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The impact of oil palm plantation on ecology of rambutan (*Nephelium lappaceum*) insect pollinators

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Abstract. *Syarifuddin, Hafnisiregar E, Jambak J, Suryani C. 2018. The impact of oil palm plantation on ecology of rambutan (*Nephelium lappaceum*) insect pollinators. Biodiversitas 19: 1347-1351.* The establishment of oil palm plantation in Sumatra was the result of massive conversion of its rainforest. Many studies have shown that oil palm plantation is a main threat to biodiversity including insect pollinators. However, its effect on the ecology of insect pollinators is still poorly studied. In this study, we investigated the impact of oil palm plantation on the species richness and composition, abundance as well as pattern of time period and duration of insect visit on rambutan, *Nephelium lappaceum*, flowers. Insect visitors of flowers were compared between rambutan grown in the Oil Palm Plantation (OPP) ecotone and the one in the mixed Oil Palm Garden Forest (OPGF) ecotone. Number of visiting insects on each pannicle in ten minutes period and number of flowers and pannicles visited within 2 minutes were enumerated. The length of time of a randomly selected individual of the most abundant insects visited a flower and a pannicle was also recorded. The results showed that species composition of insect visitors was different between the two ecotones and total insect abundance was significantly higher on rambutan flowers located in the OPGF ecotone compared to rambutan trees grown close to oil palm plantation. The insect visitors on rambutan flowers in the OPGF ecotone were dominated by bees while in the OPP was dominated by Calliphorid fly. Among the main pollinators, the bee *Apis cerana* visited far more flowers and pannicles compared to *Trigona* sp and *Chrysomya* sp. Thus, more evidence showing that oil palm plantation probably has caused the disappearance of main species of bee pollinators, reduced abundance of flower-visiting insects, change of pollinator species composition, change of the pattern of time and change the duration of insect visit of rambutan flowers.

Keywords: Abundance, insect visitors, oil palm plantation, rambutan, species composition

INTRODUCTION

Most flowering plants depend on insects for pollination to occur successfully; however forest conversion has reduced insect diversity and abundance including bees. Rate of visitation to crop flowers by wild insects has positive correlation with flower-visitor richness (Garibaldi et al. 2013). Worldwide the most important bee pollinators, *Apis mellifera* dominates crop pollination (Abrol 2011), however, stingless bees are the largest and the most widely distributed genus in the tropics and subtropics, i.e., ± 130 species. These small size bees have shown to play very important role in pollinating agricultural as well as forest plants.

Despite their critical role in most plant fertilization bee pollinators have declined due to a number of factor including forest fragmentation, clearing or conversion. Ricketts (2004) showed that forest conversion into plantation has caused 50% drop in *Apis* visitation rates from 2001 to 2002, however, the reduction was only 9% near the forest. Further, where *Apis* was not present, wild stingless bees such as meliponine bees replaced the role of *Apis* for most of the visits at near forest sites (Ricketts 2004). In countries where intensive land usage and loss of habitat for pollinators it was recorded that their coffee plantations had reduced yields (loss of 20-50%), in spite of their attempt to increase cultivation (Roubik 2002).

Palm plantations are blamed to be the major cause of fragmentation and loss of forest habitats in Indonesia (Buckland 2005; Koh and Wilcove 2008). The establishment of these plantations usually results in the near total clearing of former vegetation. A number of studies shown that the diversity of natural flora and fauna in oil palm plantations are greatly reduced when compared to lowland rainforests (e.g., PORIM 1994; Gillison and Liswanti 1999; Peh et al. 2006; Maddox 2007;) and even when compared to disturbed natural forest (Fitzherbert et al. 2008). Thus the palm plantation has become the main threat to biodiversity in Indonesia, especially in Sumatra and Kalimantan.

Rambutan (*Nephelium lappaceum* L), one of the most important tropical fruits in Binjai, North Sumatra, Indonesia, and the adjacent areas. This native plant, requires insects for cross-pollination for fertilization to occur. Rincon-Rabanales et al. (2015) found that rambutan pollinated by stingless bees increased fruit production by nearly ten folds. However, lately many farmers have replaced their farm with oil palm plants. Thus, most of the remaining rambutan plants in this area has been surrounded by oil palm plantation. In this study, we investigated whether oil palm plantation affects the biodiversity, composition and abundance and the main pollinators of rambutan. We compared visiting insects to rambutan flowers in two sites, one location rambutan trees grew neighboring to merely oil palm plantation (oil palm) versus the rambutan trees close to oil palm plantation which close to a mixed garden and natural forest.

MATERIALS AND METHODS

Study site

The study took place in five locations near the Leuser National Park, North Sumatra, Indonesia where rambutan trees (*Nepheliuma lappaceum* var. *Binjai*) were grown. Five rambutan trees and five pannicles from each tree were randomly selected for observing the visiting insects. Some of the rambutan trees neighboring only oil palm plantation, called "OPP (Oil Palm Plantation) ecotone", and the rest grew close to oil palm plantation but also neighboring to mixed garden and forest, called "OPGF (Oil Palm Garden Forest) ecotone". The study was carried out during rambutan flowering period, i.e. May and July in 2015 and 2016.

Observation procedure

The observation started at 7.30 am in the morning and ended at 16.30 pm, and a one hour break between 12.00 to 13.00 as based on the trial observation prior to the data collection shown that generally, very little insect activities occurred, during midday. Each pannicle was observed for 10 minutes and a three minutes pause before observing the next pannicle. Data of duration of insect visit on a flower and a pannicle was carried out by randomly select one individual from the most common visiting insects. Length of visit by an insect since it landed on a flower, and followed it until the insect flew off. The time to record this duration of visit was limited for 25 minutes. Thus, a total of 90 minutes was needed to complete a cycle of observation.

Prior to the data collection, five observers practiced for three days in each location to recognize each visiting insects and counted the numbers for each taxon and later measure the length an insect visiting a rambutan pannicle. This meant to ensure that the observers knew the insects on naked eyes to be recorded. For the purpose of insect recognition, unknown insects were caught insect were roughly matched to Michener (2007) for bees in general; Rasmussen (2008), Sakagami (1975) and Sakagami et al. (1990) for *Trigona* and McAlpine (1981) for other dipterans, to family or genera level where possible. Many insects were named with their prominent characteristics. Proper identifications were carried out in the laboratory.

Data analysis

Comparison of number insect taxa visiting flowers in OPGF and OPP was analyzed using t-test. Comparison among insect visitors from morning to late afternoon in both ecotones was analyzed using two-way ANOVA followed by Tukey test. Data about the duration of insect visited a rambutan flower, and a pannicle was analyzed using Kruskal-Wallis. All of the analysis was carried out using SPSS v. 21.

RESULTS AND DISCUSSION

Results

Thirty-five species of insect were observed visited the rambutan flowers in both ecotones, OPGF ecotone and OPP ecotone, however only 21 species were found on rambutan, *N. lappaceum*, flowers grown in OPGF ecotone versus 24 species of insects in OPP ecotone (Table 1). Among the 21 insect species visiting the rambutan flowers in the OPGF ecotones, 11 species were not observed in the OPP ecotones, on the other hand from the 24 insect species found on the rambutan flowers in the OPP ecotones 13 of them were not found on rambutan flowers in the OPGF ecotone. The most abundant insect visitors were *Trigona* sp., *Chrysomya megacephala*, and *Apis cerana*. However, *A. cerana* were absent on rambutan flowers in the OPP ecotone and the main visiting insects were *C. megacephala,* a calliphorid insect species.

Table 1. Visiting insect pollinators on rambutan flowers based on a 10 minutes observation on each pannicle in mixed Oil Palm Garden Forest (OPGF) ecotone and in Oil Palm Plantation (OPP) ecotone

Order Family	Species	OPGF	OPP
Hymenoptera			
Apidae	*Apis cerana*	**	
	Apis dorsata		*
	Trigona sp.	***	*
	Xylocopa latipes	*	
	Xylocopa confusa	*	*
	Ceratina sp.	*	*
Halictidae	Nommiinae		*
Megachilidae	*Lithurgus* sp.	*	
Braconidae	*Tachytes* sp.		*
Vespidae	*Delta campaniforme*	*	*
	Allorhynchium sp.		*
	Vespa affinis		
Diptera			
Syrphidae	*Episyrphus balteatus*		*
	Eristalis arvorum	*	
	Epistrophe grossulariae		*
	Eristalinus quinquelineatus		*
	Dideopsis aegrota	*	*
	Chrysotoxum sp.	*	
Sarcophagidae	*Sarcophaga carnaria*	*	*
	Sarcophaga sp.		*
Calliphoridae	*Chrysomya megacephala*	**	***
Stratiomyidae	Stratiomyidae		*
Muscidae	*Musca domestica*		*
Platystomatidae	*Scholastes* sp.	*	
	Diptera sp.1	*	
	Diptera sp.2	*	
	Diptera sp.3	*	
	Diptera sp.4	*	*
Lepidoptera			
Pieridae	*Neptis hylas*	*	*
	Leptosia nina	*	*
Arctiidae	*Amata huebneri*		*
	Arctiidae	*	
Nymphalidae	*Ideopsis vulgaris*		*
	Hypolimnas bolina		*
	Euploea mulciber	*	
Lycaenidae	*Rapala suffusa*		*

The number species of insect visitors per pannicle in 10 minutes observation was significantly higher on rambutan flowers in the OPGF ecotone, 3.24 ± 1.73 ($\overline{X}$ ± SD), compared to rambutan trees grown in proximity to OPP ecotone, 1.24 ± 0.90 (t = 16.387; P = 0.000) (Figure 1.A). The abundance of insect rambutan flower visitors was significantly higher in rambutan trees near mixed garden and natural forest, 37.89± 29.49 ($\overline{X}$ ± SD) ind./pannicle/10 minutes, than the visitors on the trees close to the oil palm plantation, 7.21 ± 8.39 (t = 20.404; P = 0.000) (Figure 1.B). This means that 425.52% more insect number in rambutan flowers observed in proximity to mixed garden and forest compared to the visiting insects in rambutan near the oil palm plantation.

The stingless bees, *Trigona* spp. were observed only on rambutan trees in mixed garden-forest ecotone. In contrast, the most abundant flower visitors of rambutan near the monoculture oil palm plantation, *Chrysomya* fly, 6.48 ind./pannicle/10 minutes, was more than 50% that of visited rambutan flowers in the mixed oil palm garden-forest ecotone, 4.31 ind./pannicle/10 minutes (t = -2.413; P = 0.016). The second most abundant insect visitor on the rambutan flowers in the OPP ecotone, *Vespa affinis*, 0.131 ind./pannicle/10 minutes, was about 10 times higher compared to *V. affinis* visiting the flowers rambutan in mix OPGF ecotones.

There were more insects visited the rambutan flowers in the morning and peaked around mid-day and this pattern was almost similar in both ecotones, OPGF and OPP ecotone (F = 4.352; P = 0.002; Tukey Test) (Figure 2.). Although, the number of insects visited the rambutan flowers was more twice higher in MGF ecotone compared to OPP ecotone. However, this pattern was not consistent in *Chrysomya* flies, in which in rambutan found in OPP ecotone this insect showed its peaked visit in the morning and dramatically declined in the afternoon, especially between 14.30-16.00 (F = 6.549; P = 0.000; Tukey Test; Figure 3). The number of *Chrysomya* flies visited the rambutan flowers in the OPP ecotone in the morning, in general, was also more than twice than that in the MGF ecotone. In contrast, in the MGF ecotone, the number of *Chrysomya* flies recorded on the rambutan flowers was consistently low and statistically no varied. Did the flies adjust its pattern of visits to the rambutan flowers due to more competition with other dominant insects?

The duration of visits to the rambutan flowers and pannicle were compared among the most three abundant visiting insects, it showed that *A. cerana* needed the shortest time to visit both a flower and a pannicle, followed *Trigona* sp. and the longest time used to visit the flower and pannicle was shown by *Chrysomia* flies (Kruskal Wallis Test). On the other hand, in term of number of flowers and pannicle visited in two minutes it showed that *A. cerana* visited both most flower and pannicle numbers, followed by *Chrysomia* flies and *Trigona* sp. (Kruskal Wallis Test) (Figure 4).

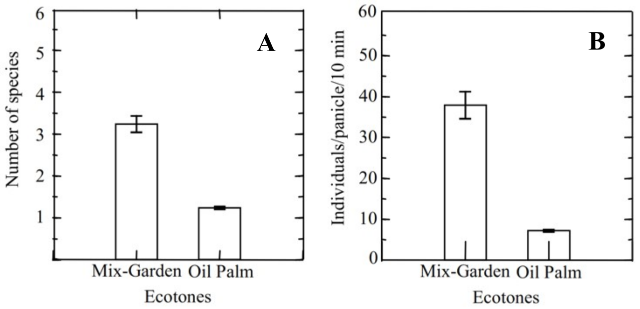

Figure 1. Number of species (A) and density of visitor insects (B) to rambutan flowers in OPGF and OPP ecotones in North Sumatra Province. Both were significantly higher on rambutan flowers grown in mixed garden close to forest ecotones, (t = 16.387; P = 0.000) and (t = 20.404; P = 0.000) respectively.

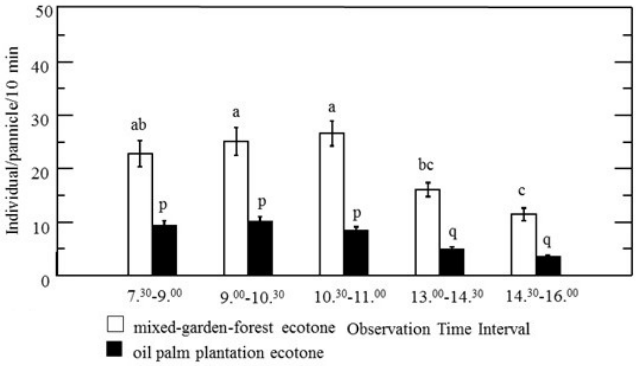

Figure 2. The abundance of insect visitors to rambutan flowers among time interval from morning to afternoon, in May and July 2015 (F = 4.352; P = 0.002). Different letters above the diagrams indicating significant different, based on Tukey test (a, b, and c for insect visiting rambutan flowers in mixed Oil Palm Garden Forest (OPGF) ecotone: p and q for Oil Palm Plantation (OPP) ecotone.

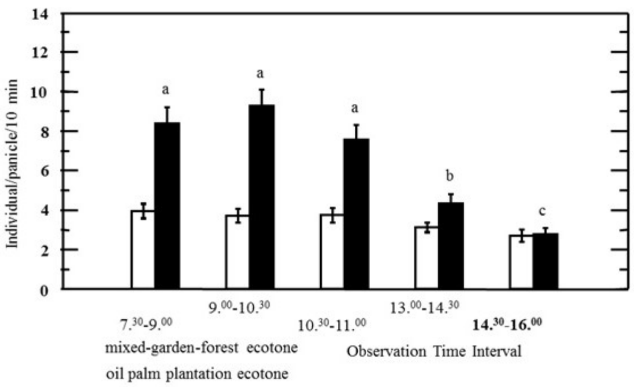

Figure 3. The effect of oil palm plantation on the abudance of *Chrysomya* sp visiting to rambutan flowers among time interval from morning to afternoon (F = 6.549; P = 0.000). Different letters above the diagrams indicating significant different, based on Tukey test.

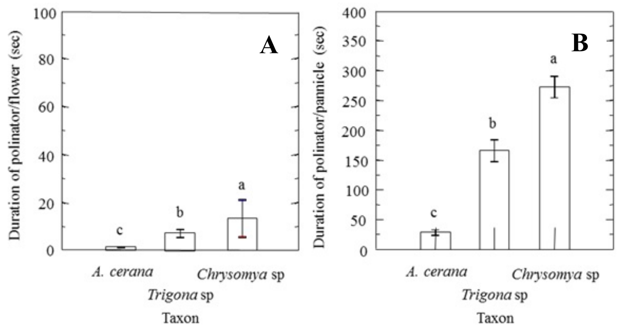

Figure 4. The duration of an individual insect visited a flower (A) and a pannicle (B) of rambutan. Different letters above the diagrams indicating significant different, based on Kruskal Wallis test

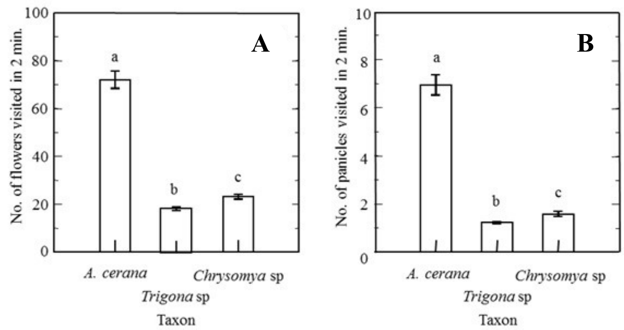

Figure 5. Number of flowers (A) and pannicles (B) of rambutan visited by main pollinator insects visited in 2 minutes, in May and July 2015. Different characters above the diagrams indicating significant different, based on Kruskal Wallis test

Discussion

Most reports about the pollinators of rambutan from a number of places including Mexico (Rincón-Rabanales 2015), India (Shivaramu et al. 2012), Malaysia (Norawi et al. 2008); Australia (Lim and Diczbalis 1998) showed that both honey bees and stingless bees were the main pollinators of this plant. Corlett (2004) found that pollination in lowland forest in Indomalayan region is dominated by social bees, especially *Trigona* and *Apis* species. However, the only three species of stingless bees in the mixed-garden-forest ecotone was considered very low. Salim et al. (2012) found 17 species of stingless bees in six Dipterocarps reserve forest of Peninsular Malaysia. In a study of rambutan pollinators in Chiapas, Mexico 15 species of bees were recorded visiting the flowers (Rincón-Rabanales 2015).

The natural flora and fauna which occur in oil palm plantations are greatly impoverished when compared to lowland rainforests (e.g., PORIM 1994; Peh et al. 2006) and even disturbed natural forest (Fitzherbert et al 2008). Extensive field research carried out in oil palm frontier areas on the island of Sumatra has concluded that oil palm plantations result in a significant reduction in biodiversity if plantations replace natural forests, secondary forests, agroforests, or even degraded forests and scrubby unplanted areas (Gillison and Liswanti 1999; Maddox 2007). Oil palm monocultures have reduced 90% terrestrial mammal species (Maddox 2007), and least 60% reduction in bird species richness (Aratrakorn et al. 2006). Biodiversity in oil palm plantations can be enhanced by altering vegetation characteristics at the local level (e.g., percentage ground weed cover), or by increasing natural forest cover at the landscape level; however, the gains in biodiversity resulting from these practices are quite minor relative to the losses that occur when forests are cleared (Koh and Wilcove 2008).

Countries that experienced an intensive land usage and loss of habitats for pollinators in coffee plantations had reduced yields (loss of 20-50%), although they had increased cultivated areas (Ivory Coast, Ghana, Kenya, Cameroon, Indonesia, El Salvador and Haiti) (Roubik 2002). Ricketts (2004) found that bee richness, overall visitation rate, and pollen deposition rate on coffee (*C. arabica*) shrubs were all significantly higher in sites within approximately 100m of forest fragments than in sites far away (up to 1.6 km). *A. mellifera* foragers accounted for more than 90% of all visits in distant sites, and where *Apis* was not present, native species as meliponine bees accounted for most of the visits at near sites (Ricketts 2004). This is due to the smaller flight range of meliponine bees which have a typical flight range of 100-400 m (van Niewestadt and Iraheta 1996; Heard 1999), although maximum observed flights ranged from 1 to 2 km (Roubik and Aluja 1983).

When *Apis* abundance declined substantially, from 2001 to 2002, visitation rates dropped about 50% in distant sites, but only 9% in near sites. This can be explained by the compensating effect of native bees, which replaced *Apis* as the most important visitor in nearby sites. So, according to the author, forest fragments provided nearby coffee with a diversity of bees that increased both the amount and stability of pollination services by reducing dependence on a single introduced pollinator (Ricketts 2004). Similarly, *C. canephora* and *C. arabica* fruit set increased with the increase of diversity and abundance of flower-visiting bees (*C. arabica*: 90% when 20 bee species were present and 60% when only three species were present (Klein et al. 2003a). *C. canephora*: 95% when 20 or more bee species were present and 70% when only six species were present (Klein et al. 2003b), and the number of social bees species decreased with distance to forest fragments and the number of solitary bees increased with light intensity (less shade) and greater quantities of blossoms.

On the other hand, the absence of bees on rambutan flowers in the oil palm plantation indicating that this monoculture vegetation resulted in the negative impact on the most important pollinators. A number of other studies also showed the conversion forest showed similar phenomenon (e.g., Liow et al. 2001; Venturieri 2009; Winfree 2011). Among pollinators, it was suggested that bees are the highest proportion received negative impact due to human activities (Winfree 2011).

The absence of bees on rambutan flowers in the oil palm plantation ecotone indicated that the vegetation is not suitable for nesting or foraging sites or both for bees. In general, prior to the establishment of oil palm plantation, all of the existed vegetations were cleared. Thus, given the vast area of oil palm plantation making the cleared area are beyond bee flying distance. In addition, oil palms do not produce nectar and no hollows are available for cavity-nesting bees, making them unsuitable for nest building (Oldroyd and Nanork 2009; Venturieri 2009).

It seems that the larger the visiting insects the more effective they use time to visit *A. cerana* needed the shorter time to visit both a flower and a pannicle, followed *Trigona* sp. and the longest time used to visit the flower and pannicle was shown by *Chrysomia* flies.

This study thus showed that oil palm plantation has caused the disappearance of main of bee species as the important pollinators, the reduction in visiting insect diversity and abundance, the change of the main pollinator species composition (dominated by bees in mixed garden-forest ecotone vs. Calliphorid flies in oil palm plantation), the change of the pattern of duration of insect visit, and in term of duration of visits and number flowers and pannicles visited by the insects in mixed garden-forest ecotone were more effective than insects in oil palm plantation ecotone of rambutan flower. Thus, it suggests that oil palm plantation has caused disappearance of bees as important pollinators and dramatically reduced the abundance of pollinators in rambutan. This negative impact on the ecology of pollinator insects probably due to the vegetation in the oil palm plantation do not provide both foraging and nesting sites for bees.

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