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CONTRIBUTION OF EPIPHYTES ON THE CANOPY INSECT POPULATION IN OIL PALM PLANTATIONS IN NORTH SUMATERA

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ABSTRACT

Epiphytes are one kind of plant that has an important role in oil palm plantation ecosystems. Growing on the stem of the tree, epiphytes provide an important source of energy and habitat for many creatures and microorganisms including arthropods. Because of this, the role of epiphytes in increase in the diversity of the canopy insect population in oil palm plantations needs to be calculated. The epiphyte population in oil palm plantations and the contribution it makes to this has yet to be studied extensively and there is no commonly agreed management strategy for epiphyte control. This research was conducted in five oil palm plantations in North Sumatera; Bukit Sentang, Padang Mandarsah, Ajamu, Sijambu-jambu dan Aek Pancur using fifty ha of trees ranging in age from six to fifteen years at each site. To establish the diversity of vascular epiphytes three 20 x20 meter plots were chosen in each location while the diversity of the canopy insects was measured in ten trees from the same sites using squares of cloth to collect the insects after the trees were sprayed with Deltamethrin spray. The epiphyte contribution to canopy insect diversity was investigated by removing all the epiphytes from some trees, cutting off half of them from others and leaving a third group of trees with epiphytes undisturbed. The result of this research shows that the diversity index for vascular epiphytes and canopy insects was in the moderate to low categories. Plantations where the epiphytes were undisturbed had a greater number and diversity of insects than those where the epiphytes had been reduced or eliminated completely.

Keywords: vascular epiphyte, canopy insects, biodiversity.

INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) (Palmaceae) is a native of Guinea West Africat. It grows to twenty-five to thirty meters high (Owusu-Appiah 2007) and has economic importance in providing foreign exchange, providing employment for rural communities in particular, improving the standard of living, reducing poverty and migration to urban areas. For tropical countries and countries with low living standards oil palm plantations provide a strong force for economic development (Casson, 2000; McCarthy dan Zen, 2010; Sheil *et al*, 2009.; World Growth, 2011), so are often described as "green gold" (Friends of the Earth, 2008).

On the other hand clearing land for oil palm plantations results in a change in the ecosystem from a natural ecosystem to a plantation ecosystem that tends to be a monoculture). This reduces the biodiversity of the local habitat resulting in instability in the ecosystem and an increase in pest infestation. One way to reduce pest infestation is to increase the variety of plants in the plantation to increase the ecosystem stability. According to Fitzherbert *et al.* (2008) an oil palm plantation has only about 23% the biodiversity of a natural forest.

One type of plant that provides some diversity in oil palm plantations is the vascular epiphyte. The existence of vascular epiphytes on oil palms has yet to be explored in detail, hence the information related to their ecology, biodiversity and role is very minimal. A number of researchers class epiphytes in oil palm plantations as weeds (Ginting *et al*. 2004; Essandoh *et al*. 2011), and because they represent only a small percentage (1, 5%) of the total number of weeds (Essandoh, *et al*, 2011), often little notice is taken of their existence.

Attached to the crown of the tree, epiphyte vegetation provides an important resource and habitat for many creatures and microorganisms. (Stuntz *et al*. 2002, Cruz-angon *et al.* 2009) including Arthropoda, insect eaters, nectarivorous dan fruit eaters particularly bats and birds (Fleming *et al.* 2004). Epiphytes have an important role in tatched arthropoda kanopi in several different ways. Epiphytes, which have a long life span like bromeliad (Benzing 1994), provide an important protective microhabitat from harsh conditions in the rain forest canopy. (Ellwood *et al*. 2002; Stuntz *et al*. 2002). Epiphytes also increase the variety of insects by creating a soil environment and litter habitat and foliage that provides food for herbivorous insects (Schmidt and Zotz 2000). Epiphytes attract herbivorous insect predators and parasites along with pollenators for epiphytic angiosperms (Wittan 2000). Because of these factors it is important to evaluate the role of epiphytes in protecting the biodiversity of the forest canopy. (Ellwood *et al*. 2002; Kitching *et al*. 1997; Odegaard, 2000; Stork, 1987).

Several writers have focused their studies on arthropod biodiversity of epiphites (Richardson *et al.* 2000; Stuntz, 2001; Wittman, 2000; Yanoviak *et al*. 2006); very few have studied the overall contribution of epiphytes to the canopy insect biodiversity (Ellwood *et al*. 2002, Stuntz *et al*. 2003). One of these studies is Cruz-Ang *et al*. (2009) who researched the contribution of epiphytes to

canopy insect diversity in coffee plantations in Mexico. It was observed that coffee plantations that contained epiphytes had a larger insect population than those without, both in terms of variety and total number of insects.

The impact of epiphytes in oil palm plantations has yet to be extensively studied and there is no uniform management process of epiphytes in these plantations. For many years, several plantations have adopted a policy of removing epiphytes from oil palm trunks to make harvest easier (Ferwerda, 1977). However in other cases, Meijaard and Sheil (2013) encourage the growth of fern epiphytes as a biodiversity strategy in palm oil plantations. Increased biodiversity and reduction in the loss of species through preserving natural vegetation is recommended by Lucey *et al.* (2014) to raise sustained oil palm production in the long term.

Research is needed to discover the most appropriate strategy with regard to vascular epiphytes in oil palm plantations. The effect on the insect population of the canopy of several usual management strategies will be studied. Knowledge of the biodiversity of insects and their role in the ecosystem would provide a clearer picture of the contribution of vascular epiphytes on the insect population in oil palm plantation canopies.

MATERIALS AND METHOD

This research was carried out from October 2012 until February 2013. Field data was collected from Pusat Penelitian Kelapa Sawit (PPKS) plantations from five different locations in North Sumatera; Bukit Sentang in the north, Padang Mandarash in the south, Ajamu and Labuhan Batu to the east and Jambu-jambu and Siloga in the west and Aek Pancur and Tanjung Morawa in the center. Each location was represented by a plantation area of 50 ha of trees of similar age. Epiphyte identification was carried out in the biology laboratory and Medan Herbarium of USU Insect identification was conducted in the PPKS Marihat laboratory in collaboration with LIPI Cibinong.

Field observations

In each research location finding appropriate representative trees of the same age proved difficult. To ensure uniformity of data 20 x 20m plots of 6 - 15 year old oil palms were selected in each plantation. Five plots were selected for study in each of the five locations; a total of twenty five plots.

Purposive sampling was used to select the plots. Observation of epiphytes on the trunk and in the canopy was conducted by climbing the trees or using a long pole to reach them. If this proved impossible observation with the aid of binoculars was used. The total number and type of epiphytes was noted. Identifiable genus were recorded at the site, samples of those that could not be identified were collected for the herbarium. Efforts were made to include and label spores and reproductive organs in each sample. The samples were then stacked between sheets of newspaper placed in a plastic bag and preserved with 70% alcohol.

Observations of insect variety was conducted in the epiphyte study plots .At each location insect variety was calculated both at daytime and nighttime using spraying. Insects were sprayed at around 9am and 7pm local time around ten trees for each site. Two one meter square cloth containers were placed under each tree. Then each tree was sprayed with the recommended dose of pesticide containing Deltamethrin (a synthetic pyrethroid). After thirty minutes the insects that had fallen into the cloth were collected and placed in 70% alcohol for later identification.

The study of the influence of epiphytes on insect variety was conducted at the same locations. At each location three 1 ha plots were randomly chosen, each being at least 100m from the others. Then the palms in one 1 ha were stripped of epiphytes using the recommended dose of herbicide, another 1 ha plot had half the epiphytes removed by cutting them down and epiphytes on the third 1 ha plot were left undisturbed. Insects were collected from three trees in each plot one week after the epiphytes had been removed. Two one meter square cloth containers were placed under each tree. Then each tree was sprayed with the recommended dose of pesticide containing Deltamethrin (a synthetic pyrethroid). Insects were also collected from the other chosen trees that had half or all their epiphytes intact. After thirty minutes the insects that had fallen into the cloth were collected and placed in 70% alcohol for identification in the laboratory

Laboratory observations

Epiphyte samples from the field were unpacked in the laboratory and oven dried at 60^{o}C for 24 hours. The dried samples were identified with the aid of reference books: Piggot (1984), Holltum (1959), Backer dan Bakhuizen van den Brink (1963; 1965; 1968), dan Hutchinson (1959; 1960).

The insects preserved in alcohol were divided according to the location they were found and identified according to their morphology with the aid of a magnifying glass and a binoculor stereo microscope.

Data analysis

The level of consistency of the epiphyte population in each location was calculated using the Shannon-Weiner diversity Index level ($H' = -\sum Pi\ ln\ Pi$) and Pielou's evenness index = H‘/ln(s) (Magurran, 1988). Where Pi is the proportion of individuals and s the number of species. The range of values for the diversity index can be grouped as follows; diversity is low if $H' < 1$, moderate if $1<H'<3$ and high if $H'>3$. An evenness index $E < 0.3$ indicates low species evenness, $E = 0.3 - 0.6$ moderate genus evenness and $E > 0.6$ high species evenness. To evaluate the epiphyte contribution to canopy insect variety, the data was analysed using a one way ANOVA, if the result showed a significant difference it was tested further using the Duncan New Multiple Range Test (DNMRT) at the 5%. level.

RESULTS AND DISCUSSIONS

Composition of Vascular Epiphyte population in oil palm plantations in North Sumatera

Overall 70 species of vascular epiphytes were observed in oil palm plantations inNorth Sumatera (twenty five were ferns, forty dicotyledon and five monocotyledion). The total number of individuals were 10, 346 spread over observation areas totaling 10.000 m^2. The study location with the greatest variety of species (44) was at Sijambu-jambu followed by Aek Pancur, Padang Mandarsah, Ajamu then Bukit Sentang with 26, 21, 18 and 14 species respectively. The locations with the greatest number of individual epiphytes was Bukit Sentang followed by Aek Pancur, Ajamu, Sijambu-jambu and Padang Mandarsah (Appendix 1).

Table-1. Ten most frequently occurring species of vascular epiphytes in oil palm plantations in North Sumatera.

	Species	I	II	III	IV	V	Total
1	*Nephrolepis biserrata*	2868	312	537	520	1566	5803
2	*G. verrucosum*	501	64	246	44	511	1366
3	*Elaeis guineensis*	447	146	73	59	43	768
4	*Asystasia gangetica*	84	305	16	51	55	511
5	*Vittaria elongate*	-	50	157	8	173	388
6	*Davalia divaricata*	24	75	81	34	51	265
7	*Asplenium* sp.	99	96	21	22	-	238
8	*Clidemia hirta*	66	-	4	71	79	220
9	*Peperomia pellucida*	48	2	12	121	8	191
10	*Stenochlaena pallustris*	9	-	42	-	3	54
	Total	4146	1050	1189	930	2489	9804

Ket: I: Bukit Sentang - : not found
II: Padang Mandarsah
III: Ajamu
IV: Sijambu-jambu
V: Aek Pancur

The following species were found at all study locations; *Nephrolepis biserrata, Goniophlebium verrucosum, Elaeis guineensis, Asystasia gangetica, Davallia divaricata,* and *Peperomia pellucida. Vittaria elongata, Asplenium* sp. and *Clidemia hirta* were found in four locations while *Stenochlaena pallustris* was only found in three locations; Bukit Sentang, Ajamu and Aek Pancur (Table-1).

In the five study locations, the species with the highest population *Nephrolepis biserrata* (Figure-1). The second most common at Bukit Sentang, Ajamu and Aek Pancur was *Goniophlebium verrucosum* (Figure-2) while at Padang Mandarsah *Asystasia intrusa* was more common and at Sijambu-Jambu *Peperomia pellucida* (Table-1).

Figure-1. *Nephrolepis biserrate.*

Figure-2. Goniophlebium verrucosum.

The number of individuals of *Nephrolepis biserata* and *Goniophlebium verrucosum* was 30-40% greater than that of any other species. This high index indicates a dominant ecological position for these species in their community. According to plant taxonomy both species are members of the fern or Pteridophyta group that reproduces using spores (Zimdahl, 2007). According to Khronc (1989) spores are easily dispersed by wind allowing for easy propogation. In the sporophytic phase, members of the pteridophyta group usually form leaf stems that are wide and complex to facilitate the spread of the spores (Ambrosio and Franklin de Melo, 2004).

While these Pteridophyta occupy a dominant position, other Pteridophyta also occur frequently in each location. *Nephrolepis biserata, Geniophlebium verrucosum,* and *Davallia divaricata* were found in this study and also by Yusuf *et al.* (2003) in oil palm plantations in Malaysia and Singapore. According to Yusuf *et al.* (2003), oil palm plantations are the only habitat where these three species coexist.

Asystasia gangetica and *Peperomia pellucida* are in fact not true epiphytes but commonly found oil palm plantation weeds. *Asystasia gangetica* and *Peperomia pellucida* is a bush that grows invasively in disturbed habitats (De Poorter, 2007) is a accidental epiphyte (Benzing, 2004). *Elaeis guineensis* is also found frequently in all plantations (447, 147, 73, 59 and 43 individuals). This is related to the hygene practices of the plantation because this plant germinates and grows from the debris left over from harvest. Initially this species is not detrimental but is it is allowed to grow unchecked it will compete with the host tree (Figure-3).

Figure-3. Elaeis guineensis

Variety of Insects in the Canopy of Oil Palm plantations in North Sumatera

To study the range of insect species present in the canopy 5416 specimens were collected from 107 different families and 12 orders. The largest number of families: 69 was discovered in the Padang Mandarsah plantation, followed by Sijambu-jambu, Bukit Sentang, Ajamu and Aek Pancur with 59, 51, 45 and 37 families respectively. The largest number of individuals were found at Aek Pancur plantation; 2569 While Bukit Sentang had the smallest number of individuals; 406 (Appendix 2).

The ten families of insect that were found in the largest numbers can be seen from Table-2. Curculionidae, Formicidae, Blattidae, Blatellidae, Braconidae and Tipulidae were found in the five locations, Dolichopodidae was not found at Aek Pancur and Reduviidae, Anthicidae and Stratiomyidae were not found at Ajamu. The family with the largest number of

individuals was Curculionidae with 3187. This was followed by Formicidae and Blattidae with 1199 and160 individuals (Table-2).

The high number for Curculionidae is because many *Elaeidobius camerunicus* were collected. This insect is a pollinator for the oil palm tree. Usually this insect is attracted by the scent of the male flower. (Rahayu, 2009) Hence the reason for the large numbers of this insect may be that the male flowers were flowering at the time of the study.

The second most commonly observed insect family was Formicidae. These insects are ants that live in colonies hence were often found in the ecosystem. The most commonly observed species of ant was *Anoplolepis gracillipes*. This is an invasive species that is often found in disturbed habitats like oil palm plantations. Bruhl *et al*. 2009 also reports that the invasive species Yellow crazy ant (*Anoplolepis gracilipes*) is the dominant species on 70 % of the bait placed in oil palm plantations in Sabah, Malaysia.

Table-2. Ten most commonly found insect families in Oil Palm Plantations in North Sumatera.

No.	Family	I	II	III	IV	V	Total
1	Curculionidae	63	190	1	552	2381	3187
2	Formicidae	177	655	107	158	102	1199
3	Blattidae	26	23	94	8	9	160
4	Blatellidae	8	20	29	9	7	73
5	Braconidae	6	38	6	17	1	68
6	Tipulidae	15	32	3	8	2	60
7	Dolichopodidae	1	23	5	4	-	33
8	Reduviidae	6	2	-	7	8	23
9	Anthicidae	2	19	-	1	1	23
10	Stratiomyidae	4	11	-	5	2	22
	Total	308	1013	245	769	2513	4848

Key: I: Bukit Sentang - : not found
II: Padang Mandarsah
III: Ajamu
IV: Sijambu-jambu
V: Aek Pancur

Variety Index (H') and Evenness Index (E) for Vascular Epiphytes and Canopy Insects Epifit Vaskular dan Serangga Kanopi in Oil Palm Plantations in North Sumatera

According to Michael (1995), values for insect diversity can be classified into three categories; that is if H' < 1 diversity of insects is low meaning populations of pest insects and their natural enemies are not in balance resulting in possible destruction of plants, if H' 1-3 the diversity is moderate. This is a better situation where the populations of pests and natural enemies is almost in balance. If H' > 3 insect diversity is high and there is a balance between the pests and their natural enemies eliminating the need for external efforts to kill insect pests.

Table-3. Diversity Index (H') and species evenness Index (E) for vascular epiphytes and canopy insects in five oil palm in North Sumatera.

Site	Vascular Epiphytes		Canopy insect	
	H'	E	H'	E
Bukit Sentang	1,16	0,42	2,39	0,61
Pd. Mandarsah	2,00	0,66	2,05	0,48
Ajamu	1,78	0,62	2,43	0,64
Sijambu-jambu	2,19	0,58	1,64	0,4
Aek Pancur	1,46	0,44	0,42	0,12

The diversity Index for vascular epiphytes ranges between 2.19 and 1.16 so fitting the moderate category. The highest diversity is at Sijambu-jambu and the lowest at Bukit Sentang. The diversity Index for insects at the five

study locations ranges between 2, 43 and 0, 42 so fitting the low or moderate categories. The highest diversity is at Sijambu-jambu Ajamu and the lowest at Aek Pancur (Table-2). The ecosystem at is Sijambu-jambu almost in balance while at Aek Pancur it is unbalanced. This is due to the fact that at Aek Pancur pests are often controlled using pesticide sprays that probably not only kill the pest insects but also other more helpful insects. As Untung (1993) states that the use of non selective pesticides can reduce the number of natural preditors of pests, beneficial insects and untargeted creatures resulting in a lost of species diversity of the ecosystem and hence its stability.

At no location was the insect canopy diversity index high. Natural forest however usually does have a high diversity index (Pelawi, 2009). This difference in diversity may be related to the diversity of epiphytes in oil palm plantations Table-2). The difference in vegetation structure and floristic diversity between a natural forest and an oil palm plantation will result in a different canopy insect population. The vegetation structure and floristic diversity of a natural forest is complex supporting a high diversity of insects. This is emphasized by Haddad *et al*. (2011) and Mulder *et al*. (1999), who state that a large diversity of plants influences the diversity of the insect population.

Unlike natural forest, oil palm plantation vegative structure is monocultural consisting of only one type of plant to host epiphytes. Also, the way the plants are cultivated results in simultaneous planting in particular years and periodic management of the growth of danau pelepah (Sulistyo *et al.,* 2010). This is thought to have a relationship to the low value of the *Shannon-Wiener* diversity index for vascular epiphytes and canopy insects in all the oil palm plantations studied. According to Fitzherbert *et al.* (2008) oil palm plantations support fewer species compared to forest or other cultivated plants and this is considered to influence the stability of the diversity of life in the ecosystem.

In a natural ecosystem all living things exist in balance and the population of each species is controled by others so no variety can become a pest. A natural ecosysten has a large diversity of species meaning each part of the habitat has a similar range of flora and fauna. The level of diversity influences the occurance of pest problems. Cultivation systems with high diversity influences pest species population numbers (Oka, 1995).

The contribution of vascular epiphytes to the canopy insect diversity

There is a great variety of epiphyte types (Benzing 1990), their existence adds to the complexity of the tree canopy structure, increases the food (available for insects?) and is a source of energy. Hence they have the potiential to diversify various micro habitats for tree canopy arthropods (Chan 2003, Cruz-Ang'on & Greenberg 2005 Cruz-Ang'on *et al*. 2008). Analysis of the possible influence of epiphytes on the canopy arthropods can be conducted at the level of individual epiphytes or over the entire tree canopy. In line with the objectives of this research analysis was conducted over the entire tree canopy.

Generally, the structure of the vegetation and high diversity of plants is thought to support a large variety of insects. Epiphytes consist of a group of plants that are very varied, increase the complexity of the structure of the tree canopy, increase the food (available for insects?) and are a source of energy.

To discover the degree of contribution vascular epiphytes have on the diversity of oil palm plantation canopy insects an epifit was conducted with several common plantation management practices. Some farmers completely eliminate epiphytes from trees with herbicide sprays, others cut down epiphytes only if they appear to be interfering with the health of the trees and a third group let the epiphytes grow undisturbed.

The result of ANOVA analysis indicates that the way epiphytes are managed has a very real impact on the number and diversity of the canopy insect population in oil palm plantations. Further testing using DNMRT at the 5% level resulted in the values tabulated in Table-4.

Table-4. The effect of Epiphytes on the total number of species of insects and the total number of individuals in the canopy insect population in oil palm plantations in North Sumatera.

Treatment	Species	Individuals
Epiphytes undisturbed	26.00^{b}	113.80^{b}
Half Epiphytes removed	18.40^{ab}	48.80^{a}
All Epiphytes removed	13.20^{a}	46.60^{a}

The number a line of followed letters that the same not significant at level 5% DNMRT

Where the epiphytes are left undisturbed the number and variety of canopy insects is greater than when all are removed. However leaving half the epiphytes on the trees does not appear to result in a significantly larger number and variety of canopy insects compared to removing all the epiphytes (Table-4). This result is in line with a previous study (Cruz-ang, 2009) where plantations that left epiphytes undisturbed had a higher and more varied population of insects compared to plantations where epiphytes were removed.

Leaving vascular on oil palms is one way to improve the biodiversity of oil palm plantations. Meijaard dan Sheil (2013) suggest increasing the opportunity for the growth of Leaving vascular on oil palms is one way to improve the biodiversity of oil palm plantations. Meijaard dan Sheil (2013) suggest increasing the opportunity for the growth of epiphyte ferns as a strategy to increase oil palm plantation biodiversity. The greater the diversity of life in an ecosystem the more balanced it will be and the easier to prevent pest outbreaks. Increasing biodiversity and reducing the loss of canopy insect species by retaining naturally growing vegetation in plantations is also

recommended by Lucey *et al.* (2014) as a way of improving long term palm oil production.

CONCLUSIONS

The dominant vascular epiphytes present in oil palm plantations in the five North Sumateran locations studied are *Nephrolepis biserrata*, *Goniophlebium verrucosum, Elaeis guineensis, Asystasia gangetica* and *Vittaria elongata.* The dominant canopy insect species are from the families Curculionidae (*Elaiodobius camerunicus*), Formicidae (*Anoplolepis gracillipes*), Blattidae, Blatellidae dan Braconidae. In these oil palm plantations, the diversity index for vascular epiphytes present shows a moderate level of diversity and a low to moderate level of diversity for canopy insects. The existence of vascular epiphytes has a significant effect on the variety and number of canopy insects. Plantations with a high diversity of epiphytes provide a greater number and variety of habitats and food sources for canopy insects. This condition enables a greater degree of ecological balance in the plantation so reducing pest infestation.

Based on the result of this research it is suggested that the management of oil palm plantations avoid the removal of epiphytes from trees unless they are clearly interfering with production. If there are problem species such as *Ficus ssp.* or others like *Eleuis guineensis* that have the potential to become parasitic should they be cut off or removed manually. Use of herbicides should be avoided because they will kill beneficial epiphytes that support the diversity of the palm oil plantation.

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Appendix 1. Species of vascular epiphytes in oil palm plantations in North Sumatera.

No. No.	Species of epiphytes	Individual					Total
		I	II	III	IV	V	
1	*Adiantum sp.*	-	-	-	7	-	7
2	*Alocasia macrorrhiza*	-	-	7	-	5	12
3	*Amphineuron opulentum*	18	-	-	4	2	24
4	*Asplenium nidus*	-	-	-	1	-	1
5	*Asplenium salignum*	-	-	36	-	-	36
6	*Asplenium* sp.	99	96	21	22	-	238
7	*Asystasia intrusa*	84	305	16	51	55	511
8	*Baccaurea sp.*	-	-	-	1	-	1
9	*Borreria articularis*	-	-	-	4	-	4
10	*Borreria setidens*	-	-	-	-	50	50
11	*Botrychium daucifolium*	-	-	-	1	-	1
12	*Bouea macrophylla*	-	-	-	2	-	2
13	*Christella dentate*	-	-	-	-	7	7
14	*Cleome rutidosperma*	-	1	1	-	6	8
15	*Clidemia hirta*	66	-	4	71	79	220
16	*Cofea robusta*	-	-	-	9	-	9
17	*Commelina nudiflora*	-	-	-	1	1	2
18	*Coryphopteris sp.*	-	2	-	-	-	2
19	*Crypsinus trilobus*	-	10	-	19	-	29
20	*D. piloselloides*	-	-	-	4	-	4
21	*Davalia divaricata*	24	75	81	34	51	265
22	*D. trichomanoides*	-	23	-	-	-	23
23	*Diplazium* sp1.	9	-	42	-	3	54
24	*Diplazium sp2.*	-	-	-	-	2	2
25	*Elaeis guineensis*	447	146	73	59	43	768
26	*Ficus benjamina*	-	-	-	1	-	1
27	*Ficus depresa*	-	-	-	2	-	2
28	*Ficus elastic*	-	-	-	4	-	4
29	*Ficus parietalis*	-	-	2	-	-	2
30	*Ficus recurva*	-	-	-	1	-	1
31	*Ficus sp.*	-	-	-	-	1	1
32	*G. integrifolium*	-	-	-	1	-	1
33	*G. verrucosum*	501	64	246	44	511	1366
34	*Glochidion superbum*	-	-	-	10	-	10
35	*Gynura ovalis*	-	-	-	1	-	1
36	*Hedyotis congesta*	-	-	-	1	-	1
37	*Hedyotis costata*	-	-	-	3	-	3

38	*Hibiscus tiliaceus*	-	-	-	4	-	4
39	*Homalomena rubra*	-	-	-	-	1	1
40	*Hoya sp.*	-	-	2	-	-	2
41	*Ischaemum muticum*	-	-	-	52	-	52
42	*Laportea interrupta*	-	-	-	-	4	4
43	*Loxograme avenia*	-	6	-	-	-	6
44	*M. malabathricum*	-	1	-	4	-	5
45	*Macaranga tanarius*	-	-	-	1	-	1
46	*Mallotus paniculatus*	-	-	-	3	-	3
47	*Melothria heterophyla*	-	4	3	1	-	8
48	*Microsorum sp.*	-	2	-	-	-	2
49	*Mikania micrantha*	-	3	-	3	-	6
50	*Mimosa pudica*	18	-	-	-	-	18
51	*Nephrolepis biserrata*	2868	312	537	520	1566	5803
52	*Nephrolepis sp.*	-	-	-	-	28	28
53	*Ophioglossum pendulum*	-	-	-	1	-	1
54	*Paspalum conjugatum*	-	2	-	-	-	2
55	*Peperomia pellucid*	48	2	12	121	8	191
56	*Phillantus niruri*	-	-	-	-	2	2
57	*Piper betle*	-	-	1	-	-	1
58	*piper crocatum*	3	2	-	2	-	7
59	*Piper sp.*	3	-	-	-	-	3
60	*Rhinacantus nasurus*	15	-	-	40	-	53
61	*Rubus molucannus*	-	-	-	1	-	1
62	*S. calyptrate*	-	-	2	-	-	2
63	*Solanum blumei*	-	-	-	3	6	9
64	*Solanum trilobatum*	-	-	-	2	11	13
65	*Tectaria barberii*	-	-	-	-	3	3
66	*Theobroma cacao*	-	-	-	5	-	5
67	*Thunbergia sp*	-	8	-	-	6	14
68	*Trichomanes sp.*	-	-	-	1	-	1
69	*Vittaria elongate*	-	50	157	8	173	388
70	*Vittaria ensiformis*	-	12	-	-	22	34
	Total of individuals	4203	1126	1243	1130	2646	10346
	Total of species	14	21	18	44	26	

Key: I : Bukit Sentang
II : Pd. Mandarsah
III: Ajamu
IV: Sijambu-jambu
V : Aek Pancur

Appendix 2. Diversity of canopy insects in oil palm plantations in North Sumatera.

No.	Order	No	Family	I	II	III	IV	V	Total
1	**Blattodea**	1	Blattidae	26	23	94	8	9	160
		2	Blatellidae	8	20	29	9	7	73
		3	Blaberidae		1	3			4
2	**Coleoptera**	4	Aderidae	3		1	2	1	7
		5	Allecullidae			1			1
		6	Anobiidae					1	1
		7	Anthicidae	2	19		1	1	23
		8	Anthribidae	7		1	2	4	14
		9	Bothrideridae		1				1
		10	Carabidae	9	2		3		14
		11	Chrysomelidae	8	3	7	3		21
		12	Cleridae	1		2	2		5
		13	Coccinelidae	3	5		5	5	18
		14	Cryptophagidae	1		1			2
		15	Cucujidae			1			1
		16	Curculionidae	63	190	1	552	2381	3187
		17	Elateridae	-	1				1
		18	Endomycidae		2				2
		19	Eucnemidae		2				2
		20	Erotylidae	1		1	1	2	5
		21	Histeridae	-		1			1
		22	Lagriidae		1				1
		23	Lampyridae	1		5	1		7
		24	Lycidae	3	1	4	2		10
		25	Lyctidae		1	1			2
		26	Melandryidae		3		1		4
		27	Meloidae				1		1
		28	Mordellidae					1	1
		29	Scirtidae		1				1
		30	Staphylinidae		10				10
		31	Tenebrionidae	5		3	2	9	19
3	**Diptera**	32	Aximiidae				1		1
		33	Celyphidae	3	3	1			7
		34	Ceratopogonidae		3				3
		35	Chamaemyiidae	1	1		1	1	4
		36	Chironomidae	3	7	9			19
		37	Chloropidae	1	2	3	8		14
		38	Conopidae			1			1
		39	Culicidae					1	1

		40	Dolichopodidae	1	23	5	4		33
		41	Drosophilidae	1	1				2
		42	Empididae		1	1			2
		43	Ephydridae		8	3	7	1	19
		44	Heleomyzidae				1		1
		45	Hilarimorphidae		1		1		2
		46	Lauxaniidae	2	5	4	2	1	14
		47	Lonchaeidae		1				1
		48	Micropezidae	7	1	3	1	1	13
		49	Milichiidae	1	1	6	1		9
		50	Muscidae	2			1	1	4
		51	Mycetophilidae	-	1	2	3		6
		52	Neriidae	2		8	2	1	13
		53	Phoridae		1				1
		54	Ottidae	1		3			4
		55	Platystomatidae	-			1		1
		56	Pipunculidae	1		2	1		4
		57	Sciaridae	1	4	3	2	2	12
		58	Sciomyzidae	-			1		1
		59	Sepsidae	1		1	1		3
		60	Stratiomyidae	4	11		5	2	22
		61	Strongylophthalmydae		1				1
		62	Syrphidae		1			1	2
		63	Tipulidae	15	32	3	8	2	60
4	**Entomobryomorpha**	64	Entomobryidae		1				1
5	**Hemiptera**	65	Aphrophoridae	3			1		4
		66	Alydidae			2	1		3
		67	Anthocoridae	-			1		1
		68	Cicadellidae	1			2	2	5
		69	Colobathristidae		1		1		2
		70	Derbidae	1	1			2	4
		71	Diapridae				1		1
		72	Idiostolidae		1				1
		73	Lygaeidae	1	5				6
		74	Miridae	-	5		1		6
		75	Reduviidae	6	2		7	8	23
6	**Hymenoptera**	76	Braconidae	6	38	6	17	1	68
		77	Chalcididae	2	13	2	1		18
		78	Encyrtidae	-	5	1	3		9
		79	Eulophidae	2	8	1	4	1	16
		80	Evaniidae		1		2		3
		81	Figitidae				2		2

		82	Formicidae	177	655	107	158	102	1199
		83	Ichneumonidae	4	9	3	16	1	33
		84	Pompilidae					1	1
		85	Pteromatilidae					2	2
		86	Scelionidae	-	6	1	1		8
		87	Sphecidae					1	1
		88	Trichogrammatidae		2				2
7	**Lepidoptera**	89	Hesperidae		1				1
		90	Lycaenidae	1			2	2	4
		91	Oecophoridae	-	3				3
		92	Blastobasinae	1					1
		93	Gelechiidae	1					1
		94	Pyralidae	3					3
8	**Mantodea**	95	Mantidae		1		5	2	8
9	**Neuroptera**	96	Ithonidae		2				2
		97	Myrmeleontidae		1				1
10	**Orthoptera**	98	Acrididae	-	6				6
		99	Gryllidae	2	19	2	5	3	31
		100	Pyrgomorphidae		1				1
		101	Rhaphidophoridae		1				1
		102	Tettigonidae		2				2
		103	Tetrigidae	1	22	2	2	5	32
		104	Tridactilidae		3		1	1	5
11	**Psocoptera**	105	Myopsocidae	-	2	1	5		8
		106	Psocidae	2	1				3
12	**Thysanoptera**	107	Phlaeothripidae	4					4
	Total individual			406	1213	342	886	2569	5416
	Total family			51	69	45	59	37	

Key: I: Bukit Sentang
II: Padang Mandarsah
III: Ajamu
IV: Sijambu-jambu
V: Aek Pancur

Appendix 3. Canopy insect population after different treatments of oil palm epiphytes in North Sumatera.

No.	Genus of insect	A1			A2			A3			A4			A5		
		B1	B2	B3	B1	B2	B3	B1	B2	B3	B1	B2	B3	B1	B2	B3
1	**Aranea**															
	Aranea sp. 1	8	-	7	-	-	3	2	5	-	3	2	-	5	3	6
	Aranea sp.2	2	-	8	-	-	1	7	2	2	-	-	-	4	-	9
	Aranea sp.3	6	5	8	3	3	2	6	-	-	-	-	-	-	4	8
2	**Blattodea**															
	Blaberidae sp.1	-	-	-	1	2	-	5	1	1	1	-	-	6	1	2
	Blatellidae sp.1	-	1	-	-	-	-	1	3	2	1	-	-	1	1	-
	Periplaneta australasiae	-	-	-	-	-	-	-	-	-	-	1	-	2	1	-
	Phyllodromia anceps	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-
	Blattidae	-	-	-	-	-	-	5	3	1	1	-	-	-	-	1
	Blatta lateralis	1	-	-	1	-	-	7	3	-	-	-	-	-	-	-
	Blatella germanica	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-
3	**Coleoptera**															
	Amarygmus sp.1	-	-	-	-	-	-	-	-	-	3	1	-	2	-	-
	Amarygmus sp.2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	E. kamerunicus	-	1	1	19	23	-	-	-	-	1	1	2	65	6	4
	Leptotrichalus sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
	Tritomidea sp.	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-
	Tillus sp.	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-
	Elateridae sp.1	-	-	-	-	-	-	1	-	-	-	-	-	2	-	1
	Luciola sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
	Platymetopus sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
	Colaspoides	-	-	-	-	-	-	6	1	-	-	1	1	-	-	-
	Illis sp.	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-
	Monolepta	-	-	-	3	-	-	-	1	-	-	-	-	-	-	-
	Aulocophora	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cautires sp.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	Saula nigripes	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	Abacetus sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Chrysomelidae sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Scirtidae sp.	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
	Alecullidae sp.	-	-	-	1	-	-	-	-	-	1	1	-	-	-	-
	Coccinela repanda	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	Scymnus frontalis	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
4	**Dermaptera**															
	Dermaptera sp.1	-	-	-	9	1	-	-	-	1	-	-	-	4	7	3
	Dermaptera sp.2	-	-	-	5	-	2	-	-	-	-	-	-	1	12	
	Dermaptera sp.3	-	-	-	8	-	-	2	-	-	3	-	1	3	9	6

	Dermaptera sp.4	-	-	-	7	-	-	-	-	-	-	-	-	-	6	7
	Dermaptera sp.5	-	-	-	-	-	-	-	-	-	-	-	-	9	8	-
5	**Diptera**															
	Limonia immatura	-	-	-	-	-	-	-	-	-	2	-	-	1	2	2
	Dieuryneura stigma	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
	Limonia triocellata	-	-	-	-	-	-	-	-	-	2	-	-	1	2	1
	Nemotelus canadensis	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-
	Limonia whartonii	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-
	Ptecticus trivittatus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
	Trisapromyza vittigera	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
	Hermetia illucens	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
	Glyphidops flavifrons	3	-	3	1	2	-	1	4	-	-	-	-	-	-	-
	Microchrysa polita	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rhodesiella sp.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	Leucopis pinicola	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Decachaetophora aenipes	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
	Hexatoma longicornis	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Physiphora clausa	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Lycoriella sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Pelina truncatula	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-
	Homoneura sp.	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-
	Leptometopa sp.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
	Leptocera sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	Homoneura bispina	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
	Phoridae sp.1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
6	**Hemiptera**															
	Canthecona sp.	1	-	-	-	-	1	-	-	-	-	-	-	1	-	-
	Salduda sp.	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
	Empicoris sp.	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
	Velinus nigrigerius	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Physoderes sp.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Myiophanes sp.	1	1	-	-	-	-	-	-	-	1	-	-	-	-	-
	Deraeocoris sp.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	Polymerus sp.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	Leptocorisa sp.	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-
	Zoraida sp.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	Anthocoris sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
7	**Hymenoptera**															
	Oecophylla smaragdina	4	-	3	1	-	-	-	-	-	-	1	-	1	1	1
	Anoplolepis gracillipes	102	30	-	60	6	68	3	-	10	-	-	-	41	1	-
	Camponotus sp.	-	-	-	1	-	-	7	5	-	5	4	-	2	-	7

	Polyrhachis sp.	-	-	-	-	3	-	-	1	2	-	-	-	3	-	-
	Ascogaster sp.	-	-	-	-	1	-	-	-	-	-	1	-	2	-	-
	Phanerotoma sp.	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
	Orgilus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Hypoponera sp.1	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-
	Hypoponera sp.2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
	Iridomyrmex sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Monomorium sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
	Spathius sp.	-	-	-	1	-	1	1	-	-	-	-	-	-	1	-
	Pachycondyla sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-
	Goryphus sp.	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-
	Nylanderia sp.1	-	-	-	1	-	-	1	-	-	1	-	-	-	-	-
	Cardiocondyla sp.	-	-	-	-	2	-	3	-	-	-	-	-	-	-	-
	Solenopsis sp.	-	-	-	4	-	-	-	-	1	-	-	-	-	-	-
	Theronia sp.	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-
	Leptogenys sp.2	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-
	Tetramorium sp.1	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-
	Tetramorium sp.2	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-
	Tetramorium sp.3	-	-	-	2	-	-	-	-	-	9	-	4	-	-	-
	Odontomachus sp.1	-	-	1	-	2	-	-	-	-	1	2	1	-	-	-
	Nipponochalcidia sp.	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	Aphytis sp.	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-
	Eumenes sp.	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	Pheidole sp.	-	-	-	2	3	-	-	-	-	2	-	-	-	-	-
	Euplectrus sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Tamarixia sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Anastatus sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Apanteles sp.	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-
	Crematogaster sp.	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-
	Gavrana sp.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
	Dolichoderus sp.	-	-	-	1	-	-	-	-	-	1	-	2	-	-	-
	Technomyrmex sp.1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
	Technomyrmex sp.2	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
	Odontoponera sp.	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-
	Paratrechina longicornis	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
8	**Isopoda**															
	Isopoda sp.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
9	**Lepidoptera**															
	Lycaenidae sp.1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
	Oecophoridae sp.1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
10	**Mantodea**															

	Tenodera sp.	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
	Odotomantis sp.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Amantis sp.	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
11	**Orthoptera**															
	Tetrix sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
	Tridactylidae sp.1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
	Systolederus affinis	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
	Nisitrus hyalinus	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	Neotettix sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
12	**Psocoptera**															
	Myopsocus sp.	1	-	1	-	-	-	1	-	-	-	-	-	3	-	-
13	**Thysanoptera**															
	Haplothrips sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Total number of individuals	137	43	36	144	65	83	63	32	24	53	25	19	172	79	71
	Total genus	17	10	12	30	26	12	20	14	11	30	18	13	33	24	18

Key: A1: Bukit Sentang
A2: Padang Mandarsah
A3: Ajamu
A4: Sijambu-jambu
A5: Aek Pancur

B1: Epiphytes undisturbed
B2: Half epiphytes removed
B3: Total removal of epiphytes