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Study Of The Potential For Integration Of Heterotrigona Itama L. With Melon Crop Cultivated In Closed Greenhouse

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Abstract
The practice of cultivating melons so far has only been limited to producing fruit not honey. However, it has the potential to be a source of income for farmer. H. itama can collect nectar flowers to honey. This research used 200 melon crops cultivated in a closed greenhouse and one hive of H. itama was acclimatized in the center of the greenhouse. Observation were made on the behaviour of H. itama visits to melon flower, flowering phenology, melon production against several types of pollination, and honey production by H. itama and potential additional income for farmer. The ratio of the number of male flowers to hermaprodhites of melon crops is 1:20. The average of H. itama was visit a flower during 35.99 seconds and a higher number of visits on male flowers compared to hermaphrodite flowers. Based on the treatments of several types of melon pollinations, melon fruits showed better quality in flowers pollinated by hand-self of humans and repeated visits by H. itama. Meanwhile, the total amount of honey obtained in this study was four pots of honey with a total volume 16.9 ml equal to 270.400 ml/planting period.
Keywords *Insect, Integration, Melon, Nectar, Pollinator,*

1. INTRODUCTION

Melon is a fruit crop that has many benefits for human health. In 100 grams of melon contains 92.01% of water, 0.5% of protein, 0.3% of fat, 6.2% of carbohydrates, 0.5% of fiber, and 351 IU of Vitamin A (Daryono et al., 2019). In its development into fruit, melon flowers are monoecious with a ratio of male to hermaphroditic flowers of 1:18. The male flower consists of 5 petals that are fused at the base of the flower, the androceum consists of 5 stamens, and the anthers and filaments are fused. Meanwhile, hermaphrodite flowers have a larger perianth and are similar to male flowers. During the flowering period, male flowers come out and open first compared to hermaphroditic flowers. New flowers will appear 40 days after planting, the length of time for these two flowers to bloom is one day (Revanasidda & Belavadi, 2019). As a plant belonging to the herbaceous group, melon crops have discs or bowls and flower flags (Wang et al., 2024). Optimizing melon cultivation is expected to increase farmer's income (Davies & Bowman, 2016). One of the efforts can be to integrate it with pollinators with the concept of symbiosis mutualism (Budianto & Sukendah, 2022). Pollination is very important in increasing agricultural production (Dainese et al., 2019), it can even increase 10% of the economic value of global crop production (Chaplin-Kramer et al., 2014). Heterotrigona itama is a pollinator species on this crop (A'yunin et al., 2019). For melons, the presence of pollinators is expected to deliver pollen to the stigma, while for pollinators, they will get nectar from flowers as food (Linhart, 2014)(Power et al., 2018), while for farmers it can increase economic profits (Castle et al., 2019).

Heterotrigona itama is a species of pollinating insect belonging to the Hymenoptera and widely distributed in tropical areas (Trianto & Purwanto, 2022). The concept of integrated agricultural activities creates an ecological farming system that can make the best of local resources as efficiently as possible for a sustainable environmentally friendly farming system (Putri et al., 2022).

Pollinator species with high densities can influence other pollinators in competing for flower resources (Torné-Noguera et al., 2016), so it is hoped that with integration through acclimatization, the use of H. itama species as specific pollinators can increase the efficiency of melon pollination and increase the income of melon farmers.

Cultivation of plants in a greenhouse can generally be used to maintain plant production without being influenced by weather conditions, such as in cultivating tomatoes where production does not differ in summer and autumn (Hikawa & Miyanaga, 2021). Likewise reports with other plants such as melons. Apart from the hope of getting melon production, it also hoped that farmers would get additional income through honey production as a result of the integration with H. itama.

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2. MATERIAL AND METHODS

This research was carried out on melon cultivation in the Closed Greenhouse in Pulau Godang Kari and the field of Melon Cultivated in Kuantan Singingi Regency, Riau, Indonesia, located at coordinates -0.5464378176278757, 101.55132594355901 (Fig 1.) The research was carried out during 3 months June-Augustus
2024.

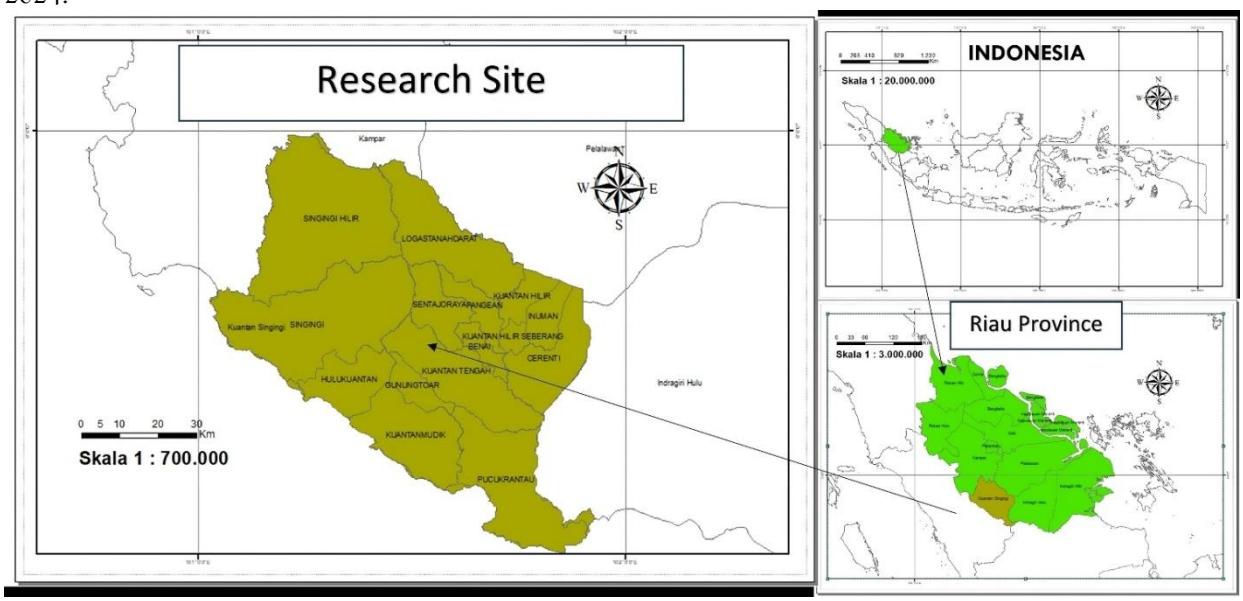

Figure 1. Research Location in Kuantan Singingi Regency, Riau Province, Indonesia

2.1. Melon Planting and H. itama Colony Placement

Melons were planted in a closed greenhouse (6 x 11 meters) with a planting distance of 1 x1 meter, and the total population of melons was 200 plants. Each plant were attached with a melon stake around 2 meters for the melon to spread. Fertilization is provided through hydroponic nutrition which is given by the drip system. When the plants were 2 weeks after planting, one colony of H. itama was acclimatized in the center of the greenhouse. According to (Prešern et al., 2019) the total number of colonies will influence the maximum yield in beekeeping which will further determine the profits from the beekeeping business. During melon cultivation, pesticides and fungicides were sprayed to know the effect of pesticide use on H. itama activity.

2.2. Melon Flowering Phenology

A total of 25 plants were sampled for this observation. Observations of melon flowering phenology include the day the plant begins to flower and the number of male and hermaphrodite flowers that appear. All flowers are observed starting from the first flower appearing until the melon to the harvest period. The number of male and hermaphrodite flowers formed was counted and recorded. Apart from that, it was also observed when individual flowers started to open.

2.3. Daily Visitation Patterns of H. itama on Melon Flowers

Observations of visiting activities were carried out by census. A total of 10 male flowers and 10 hermaphrodite flowers visited by H. itama were observed. Observations were carried out four times a day, each for 60 minutes so that the observation time was 240 minutes/flower/day.

2.4. Rate and Duration of Flower Visitation by H. itama

Observation of visitation rates was based on the number of male and hermaphrodite flowers visited by H. itama. A total of five H. itama individuals were observed from the moment they left the nest, visiting the first, second, and subsequent flowers until the individual returned to the hive. The total number of flowers visited is the visit rate. Meanwhile, the duration of visits was observed by calculating the time spent by H. itama individuals on one flower. This calculation starts from the first flower visited by the H. itama individual to the last flower visited until the individual returns to the hive.

2.5. Effect of Several Types of Pollination on Melon Fruit Set

The effectiveness of pollination is based on the type of pollination in the hermaphrodite melon flowers. In this experiment, four treatments were used on 100 hermaphrodite flowers. These treatments were, unpollinated (A); hand-self-pollinated (B); pollinated by a single visit of H. itama (C); and pollinated through repeated visits by H. itama (D). Each treatment level was observed on 10 hermaphrodite melon

flowers and repeated three times so that the total number of flowers observed was 120 flowers. In treatment A, 10 hermaphrodite flowers were covered in the afternoon before the flower's anthesis. In treatment B, 10 flowers were pollinated by humans by hitting pollen from 2 male flowers against hermaphroditic flowers. In Treatment C, 10 flowers were observed from the beginning of anthesis until they were visited once by H. itama and then covered using plastic fruit wrappers; in Treatment D, 10 hermaphrodite flowers were allowed to be visited repeatedly and then wrapped.

2.6. Honey Volume Production

Honey volume observations were carried out at the end of the study. The honey formed in the H. Itama hive was taken and measured using a graduated cylinder. To determine the potential for additional income for the farmer, the honey production produced is converted into hectare unit and multipled by the price of honey from stingless bee.

3. RESULTS

3.1. Temperature in Greenhouse

During the research, the highest average temperature in the greenhouse was observed during the day from 13.00 WIB to 14.00 WIB, namely around 350C. while the lowest temperature was observed at 07.00 WIB to 08.00 WIB, namely 210C. These temperature conditions will affect the activity time of Heterotrigona itama. Especially in looking for food (Figure 2).

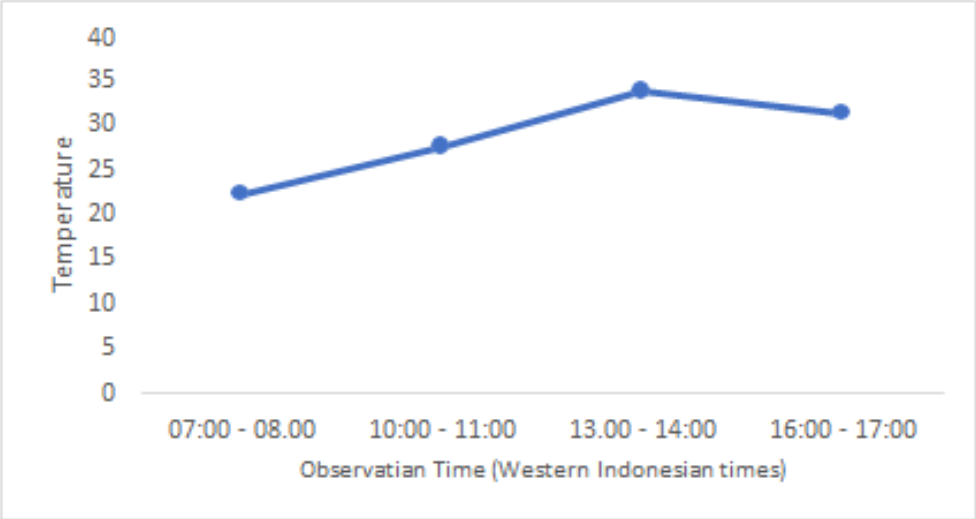

Figure 2. Temperature conditions in the Greenhouse (b)

3.2. Comparison of the number of Heterotrigona itama individuals with the number of melon flowers per crop

A total of one colony of Heterotrigona itama was acclimatized when the melon plants entered 2 weeks after planting. The number of Heterotrigona itama individuals visiting melon flowers continues to increase along with the increase in the number of melon flowers. As the number of melon flowers decreased, the number of Heterotrigona itama individuals visiting the melon flowers also decreased (Table 1).

Table 1. Number of active Heterotrigona itama individuals and average number of melon flowers

	Number of individuals active		Average number of Melon flowers/plant
Day	Morning	Evening	
7	9	6	0
14	12	6	0
21	17	9	5
28	23	18	13
35	24	22	38
42	35	23	54
49	34	22	62
56	38	23	87
63	35	21	67

70	28	18	54
77	28	18	44
Average	25,72727	16,90909	38,54545
Stdev	9,778455	6,685126	29,94115

During morning observations, the highest number of individuals was observed on day 56, namely 38 individuals. Meanwhile, the lowest number of individuals was observed on day 7, namely 9 individuals. The high number of individuals on the 56th day is in line with the high number of melon flowers, namely 87, and the low number of individuals on the seventh day is also caused by the absence of melon flowers that have not yet bloomed.

During the afternoon observations, the number of Heterotrigona itama individuals was observed on day 56, while the lowest number of individuals was observed on days 7 and 14, namely 6 individuals. The high number of individuals observed this afternoon was in line with the large number of flowers that day, namely 87 flowers that bloomed.

3.3. Phenology of Flowering in Closed Greenhouse

Melon cultivation is carried out in a closed greenhouse and begins to flower at an average age of 19.9 to 24 days after planting by starting with the appearance of the first flower, which is a male flower.

These male flowers appear one by one on the axils of the leaves. Hermaphrodite flowers come out on one stalk with only one flower (some records have two flowers). Male and hermaphrodite flowers open in the morning at the same time, taking approximately 95 minutes to open perfectly. Melon flowers began to open at around 06.13 (Western Indonesian Times) at a temperature of 21^{0}C. and open perfectly perfectly at 07:48 (Western Indonesian Times) at a temperature of 25^{0}C. The flowers bloom during the day and begin to close slightly at

17.25 (Western Indonesian Times) at a temperature of 28^{0}C and reopen perfectly again the next day. Melon flowers only bloom for 1-2 days, and then they will wither and fall off.

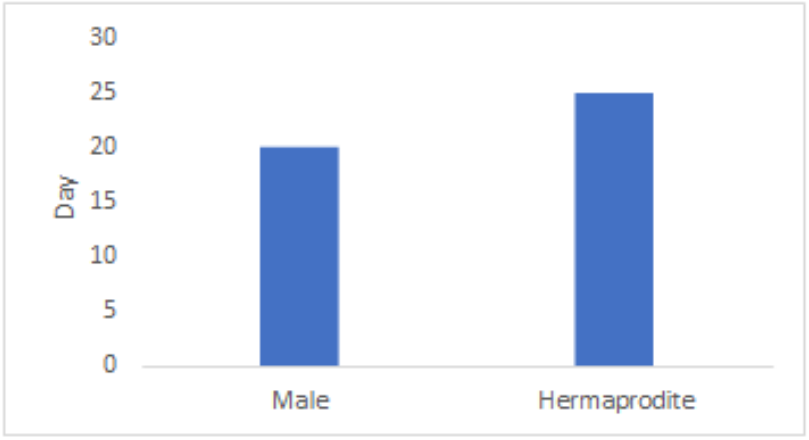

Figure 3. Age of appearance of male and hermaprhodite flowers on melon plants

In this study, The average number of hermaphrodite flowers in melon plants was 314,6 while male flowers were 17 with a ratio of 1:18.

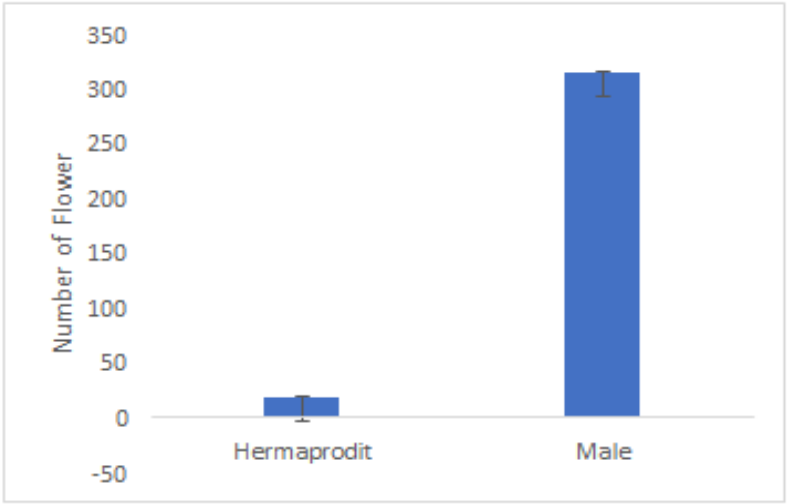

Figure 4. Number of hermaphrodite and male flowers on melon plants (b)

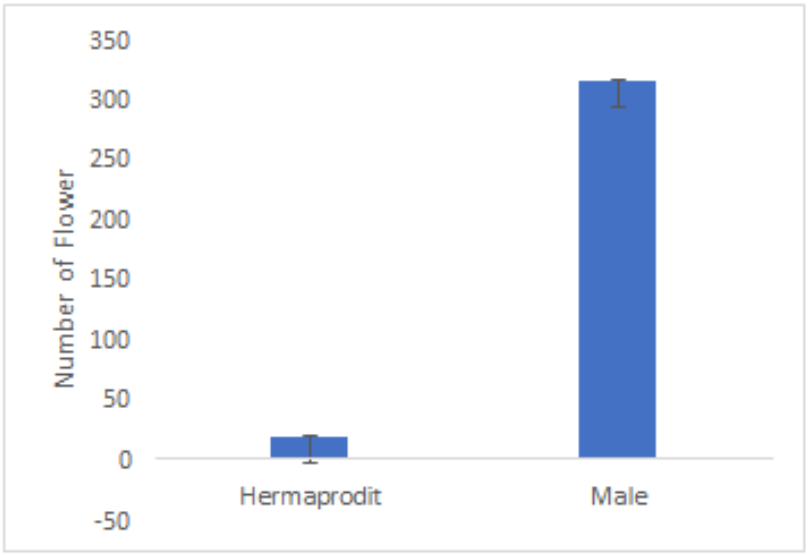

Figure 4. Number of hermaphrodite and male flowers on melon plants (b)

3.4. Daily Visit Pattern

H. itama begins to visit male flowers on the first 06.45 (Western Indonesian Times), then increases at the next observation at 07.45 (Western Indonesian Times), 08.45 (Western Indonesian Times), and peaks at 09.45 (Western Indonesian Times). After that, along with the increase in temperature, the number of individuals who actively visit one melon flower also decreases during the day and increases again in the afternoon. The observation results showed that the average number of visits to hermaphrodite flowers was 42.5 ±21.99 times, while in male flowers it was higher at 48.25±24.5 times.

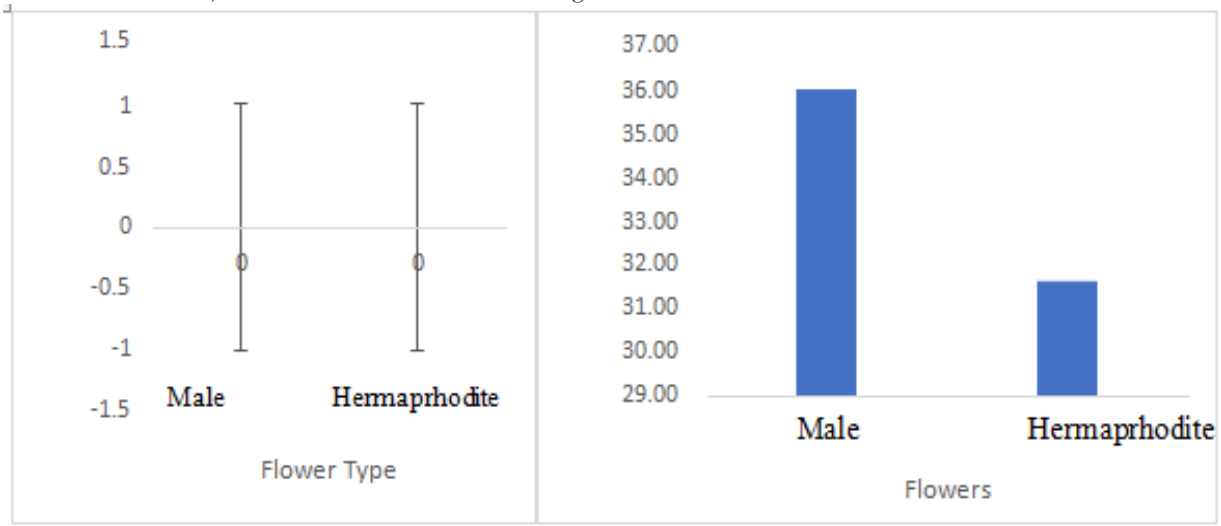

Figure 5. Rate (a) and duration of visits (b) of male and hermaprhodite flowers by Heterotigona itama individuals

The total visits on male flowers are less compared to hermaphrodite flowers, this is because the number of hermaphrodite flowers is much less compared to male flowers (figure 5). In this study, The average number of hermaphrodite flowers in melon plants was 314,6 while male flowers were 17 with a ratio of 1:18.

3.5. Visit Rate

The number of visits by heterotrigona itama was greater on male flowers than on hermaprhodite flowers, namely 35.99 times on male flowers, while on hermaphrodite flowers it was only 31.61 times. However, the duration of visits is longer for hermaphrodite flowers compared to male flowers. In hermaprhodite flowers, the visit duration is 64 seconds, while in male flowers it is only 51 seconds (Table 2.)

Fruit Set

Pollination treatment on melon flowers had a significant influence on fruit formation, fruit weight, number of seeds and sugar content in melons cultivated using a hydroponic drip system in a greenhouse (Table 3.).

Table 2. Average number of Visit and duration visit melon Flowers by Heterotrigona itama

Flowers type	Visit rate (times)	Duration Visit (second)
Male	35,99± 28,87	51
Hermaprodhite	31,61±23,14	64

Melon Fruit Formation Percentage.

Melon fruit formation is greatly influenced by the type of pollination. The difference in results between treatments in this study was statistically significant (Tukey's Test 5%).

Pollination of melon flowers using human hands resulted in the highest percentage of fruit formation (93.3%). This result was the same as the repeated visit treatment by Heterotrigona itama (93.3%), followed by the repeated visit treatment by Heterotrigona itama (66.77%). And the lowest yield was in the treatment without pollination (26.7%).

Melon Fruit Shape

The pollination type treatment in the study influenced fruit shape. The fruit resulting from pollination is round in fruit from treatment with the help of human hands, a single visit by Heterotrigona and a single visit by Heterotrigona itama. Meanwhile, with treatment without pollination, the melons produced are not round.

Weight of Melon Fruit

The pollination type treatment in this study had a significant influence on melon fruit weight. The best treatment resulted from pollination treatment with the help of human hands (917.8 g) and was not significantly different from the fruit produced from repeated visits by Heterotrigona itama with a fruit weight of 896.13 grams. This was followed by pollination with a single visit (300.9 g) and the lowest weight without a polinator (249.47 g).

Number of Melon Seeds

Pollination treatment of melon plants had a significant influence on the number of seeds. The best treatment was found in the treatment with assistance from human hands (416.47 seeds) and followed by the flower treatment, which was visited repeatedly by Heterotrigona itama (411 eggs), visited once by Heterotrigona itama (300.9 seeds). And finally in the treatment without pollination (55.8 seeds). The pattern of results in this treatment showed the same pattern as the fruit weight observation parameters, namely the best in treatment with human assistance, and did not differ from repeated visits by Heterotrigona itama.

Sugar Content in Melons Fruit

Pollination treatment of melon flowers has a significant influence on the sugar content of melon fruit. The best average sugar content of melons was produced by repeated visitation treatment by Heterotrigona itama (9.93 Brix) and followed by pollination treatment with human assistance, namely 9.76 Brix, stay visitation treatment by Heterotrigona itama (8.1 Brix). The lowest sugar content resulted from the treatment without pollination, namely 7.96 Brix.

Table 3. Comparison average of fruit formation, weight, number of seeds and sugar content.

Parameters (Average)	Treatments			
	Without pollinator	Hand-self pollination	Once visited by H. itama	Repeated
Percentage of fruit formation (%)	26,7±11,577^{c}	93,3±5,77^{a}	66,77±,5777^{b}	93,3±5,7777^{a}
Fruit shape	Not rounded	Rounded	Rounded	Rounded
Weight of fruit (g)	249,47±107,5177c	917,8±48,1177^{a}	684,9±45,077777^{b}	896,13±40,6677^{a}
Number of Seeds (Unit)	55,8±30,32	416,47±21,18	300,9±18,80	411±17,97
Sugar Content (Brix)	7,96±0,5077^{b}	9,76±0,7277^{a}	8,1±0,177^{a}	9,93±0,3277^{a}

Note: different letters in the column indicated significant differen among means based Tukey's test 5%

3.6. Honey Volume Production

During research with a total of 200 melon plants cultivated in this study, it was found that the amount of honey produced by Heterotrigona itama which was collected from melon flowers was 16.9 ml. This honey volume is the total of 4 pots of honey produced with the average honey volume being 4.225 ml/pot (Table 4.).

Table 4. Nectar volume from Heterotrigona itama hive

Pot	Honey Volume (ml)
1	3,8
2	4,2
3	5,1
4	3,8
Total	16,9
Average	4,225
SD	0,613052

4. DISCUSSION

4.1. Life History of the Colony within the Observation Hive

H. itama was introduced on June 6, 2024, which is as many as one colony. The conditioning of this colony is in the form of emptying the honey pot and only 2 honey pots are left on the colony's stuff. The acclimatization is carried out on melon plants with conditions that are 2 weeks after planting. In the first week of acclimatization, it was observed that as many as 8 individuals of H. itama began to be active in the hole of the hive, and the number of colonies increased as the acclimatization period increased. As the number of flowers increases, the population of H. itama is also increasing. This statement is also reinforced by the fact that flowering plants can increase the population of pollinator insects (Rahayu et al., 2018), the wealth of pollinator insects increases along with the increase in the number of flowers in Prunus avium (Gilpin et al., 2022), especially with the distance of the flower to hive makes it very easy for H. itama to collect its food. This theory is reported from the species Tetragonula biroi which prefers food sources around the hive especially 1 meter from the hive (Kusuma et al., 2020).

4.2. Phenology of Flowering in Closed Greenhouse

The development of male and hermaphrodite flower formation in melon plants starts from the age of 18 days after planting and continues to release flowers until the plant dies.

The number of male flowers is always more than the number of hermaphrodite flowers. Overall, the ratio of the number of male and hermaphrodite flowers is 20:1. Hermaprodhite flowers emerge on leaf axillary buds and continue to extend to form new branches on melons (some hermaphrodites flowers emerge from leaf axils on the main stem). Meanwhile, male flowers come out of the leaf axils on the main stem around 8-18 flowers that bloom alternately. Male flowers that bloom on the branches are only 6-12 flowers. The average hermaphrodite flowers of planting were 17 ± 2.35 fruits while the male flowers were 314.6 ±20.33. The number of male flowers is much more compared to hermaphrodite flowers. The number of flowers is influenced by genetic factors such as the variety used (Khotimah & Barokah, 2023) and environmental factors (Riza Aristya et al., 2014). In addition, it is also due to the concept of pollination in melon flowers that tend to require pollinator services, so the number of male flowers allows pollinators to visit more. This will open up a greater possibility of pollen reaching the pistils as a result of pollinator activity (Gilpin et al., 2022).

4.3. Daily Visit Pattern

In addition to male flowers, H. itama also visits hermaphrodite flowers and melon plants. As in male flowers, H. itama also shows the same pattern as visits in hermaphrodite flowers. At 07.00 – 10.45 (Western Indonesian Times)the frequency of visits ranges from 8-20 times for each flower (Pigure4.). During the day, there is a decrease in visits due to environmental conditions with high temperatures, causing H. itama to tend to stay in the hive to avoid unfavorable conditions such as dehydration or running out of energy. Peak activity leaving and returning to the hive occurs at 09.00-10.00 (Western Indonesian Times). In oil palm and rubber plantations, foraging activities are also high in the morning and slowly decrease in the afternoon (Ramadani et al., 2021). The time of visit to the flowers was also found to be highest in the morning in strawberry plants (Atmowidi et al., 2022).

4.4. Duration Visits

There are also differences in the pattern of H. Itama's visits to male and hermaphrodite flowers. Male flowers are more visited compared to hermaprhodite flowers. The average visit to male flowers was 48.25±24.5. Meanwhile, hermaphrodite flowers with an average of 42.5 ±21.99. H.itama is a stingless bee that has a large enough body size to have enough ability to visit more flowers (Oronje et al., 2012). The more flowers that can be visited, the more efficient an insect is as a pollinator (A'yunin et al., 2019). However, it is also influenced by the number of pollen per visit that is successfully transferred from male flowers to hermaprhodite flower stigma (Artz & Nault, 2011).

4.5. Percentage of Fruit Set

The efficiency of pollination by using pollination services on tomato plants cultivated in greenhouses was also reported to be very high in 2005 (Hikawa & Miyanaga, 2007) and also in eggplants (Hikawa & Miyanaga, 2021), apples, pears, and others (Warmund, 1996).

The highest average fruit weight was produced in pollination treatment with repeated visits by H. itama, which was 1,444 grams. Then followed by those pollinated by humans, which is an average of 1,376 grams. While the lowest was produced by unpollinated treatment, which was only 423 grams. However, the size of melons pollinated by Apis indica and Bombus ignites was smaller than the growth stimulant treatment (Shin et al., 2007). The help of pollinators on apples also increases the size of the fruit (Samnegård et al., 2019). High fruit formation was also found in Cucurbita pepo L with the help of open pollination and hand pollination, which was 71.25% (Rani et al., 2016). Likewise, the weight of sweet melons of Terengganu with the help of hand-cross pollination produced a good weight of palig fruits (Azmi et al., 2022). In addition to melons, it has also been reported that pollination using natural pollinators can increase the number of pods in soybean plants (Rahayu et al., 2018).

The average number of seeds produced was highest in the pollination treatment with repeated visits by H. itama which was 502 seeds followed by the number of seeds pollinated by humans which was 489 seeds and pollination with single visit by H. itama which was as many as 318 seeds and the least was the number of seeds that were not pollinated by H. itama. In contrast to the results of other studies that only reported that melon seeds were only formed in the range of 179-341 grains with the treatment of planting media and organic pesticides (Afriyani et al., 2024). An increase in the number of seeds pollinated by natural pollinators was also found in soybean plants (Rahayu et al., 2018). The visit of pollinator insects is so influential in the delivery of pollen to the pistil head that it will also affect the number of seeds to be formed (Neira et al., 2024).

The sugar content produced in all treatments was the same, namely 9 brix. This value was higher than that of sugar content in melons based on maturity stadia from $5{,}51^0$-$8{,}18^0$ brix (Huda et al., 2018a). The high sugar content in this study is also caused by the cultivation technique carried out in the greenhouse. According to (Huda et al., 2018b) with the application of potassium addition, it can increase the sugar content of melon by 2.3^0 Brix.

4.6. Honey Volume Production

The total number of honey pots produced from the integration of H. itama with melons is 4 pieces with an average of 4±613 honey produced per pot. The total volume of honey produced is 16.9 ml. The number of volumes per pot of honey in this study was more than the results of the research on the adaptation and production process of Heterotrigona itama honey in the environment around the hive, which was 4.1 ml (Seprido & Hadi, 2024). If the honey production from this research is converted per hectare, the volume of honey produced is 270.400 ml (equal to 270 liters).

5. CONCLUSIONS

In the greenhouse, melons begin to flower 19 days after planting and are visited by Heterotrigona itama on the third day after flowering. The number of male flowers is greater than that of hermaphrodite flowers. Heterotrigona itama was recorded to visit flowers more often in the morning, especially hermaprhodite flowers, while the duration of visits was recorded to be longer for male flowers. The percentage of melon fruit formed was better with pollination treatment with the help of Heterotrigona itama with repeated visits and human assistance. In one cultivation period of 200 melon stems, the volume of honey produced is 16.9 ml or the equivalent of 270,400 ml/ha.

Ethical Statement

Ethical approval is not required for this study because the study is on melon pollination and integration with Heterotrigona itama and the species used are not poisonous to humans.

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