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Efficiency of Local Indonesia Honey Bees (*Apis cerana* L.) and Stingless Bee (*Trigona iridipennis*) on Tomato (*Lycopersicon esculentum* Mill.) Pollination

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Abstract: Tomato (*Lycopersicon esculentum* Mill.) is considered as one of major agricultural commodity of Indonesia farming. However, monthly production is unstable due to lack of pollination services. Common pollinator agent of tomatoes is bumblebees which is unsuitable for tropical climate of Indonesia and the possibility of alteration of local wild plant interaction with their pollinator. Indonesia is rich with wild bees and some of the species already domesticated for years with prospect as pollinating agent for tomatoes. This research aimed to assess the efficiency of local honey bee (*Apis cerana* L.) and stingless bee (*Trigona iridipennis*), as pollinator of tomato. During this research, total visitation rate and total numbers of pollinated flowers by honey bee and stingless bee were compared between them with bagged flowers as control. Total fruit production, average weight and size also measured in order to correlated pollination efficiency with quantity and quality of fruit produced. Result of this research showed that *A. cerana* has slightly higher rate of visitation ($p>0.05$) and significantly shorter handling time ($p<0.05$) than *T. iridipennis* due to their larger colony demand and low reward provide by tomato flowers. However, honey bee pollinated tomato flowers more efficient pollinator than stingless bee (80.3 and 70.2% efficiency, respectively; $p<0.05$) even though the average weight and size of tomatoes were similar ($p>0.05$). Based on the results, it is concluded that the use of *Apis cerana* and *Trigona* spp., for pollinating tomatoes in tropical climates could be an alternative to the use of non-native *Apis mellifera* and bumblebees (*Bombus* spp.). However, more researches are needed to evaluate the cost/benefit on large-scale farming and greenhouse pollination using both bees against other bee species and pollination methods.

Key words: Honey bees, pollination, stingless bees, tomatoes

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is considered as one of major agricultural commodity of local farming in Indonesia. Tomato flowers are self-compatible and wind pollinated when planted in open field (Free, 1993) which is common in Indonesia. However, in order to produce best fruit they need a mechanical agent to vibrate the anthers and release the pollen (Banda and Paxton, 1991). On the other hand, this agent also allow farm to synchronize their production to gain more profit. In temperate areas, European honey bee (*Apis mellifera* L.) and bumble bees (*Bombus* spp.) have been widely used for tomato pollination. However, in tropic the usefulness of European honey bee and bumble bee colonies is limited because differences in climate and if colonies are not properly handled, the bees can invade natural habitats that may compete and displacing local bees in process (Hingston and McQuillan, 1999; Delaplane and Mayer, 2000).

Naturally, wild insects around agriculture area would provide pollination services for crops (Ricketts, 2004; Tscharntke *et al*., 2005; Greenleaf and Kremen, 2006; Klein *et al*., 2007; Kremen and Chaplin-Kramer, 2007; Winfree *et al*., 2008). However, changes in natural landscape, the use of synthetic pesticide, lost of food plants, invasive species etc. caused rapid declines of wild insect pollinator (Buchmann and Nabhan, 1996; Kearns *et al*., 1998; Biesmeijer *et al*., 2006; Klein *et al*., 2008). This situation led to decreasing agriculture yield due lack of pollination (Kevan and Philips, 2001). In order to overcome this problem, honey bees usually apply as pollinator agent.

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In Indonesia, there are numerous wild bees and some studies have shown their importance as pollinator for some Indonesian major perennial crops (Notodimejo, 1995; Klein *et al.*, 2003a, b; Olschewski *et al.*, 2006). Furthermore, many small local communities have tradition of managing and cultivating wild bees for their products (honey, wax and propolis) that has been passed down for generations. Among domesticated wild bee species of Indonesia, honey bee (*Apis cerana* L.) and stingless bee (*Trigona* sp.) are the most common species manage in artificial lodging. Thus, colonies are readily available for transporting and establishment elsewhere. These properties made them as potential pollinator agent. Unfortunately, their use as possible pollinator agent for crops mostly neglected. As economic value of honey is stagnant, most bee farmers hardly maintain their bee colonies in good condition. This research will help local bee farmers to increase their income through possibility of using their bee colonies as pollinator agents. On long run will encourage responsible use of synthetic pesticide which toxic to these bees. The objective of this study is to evaluate of colonies of the native honey bees (*A. cerana* L.) and stingless bees (*Trigona iridipennis*) as pollinator agent for tomato (*L. esculentum* Mill.).

MATERIALS AND METHODS

Study area: The pollination experiment was conducted at local farm in North Bandung, West Java, Indonesia from March to August 2011. Average daily temperature of study site was 18-25°C with humidity 60-75%.

Tomatoes: Each plant was planted on medium with 40% soil, 30% sand and 30% compost. Plants selected for this research were free of pest with average height of 50 cm. During this study, 30 tomato plants arranged in 3 rows of 10 plants each, with wide aisle (about 2 meters) between the rows.

Bees: Three colonies (~1500 bees colony^{-1}) of *T. iridipennis* and three colonies of *A. cerana* (~10,000 bees) were introduced into farm. All colonies originated from wild colonies found at area surrounding farm, kept in bee hive made from wood and acclimatize for 3 months prior to study.

Bee visitation frequency: Frequency of bee visitation was observed during flowering period based on method developed by Klein *et al.* (2003a). Observation conducted only at sunny day between 0700 and 1600 (local time). Observation conducted 5 min h^{-1} for three consecutive days at different plant. Total number of flowers observed was 100 and total visitation frequency calculated by polled all data obtained from three days observation.

In simultaneous time, another observer recorded amount of time spent by individual bees in one flower and defined as handling time.

Bee pollination efficiency: For this experiments, 10 flowers, that still not bloomed, in each of 10 plants per treatment were randomly selected and tagged. Each group of flower was bagged with mesh nylon bag (diameter 1 mm). Glue were applied at the twig were flowers located to prevent ants from entering flower. Bags were removed when flowers started to bloom. Observation for bee pollination efficiency started from removal of the bag until bee transferred pollen to female flower by bee. After pollination process, flowers were bagged until fruit was produced. This group of treatments stated as Honey Bee (HB) and Stingless Bee (SB) group. As for Non-Pollinated (NP) treatment, bags were not removed when the flowers started to bloom. Each treatment group was separated 2 m in order to prevent possible visitation by unexpected pollinator agent.

Pollination efficiency were measured by:

$$\text{Pollination efficiency} = \frac{\text{Total No. of flowers that produce fruits}}{\text{Total No. of observed flowers}}$$

Fruit production, weight and size produced by each treatment were measured for every type of pollination. Fruit production measured by subtracted total numbers of broken fruit from total fruit produced. Total fruit produced in each treatment was weighed to calculate the average weight and production in kilograms per plant. Diameter of fruit was measured by digital caliper to nearest milimeter.

Data analysis: Data analyzed by statistic program Statistica 8.0 (Statsoft Corp.). Prior to analysis, normality of data was tested. Difference of bee visitation frequency between honey bees and sweet bees was analyzed by t-test analysis. Pollination efficiency of each treatment was estimated by ANOVA. Average weight, total kilograms and average size of fruit produced per treatment were compared using ANOVA and LSD as *post-hoc* test. Significant value for both tests were $p<0.05$.

RESULTS

Foraging activity of bee: Pollen foraging by HB started earlier than SB at ~18°C and increased until around 30°C and above which it started decreasing. After 1300 h

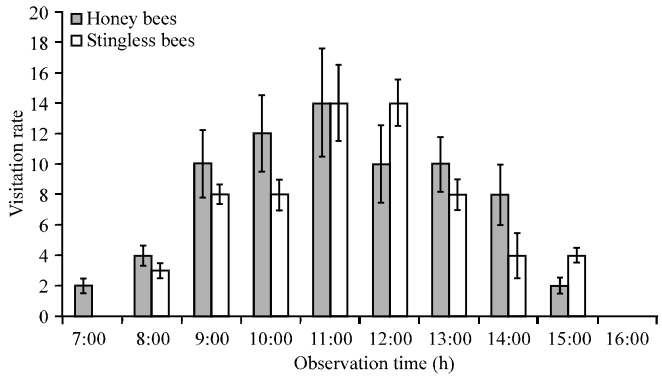

Fig. 1: Foraging activity of honey bees and stingless bees for 5 min h^{-1} across experiment

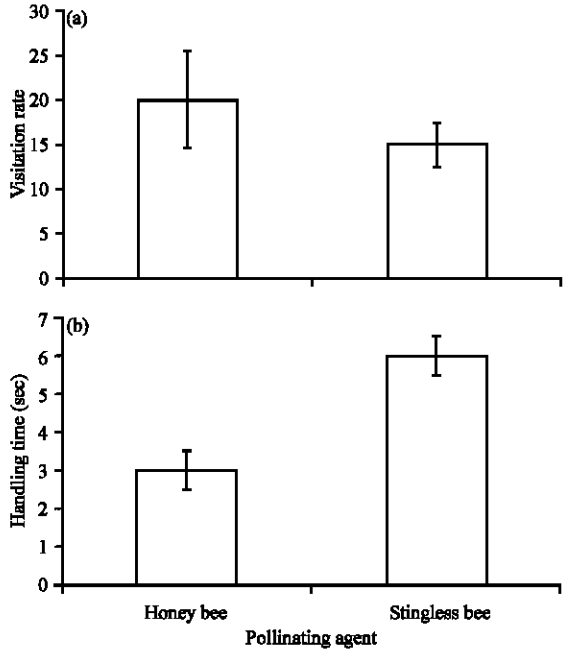

Fig. 2(a-b): Average visitation rate per flower and handling time of honey bee and stingless across the experiment

activity started decreasing until 1500 h. On the other hand, SB activities started later at 800 h and reached peak period around 1100 h and 1200 then started decreasing (Fig. 1). All flower visited by bees showed necrotic marks on the anthers as indication of pollen removal.

Even though there is differences in pattern of foraging activity, visitation rates of honey bees was similar to stingless bee (7.2±1.8 and 6.3±1.15, respectively, $p>0.05$). However, compare with honey bees, stingless bees more likely to visit and spend more time in tomato flowers (t-test analysis, $p<0.05$) (Fig. 2).

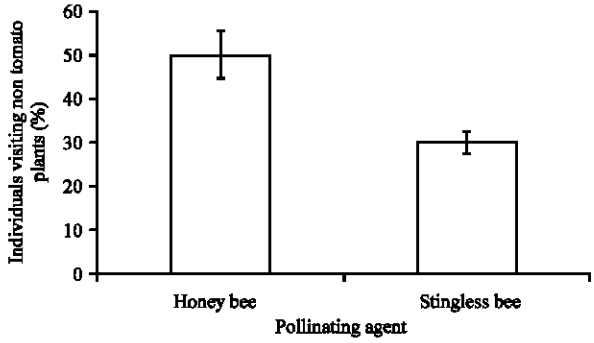

Fig. 3: Percentage of individuals visiting non tomato plants

Table 1: Pollination efficiency (%), average fruit production, weight and diameter produced by insect and wind pollination (N = 50)

Group	Honey bee (HB)	Stingless bee (SB)	Not pollinated (NP)
Pollination efficiency (%)	80.3±2.3*	70.2±5.4*	60.3±4.4*
Total fruit production $plant^{-1}$	52.05±5.5	51.58±6.2	48.06±7.4*
Average fruit weight (g)	30.05±2.50	27.44±8.23	26.40±6.23
Average fruit size (diameter in mm)	32.56±4.18	30.19±4.16	27.19±3.16

*Significant at $p<0.05$

During this experiment, 50% of forager of honey bee colony preferred to visit flower of wild plant other than tomato flowers while only 30% of stingless bee did that (t-test analysis, $p<0.05$) (Fig. 3).

Pollination efficiency of local honey bees and stingless bees on tomatoes: A summary of the pollination efficiency of HB, SB and NP is presented in Table 1. The general trend showed that HB and SB gave better results than NP. The pollination efficiency was significantly different in among all treatment with HB gave best result (t-test analysis, $p<0.05$). The average weight of individual fruit was similar for the three treatments (26-30 g) (ANOVA; $p>0.05$). However, the production per plant was higher for HB and SB compared with NP (ANOVA; $p>0.05$). On the other hand, size of fruit was similar for all treatment (27-32 mm in diameter) (ANOVA; $p>0.05$).

DISCUSSION

The results of our experiments showed that *A. cerana* and *T. iridipennis* colonies can potentially applied as pollinator agents of tomato to improve quantity and quality of production. Furthermore, since bee farming is common practice and colonies of these bees are readily available in low price, the use of them as pollination agents more affordable for low income farmers whom common in Indonesia. However, further studies are needed especially on the comparison with pollination by bumblebees and mechanical vibration by human labor that considered as the best way to produce high quality tomatoes.

There are other factors that need considering in application of these bees. For instance, both bees preferred to visit wild plants than crops plants (personal observation) which may be a factor that explain low visitation rates to tomato flowers. This result showed the limitation of application of both bees as pollinator for tomato planted in open farming system. It is probably because tomato flowers need to be vibrate to release pollen and do not produce nectar. Lack of reward and high energy cost to obtain it may reduce foraging activity of social bees, especially honey bees, because it held no benefit for colony.

During this study, *T. eridipennis* visited less numbers of wild plants flowers than honey bees. High floral constancy, in which forager visits only one plant species on a single trip, is typical behavior of many polyphagous bee (Eickwort and Ginsberg, 1980) and stingless bee (Sommeijer *et al.*, 1983; Inoue *et al.*, 1985; Ramalho *et al.*, 1994; Cauich *et al.*, 2004). This behavior may beneficial for application of this species as high floral constancy could ensure pollination of crop even in area with various resources. However, further research is needed to investigate factors that influence this behavior. Result on pollination efficiency confirms other results reported from many regions in the world (Cauich *et al.*, 2004; Dos Santos *et al.*, 2009; Hikawa and Miyanaga, 2009; Al-Abbadi, 2010) that bees pollinated flowers will produced more, heavier and bigger tomato. Compare with those results, it is suggest that *A. cerana* and *Trigona* spp. less efficient as pollinator for tomato. However, it is almost impossible to compare directly given the different varieties of tomato as well as fertilizers and other condition used in all experiments.

This study showed that the differences on pollination ability between *A. cerana* and *T. iridipennis* only on the pollination efficiency. This could be caused by smaller foraging distance of stingless bee (Slaa *et al.*, 2000), smaller number of foragers and low pollen transfer by *T. iridipennis*.

However, lesser pollination efficiency of *T. iridipennis* may be counterbalanced beside by high floral constancy but also by their high floral handling time that highly correlated with better pollen transfer (Ivey *et al.*, 2003). While their reduced size, less aggressive behavior (Heard, 1999), make them more useful pollinators when applied in small agriculture system with limited area and the objective is to maintain genetic identities or varieties (Raw, 2000). On the other hand, honey bee would be more suitable for increase production in much larger area while production volume is the main concern.

CONCLUSION

Based on our result, it is suggested that Asian honey bee (*A. cerana*) and stingless bee (*T. iridipennis* could be used as an alternative for pollinating tomato. Each of species has their advantage that make them should apply in different type of tomato farming found in Indonesia.

Honey bees more suitable to be used in open farming system with ample supply of different floral resources either from different crop types or wild plants. Their high numbers of forager will provide good pollination services in large area even though their absconding and aggressive behavior could forbid them for greenhouse use.

Compared with local honey bee, stingless bee has lower pollination efficiency. This disadvantage is counter balanced with their characteristics that enhance their importance as managed pollinators for tomato, such as floral constancy, harmlessness and easy to handling made them suitable for greenhouse application where the use of common honey bees restricted due to safety reason. Stingless bee also showed greater diet breath, great adaptation to changes in climate condition and small foraging area that suit with common Indonesia small farming system that isolated from natural forest with small patches of wild flowers. However, further study on the biology of local *Trigona* species is needed prior to their application as pollination agent in greenhouse. On the other hand, economic valuation also needed for both bees in order to improve their acceptance as pollinator agent by farmers.

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