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Study on various control techniques to suppress the intensity of cocoa pod borer (*Conopomorpha cramerella* Snell) attacks in the field

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Abstract

Cocoa Pod Borer (CPB) is a major cause of cocoa yield loss in Indonesia. The purpose of this study was to examine various control techniques to suppress the intensity of CPB pest attacks in the field. The study was based on a Randomized Block Design (RBD) with five treatments. The treatments were: without spraying or cloaking (control) (M0), spraying with biokaolin every 2 weeks (M1), spraying with biokaolin every 4 weeks (M2), cloaking with a plastic bag (M3), and spraying with pesticides deltamethrin every 2 week (M4). Research variables included the percentage of CPB attacks, the intensity of CPB attacks and yield loss per 100 dry beans. The effect of the four control techniques was significantly different from that of the control treatment (M0), which had 80.01% attacks. The results showed that the treatment of cloaking fruit with plastic (M3) and spraying biokaolin every 2 weeks (M1) resulted in a light attack category. Both treatments provided a lower yield loss as compared to treatments of spraying biokaolin every 4 weeks (M2) and the pesticide spraying once a fortnight (M4), which were classified as moderate attacks, and the treatment without cloaking and spraying (M0) was classified as a severe attack category. Cloaking fruits with plastic, and biokaolin applications every two weeks were effective in suppressing CPB attacks, while the percentage of yield loss can be saved was around 80% from the controls.

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Introduction

Cocoa Pod Borer (CPB, *Conopomorpha cramerella* Snell) is a major cause of cocoa yield losses (Wardojo, 1980; Wiryadiputra *et al.*, 1994; Directorate of Plant Protection, 2010; Dormon *et al.*, 2004; and Susilo *et al.*, 2004). The yield loss is primarily due to the cacao seeds become sticky and the fat content is significantly reduced. The CPB attack causes the death of seed placental tissues so that the seeds can not fully develop and become sticky. Attacks on young fruit resulted in greater yield loss because the fruits ripe early causing the fruit can not be harvested (Azhar *et al.*, 1995). The presence of CPB pests, therefore, becomes a serious threat to the survival of cocoa production in Indonesia, and an effective control strategy is urgently needed to surpress the CPB attacks.

CPB control strategies can be done through technical culture approach, mechanical, chemical, as well as the use of resistant clones (Moersamdono and Wardojo 1984; Panda and Kush, 1995; Sulistyowati and Mufrihati, 2002; Susilo *et al.*, 2007; Wahab *et al.*, 2016). Despite the fruit cloaking method is proven effective in suppressing the population of CPB pests, some said that its application is costly, time-consuming, and requires a lot of labors because it must be performed on each fruit. In addition, the process of cloaking can cause the surface of the fruits become damp, which causes fruits to be easily infected with *Phytophthora palmivora*, the causes of fruit rot disease (Kresnawati *et al.*, 2010; Wahab *et al.*, 2015), and also can cause environmental pollution. Chemical insecticide applications also require high costs, and considered ineffective because it can only kill CPB imagos (Munier, 2005), have a negative impact on environment, animals and humans (Lu, 1995; Quijano and Sarojeni, 1999; Alavanja *et al.*, 2004; Opoku *et al.*, 2007; Turyanto, 2008; and Tuhumury *et al.*, 2012).

Utilization of biological agents for the control of CPB is a pest control method that has proven effective in controlling a variety of pests and diseases (Kim *et al.*, 2008; Nitu *et al.*, 2016). Biological agents often used are black ants (*Delichoderus thoraxicus*), entomopathogenic nematode *Steinernema* spp. (Rosmana, 2000), entomopathogenic fungus *Beauveria bassiana* and *Paecilomyces fumosoroseus* (Sulityowati *et al.*, 2002). Utilization of biological agents to control pests is envisaged by Law No. 12 1992 through integrated pest management (IPM). Control of IPM involves components of biological agents, resistant planting materials, and environmental management based on the ecological, economic, and sociological considerations to support environmentally friendly farming systems (McMahon *et al.*, 2010; Nguyen *et al.*, 2016; Wijayanto *et al.*, 2016; Assad *et al.*, 2017; Wijayanto *et al.*, 2017). Based on the above-mentioned circumstances, the study on various control techniques, including the utilization of a mechanical protection combined with biological agents, such as biokaolin, is important to be done, as alternative strategies for CPB control. Biokaolin is a mechanical protection, which uses kaolin mineral layers and entomopathogenic fungi *Beauveria bassiana*, which will grow and develop on the surface of the fruits or leaves. Kaolin layer and entomopathogenic fungi on the surface of the fruits or leaves can be a double function as a mechanical barrier and biological control. Results of research conducted by the Biotechnology Research Institute of Plantation, Indonesia showed that the use biokaolin effectively reduced CPB pest (Kresnawati *et al.*, 2010). The aim of this study was to examine various control techniques to suppress the intensity of cocoa pod borer (*Conopomorpha cramerella* Snell) in the field.

Materials and methods

Research location and materials used

This study was conducted in the village of Tokai, District Poli - Polia, East Kolaka, one of the centers of cocoa plantations in Southeast Sulawesi. The location is situated at 196 m above sea level, at 4° S, 121° E, and the climate was type D according to Schmidt and Ferguson. The location is categorized as CPB endemic, having been attacked by CPB for at least 2 years in a row (Sulistyowati and Susilo, 2003). The research was conducted from April to August 2013.

The materials used in this study included cacao plant, cacao fruit, biokaolin consisting of kaolin minerals and the fungus *Beauveria bassiana* and the growth media, chemical pesticide with active ingredient deltamethrin, and clean water. Equipment used included labels, plastic wrap, knapsack sprayer, drums, buckets, mixer, machetes, rope, digital cameras, scales, oven and stationery.

Experimental design

This study was based on a Randomized Block Design (RBD) with five treatments and four groups, to get 20 experimental units. Each experimental unit consisted of 20 trees, one tree consisted of 5 samples, so in one unit consisting of 100 pieces of samples. The treatments tested were: without spraying/cloaking (control) (M0), spraying with biokaolin every 2 weeks (M1), spraying with biokaolin every 4 weeks (M2), cloaking with a plastic bag (M3), and spraying with pesticide with the active ingredient deltamethrin every 2 weeks (M4).

Observed variables and data analysis

The research variables were the percentage of pest attack (PS), the intensity of CPB pest attacks (I), the number of inlets larvae, the number of larvae exit hole (outlet), and the ratio of the outlet/inlet of larvae, as well as the magnitude of the weight loss of 100 dry beans (Kh). Percentage of pests was calculated using the following equation:

$$PS = \frac{n}{N} x\ 100\%,$$

Notes: PS = percentage CPB pests attack (%),

n = number of CPB attacked fruits,

N = total observed fruits

While the formula used to calculate the intensity of CPB pest attacks was using equation reported by Sulistyowati (2008):

$$I = \frac{\sum_{0-9}^{n} (n_1\, x\, v_1)}{Z \times N} x100\%$$

Notes: I = intensity of CPB pest attacks (%),

n1 = number of CPB attacked fruits, in each attack category,

v1 = score of each category of attack

Z = a score of the highest attack category,

N = the number of observed fruits

The intensity categories were: score 0 = healthy, no CPB attack; score 1 = mild, CPB attack on fruit < 20 %; score 3 = moderate, CPB attack 20-50 %; and score of 9 = severe, CPB attack > 50 % (Azhar *et al.*, 1995).

The yield loss was calculated using the following steps: 1) specified the attack criteria based on severity scores as above, 2) fruits with the same severity were grouped, and 100 seeds were then taken, and dried in the oven for 2 × 24 hours at a temperature of 60-70° C. The seeds were then weighed to obtain the dry weight of 100 seeds in each category of severity. The formula used to determine the yield loss was using the following equation:

$$Kh = \frac{(Bks - Bki)}{Bks} x100\%$$

Notes: Kh = Yield loss (g)

Bks = Dry weight of 100 healthy seeds (g)

Bki = Dry weight of 100 infected seeds, according to disease severity

scores (g)

Data were analyzed by analysis of variance (ANOVA), using the 'R' statistic program. Treatment means were separated using the Duncan Multiple Range Test (DMRT) at α = 0.05.

Results and discussion

Percentage of CPB Attack

Results of analysis of variance in Table 1 shows that the application technique of biokaolin every 2 weeks (M1) and a plastic cloaking resulted in lower percentages of CPB attack than with other application treatments. The average percentage of CPB attack on biokaolin application every 2 weeks (M1) was 57.55%. The treatment had no significant different with application of biokaolin 4 weeks (M2) and spraying fungicide (M4).

However, the attack on the treatments was significantly different from the attack on control treatment (M0), which had an attack percentage of 80.01%. Data in Table 1 show that application of fruit cloaking resulted in decreased percentage of CPB attacks. This is because, physically, the protection afforded by the plastic layer was higher than by the biokaolin layer, which can fade due to rain. But given the technology of plastic cloaking is costly, time-consuming, as well as the fears of environmental pollution due to plastic waste (Sulistyowati, 2008), the new biokaolin technology for the protection of fruits is a hope of tackling CPB pests.

Table 1. Average of attack percentage (%) on the control of cocoa pod borer.

Treatment	Average of attack percentage (%)
Without spraying/cloaking (M0)	80.01b
Spraying biokaolin every 2 weeks (M1)	57.55a
Spraying biokaolin every 4 weeks (M2)	61.23a
Plastic cloaking (M3)	49.54a
Spraying pesticide every 2 weeks (M4)	60.71a

Note: The values followed by the same letters mean not significant the DMRT at α = 0.05.

Intensity of CPB Attack

Data in Table 2 show that the treatments gave significant effect on the intensity of CPB attacks, and can reduce the intensity of CPB attack on cocoa crops. In line with the percentage of CPB pest attack, the intensity of CPB attacks on fruits treated with plastic cloaking with plastic (M3) and spraying biokaolin every 2 weeks (M1) was relatively lower than when treated with other treatments. The intensity of CPB pest attacks on both treatments was 22.12% and 22.99%, respectively, which were significantly different with that of on the control treatment (65.78%). However both treatments were not significantly different with those of treatment of spraying four weeks (M2) and treatment of pesticide spraying (M4).

Table 2. Average of attack intensity (%) on the control of cocoa pod borer.

Treatment	Average of Attack Intensity (%)
Without spraying/cloaking (M0)	65.78b
Spraying biokaolin every 2 weeks (M1)	21.40a
Spraying biokaolin every 4 weeks (M2)	24.36a
Plastic cloaking (M3)	19.25a
Spraying pesticide every 2 weeks (M4)	25.34a

Note: The values followed by the same letters mean not significant by DMRT at α = 0.05.

The treatment of pesticide application (M4) was quite effective in suppressing the intensity of CPB attacks (25.34%); because the pesticide contained a toxin that can interfere with the respiration activity of insects, leading to the death of insects.

However, the use of pesticides intensively for a long period of time can cause pollution to the physical and biotic environments (Opoku *et al.*, 2007; Turyanto, 2008).

The low intensity of CPB attacks in fruits covered with plastic and with biokaolin application every two weeks showed that both control techniques were the best approaches, because they can provide protections against cacao pod borer.

The presence of white color biokaolin particles on the outer skin of cacao fruits and fine granules of biokaolin is a physical impediment for CPB insects, which led to the appearance of the fruits sprayed with biokaolin, was different from unsprayed fruits (Fig. 1). It was thought to cause CPB imagos do not know or were reluctant to lay their eggs. This statement was in line with Kresnawaty *et al.* (2010) which stated that the closure by biokaolin layer was a physical obstacle for the CPB insects and *Helopeltis* spp. for perch, piercing and laying eggs on the surface of the fruits. Besides, biokaolin mineral was irritant for the insects.

Table 3. Inlet, outlet and the ratio of the outlet : inlet of the cocoa pod borer attacks.

Treatment	Inlet	Oulet	Ratio of the outlet : inlet (%)
Without spraying/cloaking (M0)	89.00 c	18.70 b	21.01
Spraying biokaolin every 2 weeks (M1)	17.22 a	3.12 a	18.12
Spraying biokaolin every 4 weeks (M2)	22.70 ab	3.22 a	14.19
Plastic cloaking (M3)	13.00 a	3.03 a	23.31
Spraying pesticide every 2 weeks (M4)	30.10 b	3.40 a	11.30

Note: The values followed by the same letters at the same coloum are not significant by DMRT at α = 0.05.

Another argument led to a lower percentage and intensity of CPB pest attacks using the biokaolin spray treatment was that the spray causes *B. bassiana* conidia attached to the CPB insect, germinate and penetrate the insect's body that causes death of CPB insects. This incident was similar to that disclosed by Rahayu and Umrah (2012) who found higher mortality of CPB insects due to the high amount of conidia attached, germinated and penetrated the CPB insect body. Another possibility which caused the low intensity of CPB pest attacks on spraying biokaolin treatment was the role of *Beauveria bassian* fungus that infects pupae that moved out of the fruits, causing the death of the CPB insect pupae. This argument was supported by the statement of Rahayu and Umrah (2012) that bioinsecticide *Beauveria basssiana* was capable of killing CPB pupae.

Table 4. Lost of dry bean weight (g/100 seeds) and the percentage of yield loss (%) at various control techniques of cocoa pod borer.

Treatment	Lost dry bean weight (g/100 seeds)	Percentage of yield loss (%)
Without spraying/cloaking (M0)	75.99	71.38
Spraying biokaolin every 2 weeks (M1)	12.47	11.71
Spraying biokaolin every 4 weeks (M2)	21.76	20.44
Plastic cloaking (M3)	11.70	10.99
Spraying pesticide every 2 weeks (M4)	29.51	27.72

Note: The values followed by the same letters at the same coloum are not significant by DMRT at α = 0.05

Research results showed significant variations in the number of inlet, outlet, and the ratio between the number of the outlet and the inlet (Table 3). Such variations indicated differences in treatment responses to CPB attacks. The intensity of attacks linked to the level of CPB activity in the fruit peel (Susilo, 2004). The observation of the inlet of the larvae showed that most larvae infected fruits managed to penetrate the sclerotic layer.

There was a variation on the ratio of the outlet and inlet of the larvae. Ratio of the outlet and the inlet of the larvae is a useful variable to understand the degree of movement of the CPB larvae out from the fruit. The higher the value, the higher the degree of movement of the larvae out from the fruit. Through spraying with biokaolin it was expected that CPB population will decrease naturally until the unharm threshold.

Yield Loss

The losses of dry bean weight on the treatments with plastic cloaking (M3) and with spraying biokaolin every 2 weeks (M1) were categorized as mild category. Both treatments showed lower yield losses compared to the treatments of spraying biokaolin every 4 weeks (M2) and spraying pesticide once a fortnight (M4), which both classified as moderate attacks; while treatment without cloaking and spraying (M0) was classified as severe category (Table 4), according to classification by Azhar *et al.* (1995).

Fig. 1. **A.** Fruits treated with biokaolin, and **B.** Fruits without treatments.

Treatment without spraying and cloaking fruit with plastic resulted in the highest loss of dry beans ie 75.99 g/100 seeds, with the yield loss percentage of 71.38 %.

This was due to the low fat content of cocoa beans caused by the CPB worms that attacked the fruit placenta, which is a channel supplier of nutrients in cocoa beans so that the growth process of cocoa beans is not fully developed, and seeds cling to each other in the fruits.

Conclusion

Cloaking fruits with plastic and biokaolin applications every two weeks were effective in suppressing cocoa pod borer attacks, while the percentage of yield loss that can be saved around 80% out of the controls. Applied CPB control techniques reduced the percentage and the intensity of CPB attacks. CPB control technique with biokaolin application every 2 weeks effectively controlled CPB pest attacks and reduced the yield loss, as well as environmentally friendly as compared to other treatments.

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