Diversity of ants (Hymenoptera:Formicidae) in organic and conventional Arabica coffee plantations in Aceh Tengah Regency, Sumatra, Indonesia

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Abstract. Several ant species are known as predators of coffee berry borer (CBB), *Hypothenemus hampei*, the most damaging pest on coffee plantations. We investigated ant diversity and looked at their role in Arabica coffee plantation in Aceh Tengah Regency, Aceh Province, Sumatra, Indonesia. Ants were sampled four times between February and July 2020 using pitfall traps. We found 5 subfamilies and 17 morphospecies of ants collectively in organic and conventional plantations. Eight of them belonged to subfamily Myrmicinae, one species each for subfamily Pseudomyrmecinae and Formicinae, while others belonged to subfamily Ponerinae and Dolichoderinae. The slightly higher ant species composition in conventional coffee might have been caused by the fallen CBB infested berries on the ground that might attract more ant species to come. There was no significant different in each diversity indices calculated for both coffee cultivation, even though the Shannon-Wiener diversity index (H') in the conventional coffee was relatively higher. Most of ant species were general foragers and some of them are known as predators of CBB. This study has provided important information regarding ant fauna in coffee plantations locally which is an early step to conserve ant species to be used as biological control agents of CBB.

1. Introduction
Coffee is an important drink in most societies around the world. It is not only for consumers' pleasure, but coffee is also important for its economic value for the coffee bean producing and exporting countries, such as Indonesia [1]. Coffee plantations are found around the world particularly in the tropics where it is known for their biodiversity hotspot [2]. Coffee plantations can provide habitat for different range of biodiversity [3], [4], including ant fauna [5]-[7]. However, agricultural practice such as removing shade-trees and higher application of agrochemicals may decrease biodiversity on the plantations [8] which in turn also reducing the ecosystem services such as pest control by natural enemies [4], [9].
Gayo highland area (including Bener Meriah, Aceh Tengah and Gayo Lues Regencies) is the biggest arabica coffee plantation area in Indonesia. The coffee plantations in these three Regencies reaches 101.316 ha and tend to increase every year. The coffee produced in these areas, known as Gayo Coffee, has been recognized for its unique taste in domestic, national, and international markets [10]. High pest infestation is one the problems that reduces the coffee productivity in these areas, particularly the coffee berry borer, *Hypothenemus hampei* Ferrari (Coleoptera: Scolytidae) [11], the most damaging pests in all coffee producing countries [12]-[16]. Females of coffee berry borer (CBB) bore galleries into the coffee berries to lay eggs, the larvae then feed on and destroy the coffee beans [17]. CBB infestation can cause significant losses in terms of coffee production, and also reduces coffee bean quality which results in poor quality of coffee [18]. In worse situation, CBB can reduce coffee production up to 50% [19]. It has been reported that Arabica coffee plantation in Aceh Tengah Regency suffers up to 12.1 % of CBB attacks on organic coffee and up to 22.2 % of CBB attacks on conventional coffee plantation [11].

Several ant species (Hymenoptera : Formicidae) have been found foraging and nesting in coffee plantation, such as *Azteca instabilis*, *Phedole synanthripica*, *Technomyrmex yamanei*, *Polyrhachis* (*Myrmhopla*) sp, *Trichomyrmex* sp. [5], [13]. A study showed that the presence of ants *Azteca instabilis* and *Phedole synanthripica* in coffee plantations could reduce coffee berry borer damage on the plants [13]. Higher ant activity on coffee trees is reported to associate with lower CBB infestation on the trees. In practical terms, *Azteca* is regarded as a nuisance to coffee workers who control them by placing lime on their nest entrance [20, 21].

Recent study showed that ants (Hymenoptera : Formicidae) were found abundantly in both organically and conventionally managed coffee plantation in Aceh Tengah Regency. They were identified as predators on the coffee plantation [11]. Despite the dominant number of morpho-species and individuals, it was not determined what species these ants were and what roles they played in coffee plantation. The growers in these areas also considered ant fauna in coffee plantations as a nuisance that disturb their activities in the plantations. Here, we investigated the ant species diversity and their possible ecological role in arabica coffee plantation in Aceh Tengah Regency, Aceh Province, Sumatra, Indonesia.

2. Materials and methods

2.1. Study site

The research was conducted in coffee plantations grown by local growers in Aceh Tengah Regency which is located around 300 km from the city of Banda Aceh. There were four plots used for the study containing two plots of organic plantation and two plots of conventional one. The coffee plantations were around 1-2 Ha in size each and were in different villages which were 2-3 km away from each other (Table 1). The plots were located between 1100-1400 m above sea level, where mostly coffee trees in Aceh Tengah Regency were grown. The chemical used in conventional plantation mostly was herbicide to control weeds in the plantations when the coffee trees were still young (less than 5 years old). Chemical fertilizer was applied 1-2 times each year. All coffee plantations observed has shade trees which more varied in organic plantations. There were no agrochemicals applied in the organic plots. The coffee trees in the study plantations were between 10-15 years old and 1.5 to 2.0 m in height.

| Village     | Type of cultivation | Location coordinate          |
|-------------|---------------------|-------------------------------|
| Arul Gele   | Organic             | 4° 37’’ 24’ N, 96° 44’’ 09’ E|
| Weh Masen   | Organic             | 4° 36’’ 37’ N, 96° 47’’ 03’ E|
| Tebes Lues  | Conventional        | 4° 36’’ 11’ N, 96° 47’’ 30’ E|
| Bies Mulia  | Conventional        | 4° 37’’ 28’ N, 96° 48’’ 11’ E|
2.2. Ant sampling
Ant species diversity was investigated in each sampling plot by collecting ants in the plots, particularly the ones in the ground near the coffee trees. Ants were collected by placing 10 pitfall traps on the soil within each plot and they were placed randomly among the coffee trees. The pitfall traps were prepared from the round plastic containers with 20 cm in diameter. To place the traps, the surface soil was dug a little bit so that the edge of the traps will be about the same level as the ground surface. The traps were filled with a mixture of water and detergent for up to half and will be left for 10 hours before removing and collecting the ants trapped inside. All ants trapped were placed in plastic bottles containing 70% alcohol and brought to the laboratory for identification. The abundance of each ant species was calculated by separating the species from each other morphologically and placed them in different bottles. The ant samplings were done twice between February to March 2020 and two more times between June and July 2020.

2.3. Data analysis
Identification of the ant fauna was done morphologically at least up to genus to recognize their role in the coffee plantations. Number of ant species and their abundance per plot was calculated from 10 pitfall traps placed in each plot. The diversity indices of the ant species were calculated using Shannon-Wiener diversity index (H') [22], Species Evenness index (E) [23], and the Simpson dominance index (C) [22]. The difference of each diversity index between organic and conventional coffee plantations was also analyzed by using unpaired T-Test. Significant difference between the two types of coffee cultivation for each analysis were set at P <0.05. All analysis was carried out using R Program Version 4.0.2 [24].

3. Results and discussion
3.1. Ant species composition
We managed to sample a number of 771 individual ants during four samplings time in organic and conventional coffee plantations. They consisted of 5 subfamily and 17 morphospecies. Eight of ant morphospecies (more than 50%) belonged to subfamily Myrmicinae, one species each for subfamily Pseudomyrmecinae and Formicinae, while other ant species belonged to subfamily Ponerinae and Dolichoderinae (Table 2). The high species number in subfamily Myrmicinae was commonly occurred in several previous studies, even from different types of agricultural plants such as wheat and potato [25]. Not all ant species was found in one plot, there were 3-8 species found on each plot of organic coffee and 4-10 species in each plot of conventional one. Species Tapinoma sp was only found in organic coffee, while Tetramorium sp2. Crematogaster sp1. Technomyrmex sp. Tetraponera sp. Anoplolepis gracilipes were only found in conventional plantations. The other species were recorded in both types of coffee plantations.

The results of this study showed that number of ant species found in conventional coffee plantation was higher than those of in organic coffee (Table 2). Recent study also has reported similar result on coffee plantation in Nicaragua. On average, there were 11 ant species found in conventional coffee plantation compared to six ant species in organic farm. The ant fauna found might have been affected by the composition of ground stratum [7] including leaf litter. In conventional plots we observed that the plantations were not well managed, many leaf litter and, decomposing wood scattered around coffee trees, and also fallen CBB infested berries. This condition might have attracted more ant species to come, particularly the species of ground-foraging ants. Agrochemical applied in conventional coffee plantations mostly was herbicide to clear the ground surface from any unwanted weeds, particularly when the coffee trees were still young and another agricultural plant such as chili was planted in between coffee trees. The coffee trees we observed were between 5-15 years old, they have grown fully and the canopies prevented weeds to grow underneath the coffee trees. Thus, the herbicide was no longer in frequent use and it did not cause the ant fauna in the ground to decrease. The observed plots of organic coffee trees, on the other hand, are well managed and had good sanitation around the trees, the situation that might have reduce the number of ant species on the ground surface.
Table 2. Identification of ants and their presence among four organic and conventional coffee plantations in two districts of Aceh Tengah Regency.

| No | Ant morphospecies          | Subfamily | Presence of ants |
|----|-----------------------------|-----------|------------------|
|    |                             |           | Organic | Conventional |
| 1  | *Tetramorium* sp1.          | Myrmicinae| ✓       | ✓              |
| 2  | *Tetramorium* sp2.          | Myrmicinae| ×       | ✓              |
| 3  | *Crematogaster* sp1.        | Myrmicinae| ×       | ✓              |
| 4  | *Crematogaster* sp2.        | Myrmicinae| ✓       | ✓              |
| 5  | *Monomorium* sp1.           | Myrmicinae| ✓       | ✓              |
| 6  | *Monomorium* sp2.           | Myrmicinae| ✓       | ✓              |
| 7  | *Pheidole* sp.              | Myrmicinae| ✓       | ✓              |
| 8  | *Myrmicaria* sp.            | Myrmicinae| ✓       | ✓              |
| 9  | *Odontoponera* sp1.         | Ponerinae | ✓       | ✓              |
| 10 | *Odontoponera* sp2.         | Ponerinae | ✓       | ✓              |
| 11 | *Leptogenys* sp.            | Ponerinae | ✓       | ✓              |
| 12 | *Odontomachus* sp.          | Ponerinae | ✓       | ✓              |
| 13 | *Technomyrmex* sp.          | Dolichoderinae| × | ✓ |
| 14 | *Dolichoderus* sp.          | Dolichoderinae| ✓ | ✓ |
| 15 | *Tapinoma* sp.              | Dolichoderinae| ✓ | × |
| 16 | *Tetraponera* sp.           | Pseudomyrmecinae| × | ✓ |
| 17 | *Anoplolepis gracilipes*    | Formicinace| ✓ | ✓ |

Total number of species: 12 for Organic; 16 for Conventional.

3.2. Ant diversity and biology

The type of coffee tree cultivation phase showed no significant effect in each of the ant diversity indices calculated. The Shannon-Wiener diversity index (H') on organic coffee did not differ significantly from that of conventional coffee (T Test, P = 0.39, t = 0.89, df = 14), neither did Species Evenness index (E) (T Test, P = 0.84, t = -0.20, df = 14) nor the Simpson dominance index (C) (T Test, P = 0.59, t = -0.54, df = 14) (Table 3). The Shannon-Wiener diversity index (H') tends to be higher in conventional coffee plantation than that of in organic coffee trees. Both organic and conventional coffee plantations in this study had taller trees as shading trees for the coffee underneath. Earlier study has reported that ant diversity is higher in shaded coffee plantation than that of in exposed ones [26]. The use of shading trees in coffee plantation favours the establishment of ant community [8], [27]. The relatively higher diversity index in conventional coffee plantation may have been caused by similar factors to the ones on ant species composition. Additionally, the scattered CBB infested berries in the ground and the higher rate of CBB infestation in conventional plantation may also increase the ant fauna found in this plantation, since several species ants are known to prey on CBB [5]-[7].

Table 3. Diversity indices of ant species ((mean ± SE) on organic and conventional coffee plantations in two districts of Aceh Tengah Regency.

| Type of coffee cultivation | Shannon-wiener (H') | Species evenness (E) | Simpson dominance (C) |
|----------------------------|---------------------|----------------------|-----------------------|
| Organic                    | 1.19 ± 0.11         | 0.77 ± 0.08          | 0.39 ± 0.06           |
| Conventional               | 1.36 ± 0.15         | 0.75 ± 0.07          | 0.35 ± 0.05           |

Most of the ant species found in this study has been reported as generalized foragers [28] including as predators of other insects. Ants are known as generalist predators that can be used as biological control agents of insect pests [29]. Some species, such as *Tapinoma* sp and *Dolichoderus* sp, also tend aphids
and scale insect to provide the secretion of honeydew for the ant supplement [30]. Some of ant species belong to genus *Pheidole* are reported as seed harvester or omnivorous. Other genera found in this study such as *Myrmicaria Odontoponera*, *Leptogenys*, *Odontomachus* sp. mostly recognized as predators [28]. Ant communities in coffee agroecosystems can be grouped into several foraging and nesting types. They mostly contained two general foraging groups which are arboreal and ground ants. Potentially these two groups are the ants that interact with coffee berry borer (CBB) [31], the most damaging pest in coffee plantation around the world [12]-[16]. Higher ant activity on coffee trees is reported to associate with lower CBB infestation on the trees [21]. Arboreal ants are the species that usually nest and forage on shade trees and coffee plants [32], while ground ants are the species that normally feed and nest on the ground in soil, leaf litter, twigs and decomposing wood [6].

Ant species that belong to subfamilies *Formicinae, Dolichoderinae*, and *Myrmicinae* are known as dominant arboreal species, they usually have very large colonies. Most of ant species found in this present study fell into these arboreal subfamilies despite the method of sampling was focused on the ground underneath the coffee trees. These arboreal species may also forage on the ground in the soil, coffee leaf litter or decaying branches. During sampling time, we observed many big nests of ant on coffee trees that possibly are the nests of *Crematogaster* spp. Unfortunately, there was no sampling was done on the coffee trees, so that we cannot compare if any species found in the ground was actually the same species as the one nesting in the coffee trees. Previous study has reported that several ant species can be observed both on the ground and on the plants even on the same site, showing their generalists behaviour in foraging and nesting habitats [30]. The ant species found in this study has provided a basic information on ant communities in organic and conventional arabica coffee plantation. This is an important step in designing a method to conserve them particularly the species that is beneficial as natural enemies of important pest on coffee plantation.

4. Conclusion

The ant communities found in this study consisted of arboreal and ground species, despite the sampling method that was only focused on ground foraging and nesting species. The higher ant species composition and ant diversity (relatively) in conventional plantations might be related to higher CBB infestation as shown in another study earlier. Eleven species of ants were recorded in both type plantation, while only one species (*Tapinoma* sp) was only found in organic coffee. The others which were *Tetramorium* sp2. *Crematogaster* sp1. *Technomyrmex* sp. *Tetraponera* sp. *Anoplolepis gracilipes* were only found in conventional coffee. The study has provided a basic information on ant communities in organic and conventional arabica coffee plantation. This is an important step in designing a method to conserve them particularly the species that is beneficial as natural enemies of important pest on coffee plantation.

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