



Response of the coffee berry borer (*Hypothenemus hampei*) to attractant traps in Robusta coffee plantations

JIMMY RIMBING^{1*}, REITY ENGKA¹, SHERLIJ DUMALANG¹ and FRANGKY RORONG¹

Faculty of Agriculture, Sam Ratulangi University, Manado 95115, Indonesia

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ABSTRACT

Coffee berry borer (CBB), *Hypothenemus hampei* Ferrari, is a big challenge for farmers worldwide. The CBB life cycle may be found in coffee beans, making attractant traps an effective management method. Furthermore, during 2021 and 2022, the attractant traps were used to examine the effect on population density in Robusta coffee plantations. The treatment consisted of *Cap Tikus* ethanol (local), methanol, and a mixture of *Cap Tikus* ethanol-methanol. The results showed that all three traps could attract female beetles, and the highest CBB population caught was in 2021. A significant mixture towards the population was 68.15 ± 60.42 CBB/trap/7 days and 35.75 ± 8.39 CBB/trap/7 days in 2021 and 2022. The lowest fluctuation population of beetles caught was in *Cap Tikus* ethanol. The population was low at the first 7 days of observation, then increased at 21 and 28 days in 2021 (418–532 CBB/7 days) and 2022 (194–294 CBB/7 days). Furthermore, the high rainfall and rainy days negatively affect the caught beetles' population. Based on the results, the attractant traps are a method to monitor and control CBB in coffee plants.

Keywords: Attractants, Coffee berry borer, Robusta, Traps

Indonesia is the world's fourth largest coffee producer after Brazil, Vietnam, and Colombia. The dominant cultivation of this country is 90% robusta and 10% arabica, even though the market share is dominated by arabica coffee. The main problem in coffee-producing countries is CBB, *Hypothenemus hampei* (Coleoptera: Curculionidae), which attacks coffee beans from planting to storage. Young and old berry attack cause falls and decrease in quality and quantity. CBB remains a major challenge for farmers because this pest lives inside the coffee beans. The damage exceeds 50% in Indonesia (Wiryadiputra 2012) and can reach 80% in untreated coffee plantations (Silva *et al.* 2012). Defective coffee beans negatively affect the composition of their chemical compounds, especially caffeine and reducing sugars. Annual losses are around US\$ 500 million, and 25 million farmers are affected by CBB worldwide (Jaramillo *et al.* 2013).

Endosulfan insecticides are commonly used to control CBB but cause resistance (Uemura-Lima *et al.* 2010). 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 contamination on coffee berries makes them more resistant. The attractants can be an alternative to reduce the use of synthetic insecticides for beetle control. Using kairomone compounds or attractants is an appropriate and environmentally friendly control solution. The attractants are important in monitoring pest populations to determine when and where control is warranted for decision making that would lead to appropriate management intervention. Meanwhile, attractants are chemical compounds to attract beetles and produce smells capable of stimulating their returns. *Cap Tikus* ethanol and methanol are volatile attractant compounds and play a role in attracting insects. A 1:1 ethanol-methanol mixture is widely used as a trap for CBB beetles. The highest population caught in the ethanol-methanol mixture was compared separately (Silva *et al.* 2006, Dufour and Frerot 2008), and the trapping can reduce coffee berry damage by 80 to 85% (Margina *et al.* 2016). Testing of *Cap Tikus* brand ethanol and methanol attractants was conducted for two years. Therefore, the research aims to describe population abundance in the mixture and *Cap Tikus* ethanol and methanol separately in 2021 and 2022.

MATERIALS AND METHODS

The present study was carried out at Modayag Sub-district, North Sulawesi Province (675 m amsl, 00°72'08.0

¹Faculty of Agriculture, Sam Ratulangi University, Manado, Indonesia 95115. *Corresponding author email: jimmyrimbing@gmail.com

“N, 124°00’06.9 “E), during 2021 and 2022 on the robusta coffee plantations. Robusta coffee are planted in monoculture with a spacing of 2.5 m × 2.5 m. Moreover, it grows well, and there are shade plantations of tiger’s Claws (*Erythrina* sp). Rainfall data were obtained at the Agricultural Extension Center in Modayag, and the distance from the experimental location was ±1.0 km. Trials testing *Cap Tikus* ethanol and methanol attractants were carried out in 2021 and 2022. From April to June, experimental activities were conducted on coffee plantations aged ±15 years. *Cap Tikus* ethanol is a local wisdom of North Sulawesi obtained through simple distillation by the farming community from the male flowers of *Arenga pinnata* palm trees, while synthetic methanol is readily available in the market.

The *Cap Tikus* ethanol and methanol attractant traps experiment was arranged in a Randomized Block Design (RBD) with 3 treatments and 4 repetitions. The attractant treatment consisted of methanol (99%), *Cap Tikus* ethanol (50%), and a mixture of *Cap Tikus* ethanol-methanol (1:1). The attractant traps were placed in rows of coffee plants, and each point was placed in one attractant trap. The attractant traps were randomized in rows of coffee plants, and 4 repetitions resulted in 12 traps per year (3 treatments × 4 repetitions × 2 years = 24 traps). The experimental area is 0.2 ha, the distance between traps in rows is 10 m, and between replicates (blocks) is 20 m. During the 7 days, the attractants in the coffee plantations were replaced, and the insect population was sampled. Beetle population sampling was taken 5 times with an interval of 7 days, and the 50% *Cap Tikus* ethanol content was measured with an alcohol meter. A 1.5 litre capacity mineral bottle is made with a 5×7 cm hole as a place for CBB to enter. A 25 ml bottle (3×5 cm) as place for the attractant is hung in a mineral bottle, filled with 200 ml water + 2 ml of liquid detergent as a reservoir for insects. *Cap Tikus* ethanol and methanol are mixed according to the treatment and then put into the bottle. The bottle was made with several holes measuring 0.5 mm to allow the attractant to diffuse and attract female CBB beetles. Each *Cap Tikus* ethanol-methanol mixture treatment was used at 15 ml for 7 days. The attractant traps are hung on coffee plants with a height of ±1.25 m from the ground. The abundance of the CBB population was based on the ratio of the ethanol-methanol and was analyzed separately for variance. Subsequently, it was tested for a significant (P<0.05; DMRT) using Duncan’s test on the SPSS version 23 program.

RESULTS AND DISCUSSION

The abundance of beetle populations: The attractant traps positively affected the CBB population caught. Attractants like ethanol and methanol pique a beetle’s interest since they are gaseous volatile chemical compounds that can influence the insect’s behavior towards prey. Ethanol and methanol attractants are gradually released into the air as vapour or gas. The smell produced usually lures the CBB insects to enter the trap, where they collide with the inside of a bottle and fall into the soap solution at the bottom, leading

Table 1 The abundance of the CBB beetle population in 2021 and 2022

Attractant	CBB Population/Trap/7 Days	
	2021	2022
<i>Cap Tikus</i> ethanol	9.95±6.06 a	6.10±1.85 a
Methanol	66.80±44.31 b	28.8±20.67 b
<i>Cap Tikus</i> ethanol - methanol	68.15±60.42 b	35.75±8.39 b

Columns followed by the same letters were not significantly different (P>0.05; DMRT).

to death after losing the ability to fly or escape. Aside from CBB caught, insects of the order Hymenoptera, Coleoptera, Orthoptera, Diptera, Dermaptera and Lepidoptera were found, but the population was insignificant. This indicates a specific ethanol-methanol mixture on CBB. Attractants traps was not found natural enemies for plant crop pests. The application of the attractant traps significantly affects the abundance of the population caught for 2021 P<0.03 and 2022 P<0.008, for 5 times taking population samples.

The maximum population caught sample is in the *Cap Tikus* ethanol-methanol mixture for 2021 and 2022 at 272 CBB/trap/7 days (10.81%) and 92 CBB/trap/7 days (6.53%). Insect flight is affected by many factors, including rainfall, rainy days, attractant diffusion, wind, and temperature. Trapped Scolytinae beetles are affected by flight, temperature, relative humidity, and wind speed (Dossantos *et al.* 2022, Wermelinger *et al.* 2021). The measured abiotic factors are still limited to rainfall. Furthermore, rainfall and monthly rainy days have had a negative effect on the captured beetle. Likewise, the small-sized CBB has limited movement by rainfall. The results include the rainy season, except for June, which is the dry season, because the monthly rainfall is <100 m (Table 2). Dayantolis *et al.* (2016) stated that monthly rainfall was >150 mm and <150 mm, including the rainy and dry seasons. Monthly rainy days are the main factor influencing the abundance of the population caught. The number of rainy days in 2021 was lower in 2022, hence, the population caught is high.

Increases in temperature and rainfall positively or negatively affect the beetle population. Warmer temperatures in Brazil have a positive correlation with higher number of Scolytinae insects, *Xyleborus affinis* (Silva *et al.* 2020). Areas with low air temperatures experience increased CBB attacks, specifically on unshaded coffee plants. There are often more attacks on coffee plants during the dry than rainy

Table 2 Rainfall situation in Modayag Sub-district

Rain	2021			2022		
	April	May	June	April	May	June
Rainfall	208 mm	438.8 mm	92.3 mm	169 mm	357 mm	81.50 mm
Rainy day	7	12	8	12	18	9

Source: Agricultural Extension Center in Modayag.

season. The altitude of a place affects air temperature because at higher altitudes, the condensation process is faster and the temperature becomes lower (Prakoso *et al.* 2018). It also affects humidity and wind, which both influence the spread of insects. This aspect is closely related to the impact of air temperature changes in limiting insects' metabolism and life processes including feeding, growth, and development. CBB female beetle flights occur at temperatures of 20 to 26°C, humidity below 94%, and rainfall at 100 mm. Heavy rain of more than >100 mm reduces alcohol volatilization and inhibits beetle flight (Johnson and Manoukisi 2021, Sanguansub *et al.* 2020). Meanwhile, wind speed may assist and provide olfactory cues for resources, but strong gusts impede flight. The population caught is still relatively high in the *Cap Tikus* ethanol-methanol mixture. Uemura-Lima (2010) noted that from March through April, several populations were caught using 1:1 ethanol-methanol traps, with a total of 21.1 ± 9.53 CBB collected. The ethanol-methanol mixture has not been significant for the population caught. Rostaman and Prakoso (2019) application of ethanol-methanol (1:1) on coffee plants caught the highest and lowest CBB population of 29 CBB/7 days and 2 CBB/7 days. *Cap Tikus* ethanol from palm trees is an appropriate attractant mixed with methanol to increase the population. Furthermore, the CBB population caught 8.8 CBB/trap/2 days on coffee beans, better than berry skins of 4.0 CBB/trap/2 days (Rasiska *et al.* 2016). The attractant releases several volatile chemical compounds to attract insects, perhaps becoming the repellent. About 50 volatile compound components can attract insect pests. The dominant volatile chemical compounds include spiroacetal, conophthorin, frontalin, and methyl 3-ethyl-4-methyl pentanoate (Jaramillo *et al.* 2013). The ethanol-methanol attractant combined with frontalin has a repellent effect and affects the catch of 77% CBB in coffee plantations (Njihia *et al.* 2014).

Cap Tikus ethanol is a volatile compound but less responsive to CBB, and the population caught is known to be relatively low (Table 1). In the methanol and *Cap Tikus* ethanol-methanol experiment, the population caught with the highest tendency was found in the *Cap Tikus* ethanol - methanol mixture. Meanwhile, the CBB population was caught at ethanol 1.4 ± 1.2 CBB/trap/11 days (Dufour and Frerot 2008), and the volatile compounds diffused highly depending on temperature. *Cap Tikus* ethanol diffuses slowly, affecting the population caught, and the compounds occur through evaporation at high temperatures. The diffusion speed affects the captured population. The diffusion rate of volatile chemicals into the attractant trap is optimized at 0.175 g/trap/day (Dufour and Frerot 2008). Mathieu *et al.* (1997) stated that catches decreased for ethanol-methanol release rates of 1.5–20 g/day.

The *Cap Tikus* ethanol slow diffusion can be seen in 15 ml for 7 days on coffee plants. There is still 5 to 7 ml/bottle compared to the *Cap Tikus* ethanol-methanol mixture of 1–2.5 ml/bottle. The more attractant solution remaining in the trap, it means that less is evaporated, conversely if there is less remaining attractant solution, it

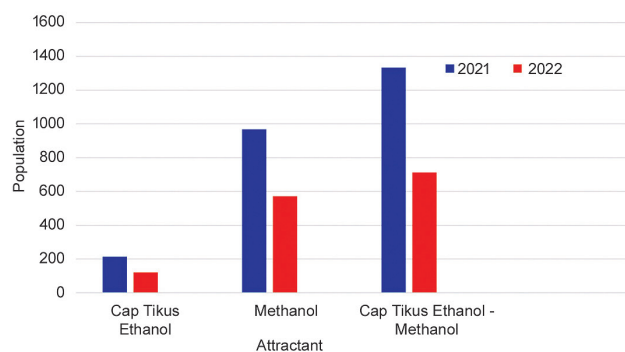


Fig 1 The abundance of CBB beetle populations caught in attractants for 35 days.

means more is evaporated. The diffusion rate probability is very low, affecting the capture population. The lower the temperature, the longer the shelf-life of the attractant compounds. Furthermore, the higher the air temperature, the faster the active period of volatile compounds ends. During the research, the rainy season affected the decrease in air temperature, made the attractant last a long time, and affected evaporation with an impact on the beetle population caught. The mixture of carpet-methanol ethanol has a synergistic effect on the captured population (Table 1) and acts as a strong attractant against female beetles. Volatile compounds mixed with others may not necessarily be able to attract certain insects. Meanwhile, a mixture of ethyl acetate-methanol or ethanol-ethyl acetate cannot increase the CBB population compared to ethanol-methanol (De Souza *et al.* 2018). Ethylene is a potential attractant for natural enemy insects such as ants but this compound has less effect on the CBB (Castro *et al.* 2017). The chemical compounds did not have a repellent effect on the beetles, and the highest population caught was in the *Cap Tikus* ethanol-methanol mixture (Table 1, Fig 1).

The *Cap Tikus* ethanol and methanol were insignificant in the population caught, except for the mixture (Fig 1). The maximum population was in the *Cap Tikus* ethanol-methanol mixture of 2021 and 2022 at 53.02% and 50.68%, which was higher than in each. In the ethanol-methanol trap (1:1), the total CBB population caught is low (Uemura-Lima *et al.* 2010, Rostaman and Prakoso 2019), and the application showed a population of 30–40 CBB/14 days (Sihaloho 2019). The CBB population level is linked to the size of the attacked coffee fruit. According to Sinaga *et al.* (2015), since adult insects attack coffee fruit for food, ethanol-methanol traps placed at a height of 1 m will effectively catch CBB, with an average of 5.33 individuals affecting 23.33% of the fruit. Population density has a relationship with the percentage of attacks and yield loss. The intensity of attacks performed by the CBB pest depends on food availability, rainfall, and environmental temperature. Temperature changes greatly affect insect population dynamics, including physiology, abundance, distribution, and development (Shi *et al.* 2011). Environmental temperature affects insects' metabolism by hampering their survival ability, leading to

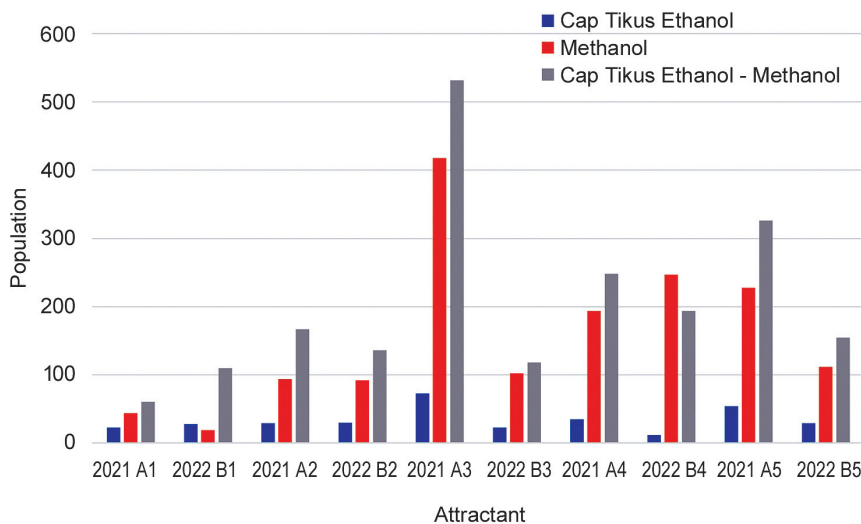


Fig 2 The abundance of CBB populations caught at attractants 7 days/5 times sampling (35 days).

decreased abundance.

The population development of CBB: Catching beetle with fluctuating attractants. In the initial 7 days, the population caught was low and then increased in the second observation. It reached a population peak of 21 and 28 days in 2021 and 2022 as shown in Fig 2. Furthermore, the CBB population fluctuated, and the initial population was low, but there was an increase in subsequent observations (Rostaman and Prakoso 2019). Population decline occurred between 21 and 28 days due to high rainfall of 40.2–70.5 mm/day, affecting the population.

Due to the rainfall, female beetles are less active in flying and slow the diffusion of the attractants because the air temperature becomes low. The evaporation can be better when the air temperature increases and releases the scent. It shows that the dynamics of the beetle population are related to climate. Furthermore, the rainfall factor decreases the female beetle population and can even increase mortality (Aristizabal *et al.* 2016). Temperature and sunlight are factors affecting insect activity as Poikilotherms. Insects need heat from their environment to start metabolic activities and are poikilothermic. Beetles may die or not mobilize when below or above the optimum temperature tolerance range. Population fluctuations are related to the CBB, where the life cycle from egg to beetle is ± 1 month. Meanwhile, the population increase is the second generation of the CBB population, because of duration of population caught more than 1 month. The IAPAR traps baited with ethanol-methanol had very low caught CBB in March and July, then increased in August when dried berries began to appear on trees and the soil surface (Pereira *et al.* 2012). CBB insects will attack coffee plants more during the dry season than during the rainy season.

Integrated pest management (IPM) is a strategy for controlling pests through the combination of various methods, including physical and mechanical controls with attractants, cultural techniques, and biological controls to

achieve significant population decline. This approach reduces losses caused by the CBB more effectively. In Indonesia, the implementation of IPM for the CBB in coffee plants involves tree sanitation, pruning, using predators (birds and ants), parasitoid *Prorops nasuta*, and entomopathogenic *Beauveria bassiana*, as well as monitoring with traps (Wiriyadiputra *et al.* 2008). Based on the CBB population caught, the optimal density for ethanol-methanol attractant traps to achieve maximum capture in coffee plantations is 22–24 traps/ha.

All attractants can be used as CBB traps, but the maximum trap was caught in the ethanol-methanol mixture (1:1). Therefore, it can be programmed for monitoring and control. For two years, research has shown that the population caught in 2021 will be higher in 2022, and the amount of rainfall and monthly rainy days negatively or positively affect the beetle population caught.

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