UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL: DIVERSITY & FAUNAL COMPOSITION OF SOIL INVERTEBRATES ~~IN~~ TREATED WITH CHEMICAL, BIOORGANIC, BIOCHEMICAL AND MYCORRHIZA PLUS CHEMICAL FERTILIZERS AT SEKONG OIL PALM PLANTATION

IJAZAH: DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

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DIVERSITY AND FAUNAL COMPOSITION OF SOIL INVERTEBRATES TREATED WITH CHEMICAL, BIOORGANIC, BIOCHEMICAL AND MYCORRHIZA PLUS CHEMICAL FERTILIZERS AT SEKONG OIL PALM PLANTATION

SANTHIYA A/P ARUMUGAM

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

CROP PRODUCTION PROGRAMME
FACULTY OF SUSTAINABLE AGRICULTURE
UNIVERSITY MALAYSIA SABAH

2015

DECLARATION

I hereby declare that this dissertation is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that no part of this dissertation has been previously or concurrently submitted for a degree at this or any other university.

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ACKNOWLEDGEMENT

First of all, I am very grateful to God Almighty for His graces and blessings as without that, this would not have been possible. I would like to take an opportunity to express my sincere thanks to my supervisor, Dr. Suzan Benedick @ Sarah Abdullah who suggested me a good study opportunity to be studied and worked as desired. The knowledge was shared with patience even at peak time. The supportive character of my supervisor provides a good pathway for my success.

Besides that, I would like to thank my parents, Mr. Arumugam Suppiah and Mrs. Mageswary Savarimuthu who stand as supportive person that initiates my studies from beginning. Without their presence, I will be lost in my education. The morale supports and values that taught by my parents brought me up to success path. I also would like to thank my brother and sister-in-law for their support and encouragement as well throughout this paper dissertation.

Furthermore, I would like to thank my friends and the respective authorities that were responsible in my study. Finally, I would like to thank all individuals that involved along my project journey. Appreciation goes to all the hard work.

Thank you.

ABSTRACT

This research was conducted in Sekong Estate Sabah located in Kinabatangan to study the diversity and faunal composition of soil invertebrates in the soil treated with chemical, bioorganic, biochemical, mycorrhiza plus chemical fertilizers. The objectives of this study were to compare the diversity and faunal composition of soil invertebrates, to identify the soil invertebrates occurring in oil palm plantation and to compare the faunal composition of the beneficial and non-beneficial soil invertebrates in the different treatments; chemical, bioorganic, biochemical and mycorrhiza plus chemical fertilizers. Sampling was done three times in the month of March, April and May. The identification of soil invertebrates was done in the laboratory. The samples were placed in Berlese - Tullgren funnels and 75% of ethanol was used as solvent. Each treatment has four replicates. The soil invertebrates were operated for five days. The experimental design was Randomized Complete Blocked Design (RCBD) which was used for soil sampling. Due to insufficient data, visual inspection was made based on the result obtained from species-diversity indices. The alpha diversity indices (Shannon-Weiner, Margalef, Simpson) show that bioorganic treatment had the highest species diversity, richness and evenness compared to chemical, biochemical, mycorrhiza plus chemical and control. In term of abundance of beneficial and non-beneficial soil invertebrates, there were no significant difference in treatments of chemical, bioorganic, mycorrhiza plus chemical and control (Mann-Whitney U Test; $p>0.05$). However, there is a significant difference between beneficial and non-beneficial soil invertebrates in biochemical treatment (Mann-Whitney U Test; $p<0.05$). Fewer studies have been conducted on the effect of different types of fertilizers to abundance of soil fauna and the role of beneficial and non-beneficial soil invertebrates to oil palm plantation. Through this study, it can be concluded that bioorganic fertilizer could provide more benefit to oil palm plantation compared to other treatments because it supports the soil ecosystem as it provides the suitable conditions for soil invertebrates to survive. Thus, the diversity and faunal composition of soil invertebrates can be enhanced as the ecosystem is well-protected.

DIVERSITI DAN KOMPOSISI FAUNA INVERTEBRAT TANAH DI TANAH YANG DIRAWAT DENGAN BAJA KIMIA, BIOORGANIK, BIOKIMIA DAN MIKORIZA DENGAN CAMPURAN KIMIA DI LADANG KELAPA SAWIT SEKONG

ABSTRAK

Satu kajian telah dijalankan di Ladang Sekong Sabah yang terletak di Kinabatangan untuk mengkaji diversiti and komposisi fauna invertebrat tanah di tanah yang dikaji dengan baja kimia, bioorganik, biokimia dan mikoriza campuran kimia. Objektif kajian ini adalah untuk mengkaji kelimpahan invertebrat tanah di dalam rawatan yang berbeza, untuk mengenalpasti jenis invertebrat tanah yang terdapat dalam rawatan tersebut dan mengkaji kelimpahan invertebrat tanah yang berfaedah dan tidak berfaedah di dalam rawatan yang berbeza; baja kimia, bioorganik, biokimia dan mikoriza campuran kimia. Pensampelan tanah telah dilakukan sebanyak tiga kali iaitu dalam bulan Mac, April dan Mei. Identifikasi invertebrat tanah telah dilakukan di dalam makmal. Sampel tanah tersebut diletakkan di dalam corong Berlese- Tullgren dan 75% etanol telah digunakan sebagai pelarut. Setiap rawatan mempunyai empat replikasi. Kajian invertebrat tanah dilakukan selama lima hari. Reka bentuk eksperimen yang digunakan adalah Randomized Complete Blocked Design (RCBD) untuk pensamplean tanah. Oleh sebab kekurangan data, perbandingan dilakukan secara pemerhatian visual dengan menggunakan keputusan daripada indeks spesies-diversiti. Indeks alfa diversiti (Shannon-Weiner, Margalef, Simpson) menunjukkan bahawa rawatan bioorganik mempunyai diversiti species, kelimpahan dan kepadatan yang paling tinggi berbanding rawatan baja kimia, biokimia dan mikoriza campuran kimia dan kawalan. Tiada perbezaan signifikan dalam kelimpahan invertebrate tanah berfaedah dan tidak berfaedah dalam rawatan kimia, bioorganik, mikoriza campuran kimia dan kawalan ($p>0.05$). Walau bagaimanapun, terdapat perbezaan signifikan dalam rawatan biokimia ($p<0.05$). Kurang kajian yang dilakukan untuk mengkaji kesan rawatan yang berbeza terhadap kelimpahan invertebrat tanah dan peranan invertebrat tanah yang berfaedah dan tidak berfaedah kepada ladang kelapa sawit. Dalam kajian ini, baja bioorganik memberi banyak kebaikan dalam ladang kelapa sawit berbanding rawatan yang lain kerana membantu ekosistem tanah dengan memberi keadaan yang sesuai untuk invertebrate tanah untuk hidup. Oleh sebab itu, diversiti dan kelimpahan invertebrat tanah dapat ditingkatkan kerana ekosistem terjaga.

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%	Percent
ANOVA	Analysis of Variance
CPO	Crude Palm Oil
°C	Degree celcius
EFB	Empty Fruit Bunch
FFB	Fresh Fruit Bunch
LSM BP	Living Soil Microbes Best Practice
NEP	Normal Estate Practice
OPF	Oil Palm Frond
OPT	Oil Palm Trunk
PKC	Palm Kernel Cake
PKO	Palm Kernel Oil
PKS	Palm Kernel Shell
POME	Palm Oil Mill Effluent

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Malaysia is the world's second largest oil palm producer after Indonesia. To date, the yield production from good commercial plantings are about 30 tonnes fresh fruit bunch (FFB) per hectare with five to six tonnes oil (MPOB, 2014). One hectare of oil palm plantation is able to produce up to twelve times more oil than other leading oilseed crops. In Malaysia, oil palm plantations make up 71% of agricultural land or 14.3% of total land area. The most efficient producers may achieve yields as high as eight tonnes of oil per hectare (Basiron and Weng, 2004). According to statistics obtained from Sime Darby, the average yield of oil palm is 4.1 tonnes per hectare per year.

The oil palm needs huge amount of nutrients to maintain its growth and yield so that level of high production can be obtained due to the low soil fertility in nearly all Malaysian soils. High fertilizer rates are also important to avoid soil nutrient in balance and to make sure that adequate nutrients are available in the soil (Ng *et al.*, 2011). Oil palm plantations have low nutrient and high toxicity as they contain aluminium and iron in the soil. It then leads to biotic and abiotic stresses (Wickasono and Buana, 2012). Excessive agricultural practices affect the biodiversity and soil condition. The diversity of soil organism faces deleterious effect when physical disturbance of soil such as tillage take place (Mikula *et al.*, 2010). Thus, this study shows the effect of different types of fertilizers application to the abundance of soil invertebrates in the soil.

The palm oil industry contributes to the economy of agricultural sector in Malaysia. This industry provides direct employment for about 570000 people including both high-skilled and low-skilled labour (MPOC, 2011). The industry also offers a long-term and stable income source for its smallholders. The number of new jobs has been escalating to the Malaysian economy every year with the presence of research and innovation. This industry benefits our country by profitability through employment and development, downstream industries and tax receipts. It also provides income from exports.

Soil provides a wide diversity of ecosystem services which benefits human populations. For instance, soils mediate soil formation, nutrient cycling and primary production. In the ecosystem, soil invertebrates are enormously diverse (Lavelle *et al.*, 2006). Soil invertebrates act as decomposers, sustenance of soil physico-chemical properties, litter transformers, ecosystem engineers and nutrient cycling (Cock *et al.*, 2012). Soil invertebrates widely known to improve soil structure by reducing bulk density, enhance soil pore space and aeration, soil horizon mixing and drainage, improving soil aggregate structure, increase water holding capacity and litter decomposition. The loss of soil invertebrates can lead to extreme ecological effect. Soil organisms are believed to be essential in the soil ecosystem, especially in the decaying of soil organic matter and nutrient cycling (Wardle and Giller, 1997). Therefore, this study is done to identify the abundance and occurrence of types of soil invertebrates in the treated soil in the oil palm plantation.

Living soil microbes is a biological soil amendment which contains beneficial microorganisms. These microorganisms enhance the decomposition of crop residue and organic waste. They also help in suppressing soil-borne pathogens to stimulate growth of crop and regulate pH of soil. The presence of microbes makes nutrients available to the crop by breaking down the organic compounds through mineralization process (Ingham *et al.*, 1985). Bioorganic fertilizer is processed inoculated compost from any organic material such as animal manures that has undergone rapid decomposition. Biochemical fertilizer is a substance containing soil living microbes with the addition of chemicals such as Nitrogen, Potassium and Phosphorus. These fertilizers help in increasing yield and improve crops quality, improve soil structure and improve soil chemical properties. Although it has benefits to the crop production, there is also effect to the soil organisms underneath. However, less research is being carried out using living soil microbes in the fertilizers applied to soil. It is very little known about the benefit or impact of using them to the productivity of oil palm and soil invertebrates underneath. Thus, the interaction between living soil microbes and soil invertebrates in the oil palm plantation will be studied throughout this research.

The use of chemical fertilizers could increase the production of yield in a short period of time. However, the extensive use of this fertilizer leads to accumulation of toxic components, soil contamination and pollution (Lazcano *et al.*, 2012). According to Wilcove and Koh (2010), the amount of chemical fertilizers taken up by plants normally is only about 20-30%. The rest is lost through leaching and other losses, fixed in the soil and unavailable for plant uptake. It directly affects and reduces the abundance of soil organisms in the soil. MycoGold or mychorriza fertilizer is a substance which contains a mixture of several species of beneficial soil fungi, Arbuscular Mycorrhizal (AM) fungi isolated from different soil series. When the fertilizer is applied in the plantation, it is added together with chemical inputs such as Nitrogen, Potassium and Phosphorus. The application of this fertilizer generally increases nutrient and water uptake, provides resistance to soil borne disease and promotes higher yield. This fertilizer application usually reduces the requirement of chemical fertilizer. Thus, this study is conducted to identify the impact of adding chemical input during fertilizer application to abundance of soil organisms and growth of oil palm tree.

At the moment, the effect of agricultural practice on biodiversity is passionately discussed and arthropods are often used as bioindicators for estimating the consequence of landscape and management and soil quality (Paoletti, 1999). Soil invertebrates are obviously altering litter decomposition rates, soil aeration, nutrient mineralization, primary production and other ecosystem services linked to the soil ecosystem function and agroecological conservation (Six *et al.*, 2002). Interruption of the soil structure has a major effect on the capability of soil to obtain and store water, cycle carbon and other nutrients, assist plant growth and soil dwelling organisms (Neese, 2004). Hence, this study helps to identify the effect of application of different types of treatments or fertilizers; chemical, bioorganic, biochemical and mycorrhiza plus chemical to the abundance of soil invertebrates in the soil.

1.2 Justification

When the community of soil invertebrates is reduced, this eventually reduces the beneficial functions and services in the ecosystem. High inputs of chemical fertilizers and pesticides plus no or less input of organic fertilizer caused biomass to be burned. It leads to loss of soil invertebrates. Thus, this study of comparing the abundance of soil invertebrates between different treatments; chemical, bioorganic, biochemical and mycorrhiza plus chemical that had been applied in respective plots in the oil palm plantation is essential as a potential reduction in the oil palm cost and increase in crop yield. Besides that, studies on alpha diversity (species richness and evenness) and faunal composition including the identification of beneficial and non-beneficial soil invertebrates contribute to biodiversity of the oil palm. There were fewer studies conducted on identification of beneficial and non-beneficial soil invertebrates in the oil palm plantation and their roles towards growth and productivity of oil palm tree especially in term of yield production. There were also fewer studies conducted using fertilizers incorporated with living soil microbes; bioorganic and biochemical and their roles in enhancing the growth of tree and effect to soil invertebrates. Thus, the findings from this study can be utilized by oil palm companies to understand the pros and cons of using these different types of fertilizers. They will realize the long-term impacts of incorporating the chemical inputs in the plantation and the effect to the soil fauna abundance and yield production.

1.3 Objective

The objectives of this study were:

a) To compare the diversity and faunal composition of soil invertebrates in the different treatments; chemical, bioorganic, biochemical and mycorrhiza plus chemical fertilizers

b) To identify the soil invertebrates occurring in oil palm plantation treated with different treatments; chemical, bioorganic, biochemical and mycorrhiza plus chemical fertilizers

c) To compare the faunal composition of the beneficial and non-beneficial soil invertebrates in the different treatments; chemical, bioorganic, biochemical and mycorrhiza plus chemical fertilizers

1.4 Hypothesis

The hypotheses of this study were:

H_0:

i. There is no significant difference between the diversity and faunal composition of soil invertebrates in the different treatments; chemical, bioorganic, biochemical and mycorrhiza plus chemical fertilizers
ii. There is no significant difference between faunal composition of beneficial and non-beneficial soil invertebrates in the different treatments; chemical, bioorganic, biochemical and mycorrhiza plus chemical fertilizers

H_a:

i. There is a significant difference between the diversity and faunal composition of soil invertebrates in the different treatments; chemical, bioorganic, biochemical and mycorrhiza plus chemical fertilizers
ii. There is a significant difference between faunal composition of beneficial and non-beneficial soil invertebrates in the different treatments; chemical, bioorganic, biochemical and mycorrhiza plus chemical fertilizers

CHAPTER 2

LITERATURE REVIEW

2.1 Oil Palm Industry in Malaysia

The oil palm (*Elaeis guineensis*) is originated from the West African tropical rainforest and introduced into Bogor, Java as ornamental plants. There are about 2500 to 3000 fruits borne on 100 to 120 spikelets attached to a peduncle from the axil of a frond produced by female bunch. Two main products that are produced by the fruits are palm oil from the outer mesocarp and palm kernel oil from the kernel within the nut (Basiron and Chan, 2004). The mesocarp is made up of about 49% oil and about 50% kernel. The palm fruit is about the size of a small plum. The oil palm is declared as eco-friendly since it maintains its green canopy throughout its economic lifespan of 30 years and does not cause any environmental degradation such as soil erosion (Kalidas, 2012).

The oil palm is cultivated on tropical soils predominantly that belong mainly to the soil orders Ultisol, Oxisol and Inceptisol. On top of that, these soils are characterised as highly acidic and have low buffering capacities. Tenera hybrid is the oil palm that is currently being planted. This hybrid yields about 4 tonnes of palm oil per hectare, together with 0.5 tonnes of palm kernel oil and 0.6 tonnes of palm kernel cake. The economic life span of oil palm is about 25 years (Zwart, 2013). The harvesting of the palm can be done beginning 30 months after field planting.

In Malaysia, the total area covered by oil palm plantations is almost 5 million hectares (Zwart, 2013). The products produced from the plantations have been of prime interests which are CPO, PKO and PKC. These commodities are considered as traditional ingredient to make large scale of food variety, feed and non-food products. In the year 2011, Malaysia produced CPO about 18.91 million metric tons (Mmtons), 2.39 Mmtons for PKC and 2.15 Mmtons for PKO (Zwart, 2013). The production of CPO and PKO has been focused as the most important commercial products (Sharma, 2013). Other fractions of biomass such as PKS, EFB, OPF and OPT have many different applications. This ranges from fuel for the local palm mill boiler (PKS, EFB) to mulching and fertilizer agent (EFB, OPF, OPT) to the production of packaging and building materials (OPT, EFB and others).

Meanwhile, the soil conditions can be maintained by returning OPF and EFB to the plantations. Besides, PKS and EFB can be vital as a fuel for local and remote palm mills. Palm oil industry has the potential to utilize the oil palm biomass for the production of energy and chemicals. It can be a significant contribution to the economy of Malaysia and leads to a sustainable world with the potential market growth and value (Zwart, 2013).

2.2 Biodiversity and Tropical Ecosystem

Biodiversity is defined as the total genetic, morphological and functional diversity of all individual organisms that are the members of an ecological community or ecosystem (Mathews *et al.*, 2007). Tropical ecosystems are warm which ranges from 24°C to 31°C year-round as they are located near the equator. They receive at 2000 millimetres of rainfall annually. It covers less than 7% of the Earth's surface but estimated to contain about half of the plant and animal species on the planet. Therefore, the level of biodiversity may be higher in tropical rainforests ecosystems than any other place on Earth including temperate region. For instance, an average of 20 to 86 tree species exists per acre in a tropical rainforest. Meanwhile, in a temperate zone forest, there are about four tree species per acre. Arthropods fill many roles in the tropical rainforest ecosystem. They eat leaves and are eaten by other animals. They also break down leafy debris and recycle other animals' wastes. There could be as many as ten million arthropods species living in tropical rainforests around the world (Lowman *et al.*, 2003).

The diversity can be calculated with alpha diversity indices (Peet, 1974). Most diversity indices require an estimate of species importance. Alpha diversity is the diversity within-habitat or intracommunity that is the subject of the present contribution. The indices include Shannon-Wiener used for measuring species diversity, Margalef for measuring species richness and Simpson for species evenness. Shannon-Wiener is used as a measurement of each species present within a community while Margalef index is the measurement of the total number of different organisms present in a community. It does not take into account the proportion and distribution of each species within the local community. Simpson index expresses how evenly the individuals in a community are distributed among the different species (Magurran, 1988; Peet, 1974).

2.2.1 Oil Palm Plantation and Biodiversity

Elaeis guineensis is one of the most rapidly expanding and established crops in the tropics (Koh, 2008). In Malaysia, species are lost before even being discovered (Danielsen and Heegard, 1995). Oil palms are planted in the primary forest that have been modified by selective logging or cleared and replaced. Plantation of oil palm has no or little benefit in conserving biodiversity (Danielsen and Heegard, 1995). The stability of ecosystem functions increases with a wider range of species (Turner *et al.*, 2008). Thus, it is necessary to make oil palm plantations habitable to conserve Malaysian natural biota and persistence of the ecosystem functions. It is also to stop further expansion onto land with high biodiversity.

It is important for us to diversify our knowledge of biodiversity to understand the makeup of microorganisms and their roles in agro-ecosystems. Microorganisms are very sensitive to disturbance and may function as early indicators for quality changes which may lead to decline in biological, chemical and physical stability of ecosystems besides causing dramatically changes in global carbon cycling due to carbon loss from the environment (Elliott and Lynch, 1994).

The value of biodiversity of oil palm plantations is depleted as compared to natural forest, disturbed forest and other plantation crops. This is identified by the abundance of species present and difference in community composition. It indicates that there is fluctuation of species richness and changes in community composition. Invertebrates are involved in ecosystem functioning including nutrient cycling and pollination. Therefore, they are very important in biodiversity assessments. According to Fitzherbert *et al.* (2008), there are more variables for studies that focused on invertebrates than vertebrates in oil palm plantations as compared to primary forest. The number of beetle, ant and moth species is reported to be lower but high number of bee species in the oil palm plantations. However, there is no difference in the number of terrestrial isopods (Danielsen and Heegard, 1995).

Invasive species of invertebrate groups are highly successful in the habitat of oil palm and the population is escalating. For instance, the community of scarab beetle in Ghana is dominated by high densities of invasive savannah species (Danielsen and Heegard, 1995). It is also reported that the invasive Yellow crazy ant (*Anoplolepis gracilipes*) is the most dominant species which comprises about 70% of population within the oil palm plantations in Sabah (Danielsen and Heegard, 1995). The species richness of forest butterflies within oil palm plantations tend to be higher. Factors such as low-lying vegetation near natural forest and oil palm stand age influence the species richness of ground dwelling ants within oil palm monoculture. In order to control the invasive species and pest outbreaks in the natural habitats, the biodiversity within and around the oil palm plantation should be conserved for regulation and monitoring of inhabitants continue to function.

Besides that, severe insect pest outbreaks occur in oil palm like most monocultures which causes massive defoliation and reductions in yield. In order to avoid economic loss due to this problem, integrated pest management of non-chemical used method is used by establishing beneficial plants such as *Euphorbia heterophylla.* They attract the insect predators and parasitoids of oil palm pests such as the wasp, *Dolichogenidea metesae* (Koh, 2008). The biodiversity in the oil palm plantation is enhanced with the community of birds which prey on insects.

Insectivorous birds are vital pest control agents in the agriculture of oil palm. By the absence of these birds, it can cause about 28% of foliage damage over the life span of an oil palm leaf. A study reports that the insectivorous birds in the oil palm plantation such as *Centropus sinensis, Copsychus saularis, Orthotomus ruficeps* and

Pycnonotus goiavier prey on leaf eater pests such as *Setora nitens* and *Metisa plana* (Koh, 2008). These birds help to balance the ecosystem as well as the biodiversity. Local vegetation is modified by growing ground and epiphytic ferns to maintain insectivorous birds which show a positive effect on their diversity in the oil palm plantation. It eventually reduces the use of chemical inputs which can be harmful to the environment.

The primary factor for the lower biodiversity value of oil palm monocultures is the absence of forest vegetation components such as forest trees, lianas and epiphytic orchids. The population of birds is getting smaller in the oil palm plantation. It is important to maintain bird diversity within oil palm area as it helps in pest control of the insects responsible for leaf damage and fruit yield loss (Danielsen and Heegard, 1995).

Agricultural intensification has detrimental effects on biodiversity. It leads to an accelerating loss of biological diversity (Tidsskrift, 2006). There are many reasons for this loss. This includes increasing homogenization of agricultural systems, monocultures, agrochemicals use and excessive soil disturbance caused by continuous tillage. Soil biological communities are very responsive to land-use practices that directly modify the availability of trophic resources for soil organisms and hence affect the functions performed in the soil (Swift *et al.*, 1996). Sustainable management practices can reduce the negative impacts on soil invertebrates with beneficial functions and maximize the positive effects in agricultural lands.

Direct management practices of soil invertebrate activities involve intervening in the production system in an attempt to alter the abundance or activity of specific groups of organisms. Examples of direct interventions include inoculation of seeds or roots with rhizobia, mycorrhizae, fungi and rhizobacteria to enhance soil fertility and inoculation of soil or the environment with biological control agents, antagonists or beneficial fauna. It is possible to initiate synergisms that subsidize ecological processes such as the activation of soil biology, the recycling of nutrients and the enhancement of beneficial arthropods. These are done by assembling functional biodiversity which are important in determining the sustainability of ecosystems (Altieri, 1995; Gliessman, 1999). In order to conserve the oil palm biodiversity, the preservation of natural habitats is important. It should be integrated into the development of better and improved management practices in the oil palm agriculture (Koh, 2008).

2.2.2 Biodiversity of Invertebrates

According to Ananthakrishnan (2010), the definition of biodiversity can be as the variety of life on earth at all its levels which are from genes to ecosystems and the ecological and evolutionary processes that sustain it. The most diverse group of organisms on earth is insects and related arthropods. They make up more than 95% of animal diversity globally and considered as an important component of biodiversity (Neher, 1999; Giller, 1996).

The estimation of total global biodiversity is about 80 million species. Invertebrates represent most of these while most invertebrates are arthropods and most arthropods are terrestrial insects (Giller, 1996). Soil microbial community contributes to diversity of insects through plant diversity. Insect diversity is also play a role in contributing to diversity of plant. This is because the abundance and richness of plant species can be strongly influenced by insects during insect outbreaks. It eventually limits the fitness and abundance of certain plant species (Bennett, 2010). Additionally, the composition of the soil community can be changed by the presence of a particular plant as organisms that have high relative growth rates on that species of plant increase (Bever, 2003). It results in alteration of growth rate of that particular plant species due to changes in soil community and this shows a two-way process.

Insects are major contributors to biodiversity of the largest ecosystems which is agro-systems. It comprises about 40% of the area of land on earth (Ananthakrishnan, 2010). In most cases, species mixes of litter have increased the diversity of soil invertebrates. However, the allelopathic chemicals released by plants can be deleterious to soil organisms and cause reductions in soil communities. It also impacts the neighbouring soil organisms (Bennett, 2010).

Insect biodiversity is vital in agro-ecosystems as it plays role in crop production through pollination and in ecological services such as nutrients recycling, decomposition of organic matter, elimination of unwanted organisms and part of food chain (Patra *et al.*, 2005; Ananthakrishnan, 2010). The falling of aging plant tissue to soil surface directly affects the soil communities especially bacteria and fungi which act as decomposer. An analysis of a research shows that the presence of legumes cover crop increased the composition of insect (Bennett, 2010). The presence of legumes in the ecosystem is vital and leads to higher number of most invertebrate groups (Koricheva *et al.*, 2000).

Insect biodiversity is a sensitive health indicator of diverse ecosystems which includes agro-ecosystems. It is due to their abundance and rapid response to the climate and other environmental changes. The biodiversity of insect is also influenced by the presence of other crops and unwanted plants such as weeds and natural enemies in these ecosystems. In term of environmental factor, climatic changes impact the soil community. Lower rainfall and temperature variation have resulted in changes in insect biodiversity of some species in the ecosystems (Ananthakrishnan, 2010). Low pH conditions also cause a reduction in diversity and abundance of soil fauna. In addition, there are also other factors that influence the abundance of soil invertebrates such as mechanical destruction, desiccation, soil compaction, reduced pore volume, interruption of access to food resources, application of pesticides, large predators and pollution (Giller, 1996). Soil water also may bring impact to soil organisms (Neher, 1999). Since very little quantitative data available for insects in these ecosystems, it becomes a problem in estimating biodiversity (Ananthakrishnan, 2010).

2.3 Soil Arthropods

Arthropods are the dominant animal group throughout the world. Arthropods are among the most species rich in ecosystems (Giller, 1996) but weakly understood (Hall, 1996). Soil fauna can be divided into microfauna, mesofauna and macrofauna based on the size (Giller, 1996). Microfauna include protozoa and some nematodes while mesafauna includes mites, Collembola, nematodes, primitive insects and Enchytraeidae or earthworm-like organisms. Myriapoda, Lumbricidae, Crustacea, gastropods and other insects belongs to Macrofauna group.

A number of orders of organisms that belong to phylum Arthropods can be found in the oil palm plantation (Ananthakrishnan, 2010). They are Coleoptera, Collembolla, Diptera, Hymenoptera, Thysanoptera, Haplotaxida, Araneae and a subclass, Acari.

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