Control of *Conopomorpha cramerella*, *Helopeltis* sp., and *Phytophthora palmivora* using botanical and biological pesticides

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Abstract. Control of main pests and diseases of cocoa using biopesticides has been carried out on a 10 ha farmer land in the village of Liliariawang, South Sulawesi. The aim is to determine the effectiveness of α-elaeostearic acid and Citronellal formulas of botanical pesticides, and *Beauveria bassiana* of biological pesticide on pod borer (*Conopomorpha cramerella*), fruit suckers (*Helopeltis* spp.), and fruit rot (*Phytophthora palmivora*) of cocoa. The treatments were arranged in a randomized group. Sampling was carried out systematically as much as 120 healthy cocoa fruits <8 cm long from about 40 sample plants in each treatment to observe the extent of damage. The sample fruits are sprayed treatments every 2 weeks until harvest. Observations were made on the degree of damage to the fruits and their effects on non-target organisms such as natural enemies of pests. The results shows that both of botanical pesticides and biological pesticide can reduce the intensity attacks of the cocoa pests and diseases. Yield loss in all treatments were below 10%, lower and significantly different compared to control which reach 36.5%. In addition to reducing damage caused by pests, the quality and weight of the cocoa beans produced was better than the control.

Keywords: α-elaeostearic acid, Citronella, *Beauveria bassiana*, cocoa, pest and disease

1. Introduction

Cocoa is one of the important plantation crops in Indonesia as a foreign exchange earner, a source of income for farmers and other communities. The problem of yield loss due to attack by Plant Pest Organisms is one of the main obstacles in cocoa cultivation. It is estimated that the average yield loss due to pests reaches 30% every year, there are even diseases that can cause plant death [1], so that the cost of pest and disease control in cocoa plantations reaches around 40% of the cost production [2].

Several pests and diseases are reported attacking cocoa plants, including Cocoa Pod Borer/CPB (*Conopomorpha cramerella* Snell) [3], fruit-sucking pests (*Helopeltis* spp) [4], and Black Pod Disease of Cocoa or Cocoa Pod Rot caused by *Phytophthora palmivora* [5], that cause significantly yield losses. To control these pests, farmers are mostly depends on application of synthetic pesticides, so it is feared to cause negative effects on the environment. Utilization of botanical pesticides in the management of plant pests is a promising method of control because the basic ingredients come from plants that are easily biodegradable so that they are relatively harmless to life [6, 7, 8].

Indonesia is the third largest cocoa producer country in the world, after Ivory-Coast and Ghana, whose production value reaches 593,331 tons / year with covering an area of 1,709,284 ha, and almost 97% of the area is smallholder plantations [9].

Pests and diseases are one of the important factors that hinder the achievement of the target of production and quality of cocoa products. It is estimated that an average of 30% reduction in yield...
is due to pest attacks, which include groups of pests, diseases and weeds, even important diseases that cause death if not properly controlled [1]. The main insect pests of cocoa plants include Cocoa Pod Borer (CPB), *Conopomorpha cramerella* and *Helopeltis* spp.

CPB pest, *C. cramerella* (Family Gracillariidae: Order of Lepidoptera) is known attacking cocoa plants in almost all the main cocoa-producing regions in Indonesia. The insect attacks starting from young fruit to ripe fruit, causing cocoa fruit production decreasing by more than 80%; and this insect pest is relatively difficult to be controlled [2]. In addition to reducing the production of this pest attack also causes the quality of seeds to be low [10, 11]. CPB pests were initially only known to attack cocoa in North Maluku and Sebatik Islands in East Kalimantan. Furthermore, in the 1990s these pests have spread rapidly to other areas in East Kalimantan, Central Sulawesi, South Sulawesi, Southeast Sulawesi and other cocoa production centers [12]. This pest can reduce yield up to 82%

In addition to CPB, *Helopeltis* spp (Family of Miridae: Order of Hemiptera) is another pest oftenly found in cocoa plantations. In cocoa plants more than one species of *Helopeltis* species have been reported, namely *H. antonii*, *H. theivora* and *H. claviver* [1]. The nymphs and the imago stages are destructive phase of these pest, attacking young fruit by sticking their mouth tools. While sucking, the ladybug also emits toxic fluids killing cells around the puncture site. Besides the fruit, these pest also attacks young shoots and leaves. Yield lost due to serious infestation of this pest may reach up to 50-60% [13].

Generally, pest control in cocoa plants, farmers still use chemical insecticides. Inappropriate use of chemical insecticides will have a bad impact, more detrimental than the benefits generated, such as can cause pest resistance, the emergence of secondary pests, environmental pollution and product rejections due to residual problems that exceed the tolerance threshold. Control of CPB pest can be carried out in several ways, including sanitation, pruning, frequent harvesting, fertilization, sarongation and biological control [1, 7]. Likewise for the control of *Helopeltis* sp. can be done biologically with natural enemies, sanitation, chemically etc.

The use of botanical pesticides in the management of pests is quite promising because the basic ingredients come from plants, are relatively easy to make and enough with limited ability and knowledge. In addition, because it is made from natural ingredients, namely plant material, these pesticides are easily biodegradable so that they are relatively harmless to life [7, 8]. This pesticide also has a fast influence in inhibiting insect appetite so that it can suppress plant damage. Another advantage is that botanical pesticides usually have a broad and effective control spectrum to control pests that have been resistant to synthetic insecticides.

On the other hand, botanical pesticides still have weaknesses, because they are easily decomposed, the pesticides cannot be stored for long. In addition, since the work effect is relatively slow, the application must be carried out more often than synthetic pesticides. In general, botanic pesticides have a low level of toxicity that does not directly kill the target pest. Mass production of botanical pesticides is still constrained due to limited raw materials.

The use of botanical pesticides originating from plant secondary compounds has been widely used to control agricultural plant pests [14]. With the increasingly urgent need and public awareness of environmentally friendly controls the use of botanical and biological pesticides in the control of integrated plant pests and diseases is increasingly needed, in addition to other safe control methods. The Agricultural Research and Development Agency through the Center for Plantation Research and Development has produced many botanical and biological pesticides products [15]. These products have been patented and some of them have been widely used at the farm level. In order to control cocoa pests, field scale test has been carried out to determine effectiveness of plant and biological based pesticides, for controlling of mainpests and diseases of cocoa.

2. Materials and Method

2.1. Time and Location

The research was carried out in farmer’s cocoa plantation about 12 – 15 years old in Liliariawang village, Bengo sub-district, Bone district, South Sulawesi Province from January – December 2016.
2.2. Materials and Equipment
The material used was cocoa plantation, botanical pesticides ie. α-eleostearic acid formula produced by Industrial and Bavarage Crops Research Institute and Citronellal formula produced by Spice and Medicinal Crops Research Institute, and biological pesticide ie Beauveria bassiana formula produced by Spice and Medicinal Crops Research Institute.

2.3. Method of Study
The cocoa pest control treatment consists of: (1) α-eleostearic acid formula, recommended dosage: 5 ml.L⁻¹ of water, (2) Citronellal formula, recommended dosage: 5 ml.L⁻¹ of water, (3) Beauveria bassiana, recommended dosage: 15 g.L⁻¹ of water, and (4) control (without treatment). Citronellal formula is botanical pesticide contains citronellal acid and salicylic acid. Cytronellal is anti-bacterial, anti-fungal, anti-nematode and insect repellent. While salicylic acid is a phenolic compound that functions as a growth hormone and plant development and induces plant resistance. α-eleostearic acid formula is botanical pesticide with the main active ingredient α-eleostearic acid which is anti-feedant, also contains lauric acid, myristic and citronellal acid. Beauveria bassiana is a biological pesticide made from an entomopathogenic fungus.

The treatments were tested on a trial unit of about 3 ha with 1 ha of control, so the total area needed was covering approximately 10 ha. Treatment by spraying these botanical pesticides on cocoa fruit with a frequency of treatment of once per 2 weeks until harvest. In addition to the control treatment with botanical pesticides and biological pesticide, all crop plots were given a standard treatment in the form of pruning cocoa and shade plants, fertilizing according to standard doses, especially with organic fertilizers/manure, and making ‘rorak’ between cocoa plants.

Observations were made on the effectiveness of the treatment by observing the level of damage of cocoa fruit and fruit production in each experimental unit with systematic sampling of at least 120 healthy cocoa fruits measuring <8 cm from about 40 sample plants in each treatment. The level of attack / damage of the main pest is observed by grouping mildly/lightly attacked fruits (0-25%), moderate (25-50%), severe (> 50%) or healthy (not affected) for primary pests, PBK, Helopeltis and rot disease of fruit. Fruit production was observed by recording harvested sample fruits and cocoa beans obtained. In addition, it is also observed the effect on insect populations or non-target organisms such as beneficial insects and natural enemies of pests.

2.4. Data analysis
The percentage of yield loss due to cocoa pests attacks is calculated based on the regression equation proposed by [16] using the formula:
\[ Y = -0.0210 + 0.1005X \]
That is:
\[ Y = \text{percentage loss of yield} \]
\[ X = \text{intensity of attack} \]
The intensity of this attack is an index value obtained through the formula: 1 * the number of lightly attacked fruits + 3 * the number of fruits attacked medium + 9 * the number of fruits attacked severely divided by the total number of fruits observed. The results of the observation of cocoa pests attack rate and the percentage of yield loss in the treatment of botanical and biological insecticides were tested compared to control. The data were then tested based on the Duncan multiple range test with the level of difference expressed at the level of 5%.

3. Result and Discussion
The results of the previous study showed that control of cocoa pests and diseases using botanical pesticides and biological pesticides combined with pruning, organic fertilization and making rorak significantly reduced the level of damage on cocoa fruit compared to control. α-eleostearic acid formula and Citronellal formula, and B.bassiana is effectively suppressing cocoa main pests population, but the effectiveness is only slightly below the comparative pesticide treatment. From the 2015 cocoa harvest, generally the treatment of botanical and biological pesticides produced good enough cocoa fruit harvests, and was capable of suppressing cocoa pests and disease, especially CPB and Helopeltis, while for pod rot disease the suppression was relatively less. This condition is totally different from control, which the pests and diseases incidence is much higher. The high rate of pod
rot disease occurrence seems to be related to the high rainfall that was happened several weeks before the fruit harvest. Attacking on cocoa fruit is usually only develops on the skin surface of the fruit, and no showed significant effect on seed quality.

The results (Table 1, Figure 1.) showed symptoms of low pest attack at the beginning of observation both CPB, *Helopeltis* and pod rot symptoms. In further development, the symptoms of fruit rot are found in almost all treatments, especially in controls that were not given spray treatment. where nearly half of the sample become rot, dry and fall.

![Figure 1. The histogram of the damage level development of the main cocoa fruit pest in several treatments tested (February-May 2016 period)](image)

While the treatment of α-oleostearic acid formula, Citronellal formula and *B. bassiana*, the fruit rot symptoms are relatively also increasing, but the fruit retains attaching to the stem and not falling. The percentage of fruit rot attack before harvest in the α-oleostearic acid formula, Citronellal formula and *B. bassiana* treatments were 17.5%, 21.7% and 20.8% respectively; while in the control reached 61.7%. This result shows that the treatment of α-oleostearic acid formula, Citronellal formula and *B. bassiana* are indirectly able to suppress the attack of fruit rot 40-44%. Results of the same study by [17] showed that insecticides based on citronella oil formula were able to suppress the CPB attack and produce better production. Whereas [18] reported that α-oleostearic acid formula was effective in suppressing CPB attacks and reducing yield loss.

Other visible pest attacks are *Helopeltis* sp. especially in α-oleostearic acid formula treatment, although it is still relatively low but shows an increase in attacks. The fruit that is attacked by *Helopeltis* is generally still able to survive and relatively does not cause significant damage, because generally attacks occur after the fruit is large enough so that the attack only affects the outer part of the cocoa fruit. The use of botanical pesticides and biological pesticides is able to suppress or resist Helopeltis attack so that it does not cause significant damage. While CPB symptoms are relatively not seen in the outer appearance of the fruit that is still developing, because the damage to this pest occurs in the fruit. These symptoms will be clearly seen in fruit that has been harvested and cleaved.

In the observation of the second cocoa fruit season, the pattern of symptoms of pest attacks was still similar, but from the intensity of the attacks appeared increasing compared to the first fruit season, especially fruit/pod rot disease then followed by *Helopeltis* sp(Table 2 and Figure 2.).
probably due to more favorable climatic conditions, where during the second season the intensity of rainfall is relatively higher and more even. Fruit rot disease and *Helopeltis* sp. is very responsive to wet and humid conditions [2, 18], so the population is rapidly increasing. Increasing of *Helopeltis* attacks occurred in plants with α-elaostearic acid formula, Citronellal formula and *B. bassiana* treatment especially in α-oeleostearic acid formula which showed until the end of the observation, the attack rate reached 12.2%, while Citronellal formula treatment reached 9.2% and *B. bassiana* reached 5.6%. In control, attack symptoms of *Helopetis* are not visible because it is covered by a severe rotten fruit attack. The intensity of pest attacks in control, especially fruit rot disease is quite high, although most do not fall out, but the intensity is high, covering the surface of the cocoa fruit.

Figure 2. The histogram of the damage level development to the main cocoa fruit pests in several treatments tested (July - October 2016)

The rainfall intensity in 2015 mainly occurred in the first 6 months, while in the following 6 months the intensity of the rain was very low and there was almost no rain for several months so that the cocoa plants meet enough drought, only in December there was a high rainfall of around 162 mm with number of rainy days is only 8 days so the conditions are still relatively dry. In 2016, rainfall increased relatively even though it was not high, but it was quite evenly. Rainfall intensity mainly occurs from May to October. This condition seems to be sufficient to support an increase in pest attacks that occur, especially fruit rot and *Helopeltis* sp. The increase in *Helopeltis* population follows the pattern of rainfall and humidity [19]. [20] also showed that *Helopeltis* populations in cashew nuts were directly affected by the availability of food in the form of young shoots and leaves and indirectly affected by rainfall and humidity.

The treatment of cocoa pest control apart to reducing the intensity of pest attacks and suppressing the development of the pest population also indirectly affect the yield of cocoa fruit. The yield of cacao fruit samples from two harvests periods during the observation showed that the highest yield was obtained from the treatment of *B. bassiana* formula which was equal to 57,550 grams with a total seed weight of 13,000 grams(Table 1).Then followed by the Citronellal and α-elaostearic acid formulas . The lowest yield was obtained in the control with a total wet fruit of 24,490 grams with a total seed weight of 6,620 grams. These shows the real effect of control treatment with botanical and
biological pesticides on the loss of cocoa fruit yields. Likewise, the quality of fruit / cocoa beans is better than the control. The average seed weight of cocoa in botanical and biological pesticides treatment was much higher than in control. The average weight of cocoa beans/cocoa seeds in the three treatments (≥ 214 gr) were much higher than the control treatment (127,3 gr).

Table 1. Total yield of cocoa fruit in the observation sample treated by botanical and biological pesticides in 2016

| Treatments                  | Total weight of fruit (gr) | Average of fruit weight (gr) | Total weight of seed (gr) | Average weight of seed (gr) |
|-----------------------------|---------------------------|-----------------------------|--------------------------|----------------------------|
| α -elaeostearic acid formula| 40,674                    | 443.9                       | 9,657                    | 214.1                      |
| Citronellal formula         | 41,730                    | 543.3                       | 9,430                    | 244.3                      |
| B. bassiana formula         | 57,550                    | 478.5                       | 13,000                   | 229.5                      |
| Control                     | 24,490                    | 470.9                       | 6,620                    | 127.3                      |

Table 2. The rate of CPB attack and yield loss of cocoa fruit in some treatments of botanical and biological insecticides

| Treatments                  | Damage category (%) | Yield loss (%) |
|-----------------------------|---------------------|----------------|
|                             | light               | Moderate       | high            | Total            |                     |
| α -elaeostearic acid formula| 19.00 bc            | 9.00 bc        | 3.00 b          | 31.00 c          | 5.24 b              |
| Citronellal formula         | 26.00 a             | 12.00 ab       | 5.00 b          | 43.00 b          | 8.65 b              |
| B. bassiana formula         | 20.00 bc            | 10.00 bc       | 2.00 b          | 32.00 c          | 4.73 b              |
| Control                     | 16.00 c             | 6.00 c         | 39.00 a         | 61.00 a          | 36.59 a             |

The numbers in column followed by the same letters are not significantly different (DMD test, α = 0.05)

The treatment on CPB control with botanical and biological pesticides did not produce significant different damage from control in mildly/lightly attacked fruits except in the Citronellal formula treatment, as well as those with moderate damage. However, on heavily attacked fruits, it was seen to be very significantly different in all tested treatments compared to controls, where fruit/pod damage in the three treatments was tested (≤5%), far below the damage of fruit/pod on control which was very high (39%). Likewise when viewed from the symptoms of fruit/pod in total, the treatments of CPB control using botanical and biological pesticides resulted lower damage and significantly different from the control. The use of botanical and biological insecticides that sprayed on cocoa fruit every 2 weeks can reduce yield loss due to the attack of cocoa fruit borer. Yield loss in all treatments was below 10%, lower and significantly different compared to control which reached 36.59% (Table 2).

The observation of natural enemies in the field shows that the use of botanical pesticides (α-elaeostearic acid formula, Citronellal formula) and biological pesticide (B. bassiana) does not affect pollinating insects or natural enemies. The population of black ants (Dolichoderus thoracicus), weaver ants (Oecophylla smaragdina) and spiders which are natural enemies of cocoa pests and some types of pollinating insects are still often found in the field despite spraying.

4. Conclusion

Application of α-laeostearic acid formula, Citronellal formula and B. bassiana reduced the attack intensity of C. Cramerella, Helopeltis sp., and P. palmivora. Yield loss by C. Cramerella in all treatments were below 10%. Apart of reducing damage by pests and disease, the quality and weight of the cocoa beans produced is better than the control. The treatment of α-elaeostearic acid formula,
Citronellal formula (botanical pesticides), and B. bassiana formula (biological pesticide) respectively can produce total weight of fruit much higher than control.

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