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Role of native buzz pollinator bees in enhancing fruit and seed set in tomatoes under open field conditions

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Abstract
Tomato, *Solanum lycopersicon* flowers with poricidal anthers needs sonicating bees for release of pollen from the anthers for effective pollination. In this study, we investigated the potential of two buzz pollinating native bee species viz., blue banded bee, *Amegilla zonata* (Anthophorinae: Apidae) and sweat bee, *Hoplonomia westwoodi* (Nominae: Halictidae) over the fruit and seed setting in tomatoes under field conditions. *A. zonata* pollinated flowers recorded significantly the highest fruit weight and number of seeds compared to the flowers pollinated by sweat bee, *H. westwoodi* and wind pollination. The numbers of fruits set were found to be higher in the flowers pollinated by buzz pollinating bees, *A. zonata* and *H. westwoodi*. The numbers of aborted fruits were found to be more in the wind assisted self pollinated fruits. The results of the study established that blue banded bee, *A. zonata* could be viable buzz pollinating bee for the pollination of tomatoes.

Keywords: *Amegilla zonata,* fruit set, fruit weight, *Hoplonomia westwoodi,* tomato, seeds

1. Introduction
Tomato (*Solanum lycopersicum* L.) flowers possess distinct floral morphology with poricidal anthers in which the anthers are trapped inside a tube and the distal end of the tube dilates to form a minute opening [2, 10]. This tubular opening needs a vibratory motion made by the wings of the bees referred as sonication to release the pollen [3]. This mechanism referred as buzz pollination is a behavior of wild native bees like *Amegilla zonata* L. (Anthophorinae: Apidae) and *Hoplonomia westwoodi* (Nominae: Halictidae) [10, 12] and bumble bees (*Bombus* sp). Honeybees seldom visit tomato flowers as they do not get neither nectar nor pollen reward because of their inability for buzz pollination. Green house tomatoes were hand pollinated that resulted in increased manual labor costs accounting to cost of US$12,000/ha/yr thereby increasing the cost of production [5. 6].
For the effective pollination of green house tomatoes, bumble bee colonies are being commercially used in many countries [16]. In addition to bumble bees, supplementary pollination of greenhouse tomatoes manually using vibrating 'electric tool' was being practiced which is again a labor intensive measure [4, 7, 15]. There is a vital need to explore the potentiality of native bee fauna in the pollination and fruit set of tomatoes. Tomato flowers in the experimental field at ICAR-National Bureau of Agricultural Insect Resources (NBAIR) Yelahanka Campus Bengaluru were visited by a number of native bees such as *Amegilla* sp, *Hoplonomia* sp, *Nomia* sp. which are known to be buzz pollinators. The frequency of the visits made by the native bees and number of flowers visited is relatively higher under open field conditions. The blue banded bees were observed to make multiple visits to the same flower. Solitary bee, *Amegilla holmesi* as an ideal candidate pollinator for greenhouse tomatoes as evident by increased fruit set, individual fruit weight, and diameter compared with the control treatment was reported [1]. Native blue banded bees plays a vital role in the pollination of tomatoes in open field conditions resulting in better fruit and seed production. Keeping the important role of several species of native buzz pollinating bees in tomato pollination, the present study was undertaken to investigate the effect of blue banded bee, *A. zonata*, Sweat bee, *H. westwoodi* over the fruit set, fruit weight and seeds set of tomato under field conditions.

2. Materials and Methods

2.1 Experimental site

The study was carried out in the experimental farm of ICAR-National Bureau of Agricultural Insect Resources (NBAIR) Bangalore Yelahanka Campus (13.096792N, 77.565976E). The seedlings of the cultivar-Abhinav (Syngenta India) were transplanted in raised beds during March 2017 in an area of 0.2ha with plant to plant spacing of 60cm and inter-row spacing of 90cm. All the necessary cultural practices were undertaken as per the standard package of practices developed for the area. The pollinator exclusion studies were initiated soon after the first appearance of the flowers.

2.2 Pollination treatments

Three pollination treatments viz., no supplemental pollination, pollination by blue banded bees, *A. zonata* and pollination by halictid bee *H. westwoodi* were applied to randomly selected thirty tomato plants (n=30) in the field.

2.3 No supplemental pollination

To ensure no supplemental pollination, the flowers were covered using tiny muslin cloth well before the opening of the flowers. The cloth was removed as soon the fruit set was observed in the bagged flowers.

2.4 Pollination by blue banded bee, *A. zonata*

Thirty tomato plants were prior marked and fully mature flower buds were closed during the previous day evening hours. During the morning hours of the experiment (8.00 am), two freshly opened flowers of each plant were selected as the target flowers. The target flowers were monitored for the visitation by the blue banded bee, *A. zonata*. After permitting the visitation by the blue banded bee, the visited flowers were loosely closed using a butter paper cover around their pedicel to exclude other pollinators from the visiting the marked flowers. The presences of bruises on the anther cone were considered as the successful flower visit made by *A. zonata* apart from visual sighting of the bees visiting the target flowers. The flower buds were tagged well before the stem so as to prevent any obstruction in the bee visitation. The butter paper covers wrapped around the flowers were removed after the dehiscence of the flowers and setting of the fruit. The tomatoes in all the treatments were harvested at the same time based on the visual assessment of fruit color. The fruits were considered to be ripened when they attain uniform red color. Ripening date was considered from the time interval between the fruit set and final harvest. When the tomatoes at the same stage of ripeness, the fruits were harvested and brought to the laboratory for further observations.

2.5 Pollination by sweat bee, *H. westwoodi*

The same procedure of the pollinator exclusion studies as mentioned for *A. zonata* was done but the target flowers were allowed for the visitation and pollination by the sweat bee, *H. westwoodi*.

2.6 Observations recorded

The effect of pollination treatments was measured by calculating the number of fruits formed, fruit size, fruit weight, days taken for ripening and number of seeds set per fruit. The numbers of seeds per fruit were recorded by extracting and separating the seeds from the flesh. The fruit weight was recorded by measuring ripened fruits in electronic weighing balance. The days taken from the initiation of fruit set to ripening of fruit was considered as the days taken for fruit ripening.

2.7 Data analysis

The means were compared and analyzed by analysis of variance (ANOVA) and treatment means were compared using Tukey's significance test at 0.5% level of significance.

3. Results and Discussion

Data analysis of the results showed significant difference (Table 1) between the three pollination treatments with respect to fruit weight (F value = 59.64; P<0.0001), fruit diameter (F value = 34.59; P<0.0001) and number of seeds per fruit (F value = 61.39; P<0.0001). There was no significant difference between the pollination treatments with respect to time taken for ripening of tomatoes. The fruit weight was significantly the highest in the flowers pollinated by blue banded bee, *A. zonata* (63.79g) followed by *H. westwoodi* (46.96g) and the least weight recorded in the flowers that received no supplemental pollination (25.11g). Fruit diameter was found to be the highest in the flowers pollinated by *A. zonata* (57.04 mm) and the lowest in the flowers that did not received any supplemental pollination (25.50 mm). Irrespective of the pollination treatments, the ripening time ranged between 29-37 days. The number of seed set per fruit was found to be the highest in the flowers pollinated by *A. zonata* (177.12 seeds) followed by *H. westwoodi* (140.50 seeds) and the least number of seeds set in no supplemental pollination treatment (56.63 seeds). The number of formed fruits per plant was relatively higher in the flowers pollinated by blue banded bee, *A. zonata* followed by those flowers pollinated by sweat bee *H. westwoodi*. The numbers of aborted flowers were found to be more in the wind assisted self pollinated flowers (Fig 1).

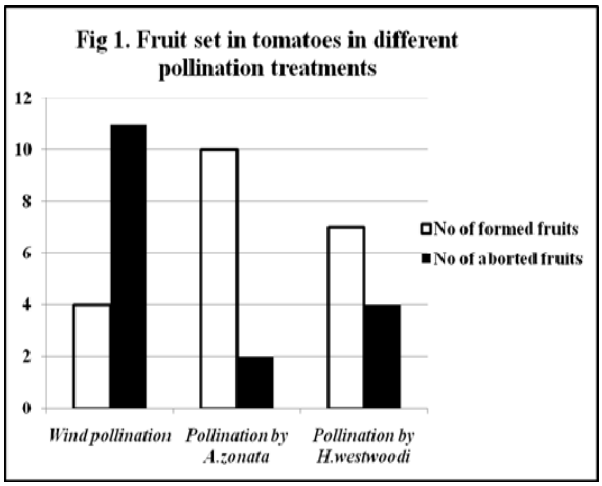
The results of the present study indicated the indispensable role of blue banded bee, *A. zonata* in increasing the fruit and seed quality parameters of field grown tomatoes. Since tomato flowers were found to have poricidal anthers, the blue banded bee, *A. zonata* and halictid bee *H. westwoodi* were found to utilize their body vibration to dislodge the pollen from the intact anthers which is typically referred as buzz pollination. The pollen grains were found attached over the bee's thorax and legs. Native buzz pollinating bee, *Exomalopsis analis* visited tomato flowers recorded on an average of 183.94 seeds per fruit compared to bagged flowers (59.63 seeds per fruit) [13]. The tomato flowers that received multiple buzzes by blue banded bee, *A. chlorocyanea* increased the fruit weight by 21% compared to wind pollination [8]. The number of seeds set in *A. chlorocyanea* pollinated fruits was significantly more compared to the fruits pollinated by wind because of improved pollination caused by the buzz pollinating bee, *A. chlorocyanea.* The results of the present study suggested that the flowers pollinated by the buzz pollinating bee *A. zonata* set more fruits with relatively lesser number of aborted fruits. In case of wind pollinated flowers, the aborted flowers were found to relatively more. This is a clear indication that mechanical movement caused by the wind is not sufficient enough to release pollen for setting fruits in tomato under open field conditions. Therefore the role of native buzz pollinating bees becomes indispensable for the successful release of pollen and fruit set in tomatoes. The role of several species of native solitary bees in increasing the fruit set of tomatoes under open field conditions was reported [14].

The number of seeds formed is an important factor for deciding the efficiency of the pollination treatment in tomato. The flowers pollinated by the buzz pollinating bee, *A. zonata* were found to set more number of seeds unlike the flowers

that received no supplemental pollination. The results were in conformity with the observations made by [11] who reported that tomato flowers visited by a buzz pollinating bee, *Exomalopsis analis* were found to set more seeds per fruit. Pollination of tomatoes under green house conditions is a challenging task wherein the abiotic factors like wind has no role in pollination. Bees belonging to the genera *Hoplonomia* (Family Halictidae) and *Amegilla* (Family Apidae) were observed to buzz the flowers with poricidal anthers in Sri Lanka [9]. The fruit set, seed set, and seed germinability of *Solanum violaceum* in flowers visited by different species of buzzing bees (*Hoplonomia westwoodi, Amegilla comberi and Patellapis kaluterae*) were significantly higher than those of the flowers bagged to exclude pollinators [17]. The potential utilization of solitary bees for effective crop pollination is an unexplored area of research with the current scenario of decline in pollinator decline for sustainable crop production. Pollination by native bees is of vital importance for increasing agricultural production as they occur abundantly in natural and diverse habitats. The utilization of honeybees for pollination of tomatoes is irrelevant as the flower morphology needs buzz pollinating bees for effective pollination and fruit set. Under such conditions, for the successful pollination and fruit set of tomatoes under greenhouse conditions, rather than relying upon the exotic introductions, native blue banded bees could be utilized for successful pollination of tomatoes.

Table 1: Influence of three pollination treatments over the fruit parameters of tomatoes

Pollination treatments	Fresh fruit weight (g)	Fruit diameter (mm)	Number of seeds per fruit
Pollination by blue banded bee, *Amegilla zonata*	63.79a	57.04a	177.12a
Pollination by sweat bee, *Hoplonomia westwoodi*	46.96b	43.04b	140.50b
No supplemental pollination	25.11c	25.50c	56.63c
Tukey's HSD (0.05%)	59.64	34.59	61.39
P value	P<0.0001	P<0.0001	P<0.0001



4. Conclusion

The results of the study concluded the vital role of native buzz pollinating blue banded bee, *A. zonata* in the successful pollination and fruit set of tomatoes under open field conditions. The domestication and artificial rearing of blue banded bee, *A. zonata* using soil nests need to be explored and standardized for effectively utilizing these bees for pollination of tomatoes.

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