BIODIVERSITAS
Volume 23, Number 5, May 2022
Pages: 2544-2552

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d230535

Economic values of pollination service of open pollination with the help of *Tetragonula laeviceps* (Hymenoptera: Apidae: Meliponini) on tomato and chili

NADZIRUM MUBIN♥, ALLEN OKTA KUSMITA, ATIA ROHMAH, ALI NURMANSYAH
Department of Plant Protection, Faculty of Agriculture, Institut Pertanian Bogor. Jl. Kamper, IPB University Campus Dramaga, Bogor, West Java, Indonesia. Tel.: +62-251-8629364, Fax.: +62-251-8629362, ♥email: mubin.nadzirum@apps.ipb.ac.id

Manuscript received: 4 March 2022. Revision accepted: 25 April 2022

Abstract. *Mubin N, Kusmita AO, Rohmah A, Nurmansyah A. 2022. Economic values of pollination service of open pollination with the help of* Tetragonula laeviceps *(Hymenoptera: Apidae: Meliponini) on Tomato and Chili. Biodiversitas 23: 2544-2552.* Insects have various roles, one of which is as pollinators. Horticultural crops such as tomatoes and chilies need the help of pollinating insects to increase productivity. The stingless bee, *Tetragonula laeviceps*, is one of the potential pollinating agents. This study aimed to determine the effect of pollination by *T. laeviceps* on crop production and estimated pollinating insects' economic value. The study was conducted using a field experiment with 3 pollination treatments including pollination with the help of *T. laeviceps* (open pollination / OP), pollination by wind (WP), and self-pollination (SP). The estimated economic value of pollination was calculated using a bio-economic approach based on the level of dependence of the plant on pollination. The results showed that open pollination (OP) treatment by *T. laeviceps* increased fruit yield and seed set by 2-3 times that of wind pollination and 4-5 times that of self-pollination. The open pollination treatment significantly affected the diameter and weight of tomato fruit compared to the WP and SP treatments but not on chili. Meanwhile, OP can increase the length of chili fruit. OP, WP, and SP treatments had no significant effect on tomatoes and chilies' weight loss, damage level, and hardness level. Based on tomato and chili production, the economic value of *T. laeviceps* was 44 times (tomato) and 20 times (chili) from self-pollination and 65 times (tomato) and 11 times (chili) from wind pollination.

Keywords: Economic value, pollinator of bee, stingless bee

INTRODUCTION

Tomato (*Lycopersicon esculentum*) and chili (*Capsicum annum*) are important horticultural commodities in Indonesia. Production of tomatoes and chili peppers tends to rise and fall every year, this is influenced by several factors, including cultivation techniques, plant health, and pollination (Steward et al. 2014; Reilly et al. 2020). Pollination is one of the important factors forming fruit and plant seeds. In natural pollination, two types of pollination occur i.e. cross-pollination and self-pollination (Ritonga et al. 2018; Zeist et al. 2018). Pollination assisted by honey bees or wild bees can increase crop productivity (Garibaldi et al. 2013; Cooley and Vallejo-Marin 2021). In addition, the lack of pollination can affect the reproductive system of plants, so the resulting offspring become weak due to inbreeding (Reilly et al. 2020). The reduced number of pollinators is caused by monoculture cultivation, parasites and diseases, use of pesticides, unavailability of natural ecosystems around crops, reduced sources of pollinator food, and less strategic nesting conditions (Althaus et al. 2021; Mubin et al. 2022).

One group of bees with high potential as pollinating agents is the stingless bee (*Tetragonula laeviceps*). *T. laeviceps* (Apidae: Meliponini) is a stingless bee that is easy to care for and cultivate. This bee can produce honey and propolis higher than other types of bees. With a small body size, these bees can move more easily in accessing various flowers, so these bees are known as general visitors of flowering plants in the tropics (Witter et al. 2015; Trianto and Purwanto 2020). Based on the research of Putra and Kinasih (2014) that pollination with the help of bees without stingers was able to produce a percentage of successful tomato fruit formation which was 70.2% and produced 51.58 fruits/plant, while without the help of bees it only produced 60.3% successful fruit formation and 48.06 fruit/plant.

Pollination by insects, especially bees, has increased crop yields in various plant species. The positive influence of pollinating insects, especially honey bees, has long been known in pollination events (Rollin and Garibaldi 2019; Layek et al. 2021; Nkoba et al. 2022). The honey bee group is the most important in pollination compared to other pollinating insects (Picanço et al. 2017). Bees have high economic prospects in increasing the quality and quantity of flowering plants. FAO (2018) reported that bees carry out more than 80% of pollination. Furthermore, Putra et al. (2014) said that in chili plants pollinated by *T. laeviceps* there was an increase in fruit set success of 17.64%, an increase in fruit weight by 21.83%, an increase in fruit size by 20.41%, than self-pollinated.

Pollinators provide the economic valuation of pollination (EVP) by increasing the quality and quantity of crop production, it increases economic output which affects its market price. The main crops whose pollination depends on pollinating insects are vegetable and fruit groups, each producing an economic value of IDR 882 trillion (Lautenbach et al. 2012). Alebachew (2018) reports that the economic value of pollination in Ethiopia has a total of 815.2 million US dollars. Another study reported that the economic value of pollinating insects in Australia in 2014-2015 was 28.4 billion Australian dollars (Karasiński 2018). Furthermore, economic contribution of pollinators on Terceira Island is about 32.2% total mean annual agricultural income of the dependent crops (Picanço et al. 2017). Research on the economic value of bee pollination in Indonesia itself has not been widely carried out. Therefore, research on the estimation of the economic value of pollination by insects, especially *T. laeviceps* bees on tomato and chili plants (Solanaceae) needs to be done.

MATERIALS AND METHODS

Place and time research

The research was carried out in Cikarawang Field Trial, IPB University, Bogor and Rahayu Hamlet, Cicadas Village, Ciampea, Bogor, Indonesia from February to June 2020.

Land and plant preparation

Land preparation was done twice before planting tomato and chili seedlings. The first was done to clean weeds and the second was to make beds. The beds' size was 4 m x 1 m with a distance between beds of 0.4 m. Subplots were made of 15 beds. Each bed was covered with black silver plastic mulch and perforated according to the spacing of 0.5 x 0.6 m. Each planting hole was applied with 100 g of manure. Following Maryanto and Rahmi (2015), a dose of 20 tons/ha of manure was equivalent to 100 g per polybag.

The plants used were tomatoes with the New Mutiara F1 variety, while the chili varieties used were TM 999 F1. Tomatoes and chilies are first sown on the tray and then transplanted when the plant has 4 leaves or 40 DAS (days after sowing).

Pollination treatment of tomato and chili

The field experiment was conducted using a randomized block design with 3 pollination treatments repeated 5 times. The three treatments included open pollination (OP), wind pollination (WP), and self-pollination (SP). OP treatment was pollination with the help of *T. laeviceps*, while WP and SP treatment were pollinated by wind and self-pollinated, respectively.

Following Putra et al. (2014), the OP treatment used *T. laeviceps* bees as pollinating agents in the experimental field. The number of bees introduced into each commodity was two colonies. The bee's introduction was carried out when the tomato and chili entered the flowering phase. When the tomato and chili plants began to flower, the flowers in the OP treatment were marked using wire tape (Fig. 1a). Plant flowers with WP treatment were marked and covered with tile before the flowers bloomed (Fig. 1b). Covering with tile is aimed to keep the flowers pollinated by the wind, but insects cannot pollinate the flowers. Flowers of tomato and chili plants with SP treatment that had not yet bloomed were marked and covered with oil paper (Fig. 1c). Covering using oil paper aims to avoid pollination by wind and pollinating insects. Then, the WP and SP treatments lid was removed when the flowers had become fruit.

Research indicators

Yields quantity

The effectiveness of pollination on tomato and chili yields was determined by counting fruit set, seed set, fruit length (cm), fruit diameter (cm), and weight per fruit (g) (Suharsi et al. 2015). This measurement was carried out using 10 fruits for each replicate plot.

A B C

Figure 1. Flower treatment OP (A), WP (B), and SP (C)

Fruit longevity

The fruits harvested in each pollination treatment were tested for resistance or shelf life (Rochayat and Munika 2015). The effect of pollination on shelf life was observed with several indicators, including the level of damage, the level of hardness, and weight loss (Istianingsih 2010; Sulistyaningrum and Darudriyo 2018). Observations of tomatoes were carried out on days 3, 6, 9, 12, and 15 after harvesting, while chili peppers were observed on days 4, 8, 12, 16, and 20. Tests were carried out using 10 replicates so that 30 fruits from the three pollination treatments.

The organoleptic test assessment of damage, hardness, and fruit freshness was performed qualitatively based on scores (Table 1). Andriani et al. (2018) stated that the measurement of the level of fruit damage was measured in the range of 0-20%. If the level of fruit damage was >20%, then the fruit was considered unfit to be a test sample. The criteria for testing the level of damage observed were brown or black spots or streaks on the fruit skin, microorganism attack, dry rot of fruit, and soft fruit due to internal tissue damage.

Based on Andriani et al. (2018), the calculation of fruit weight loss was carried out using the equation:

$$WL\ (\%) = \frac{W_0 - W_n}{W_0} \times 100\%$$

Where, WL was weight loss (%); W_0 initial weight (g); and W_n final weight (g).

Estimated economic value of pollination

The estimated economic value of pollination on tomato and chili was calculated using the economic valuation method. The Economic Value of Pollination (EVP) evaluates economic value by using the value approach of dependence on pollinating insects. The percentage of plant dependence on pollinators can be calculated by the formula (Carr and Davidar 2015)

Dependency (%) = fruit set with the pollinator-fruit set without a pollinator

Fruit set with pollinator was the percentage of fruit-formed with the help of pollinating insects, in this case, the OP treatment. The fruit set without pollinator was obtained from the percentage of the number of fruit-formed without the help of insects, in this case, the WP and SP treatments. The percentage dependence on pollination was used to determine the value of the reliance of plants on pollinating insects. The pollination dependency value criteria were listed in Table 2.

The economic value of the role of pollinating insects (EVP, in IDR) was calculated by the following formula (Alebachew 2018):

EVP = P x Q x D

Where, P represents the commodity price (IDR/kg); Q was the total production (kg); and D was the value of pollination dependence. The tomatoes and chilies used were the average prices from interviews with farmers. In this study, the cost of tomatoes used was IDR 4000/kg while the cost of chili was IDR 20,000/kg. Total production to calculate the economic value of pollination resulted from multiplying the productivity of plants per hectare with the harvested area of tomatoes and chilies in Indonesia in 2019. Based on the Ministry of Agriculture (2020) data, the tomato and chili harvested areas in 2019 were 54,780 ha and 133,436 ha, respectively.

The economic value of pollination of *T. laeviceps* can be calculated using the EVP formula. However, the total production used was based on the net productivity of pollination by *T. laeviceps*. Also did this to estimate the economic value of wind pollination by using the net productivity of wind pollination without any influence from self-pollination.

Farming profits

Calculated profits from both commodities farming from net income. Net income or net profit (NP) was farming income after deducting farm costs using the following formula (Saediman et al. 2015):

NP = TR-TC

Where, TR represents total revenue (gross revenue) and TC represents a total cost. Generated gross income by multiplying total production (Q) with commodity prices (P). Total costs were all costs incurred until sold the product. The total cost for OP treatment in tomatoes was IDR 29,778,000/ha, while the treatment for WP and SP was IDR 26,778,000/ha. Meanwhile, chili's total farm production cost was calculated at IDR 38,412,500/ha for OP treatment and IDR 34,412,500/ha for WP and SP treatment in each growing season. This calculation was based on interviews with smallholder farmers and related literature studies. Total revenue was obtained by multiplying the selling price of chili with the total productivity of the plant.

Table 1. Level score of damage, hardness, and freshness

Score	Damage (%)[a]	Hardness[b]	Freshness[b]
0	0	-	-
1	1-5	Soft	Very withered
2	6-10	Mild	Withered
3	11-15	Hard-enough	Fresh-enough
4	16-20	Hard	Fresh
5	20-25	Very hard	Very Fresh
6	> 25	-	-

Note: [a]Andriani et al. (2018); [b]Widyastuti and Aminudin (2013); [c]Sulistyaningrum and Darudriyo (2018)

Table 2. Dependency value of pollination (Alebachew 2018)

Class[a]	Dependency (%)[a]	Info[a]	Pollination dependency value [b]
0	< 0	n/a	0.00
1	>0-10	Little	0.05
2	>10-40	Ordinary	0.25
3	>40-90	High	0.65
4	> 90	Essential	0.95

Note: [a]Klein et al. (2006) and [b]Gallai et al. (2009)

The calculated farming profits obtained from pollination by *T. laeviceps* based on net productivity. The total income from pollination by *T. laeviceps* was net productivity multiplied by commodity prices. Total income from wind pollination was the product of productivity with commodity prices.

RESULTS AND DISCUSSION

Effectiveness of pollination on tomato and chili production

Pollination is a mechanism that occurs because of the interaction between pollinators and plants that need each other. Insect pollinators such as *T. laeviceps* provide significant results compared to pollination only by wind or self-pollination by the plant itself. Table 3, showed that the OP treatment produced the highest percentage of fruit set compared to the other treatments (WP and SP). The average portion of fruit set produced by the OP treatment was 74.86% (tomato) and 39.73% (chili), while the WP and SP treatments were 22.86% and 15.43% (tomato) and 17.20 and 10.82% (chili) (Table 3). It was shown that open pollination by *T. laeviceps* could produce fruit 2 to 3 times that of wind pollination and 4-5 times that of self-pollination. This indicated that pollination with *T. laeviceps* increases the chance of pollen falling onto the flower stigma, resulting in a fertilization process that results in higher fruit formation in tomatoes and chilies. Neto et al. (2013) also showed similar results. Open pollination resulted in a higher percentage of fruit set than pollination caged with gauze (WP and SP), although the difference was small. OP treatment increases the chance of cross-pollination. Based on the research of Deprá et al. (2014), cross-pollination has a higher fruit set (84%) compared to self-pollination (55%). Pollination by bees enhancing yield of *Nigella sativa* (Tesfaye et al. 2020) and *Cucumis* sp. (Zidni et al. 2020; Kiatoko et al. 2022)

In general, OP treatment increased fruit set, weight, and length of chili compared to WP and SP treatments. While in tomato, OP treatment increased fruit set, seed set, and weight (Table 3). This result was in line with the research by Putra et al. (2014) that the effect of pollination of *T. laeviceps* on chilies has a significant impact on fruit set, namely an increase in fruit set by 17.64%, than self-pollination. In addition, pollination of chilies by *T. laeviceps* increased fruit weight per plant by 24.25-49.75% and did not produce a significant difference in fruit diameter compared to pollination by wind (Putra et al. 2016).

Based on the calculation, the average number of tomato and chili seeds formed in the OP, WP, and SP treatments was 74.04, 33.54, and 28.90 seeds/tomato and 68.63, 55.07, and 42.79 seeds/chili, respectively (Table 3). Seeds produced by the OP treatment were higher than the WP and SP treatments. The number of seeds formed was influenced by the pollen that falls on the flower stigma. OP treatment causes the amount of pollen attached to the stigma to be more (Rakshit and Bellundagi 2019), so the number of seeds produced was greater. This was following the research conducted by Bashir et al. (2017), self-pollination (SP) produced 42.96 seeds/fruit, wind pollination (WP) had 63.22 seeds/fruit, and insect pollination (OP) produced 65.82 seeds/fruit. This study was also supported by Neto et al. (2013), the number of seeds per fruit in tomato covered with bagged fewer seeds than not-bagged. This showed that pollination by insects can increase the number of seeds formed on each fruit.

Measurement of tomato average length in the three treatments did not show a significant difference (Table 3). In contrast, the OP treatment for chili had a considerable difference between WP and SP, namely 11.47, 10.05, and 9.03 cm (Table 3). Putra et al. (2016) and Azmi et al. (2016) stated that the treatment of stingless bees (*T. minangkabau*, *T. laeviceps*, and *Heterotrigona itama*) which was infested in chili, did not have a significant effect on the length of the chili.

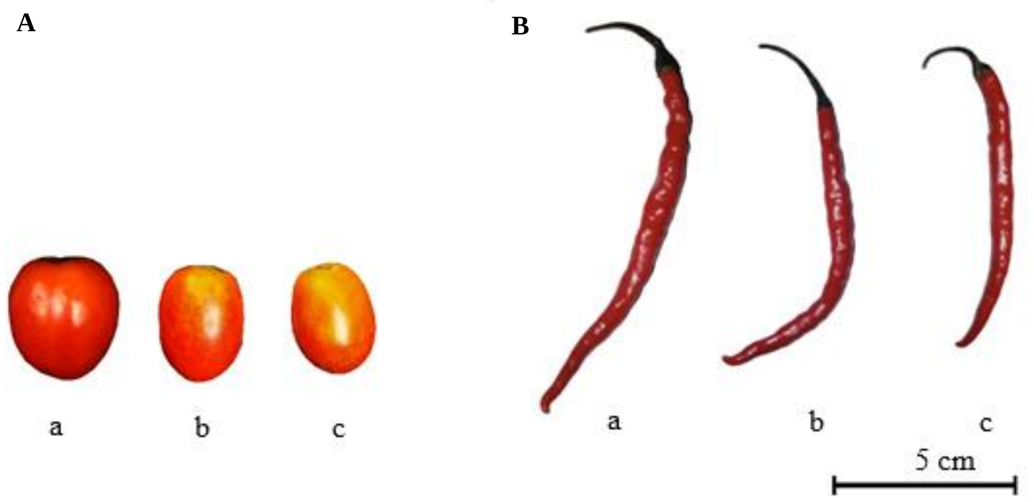

Figure 2. Comparison of fruit phenotypes resulting from OP (a), WP (b), and SP (c) in tomatoes (A) and chilies (B)

Tabel 3. Indicators of yield quality in various pollination treatments

Indicators	Average on treatments[1,2]					
	OP		WP		SP	
	T	C	T	C	T	C
Fruit set (%/plant)	74.86±8.47a	39.73±10.43a	22.86±2.27b	17.20±6.38b	15.43±5.00b	10.82±6.29b
Seed set (seed/fruit)	74.04±9.83a	68.63±4.34a	33.54±4.26b	55.07±6.73b	28.90±3.06b	42.79±8.26c
Length (cm)	3.74±0.27a	11.47±0.43a	3.44±0.15a	10.05±1.00b	3.41±0.30a	9.03±1.26b
Diameter (cm)	3.29±0.18a	0.69±0.02a	3.00±0.11b	0.60±0.05a	2.97±0.21b	0.59±0.09a
Weight (g)	21.25±3.73a	2.88±0.34a	16.12±1.68b	2.28±0.37ab	15.87±3.15b	1.96±0.54b

Note: [1)]The number after ± represents the standard deviation. [2)]Numbers in a row followed by the same letter show no significant difference (Tukey's test, α = 5%) in the same commodity (T: Tomato, C: Chili)

Measurements of diameter and weight of tomatoes also showed significant differences in the WP and SP treatments. The two sizes did not show any difference with the OP treatment in chili. The diameter of the tomatoes produced in the OP treatment was greater than the WP and SP treatments were 3.29, 3.00, and 2.97 cm, while in chilies 0.69, 0.60, and 0.59 cm, respectively (Table 3). The average diameter of tomatoes in the WP treatment was relatively the same as in the SP treatment. While the diameter of chili, has a higher value in the OP treatment, it did not show a statistically significant difference (Table 3). This was by research conducted by Bashir et al. (2017), the diameter of tomatoes produced in the treatment of open treatment showed an average greater than the treatment of plants covered with gauze. The addition of the number of seeds produced in the OP treatment resulted in the contents of the tomatoes being more, so that the tomatoes made had a larger diameter (Figure 2).

OP treatment increased the weight of tomatoes and chilies higher than the WP and SP treatments. The importance of chili fruit numerically showed a higher value in the OP treatment, but statistically, the OP and WP treatments were not significantly different (Table 3). The average weights of tomatoes produced in the OP, WP, and SP treatments were 21.25, 16.12, and 15.87 g, while the fruit weights of chilies produced were 2.88, 2.28, and 1.96 g, respectively. The WP treatment resulted in the fruit weight of tomatoes and chilies which were not significantly different from the fruit weight of the SP treatment. Tomatoes and chilies with open pollination treatment produced larger fruit sizes (Figure 2), so the fruit weight made in open pollination treatment became higher. Bashir et al. (2017) research, showed that the fruit weight produced in the OP treatment was higher than the wind pollination and self-pollination treatments. Open pollination can increase the importance of the fruit produced in tomato plants (Colley and Vallejo-Marin 2021).

The difference in the quantity of fruit produced in each pollination treatment was caused by pollination success factors that affected the quality of fruit formation. The success of pollinating chilies by pollinating insects depends on the pollinator's size (Putra et al. 2016). Stingless bee, *T. laeviceps,* has around 3.44-3.76 mm in size (Trianto et al. 2020) smaller than chili flowers making bees move more easily in accessing the anther so that they are effective in pollination. Other factors that influence pollination success besides pollinator size are the position of the reproductive organs of plant flowers, ease of access to nectar, and flower structure (Putra et al. 2016). The interest in pollinating insects in plant flowers is also influenced by the color and number of flowers, and the availability of nectar and pollen in flowers. The characteristics of *T. laeviceps* bees which are aggressive foragers who can communicate with other members of the colony regarding the location of the feed support the success of pollination (Trianto and Purwanto 2020).

Effect of pollination on longevity

The empty fruit is one of the physiological disorders caused by inadequate pollination (Sawe et al. 2020). This can accelerate the rate of respiration and damage the fruit. As a climacteric fruit, tomatoes will continue to respire resulting in increased weight loss and damage, while the level of fruit hardness decreases (Andriani et al. 2018). The respiration process occurs significantly at the beginning of storage, and over time, respiration will slow down. The slowing of the respiration process in fruit causes water and substrate loss to slow down. In addition to the respiration process, pathogenic microbes can accelerate fruit damage and wilting conditions (Blomme et al. 2017).

Analysis of the effect of pollination on weight loss and fruit damage of chilies showed relatively the same results in the three treatments, except on the 9th day of weight loss which showed a significantly different effect between OP and SP treatments of 28% and 12%, respectively. The hardness level on the 6th day of OP showed a significant difference with SP, while on the other day of observation, the results were relatively the same between the three treatments. The same thing also occurred to the level of fruit freshness which showed somewhat the same results for the three treatments except on the 15th day, which had a significant difference between the OP treatment and the other two treatments (Table 5). Changes in fruit quality in this longevity test occur due to a decrease in fruit moisture content caused by the metabolic process of living tissue in the form of respiration and transpiration even though they have been harvested. The reduction in weight loss affects fruit damage through the occurrence of rot and dryness in stored fruit. Rochayat and Munika (2015) stated that the factor that affects fruit damage is the contact between fruit and oxygen. This damage causes withering and shrinking of the fruit. Besides being driven by a decrease in weight loss, changes in the level of fruit hardness also occur due to changes in the components of compounds in the cell wall from complex compounds to simpler compounds. Changes in fruit texture or hardness occur due to factors that influence it, cell wall turgidity, intercellular adhesion, cell size, shape, and supporting tissues and cell chemical composition. Surface condition and fruit color caused the difference in the level of fruit freshness between the three treatments. Fresh fruit has a smooth surface or does not shrink and is shiny red to dark red (Rahman et al. 2012).

Estimated economic value of pollination

The net productivity of pollination by *T. laeviceps* showed a large effect compared to pollination by wind and self-pollination. The net productivity of open, wind, and self-pollination in tomatoes were 14.17, 1.46, and 2.72 tons/ha, respectively (Table 6).

Table 4. Indicators of tomatoes longevity in three treatments

Indicators	Days	Treatments[1]		
		Open pollination	Wind pollination	Self pollination
Weight loss (%)[2]	4	1.71±0.83b	2.47±0.85ab	3.31±1.63a
	8	3.47±1.37b	5.17±1.94ab	6.18±3.12a
	12	5.25±2.31a	8.48±4.30a	10.36±7.30a
	16	6.52±2.51a	11.88±8.64a	14.98±13.78a
	20	8.38±3.18a	15.78±13.80a	22.61±23.68a
Damage level[3]	4	0.00a	0.00a	0.00a
	8	0.00a	0.00a	0.00a
	12	0.00a	0.00a	0.00a
	16	0.00a	0.00a	0.00a
	20	0.00a	0.00a	0.00a
Hardness[2,3]	4	5.00a	5.00a	5.00a
	8	5.00a	5.00a	5.00a
	12	5.00a	4.00a	4.00a
	16	4.50a	4.00a	4.00a
	20	4.00a	4.00a	3.50a

Note: [1)] The number before the ± sign represents the mean and after the ± sign represents the standard deviation. [2)] Number represents the median value. [3)] Numbers in a row followed by the same letter are not significantly different (Tukey's test/Dunn's test, α: 5%).

Table 5. Indicators of chilies longevity in three treatments

Indicators	Days	Treatments[1]		
		Open pollination	Wind pollination	Self pollination
Weight loss (%)[2]	3	0.32 ± 0.15a	0.37 ± 0.16a	0.43 ± 0.13a
	6	0.28 ± 0.16a	0.35 ± 0.18a	0.30 ± 0.19a
	9	0.28 ± 0.17a	0.16 ± 0.11ab	0.12 ± 0.06b
	12	0.23 ± 0.14a	0.16 ± 0.14a	0.28 ± 0.19a
	15	0.13 ± 0.11a	0.14 ± 0.15a	0.16 ± 0.13a
Damage level[3]	3	0.25 ± 0.46a	0.50 ± 0.53a	0.63 ± 0.92a
	6	0.75 ± 0.71a	0.88 ± 0.99a	1.38 ± 1.06a
	9	1.38 ± 0.92a	1.38 ± 0.92a	2.00 ± 1.07a
	12	1.75 ± 1.19a	1.75 ± 0.71a	2.75 ± 1.04a
	15	2.38 ± 0.99a	2.38 ± 1.06a	3.38 ± 0.92a
Hardness[2,3]	3	4.63 ± 0.74a	4.75 ± 0.46a	4.38 ± 1.06a
	6	4.00 ± 0.53a	2.75 ± 0.71b	2.50 ± 0.93b
	9	3.00 ± 1.31a	1.75 ± 0.71a	1.75 ± 0.71a
	12	2.25 ± 1.04a	1.50 ± 0.76a	1.63 ± 0.74a
	15	1.63 ± 0.52a	1.13 ± 0.35a	1.25 ± 0.46a
Freshness[3]	3	4.13 ± 1.36a	4.50 ± 0.93a	3.75 ± 1.04a
	6	3.38 ± 1.06a	2.88 ± 0.99a	2.38 ± 0.74a
	9	2.38 ± 0.74a	1.75 ± 0.71a	1.63 ± 0.92a
	12	2.00 ± 0.53a	1.50 ± 0.53a	1.00 ± 0.92a
	15	1.75 ± 0.53a	1.13 ± 0.35b	0.63 ± 0.00b

Note: [1)] The number before the ± sign represents the mean and after the ± sign represents the standard deviation. [2)] Number represents the median value. [3)] Numbers in a row followed by the same letter are not significantly different (Tukey's test/Dunn's test, α = 5%).

Table 6. Estimated economic value of pollination in three treatments

Treatments	Productivity (ton/ha)[1]		EVP (trillion rupiah)[1]		Farming profits (million rupiah/ha)[1]	
	T	C	T	C	T	C
OP	14.17a	8.77a	1.31a	4.13a	26.89a	136.99a
WP	1.46b	2.91b	0.02b	0.38b	-20.93b	23.69b
SP	2.72b	1.56b	0.03b	0.20b	-15.91b	-3.17b

Note: [1]Numbers in one column followed by the same letter show no significant difference (SNK test, α = 5%) in the same commodity (T: Tomato, C: Chili)

The OP productivity of tomatoes was 9.7 times greater than WP and 5.2 times greater than SP. While in chili, the net productivity of open, wind, and self-pollination were 8.77, 2.91, and 1.56 tons/ha, respectively (Table 6). The OP productivity was 3 times greater than WP and 5.5 times greater than SP. This showed that most of the productivity of tomatoes and chilies was the result of the contribution of pollinating insects, while pollination by wind had an insufficient effect.

Insects were able to increase the production of tomatoes. Putra and Kinasih (2014) stated that the average productivity of tomatoes with the introduction of honey bees, stingless bees, and no other pollinators were 52.05, 51.58, and 48.06 fruit/plant, respectively. Pollinators influenced the increase in tomato production.

Based on the productivity of tomatoes and chilies pollinated by *T. laeviceps* can estimate the economic value. In tomatoes, the economic value of *T. laeviceps* was around IDR 1.31 trillion or equivalent to 44 times the economic value of self-pollination and 65 times the economic value of wind pollination. In chili, the EVP IDR 4.13 trillion is equivalent to 10 times the EVP of wind pollination and 20 times the EVP self-pollination (Table 6). However, the SP treatment's EVP of tomatoes and chili showed relatively the same results as the WP. These results indicate that pollination of tomatoes and chili with the help of *T. laeviceps* provided the highest EPV compared to wind pollination and self-pollination, thereby increasing the total plant productivity and profits. Lautenbach et al. (2012) reported that vegetables and fruit are the main crops whose pollination depends on pollinating insects with an economic value of IDR 882 trillion each. In addition, honey bees are classified as the main pollinators of crops with the highest economic value contribution of 238-285 billion US dollars or equivalent to IDR 3 528-4 225 trillion. Alabachew (2018) also reports estimated the economic value of pollination on red pepper in Ethiopia at 5.71 billion rupiahs and 210 million rupiahs for green pepper.

The higher OP treatment's total productivity, tomato, and chili, resulted in the highest farming profits obtained among the other treatments, IDR 26.89 and 136.99 million/ha (Table 6). This proved that open pollination with the help of *T. laeviceps* could significantly increase tomato and chili productivity to increase farmers' profits. The profit obtained from wind pollination was IDR 23.69 million/ha on chili but suffered a loss of IDR 20.93 million/ha on tomato. While the SP treatment in both commodities sustained a loss of IDR 15.91 and 3.17 million/ha (Table 6). Lower profits in wind pollination (WP) and self-pollination (SP) were due to lower crop productivity than open pollination (OP) treatments so the gains obtained were small or even suffered losses.

The economic value of pollination on fruit productivity was influenced by the total commodity productivity, commodity prices, and the value of pollination dependence. The cost of chili used in this study was IDR 20 000/kg and 4 000 for tomatoes, which was obtained from interviews with farmers who own chili and tomatoes also other farmers in the vicinity.

The pollination dependence value of chili in OP, WP, and SP treatments were 11.71, 0, and 0%. These results indicated that the pollination dependence of OP, WP, and SP were 0.25 (medium), 0.05 (small), and 0.05 (small). Alebachew (2018) based on the grouping of Klein et al (2006) noted the value of pollination dependence on red chili and green chili commodities of 0.05, which is included in the small dependence group.

Meanwhile, the pollination dependence value of tomatoes in OP, WP, and SP treatments was 0.25-0.65, 0.05, and 0.05. Based on this, the dependence value of tomato plants for each treatment was simple to high category for the OP treatment, low category for WP and SP treatment. Based on the results by Chaudhary and Chand (2017), tomatoes in India had a high level of dependence on pollinators with a dependency value of 0.65. Giannini et al. (2015) analyzed 141 crops and found that 85 depend on pollinators. This shows that if there are no pollinating insects, it will greatly affect fruit production in tomato plants.

Pollination by *T. laeviceps* had a massive effect on farm profits. The presence of insects as pollinators increases the profits of the farming business (Hanley et al. 2014). More than 50% of farming profits from OP treatment resulted from *T. laeviceps* pollination. Although tomatoes and chilies had a perfect flower structure that can self-pollinate, both of them still need insects as pollinating agents to increase their productivity. Loss of pollinating agents in nature would greatly impact crop yields (Bartomeus et al. 2014; Garibaldi et al. 2016).

In conclusion, open pollination (OP) treatment with the help of *T. laeviceps* increased the percentage of fruit formed, fruit diameter, fruit weight, number of seeds formed, speed up fruit set time, and reduce the percentage of weight loss. Based on the economic value of tomato and chili productivity, the economic value of pollination service of *T. laeviceps* was 44 times (tomato) and 20 times (chili) from self-pollination and 65 times (tomato) and 11 times (chili) from wind pollination.

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