Diversity of Hymenoptera parasitoid in organic and conventional arabica coffee plantations in Aceh Tengah District, Aceh Province, Indonesia

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Abstract. This research is a descriptive exploratory study. The purpose of this study was to determine the diversity of parasitoids in coffee plantations that are managed organically and conventionally. Based on statistical analysis shows that the composition and diversity of the Hymenoptera parasitoid in Arabica coffee plantations in Aceh Tengah District is influenced by cultivation techniques (organic and conventional). Both the number of families and species of Hymenoptera parasitoid found in organic coffee plantations were higher than those found in conventional ones. In organic coffee plantations, 8 families and 15 species were found, while in conventional plantations there were only 4 families and 10 species. The parasitoid species diversity index value ($H'$) in organic coffee plantations was better than conventional coffee plantations, while the evenness index value ($E$) on organic and conventional coffee plantations was relatively more likely (not statistically different) and to be classified as good categories. This indicates that there are several families of the Hymenoptera parasitoid that dominate both in organic and in conventional coffee plantations. The low diversity of the Hymenoptera parasitoid in conventional coffee plantations is thought to be a result of the continued application of synthetic pesticides, thus affecting the extinction of various parasitoid species.

1. Introduction
The biodiversity of insects has become an important concern of ecologists, especially insect diversity. Ecologically insects can be used as an indicator of good or damage to the environment [1]. The stability of pest insect and natural enemy populations generally occurs in natural ecosystems, so that the presence of pest insects is no longer detrimental. The situation needs to be developed so that it can suppress the use of synthetic pesticides [2]. One component of natural enemies that is very important in maintaining the balance of insect pest populations is the parasitoid group. The parasitoid group comes from the insect class which is mostly the Hymenoptera Order [3].

Taxonomically 80% of parasitoids belong to the order Hymenoptera. Hymenoptera is the largest order in the insect class which is estimated to have more than 300,000 species [4]. The diversity of natural enemies is found to be higher in habitats that have many flowering plants and are not polluted by chemicals in coffee plants [5]. To maintain parasitoid populations in the field, proper habitat...
management is needed. Habitat can be a natural environment that is maintained or created an environment that is modified so that it is suitable for natural enemies to survive and reproduce [6].

One of the creative environments that are often modified is coffee plantations. Coffee plantations are generally quite extensive agricultural areas, including arabica coffee plantations in Indonesia. One of the largest arabica coffee growing areas in Indonesia is in the district of Aceh Tengah, Aceh Province [7]. According to Aceh Province Plantation and Forestry Service Statistic every year there continues to be an increase in the expansion of the area of arabica coffee growing in Central Aceh district. A significant increase in planting area especially occurred in organic arabica coffee. This is related to the growing international market demand for organic coffee, besides growing coffee farmers' awareness of the dangers of using synthetic chemicals, especially those from pesticides.

Organic Arabica coffee cultivation aside from providing higher economic benefits is also ecologically beneficial because the cultivation system prioritizes natural ways of controlling plant-disturbing organisms. In this organic coffee cultivation system, pest control is mainly expected in the role of various natural enemies including parasitoids. Recent research Husni et al., [8] in arabica coffee plantations, Aceh Tengah District showed that the level of major coffee pest attacks (Hypothenemus hampei) on organic arabica coffee plantations was much lower compared to conventionally managed arabica coffee plantations. Husni et al., [8] suspect that in organic coffee plantations there are more diverse species of natural enemies than conventional coffee plantations.

The existence of scientific information about the presence of various natural enemy species is very important to know because there is a special relationship between natural enemies and their habitats and the implications for effectiveness in pest control [9]. This study aims to investigate the diversity and abundance of natural enemies, especially the Hymenoptera parasitoid in the organic and conventional arabica coffee plantations in Aceh Tengah District, Aceh Province, Indonesia.

2. Materials and methods
This research is a descriptive exploratory study. Sampling was carried out in an area in Bies Sub District, Aceh Tengah District. Determination of the location of the study was carried out by using a purposive sampling method, namely by selecting an expanse of coffee plantations that are managed organically and conventionally.

2.1. Insect sampling
Insect sampling was carried out three times at intervals of 3 weeks, by using four types of traps, namely the yellow pan trap, pitfall pan trap, malaise trap, and light trap (Fig 1). These four types of traps are placed both on organic and conventional coffee plantations. In both organic and conventional coffee plantations, two sampling plots were chosen. Installation of all traps carried out for 12 hours. Yellow pan traps, pitfall traps, and malaise traps were installed from 06.00 am to 06.00 pm, while light trap traps were installed from 06.00 pm to 06.00 am.

2.2. Insect sorting and identification
Every insect that caught was collected and then sorted at the Biology Control Laboratory at Universitas Syiah Kuala. Then the insect samples were sent to the Bogor Institute of Agriculture's Insect Biotaxonomics Laboratory to be identified. Identification of insect samples using the Olympus SZ61 microscope. In addition, the insect identification process also uses several insect identification manuals [10]-[14]. All Hymenoptera insects which act as parasitoids were photographed with a camera microscope (Leica M205C).
2.3. Data Analysis

Differences in the composition of Hymenoptera parasitoid (number of families, number of species, and number of individuals) in organic and conventional Arabica plantations were analysed using an unpaired T-test. The diversity indices of the Hymenoptera parasitoid species were calculated using the Shannon-Wiener diversity index (H') and Species Evenness index (E) (Table 1). The difference in each diversity index between organic and conventional Arabica coffee plantation was also determined by using T-Test. A significant difference between the two groups of coffee plantations was set at P <0.05.

**Table 1.** Formulas used for calculating the diversity and evenness indices of the Hymenoptera parasitoid species on organic and conventional plantations.

| No | Diversity Index | Formula | Remarks |
|----|-----------------|---------|---------|
| 1  | Shannon-Wiener Diversity Index (H') | $H' = - \sum_{i=1}^{S} \pi_i (Ln \pi_i)$ | $H'$ = Diversity index, $\pi_i$ = Proportion of individuals of species $i$ in the community, $S$ = Number of species per collected samples |
| 2  | Species Evenness Index (E) | $E = \frac{H'}{ln(S)}$ | $E$ = Evenness index, $H'$ = Diversity index, $S$ = Number of species per collected samples |
3. Results

3.1. Composition of hymenoptera parasitoid

The results showed that the composition of the Hymenoptera parasitoid in arabica coffee plantations in Central Aceh District was influenced by coffee cultivation techniques (organic and conventional). Inorganic coffee plantations found a higher number of families, species richness, and the number of individual parasitoid Hymenoptera compared to conventional coffee plantations. In organic coffee plantations, 8 families and 15 Hymenoptera parasitoid species were found, while in conventional coffee plantations 4 families and 10 Hymenoptera parasitoid species were found (Figure 2).

![The composition of Hymenoptera parasitoid](image)

**Figure 2.** The composition of the Hymenoptera parasitoid is based on the number of families, the number of species, and the number of individuals (mean ± SE) in organic and conventional coffee plantations. (*: p<0.05, **: p<0.01 by paired t-test).

3.2. Diversity and evenness of Hymenoptera parasitoid species

A diversity index is a comparison of the value of species with the total value of all species in a community. While the evenness index is a comparison of the dominance values of species in a community. The results of the diversity index values (H') and evenness index (E) are calculated based on the weighting criteria values according to the Krebs rating scale [15]. The results showed that the diversity index value (H') in organic coffee plantations was higher compared to conventional coffee plantations which were 1.33 and 0.98, respectively (Table 2). Furthermore, the value of evenness index (E) tends to be the same between organic and conventional coffee plantations, namely 0.77 and 0.80 (Table 2).

![Table 2](image)

**Table 2.** Hymenoptera diversity and evenness index (mean ± SE) of the parasitoid in organic and conventional coffee plantations.

| Location                  | Diversity (H') | Evenness (E)   |
|----------------------------|----------------|----------------|
| Organic Coffee Plantation  | 1.33 ± 0.12 a  | 0.77 ± 0.06 a  |
| Conventional Coffee Plantation | 0.98 ± 0.10 b | 0.80 ± 0.05 a  |

Note: Numbers that are followed by the same letter in the same column are not shown significant differences by paired t-test.

4. Discussion

The results showed that the value of the parasitoid Hymenoptera diversity index in organic coffee plantations was higher compared to conventional coffee plantations, namely 1.33 and 0.98, respectively. According to the Krebs rating scale [15], the diversity value of 1.33 is included in the medium category,
while the value of 0.98 is included in the bad category. The results also showed that the composition of the parasitoid Hymenoptera, which is the number of families, species, and individuals in organic coffee plantations is also higher than conventional coffee plantations. It is suspected that in organic coffee plantations the environmental conditions are relatively more ideal for the growth and development of the Hymenoptera parasitoid, whereas in conventional coffee plantations the development of parasitoids is disrupted by various chemicals that are applied continuously, especially those originating from pesticides. Research conducted by Nelly et al., [16] in coffee plantations in West Sumatra also showed the number of natural enemies found in organic coffee plantations was higher than coffee plantations that were routinely applied with pesticides.

Hole et al., [17] has reviewed 14 articles that stated that the abundance of natural enemy individuals is higher on organically managed agricultural land compared to conventionally managed land. Blibeck et al., [18] suggested that insecticides are very dangerous to various parasitoid species, especially in the order Hymenoptera. Furthermore, Sebai et al., [19] suggested that the influence of broad-spectrum herbicides can limit efficiency and affect parasitoid activity by destroying food sources, eliminating microhabitats, or killing directly parasitoids. According to Pedigo [20] the parasitoids are unable to detoxify the insecticide. Hidrayani et al., [21] stated that generally, parasitoids are more susceptible to insecticides than their hosts.

The results showed that the evenness of the Hymenoptera parasitoid species tends to be the same (not statistically different according to t-test) between organic and conventional coffee plantations. The value of the evenness index is used as an indicator of the dominance of a type in a community. The value of the evenness index is a measure of the balance between one community and another. According to Krebs [15] the value of evenness between 0.61-0.80 is in a good category. The species evenness value will tend to zero if the community is dominated by one species [22].

The most dominant parasitoid of Hymenoptera in both organic and conventional coffee plantations was the family Braconidae and Ichneumonidae. In organic coffee plantations, there are 5 and 4 species of the Braconidae and Ichneumonidae, respectively, while in a conventional coffee plantation, there are 4 Braconidae and Ichneumonidae families, respectively. Previously Casas [23] also found that the parasitoid family Braconidae and Ichneumonidae were the dominant families in coffee plantations in the United States. Radiyanto et al., [24] also states that the Braconidae and Ichneumonidae families are the dominant Hymenoptera parasitoid family in coffee plants. The occurrence of Ichneumonidae and Braconidae families in coffee plantations, allegedly because these two families have a wider host range and the ability to find a better host than other family types.

The results of this research showed that some species of the family Braconidae, such as Heterospilus coffeicola and Bracon zeuzerae have many hosts which are insect pests in coffee plants, such as Coccus viridis, Hypothenemus hampei, Planococcus citri, Xyloladrus compactus, X. morigerus, Zeuzera coffea and Z. roricyanea [25-26]. This research discovered that the diversity of the parasitoid Hymenoptera in organic coffee plantations was higher compared to conventional coffee plantations. This is due to organic coffee plantations without application with synthetic pesticides. While the diversity of the Hymenoptera parasitoid is low in conventional coffee plantations causing the continued application of synthetic pesticides.

5. Conclusion

The composition and diversity of the Hymenoptera parasitoid in arabica coffee plantations in Aceh Tengah District are influenced by coffee cultivation techniques (organic and conventional). The parasitoid species diversity index value in organic coffee plantations is better than conventional coffee plantations. The low diversity of the Hymenoptera parasitoid in conventional coffee plantations is thought to be a result of the continued application of synthetic pesticides, thus affecting the extinction of various parasitoid species. The results also showed that the evenness index value on organic and conventional coffee plantations was relatively more likely to be classified as good categories. This indicates that several families of the Hymenoptera order dominate both in organic coffee plantations and conventional coffee plantations, namely the Braconidae and Ichneumonidae families.
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