Entomology

Study ecology of insects on cocoa (*Theobroma cacao* L.) plantation with and without insecticide application in North Sumatera, Indonesia

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Abstract

This study aimed to analyze the diversity, dominance, evenness, and environmental factors of insects in two different habitat conditions, namely cocoa plantations with insecticide application and without insecticide application in Siantar Marimbun District, Pematangsiantar City. Samples were collected using purposive sampling with yellow sticky traps. A total of 3,649 individuals representing 24 insect species from four orders (Coleoptera, Hemiptera, Hymenoptera, and Diptera) were successfully identified. Hymenoptera was the most abundant order, with *Messor barbarus* as the dominant species. The Shannon-Wiener diversity index was higher in non-insecticide-treated fields (H1′ = 2.41) compared to insecticide-treated fields (H2′ = 2.28). The dominance index was relatively greater in insecticide-treated fields, while the evenness values in both habitats were categorized as high. The t-test indicated a significant difference in insect diversity between the two habitats (t-value = 3.71 > t-table = 1.96). The measurement results for environmental factors indicate that the temperature ranges from 27.8 to 29.5 °C, the humidity ranges from 69% to 79%, and the wind speed ranges from 1.0 m/s to 1.6 m/s.

Keywords: Insects, Cocoa, Diversity, Abundance, Insecticide, Environmental Factors

1. Introduction

Cocoa (*Theobroma cacao* L.) is a strategic plantation commodity that plays an important role in the national economy. Indonesia is among the world's top three cocoa producers, along with Côte d'Ivoire and Ghana, with an annual production of 1,315,800 tons. Approximately 90% of this production is managed by smallholder plantations, providing livelihoods for more than 1.3 million farming households (Farhanandi & Indah, 2022) [2]. As a leading commodity, cocoa contributes to employment, income generation, foreign exchange, and promotes the growth of agro-industries (Latip & Hasriyanti, 2015) [6].

Cocoa productivity largely depends on environmental conditions such as climate, soil type, and topography. This crop requires a typical tropical rainforest ecosystem characterized by stable temperatures, high rainfall, adequate humidity, and optimal sunlight intensity (Latip & Hasriyanti, 2015) [6]. According to Central Sulawesi Statistics (BPS), the area of smallholder cocoa plantations reached 295,874 hectares with a production of 181,523 tons. As a megadiverse country, Indonesia possesses rich biodiversity, including insects that play roles as predators, pollinators, and decomposers. However, some insect species also act as significant agricultural pests (Hommy *et al*., 2024) [4]. Insects found on cocoa plants generally belong to the orders Diptera, Lepidoptera, Coleoptera, and Hymenoptera, with pest species such as Ceratitis capitata and Dasychira inclusa, as well as beneficial insects like *Oecophylla smaragdina* (Ali *et al*., 2024) [1].

The main problem in cocoa cultivation is pest infestation, which reduces productivity. Control efforts generally rely on chemical insecticides; however, excessive use may lead to pest resistance, loss of natural enemies, and environmental pollution (Latip & Hasriyanti, 2015) [6]. In fact, insect diversity plays a crucial role in maintaining the balance of agricultural ecosystems (Hommy *et al*., 2024) [4].

2. Research methods

This research was conducted in Siantar Marimbun District, Pematangsiantar City, North Sumatra Province, and in the Biology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, from May to July 2025. Samples were collected from cocoa plantations treated with insecticides and those without insecticide application in Siantar Marimbun, Pematangsiantar, North Sumatra, Indonesia.

The tools used in this study included yellow sticky traps for capturing insects, bottles for storing specimens, a microscope for observing and documenting insect samples, and other supporting materials such as pens and paper. The main preservative material used was 70% alcohol. The research procedure consisted of two main stages:

a) Insect sampling

- Sampling sites were selected on cocoa (*Theobroma cacao* L.) plantations in Siantar Marimbun District, Pematangsiantar City, covering an area of 1 hectare.
- Observation points were determined randomly.
- Traps were placed randomly at each observation point.

- Ready-to-use insect traps with adhesive and pheromone bait were utilized.
- Traps were installed in the morning at 08:00 and retrieved at 17:00 in the afternoon. Sampling was conducted a total of 4 times.
- Captured insects were preserved in 70% alcohol and taken to the laboratory.

b) Insect identification

- Insect specimens were identified at the Biology Laboratory, FMIPA, Universitas Negeri Medan.
- Identification was carried out using a stereo microscope to examine morphological structures.
- Then, identifying insect specimens referring to the books by Jumar, 2000, Borror *et al*., 1992, Lilies *et al.,* 1991, and Siwi *et al*., 1991.

3. Data analysis techniques

a) Diversity index

The insect diversity index in this study was calculated using the Shannon-Wiener formula (H') as described by Syari *et al.* (2023) [10]. The formula is as follows:

$$H' = - \sum pi \ ln \ pi$$

Where, $pi = \frac{ni}{N}$

Description

H': Diversity Index value
pi: Proportion of individuals of species *i* (ni) to the total number of individuals N: Total number of individuals of all species
ni: Number of individuals of species *i*

b) Dominance index

The dominance index was used to determine the level of insect dominance. According to Manurung (2020), dominance can be calculated using the following formula:

$$D = \sum (\frac{ni}{N})2$$

Description

D: Dominance Index
ni: Number of individuals of a species
N: Total number of individuals of all species

c) Evenness index

According to Habibi & Yudha (2022) [3], insect evenness can be calculated using the following formula:

$$E = \frac{H'}{ln \, S}$$

Description

E: Evenness Index
H': Shannon-Wiener Diversity Index
S: Number of insect species
ln: Natural logarithm

d) *t*-test

According to Sari *et al*. (2021) [9], the t-test was applied to examine whether there was a significant difference in diversity between the two insect communities. The formula used is:

$$t \ h \ = \frac{H'1 \ - \ H'2}{\sqrt{Var \ H'1 \ + \ Var \ H'2}}$$

The variance value can be calculated using the following formula:

$$Sp = \frac{(X \ - \ \mu \ )^2}{N}$$

The degrees of freedom used to determine the *t*-table value can be calculated using the following formula:

$$df \ = \frac{(VarH'1 \ + \ VarH'2 \ )^2}{\frac{(\sqrt{Var \ H'1 \ })^2}{N1} + \frac{(\sqrt{Var \ H'2 \ })^2}{N2}}$$

Description

H'1: Insect diversity index in cocoa plantations with insecticide application.
H'2: Insect diversity index in cocoa plantations without insecticide application.
Var H'1: Variance value in cocoa plantations with insecticide application.
Var H'2: Variance value in cocoa plantations without insecticide application.
N: Total number of individuals.
X: Number of individuals of each species.
μ: Mean value.

4. Results and Discussion

A. Species and number of insects in cocoa plantations with and without insecticide application in Siantar Marimbun, Pematangsiantar

The species and number of insects found in cocoa plantations in Siantar Marimbun District, Pematangsiantar City, from May to July 2025, totaled 3,649 individuals consisting of 24 species belonging to four insect orders: Coleoptera, Hemiptera, Hymenoptera, and Diptera. The insect species identified are presented in Figure 1, while the number of individuals and species found in cocoa plantations with insecticide application and without insecticide application in Siantar Marimbun District, Pematangsiantar City, are shown in Table 4.1

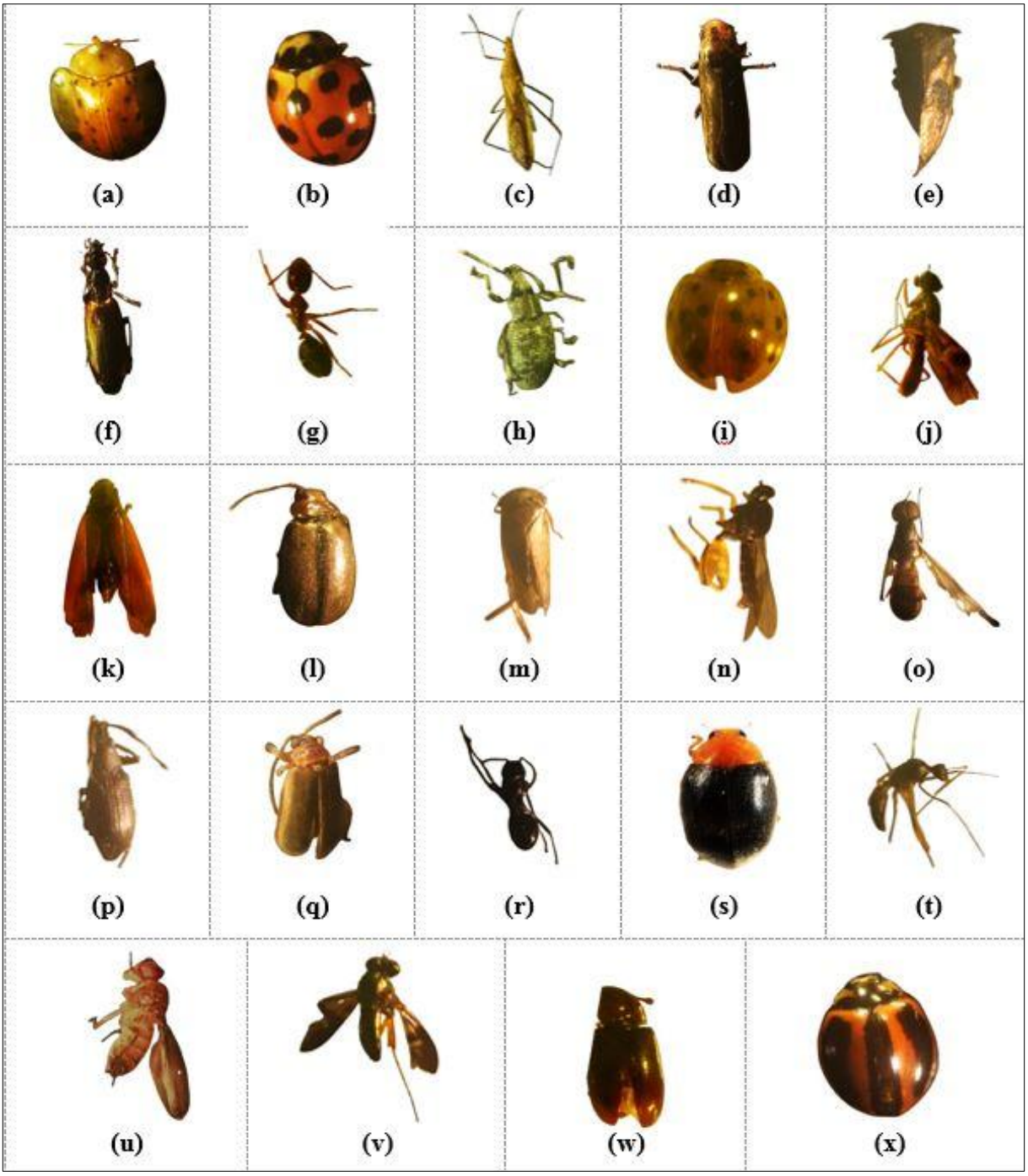

Fig 4.1: Insect species found on cocoa plants (*Theobroma cacao* L.) include: (a) *Aspidimorpha miliaris,* (b) *Harmonia conformis,* (c) *Leptocorisa oratorius,* (d) *Bothrogonia addita,* (e) *Nilautama minutispina, (f) Calleida viridipennis,* (g) *Formica integra,* (h) *Phlyctinus callosus,*(i) *Harmonia sedecimnotata*, (j) *Comptosia insignis,* (k) *Bothrogonia duplex,* (l) *Lochmaea crataegi,*(m) *Deltocephalus maculiceps,* (n) *Dioctria lateralis,*(o) *Astomaspis crassa,* (p) *Notaris acridulus, (q) Galeruca tanaceti,* (r) *Messor barbarus, (s) Scymnus cervicalis, (t) Odontomachus bauri, (u) Bactrocera dorsalis,* (v) *Sargus albarius, (w) Necrobia rufipes dan* (x) *Micraspis lineata*

Table 4.1: Species and number of insects in cocoa plantations with and without insecticide application

Order	Family	Species	Number of individuals trapped	
			Insecticide application	Without insecticide
Coleoptera	Chrysonelidae	*Aspidimorpha miliaris*	1	10
	Coccinellidae	*Harmonia conformis*	5	22
	Carabidae	*Calleida viridipennis*	12	25
	Curculionidae	*Phlyctinus callosus*	8	16
	Coccinellidae	*Harmonia sedecimnotata*	4	19
	Chrysonelidae	*Lochmaea crataegi*	6	20
	Curculionidae	*Notaris acridulus*	0	4

	Chrysomelidae	*Galeruca tanaceti*	10	30
	Coccinellidae	*Scymnus cervicalis*	8	70
	Cleridae	*Necrobia rufipes*	6	3
	Coccinellidae	*Micraspis lineata*	6	18
Hemiptera	Alydidae	*Leptocorisa oratorius*	15	40
	Cicadellidae	*Bothrogonia addita*	18	32
	Membracidae	*Nilautama minutispina*	120	325
	Cicadellidae	*Bothrogonia duplex*	40	63
	Cicadellidae	*Deltocephalus maculiceps*	20	35
Hymenoptera	Formicidae	*Formica integra*	180	425
	Braconidae	*Astomaspis crassa*	0	25
	Formicidae	*Messor barbarus*	180	465
	Formicidae	*Odontomachus bauri*	190	443
Diptera	Bombyliidae	*Comptosia insignis*	10	55
	Asilidae	*Dioctria lateralis*	46	135
	Tephritidae	*Bactrocera dorsalis*	144	315
	Stratiomyidae	*Sargus albarius*	0	25
Total		24	1.029	2.620

Based on insect observations in cacao (*Theobroma cacao* L.) plantations in Siantar Marimbun Subdistrict, Pematangsiantar City, a total of 3,649 insect individuals were recorded, consisting of 24 species classified into four orders: Coleoptera, Hemiptera, Hymenoptera, and Diptera. When comparing the two habitat conditions, the number of insect individuals in the non-insecticide-treated area (2,620 individuals, 24 species) was much higher than in the insecticide-treated area (1,029 individuals, 21 species). This indicates that the use of insecticides has a significant effect on the number of insects found in the study area. Several species were recorded only in the non-insecticide-treated cacao plantation and were absent in the insecticide-treated plantation, namely *Notaris acridulus*, *Astomaspis crassa*, and *Sargus albarius*. This finding is consistent with Latif (2015), who reported that insect abundance and diversity are generally higher in non-insecticide-treated areas compared to insecticide-treated plantations. In general, insecticides sold in the market are chemically synthesized. Their application is simple and provides rapid control of pest organisms. However, the residues left behind can enter environmental components, as the active ingredients are difficult to degrade naturally. As a result, some non-pest insects are also killed due to exposure to these chemicals

A. Diversity index

The calculation results of the insect diversity index in cacao plantations treated with insecticides and without insecticides are presented in Table 4.2.

Table 4.2: Insect diversity index in cacao plantations treated with insecticides and without insecticides

No	Habitat	Diversity Index
1	Cacao plantation treated with insecticides	2.28
2	Cacao plantation without insecticides	2.41

Based on Table 4.2, the insect diversity index (H') in cacao plantations treated with insecticides was 2.28, while in non-insecticide plantations it was higher at 2.41. According to the Shannon-Wiener criteria, these values fall within the medium diversity category. This indicates that insect communities in both habitats are relatively diverse, although the number of species and individuals was more abundant in the non-insecticide-treated area. The higher diversity observed in the non-insecticide plantation may be attributed to the absence of chemical pressure that suppresses insect populations, including both pests and natural enemies. This finding is consistent with Sari *et al*. (2021) [9], who reported that intensive insecticide application tends to reduce the diversity of non-target insects, thereby decreasing ecosystem stability.

B. Dominance index

The calculation results of the insect dominance index in cacao plantations treated with insecticides and without insecticides are presented in Table 4.3.

Table 4.3: Insect dominance index in cacao plantations treated with and without insecticides

No	Habitat	Dominance index
1	Cacao plantation treated with insecticides	0.13
2	Cacao plantation without insecticides	0.12

Based on Table 4.3, it can be observed that the dominance index values show a noticeable difference between the two habitats. The dominance index in insecticide-treated cacao plantations was 0.13, while in non-insecticide plantations it was slightly lower at 0.12. Although the difference is relatively small, this indicates that insect populations in cacao plantations treated with insecticides tend to be more concentrated in certain species compared to those in non-insecticide habitats. The lower dominance in non-insecticide plantations reflects habitat conditions that are more favorable for a wider range of insects, including both pests and predators. This finding is consistent with Kurnia *et al*. (2023) [5], who reported that habitat complexity without chemical pressure allows more species to thrive.

Thus, it can be concluded that insecticide application influences the pattern of insect dominance in cacao plantations,

where insect communities in non-insecticide plantations tend to be more stable and possess higher potential diversity.

C. Evenness index

The calculation results of the insect evenness index in cacao plantations treated with insecticides and without insecticides are presented in Table 4.4.

Table 4.4: Insect evenness index in cacao plantations treated with and without insecticides

No	Habitat	Evenness index	Category
1	Cacao plantation treated with insecticides	0.75	High
2	Cacao plantation without insecticides	0.76	High

Based on Table 4.4, the evenness index (E) in insecticide-treated cacao plantations was 0.75, while in non-insecticide plantations it was slightly higher at 0.76. These values are categorized as high, indicating that the distribution of individuals among species was relatively even in both habitats. Although the numerical difference is small, the higher evenness value in the non-insecticide plantation suggests that the insect community structure in this habitat is more stable and balanced. According to Pelealu *et al*. (2022) [8], an evenness index approaching 1 reflects a healthy ecosystem condition, where various insect species are well distributed without absolute dominance.

Thus, it can be concluded that non-insecticide conditions are more favorable for supporting stable and balanced insect communities, whereas insecticide use may lead to dominance by certain species, even though overall species evenness remains relatively high.

D. Differences in insect diversity and abundance in cacao plantations with and without insecticide application

Based on the t-test results, there was a significant difference in insect diversity and abundance between cacao plantations treated with insecticides and those without insecticide application. The t-test results for insect diversity and abundance in both conditions are presented in Table 4.5.

Table 4.5: *t*-test of insect diversity in cocoa plantations with and without insecticide application

Statistical test parameter	Value
H' (cocoa plantation with insecticide)	2.28
H' (cocoa plantation without insecticide)	2.41
Standard Deviation (SD) – cocoa plantation with insecticide	0.00087
Standard Deviation (SD) – cocoa plantation without insecticide	0.00038
Calculated *t*-value	3.71
Degree of freedom (df)	1,977
t-table value (α = 0.05)	1.96
Significance	Significant

Based on Table 4.5, the results of the *t*-test showed that insect diversity and abundance between the two habitats were significantly different (*t* calculated = 3.71 > *t* table = 1.96). Thus, the conditions of cocoa plantations with and without insecticide application at the study site caused a meaningful difference in insect diversity.

E. Environmental factors in cocoa plantations that apply insecticides and those without insecticides

Environmental factor data were used to describe the conditions during the study period, particularly when insects were encountered. These environmental conditions were obtained from direct measurements at the study sites. The abiotic environmental factor data are presented in Table 4.6.

Table 4.6: Abiotic environmental factors recorded during the study

No	Parameter	Cocoa plantation with insecticide	Cocoa plantation without insecticide
1.	Temperature	27,8 – 29,5 °C	27,2 – 28,1 °C
2.	Air Humidity	69 – 73 %	75 – 79 %
3.	Wind Speed	1,0 – 1,3 m/s	1,3 – 1,6 m/s

Based on Table 4.6, differences in environmental factors were observed between cocoa plantations with insecticide application and those without insecticides. In plantations treated with insecticides, air temperature was relatively higher (27.8-29.5 °C) compared to non-insecticide plantations (27.2-28.1 °C). Meanwhile, air humidity in insecticide-treated plantations tended to be lower (69-73%) than in non-insecticide plantations (75-79%). Wind speed also showed variation, with insecticide-treated plantations ranging from 1.0-1.3 m/s, whereas non-insecticide plantations recorded slightly higher values of 1.3-1.6 m/s.

These differences in microclimatic conditions may influence insect presence. Higher temperatures and lower humidity in insecticide-treated plantations may limit the activity of certain insect species that prefer moist conditions. Conversely, non-insecticide plantations with higher humidity and slightly stronger wind may provide a more suitable environment for specific insects, particularly those that depend on humid air conditions for flight activity and physiological processes. This indicates that insect occurrence is influenced not only by chemical factors (such as insecticide use) but also by abiotic environmental factors that determine habitat suitability.

5. Conclusion

Research conducted in cocoa plantations with and without insecticide in Simarimbun District, Pematangsiantar City, collected a total of 3,649 individuals of insects belonging to 24 species across four orders (Coleoptera, Hemiptera, Hymenoptera, and Diptera), with a dominance of Coleoptera and Hymenoptera orders. The Shannon-Wiener diversity index showed a moderate value (2.28-2.41). The relative dominance index was higher in areas treated with insecticide, while the evenness value in both habitats was classified as high. T-tests showed a significant difference in insect diversity between the two habitats.

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