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Original research article

Diversity and Abundance of Insect Pollinators in Different Agricultural Lands in Jambi, Sumatera

Elida Hafni Siregar,[1,2] Tri Atmowidi,[1*] Sih Kahono[3]

[1] Department of Biology, Faculty of Mathematic and Natural Sciences, Bogor Agricultural University, Dramaga Campus, Bogor, Indonesia.
[2] Department of Biology, Faculty of Mathematic and Natural Sciences, State University of Medan, Medan, Indonesia.
[3] Laboratory of Ecology, Zoology Division, Research Center for Biology, Indonesian Institute of Sciences (LIPI), Cibinong, Indonesia.

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ABSTRACT

Agricultural land use is an artificial ecosystem. Insect pollinators are important keys to success of the agroecosystem. Converting natural landscapes to agricultural land, such as oil palm and rubber plantations, affects the insects. The research aims to study diversity and abundance of insect pollinators in three different agricultural land uses, i.e. oil palm plantation, rubber plantation, and jungle-rubber. Scan sampling method was used to explore the diversity of insect pollinators. Observations of the insects were conducted from 08.00 to 10.00 AM and 02.00 to 04.00 PM in sunny days. There were 497 individuals of insect pollinators collected, which belong to 43 species in three orders (Hymenoptera, Diptera, and Lepidoptera). Number of species and individual of insect pollinators found in rubber plantations (31 species, 212 individuals) and oil palm plantation (23 species, 188 individuals) were higher than that in jungle rubber (7 species, 97 individuals). Insect pollinators in oil palm plantations were dominated by giant honey bee (*Apis dorsata*) and stingless bee (*Trigona* sp. [=aff. *T. planifrons*]), whereas in rubber plantation, they were dominated by small carpenter bees (*Ceratina lieftincki* and *Ceratina simillima*), and in jungle-rubbers were dominated by hoverfly (*Syrphid* sp.) and *Apis andreniformis*. Higher foraging activities of insect pollinators occured in the morning.

1. Introduction

Tropical rain forests are a source of insect biodiversity. Among tropical regions in the world, Indonesia has the highest rate of deforestation. About 1.7% of natural forests were lost annually from 1990 to 2005 (Sodhi *et al.* 2010a). In central Sumatera, including Jambi, annual deforestation rate reaches 3.2%–5.9% (Achard *et al.* 2002). Forests are degraded by illegal logging and converted to agricultural land (Sodhi *et al.* 2010b). Deforestations and habitat changes have been a major threat to tropical biota (Dirzo and Raven 2003), such as reduced species richness of plants and animals (Schulze *et al.* 2004). Insects occupy various types of ecosystems and perform many important ecological functions (Sodhi *et al.* 2010b). Insect pollinators, seed predators, decomposers, and parasitoids are highly susceptible to the adverse effects of both forest fragmentations and habitat changes. It is beyond any doubt that ecosystem changes induced in abundance and species richness of many insect groups (Didham *et al.* 1996).

Habitat destruction affects insect pollinators because of the destruction of food sources, nesting, oviposition, resting, and mating sites (Kevan 1999). Currently, decrease of insect pollinators is well documented, such as decreasing abundance and richness of wild pollinators significantly in agricultural landscapes with extreme habitat loss or increased distance to natural habitat (Ricketts 2004). However, the biodiversity study of insect pollinators in fragmented forests is still in its infancy and lacks real direction (Didham *et al.* 1996) and relatively does not acquire enough attention (Sodhi *et al.* 2010b).

Insect pollinators and flowering plants have mutual relationships. Nectar and pollen are food rewards for pollinators (Bezzi *et al.* 2010; Arenas and Farina 2012). Pollinators transport pollens from anthers to stigmas and fertilization occurs (Brandenburg *et al.* 2009). Interaction between plant and pollinator can help pollination, especially in plants that are *self-incompatible* (Aizen and Feinsinger 2003). Many groups of insects are known as pollinators of various plants. Bees, butterflies, moths, beetles, wasps, and flies are reported as pollinators of plants. Bees are the most

* Corresponding author.
E-mail address: atmowidi@gmail.com (T. Atmowidi).
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important and effective pollinator than other group of insects (Tylianakis *et al.* 2007). Bees are a diverse group of insects and organized into two groups based on their nesting, i.e. solitary and social bees (Rehan *et al.* 2010). Pollinators maintain healthy ecosystem, ensure plant reproduction, and increase genetic diversity of plants. Insect pollinators also increase the yields, such as the number of pods, seeds per pod, seed weights per plant, and seed germination of *Brassica rapa* (Atmowidi *et al.* 2007), fruit and seed sets of *Jatropha curcas* (Rianti *et al.* 2010).

Agricultural land use is an artificial ecosystem that attracts numerous insects for nesting, resting, hunting available foods, or biological activities. Insects are important keys to success of the agroecosystem. Converting natural landscapes to agricultural land, such as oil palm and rubber plantations, affects insect pollinators. Studies of insect pests on both oil and rubber plantations have already been done, but diversity and abundance of insect pollinators in both locations were still unknown. Therefore, this study aimed to investigate diversity and abundance of insect pollinators in three different agricultural land uses, i.e. oil palm plantation, rubber plantation, and the jungle rubber in Jambi Province, Sumatera.

2. Materials and Methods

2.1. Observation of insect pollinators

Observations of insect pollinators were conducted from November to December 2012 at Bajubang, Batanghari district, Jambi Province, in three different land uses, i.e. oil palm plantation (48 m asl S 01.78723, E 10327071), rubber plantation (76 m asl, S 01.91099, E 103.26664), and jungle rubber (63 m asl, S 01.78538, E 103.27663). Diversity and abundance of insect pollinators were observed by scan sampling method (Ratti and Garton 1996) in two different periods, i.e. in the morning (08.00–10.00 AM) and afternoon (02.00–04.00 PM) on sunny days. In each site, insect observations were conducted in three days. Samples of insect pollinators were caught by sweep net around herb layers and understory canopy. The insect specimens were preserved into the killing bottle containing ethyl acetate and then stored in papilot paper for identification process. Climatic factors in the fields, i.e. air temperature, air humidity, light intensity, and wind velocity, were measured every 30 minutes. Flowering plants visited by insect pollinators were recorded.

2.2. Data analysis

Diversity of insect pollinators was analyzed using Shannon diversity index (H') and its evenness (E) using Primer E-5 for Windows. Similarity of insect pollinators between three sites was analyzed using Bray–Curtis similarity by using PAST program (http://folk.uio.no/ohammer/past) version 2.17c.

3. Results

3.1. Description of study area

Oil palms and rubber plantations are monoculture plant. In the oil palm plantations, herb and understory flowering plants visited by insect pollinators were *Stachytarpetha indica, Ageratum conyzoides, Asystasia gangatica, Borreria laevis,* and *Oxalis barrelieri.* Whereas, in the rubber plantations, understory flowering plants were dominated by *Clibadium surinamense, Melastoma malabathricum, A. gangatica,* and *S. indica.* Jungle-rubbers are polyculture plants dominated by *Hevea brasiliensis* and other economic plants, such as *Eusideroxylon zwageri, Sloetia elongata, Schima wallichii, Artocarpus elasticus, Fagraea fragrans,* and *Parkia speciosa*. In all study areas, air temperature, relative humidity, light intensity, and wind velocity during observations of insects were 24.70°C–29.90°C, 52.20%–66.15%, 20.32–87.95 lux, and 0.11–1.12 m/s, respectively (Table 1).

3.2. Diversity of insect pollinators

This study found 497 individuals of insect pollinators belong to 43 species, three orders, and seven families. Three orders of insect pollinators found were Hymenoptera (family Apidae, Megachillidae, and Hallictidae), Diptera (family Syrphidae), and Lepidoptera (family Nymphalidae, Lycaenidae, and Arctiidae). Bees (order Hymenoptera) have the highest abundance (388 individuals, 31 species, 9 genera, and 3 families), followed by hoverflies (order Diptera; 91 individuals, 6 species, and 1 family). The lowest abundance was butterflies (order Lepidoptera; 18 individuals, 6 species, 5 genera, and 2 families). Small carpenter bees, *Ceratina* (9 species), and stingless bees, *Trigona* (8 species), have high abundance (Table 2). Bees and hoverflies were abundant in the morning (Figure 1).

Number of species and individual of insect pollinators found in rubber plantation (31 species, 212 individuals) and oil palm plantation (23 species, 188 individuals) were higher than those in jungle-rubber (7 species, 97 individuals) (see Figure 2). Insect pollinators in rubber plantation (H' = 2.28) and palm oil plantation (H' = 2.25) were more diverse than in the jungle-rubber forest (H' = 0.88). Similarity of insect pollinators found in rubber plantation and oil palm plantation was higher (29%) than that between jungle-rubber and oil palm plantation (12%) and between jungle-rubber and rubber plantation (9%; Figure 3).

4. Discussion

Three groups of insect pollinators were observed, i.e. bees (Hymenoptera), flies (Diptera), and butterflies (Lepidoptera). Bees (Apidae) were abundant in rubber and oil palm plantations, whereas syrphid flies were dominant in jungle rubber. Bees are the most important pollinator group (Bawa 1985) and essential pollinators for crops and wild plants (Aebi *et al.* 2011) because of their behavior and flight patterns (Didham *et al.* 1996). In central Sumatera, Inoue *et al.* (1990) reported that 73.5% of flowers were visited by bees (Apidae). Giant honey bee (*Apis dorsata*) was found in oil palm plantation in high abundance. The species actively visited flowering herb to harvest nectar and pollen. Bee, *A. dorsata,* was reported as pollinator in lowland dipterocarp forest at Sarawak, and the species can migrate over 100 km (Momose *et al.* 1998). In oil palm plantation at Johor, Malaysia, Liow *et al.* (2001) reported that dominant pollinators were halictid bees.

Two species of stingless bees (*Trigona* sp. [=aff. *T. planifrons*]) and *Trigona apicalis* Smith were dominant in oil palm plantations. Stingless bees were also reported in central Sumatera (Sakagami *et al.* 1990). The abundance of stingless bees found indicates that are habitat preference. We also found a nest of stingless bee in the trunk of rubber tree. Liow *et al.* (2001) reported that the abundance of stingless bees increases in accordance with the increasing number of trees. Population of the species decreases with the

Table 1. Climatic conditions in study sites

Climatic factors	Means ± SD		
	Oil palm	Rubber plantation	Jungle-rubber
Temperature (°C)	27.6 ± 2.2	27 ± 2.15	26 ± 1.6
Relative humidity (%)	62.8 ± 6.9	59 ± 8.85	66 ± 5.8
Light intensity (lux)	53.3 ± 30	44 ± 29.23	20 ± 14
Wind velocity (m/s)	0.32 ± 0.4	0.4 ± 0.34	0.1 ± 0

SD = standard deviation.

Table 2. Species and individual number of insect pollinators in study sites

Order	Family	Species	Oil palm plantation	Rubber plantation	Jungle-rubber
Hymenotera	Apidae	*Apis dorsata*	86	0	0
		A. cerana	2	3	0
		A. andreniformis	0	0	8
		Trigona sp. (=aff. *T. planifrons*)	32	1	0
		T. laeviceps	1	2	0
		T. apicalis Smith	23	0	1
		T. thoracica	3	0	0
		T. terminata	0	1	0
		T. fuscoblateata	0	3	0
		T. flaviventris Fabricius	3	0	0
		T. moorei Schwarz	1	0	0
		Xylocopa latipes	1	0	0
		X. confusa	2	0	0
		X. collaris	1	0	0
		Ceratina collusar Cockerell	4	9	0
		C. bryanti Cockerell	1	11	0
		C. lieftincki van der Vecht	0	78	0
		C. jacobsoni	0	10	0
		C. simillima	0	16	0
		C. cognata	0	3	0
		C. unimaculata	0	6	0
		C. smaragdulla	0	6	0
		C. comberi	0	3	0
		Amegilla sp.	4	0	0
	Megachillidae	*Megachille* sp.	14	1	0
		Lithurge sp.	1	3	0
	Halictidae	*Nomia* sp.	7	15	0
		Nomiinae sp.	5	1	0
		Lasioglossum sp1	4	3	0
		Lasioglossum sp2	1	6	1
		Thrincostoma sp.	1	0	0
Subtotal individuals = 388			197	181	10
Subtotal number of species			21	20	3
Diptera	Syrphidae	*Eristalis arvorum*	0	1	0
		Syrphus balteatus de Geer	1	0	0
		Syrphidae sp1	1	1	0
		Syrpidae sp2	1	0	0
		Syrpidae sp3	1	0	75
		Syrpidae sp4	1	5	4
Subtotal individuals = 91			5	7	79
Subtotal number of species			5	3	2
Lepidoptera	Nymphalidae	*Hypolimnas bolina*	3	0	0
		Ypthima philomela	3	0	0
		Ypthima horfieldii	1	0	0
		Junonia orithya	2	0	0
		Nymphalidae sp1	0	0	6
	Lycaenidae	*Lampides boeticus*	1	0	2
Subtotal individuals = 18			10	0	8
Subtotal number of species			5	0	2
Total individuals (*n*) = 497			212	188	97
Total species (S) = 43			31	23	7
Pielou's evenness (J')			0.66	0.73	0.45
Shannon index (H')			2.25	2.28	0.88

increasing temperature and flowering intensity of both trees and shrubs. Small carpenter bees (*Ceratina* spp.) were also found in high individual numbers at rubber plantations, and *Ceratina lieftincki* was very abundant. We observed that small carpenter bees used broken twig to build their nests. Rehan and Richards (2010) reported *Ceratina* species are mass provisioners that form their nests in the pith of dead and broken twigs. Another pollinator was syrphid flies, mainly in jungle rubber. The species visited flower of Piperaceae plants. Syrphid flies were also reported as pollinators in two *Peperomia* species (Piperaceae) that are *self-incompatible* (de Figueiredo and Sazima 2007).

Insect pollinators in rubber and oil palm plantations were higher than in jungle-rubber. These might be due to higher density of flower in rubber and oil palm plantations rather than in jungle rubber. These suggest that insect diversity related to flower density (Scriven *et al.* 2013). In contrast to rubber and oil palm plantations, low diversity of insect pollinators in jungle-rubber might be because flower density, as food resources, was low and the high canopy coverage leads jungle rubber to have more humidity than the other two sites. In addition, jungle rubber may be used only as nesting site for stingless bees and they forage to open area, such as rubber and oil palm plantations. Locations of oil palm and rubber plantations were close to jungle rubber. Similar results were reported by Otero and Sandino (2006) where the abundance of bees in the farm habitat was higher than in forest habitat. In both locations, flowering plant species as food resources for bees are *O. barrelieri, M. malabathricum, A. gangatica,* and *S. indica.* The last three plant species were reported as flower-visiting bees (Liow *et al.* 2001). Species richness and abundance of insect pollinators have been shown to be directly affected by the different environmental conditions, such as diversity and abundance of understory flowers. Flight and foraging of insect pollinators can be affected by some factors, such as food quantity, competition, and climatic conditions (Kajobe and Echazarreta 2005).

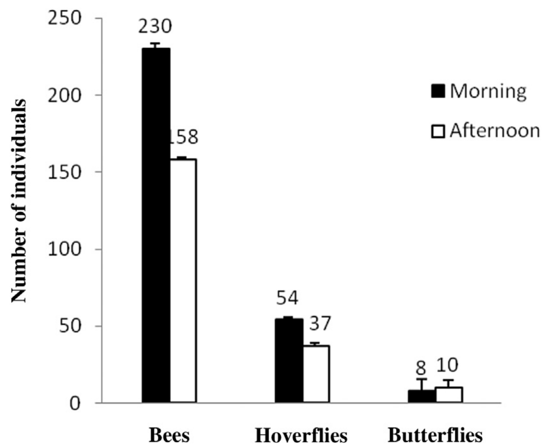

Figure 1. Number of individuals of insect pollinator in the morning and afternoon.

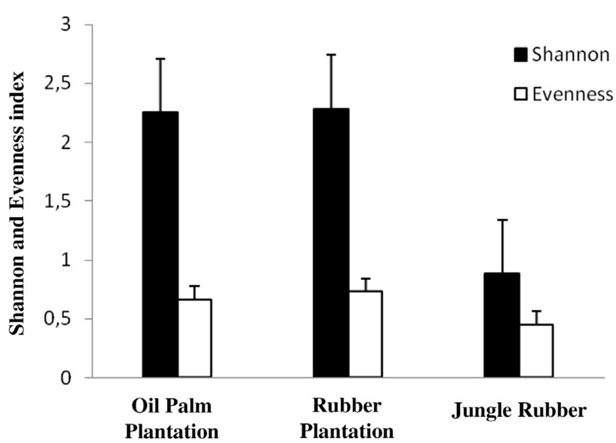

Figure 2. Shannon and evenness index of insect pollinators in study sites.

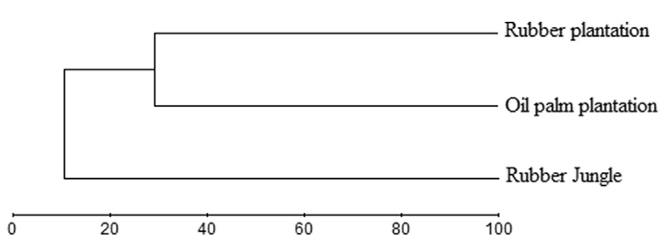

Figure 3. Bray–Curtis similarity index of insect pollinators in oil palm plantation, rubber plantation, and jungle-rubber.

In rubber and oil palm plantation, abundance and species richness of insect pollinators were highest in the morning, but in jungle-rubber, species richness was highest in the afternoon. High abundance and species richness of insect pollinators in the morning related to the availability of nectar and pollen as food source of insect. Sugar concentration of nectar fluctuated from time to time because of nectaries activity, such as secretion or reabsorption, evaporation, condensation, and removal of nectar by flower visitors (Abrol 2005). Foraging activity of social, solitary bees and hoverflies was higher in the morning and afternoon, whereas that of butterflies was higher in the afternoon. Albrecht *et al.* (2012) also reported that social bees foraging activity was higher in the afternoon, solitary bees in the morning, and hoverflies in the morning and afternoon.

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