Impact of Wild Bees (*Apis cerana*) and Stingless Bees (*Tetragonula laeviceps*) to Some Crops of Small-Scale Farm in West Java

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Abstract. One of the essential ecosystem services which profoundly affect the human population is pollination. Studies in subtropical countries which applies modern and expansive agricultural systems showed the significant impact of pollinator agent. However, the study on pollination service impact on the productivity of farms in Indonesia is quite rare. This research was conducted to determine pollination efficiency both open pollination by wild bees (*Apis cerana*) and stingless bees (*Tetragonula laeviceps*) to the quality and quantity of green beans, cucumbers, and tomatoes in a monocropping system of a local small-scale farm. This research was conducted from January to April 2018 in Sukawangi Village, Pamulihan, Sumedang, West Java. The observation was started at 08.00-16.00 every five minutes during the flowering period. In these experiments, ten flowers that still not bloomed, in each of 10 plants per treatment were randomly selected. The effects of the pollinator were assessed by the visitation pattern of visits and plant reproductive success. This study showed that each of the pollination treatments did not affect the weight and the average length of all tested fruits. However, the application of stingless bees as pollinator revealed a significant difference in the average diameter (p=0.013) and fruit shape of the cucumbers.

1. Introduction

Agriculture is one of the main economic activities in Indonesia. As a developing country, most of the agriculture systems in Indonesia highly depend on the ecological services of an agroecosystem. Fully working ecological services, highly depend on the organic agents to provide the services, such as insects. Insects have been considered as one of the essential variables on agriculture system as they act as agents of ecosystem service, namely pest control, nutrition cycle, and pollination [1, 2, 3,4]. Among those services, pollination is considered as the service that directly responsible for the sustainable yield of agriculture [5]. It has been estimated that 70% of plants cultivated around the world depend on pollination [6] with an economic value of about 153-285 billion Euros annually [5, 7]. About 50 years, there have been growing concerns about the declining of pollinator diversity and abundance [8, 9, 10, 11, 12] due to the simplification of agriculture landscapes and intensification [2, 3,13]. Loss of wild pollinators could produce a negative economic impact on pollinator-dependent crops [14, 15] even may lead to a deficiency of supply of essential minerals and vitamins for human diets from pollinator-mediated crops [16]. Decline pollination service also could create a detrimental cascade effect on the
food web [17], which furtherly negatively impact whole ecosystem services on agroecosystem along with with human food supply and well-being [15].

This condition leads to the application of domesticated bees as pollinator agents of the agriculture system. Honey bees are the most common species that apply as pollination agents in many countries. However, there is a lack of application of honey bees in Indonesia as application mostly due to problems with diseases, absconding behavior, a requirement of constant food supply, and lack of farmers' knowledge on the impact of pollination for crop production. Moreover, most of farm in Indonesia has a small size and usually planted with perennial crops through intercropping. Although the primary purpose of intercropping in the local farm of Indonesia is more on economic benefit, a study showed several benefits of intercropping to ecosystem services of agroecosystems such as reducing the requirement for fertilizer [18] and risk of infestation by pests [19] and diseases [20]. Studies also showed that the availability of flowering plant strips in agriculture area improves the diversity and abundance of pollinators [21, 22].

In this study, we observed the pollination services at local small intercropping agriculture of West Java to have a better understanding of pollination system of the typical agriculture system of West Java. We also applied local stingless bees (Tetragonula laeviceps) as domesticated bees as pollinator agents in order to understand the possible future application simple greenhouse for crop production in the small village.

2. Methods

2.1. Study area

The study was conducted from January to April 2018 at Desa Sukawangi, Kecamatan Pamulihan, Kabupaten Sumedang, Jawa Barat. Research is located at 968 m above sea level with average temperature 18-26°C, relative humidity 67-92%, wind speed 7-11 km/h, and light intensity 2690-12060 Lux.

![Figure 1. Planting arrangement](image)

2.2. Crops

In this study, we conduct observation on the pollination system on intercropping of common green bean (Phaseolus vulgaris) (Logawa cultivar), tomato (Solanum lycopersicum) (Permata cultivar), and cucumber (Cucumis sativus) (Bella cultivar). Each plant was planted on the field with additional synthetic fertilizer mixed with manure (50:50).
2.3. Stingless Bees

In this study, three colonies of local stingless bees (T. laeviceps) (± 500 bees) were introduced as pollinator agents. All colonies originated from the north part of West Java and acclimatized to an area near the study field about three months prior to the study.

2.4. Pollination Study

Crops of the control group were planted in the field, while crops of application group were kept inside the greenhouse according to arrangement showed in figure 1. All plants were cultivated by standard procedure commonly applies at the farm.

2.4.1. Bee visitation frequency

The observation conducted only on sunny days between 0800 and 1600 (local time). Pollinator visitation frequency was observed on ten flowers from 10 plants randomly selected. It was conducted with an interval of 5 minutes per hour for three consecutive days at different plants. The total number of flowers observed was 600 flowers, and total visitation frequency calculated by polled all data obtained from three days of observation.

2.4.2. Foraging rate and flower handling time

Assumption of the ability of an insect as a pollinator is usually stated as foraging rate and flower handling time. Foraging rate is a total number of flowers visited by pollinator for one minute while flower handling time is time spent by an insect at one flower.

2.4.3. Pollination success

Ten flowers, that still not bloomed, in each plant were randomly selected and tagged. The flowers were bagged with mesh nylon bag (diameter 1 mm), and the bag was glued to a twig to prevent ants from entering the flower. The bags were removed when flowers started to bloom. Observation for pollination efficiency started from the bag removal up to pollen transferred by a bee to the female flower by any pollinator (open) or Tetragonula laeviceps (Tetragonula).

Pollination efficiency was measured by:

\[
\text{Pollination efficiency} = \frac{\text{Total numbers of flowers that produce fruits}}{\text{Total numbers of observed flowers}}
\]

Fruit weight, diameter, and length produced were measured for every type of pollination. Fruit weight was measured to the nearest gram, and their diameter and length size were measured to nearest centimeter.

2.4.4. Data Analysis

Prior to analysis, all data were tested for normality by Kolmogorov-Smirnov. The differences in normally distributed data were analyzed by the T-test, while the Mann-Whitney test was applied for nonnormal distributed data. All analysis was conducted by SPSS 22.0

3. Results

3.1. Pollinator visit pattern

In this study, we only found Asiatic honey bees (Apis cerana) visited the flowers of cucumber and green bean while T. laeviceps only visited green bean flowers. On the other hand, none of the pollinators visited tomato flowers (Fig. 2).
In general, *A. cerana* showed longer flower handling time and a higher foraging rate than *T. laeviceps*, although the differences were not significant for each crop (Table 1).

**Figure 2.** Visitation pattern of pollinator at monoculture system
Table 1. Flower handling time and foraging rate

| Crop      | Pollinator      | N  | Flower Handling Time (flower/second) | Foraging Rate (flower/second) |
|-----------|----------------|----|-------------------------------------|------------------------------|
| Cucumber  | *Apis cerana*   | 5  | 1.57 ± 2.55a                        | 0.21 ± 0.55a                 |
|           | *Trigona laeviceps* | 0  | 0 ± 0a                              | 0 ± 0a                       |
| Green Bean| *Apis cerana*   | 7  | 2.04 ± 2.59a                        | 0.29 ± 0.33a                 |
|           | *Trigona laeviceps* | 6  | 1.67 ± 3.71a                        | 0.10 ± 0.23a                 |
| Tomato    | *Apis cerana*   | 0  | 0 ± 0a                              | 0 ± 0a                       |
|           | *Trigona laeviceps* | 0  | 0 ± 0a                              | 0 ± 0a                       |

Note: N = number of flower visited

3.2. Pollination success

In general, the pollination success of the open group was higher than *Tetragonula* group (Fig. 3), although there were no significant differences between groups for each crop.

![Figure 3. Visitation pattern of pollinator at monoculture system](image)

In general, the length of cucumber and green bean produced inside the greenhouse supplemented with *T. laeviceps* was higher than fruit produced in the field, while other variables showed the opposite pattern (Table 2). However, the difference in fruit quality of both groups was relatively not significant.

Table 2. Harvest quality of crops with open pollination and *Tetragonula laeviceps* pollination

| Variables     | Pollination      | Crops                                      |
|---------------|------------------|--------------------------------------------|
|               |                  | Cucumber | Green bean | Tomato          |
| Weight (gr)   | Open             | 97.18 ± 20.18a | 7.89 ± 3.31a | 33.48 ± 10.94a |
|               | *Tetragonula laeviceps* | 90.64 ± 21.92a | 6.89 ± 4.01a | 32.48 ± 10.99a |
| Diameter (cm) | Open             | 4.37 ± 0.74a | 1.12 ± 0.59a | 3.77 ± 0.42a    |
|               | *Tetragonula laeviceps* | 3.86 ± 0.39b | 0.94 ± 0.17a | 3.76 ± 0.44a    |
| Length (cm)   | Open             | 13.06 ± 1.39a | 15.53 ± 3.38a | 4.10 ± 0.46a    |
|               | *Tetragonula laeviceps* | 13.38 ± 1.39a | 15.79 ± 3.11a | 4.04 ± 0.44a    |

The different letters showed a significant value based on T-test and Mann-Whitney test at confidence level of 95%.
4. Discussion

4.1. Effect of pollination agent to cucumber

Visitation of *Apis cerana* to cucumber flowers in this study also reported by Thakur and Rana [23], and it significantly improves the fruit yield and quality [24]. A study by Gadihya and Pastagiya [25] showed that *T. laeviceps* visited cucumber flowers. In this study, the stingless bees species applied showed low preference to cucumber flowers even though some studies showed a high preference of stingless bees to these flowers [26, 27].

This study showed higher pollination success of greenhouse that mostly due to a higher number of surviving fruits. Most fruits planted in the field showed diminished quality because of pest attack and environmental factors, while the greenhouse provides protections against both factors [26].

4.2. Effect of pollination agent to green bean

*Apis cerana* and *T. laeviceps* visited the flowers of green bean. Bean itself known as one of the food plants for *A. cerana* [28, 29]. As far as our knowledge, *T. laeviceps* does not visit green bean flowers. The small flower size of the green bean more likely is to attract stingless bees than big flowers of cucumber. High preferences of these bees to small flowers have also been reported on their high visitation on crops with small flowers such as red pepper [30, 31].

We also recorded the differences in the foraging activities of both *A. cerana* and *T. laeviceps*, which also reported by previous studies when both species were available for crop pollination [27, 30, 32]. Honey bees (*A. cerana*) started to visit the flower in the early morning and peaked at a similar period with *T. laeviceps*. Early flower visits by honey bees probably related to the availability of fresh pollen and nectar for colony needs. Early peak then followed by low visitation rate, which probably related to the availability of the other pollen and nectar sources in the field as honey bees colony usually shifting their foraging force among food source to gain more energy for colony [33, 34, 35]. On the other hand, stingless bees more likely to forage at noon due to (1) their tendency to take a long exploratory flight to find economic resources to counter to rapid loss of energy due their small size and (2) the less aggressive behavior of stingless bees produces made their tend to avoid direct competition with much bigger and aggressive honey bees.

Lower flower handling time and foraging rate may influence to reduce the pollination success of green bean flowers pollinated by *T. laeviceps*. Small body size may limit the flying distance and activities [36], while small colony size may reduce the need to harvest more nectar for colony needs.

Although the pollination success was much lower than *A. cerana*, there was no significant difference in the quality of harvested products. This result indicated the high potential of the application of *T. laeviceps* as pollinator agents of green been cultivated inside the greenhouse.

4.3. Effect of pollination agent to tomato

This study showed no insect visitation on tomato flowers. Tomato flowers could be considered as the least economic resources for honey bees and stingless bees, although some studies showed they were visited by *A. cerana* [32, 37] and *T. laeviceps* [25, 32] or other stingless bees species [38]. Although not visited by bees, this plant is able to produced fruits through the vibration of anther by wind, which releases the pollen for self-fertilization [39]. Lack of wind movement inside the greenhouse may explain lower pollination success of tomatoes of *Tetragonula* group.

5. Conclusion

A low diversity of pollinator insects was found at conventional smallholder farms in West Java. The application of monoculture and conventional farming systems may be the cause. Application of local stingless bees, *T. laeviceps*, as additional pollinator only work for green bean flowers which indicated that suitability of stingless bees as pollinator agent depends on the types and characteristic of flowers beside the behavior of the stingless bees. Local stingless bees had the potential to be applied as pollination agents of a closed system as long as the flowers suitable for them.
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