Impact of bee pollination on chilli, *Capsicum annuum* under the low-hill conditions of Nagaland

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ABSTRACT

Keeping in view the abundance of different insect visitors on chilli, an experiment was laid out with 4 different pollination treatments viz stingless bee (*Tetragonula iridipennis*) pollination, *Apis cerana* pollination, open field pollination and pollinator exclusion (control) to know the role of these visitors on production (fruit set, deformed fruits, fruit weight and fruit yield) and quality (fruit length, seed number, seed weight and moisture) in chilli. Chilli crop was grown as per good agricultural practices. Plants were caged with insect proof nylon nets for pollination treatments. A total of 11 major insect visitor fauna species were recorded foraging on chilli blooms under open field conditions. The Shannon-Wiener diversity index of chilli's insect pollinator revealed higher diversity. Pollination efficiency index for pollinators was also calculated. The maximum diurnal abundance of pollinators was recorded between 0800-1200 h and the maximum foraging rate was found with syrphid flies, houseflies and stingless bees. Yield and quality parameters under different modes of pollination revealed that bee pollination was significantly superior over without pollination. In open conditions for adequate pollination of chilli, stingless bees, honey bees and Diptera fauna should be conserved along with non-*Apis* bees. Without pollination the yield and quality were too less in chilli. Stingless bees, honeybees and halictid bees were the major pollinators of chilli.

Keywords: Stingless bees; chilli; pollination; yield; quality

INTRODUCTION

Pollination is one of the important components for the sustenance of agroecology. India, which is a home of a variety of crops and their associated fauna, has different regions as the biodiversity hotspots harbouring thousands of species which are contributing directly or indirectly to the production of crops. Several groups of insects (Hymenoptera, Diptera, Lepidoptera, Coleoptera etc) visit flowers to collect pollen and nectar as food. As they forage, these insects spread pollen grains among flowers, accomplishing pollination. Pollination results in the increase in food security and improvement of livelihood (Costanza et al 1997). Many flowers offer sugary liquid nectar as an added enticement for these pollinating insects. Among insect pollinators, bees are especially efficient because they eat pollen and nectar exclusively, visit many flowers of the same species during a single trip and have hairy bodies that easily pick up the pollen grains. Bees play a very important role in the pollination of flowering plants resulting in increased quantity and quality of fruits and seeds. They are also known to pollinate about 70 per cent of the crops that account for 35 per cent of all agricultural production that depends on varying extents on pollinators for high-quality and high-quantity seed and fruit production (Klein et al 2007, Kearns and Inouye 1997).

Honeybees, stingless bees, bumble bees, halictids, syrphids and other solitary bees are an important group of insects which are very indispensable for regulating the food and forage cycle of the ecosystem. They are found in different habitats with different nesting attributes (Chauhan et al 2019). Among these pollinators, collection and domestication of feral stingless bee colonies, their identification and use them in crop pollination are the areas of interest for sustainable farming in northeast India. Northeast India comprises eight states viz Arunachal Pradesh, Assam, Meghalaya, Mizoram, Manipur, Nagaland, Sikkim and Tripura (Anon 2018). These states are endowed with a wide range of physiographic and eco-climatic conditions. Propagation of stingless bee colonies contributes to preservation of biodiversity by conserving populations of species that may otherwise decline owing to human disruption of ecosystems (Watanabe 1994, Buchmann and Nabhan 1996, Kearns and Inouye 1997, Allen-Wardell et al 1998, Cane and Tepedino 2001, Goulson et al 2008). The pollination potential of stingless bees in managed cropping system is still unexplored and requires an insight to utilize these important pollinators for enhancing the crop productivity.

Stingless bees are used as pollinators in greenhouse crops in both temperate and tropical regions (Del Sarto et al 2005, dos Santos et al 2009, Chauhan et al 2019). Bumble bees, particularly *Bombus haemorrhoidalis* Smith, have been used in north India for greenhouse tomato (Yankit et al 2018) and cucurbits pollination (Chauhan and Thakur 2014, Kishan et al 2017). However, in northeast region, these are not widely used due to lack of colonies and rearing technology. In recent years, there has been an increasing interest in finding native bee species that have a pollination efficiency that is equal to or at least similar to that of bumble bees. Therefore, stingless bees being the native dominant pollinators, can prove better alternative for tropical and subtropical regions of the globe.

Stingless bees are better pollinating agents due to their characteristics like, they can pollinate small flowers, they thrive much better in tropical areas, are harmless to humans, they co-exist with other bee species, they can adjust in confined space of greenhouse or net house conditions, are more environment friendly, have very less swarming ability, have less chances of insect pest and disease attack, have short foraging range etc which make them effectively be utilized for pollinating cucurbit flowers in net house condition. Further utilization of stingless bees reduces the labour requirement and tedious procedure of hand pollination. So, the stingless bees are valuable for cross pollination of crops in net house conditions (Gadhiya 2015). The cucurbit vegetables, pumpkins and squash (Cucurbita) cucumbers and gherkins (*Cucumis sativus*), balsam pear (*Mormodica charantia*), musk melon (*Cucumis melo*), other watermelons (*Citrullus*) and gourds, including bottle gourd (*Lagenaria siceraria*), ash gourd (*Benincasa hispida*) and sponge gourd or luffa (*Laffa aegyptica*), require pollinators for fruit set (Roubik 1995). Similarly, solanaceous crops tomato, brinjal and chillies are highly dependent on wild pollinators as honeybees do not prefer to visit their flowers.

Chilli, *Capsicum annuum*, is a major spice in the Indian cuisine and is grown widely in all parts of the country. It is a rich source of vitamin A, B and C and is pungent because of the presence of capsaicin. These are self-pollinating but production increases on introduction of pollinators under protected conditions. It is widely grown in Nagaland and all northeastern states as a spice and is used as a delicacy enhancer in all the meals of the day. The flowers of chilli are visited by a number of insects and to know the impact of these visits on the production and productivity has not been assessed in this region. Keeping in view the importance of role of different bees, *Apis cerana*, stingless bees and other wild visitors as pollinators, present studies were undertaken to know the effectiveness of different modes of pollination on chilli production and productivity.

MATERIAL and METHODS

The experiment was carried out at the experimental farm of AICRP Honeybees and Pollinators, Department of Entomology, School of Agricultural Sciences (25.75961°N, 93.853698°E) to evaluate the use of different bee species for pollination of chilli under protected conditions. Three net houses (100 m^2 each) were selected and one medium sized stingless bee colony in net house and similarly one honey bee hive of *A cerana* having 5 frames of bees were introduced in second net house at 10 per cent flowering. The other net house was kept as control (no pollinator was introduced). Similarly, crop was grown under open field conditions for comparison. The impact of introduced stingless bee colonies and honey beehives in net house on effective pollination to improve fruit quality and quantity was studied. All agronomical practices were done as per good agricultural practices and kept same in three different conditions.

The crop was sown in the third week of February 2023. Total sixteen beds were raised in each net house and crop was transplanted at a spacing of 60 cm × 60 cm. The crop came to bloom in the last week of May

2023. The colonies were shifted to the net house and data were recorded on different parameters. Foraging activity of bees and other pollinators was recorded as per the method adopted by Chauhan (2015) under open field conditions from early morning (0600 h) till late evening (1600 h) at two hours interval for seven days continuously. Shannon Weiner index was calculated for diversity. Similarly, pollination efficiency of pollinators was worked out as per Bohart and Nye (1960).

Impact of bee pollination on chilli was evaluated with fruit set. Ten plants from each treatment were selected and tagged randomly. The fruit set on these plants was recorded and total yield was calculated on fruit set basis. Healthy fruits and crooked/deformed/ curled fruits were also calculated. Fruit length and fruit weight were recorded in all treatments (20 fruits/ treatment) using the scale, digital vernier callipers and digital weighing balance. Similarly, seed weight and seed number were also calculated along with the moisture content. The data recorded on various parameters were statistically analysed with suitable transformation in RBD designed by Gomez and Gomez (1984). Data on temperature and humidity were also recorded using the digital thermometer and hygrometer.

RESULTS and DISCUSSION

Stingless bees (*Tetragonula iridipennis*, *Lophotrigona canifrons*, *Lepidotrigona ventralis* and *Tetragonula gressitti*), honey bees (*A cerana, A dorsata*, *A florea* and *Amelifera*), halictid bees, *Semiaerinus* sp and *Amegilla* sp were the visitors visiting the crop throughout the day while syrphid flies, *Xylocopa* sp and solitary bees were frequent visitors during noon hours. Yourstone et al (2021) observed hymenopterans as important visitors on chilli. The diversity index on chilli was found to be 1.54 which showed higher diversity of pollinator fauna in this region. The pollination efficiency index (PEI) was found same for both the test insects (6) (Table 1).

The different pollination attributes like relative abundance, foraging rate, foraging speed and loose pollen grains have been discussed by several researchers (Chauhan et al 2019, Chauhan and Singh 2020) and revealed the importance in pollination efficiency index (Bohart and Nye 1960, Sihag and Rathi 1994). After assigning the pollination index to different pollinators visiting a particular crop, the pollinator having higher pollination index is suitable to be selected as a pollinator for that particular crop (Chauhan 2015).

Data given in Table 2 show that maximum fruit set (70.40%) was recorded in open pollination followed by *A cerana* (67.66%) and *T iridipennis* (65.90%) pollination, the latter two being at par. In control, the fruit set was minimal (61.35%). The healthy fruits were maximum in *T iridipennis* (85.90%) and *A cerana* (84.32%) pollination, the two being at par followed by control (79.60%) while minimum in open field (76.82%) conditions. Similar observations were made for deformed fruits. Crooked fruits were maximum in *A cerana* (15.68%) and *T iridipennis* (14.10%) pollination, the two being at par followed by open pollination (23.18%) and minimum in control (20.40%). The fruit length was maximum in open pollination (8.72 cm) followed by stingless bees (7.32 cm) and control (7.16 cm), the latter two being at par. However, in control, the fruit length (7.16 cm) was at par with pollinated crop of *A cerana* (7.08 cm). The fruit weight was maximum in open pollinated crop (2.84 g) and *T iridipennis* (2.66 g), the two being at par followed by *A cerana* (2.14 g) while the minimum was recorded in control (1.84 g). The moisture content was highest in open pollination (87.14%) followed by *T iridipennis* (84.60%) and *A cerana* (84.46%) pollinated crop, whcih were at par and minimum in control (84.20%). The number of seeds per fruit was highest in open pollination (28.16) and lowest in *T iridipennis* pollinated (18.00), control (17.44) and *A cerana* pollinated (16.24) conditions, the latter three being statistically at par. The 1000-seed weight was higher in open pollination (5.44 g) and *T iridipennis* (5.44 g) and *A cerana* (5.02 g) pollinated crops as compared to control (3.21 g).

In Japan, pollination tests of stingless bees (*Trigona carbonaria* and *Scaptotorigona bipunctata*) and honeybees (*A mellifera*) on white clover, tomatoes, cucumbers, eggplants, paprika and red peppers in greenhouse and apiary areas showed that stingless bees pollinate just as honeybees (Amano 2004). In Mexico (Yucatan), González-Acereto et al (2006), on the basis of pollination efficiency for tomato (*Lycopersicon esculentum*) and habanero pepper (*Capsicum chinense*) in the greenhouses by *Nannotrigona perilampoides* and *Meliponula beecheii*, showed that this species of stingless bees could be used as an alternative pollinator to *A mellifera* or bumble bees (*Bombus* spp). Evaluation of

Table 1. Foraging activity and pollination efficiency index of pollinators on chilli, *Capsicum annuum*

Time (h)	*A cerana*				*T iridipennis*			
	Relative abundance	Foraging rate	Foraging speed	Loose pollen grains	Relative abundance	Foraging rate	Foraging speed	Loose pollen grains
0600	3.92	9.66	5.44	1440 ± 39	2.44	5.20	14.61	1210 ± 31
0800	5.94	9.67	5.52		7.21	5.46	11.27	
1000	6.66	7.62	5.56		7.00	5.24	11.24	
1200	6.24	7.44	4.96		7.76	4.69	9.65	
1400	4.80	6.86	3.82		6.64	5.12	10.54	
1600	3.85	5.36	3.70		4.46	6.64	9.67	
Mean	5.23	7.76	4.83		5.91	5.39	11.16	
$CD_{0.05}$	0.22	0.31	0.12		0.77	0.11	0.17	

Pollination efficiency index

A cerana	*T iridipennis*
6	6

*Relative abundance = Number of foragers/5 min/m^2, Foraging rate = Number of flowers visited/5 min, Foraging speed = Time spent (sec)/flower

Table 2. Impact of different modes of pollination on fruit quality and production in chilli, *Capsicum annuum*

Treatment	Fruit length (cm)	Fruit weight (g)	Fruit set (%)	Healthy fruits (%)	Crooked fruits (%)	Number of seeds/fruit	1000-seed weight (g)	Moisture (%)
A cerana pollination	7.08	2.14	67.66	84.32	15.68	16.24	5.02	84.60
T iridipennis pollination	7.32	2.66	65.90	85.90	14.10	18.00	5.16	84.46
Open pollination	8.72	2.84	70.40	76.82	23.18	28.16	5.44	87.14
Pollinator exclusion (Control)	7.16	1.84	61.35	79.60	20.40	17.44	3.21	84.20
$CD_{0.05}$	0.16	0.27	2.01	2.14	2.44	3.67	0.67	0.21

Meliponula beecheii for pollination of habanero pepper in enclosures showed that it was efficient at pollinating this crop. dos Santos et al (2009) studied the pollination efficiency of the stingless bee, *Melipona quadrifasciata* and the honeybee, *A mellifera* in tomato plots in Brazil. They revealed that the highest number of fruits, the heaviest and largest tomatoes and the ones with the higher number of seeds were collected from the greenhouses provided with stingless bees. The stingless bee *M quadrifasciata*, was found to be more ef-ficient remarkably than honeybees in pollinating greenhouse tomatoes. In Mexico, the stingless bee *Nannotrigona perilampoides* species has been reported to be a beneficial alternative pollinator to *Bombus impatiens* in the pollination of habanero pepper (*Capsicum chinense* Jacquin) because no significant differences in the quality of fruit produced was recorded in the greenhouse under tropical climates (Palma et al 2008).

In Australia, pollination of green pepper by *Trigona carbonaria* increased fruit weight by 11 per cent and the number of seeds per fruit by 34 per cent compared to the crops that were self-pollinated (Occhiuzzi 2000). In Brazil, de Oliveira Cruz et al (2005) suggested that *Melipona subnitida* can be considered as an efficient pollinator of sweet pepper and seed growers could use *M subnitida* to increase seed production of sweet pepper variety. In Brazil, pollination by *M fasciculata* increased both the yield and quality (weight) of the harvested fruits, thereby, showing *M fasciculata* as an efficient pollinator of eggplants which also suggested that they may be a feasible alternative to bumble bees in Brazil (Nunes-Silva et al 2013). It was proven that bee pollination notably increased fruit weight by 96 per cent as compared to the control group and also by 34 per cent as compared to the autogamy treatment which was evaluated by Nunes-Silva et al (2013).

CONCLUSION

The chilli crop, when pollinated by bees, increases the crop production and quality as compared to crop where pollination is not accomplished. For supplementing the pollination deficit in chilli, stingless bees, honeybees, *A dorsata*, *A florea* and other wild bees like halictid bees, syrphid bees and *Amegiella* bees need to be conserved.

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