinated ash gourd. Likewise, Hodges and Baxendale (1991) reported less deformed fruits in bee pollinated cucumber vines and observed more deformed fruits otherwise. Chauhan and Thakur (2014) also reported less crooked fruits in cucumber when pollinated by bumble bees under protected conditions. Chauhan et al. (2019) observed better quality ash gourd fruits with healthy fruits when pollinated by stingless bees as compared to honey bees.

Significantly maximum seeds were produced in plots pollinated by honey bees (402) as compared to those by stingless bee (394) and open pollination (371). In contrast, seed weight of 1000 seeds was significantly more (32.42 g) in stingless bee pollinated crop (Table 3). Similar results were obtained in ash gourd (Chauhan et al., 2019), in green pepper (Santos et al., 2008), in chilli (Azmi et al., 2016), in tomatoes (Sarto et al., 2005) and in cucumber (Santos, 2004; Azmi et al., 2017) with stingless bee pollination under protected conditions. Impact of stingless bee pollination over control revealed an increase of 87.48% in fruit set, 46.47% in healthy fruits, 98.38, 47.89 and 56.87% in fruit length, diameter and weight. Reduction in deformed fruits (69.13 %) was also observed in stingless bee pollinated plants. The seeds number increased by 275.23% and an increase of 94.83% was reported on introduction of stingless bees as a pollinator of cucumber crop. Similarly, Azmi et al. (2017) reported with stingless bee pollination, the fruits were heavier and longer in cucumber. However, no significant differences were observed in seed weight. Likewise, in Australia, Occhiuzzi (2000) reported 11% increase in fruit weight and 34% in number of seeds/ fruit when sweet pepper was pollinated by *Trigona carbonaria* under greenhouse conditions. Viana et al. (2014) also observed more fruit and seed production in honey bee plus stingless bee pollinated apple crop. Similarly, Nunes-Silva et al. (2013) reported *M. fasciculata* as an efficient pollinator of eggplants which increased the fruit set by 29.50% in Brazil. Similarly, Rajasri et al. (2012) observed increased seed yield in sunflower with stingless bee pollination, and honey bee revealed more mortality (13%) as compared to stingless bees (5.1%). Thus, for effective pollination of cucumber under caged conditions *T. iridipennis* is more suitable than *A. cerana*. This is because, initially for acclimatization, *A. cerana* worker mortality was observed while in *T. iridipennis*, the mortality was very less. However, under open conditions, both pollinators can effectively pollinate the crop.

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