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Research Article
Diversity and Abundance of Predatory Arthropods on Immature and Mature Oil Palm (*Elaeis guineensis*) Plantations

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Abstract

Background and Objective: Predatory arthropods may play a crucial role in decreasing the pest population that causes a significant loss in oil palm production. In this study, we investigated the diversity of predatory arthropods and their abundance on immature and mature oil palm plantation grown in Aceh Tamiang, Sumatra, Indonesia. **Materials and Methods:** Arthropod predators were collected by using light trap, yellow-pan trap and pitfall trap that were placed on an immature and mature oil palm plantation. Specimens were sorted and identified in the Laboratory. **Results:** The results showed that there were 674 individuals arthropod predators (insects and spiders) consisted of 7 orders, 22 families and 37 morphospecies collected in the immature plantation. While in mature plantation, arthropod predators found were 740 individuals consisted of 6 orders 23 families and 42 morphospecies. Ants (Hymenoptera: Formicidae) dominated other families regarding morphospecies and individual numbers. There was no significant difference in term of species richness and abundance of predators between both phases of the plantation which implied that the two plantations hosted a similar composition and abundance of predators. The diversity indices of predators calculated in both plantations showed that the predators were categorized as middle level of diversity and middle level of individual distribution, However, the community is unstable. **Conclusion:** Our results suggested that predatory predators were present in similar structure in both phases of oil palm plantations. Efforts to conserve them are needed to enhance their performance as part of a sustainable and environmentally friendly method for controlling pests in oil palm plantation.

Key words: Pest control, biological control, natural enemy, biodiversity, oil palm plantation

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Palm oil (*Elaeis guineensis*) is an important commodity that plays a crucial role in the economic activities in Indonesia, particularly from plantation sector. Indonesia is the world's largest producer and exporter of crude palm oil with a total area of 14.6 million ha and expected to produce over 42 million tons by 2019[1]. Oil palm plantation expansion in Indonesia occurs at a rapid pace[2] which is the result of several factors. Oil palm is a very productive crop and claimed to be the highest-yielding vegetable oil crop per unit area[3,4]. The increase of global demand for vegetable oil also has caused oil palm plantations to expand in Indonesia, particularly in Sumatra island. The increased request for palm oil has caused its cultivation to change from traditional way which many crops have grown in small-scale agricultural systems, to becoming the only crop planted in big plantations[5].

The expansion of oil palm plantation in Indonesia is often blamed for tropical biodiversity loss[6,7]. On the other hand, pest attacks are becoming an important factor in reducing production of oil palm in Indonesia[8,9]. Several insect pests are known to attack oil palms, such as trunk borers and defoliators which can reduce oil palm production significantly[10]. The main pests that often attack oil palm are nettle caterpillars (Lepidoptera: Limacodidae) and bagworms (Lepidoptera: Psychidae)[11-13]. An attack of 50% by these pests will reduce yield around 43% over the next two years. Even at lower attack rates such as 10-13%, they may also cause a similar decrease in the oil palm yield[14]. The use of insecticide is a very common control method applied in oil palm plantations, particularly during the pest's outbreak. However, prolong use of insecticide can cause negative impacts, such as pest resistance, resurgence, the killing of natural enemies and even high risks to human health[15]. Pesticide application also needs a high cost and it reduces the competitiveness of oil palm products[16].

Natural enemies including predatory or parasitic insects could effectively keep the pests attack below the economic damage level[17]. Conservation of natural enemies in the field is an environment friendly control technique due to its existence that can maintain the balance of the ecosystem[18]. Predatory insect *Forficulla auriculara* (Dermaptera: Forficulidae) is known to be quite effective and it has the potential to reduce the population of nettle caterpillar pests[19], while *Cosmolestes picticeps* (Hemiptera: Reduviidae) cause a decrease in the population of bagworm in oil palm plantations[12].

Previous studies have shown that the presence of arthropod predators as natural enemies in oil palm plantation is quite high despite the biodiversity reduction that often said as a result of the expansion of oil palm plantations. Several orders of predatory insects such as Hymenoptera, Coleoptera, Diptera, Hemiptera, Thysanoptera dan Orthoptera have been found on oil palm plantation[20]. Predatory arthropods were also found in oil palm plantation in West Java and West Sumatra, Indonesia[21,22]. Considering the importance role of predators and the lack of information about their diversity on oil palm plantation in Indonesia, it is crucial to study further on this subject to promote predators as biological control agents in decreasing the pest population on oil palm plantation. In this study we investigated the diversity of predators and their abundance on immature and mature oil palm plantation in one area of the plantations grown in Sumatera, Indonesia. The results of this study provided early information that can be used to increase conservation efforts in oil palm plantation in order to maintain ecosystem balance, to reduce pest outbreaks and to maintain the high production levels of palm oil.

MATERIALS AND METHODS

Study site: The study was conducted from February until August 2019 by taking arthropod samples from oil palm plantations owned by PT Mopoli Raya located in Bendahara District, Aceh Tamiang Regency, Aceh Province, Sumatra, Indonesia. The site was located around 450 km away from the city of Banda Aceh, the capital of Aceh Province (Fig. 1). It was located at 98°06'30" E and 04°22'10" N having an altitude of 20 m above sea level. The oil palm plantations were located close to residential area where people lived and worked for the company. The oil palm trees grown in this location were distributed throughout the area of 814.25 ha which was divided into 41 blocks and was categorized as immature plantation (20 blocks) and mature plantations (21 blocks). The immature plantations were the trees between 1- 4 years old and have not been yet harvested, while the mature ones were between 4-20 years old and have been harvested several times. The immature plantations had less vegetation and better sanitation than those of in mature ones. The vegetation found in between the trees was mostly weeds (grass groups) and also cover crops which were *Mucuna bracteata* and *Pureraria phaseoloides*, both were included in Family Fabaceae. Insecticides were applied regularly in both phases of plantations, 2-3 times per month on immature plantations and once a month in mature ones.

The arthropod samplings were done on two blocks of immature plantations and two blocks of mature ones which had an area around 8 ha each block. The oil palm trees in immature blocks were less than four years old with a height

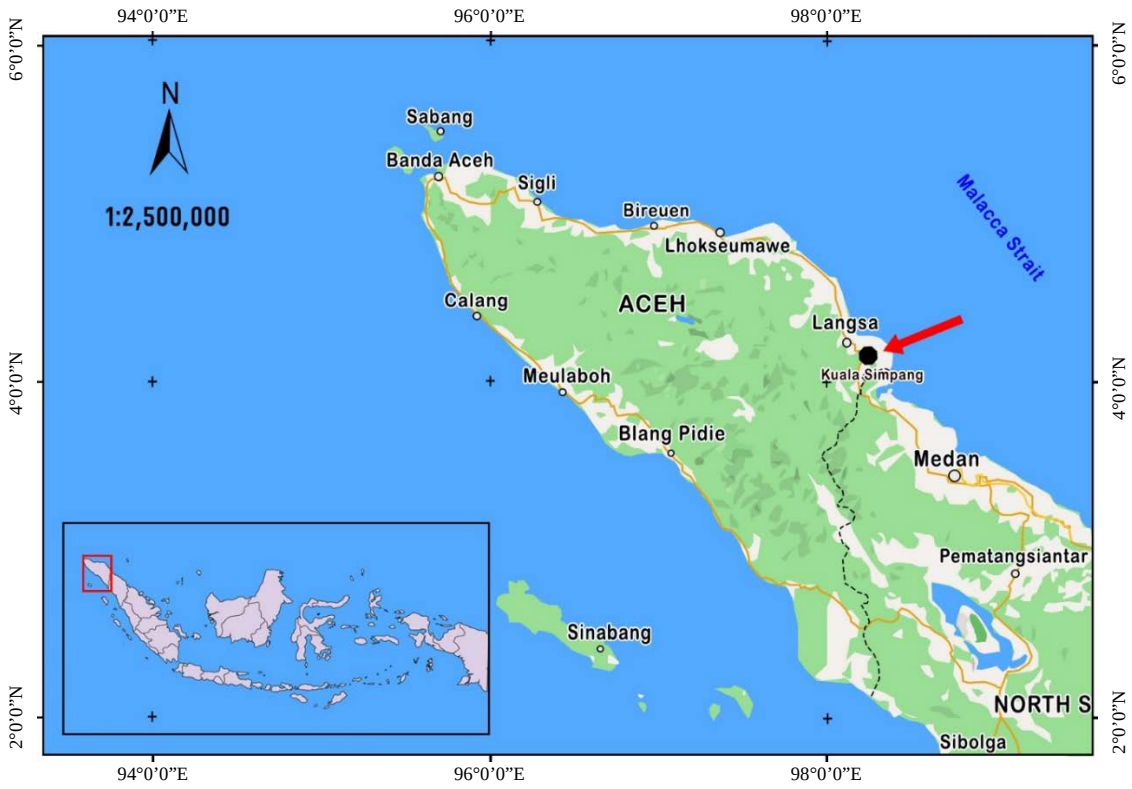

Fig. 1: Map of sampling location in Bendahara District, Aceh Tamiang Regency, Aceh Province, Sumatra Indonesia (study site is shown by red arrow)

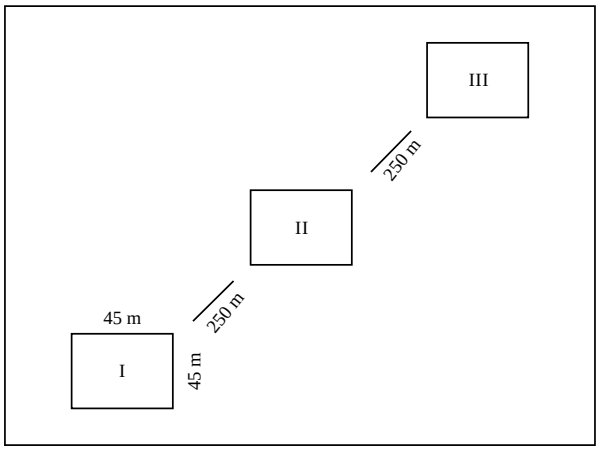

Fig. 2: Design of sampling plots within each sampling block

between 3-5 m and the mature ones are between around 10 years old with a height of 9-10 m. The sampling blocks were located in the middle areas surrounded by other plantations in other blocks and were away from residential area. Each block divided into three plots diagonally measuring 45×45 m, the distance in between blocks was 250 m (Fig. 2).

Arthropods samplings: Arthropods samples were collected by using different traps, namely light trap, yellow-pan trap and pitfall trap (Fig. 3). The light trap used was a double-neon lamp trap that was built inside a glass structure which was 50 cm tall and 10 cm in diameter. A small plastic container filled with a mixture of water and detergent was attached to the base of this structure. It was expected that the arthropods attract to the light will feel hot and fell into the plastic container without any way to get out. One light trap was placed in each plot. The light trap was hung on an oil palm tree about 2-3 m above the soil surface for 14 hours, starting from 5 pm. The arthropods trapped were collected in the next day at around 7 am in the morning. The yellow-pan trap used was actually a yellow plastic pan measuring 22 cm in diameter and 4 cm in height, filled with a mixture of water and detergent in half of the pan height. There were four yellow-pan traps placed in each plot among the trees for 10 hours from 8 am until 6 pm. Another type of trap used was a self- made pitfall trap. The pitfall traps were made from used plastic cups of 250 in volume with a height of 10 cm and 8 cm in diameter. Before placing the pitfall trap, the soil was dig so that when the trap was inserted the surface of the trap was the same level as the surrounding soil surface. There were four pitfall traps placed for 10 hours in each plot (8 am-6 pm). To prevent

Fig. 3(a-c): The traps used to collect arthropod samples in immature and mature oil palm plantations: (a) Light trap, (b) Yellow pan trap and (c) Pitfall trap

rain plastic covers were hang around 20 cm above the yellow-pan traps and pitfall traps. In total there were 3 light traps, 12 yellow-pan traps and 12 pitfall traps for each block. Arthropod samplings were conducted three times with a month interval between sampling times.

Arthropods identification: All collected samples were stored in plastic containers filled with alcohol 70%, then they were brought to the Biological Control Laboratory, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh for further observation and sortation. All samples collected were identified based on their morphology into order level using the identification keys[23]. The ecological roles of the samples were determined, such as: herbivore, decomposer, pollinator, parasitoid, predator. The predator group was further identified into morpho-species by differentiating the morphological characters from samples in the same family. Individual numbers of each morpho-species that belong to the predator group were calculated to determine their abundance.

Data analysis: Differences in species richness and abundance of predatory arthropods in immature and mature oil palm plantations were analyzed using unpaired T-test. The diversity indices of the predatory arthropods were calculated using the Shannon-Wiener diversity index (H'), Species Evenness index (E) and the Simpson dominance index (C) (Table 1). The difference in each diversity index between immature and mature oil palm plantation was also determined by using T-Test. A significant difference between the two groups of oil palm plantations was set at $p<0.05$. All analysis was carried out using R Program Version 3.6.1[24].

Table 1: Formulas used for calculating the diversity indices of the predatory arthropods on immature and mature oil palm plantations

Diversity Index	Formula	Remarks
Shannon-Wiener Diversity Index (H')[25]	$H' = -\sum_{i=1}^{s} pi\ (Ln\ pi)$	H' : Diversity index pi : Proportion of individuals of species i in the community S : Number of species per collected samples
Species Evenness Index (E)[26]	$E = \frac{H'}{\ln(S)}$	E : Evenness index H' : Diversity index S : Number of species per collected samples
Simpson Dominance Index (C)[25]	$C = \sum\left[\frac{ni}{N}\right]^2$	C : Simpson's dominance index ni = population of i-species N : Population total of all species ni : Population of i-species
Index Similarity[27]	$IS = \frac{2C}{A+B} \times 100\%$	IS : Similarity index A : Number of species only found in Station A B : Number of species only found in Station B C : Number of species found in Station A and B

RESULTS

Species richness and abundance of predatory arthropods: There were 1294 and 2326 individual arthropods collected from immature and mature oil palm plantations consecutively during the three times observation. The specimens consisted of insects and spiders which were categorized as herbivore, decomposer, pollinator, bloodsucker of mammalian, parasitoid and predator. In immature oil palm plantations, the predators found belonged to 7 order 22 families and 37 morphospecies with a total of 674 individuals, while in mature plantations, the predators consisted of 6 order 23 families and 42 morphospecies with 740 individuals. The orders of predators found were Araneae, Coleoptera, Dermaptera, Diptera, Hemiptera, Hymenoptera, Orthoptera in immature plantations. Similar orders were also found in mature plantations but missing one order which was Orthoptera (Table 2). There were 25 morphospecies always found in both phases of plantations. They belonged to family Araneidae, Lycosidae, Anthicidae, Cantharidae, Carabidae, Cicindelidae, Coccinellidae, Hydrophilidae, Staphylinidae, Anisolabididae, Chelicosidae, Dolichopodidae, Muscidae, Scenopinidae, Reduviidae, Formicidae and Sphecidae. The predator species that were always found on each observation belonged to family Formicidae, Lycosidae and Hydrophilidae. Ants (Hymenoptera: Formicidae) dominated others in term of species and individual numbers collected. Order Hymenoptera had the highest number of species and abundance in both immature and mature plantations. The number of morphospecies found from order Hymenoptera was 6.83±0.54 (Mean±SE, N = 6) in immature plantation and was 7.17±0.87 (Mean±SE, N = 6) in mature plantation (Fig. 4a). Abundance of predator belongs to order Hymenoptera was

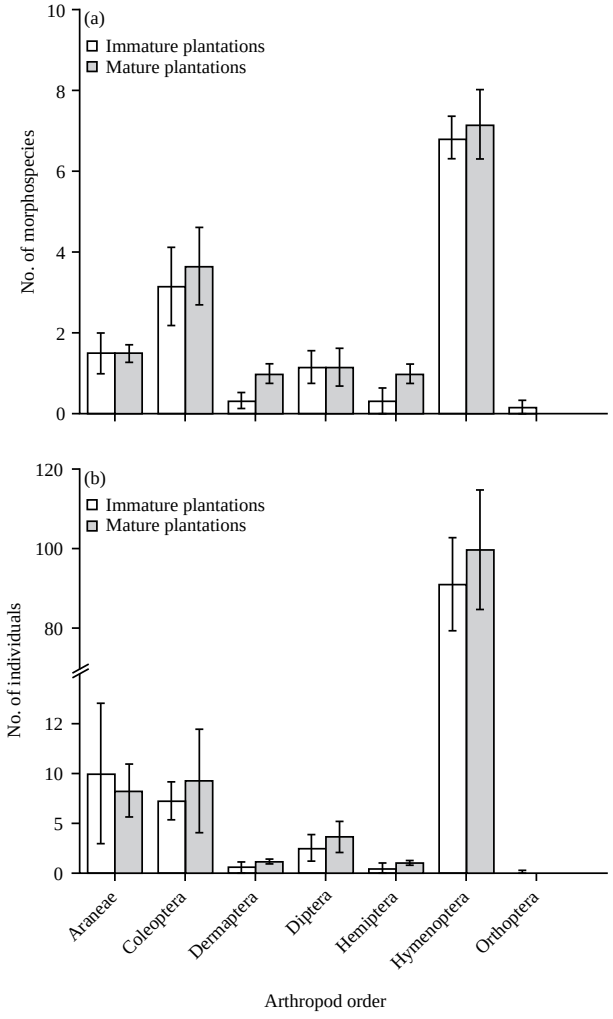

Fig. 4(a-b): (a) Species richness and (b) abundance of predators per block for each order collected in immature and mature plantations (Mean±SE, N = 6)

Table 2: Distribution of order, family and morphospecies of predators found on immature and mature oil palm plantations

			The presence of morphospecies	
			Phase of oil palm plantations	
Order	Family	Number of morphospecies	Immature	Mature
Araneae	Araneidae	1	✔	✔
	Cheiracanthiidae	1	✔	×
	Lycosidae	1	✔	✔
	Oxyopidae	1	×	✔
	Pholcidae	1	×	✔
Coleoptera	Anthicidae	1	✔	✔
	Cantharidae	1	✔	✔
	Carabidae	2	✔	✔
	Cerambycidae	1	✔	×
	Cicindelidae	1	✔	✔
	Coccinellidae	3	✔	✔
	Hydrophilidae	1	✔	✔
	Pyralidae	2	×	✔
	Salpingidae	1	✔	×
	Scaritidae	1	×	✔
	Staphylinidae	4	✔	✔
Dermaptera	Anisolabididae	1	✔	✔
	Chelisochidae	1	✔	✔
Diptera	Dolichopodidae	3	✔	✔
	Muscidae	2	✔	✔
	Scenopinidae	1	✔	✔
	Syrpidae	1	✔	×
Hemiptera	Reduviidae	3	✔	✔
Hymenoptera	Formicidae	14	✔	✔
	Sphecidae	3	✔	✔
	Tiphiidae	1	×	✔
	Vespidae	1	×	✔
Orthoptera	Gryllidae	1	✔	×

✔: Present, ×: Absent

Table 3: Diversity indices of predatory arthropods (Mean±SE) on immature and mature oil palm plantations

	Diversity index		
Phase of oil palm plantation	Shannon-Wiener (H')	Species evenness (E)	Simpson dominance (C)
Immature	1.61±0.11[a]	0.62±0.03[a]	0.32±0.04[a]
Mature	1.88±0.12[a]	0.69±0.03[a]	0.22±0.02[b]

Mean values within a column followed by the same letter shows there are no significant different by t-test at $\alpha<0.05$

91.17±11.73 (Mean±SE, N = 6) in immature plantation and 99.83±15.50 (Mean±SE, N = 6) (Fig. 4b).

The total number of morphospecies (species richness) found per block ranged from nine up to 18 morphospecies with an average of 13.5±1.31 (Mean±SE, N = 6) in immature and from 11 up to 23 morphospecies with an average of 15.5±1.84 in mature oil palm plantations. Number of individual predators (abundance) per block ranged from 58 up to 181 individuals with an average of 112.33±16.95 (Mean±SE, N = 6) in immature and from 82 up to 165 individuals with an average of 123.33±12.24 (Mean±SE, N = 6) in mature oil palm plantations. Species richness of arthropod predators in immature oil palm plantations was not significantly different from those of in mature plantations (t-test, p = 0.39, t = -0.88, df = 10) (Fig. 5a). Similarly, abundance of predators did not differ significantly between immature and mature oil palm plantations (t-test, p = 0.61, t = -0.53, df = 10) (Fig. 5b). This implies that both immature and mature plantations hosted a similar composition and abundance of predators, even though those on mature plantations tended to be higher.

Species diversity of predators on immature and mature plantations: The phase of oil palm plantation showed no significant effect in two of the diversity indices of the predatory arthropods on the plantations. The Shannon-Wiener

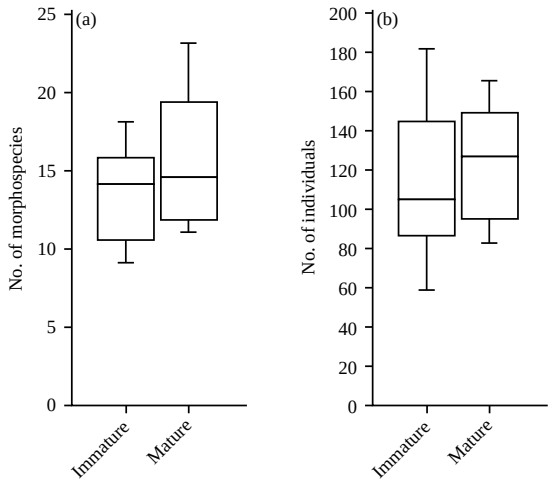

Fig. 5: Box plots showing (a) species richness and (b) abundance of arthropod predators per block on immature and mature oil palm plantations

diversity index (H') on immature plantations was not significantly different from those of immature ones (T-Test, p = 0.14, t = -1.61, df = 10), neither did Species Evenness index (E) t-test, p = 0.14, t = -1.59, df = 10). However, the Simpson dominance index (C) showed a significant difference between predatory arthropods on immature plantations and that of mature ones (t-test, p = 0.05, t = 2.22, df = 10) (Table 3). The calculation of the similarity index of predator species on both plantations resulted in a value of 62.5%.

DISCUSSION

The presence of predatory arthropods in immature and mature oil palm plantations in this study has shown that the predators still develop and survive despite the frequent use of insecticide in immature and mature of oil palm plantations. Similar results also have been shown in other studies in paddy fields[28,29]. The values of Shannon-Wiener diversity index (H') for predatory arthropods in both phases of plantations were between 1.00-3.00 which were categorized as the middle level of diversity and middle level of individual distribution[30]. Species Evenness index (E) in both phases of oil palm plantations was between 0.50-0.75 which means that the evenness in medium level and community is unstable[30,31]. While the Simpson dominance index (C) fell less than 0.50 which was categorized as low dominance of predator species[25,30] in both immature and mature plantations.

Calculation of similarity index of predator species on both plantations resulted in a value of 62.5% (more than 50%) which means that the community composition of predatory arthropods between immature and mature oil plantation was similar[32].

Previous studies have shown that arthropods were the primary predator group in oil palm plantations, among other predators such as mammals and insectivorous birds[33,34]. The species richness and abundance of predators tended to be higher in mature oil palm plantations than those of in immature plantation, even though there were no significant differences between them. The relatively higher species richness and abundance of predators in mature plantations may be due to more vegetation and more herbivore insects found in this phase than those of an immature phase. The less frequent use of insecticide in mature plantations may also be attributed to higher herbivore insects found in the plantations. Recent studies show that understory vegetation is important for providing habitat and food plants for predatory arthropods[21,33,35,36]. The higher species richness and abundance of herbivore insects and understory vegetation could be caused by the older oil palm plantation which in turn will result in higher species richness and abundance of a predator in the same area[21,37].

The presence of predatory arthropods has been shown to have an important role as a biological control agent in decreasing the pest population in oil palm plantations[33]. They are recognized as great organisms for the biological control of insect pests[38]. It was reported that 37% mortality of the bagworm population in oil palm plantations in Perak Malaysia was caused by predators from Family Cleridae (Coleoptera) and Family Reduviidae (Hemiptera). A later study showed that predatory insect *Cosmolestes picticeps* (Hemiptera: Reduviidae) was the main predator to control bagworm in several states in Malaysia[12].

Ants (Hymenoptera: Formicidae) were the most dominant predators found in this study. A similar result has been recorded earlier in Jambi Province, Sumatra[34]. The ants community is known to determine herbivore insect rate in oil palm plantation. The higher rate of ant predation on the caterpillars demonstrates the higher activity of predatory ant[39-41]. Ants community is common to be found in high humidity and around tropical rainforest areas[21,42]. Understory vegetation found in immature and mature oil palm plantations in this study may have favored the ant community due to the higher humidity caused by the presence of this vegetation.

The phase of plant development is known as important factor that affects the structure of insect communities[43], however in this study based on the diversity indices, it has

been shown that phase of oil palm plantations has no significant effect on the Shannon-Wiener diversity index (H') and Species Evenness index (E). Despite the use of insecticide regularly on both immature and mature oil palm plantations, the value of Shannon-Wiener diversity index (H') shows middle level of diversity, middle level of individual distribution for each species of predatory arthropods[30]. Evenness Index is a measure of the relative abundance of the different species found in the area. Based on Species Evenness index (E) calculated in this study, the community of predators on both immature and mature plantations was unstable[30,31] showing that community of predators may change anytime. The significant different values of the Simpson dominance index (C) on immature and mature plantations has not shown anything useful since the values under 0.5 is categorized as low dominance of predator species[25,30].

Insect diversity is influenced by several factors including understory vegetation. The more diverse the understory species, the more diverse insect community found on the vegetation which leads to a higher diversity of natural enemies (such as predators) in the area[21]. Therefore, to increase the predator diversity in oil palm plantations it is important to maintain the variation of understory vegetation including weedy understory[34]. The presence of predators is induced by the availability of prey (herbivorous insects)[44] as seen in this study that the majority of arthropods collected was herbivorous insects in immature and mature oil palm plantations as a foraging area. Therefore, the diversity and abundance of arthropod predators can be conserved by tolerating understory vegetation and minimizing the use of insecticides[33] which in turn will support sustainable agriculture management and maintain the biodiversity in general in oil palm plantation.

CONCLUSION

The results of this study provide important information about the presence of predatory Arthropods in immature and mature oil palm plantation. The species composition of predatory Arthropods found on immature and mature oil palm plantation was similar. Ants (Hymenoptera : Formicidae) dominated others in term of species richness and their abundance, however the results of Simpson dominance index (C) calculation were categorized as low dominance of predator species.

SIGNIFICANCE STATEMENT

This study records the species richness of Arthropod predators and their abundance on immature and mature plantations where insecticide was in frequent use. This study will contribute to the researchers and palm oil management in designing the methods to control insect pests as part of a sustainable and environmentally friendly method for controlling pests in oil palm plantation.

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