Insect diversity of cacao (*Theobroma cacao* L.) plantation under different shade trees in Pakuwon, Sukabumi

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Abstract. Cacao is one of important commodities which has significant contribution to Indonesian economy. One main factor in cacao cultivation is the shade tree. In Indonesia, the shade tree for cacao may vary. The study aimed to determine the most suitable shade tree for insect diversity in cacao plantation, conducted at Pakuwon Experimental Station and Integrated Laboratory of IIBCRI from January to May 2019. The shade trees in used were banana (KP), Ramayana (KR), and coconut (KK). Insect diversity was observed using yellow pan trap and pitfall trap in the field. The trapped insects were identified until order then their abundance were analysed statistically. Result showed the shade trees species are affecting the insect diversity in cacao plantation. The lowest population of insect from in cacao plantation from January to May 2019 was found in banana as shade tree, whereas the highest abundance was found in Ramayana. The highest abundance of the family in the area was from Hymenoptera order and Formicidae family.

Keywords: Abundance, Formicidae, Hymenoptera

1. Introduction

Cacao (*Theobroma cacao* Linnaeus) is one main commodity which playing important role in Indonesia economy. In nature, cacao grows in tropical forest with optimum photosynthesis by 20% irradiation. Shades are required in cacao cultivation development because of its function in maintaining humidity, temperature 10-25°C, and water availability as well as habitat for various insects. Shade trees usually intercropped with cacao are *Moghania macrophylla* as temporary shade trees and Lamtoro or *Glirisidia* as permanent shade trees. Besides, shade trees with economic value such as banana and coconut trees provide additional income to cacao farmers.

Pakuwon cacao plantation of Indonesian Industrial and Beverages Crops Research Institute (IIBCRI) is located in Parungkuda, Sukabumi, West Java province at ±400 above sea level. Cacao plantation in this area is managed according to manual of Agriculture Ministry. In this area, there are 3 kinds of shade trees combined with cacao plant as permanent shades are banana (*Musa acuminata*), ramayana (*Senna spectabilis*) and coconut (*Cocos nucifera*). These three trees are planted in cacao field because of its wide canopy and its economic value. Planting banana trees combined with cacao trees showed positive impact in increasing cocoa fruit set [1]. Other reports stated that cacao under widely spaced coconut trees can be profitable intercrop system for farmers[2].
Shades trees also contribute ecosystem service to environment as habitat for some insects. It provides food and niece for useful insect such as pollinator and natural enemy for cacao insect pests. The shade trees litters contribute as breeding site for cacao pollinator insects[3]. Research in cacao plantation of Malaysia reported more than 200 insects species were found[4]. Moreover, insect diversity in cacao plantation in Sigi, Central Sulawesi had H’ index value of 4.383, 3.356 and 2.011 in three different strata of shade tree[5]. Different insect taxa in the cacao ecosystem contributes both directly and indirectly to productivity of cacao[6]. The results of a research on cocoa plantation in West Africa showed a positive association between ant richness, wasp nests, spider webs and shade indices[7]. Good agriculture practice is important to provide the suitable habitat for natural enemy and pollinator insect. Information about effect of intercropping combination to insect diversity is important to optimize the ecosystem services in cacao plantation in Pakuwon, Sukabumi. But the information is still limited. Objective of this research was to observe the abundance and diversity of insect in cacao plantation with shade trees from banana, coconut and ramayana trees in Pakuwon, Sukabumi.

2. Methods
Observation of insect diversity in Cacao Plantation combined with different shade trees are 1) Cacao with shade banana trees (Musa paradisiaca), 2) Cacao with shade ramayana trees (Senna spectabilis), 3) Cacao with shade coconut trees (Cocos nucifera) were conducted using two methods, Yellow Pan Trap (YPT) and Pit Fall Trap (PF) (Figure 1).

![Figure 1. Observation plots of insect diversity in cacao plantation combined with three different shade trees, 1) Banana tree (Musa paradisiaca), 2) ramayana tree (Senna spectabilis), 3) coconut tree (Cocos nucifera)](image)

Yellow Pan Trap (YPT) method was performed by using yellow container filled with soap water solution. There was 15 trap installed for 1x24 hours on each observation plots. The trap installed at 08.00 in the morning and collected in the next day and it was repeated with 2 weeks intervals. The collected insect were preserved in the plastic bottle filled with Ethanol 70% and provided with appropriate records for further identification.

Pit Fall Trap (PF), the traps were made from plastic glass 10 cm height and diameter 7,5 cm filled with detergent liquid 1%, filled up to 1/3 of glass height. The plastic glass was installed in the hole in the ground and the glass tips height was adjusted same with the surface of the soil surface. This setting intended to catch the insects crawling from the soil surface on the ground and fall into the liquid. The
trap covered with ‘roof’ to prevent rainfall entering the glass. There were 15 traps installed in each plots for 1 x 24 hours and was repeated in the next 2 weeks. The trapped insect was collected and preserved as mentioned above[8].

Collected insect was sorted and identified based on their morphological characteristics [9,10]. Identified insects were preserved and managed as insect collection in laboratory of IIBCRI.

Observation variable in the research covered insect abundance and diversity. Abundance variable were the number of individuals, while the diversity variable covered order, family, Shannon Wiener Diversity index, Eveness richness index and variation richness index.

Shannon-Wiener (H') Diversity Index
Formula to calculate Shannon Wiener Diversity Index are (H')[11]:

\[ H' = -\sum i \ln pi \]  \hspace{1cm} (1)
\[ pi = \sum i/N \]  \hspace{1cm} (2)

Annotation:
\( H' \)  = Shannon-Wiener Diversity Index
\( pi \)  = Individual Proportion found in I family
\( ni \)  = Number of individual at I Family
\( N \)  = Total number of Individual

Eveness Richness Index (Evenness = E)
Eveness Richness Index (Index of Evenness = E) are function to study the eveness value of each type in every community. The formula to calculate eveness richness index are [11]:

\[ E = H' / H'_\text{max} \]  \hspace{1cm} (3)
\[ H'_\text{max} = \ln S \]  \hspace{1cm} (4)

Annotation:
\( E \)  = Eveness Index (0 – 1)
\( H' \)  = Shannon-Wiener Diversity Index
\( \ln \)  = Logarithma natural
\( S \)  = Number of Family

Species Richness Index (DMg)
To study variation or family richness in each community, the data of collected insect were calculated using Margalef Species Richness Index (Species Richness= DMg) formula as follows [11]:

\[ DMg = (S-1) / \ln N \]  \hspace{1cm} (5)

Annotation:
\( DMg \)  = Margalef Species Richness Index
\( S \)  = Number of Family
\( N \)  = Number of Individual of each sample

2.1. Data Analysis
Data of insect numbers in cacao plantation with different shade trees was analyzed using t test at 5% error level.
3. Result and discussion
The observation result of insect biodiversity in Pakuwon Field under different shades using Yellow Pan Trap and Pitfall Trap showed that there were eight different orders trapped in cacao field (Table 1). Number of insects crawling on the ground was similar in each cacao field with different shades. Insect trapped in Pitfall trap were same in different shades type (Table 1). The different result showed in number of insects trapped in yellow pan trap. Insect active in canopy was more various in cacao field under banana shade trees than other shades. But the individuals number for insect in cacao field under ramayana and coconut trees were higher than in cacao field under banana trees.

Table 1. Order and diversity of insect collected in Pakuwon Cacao Plantation with different shade trees using Yellow Pan Trap and Pitfall Trap

| Shade trees Combination | Total of Order | Number of Individual |
|-------------------------|----------------|----------------------|
|                         | YPT | PF | YPT | PF |
| KP                      | 10  | 8  | 189 | 270 |
| KR                      | 9   | 8  | 434 | 224 |
| KK                      | 8   | 8  | 390 | 261 |
| Total                   |     |    | 1.013 | 755 |

Note: KP = cacao + banana; KR = cacao + ramayana; KK = cacao + coconut; YPT = Yellow Pan Trap; PF = Pit Fall Trap

Insect diversity in cacao plantation combined with banana trees (KP) were significantly higher than other treatments. The Shannon Wiener diversity index of the three plots type also showed the same result. The H’ value of insect in KP, KR and KK were 1.724; 1.567 and 1.413 respectively while the H max value was 2.398. The Evenness richness value of insect in KP, KR and KK plots were 0.719; 0.564 and 0.589 respectively. This result showed that insect diversity in cacao plantation with banana shade trees (KP) was higher than in ramayana (KR) and coconut (KK) shade trees. Cacao farmers in Brasil and Ghana recommend banana trees as shade trees because of the plant ability to conserve the ground humidity. The water content in banana trees are high around 73.80-95.63%[12]. While in other treatment was tend to dry[2]. This differences cause variation of insects living in this plot. Predators from order Dermaptera are living in high humidity nieces.

The high diversity in Cacao-Banana (KP) combination plots different with number individual in different shade trees plot. The number individual of insect in cacao plantation with banana, ramayana and coconut were 459, 658 and 651 respectively. Insect abundance in Cacao-Banana combination was lower than in ramayana and coconut. Low insect abundance in banana plots was caused by the high insect diversity in the banana trees. The higher diversity in one area caused limitation in the number of each order.

The highest population orders was Hymenoptera (Figure 2). The number of Hymenoptera in cacao filed with coconut as shading trees (KK) was the highest than others, while the Shannon Wiener diversity index was the lowest. This confirmed the diversity theory that high diversity index tends inversely proportional to insect abundance. The high abundance value of Hymenoptera in the three shades tree types were dominated by Formicidae family. Formicidae is known as the family with the most biomass than other insects. Almost 15-25% of land animal biomass are family Formicidae [13]. Insect of Formicidae family prevalently dominates insect population in cacao plantation in Central Sulawesi [14].

Insect abundant in cacao field under banana, ramayana and coconut shade trees showed different result. There were 10 Orders trapped in yellow trap and pitfall trap then sorted according morphology and identified until family level. The highest number of insect were from order Hymenoptera (table 2). Insect from order Hymenoptera has various function in nature, mostly are as predator, decomposer and pollinators. The highest number of order Hymenoptera in Pakuwon Plantation was Formicidae, which mostly living as predator. *Oecophylla smaragdina* (Hymenoptera: Formicidae) reduced the densities of *Helopeltis* spp., *Amblypetta* spp., and *Rhyparida nitida* regardless of cacao fruit husk addition [15]. In
other research, the predator potential showed by *Dolichoderus* sp. that also tend to attack and devour the *Brontispa longissima* larvae and pupa stage [16]. In Ghana cocoa plantation, Hymenoptera order was dominated by ant species which formed the bulk of the insect biomass and Diptera order was present in significant proportion and thus dominated the cocoa ecosystem[6].

**Figure 2.** Number of insect individuals of each orders per plot collected in Pakuwon Cacao Plantation with different shade trees, KP = cacao + banana; KR = cacao + ramayana; KK = cacao + coconut

| Table 2. Insect abundance of each order in Cacao Plant with different shade trees collected using Yellow Pan Trap and Pitfal Trap |
| --- |
| **Order** | **Observation Location / Trap Type** | **KP (n=15)** | **KR (n=15)** | **KK (n=15)** |
|  |  | YPT | PF | YPT | PF | YPT | PF |
| Coleoptera | 23 | 9 | 28 | 6 | 16 | 7 |
| Collembola | 9 | 1 | 5 | 5 | 8 | 9 |
| Dermaptera | 1 | 3 | 0 | 1 | 0 | 1 |
| Diptera | 25 | 3 | 176 | 4 | 93 | 5 |
| Hemiptera | 29 | 0 | 37 | 0 | 32 | 1 |
| Hymenoptera | 48 | 182 | 130 | 150 | 219 | 184 |
| Lepidoptera | 7 | 2 | 4 | 2 | 2 | 0 |
| Orthoptera | 23 | 44 | 47 | 34 | 14 | 39 |
| Thysanoptera | 3 | 3 | 3 | 3 | 0 | 4 |
| **Total** | **168** | **247** | **430** | **205** | **384** | **250** |

Note: KP = cacao + banana; KR = cacao + ramayana; KK = cacao + coconut; YPT = Yellow Pan Trap; PF = Pit Fall Trap

Insect collected in cacao field have several roles, such as carnivores, herbivores and detrivores. The carnivores that usually found on cacao field are Hymenoptera and Diptera. Some Families of those Orders that observed in this research were Braconidae, Scelionidae, Platygastridae, Diapriidae, and
Phoridae which mostly plays role as natural enemy in nature. Scelionidae and Platygastridae are potential parasitoid to control the pest population[17]. Besides natural enemies, insect pollinator of cacao Forcipomya sp. (Diptera: Ceratopogonidae) was also found. Forcipomya hardyi was a potential pollinator of cacao in Hawaii[18]. Detritivores insect contributes main benefit in food webs process in nature, as decomposer the organic matter. The detritivores group insects, namely Coleoptera, Diptera and Collembola were consistently found in cacao field during study, particularly the famili of Scarabaeidae (Coleoptera) and Muscidae (Diptera). The herbivores insects collected in cacao field was insect pest of cacao such as Hemiptera, Lepidoptera, Orthoptera, Thysanoptera, Diptera, and Coleoptera. Helopeltis sp bllongs to Hemiptera: Miridae has been reported as major insect pest of caca [19,20].

4. Conclusion
The type of shade tree affects the insect diversity and abundance in Pakuwon Cacao Plantation. Cacao plantation with banana trees as shading showed the highest diversity and evenness richness index while has the lowest abundance of insects. The highest abundance of insect showed in combination cacao with ramayana shade trees. The highest number of insect is from Order Hymenoptera as shading the organic matter. The detritivores insect contributes main benefit in food webs process in nature, decomposer the organic matter. The detritivores group insects, namely Coleoptera, Diptera and Collembola were consistently found in cacao field during study, particularly the famili of Scarabaeidae (Coleoptera) and Muscidae (Diptera). The herbivores insects collected in cacao field was insect pest of cacao such as Hemiptera, Lepidoptera, Orthoptera, Thysanoptera, Diptera, and Coleoptera. Helopeltis sp belongs to Hemiptera: Miridae has been reported as major insect pest of cacao[19,20].

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