The Level of Coffee Berry Borer (*Hypothenemus hampei* Ferrari, 1867) Attack on Organic and Conventional Arabica Coffee Plantations at Several Altitudes

Husni HUSNI[1] (✉)
Jauharlina JAUHARLINA[1]
Syukur HAMDI[2]
Elka MULYADI[3]

Summary

This study was conducted to investigate the influence of elevation and the cultivation system of Arabica coffee against the attack of the coffee berry borer (*Hypothenemus hampei* Ferrari, 1867) in Arabica coffee plantations in Central Aceh District, Aceh Province, Indonesia. We observed the attack level of *H. hampei* on Arabica coffee plants that were cultivated both organically and conventionally. Those were planted at three different altitudes, namely: 900-1,100 m; 1,100-1,300 m and 1,300-1,500 m above sea level. The results showed that the attack level of coffee berry borer (CBB) on organic coffee plantations was lower than on conventional ones in general. The attack level of CBB on organic and conventional coffee plantations for 5 observations was between 16.9 - 26.1% and 23.4 - 33.6%, respectively. The results also showed that the attack level of CBB was influenced by the altitude of the coffee cultivation. At an altitude of 1,300-1,500 m, the attack level of CBB ranged from 11 to 17%, and this was much lower than at altitudes below 1,300 m. Meanwhile, at an altitude of 900-1,100 m and 1,100-1,300 m, the attack level by this pest was around 27-40%. The results of this study indicated that both cultivation systems (organic and conventional) and altitudes of coffee plantation greatly influenced the attack level by CBB. Altitude is directly related to the temperature, while the cultivation systems are thought to have an effect on the level of presence and the role of natural enemies in suppressing CBB pest populations. Therefore, it is recommended to cultivate Arabica coffee organically, especially on the land at an altitude between 900-1300 m to reduce the attack level by CBB.

Key words

arabica coffee, *Hypothenemus hampei*, attack level, organic and conventional coffee plantation

[1] Plant Protection Dept., Agriculture Faculty, Universitas Syiah Kuala, 23111, Banda Aceh, Indonesia
[2] Central Aceh District Plantation and Forestry Service, Aceh Province, Indonesia
[3] Agrotechnology Department., Agriculture Faculty, Universitas Syiah Kuala, 23111, Banda Aceh, Indonesia

✉ Corresponding author: husnimusannif@unsyiah.ac.id

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Introduction

The levels of insect pest attack on a plant cultivar are influenced by biotic factors as well as abiotic ones. Those biotic factors include the presence of natural enemies and competition between different pest or non-pest species in the same habitat, while the most important abiotic factors that can affect the population of an insect directly or indirectly are the temperature and relative humidity (Jaworski and Hilszczański, 2013).

It is a common phenomenon that the population of various organisms such as birds, arthropods, and many species of organisms in the soil are more abundant on agricultural land that is managed organically in comparison to the land which is managed conventionally. Organic farming systems also allow the growth of natural enemy populations ideally, so that their existence is expected to suppress the development of pest populations in agricultural land. The risk of disruption of pest attacks can be minimized by taking into account various aspects of both biotic and abiotic environment. Under ideal environmental (biotic and abiotic factors) conditions, generally the development of pest populations, especially insect pests will be balanced by the development of natural enemy populations consisting of both predators and parasitoids (Abedeta et al., 2011). Conversely, in a damaged environment, especially due to the continuous application of synthetic pesticides, the development of pest populations often increases. This happens because these chemical compounds have killed various species of Arthropods which act as natural enemies of pests. Hill et al. (2017) reported that there were some broad-spectrum pesticides such as organophosphate which had caused a decline in the population of various beneficial species and also had caused secondary pest outbreaks.

Before deciding to plant certain plants, farmers should also look at the various abiotic factors that affect the development of the population of pests, such as temperature and humidity. Several species of plant cultivation, although they can grow well in lowland areas, sometimes are not economically profitable if planted in other area, due to the high level of pest attacks. Nearly all insect species will grow better in areas with warm temperatures than in areas with cold temperatures. Jaworski and Hilszczański (2013) state that insect pests outbreak often occurs in the agricultural areas which are located in the lowland compared with those located at high altitude. This is related to warmer temperatures in the agricultural areas located in the lowland compared to the areas located at higher altitude.

One of the plantation crops often planted at an elevation of moderate to high is Arabica coffee. The most widespread area (more or less 94,000 ha) of Arabica coffee planting in Indonesia is in the Gayo Highlands, Aceh Province, which is located at an altitude of between 500 m up to 1,700 m above sea level. Central Aceh District is one part of the Gayo Highland, with the planting area of Arabica coffee reaching 49,030 ha, of which approximately 13,000 ha are organic coffee plantations (Central Aceh District Plantation and Forestry Service, 2015).

The main problem in the cultivation of Arabica coffee in those areas is the existence of the Coffee Berry Borer (CBB) attack. According to interviews with coffee farmers and the Head of the Plantation and Forestry Service of Central Aceh District, this pest attack continues to get worse from year to year. In fact, according to the farmers, currently CBB pests have attacked coffee plants planted at an altitude of 1500 m, but about 10 years ago this pest was never found to damage coffee beans on land at this altitude. The increase in pest attacks from year to year is strongly suspected to be associated with an increase in temperature due to the effects of global warming.

CBB (*Hypotenemus hampei* Ferrari, 1867) is a small type of beetle (*Coleoptera: Scolytidae*), originated in Central Africa (Kalshoven, 1981; Burbano et al., 2011). It was first discovered in a coffee plantation on the island of Java in 1909 (Kalshoven, 1981). This pest is the most important pest in coffee plants (Vijayalakshmi et al., 2013), it destroys coffee beans by feeding on the seeds, so it can lead to loss of results in both quantity and quality. As a result of CBB attacks the loss of coffee bean production can reach 30-35%, in harvest season it can reach even 100% (Barrera, 2008).

In connection with the above problems, we have conducted a series of observations to monitor the level of CBB attacks on Arabica coffee plantations located at various elevations above sea level both on plantations managed organically and conventionally.

Material and Methods

Selection of Research Plot Location

In determining the research plot, various general conditions of the research location and environmental factors were chosen as homogeneously as possible, such as varieties and age of coffee plants and shade plants. Both on organic and conventional coffee plantations, the chosen research locations are at three altitude levels, namely: 900 - 1,100 m; 1,100 - 1,300 m; and 1,300 - 1,500 m above sea level. Therefore, mapping of the area was carried out by measuring the altitude of each research location using GPS. Twenty coffee trees from each research plot were randomly selected as sample plants, so that the total sample plants were 120 coffee trees.

Visual Inspections of the Coffee Berry Borer Infestation

Visual inspections of the sample plants were carried out 5 (five) times, namely twice before the harvest, twice during the harvest and once after the harvest period. To calculate the level of CBB attack, in each observation period 200 coffee berries were sampled randomly from each sample plant.

Data Analysis

To determine the effect of the coffee plant cultivation system (organic and conventional) on the level of CBB attack, a paired T-test was used. The number of coffee plants sampled for each cultivation system was 60 plants. Meanwhile, to determine the effect of the altitude of coffee plantation on the level of CBB attack, data analysis was carried out using the ANOVA test. Because there is a significant effect of the altitude of coffee plantation on CBB attacks, a further test was conducted using the HSD Tukey test. The number of coffee plants sampled for each altitude was 40 plants.

Results and Discussion

The Level of CBB Attacks at Different Coffee Cultivation System (Organic and Conventional)

The results showed that in general the CBB attack level on organic coffee plantations was lower than conventional ones, which ranged between 16.9 - 26.1% and 23.4 - 33.6%, respectively (Fig. 1). On organic coffee plantations it is suspected that there are more organisms that act as biological control agents against CBB pests, so that the level of attack of these pests in organic coffee plantations is lower than on those conventional ones. Previous studies conducted by Hamdi et al. (2015) in Arabica coffee plantations in the District of Central Aceh showed that the abundance of individuals, number of families and species richness of Hymenopteran parasitoids on organically managed coffee plantations was higher than on those managed conventionally. Montañez and Amarillo-Suárez (2014) have reviewed various scientific articles related to the influence of organic farming systems on insect diversity. The results of the review show that on the land managed by organic farming systems, species richness and insect population abundance are higher than on those managed with conventional systems.

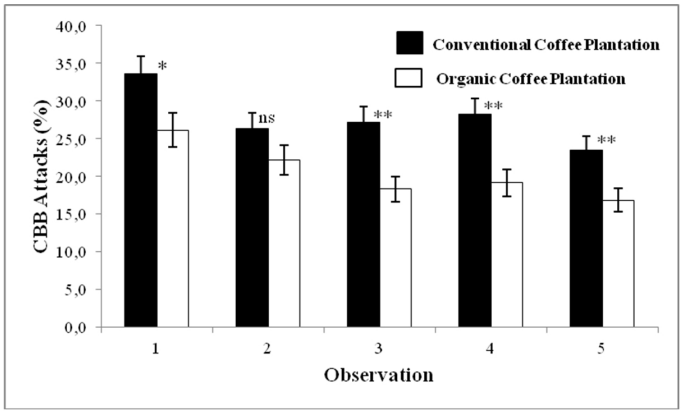

Figure 1. The level of coffee berry borer attack on conventional and organic coffee plantations for each observation time

Note: **: $P < 0.01$; *: $P < 0.05$; ns: $P > 0.05$ by paired t-test. n = 60. The vertical lines indicate SE

Muneret et al. (2018) provide evidence that organic farming can enhance pest control, although its level of effectiveness is highly dependent on the pest species. Kumar et al. (2018) reported that the application of organic farming system in the okra plant was able to reduce the level of pest attack and various diseases while improving the yield and quality of okra. A study conducted by Chau and Heong (2005) on rice plants also showed that the attack rate of pests and diseases in organically cultivated rice plants was lower than in those cultivated conventionally, and their productivity did not differ significantly compared to rice plants planted conventionally. Similarly, the study has been done by Abedeta et al. (2011) which shows that the forest coffee plant growing in the Afromontane Rainforest of Southwestern Ethiopia is much safer from CBB attacks compared to this pest attack level in other coffee producing countries. It is suspected that the ecological damage in the area is relatively lesser, so the biodiversity of natural enemies in the region is higher compared to other coffee producing countries. There are several species of Hymenoptera parasitoids reported to act as natural enemies of CBB pests. These parasitoids consist of various families, namely *Braconidae, Bethylidae, Eulophidae, Scelionidae*, and *Eupelmidae* (Vega et al., 1999; Damon, 2000; Infante et al., 2009; Hill et al., 2017). Further research is urgently needed to find domestic natural enemy species that have the potential to control CBB pest in Arabica coffee plantations in the Central Aceh District.

The level of CBB Attacks at Different Altitudes of Coffee Plantation

The results showed that the CBB pest attack rate was also influenced by the altitude of the coffee land from the sea level. On land at an altitude of 1300-1500 m above sea level, the pest attack rate ranges from 11-17%, and this is much lower than the altitude below 1,300 m. Meanwhile, on land at an altitude of 900-1,100 and 1,100-1,300 m this pest attack rate is around 27-40% (Fig. 2).

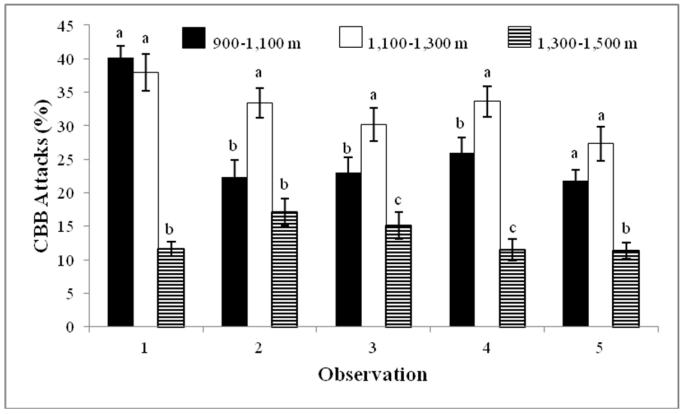

Figure 2. The level of coffee berry borer attack (Mean ± S.E.) on Arabica coffee plantation at different altitudes

Note: Different letters above bars among different altitudes of each observation time indicate significant differences (ANOVA followed by Tukey HSD test, n = 40; $P < 0.05$)

The results of this study indicated that abiotic factors, such as altitude or elevation also greatly influenced the level of CBB pest attacks. This is presumably because altitude or elevation has a direct effect on the temperature of a land. The difference in temperature between one site and another location was greatly influenced by the difference in elevation, especially during the daytime (Geiger, 1950).

At altitudes below 1,300 m above sea level, it is estimated that CBB pests can develop optimally because they are supported by temperatures that are ideal for growth and development. Almost all insect species require a certain temperature range for optimal growth. The temperature conditions in agricultural land are largely determined by sharing factors, such as elevation, vegetation density, the presence or absence of rain, and so on. Among these factors, elevation is the most important factor in determining the high and low temperatures in an area. Magina (2009) reported that CBB pest was not found above the altitude of 1,600 m from sea level of the Kilimanjaro Region, Tanzania, but were still found at the altitude between 1,200-1,600 m, although the population

was lower than the white coffee pest stem borer and *Antestia* bugs. Abedeta et al. (2011) reported that the incidence of CBB pest attack on the wild coffee population in the Afromontane Rainforest of Southwestern Ethiopia was decreasing with the rising altitude. Recent research conducted by Asfaw et al. (2019) in Southwestern Ethiopia also showed that the CBB attack rate was much higher in lowland coffee plantations compared to medium and low altitudes. Friederichs (1924 cited by Damon 2000) suspects that CBB pest prefers to attack coffee grown in the lowland because the plants condition is weaker than for the plants grown at an altitude above 1,220 m.

Many other species of insects generally also show the same tendency, which is that population is decreasing with increasing altitude. Magina (2009) stated that *Antestia* bugs were more dominant at moderate altitudes than high altitudes. Research conducted by Sanchez-Rodriguez and Baz (1995) on butterflies in the Mediterranean mountains, Spain also showed that the abundance and richness of butterfly species decreased with increasing elevation. Likewise, the research conducted by Romero-Alcaraz and Ávila (2000) shows that the abundance and diversity of species of Scarabaeoid dung beetles are also strongly influenced by elevation, which is higher in low-lying areas than in the highlands. Rasmann et al. (2014) reported that their survey and field experiment showed that the population of herbivore showed a decrease by elevation.

In conditions of warm temperatures, besides accelerating the growth and development of insects, it will also increase insect activity. Jaworski and Hilszczański (2013) have reviewed various scientific articles related to the effect of increasing temperature on growth and development and changes in insect activity. As a result of an increase in temperature many important insect pest species also grow rapidly, and this will potentially lead to even greater losses. Agegnehu et al. (2015) suspected that the increasing of CBB attacks in Ethiopia's highland coffee producing regions was caused by increasing temperatures in the region from year to year. This is also thought to be one of the factors causing an increase of CBB attacks in Arabica coffee plantations in the Central Aceh District, especially in the land below 1,300 m.

Conclusion

One of the advantages of organic coffee cultivation compared to conventional methods is that it is more effective in reducing CBB pest attack rates. The results also showed that CBB pests attacked Arabica coffee plants cultivated at an altitude between 1,300-1500 m with an attack rate ranging from 11-17%, although the level of pest attack was far lower than on those cultivated at altitudes below 1,300 m. The results of this study indicate that CBB pest attack on Arabica coffee plants is strongly influenced by biotic and abiotic factors. Growing global warming from year to year is expected to further intensify the level of pest attack on Arabica coffee plantations around the world. Therefore, to reduce the level of CBB attack in Arabica coffee plantations, it is far better to do it by cultivating Arabica coffee plants organically, especially on the land that at low or medium altitudes.

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