

Insect Community Structure in Young and Productive Coffee Farms under *Leucaena* Shade of Jember Regency, East Java, Indonesia

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Abstract

The developmental phase of Robusta coffee plantations with agroforestry systems exhibits varying ecosystem characteristics (biotic and abiotic), thereby influencing the dynamics of insect community composition within them. One of the major coffee-producing centers in East Java is Jember Regency, where coffee cultivation commonly employs agroforestry systems with various shade trees. Understanding the abundance of insect species in agroforestry coffee plantations is important for determining insect pest control measures. This research aims to study the insect community structure in young coffee and productive coffee farms. Insect sampling was conducted in young coffee farms and productive coffee farms at the Kaliwining Experimental Station, Indonesian Coffee and Cocoa Research Institute (ICCRI), by using road sampling methods with insect nets and pitfall traps. Both types of plantations utilize *Leucaena* sp. var L2 as shade trees, forming agroforestry coffee plantation systems. Data analysis was performed by calculating the Shannon-Wiener diversity index (H') to assess insect diversity and the independent sample t-test to determine differences in insect abundance based on functional roles between the two farms. The results indicate that the composition and abundance of insects in productive coffee farms are higher than in young coffee farms, resulting in a higher insect diversity index value for productive coffee farms (categorized as high), while young coffee farms fall into the moderate category. Furthermore, based on their functional roles, productive coffee farms positively influence the abundance of herbivorous, predatory, parasitoid, and detritivorous insects.

Keywords: Insects, community structure, Robusta coffee, agroforestry, shade trees

INTRODUCTION

Coffee is one of the plantation sector commodities that is widely cultivated in Indonesia. One of the coffee production centers in the country is Jember, a regency in East Java, which currently has a total area of 18,318 ha with a total production of 11,795 tons in 2022 (BPS East Java, 2023). Coffee cultivation in Jember generally applies

an agroforestry system, a planting pattern that combines coffee plants with shade plants (Istikorini *et al.*, 2023). Coffee farmers in Jember use many shade plants, including pepper, lamtoro (*Leucaena leucocephala*), and bananas. Cultivating coffee using an agroforestry system provides ecological benefits to biodiversity, including the presence of various types and numbers of insects (Wijayanto, 2023).

Insects are important in supporting coffee plant productivity (Ilhamdi, 2022). Basri *et al.* (2023) state that insects are important in the coffee agroforestry ecosystem as pollinators, natural enemies, and pests. The abundance of insects in coffee farm ecosystems can be influenced by various factors, including the plant development phase (Triyogo *et al.*, 2017).

Differences in the developmental phase or age of coffee crop will result in differences in ecosystem characteristics that can affect the insect community (Triyogo *et al.*, 2017). Young coffee farms have high weed vegetation, leading to abundant herbivorous insects (Hernawan, 2016). The flowering phase experienced by plants in productive coffee farms also influences the abundance and composition of insects (Triyogo *et al.*, 2017). Supriyadi *et al.* (2019) state that in coffee farms, plants with high flowering vegetation increase the abundance of parasitoids and predatory insects in the coffee ecosystem.

Some empirical findings show that the developmental phases of young coffee farms and productive coffee farms have different ecosystem characteristics (biotic and abiotic); this will certainly affect the dynamics of the insect community composition within the farms (Triyogo *et al.*, 2017). Studying the number of individuals and families of insect orders in young coffee farms and productive coffee farms is necessary to identify the abundance of insect species in these habitats to support coffee plant productivity and implement appropriate farm management strategies. Thus, this research aims to examine the insect community structure in the Robusta coffee cultivation system with an agroforestry planting pattern using lamtoro as the shade tree in young coffee farms and productive coffee farms.

MATERIALS AND METHODS

The study was done from January to February 2024 at the Kaliwining Experimental Station (45 m above sea level) of the Indonesian Coffee and Cocoa Research Institute, Jember, East Java, Indonesia. Insect sampling locations included two Robusta coffee farms with different planting ages and *Leucaena* sp. var L2 as the shade crop. Both study sites have a D-climate type based on Schmidt & Fergusson (1951), with an rainfall of 525 mm observed from January to March 2024, and have latosol and regosol soil types. The first farm produces productive coffee plants aged 15 years; the farm coordinates are 8°25'79.81" S, 113°61'21.28" E. The second farm is a young coffee farm with a 1.5-years-old rejuvenated plant; the farm coordinates are 8°25'85.74" S, 113°61'22.52" E. Each farm is 50 m x 50 m with a distance of 70 meters between the two trial locations.

The spacing between coffee trees in the two study sites is 2 m x 2 m, while the distance between lamtoro as shade plants is 3 m x 3 m. Maintenance of coffee and shade crops included pruning and fertilization following Indonesian Coffee and Cocoa Research Institute standards, and pest and disease control was not carried out during sampling. The weed population in the young coffee farms was denser than in the productive coffee farms. however, the leaf litter in the productive coffee farm was thicker than that in the young coffee farms.

The two insect sampling locations have different environmental parameters. Environmental parameter measurements were done in the morning, at the same time as insect sampling. Environmental parameters were measured using a thermohygrometer to measure air temperature and humidity, a lux meter to measure light intensity, and a soil tester to measure soil pH. The first location was the productive coffee farm, which had

a light intensity of 1692 lux, humidity of 67.6%, temperature of 29.9 °C, and soil pH of 5.2. Meanwhile, the second location was the young coffee farm, which had a light intensity of 1985 lux, humidity of 54.6%, temperature of 31.7 °C, and soil pH of 6.0.

Insect data were collected using road sampling and pitfall trap methods. Road sampling was performed using an insect net to catch flying insects at 08.00 - 11.00 a.m. of Western Indonesian Time (GMT-7); the road sampling was done 3 times with an interval of 7 days. Road sampling was carried out over 250 meters, divided into 5 traverse sampling routes with a distance of 10 meters each. While traversing the route, the net was swung randomly 3-5 times until the insect was caught. Insect catching was done both above and below the canopy of coffee and shade crops. All insects caught in the net were put in resealable plastic bags for preservation and identification.

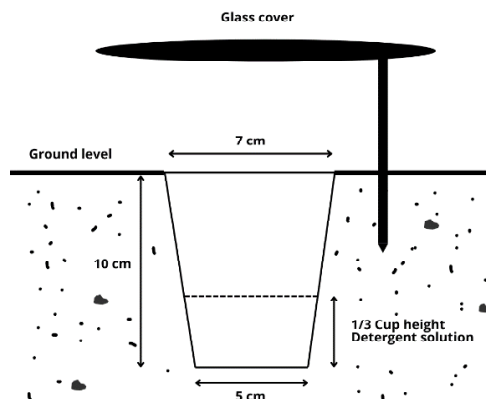


Figure 1. The installation scheme of a pitfall trap

Pitfall traps were set up to ensure ground-dwelling insects in their active state. The pitfall trap was made from a plastic cup with a diameter of 7 cm filled with detergent solution 1/3 of the height of the glass and provided with a cover on the side of the glass made of zinc and a wooden support. The glass was planted in the ground with its top

parallel to the ground surface (Figure 1) and placed at 2 points on each of the 5 traverse routes, so there were 10 pitfall trap points in both the productive (PCF) and young (YCF) coffee farms. The pitfall trap was placed for 1x24 hours. The pitfall traps were installed 3 times with an interval of 7 days. The captured insects were filtered from the detergent water and placed in a glass bottle containing 70% alcohol for identification. The taxonomic classification of all captured insects was performed following the determination key of Borror *et al.* (2005). The identification and data analysis process were conducted at the Plant Protection Laboratory of ICCRI, and the Ecology Laboratory of the Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Jember.

Data analysis was carried out by calculating the Shannon-Wiener diversity index (H') to determine the level of insect diversity and the independent sample t-test to analyze differences in insect abundance between coffee development phases based on their functional role. If the H' value is $H' \leq 1$, then the diversity is low; if $1 < H' < 3$, then the diversity is medium; if $H' \geq 3$, then the diversity is high (Krebs, 1989). The Shannon-Wiener index is calculated using the following formula:

$$H' = \sum_{i=1}^s \frac{n_i}{N} \ln \frac{N}{n_i}$$

- H' = Shannon-Wiener Diversity Index
- n_i = Number of individuals of a given type or species
- N = The total number of individuals

RESULTS AND DISCUSSION

The total number of insects collected from the productive coffee farm was 834 individuals, consisting of 8 orders and 26 families. Meanwhile, 386 insects were found from the young coffee farm, consisting of

9 orders from 20 families (Table 1). Based on the identification results, it can be seen that the abundance of insects in the productive coffee farm is higher than in the young coffee farm. The quality and quantity of food sources are the main cause of the high abundance of insects in the productive coffee farm. The productive coffee farm tends to have more food sources for insects, which come from nectar and flower pollen, with high vegetation cover and thick leaf litter on the ground, making it a preferred habitat for insects. This finding

follows Safitri *et al.* (2020), stating that the availability of food resources and adequate environmental conditions will encourage the presence of insects in the ecosystem. Furthermore, Lucatero *et al.* (2024) state that shady habitats with high vegetation cover can support the abundance of insects.

Abiotic factors can also influence the composition and abundance of insects in a habitat. Based on the observation results, the young coffee farm has higher light intensity and temperature than the productive coffee farm. Meanwhile, humidity in the young

Table 1. Identification results of composition and abundance of insects in the productive coffee farm (PCF) and the young coffee farm (YCF)

Role	Order	Sub-order	Family	Number of individuals		
				YCF	PCF	
Herbivores	Orthoptera	Ensifera	Gryllidae*	138	59	
			Caelifera	Acrididae	46	33
				Pyrgomorphidae	34	35
	Hymenoptera	Apocrita	Apidae	0	36	
			Andrenidae	2	0	
	Hemiptera	Auchenorrhyncha	Flatidae	14	35	
			Cicadellidae	5	32	
			Dictyopharidae	0	29	
		Heteroptera	Lygaeidae	0	34	
			Largidae	7	35	
			Alydidae	5	37	
			Noctuidae	1	25	
	Lepidoptera	Rhopalocera	Pieridae	3	13	
			Nymphalidae	1	9	
	Diptera	Heterocera	Papilionidae	0	4	
Lycaenidae			0	26		
Coleoptera	Polyphaga	Culicidae	35	51		
		Cleridae	0	16		
Total				291	509	
Predator	Hymenoptera	Apocrita	Formicidae*	73	93	
			Vespidae	0	27	
	Hemiptera	Reduviidae	Reduviidae	1	37	
			Libellulidae	1	0	
	Coleoptera	Polyphaga	Mantodea	1	3	
			Coccinellidae	3	0	
Total				79	160	
Parasitoid	Hymenoptera	Apocrita	Evaniidae*	4	34	
			Ichneumonidae	0	29	
			Total	4	63	
Detritivor	Diptera	Brachycera	Muscidae	0	31	
			Sarcophagidae	5	33	
	Blattodea	-	Ectobiidae*	7	38	
			Total	12	102	
Total				386	834 *	

Note: *Insect family with the highest number of individuals and the highest total individuals at the study sites

coffee farm is lower than in the productive coffee farm. High temperatures and low humidity affect flying insects such as the family Culicidae in the order Diptera. This causes the abundance of the order Diptera in the young coffee farm to be lower than in the productive coffee farm. These results support Hasyim *et al.* (2024) that flies (Diptera) like habitats with high humidity and low temperatures. Meanwhile, several insect families from the order Orthoptera, such as Acrididae and Pyrgomorphidae, like habitats with high temperatures, so the abundance of the order Orthoptera is higher in the young coffee farm. These results support Khatimah *et al.* (2024) that high temperatures can increase the abundance of Orthoptera. In addition, habitats with warm temperatures tend to speed up the hatch of Orthoptera eggs and the development of Orthoptera nymphs.

Light intensity affects insect activity in foraging, molting, reproduction, and so on. Febriyanti *et al.* (2020) state that some insects are diurnal, active during the day when there is sunlight, such as butterflies (Pieridae), and nocturnal, active at night,

such as moths (Noctuidae). Soil acidity (pH) levels influence the abundance of ground surface insects such as ants (Formicidae) of the order Hymenoptera. This causes the abundance of Formicidae in the productive coffee farm to be higher because the soil pH tends to be neutral. Rozi *et al.* (2021) state that most surface insects prefer neutral soil pH in the range of 6-7 because it has a high nutrient content.

Based on their functional role, insects in the coffee farm ecosystem are divided into four: herbivores, predators, parasitoids, and detritivores. Results of statistical analysis of independent sample t-test differences on the abundance of herbivorous insects ($t = 12.692$, $p < 0.05$), predatory insects ($t = 4.030$, $p < 0.05$), parasitoid insects ($t = 11,150$, $p < 0.05$), and detritivorous insects ($t = 3.707$, $p < 0.05$) confirmed significant differences between coffee plant development phases. The differences in insect abundance between coffee plant development phases based on their roles are presented in Figure 2.

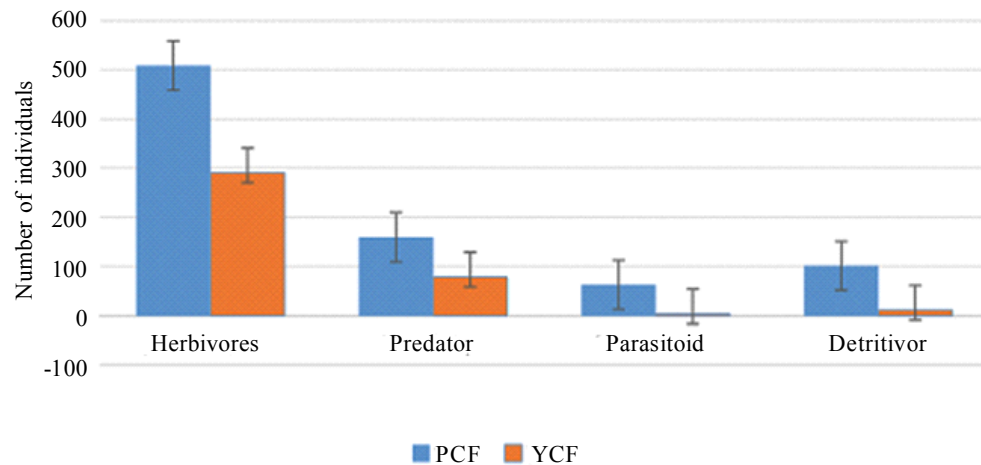


Figure 2. A comparison of the abundance of herbivorous, predatory, parasitoid, and detritivorous insects in the productive coffee farm (PCF) and the young coffee farm (YCF)

Herbivore insects are plant-eating insects or phytophagous (Borror *et al.*, 2005). Some herbivorous insects can play both beneficial and detrimental roles. Herbivore insects are considered detrimental because they eat plant parts, leading to yield loss in coffee plants, or are commonly referred to as pests. Meanwhile, herbivorous insects are considered beneficial because they can increase the productivity of coffee plants, for example, by pollinating coffee flowers, which are called pollinator insects (Soesanthy & Trisawa, 2011). Based on the identification results, herbivorous insects that are considered pests come from insect families in the Orthoptera, Hemiptera, and Coleoptera orders, while herbivorous insects that act as pollinators come from insect families in the Hymenoptera and Lepidoptera orders.

The abundance of herbivorous insects in the productive coffee farm and the young coffee farm was 509 individuals and 291 individuals, respectively. Based on the research results, herbivorous insects in the productive coffee farm have a significantly higher abundance because they have denser canopy cover, and there are grasses and flowering shrubs as a food source for herbivorous insects. This is supported by Safitri & Yaharwandi (2020), stating that the abundance of herbivorous insects in an ecosystem is influenced by the diversity of vegetation from the implemented agro-forestry system, which acts as a source of food for herbivorous insects.

The herbivorous insects with the highest abundance in the two farms come from the Orthoptera order of the Gryllidae family. The number of Gryllidae in the productive coffee



Figure 3. Herbivorous, predatory, parasitoid, and detritivorous insect families (A) Gryllidae, (B) Formicidae, (C) Evaniidae, and (D) Blattellidae

farm was 59 individuals, and 138 individuals in the young coffee farm. The high number of Gryllidae insects in the young coffee farm is caused by the soil surface, which is filled with grass, compared to the soil surface of the productive coffee farm, which is full of leaf litter. The grass on the surface of the young coffee farm is a food source for Gryllidae insects. Leksono *et al.* (2019) mention that the Gryllidae family is a herbivorous insect that uses grass and leaves as a source of food.

Predatory insects are also called entomophagous because they prey on other, smaller insects (Borror *et al.*, 2005). Predatory insects are beneficial because they act as natural enemies that can control pest insects. Predatory insects at both study sites come from the Hymenoptera, Hemiptera, Odonata, Mantodea, and Coleoptera orders. The productive coffee farm had a higher abundance of predatory insects, with 160 individuals, compared to the young coffee farm, with 79 individuals. This is due to the high abundance of herbivorous insects in the productive coffee farm, so they can attract predatory insects to come and prey on herbivorous insects in this habitat. The results of this research support Wijayanto (2023) that abundant herbivorous insects in a habitat can attract predatory insects to come and prey on herbivorous insects in that habitat.

The highest individual number of predatory insects in both the productive coffee farm and the young coffee farm came from the Formicidae family of the Hymenoptera order. The Formicidae found in the productive coffee farm was higher at 93 individuals compared to 73 individuals in the young coffee farm. The high abundance of Formicidae in the productive coffee farm is caused by the abundance of herbivorous insects in it. This is supported by Perfecto & Philpott (2023), who state that Formicidae are natural

enemies of herbivorous insects through habitat colonization. Hence, the abundance of herbivorous insects also increases Formicidae as natural enemies. Rezki *et al.* (2023) also state that the presence of abundant herbivorous insects in a habitat positively affects the presence of predatory insects.

Flowering vegetation between phases of coffee crop development in the productive coffee farm influences the abundance of parasitoid insects. Parasitoid insects live parasitically inside the bodies of insects (generally insect pests) (Borror *et al.*, 2005). Thus, parasitoid insects are grouped into beneficial insects because they can control pests on coffee farms. The parasitoid insects found at both study sites came from the Hymenoptera orders of the Evaniidae and Ichneumonidae families. The abundance of parasitoid insects was 63 individuals in the productive coffee farm and 4 individuals in the young coffee farm. The difference in the abundance of parasitoid insects in the two study sites was influenced by the presence of flowering vegetation, often found in the productive coffee farm. Flowering vegetation can be an alternative host for parasitoid insects; as stated by Farahdiba *et al.* (2023), weed vegetation and flowering vegetation are alternative hosts and food sources for parasitoid adults so that the abundance of parasitoid insects differs between phases of coffee plant development.

The highest number of individual parasitoid insects between the development phases of coffee plants came from the Evaniidae family of the Hymenoptera order. There were 34 individuals of the Evaniidae family in the productive coffee farm and 4 individuals in the young coffee farm. The abundance of parasitoid insects Evaniidae is caused by the high abundance of detritivorous insects in the productive coffee farm. Detritivorous insects become host insects for the eggs

Table 2. Shannon-Wiener diversity index at two study sites

Coffee farm	Number			H'
	Order	Family	Individuals	
Young	9	20	386	2.030 (medium)
Productive	8	26	834	3.112 (high)

and larvae of Evaniidae insects; this is supported by Farahdiba *et al.* (2023), stating that the Evaniidae family are parasitoid insects that use cockroaches as hosts to lay eggs until the end of the larval phase.

Detritivorous insects act as decomposers that eat dead plants and animals or are called saprophagous (Borror *et al.*, 2005). The abundance of detritivorous insects between the productive coffee farm and the young coffee farm differed significantly, with 102 and 12 individuals, respectively. The family of detritivorous insects with the largest number of individuals from both study sites is Ectobiidae of the Blattodea order. There were 38 Ectobiidae individuals in the productive coffee farm, and more than 7 individuals were found in the young coffee farm. This is because the productive coffee farm has organic material originating from the remains of coffee plants and shade as a food source for detritivorous insects. Lara-Pérez (2023) states that the agroforestry system in the productive coffee farm has a higher tree density so that it can increase litter production from plant residues. This higher litter availability can affect the habitat and food sources for detritivorous insects (Putri *et al.*, 2018).

The differences in the composition and abundance of insects in the two study sites influence the diversity index value. The diversity of insects in a habitat is determined by the abundance of insects occupying that habitat (Lestari *et al.*, 2022). The results of the insect diversity analysis showed that the insect diversity index value in the productive coffee farm was 3.112, while the insect diversity index in the young coffee farm was 2.030

(Table 2). The abundance of insects in the productive coffee farm is higher than in the young coffee farm because the abundance of insect families found in the productive coffee farm was more balanced compared to the young coffee farm. The results of this study support Siregar *et al.* (2019) that productive plants, like the ones in the productive coffee farm, have a higher diversity of insects than young plants, like the ones in the young coffee farm. A community has high diversity if it comprises many species with the same abundance; as stated by Sijabat *et al.* (2020), if a community in a habitat is occupied by insect species with a balanced abundance, then the diversity of insects in that habitat is high.

CONCLUSIONS

The productive Robusta coffee farm has a higher composition and abundance of insects compared to the young robusta coffee farm due to more abundant food sources found in the productive coffee farm. Furthermore, the development phase of coffee plants in the productive coffee farm has a positive effect on increasing the abundance of herbivorous, predatory, parasitoid, and detritivorous insects. Insect families with the highest abundance in both study sites include Gryllidae, Formicidae, Evaniidae, and Ectobiidae. The insect diversity index value for the productive coffee farm is in the high category, while the insect diversity index value for the young coffee farm is in the medium category; in other words, the productive coffee farm has a higher community balance.

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