AGRIVITA
Journal of Agricultural Science
www.agrivita.ub.ac.id

Types of Attractan Traps for Coffee Berry Borers (*Hypothenemus hampei* Ferr) in Robusta Coffee Plants *(Coffea canephora)*

Jimmy Rimbing*), Reity Engka, and Frangky H. Rorong

Faculty of Agriculture, Sam Ratulangi University, Manado, Indonesia

ARTICLE INFO

Keywords:
Field
Population
Semiochemistry
Trap

Article History:
Received: December 5, 2022
Accepted: May 20, 2024

*) Corresponding author:
E-mail: jimmyrimbing@gmail.com

ABSTRACT

The coffee berry borers are the major pest on coffee plants that can reduce the rate of production quality and quantity. An attractant is used to control and suppress the growth of the insects. This research aims to study and identify the combination of methanol and ethanol "cap tikus" as an attractant to protect the plants. This research used a randomized block design using the combinations of methanol-ethanol "cap tikus" with the ratios of 3:1, 2:1, and 1:1. The traps were placed on the coffee trees five times every five days. The combination of methanol-ethanol could be synergistic in attracting female beetles. The highest number of trapped coffee berry borers were on the ratios of 3:1 (28.19%) and 2:1 (27.98%), while the lowest one was found on ethanol "cap tikus" (3.74%). There was an unstable number of trapped borers. The highest trapped insects were on the 15th day, but then it declined on the 20th and 25th days. The trap could also be applied to other types of insects. The combination of methanol-ethanol could be used for monitoring and controlling the beetles, the causal of plant borer.

INTRODUCTION

The coffee berry borer (CBB), *Hypothenemus hampei* (*Coleoptera; Curculionidae*) becomes a common pest of coffee plants, *Coffea arabica*, and *Coffee canephora*. The coffee plants produce berries for a long time. Such conditions provide sufficient time for the insects to mate. They prefer to consume the ripe fruit (yellow to red skin) because it produce volatile compounds and has harder seeds for them to stay. Generally, female beetles are found in yellow and red fruit. The orange and red fruits experience the most significant damage thus reduce plant productivity (Hayata, 2016; Girsang et al., 2020; Purba et al., 2015). The insects can reduce the quality and quantity of coffee beans. Indonesian growers have suffered 50% damage when inbreak conditions (Purba et al., 2015) and the damage may reach 100% (Pereira et al., 2012).

The damage type is different from other kinds of pests because CBB directly affects the fruit and reduces the production and quality of coffee beans. Erfandari et al. (2019) stated that CBB can decrease the coffee quality and production rate by 20%-30%. Its attack worsens the quality of the coffee since there are many holes left on the surface of the beans. The affected coffea bean also has different taste and reduce the selling price. The insect attacks on unripe fruit will cause seed decay (Jaramillo et al., 2013). Public coffee plantations have suffered losses of more than 90% due to CBB. The average yield loss is higher than 20% (Wiryadiputra, 2014). Brazil is estimated to experience a $215–$358 million loss per year (Oliveira et al., 2013).

Synthetic insecticides have a rapid knockdown effect. Insecticidal and non-insecticidal methods are not effective because most of the beetles experience their stage and life cycles inside the coffee berry, except for the imago which stays outside. They have their life cycles within the coffee berry. They trigger economic losses. However, the insecticides still cannot solve this problem (Erfandari et al., 2019). The intensive use of synthetic insecticides can pollute the environment. Residue

ISSN: 0126-0537

Cite this as: Rimbing, J., Engka, R., & Rorong, F. H. (2024). Types of attractan traps for coffee berry borers (*Hypothenemus hampei* Ferr) in robusta coffee plants (*Coffea canephora*). *AGRIVITA Journal of Agricultural Science, 46*(2), 320-329. http://doi.org/10.17503/agrivita.v46i2.3998

contamination on coffee berries makes them more resistant. The attractants can be an alternative to reduce the use of synthetic insecticides for beetle control.

The attractants are used to trap the insects and it is an environmentally sound control technique. An attractant is a vapor compound that can attract insects. Alcohol (especially ethanol) is the main component of the attractant to attract and trap insects. Aristizábal et al. (2016) stated that alcohol traps have been widely used to control and monitor the population of CBB, *H. hampei*. Dufour & Frérot (2008) explained that ethanol can attract female beetles, but the trapped population is still relatively low. This type of attractant can effectively attract female beetles to a coffee plantation (Jaramillo et al., 2013; Ramli et al., 2019; Rengifo-Munoz et al., 2021).

A mixture of methanol - synthetic ethanol is a popular attractant to trap insects. It commonly targets female beetles (Aristizábal et al., 2016; Castro, et al., 2017; Rostaman & Prakoso, 2020; Sihaloho, 2019; Sinaga et al., 2015; Situmorang et al., 2018). A ratio of methanol - ethanol (1:1) has been widely used as a CBB trap in many coffee plants (De Souza et al., 2020; Dufour & Frérot, 2008; Uemura-lima et al., 2010). An attractant mixture with other chemical compounds can be a synergistic repellent for insects. It was explained that methanol-ethanol attractant and frontalin have a repellent effect and can effectively trap female beetles by 77% (Njihia et al., 2014).

The ethanol "cap tikus" obtained from the vegetable has not yet examined well as an attractant to insects. It is made from palm tree sap. It is traditionally distilled by local farmers in North Sulawesi. It is usually used as an attractant against coffee plant pests. The ethanol comes from a traditional drink for the people of North Sulawesi, containing 40-70% of ethanol. The distillation of the palm sap (*Arenga pinnata*) can produce the "cap tikus" brand ethanol with an optimum level of 95% (Gugule et al., 2019). Distillation of coffee husks with water may reduce the attractant quality (Rasiska et al., 2021). This research aims to examine the proportion of the "cap tikus" brand methanol-ethanol ratio as an attractant for trapping female beetles on coffee plants. This article report is an initial study conducted in North Sulawesi on the response of the "cap tikus" brand ethanol-methanol-attractant to trap CBB.

MATERIALS AND METHODS

Research Site

The research was conducted on February-April 2022 in Modayag sub-district of North Sulawesi province on a public coffee plantation that covers an area of 952 ha. The experimental site is located at the coordinates of 00072´08.0"N, 124040'06.9"E. The research used robusta coffee (*Coffea canephora*) planted monoculturally in a distance of 2.5 x 2.5 m. The plants grew well under the shading plants called dadap (*Erythrina* sp.). The plantation is 675 meters above sea level (m.a.s.l.) with good ecological conditions for CBB development. The coffee plants were regularly pruned and provided with good shading.

Production of Ethanol *"*Cap Tikus*"*

The ethanol was obtained from traditional distillation by local farmers. The palm flowers were peeled and the sap was stored in a bamboo container with a diameter of 12 cm and 50 cm in length. The sap was placed in a drum with a capacity of 60 liters connected to the bamboo before being heated for 2 – 3 hours to obtain the ethanol "cap tikus". The steam was channeled through the bamboo and stored in gallons. The drops that came out had 50% ethanol content as calculated using an alcohol meter and labeled "cap tikus" ethanol.

Insects Trap

The trap consisted of a 1500 ml transparent, plastic, and cylinder mineral bottle equipped with a lid. On the side, there were two 5 cm x 7 cm windows facing each other, located 8 cm from the mineral bottle cover. The windows allowed the attractant to diffuse out of the mineral bottle to attract insects. The bottom of the trap contained 150 ml of water + 2 ml of detergent. The trap was hung on a coffee tree with a height of ± 1.25 m above the land surface.

Research Implementation

The experiment employed a randomized block design (RBD) with five treatments repeated four times. The experiment involved some ratios of methanol-ethanol "cap tikus" mixtures, i.e. 1) Methanol-Ethanol 3:1; 2) Methanol-Ethanol 2:1; 3) Methanol-Ethanol 1:1; 4) Methanol and 5) Ethanol. A 20 ml transparent cylindrical plastic bottle containing the attractants was hung inside the mineral bottle 10 cm from the mineral bottle lid. There were ten 1-mm holes in the plastic bottle to diffuse the attractant out. The attractant capacity was 10 ml.

Based on treatment and replication, 20 traps were placed on a coffee plant covering an area of 0.7 ha. They were hung on four rows of coffee trees. Five traps were placed on each row with a 10-meter gap. The gap between rows or observation blocks was ± 20 m. The trapping activity was done five times every five days regularly for up to 25 days. After five days of trapping, the caught female beetles and non-targeted insects were observed. The attractant was replaced with a new one after every trapping activity had been completed.

Identification of Non-Targeted Insects

The non-targeted insects were separated morphologically and classified based on morphological characters using insect identification keys. The identification was conducted at the Entomology Laboratory of the Faculty of Agriculture of Sam Ratulangi University.

Data Analysis

The obtained data were collected and studied based on the population density of CBB on methanol-ethanol traps. The analysis was conducted using variance analysis (ANOVA) and significant $p < 0.05$ and Duncan's multiple range test supported with statistical software SPSS version 23.

RESULTS AND DISCUSSION

Population Density of CBB Beetles

The transparent plastic bottles contain the methanol-ethanol mixture as an attractant. It is produced from palm trees which function to trap female beetles and other insects. The female beetles will be attracted to modified pheromone compounds as a mixture of methanol-ethanol. The attractant is released into the air as a vapor/gas that can slowly be detected by the female beetles. They will collide with the inner wall of the bottles, and they will fall into the detergent solution at the bottom so that they cannot fly and finally die. The male insects cannot be trapped because they only live in coffee berries and cannot fly like females. Their hind wings are smaller and not well-developed. Copulation of female and male beetles occurs in orange or red coffee berries. The experiment shows that the methanol-ethanol "cap tikus" combination can trap more female beetles than the methanol and ethanol that are placed separately on coffee plants.

Based on statistical analysis, there are significant differences in the number of female beetles after they were treated in the combined and separated methanol-ethanol from five to twenty five days. The number of beetles trapped in the ethanol "cap tikus" was lower than in other treatments. There were 5.75 – 18.75 female beetles trapped in the ethanol per five days, while the mixture of methanol-ethanol catched 24.0 – 157.75 beetles per five days (Table 1). Dufour & Frérot (2008) stated that the CBB population trapped in synthetic ethanol is lower than methanol. The ethanol concentration generates 50% of the total chemical compounds that repell the female beetles. (E, E)-α-farnesene is released by coffee berries to protect them from CBB. However, the mixture of (E, E)-α-farnesene and the attractant can increase the number of trapped beetles (Vega et al., 2017). The frontalin produced by coffee berries works as a repellent, while brocaine is an attractant for the beetles (Njihia et al., 2014). The "cap tikus" brand ethanol is significant for trapping the beetles, but its concentration must be updated to lower or higher levels. Ramli et al. (2019) explained that a 30% attractant concentration can effectively reduce the beetle population by 10% or 50% concentration. The synthetic attractants with the trademark of Hypotan 500 SL, Koptan, and Antrakop 500 L show insignificant results in trapping the insects, but Koptan L catches more because it is formulated with the active ethanol (Girsang et al., 2020).

Commonly, herbivorous insects will seek a suitable host location as a food source and lay eggs using volatile attractants. The insects are attracted to the trap due to color, light, and chemical compounds (Yi et al., 2012). The combination of volatile compounds is connected to the number of female beetles and other insects in the field. Although the ethanol can only catch a few CBB, the mixture of methanol and ethanol can be synergistic in attracting many more beetles (Table 1). The combination of various volatile compounds significantly influences the attractiveness of the CBB female population (Mendesil et al., 2009).

Table 1. Number of trapped of CBB on methanol, ethanol, and mixture of both every 5 day observation

Measurement/ day	Treatments					Value	
	Methanol-Ethanol 3:1	**Methanol-Ethanol 2:1**	**Methanol-Ethanol 1:1**	**Methanol**	**Ethanol**	**F**	**p**
5	24.00±13.08 c	18.75±10.24 bc	15.25±2.87 ab	11.00±4.24 ab	5.75±1.25 a	4.24	0.023
10	46.50± 9.15 bc	56.75±30.56 c	41.75±30.22 bc	23.00±19.41 ab	7.25±2.98 a	3.82	0.032
15	157.75±109.01 b	152.25±67.30 b	133.00±97.35 b	100.25±42.13 ab	18.25±5.32 a	3.71	0.035
20	81.00±32.23 b	82.00±23.19 b	62.00±33.43 b	48.50±32.21 ab	8.75±3.77 a	5.41	0.010
25	93.73±31.93 c	90.25±21.63 bc	81.50±31.93 bc	57.00±25.58 b	13.50±3.69 a	9.06	0.001

Remarks: The captured CBB population using methanol, ethanol, and their mixture had a significant impact on the measurements taken from 5 to 25 days with p-value < 0.05. The mean values in the columns followed by the same letter indicate no significant difference ($p > 0.05$) in Duncan's Multiple Range Test (DMRT). The values presented in the table are the average scores of all parameters measured

The combination of methanol-ethanol successfully trapped more beetles than the separated synthetic ethanol and methanol from the 5th to 25th day of observation (Table 1). The resistance of methanol-ethanol to attract the insects is strongly dependent on the volume. The lower volume applied resulted in shorter attractant resistance. This would influence the number of trapped female beetles. Seven cycles of the methanol-ethanol mixture can catch 19.13 individual beetles (Situmorang et al., 2018). There are 29.8 beetles caught within one month (Uemura-lima et al., 2010). Based on previous research, the methanol-ethanol mixture can only attract a few numbers of beetles, but the mixture of methanol and ethanol caught more insects. Therefore, it is recommended to monitor and control female beetles on coffee plants. The use of coffee bean extract attractant has better results in attracting CBB female beetles than the combination of methanol-ethanol (Dufour & Frérot, 2008). Coffee has polar bioactive compounds and an attractive aroma for beetles (Marcelinda et al., 2016).

The CBB population trapped by the methanol-ethanol combination and separated methanol is calculated using the standard deviation. The result shows that the distribution of the sample data was less varied. It means that the trapped beetle population generated normally distributed data and there was no bias because the average value was higher than the standard deviation. However, other data show that the female beetle population was spreading highly on day 15. This is because the average value is almost the same as the standard deviation, especially Methanol-Ethanol 3:1 and Methanol-Ethanol 1:1 (Table 1). The methanol-ethanol traps were located at some points on coffee trees. The obtained data show that the beetle population density was classified as high, but it was only found in certain places. Placing the traps of methanol, ethanol, and a mixture of both on coffee trees resulted in a similar population of female beetles.

The traps were placed on lush coffee trees with less sunlight exposure in order to catch a relatively high number of beetles. It is assumed that to get a higher population density of female beetles, it is better to place the attractant on a lush coffee tree. Ruiz-Diaz & Rodrigues (2021) catching CBB populations with attractants is influenced by the density of coffee plants, varieties, and plant cultivation systems. Attractants have some volatile properties, so they must not be located in open spaces and scattered vertically or horizontally where there is a strong wind because the female beetles will not be able to detect the attractant well. The researcher assumes that the traps hung on high coffee trees can affect the capture of beetle populations. However, the fact is that there has not been accurate data on the influence of the height of traps on the effectiveness of the attractants. Uemura-Lima et al. (2010) described that the traps that are located 0.5, 1.0, and 1.5 m from the land surface do not significantly influence the number of the caught CBB population. Sihaloho (2019) reported that if an attractant trap is placed at 1.5 m height, it can catch 8.33 adult beetles, higher than if it is hung at 1 m and 2 m. In contrast, Sinaga et al. (2015) showed that a height of 1.2 m is the best for trapping CBB.

The best ratio of the “cap tikus” brand methanol-ethanol to trap the beetles was 3:1 (28.19 %) and 2:1 (27.98 %), 1:1 (23.33 %), and methanol alone (16.73%). Meanwhile, the worst ratio was ethanol alone (3.74%). The methanol–ethanol mixture performed the best response to catch CBB. The ratios 3:1 and 2:1 improved the possibility of a higher number of trapped beetles (Fig. 1). Ethanol should be mixed with methanol to improve the attractant’s effectiveness. The 3:1 ratio showed an increasing number of trapped CBB (Sihaloho, 2019; Sinaga et al., 2015), but the number was still relatively low, and be more effective by using the methanol-ethanol mixture. The use of 3:1 and 1:1 ratios of methanol-ethanol attractants did not show significant results (Messing, 2012; Rostaman & Prakoso, 2020). 1:1 methanol-ethanol performs limited results for trapping CBB (Njihia et al., 2014). If the methanol-ethanol and (E, E)-α-farnesene are combined, the trapped population will be 59% lower than using the attractant that contains methanol-ethanol (Vega et al., 2017).

Development of CBB Population

There are fluctuating numbers of trapped beetles using the methanol-ethanol attractant. On day 5, there were only limited trapped beetles. The population dynamic and attack intensity of *Helopetis antonii* in the three cocoa plantations are different in a year (Syarief et al., 2018). Then, the number of female beetles caught was getting higher, and reached the highest on day 15. There is a decline on days 20 and 25, but the decline in the beetle population was still relatively low because the population density was still higher than the population density on five and 10 days (Fig. 2). The decreasing number of beetles on day 20 was caused by environmental factors. During the day 25 to 20, there were heavy rains that fall on the coffee plant. The rainfall had made the female beetles less active to fly. The dynamics of the female beetles' population are influenced by their flying activities. Microclimate factors found in coffee plants could influence beetles to fly somewhere. Johnson & Manoukis (2021) stated that the metabolism and development of the CBB population are closely related to sunlight exposure, cumulative rainfall, temperature, humidity, and wind speed to a certain extent. The beetles actively fly at temperatures of 20-26˚C, humidity below 94%, and rainfall of 100 mm. If the rainfall is higher than 100 mm, they will reduce their flying activities. The rainfall can also affect the female beetle population, and even increase the mortality rate (Aristizábal et al., 2016). *Scirtothrips dorsalis* population development is influenced by climatic conditions such as rainfall, temperature, and relative humidity (Affandi et al., 2019). Temperature and sunlight are also influential factors for their effect because they are poikilothermic. Insects need heat from the environment to support their metabolic activities. Insects are poikilothermic, so their bodies are affected by the surrounding temperature. They have an optimum temperature range to move and mobilize their bodies. They can die or stay static if they are below or higher than the optimum temperature tolerance range.

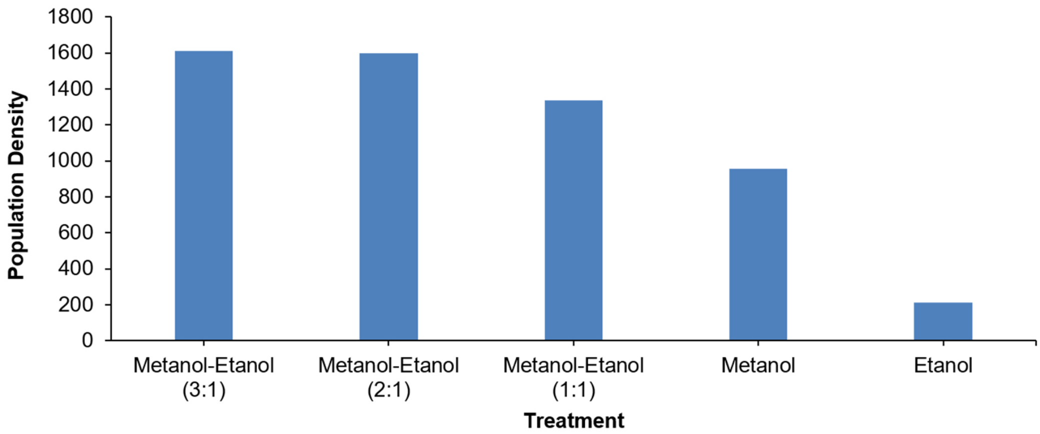

Fig. 1. The highest total population of trapped female CBB beetles on 3:1 (3 methanol to 1 ethanol in "cap tikus"), and 2:1 (2 methanol to 1 ethanol in "cap tikus"), with the smallest captured population noted in the methanol and ethanol "cap tikus" after a 25-day period

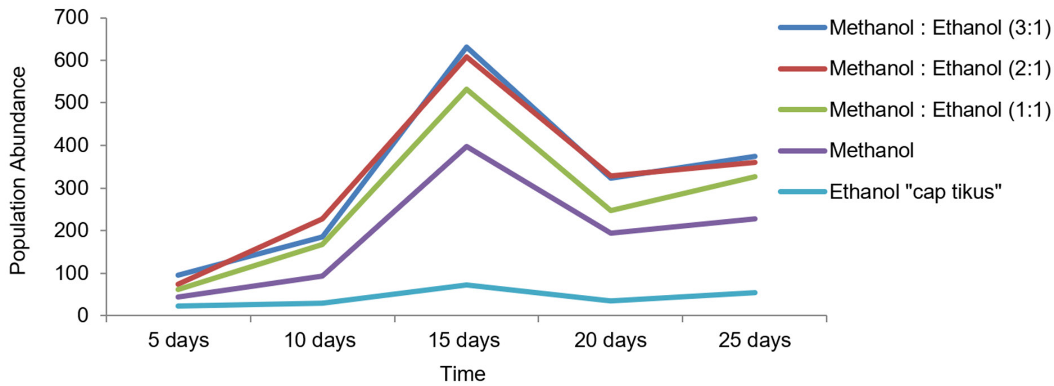

Fig. 2. The population growth of female beetles was highest with the methanol to ethanol ratio in the "cap tikus" and was lowest with the "ethanol cap tikus" over a span of 25 days. The peak in beetle population capture occurred 15 days after the attractant traps were deployed across all treatment scenarios

Table 2. Coleoptera Insect population trapped in the attractant after 25 days

No	Type of beetle	Population				
		Methanol:Ethanol 3:1	Methanol:Ethanol 2:1	Methanol:Ethanol 1:1	Methanol	Ethanol
1	Coleoptera					
	Curculioniodae	4	0	0	0	0
	Xyleborinus	12	9	6	8	6
	Xylosandrus	5	3	2	4	2
2	Nitidulidae					
	Carpophilus	17	9	11	4	5
3	Silvanidae					
	Ashverus	7	4	5	2	5
4	Staphylinidae	1	2	0	2	2
5	Carabidae	1	1	0	1	3
6	Scarabaeidae	0	2	1	1	2
7	Coccinellidae	1	0	0	0	0
8	Tenebrionidae	6	3	4	0	2
9	Cerambycidae	0	1	1	0	1

Remarks: Eight orders of non-target insects were captured, with Coleoptera being the most dominant among the captured insects. The attractants showed a higher effectiveness for the Coleoptera order

Ramli et al. (2019) showed that the most population found is at week 5 and it will reduce from week 6 to 8. This fluctuation is based on the life cycle of CBB. Starting from an egg to become a female beetle, they need more or less a month. On the other hand, the fluctuating population is also caused by their dependency on microclimate factors such as temperature and rainfall. As described earlier, the rainfall directly affects female beetles. Besides, rainfall and temperature indirectly influence female beetles' activities. The rainfall and temperature also indirectly affect the attractants' evaporation. The evaporation process will be more effective if the air is hot. It will release a fragrant aroma to attract female beetles.

Agriculture Research Institute (IAPAR) traps using ethanol-methanol can only catch a few CBB from March and July. The traps will be more effective if they are placed in August when there is dry fruit on the trees and soil surfaces (Pereira et al., 2012). This research tried to study the development of the female beetle population on a small scale of approximately 1.5 months. Therefore, there should be additional information about the beetles' activities from planting the coffee to the harvesting season, so that there would be more accurate data to identify the dynamics of CBB flying activities. More accurate information on female beetle population dynamics can be obtained by measuring specific factors continuously within a longer time limit. The information about the dynamics of the CBB population could be used to develop a threshold for control measures against female beetles. CBB control techniques using attractants should be carried out on coffee plants that have started to bear fruit. The programs must be continued to the harvesting season to prevent significant damage to coffee berries.

Before this three-month experiment, local farmers harvested coffee berries simultaneously at the research location. There are only limited numbers of orange and red coffee berries because most of them are green. Meanwhile, orange and red coffee berries are food, mating, and shelter for female beetles. Trapped beetles increased, and the most trapped beetles were found on day 15. The trapped beetles might come from another coffee plantation around the research site.

The Population of Non-Targeted Insects

The attractant compounds of methanol and ethanol were not specific for CBB. They also applied to other types of insects. Some important insects for controlling crop pests like honey bees and parasitoids were not found in the traps. The trapped non-targeted insects were divided into 8 orders, namely Coleoptera, Hymenoptera, Lepidoptera, Hemiptera, Orthoptera, Diptera, Blatoedea, and Dermaptera. The most dominant non-targeted insect was *Dolichoderus* sp. (Formicidae) as many as 391 adult insects (6.23%). *Dolichoderus* sp. is more attracted to the "cap tikus" brand ethanol than its combination with methanol. Situmorang et al. (2018) stated that besides Scolytidae, there are also 231 adult insects Formicidae found. Siregar & Dewiyana (2016) showed that the Formicidae and Scolytidae have higher population density due to the suitability of habitat and food sources.

Dolichoderus sp. is beneficial for agricultural ecosystems because it is a predator against plant pests. It consumes the eggs of the cocoa pod borer, *Conopomorpha cramerella*. The targeted insects trapped by the methanol were 91.10%, and the rest (9.02%) were non-targeted ones. Siregar & Dewiyana (2016) stated that CBB trapped by the attractants may reach 95%. Commonly, the non-target insects are trapped coincidentally, because there are only 1-2 individuals found in the traps. The most dominant non-targeted insects are Coleoptera (165 or 2.62%) (Table 2) and Hymenoptera (403 or 6.42%).

The most dominant types of trapped beetles were the Curculionidae (CBB) and *Nitidulidae* (*Carpophilus* sp.) families. *Carpophilus* sp. was dominant in the coffee plant ecosystem, but its role in the coffee plant ecosystem has not yet identified. Rimbing et al. (2021) showed that *Carpophilus* sp. and *Ambrosiophilus* sp. are the carriers of fungal pathogens.

CONCLUSION

The combination of methanol and ethanol "cap tikus" can be synergistic in fighting against and trapping CBB beetles. The ratios of 3:1 and 2:1 were the most effective to catch the female beetles on the plantation. The trapped population was fluctuating, and the highest number was found on day 15. The use of attractants to suppress the female beetle population must be done continuously until the harvesting session to prevent significant damage to the coffee berries.

ACKNOWLEDGEMENT

The author expresses his sincere gratitude to the Rector of Sam Ratulangi University and the Head of the Institute of Research and Community Service of Unsrat who have sponsored this study.

REFERENCES

Affandi, de Rosa Medina, C., Velasco, L.R.I., Javier, P.A., Depositario, D.P.T., Mansyah, E., & Hardiyanto. (2019). Population dynamic of *Scirtothrips dorsalis* Hood (Thysanopetera: Thripidae) on mango and associated weeds under low and intensive agricultural practices. *AGRIVITA Journal of Agricultural Science, 41*(3), 575–585. http://doi.org/10.17503/agrivita.v41i3.2316

Aristizábal, L. F., Bustillo, A. E., & Arthurs, S. P. (2016). Integrated pest management of coffee berry borer: Strategies from Latin America that could be useful for coffee farmers in Hawaii. *Insect*, *7*(6), 1-24. https://doi.org/10.3390/insects7010006

Castro, A. M., Tapias, J., Ortiz, A., Benavides, P., & Góngora, C. E. (2017). Identification of attractant and repellent plants to coffee berry borer, *Hypothenemus hampei*. *Entomologia Experimentalis et Applicata*, *164*(2), 120–130. https://doi.org/10.1111/eea.12604

De Souza, M. S., Costa, J. N. M., Espindula, M. C., & Silva, A. D. A. E. (2020). Performance of baited traps for integrated management of Hypothenemus hampei Ferrari (Coleoptera: Scolytinae) in a conilon coffee crop in Rondônia State, Brazil. *EntomoBrasilis*, *13*, e913. https://doi.org/10.12741/ebrasilis.v13.e913

Dufour, B. P., & Frérot, B. (2008). Optimization of coffee berry borer, *Hypothenemus hampei* Ferrari (Col., Scolytidae), mass trapping with an attractant mixture. *Journal of Applied Entomology*, *132*(7), 591–600. https://doi.org/10.1111/j.1439-0418.2008.01291.x

Erfandari, O., Hamdani., & Supriyatdi, D. (2019). Keragaman intensitas serangan hama penggerek buah kopi (*Hypothenemus hampei ferrari*) pada beberapa sentra produksi kopi robusta di Provinsi Lampung. *Jurnal Penelitian Pertanian Terapan*, *19*(3): 244-249. https://doi.org/10.25181/jppt.v19i3.1523

Girsang, W., Purba, R., & Rudiyantono. (2020). Intesitas serangan hama penggerek buah kopi (*Hipothenemus hampei* Ferr.) pada tingkat umur tanaman yang berbeda dan upaya pengendalian memanfaatkan atraktan. *Journal TABARO, 4*(1), 27-34. http://dx.doi.org/10.35914/tabaro.v4i1.358

Gugule, S., Fatimah, F., & Maanari, C. P. (2019). Pemisahan dan karakterisasi etanol dari nira aren *(Arenga pinnata)*. IPTEK *Journal of*

Proceedings Series, 4, 13–17. https://iptek.its.ac.id/index.php/jps/article/view/6109

Hayata. (2016). Hubungan persentase serangan hama penggerek buah kopi (*Hypothenemus hampei* Ferr.(*Coleoptera: Scolytidae*)) dengan dugaan kehilangan hasil di Kecamatan Betara Tanjung Jabung Barat. *Jurnal Media Pertanian, 1*(2), 85–90. http://dx.doi.org/10.33087/jagro.v1i2.20

Jaramillo, J., Torto, B., Mwenda, D., Troeger, A., Borgemeister, C., Poehling, H.-M., & Francke, W. (2013). Coffee berry borer joins bark beetles in coffee klatch. *PLoS ONE*, *8*(9), e74277. https://doi.org/10.1371/journal.pone.0074277

Johnson, M. A., & Manoukis, N. C. (2021). Influence of seasonal and climatic variables on coffee berry borer (*Hypothenemus hampei* Ferrari) flight activity in Hawaii. *PLOS ONE*, *16*(12), e0257861. https://doi.org/10.1371/journal.pone.0257861

Marcelinda, A., Ridhay, A., & Prismawiryanti. (2016). Aktivitas antioksidan ekstrak limbah kulit ari biji kopi (*Coffea sp*) berdasarkan tingkat kepolaran pelarut. *Online Jurnal of Natural Science*, *5*(1), 21–30. http://jurnal.untad.ac.id/jurnal/index.php/ejurnalfmipa/article/view/5547

Mendesil, E., Bruce, T. J. A., Woodcock, C. M., Caulfield, J. C., Seyoum, E., & Pickett, J. A. (2009). Semiochemicals used in host location by the coffee berry borer, *Hypothenemus hampei*. *Journal of Chemical Ecology*, *35*(8), 944–950. https://doi.org/10.1007/s10886-009-9685-6

Messing, R. H. (2012). The coffee berry borer (*Hypothenemus hampei)* Invades Hawaii: Preliminary Investigations on trap response and alternate hosts. *Insect*, *3*(3), 640–652. https://doi.org/10.3390/insects3030640

Njihia, T. N., Jaramillo, J., Murungi, L., Mwenda, D., Orindi, B., Poehling, H.-M., & Torto, B. (2014). Spiroacetals in the Colonization Behaviour of the Coffee Berry Borer: A ‘Push-Pull’ System. *PLoS ONE*, *9*(11), e111316. https://doi.org/10.1371/journal.pone.0111316

Oliveira, C. M., Auad, A. M., Mendes, S. M., & Frizzas, M. R. (2013). Economic impact of exotic insect pests in Brazilian agriculture. *Journal of Applied Entomology*, *137*(1–2), 1–15. https://doi.org/10.1111/jen.12018

Pereira, A. E., Vilela, E. F., Tinoco, R. S., De Lima, J. O. G., Fantine, A. K., Morais, E. G. F., & França, C. F. M. (2012). Correlation between numbers captured and infestation levels of the Coffee Berry-borer, *Hypothenemus hampei*: A preliminary basis for an action threshold using baited traps. *International Journal of Pest Management*, *58*(2), 183–190. https://doi.org/10.1080/09670874.2012.676219

Purba, R.P., Bakti, D., & Sitepu, S. F. (2015). Hubungan persentase serangan dengan estimasi kehilangan hasil akibat serangan hama penggerek buah kopi *Hypothenemus Hampei* Ferr.(Coleoptera: Scolytidae) di Kabupaten Simalungun. *Jurnal Online Agroekoteaknologi*, *3*(2), 790–799. https://dx.doi.org/10.32734/jaet.v3i2.10368

Ramli, N., Tobing, M. C., & Bakti, D. (2019). The influence of attractant from coffe bean and outer skin of coffee to imago of coffee berry borer Hypothenemus hampei Ferr. (Coleoptera: Curculionidae) on the field. *IOP Conference Series: Earth and Environmental Science*, *260*(1), 012140. https://doi.org/10.1088/1755-1315/260/1/012140

Rasiska, S., Darmawan, J.A., & Yulia E. (2021). Pengujian air sulingan kulit buah kopi dengan metode destilasi air dan efeknya sebagai atraktan penggerek buah kopi (*Hypothenemus hampei* Ferr.) (Curculionidae:Scolytiidae). *Jurnal Agrikultura*, 32(1), 49–56. https://doi.org/10.24198/agrikultura.v32i1.29960

Rengifo-Munoz, J.C., Rojas J, A., Villamar-Torres, R. O., Reyes-Peres, J. J., & Jazayeri, S. M. (2021). Effectiveness of using attractants to control *Hypothenemus hampei* in Coffea arabica crop in the Ecuadorian Amazon. *AGRIVITA Journal of Agricultural Science, 43*(3), 581-588. https://doi.org/10.17503/agrivita.v43i3.2680

Rimbing, J., Assa, B. H., Pinaria, B. A. N., & Kandowangko, D. S. (2021). Fruit bait traps of vector insect of Phyhtophtora palmivora butl in cocoa plants. *Journal of Entomological Research*, *45*(2), 280–285. https://doi.org/10.5958/0974-4576.2021.00044.X

Rostaman & Prakoso, B. (2020). Response of coffee berry borer *(Hypothenemus hampei)* to alcohol-based attractants on coffee crops in Banjarnegara, Indonesia. *Advances in Biological Sciences Research*, 8, 25–28. https://doi.org/10.2991/absr.k.200513.004

Ruiz-Diaz, C. P., & Rodrigues, J. C. V. (2021). Vertical Trapping of the Coffee Berry Borer, *Hypothenemus hampei* (Coleoptera: Scolytinae), in Coffee. *Insects*, *12*(7), 607. https://doi.org/10.3390/insects12070607

Sihaloho, M. R. (2019). *Uji Ketinggian dan Perangkap Atraktan untuk Mengendalikan Hama Penggerek Buah Kopi (Hypothenemus hampei Ferr.) (Coleoptera: Scolytidae) di Tanjung Beringin,* *Kabupaten Dairi* [Undergraduate Thesis, Universitas Sumatera Utara]. https://repositori.usu.ac.id/handle/123456789/13718

Sinaga, K.M., Bakti, D., & Pinem M.I. (2015). Uji ketinggian dan tipe perangkap untuk mengendalikan penggerek buah kopi (*Hypothenemus hampei* Ferr.) (Coleoptera: Scolytidae) di Desa Pearung Kabupaten Humbang Hasundutan. *Jurnal Online Agroekoteaknologi*, *3*(3), 829 – 836. https://dx.doi.org/10.32734/jaet.v3i3.10705

Siregar, A. Z., & Dewiyana, H. (2016). The use of traps to detect *Hypothenemus Hampei* In coffee plantation In Dairi , North Of Sumatra, Indonesia. *International Journal of Scientific & Technology Research*, 5(10), 217-220. https://www.ijstr.org/final-print/oct2016/The-Use-Of-Traps-To-Detect-Hypothetamus-Hampei-In-Coffee-Plantation-In-Dairi-North-Of-Sumatra-Indonesia.pdf

Situmorang, W.N., Marheni., & Siregar, A.Z. (2018). Uji tipe dan ketinggian perangkap untuk mengendalikan penggerek buah kopi *Hypothenemus hampei* Ferr. (Coleoptera: Scolytidae) di Desa Pegagan Julu II Kecamatan Sumbul Kabupaten Dairi. *Jurnal Pertanian Tropik, 5*(1), 113-119. https://doi.org/10.32734/jpt.v5i1.3143

Syarief, M., Mudjiono G., Abadi., L., & Himawan, T. (2018). Arthropods diversity and population dynamic of *Helopeltis antonii* Sign. (Hemiptera: Miridae) on various cocoa agroecosystems management. *AGRIVITA Journal of Agricultural Science, 40*(2), 350–359. http://doi.org/10.17503/agrivita.v39i2.1038

Uemura-Lima, D. H., Ventura, M. U., Mikami, A. Y., Silva, F. C. D., & Morales, L. (2010). Responses of coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae), to vertical distribution of methanol: Ethanol traps. *Neotropical Entomology*, 39 (6), 930-933. https://doi.org/10.1590/S1519-566X2010000600013

Vega, F. E., Simpkins, A., Miranda, J., Harnly, J. M., Infante, F., Castillo, A., Wakarchuk, D., & Cossé, A. (2017). A Potential Repellent Against the Coffee Berry Borer (Coleoptera: Curculionidae: Scolytinae). *Journal of Insect Science*, *17*(6), 1-9. https://doi.org/10.1093/jisesa/iex095

Wiryadiputra, S. (2014). Pola distribusi hama penggerek buah kopi (*Hypothenemus Hampei*) pada kopi arabika dan robusta. *Pelita Perkebunan* 30(2), 123-136. https://doi.org/10.22302/iccri.jur.pelitaperkebunan.v30i2.5

Yi, Z., Jinchao, F., Dayuan, X., Weiguo, S., & Axmacher, J. C. (2012). A Comparison of Terrestrial Arthropod Sampling Methods. *Journal of Resources and Ecology*, *3*(2), 174–182. https://doi.org/10.5814/j.issn.1674-764x.2012.02.010