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Research Article
Boosting Cocoa Black Ant (*Dolichoderus thoracicus*) (Smith) (Hymenoptera:Formicidae) Population Using Artificial Nests

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Abstract

Background and Objective: High number of cocoa black ants (CBA) in cocoa plantations are of great significant benefit in controlling cocoa pod borer (CPB) and one of the strategies is to manipulate the CBA nesting behavior. This study focused on the preference of the types of materials for the artificial nests in order to achieve high population. **Materials and Methods:** Six types of materials were used in building the artificial nests for observation of the CBA nesting preferences. From the results of the most preferable materials for the black ant nest, dry cocoa leaves were used as artificial nest to investigate the establishment of black ant colony, due to the reliability and availability in the plantations. **Results:** The number of 3639.0 and 3273.7 black ants were recorded inside coconut and dry cocoa leaves, respectively. Only 306.6 ants were discovered from synthetic materials nests. In fourteen months of observation, the CBA colony enlarged and established inside dry cocoa leaves nests and their number continuously increased until the end of the study. **Conclusion:** The dry cocoa leaves were the most suitable materials for artificial nest and CBA colony established well in the dry cocoa leaf nest. These artificial nests can be used to establish black ants for biological control of CPB in cocoa plantation.

Key words: Cocoa pod borer, cocoa black ant, artificial nest, biological control, cocoa plantation

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The black ant (CBA) (*Dolichoderus thoracicus*) is one of the effective tools for the biological control of cocoa pod borer (CBP), an important pest of cocoa besides the use of chemical control (pesticide)[1-5]. The efficiency of using the black ants to control the CBP is higher when their population in cocoa plantation is also high[6-8]. The difficulties observed in the control of the outbreaks of CPB was due to the infestation that occur inside the cocoa pod, thus spraying with insecticides is unable to eliminate this pest completely[9-10]. Moreover, a larger part of the larval life cycle (70% or between 18 and 21 days) lives inside cocoa pods thereby causing massive damage. The clumped and unused beans produce low quality dried cocoa beans which contributes up to 100% damage if left untreated[11]. According to Saripah[12], the control of CBP using black ants offers more promising results in comparison to pesticide and it reduces the population of the borer significantly and yields more than 50% of healthy cocoa pod.

The optimum population size of CBA depends on their breeding site and food and the absence of antagonist ants[13]. Nevertheless, the population of black ant also depends on the presence of mealybugs as their food source[3]. Hence, the black ant and mealybugs pupae are difficult to be established in cocoa areas where insecticides are used for controlling pests. Furthermore, the population of mealybugs always decline after a peak season of the cocoa crop because as soon as a large number of pods are harvested, most of mealybugs are destroyed[3].

Despite of the presence of mealybug as their food source, habitat and shelter are important to sustain the black ant population in cocoa plantation. Therefore, it is a common practice for cocoa planters to build/supply the artificial nests, which are made from dry cocoa leaves for breeding sites of black ant[7]. Artificial nests are hung on the cocoa trees to enhance the populations of CBA and maximize the protection of CPB infestation[14]. Besides the use of dry cocoa leaves as the artificial nest for CBA, synthetic materials which are more durable and long lasting, can be considered as artificial nesting site for CBA. However, most studies conducted in the area of artificial nests for CBA did not consider other materials as a suitable for artificial nest and potential to be used with dry cocoa leave in the plantation[12,15]. According to Offenberg[16], population of ants can be increased by modifying their artificial nests due to the adaptive behavior of ant colony to different materials. Furthermore, it is also highlighted[17] that other materials such as coconut leave can be used as artificial nest to the CBA. Therefore, by providing this type of material as a component to build the artificial nest for CBA, the population of the black ants in cocoa plantation is expected to increase to the optimum size. Furthermore, artificial nests can be used to transfer the black ant population from one area to new areas. The objective of this study was to assess the most suitable artificial nest for CBA and to evaluate the establishment method of *D. thoracicus* in cocoa plantation.

MATERIALS AND METHODS

Study site: This study was conducted in a large cocoa agro-ecosystem owned by PTPP London Sumatra (Lonsum) Indonesia in Bah Lias, North Sumatra, Indonesia (99°15'36"-99°21'36" East and 3°8'24"-3°13"12" North). In general, the average rainfall at Bah Lias during the time of investigation (2005-2008) was 1665 mm, with 140 rainy days per year and average temperature was 26.8°C and the average relative humidity was 70.01%. The altitude of Bah Lias estate is 32 m above sea level.

Materials and experimental designs: It is a common practice that cocoa plantations are divided into plots (fields) for efficient management. In this study, the selection of the fields was based on similarities in characteristics and surrounding, in order to ensure the homogeneity of the sampling site and avoid biasness. The selected fields were planted in 1975 with cocoa hybrid seedlings. The density of cocoa trees was 576 trees ha^{-1}. Together with the cocoa tree, coconut palms were planted to provide permanent shade to the cocoa trees at a density of 46 palms ha^{-1}. Based on observation, the populations of black cocoa ants in these fields were high.

Previously, cocoa leaves were used as the artificial nest to harbor the colonization of the black ants[18-19]. However, the most suitable material as the artificial nests for the black ants was scarcely reported[15,18]. Therefore, this study was conducted to investigate the most suitable materials as a component for the black ants' artificial nests. In a large cocoa plantation, artificial nests for the ants have to be economical (low cost) but durable and suitable for *D. thoracicus* breeding site. In this study, 6 materials were used to build the artificial nests for the black ants, (1) Dry cocoa leaves, (2) Dry coconut leaves, (3) Black plastic, (4) Polyester bag, (5) White plastic and (6) Canvas. The selection of the materials was based on the previous studies about the nesting habitat of ants[9,19].

At the study sites (fields), two artificial nests from each type of material (one pair of nests) were hung on the cocoa tree jorquette. For each material, three replicates were set up randomly on selected cocoa trees. Therefore, the total artificial nests that were set up at the experimental sites were 36 nests (6 types of materials×2 nests (one pair) for each cocoa tree

jorquette×3 replicates). After one month, one nest from each pair of artificial nests made from different materials was collected and secured separately in transparent plastic bags, which made a total of 18 nests (6 types of materials×one artificial nest (one nest from a pair of nest)×3 replicates) were collected during the sampling. Every bag that contained the nest was sprayed with aerosol insecticide (Baygon, PT. Johnson Home Hygiene Product, Indonesia) to kill the black ants inside the nest and transported to the insectary. As mentioned earlier, every individual of the ant was counted, separated according to stages (eggs, larvae, pupae, workers, queen and alate) and recorded for further statistical analysis.

Establishment of black ant in the most preferable nesting materials: The artificial nests for cocoa black ant (CBA) were prepared using the most reliable material recorded from the previous assessment of suitability of nesting materials. In the field, one hundred pairs of the artificial nests were set up and every pair of the nest was placed at the tree jorquette (lateral-growing branches) of 100 selected cocoa trees. Five pairs of the artificial nests were selected randomly every month, collected and each pair was stored inside a transparent plastic bag to avoid the ants from escaping. Then, insecticide was used to kill the ant colony inside the artificial nests by spraying the aerosol into the plastic bag and fastened. The sprayed bag with the artificial nests was brought back to the insectary. At the insectary, the nests were taken out from the bag and dissected. Every individual of the black ant from each of the nest was classified according to their stages (egg, larvae, pupa, soldier, queen and alate) and recorded. The artificial nests and the establishment of the ant colony were observed in fourteen consecutive months. During the observation, 70 nests were randomly collected and investigated.

Statistical analysis: Two-way ANOVA was performed to evaluate the difference of the CBA population in artificial nests that were built from 6 different materials.

RESULTS

Most preferred materials as artificial nests: The highest individual ant per nest was 3639 in total, which was recorded from the coconut leaves artificial nests (Fig. 1). Meanwhile, the second most preferred material by the CBA was dry cocoa leaves (3273.7 total individual). The number of workers found from the coconut leaves and cocoa leaves artificial nests were almost similar (2285.3 individuals and 2472.3 individuals, respectively). The number of larvae recorded from coconut leaves was higher (759.3 individual) compared to cocoa leaves artificial nests (221.7 individual). Although the total number of adults, workers, pupae and eggs of the black ants were insignificantly different in these two types of artificial nests, the number of ants' larvae were significantly different (significant when $p<0.05$).

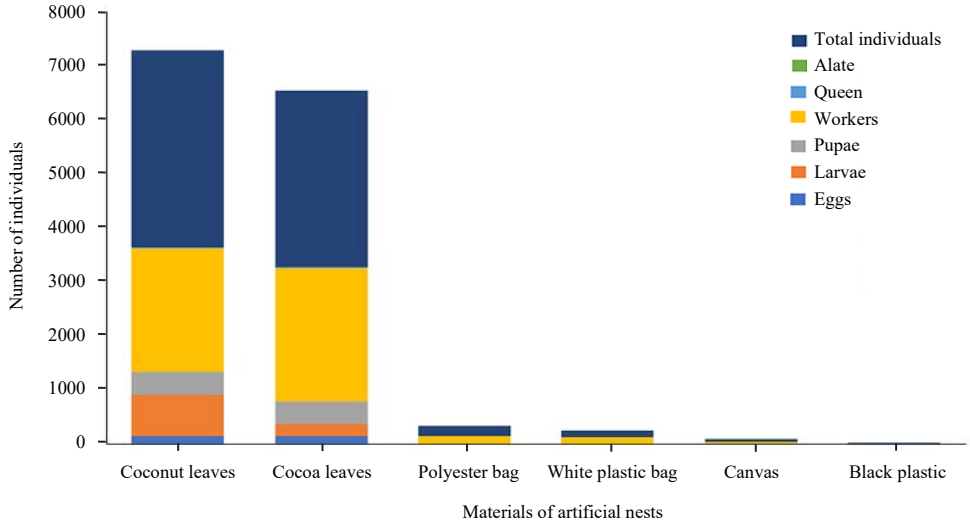

Fig. 1: Composition of *D. thoracicus* according to the different developmental stages in artificial nests made from 6 different materials after the nest was set up for 1 month on cocoa trees in Bah Lias Estate, Lonsum, North Sumatra, Indonesia

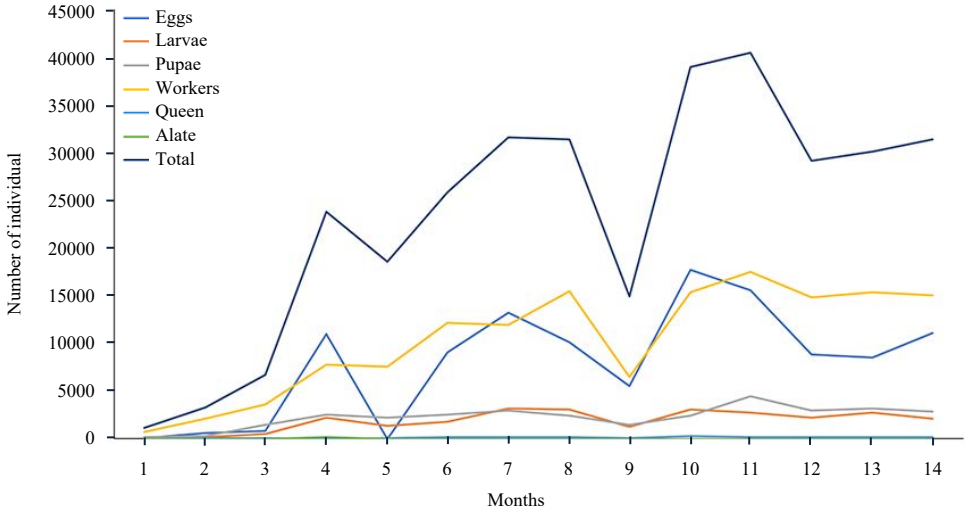

Fig. 2: Population size of *D. thoracicus* according to its different developmental stages in fourteen months of observation in artificial nest (stacked dry cocoa leaves) in Lonsum Plantation, North Sumatra, Indonesia

The number of queens in the nests of coconut leaves and cocoa leaves nests were almost similar. However, during the observation of the 6 materials to construct the artificial nests, the alate of the black ants was not found and recorded. In addition, egg, pupae and queen of the black ant were absent from the artificial nests made up from polyester bag, white plastic bag, canvas and black plastic bag. Statistically, the number of ants in these types of artificial nests were insignificantly different (significance when $p<0.05$). The least number of black ants was recorded from nest of the black plastic bag in which only one individual was recorded.

Establishment of black ant in the preferred nesting material: Based on the results of the most suitable material for CBA artificial nests, the most preferred materials by the black ant were coconut leaves and cocoa leaves. However, cocoa leaves are highly available and easier to be collected in the cocoa plantation compared to the coconut leaves. Therefore, the establishment of the ant in artificial nests was further investigated using the cocoa leaves as the component of the nests.

During the fourteen months of observation, the population of *D. thoracicus* significantly increased inside the dry cocoa leaves artificial nests (Fig. 2), although their population between the 8th month and the 9th month dropped by half (from 31387.4-14976.6 total individuals). However, the number of black ant increased by 2.5 times to 38987.2 of total individuals in the 10th month and subsequently increased in the 11th month (40478 total individuals). Following the drop in size of the ant population between the 8th and 9th month, the number of queens found in the artificial nest decreased from 181 individuals to only 92 individuals. However, the queen number increased to 307 individuals at the 10th month.

Interestingly, between the 10th and 11th month, the number of workers increased from 15369.8-17481.8 individuals. Meanwhile, the number of eggs decreased from 17742.2-15579.4 individuals. This indicated that almost all eggs survived and increased the number of workers (population) inside the nests. At the 14th month, the population of black ant was 31316.8 individuals compared to only 1120.22 individuals at the first month of the study.

In general, throughout the 14 months of the study, the population of the black ant inside the dry cocoa leaves artificial nests was established. At the different developmental stages (egg, larvae, pupae, worker, queen and alate), approximately half of the population inside the nests were workers (44.61) and eggs (36.54%). Meanwhile, 9.84% of the ant population inside the nests were pupae, 8.27% were larvae, 0.63% was queen and the least was alate (0.12%).

DISCUSSION

In this study, the CBA preferred the bunch of coconut leaves and dry cocoa leaves as their nests. The number of individuals of the black ant per nest in coconut leaves and dry cocoa leaves artificial nests were high, with small variation on the number of workers found from this two types of nests.

However, the number of the ant larvae discovered from the coconut leaves artificial nests was 3.4 times higher compared to the number of larvae inside the nests made of dry cocoa leaves. These natural materials contributed to the efficiency of the nests ventilation and provided suitable habitat to the black ants, thus contributed to the enlargement of the ant's population at the cocoa plantation, as thermoregulatory strategies are important and influence every aspect of ant biology[20]. Nevertheless, ant's behavior that actively move in and out of the nests especially during foraging activity made the coconut leaves and dry cocoa leaves as the most suitable materials to be used as their nest compared to synthetic materials. According to Wilson[21], these loose materials also provided optimum amount of humidity of nest which kept the black ant from abandoning their shelter. As a result, most of the CBA nests were found under folded palm or cocoa leaves, cocoa leaves litter, the cocoa canopy, inside curled leaflets of dried coconut fronds, underneath the dried sheath that served as coconut inflorescence protection and under the proximal ends of live coconut leaflets in their natural habitat of cocoa plantations[22-23]. As the most preferred materials in artificial nesting for the black ant, all stages of the black ant were found inside coconut and cocoa leaves nests, which indicated their colonies were successfully established in these types of nests. According to Khoo[24], as the most preferable materials for the black ant to nest, the coconut leaves and cocoa leaves litter were important and reliable materials to construct artificial nests as manipulation of the ants nesting behavior. Furthermore, both materials were easily found and readily available in the cocoa plantation. Despite that, this study also suggested that the nests made from synthetic materials were unsuitable to be used as the artificial nest for the ants. For example, 41.33 workers (total individuals) were recorded inside the canvas artificial nest and the absence of other stages indicated the unsuitability and unreliability of the material to construct artificial nests although the synthetic material nests are expected to last longer and are more durable in comparison to nests based on natural materials. According to Gassa *et al.*[25], <50 individuals of ant at a cocoa tree categorized that the trees as slightly occupied by CBA and supposedly, no nest was developed.

Based on the observation of CBA colonies inside artificial nests and the establishment of their populations in six different materials for artificial nests, the natural and loose materials were the most preferred by *D. thoracicus*. In this study, establishment of the black ant inside the most preferred and highly available dry cocoa leaves as the artificial nests was investigated. According to Saripah[11], the use of dry cocoa leaves for artificial nesting was a common practice in cocoa plantations due to behavior of the ant to build nest from the leaves. During the 14 months of observation, the population of CBA in the plantation increased 6 times in the first three months after the nests were introduced and drastically increased in the following months (between the 1st and 4th month). Adnan *et al.*[15] reported similar finding which the size of the CBA population increased in the first four months after the artificial nests were set up. However, the CBA population size in this study was higher compared to the observation made by previous study in Cocoa Research and Development Center (CRDC) of Malaysia[15]. However, other factors such as food sources, weather and established CBA nests in the plantation of the study sites also contributed to large population of the ant. According to Gassa *et al.*[25], the population of CBA was considered as abundant when more than 500 ant population occupied a tree and started to colonize the surrounding trees. Meanwhile, Saleh *et al.*[7] and Khoo[24] suggested that the nests should be transferred to a new area usually after one month, in order to increase the distribution of the ant in cocoa plantation ecosystem. Therefore, the finding of this study was similar to the common practice in cocoa plantations that the artificial nest of ants shall be transferred to a new area with low population of ants to distribute the ant colony in the plantation and maximize the protection from CPB. During the observation, the population of CBA dropped drastically at the 9th month. This situation was due to the behavior of the ant to move out and develop a new colony inside suitable nests at adjacent trees[25]. As a results, the population of black ants increased in following the months. According to Wilson[21] and Kalshoven[22], this fluctuation of CBA colony size in the nest was due to a trait factor since the ants are polygene and have the ability to control their population based on their surrounding conditions such as the food availability and the presence of their natural enemy. In addition, the decline of black ant populations can occur due to the lack of food and the competition with antagonistic ants.

CONCLUSION

The number of CBA was the highest in coconut leaves and dry cocoa leaves artificial nests as the materials provided loose and well-ventilated place with optimum humidity to the ants. The size of the ant colonies increased tremendously with the age of the nests and stable temporally which is able to control the population of the pod borer in cocoa plantations.

SIGNIFICANCE STATEMENT

This study observed that the cocoa black ant (CBA) can be established in cocoa plantations using dry cocoa leaves as materials for their artificial nests and can be beneficial to control the infestation of the cocoa pod borer (CPB). This study will help the researchers to uncover the critical areas of the establishment of the black ant populations in the cocoa plantation using the most suitable material as their artificial nest.

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