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Soil macrofauna in Oil palm plantation of Sei Liput

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Abstract. Oil palm plantation of PT. Socfindo within area of Sei Liput has been planting oil palm since 1909, with recent status consisted of generation V (± 108 years), IV (± 92 years), III (± 49 years) and II (± 32 years). The different interval of utilization and management of plantation in each generation determine both the species, density, relative density and presence frequency of soil macrofauna. Soil macrofauna are known to maintain the balance of soil ecosystem. The study was conducted at Sei Liput oil palm plantation area on February 2017 until April 2018. Determination of sampling points used purposive random sampling while sampling of soil macrofauna using quadratic and hand sorting methods. The study found 25 species of soil macrofauna grouped into 2 phyla, 6 classes, 12 orders, 20 families and 25 species. The highest density value in the Generation II plantation area was 217.46 ind / m^2 and the lowest density value in the Generation III garden area was 125.38 ind / m^2. The three most frequent species of soil macrofauna in the four generations plantations were *Pontoscolex corethrurus*, *Odontoponera denticulata*, and *Vostax apicedentatus*.

1. Introduction

Conversion and construction of oil palm plantations in the Sei Liput plantation area, East Aceh Regency (recently named Aceh Tamiang), Nanggroe Aceh Darussalam Province, was first started in 1906 by PT. Socfindo. At present there are plantation areas that being planted with the second generation (two) up to the fifth (five). The generation V garden area was initially converted from the forest area to oil palm plantations planted in 1909-1934 (± 25 years), then planted in 1934-1959 (± 50 years), which was planted in 1959-1984 (± 75 years), which was planted in 1984-2009 (± 100 years), and which was planted in 2009 until now (± 108 years).

The generation IV plantation area which was converted from forest to oil palm plantations began with planting in 1925-1950 (± 25 years), which was planted in 1950-1975 (± 50 years), which was planted in 1975-1996 (± 71 years), and those planted in 1996 up to now (± 92 years), and the generation III plantation areas which were converted from rubber plantation areas to oil palm plantations began planting in 1968-1993 (± 25 years), which was planted in the year 1993-2014 (± 46 years), and planted in 2014 up to now (± 49 years), then the generation II plantation area which was converted from forest area to oil palm plantations began its planting in 1985-2010 (± 25 years), and planted in 2010 until now (± 32 years).

Oil palm plantation in the area of Sei Liput owned by PT. Socfindo from year to year since the beginning of its activities, there has been an increase and development of plantation activities, causing

land for plantation areas to be increasingly limited, and often land is used repeatedly over and over regardless of maintenance, not even allowing land to renew physico-chemical conditions naturally.

This situation causes a decrease in the level of soil fertility regarding the physical, chemical and biological aspects. In general, oil palm plants from the beginning of planting to old age may be said to be rarely touched by the treatment of tillage, both on disks and in *gawangan*. In addition, the treatment of fertilization and application of unsustainable herbicides and harvesting of plates or harvesters' footrests, even the application of very insoluble fertilizers, such as Rock Phosphate and Doloinit will cause the soil in the disk to become denser and compact, this condition causes the narrow porosity of the soil, disruption of drainage and rooting respiration, as well as soil biota resulting in disturbed root systems.

Excessive use of chemical fertilizers may alter the physical, chemical, and biological properties of the soil, yet reducing the population and biodiversity of the land [1]. Furthermore, the decline in soil macrofauna diversity was caused by intensive tillage, fertilization and monoculture planting upon conventional farming / plantation systems [2]. Soil biodiversity, including the presence of soil macrofauna is one component in the soil ecosystem that plays a role in improving soil structure, increasing pore space, aeration, drainage, water storage capacity, decomposition of organic waste, mixing of soil particles and microbial dispersion [3]. Soil fauna in carrying out its life activities is largely determined by environmental factors, such as physical conditions, chemistry, biotic and availability of food, and methods of tillage which generally can affect soil fauna populations, both the presence, distribution, abundance and diversity of species [4].

In this study, we report a list of soil macrofauna diversity in Sei Liput, in relation to physico-chemical characteristics of plantation. We also promote the use of certain species as bioindicator (Relative Abundance ≥ 10 %, Presence Frequency ≥ 25 %) to determine the soil characteristics of Sei Liput oil palm plantation.

2. Materials and Methods

2.1. Sampling sites

Research was conducted in Sei Liput oil palm plantation owned by PT. Socfindo from February 2017 to April 2018. Study site was administratively located in Sei Liput, Aceh Tamiang regency, Nanggroe Aceh Darussalam province, Indonesia. The site was geographically located in N 04o19’10”–04o20’31” and E 98o3’14” – 98o4’34”) with elevation 25 – 100 m a.s.l. Sampling points were determined random purpossively by selecting random plot in each generation and soil type. Characteristics of plantation based on generation is presented in Table 1.

Table 1. Characteristics of Sei Liput oil palm plantation

Generation	I	II	III	IV
Pre-plantation vegetation	Rubber plant	Forest	Forest	Forest
Year of planting	1987 - now	1970 – 1995 1995 – now	1943 – 1968 1968 – 1993 1993 – now	1931 – 1956 1956 – 1981 1981 – 2006 2006 – now
Recent plant age	30 years	22 years	24 years	11 years
Year of utilization	± 31	± 47	± 74	± 86

2.2. Soil macrofauna collection and identification

Sampling of soil macrofauna was based on quadratic and hand sorting methods. Plots measuring 900 cm^2 placed in random pattern were dug for its soils using Monolith (Stainless steel). Sampling was conducted within 10 m of each quadrats. Soils in the depth of 20 cm were sampled and stored in plastic bags. Sampling time was conducted from 06:00 – 09:00 AM. Soil macrofauna were visually sorted based on morphological characteristics to respective taxa from soil samples and stored in 4% formaldehyde solutions and 70% ethanol solutions. Soil macrofauna were identified by using standard identification books [5–13].

2.3. Measurement of soil physico-chemical characteristics

Measurement of soil characteristics in Sei Liput was conducted *in situ* and *ex situ*. Physico-chemical characteristics measured in this study are listed in Table 2.

Table 2. Parameters of physico-chemical measured in this study

Parameters	**Unit**	**Tools/Methods**
In situ		
Temperature	^0C	Soil Thermometer
Humidity	%	Soil Tester
pH	-	Soil Tester
Ex situ		
Soil components		Hydrometer
	%	
Debu	%	
Liat	%	
pH H_2O	-	Decantation
C	%	Walkley & Balck
N	%	Kjeldhal
C/N	-	Mathematical model
P	ppm	Bray II
K	m.e/100 g	Extraction (NH_4OAC, pH 7)
Bulk Density	Gr/ cm^3	Soil Sampler
Porosity	%	Soil Sampler
Water content	%	Oven

2.4. Data analysis

Ecological parameters measured in this study regarding soil macrofauna: Abundance (Ind/m^2), Relative Abundance (%), and Presence Frequency (%). Relationship between ecological (Abundance) and physico-chemical parameters was generated using Pearson's Product Moment Correlation Coefficient (r) using software Statistical Package for the Social Sciences (SPSS) ver. 21.00.

3. Results and Discussions

3.1. Soil macrofauna species list

The study found 25 species of soil macrofauna grouped into 2 phylas, 6 classes, 12 orders and 20 families (Table 3). Most of species found in this study were from Insecta (6 orders, 10 families, 13 species), followed by Arachnida, Myriapoda, Chilopoda, Diplopoda and Malacostraca.

Table 3. Soil macrofauna classification in Sei Liput oil palm plantation

Phylum & Class	Order	Family	Species	Local Name	Location/ Generation			
					II	III	IV	V
Annelida :								
1. Chaetopoda	1. Oligochaeta	1. Glossoscolecidae	1) *Pontoscolex corethrurus*	*Cacing tanah*	+	+	+	+
Arthropoda :								
1. Arachnida	1. Araneae	1. Linyphiidae	*2) Tapinopa bilineata*	*Laba-laba*	+	-	+	+
		2. Lycosidae	3) *Pardosa amentata*	*Laba-laba*	+	-	+	+
			4) *Pardosa glacialis*	*Laba-laba*	+	-	+	+
		3. Phrynidae	*5) Paraphrynus mexicanus*	*Laba-laba*	+	-	+	+
		4. Sicariidae	*6) Loxosceles laeta*	*Laba-laba*	+	-	+	+
			7) Loxosceles taino	*Laba-laba*	+	-	+	+
2. Myriapoda :								
1) Chilopoda	1. Geophilomorpha	1. Geophilidae	*8) Geophilus flavus*	*Lipan/Kelabang*	-	+	+	+
	2. Scolopendromorpha	1. Scolopendridae	9) *Scolopendra morsitans*	*Lipan/kelabang*	+	-	+	-
2) Diplopoda	1. Polydesmida	1. Polydesmidae	10) *Polydesmus collaris*	*Keluwing*	-	-	+	-
3. Insecta	1. Blattodea	1. Blattidae	11) *Blatta orientalis*	*Kecoak tanah*	+	-	-	+
		2. Ectobiidae	12) *Blattella germanica*	*Kecoak jerman*	+	-	-	+
	2. Coleoptera	1. Scarabaeidae	13) *Dynastes granti*	*Kumbang badak*	+	-	-	-
		2. Lathridiidae	*14) Melanophthalma americana*	*Kumbang*	-	-	+	-
		3. Scarabaeidae	*15) Catharsius pithecius*	*Kumbang*	-	+	-	-
	3. Dermaptera	1. Labiidae	16) *Vostax apicedentatus*	*Cecopet kecil*	+	+	+	+
	4. Diptera	1. Syrphidae	*17) Syrphus vittafrons*	*Larva Lalat*	-	-	-	+
	5. Hymenoptera	1. Formicidae	18) *Odontoponera denticulata*	*Semut hitam*	+	+	+	+
			19) Oecophylla longinoda	*Semut merah*	+	-	+	+
			20) Solenopsis fugax	*Semut hitam*	+	-	+	+
	6. Orthoptera	1. Gryllotalpidae	21) *Gryllotalpa brachyptera*	*Anjing tanah*	+	-	-	-
		2. Gryllidae	22) *Gryllus pennsylvanicus*	*Jangkrik*	-	-	-	+
			23) *Gryllus assimilis*	*Jangkrik*	-	-	-	+
4. Malacostraca	1. Isopoda	1. Termitidae	24) *Macrotermes gilvus*	*Rayap*	+	+	+	-
		2. Philosciidae	*25) Philoscia muscorum*	*Kutu Kayu*	-	+	-	+
Total Number of Species					**17**	**7**	**16**	**18**
					25			

The abundance of soil macrofauna from phylum Arthropoda obtained in the oil palm plantation area is due to the fact that this soil macrofauna group has a large number of species and extensive distribution, both in forests, shrubs, grasslands, agricultural areas, lowland and highland plantations, The phyla has a high tolerance range for environmental conditions, such as temperature, humidity, pH, and the presence of basic vegetation as a source of nutrients, habitats, shelter and breeding, which play a role in maintaining the balance of the soil ecosystem. Arthropoda is a group of soil animals which generally show the highest dominance among other organisms in the soil animal community, and have a distribution, as well as a wide range of tolerance to the physical-chemical properties of the environment [4]. Most soil macrofauna are soil excavators, especially from groups of insects (insects) that live under plant litter and actively improve soil structure.

The number of soil macrofauna from the Insecta was numerously found in the study sites because Insecta is a group of fauna that has a large number of species and spread, and a very wide range of tolerance to environmental conditions, such as temperature, humidity, pH and soil organic matter. Several studies on soil macrofauna showed that soil macrofauna from the Insecta class is the most commonly found in agricultural and plantation areas [14–19].

Soil macrofauna from the Insecta Class have a wide spread distribution and are mostly found below the soil surface. These places are like forest floors, grasslands, plantation areas and agriculture, and can be found from the lowlands to the highlands. Furthermore many species of animals that exist on the surface of the earth, namely more than 750,000 species are known and named, 80% of them are members of the phylum Arthropoda, about 75% of which are distributed widely on the surface of the earth [20].

3.2. Abundance and relative abundance of soil macrofauna

In this study we found variances in terms of abundance and relative abundance of soil macrofauna in oil palm plantation. The highest abundance 217.46 ind/m^2 consisted of 17 species was obtained from generation II followed by generation IV (177.77 ind/m^2, 16 species), V (149.16 ind/m^2, 18 species), and III (125.38 ind/m^2, 7 species) (Table 4). Factors contributing to high abundance in generation II was due to sustaining environmental factors and dominant grass and shrubs vegetation such as: *Axonopus compressus*, *Cyperus rotundus*, *Panicum repens, Andropogon aciculatus, Ageratum conizoides, Sida retusa*, *Mimosa pudica* and *Amaranthus spinosus*.

When abundant species of animals are found numerously within specific environment, this may indicate that biotic environmental factors (producers, consumers, and decomposers), and abiotics (soil physics-chemistry, such as temperature, humidity, pH, organic content, and so on) in the area is very supportive of the survival of these animals. Vice versa, if no animal species is found in an area, while the surrounding area looks abundant, this indicates that environmental factors in the area do not support and hinder the survival of the animal [6].

Table 4. Abundance and relative abundance of soil macrofauna in Sei Liput oil palm plantation

Species	Local Name	Location/ Generation							
		II		III		IV		V	
		A	RA (%)	A	RA (%)	A	RA (%)	A	RA (%)
1) *Pontoscolex corethrurus*	Cacing tanah	96,81	44,52	34,92	27,85	93,64	52,67	47,61	31,92
2) Tapinopa bilineata	Laba-laba	1,59	0,73	-	-	1,59	0,89	4,76	3,19
3) *Pardosa amentata*	Laba-laba	1,59	0,73	-	-	1,59	0,89	4,76	3,19
4) *Pardosa glacialis*	Laba-laba	1,59	0,73	-	-	1,59	0,89	4,76	3,19
5) Paraphrynus mexicanus	Laba-laba	1,59	0,73	-	-	1,59	0,89	4,76	3,19
6) Loxosceles laeta	Laba-laba	1,59	0,73	-	-	1,59	0,89	4,76	3,19
7) Loxosceles taino	Laba-laba	1,59	0,73	-	-	1,59	0,89	4,76	3,19
8) Geophilus flavus	Lipan/Kelabang	-	-	15,87	12,66	25,39	14,28	19,04	12,76
9) Scolopendra morsitans	Lipan/kelabang	1,59	0,7-3	-	-	7,93	4,46	-	-
10) *Polydesmus collaris*	Keluwing	-	-	-	-	1,59	0,89	-	-
11) *Blatta orientalis*	Kecoak tanah	9,52	4,38	-	-	-	-	1,59	1,07
12) *Blattella germanica*	Kecoak jerman	7,93	3,65	-	-	-	-	1,59	1,07
13) *Dynastes granti*	Kumbang badak	1,59	0,73	-	-	-	-	-	-
14) Melanophthalma americana	Kumbang	-	-	-	-	1,59	0,89	-	-
15) Catharsius pithecius	Kumbang	-	-	1,59	1,27	-	-	-	-
16) *Vostax apicedentatus*	Cecopet kecil	12,70	5,84	30,15	24,05	1,59	0,89	7,93	5,31
17) Syrphus vittafrons	Larva Lalat	-	-	-	-	-	-	3,17	2,13
18) *Odontoponera denticulata*	Semut hitam	49,20	22,62	20,63	16,45	1,59	0,89	7,93	5,31
19) Oecophylla longinoda	Semut merah	1,59	0,73	-	-	7,93	4,46	4,76	3,19
20) Solenopsis fugax	Semut hitam	1,59	0,73	-	-	1,59	0,89	1,59	1,07
21) *Gryllotalpa brachyptera*	Anjing tanah	1,59	0,73	-	-	-	-	-	-
22) *Gryllus pennsylvanicus*	Jangkrik	-	-	-	-	-	-	3,17	2,13
23) *Gryllus assimilis*	Jangkrik	-	-	-	-	-	-	1,59	1,07
24) *Macrotermes gilvus*	Rayap	23,81	10,95	20,63	16,45	25,39	14,28	-	-
25) Philoscia muscorum	Kutu Kayu	-	-	1,59	1,27	-	-	20,63	13,83
Total		217,46	100,00	125,38	100,00	177,77	100,00	149,16	100,00

Note: A = Abundance (Ind/m^2), RA = Relative Abundance (%)

The less abundance of soil macrofauna was found in the Generation III oil palm plantation area, which was 125.38 ind/m^2 consisted of 7 species. This is due to the condition of physico-chemical factors and environmental biology that are less supportive of the survival of the soil macrofauna, including soil pH ranging from 5.2 to 6.2, this condition is categorized rather acidic [21]. Soil acidity (pH) is very important for soil macrofauna, because the presence and density of soil macrofauna in an area is very dependent on soil pH. Most soil macrofauna like neutral pH, which ranges from 6-7.5 [6]. Soil acidity in general can affect growth, reproduction and metabolism of soil macrofauna, therefore soil acidity greatly influences population and soil macrofauna activity [22].

In addition to the pH value of the soil with a rather acidic condition, it was also found that soil moisture in the location of this generation III garden is less humid when compared to other generation garden locations, which ranges from 50-65%, and the soil temperature is relatively high 31^0C when compared to the location of gardens in other generations. This situation also affects the presence and density of soil macrofauna. The presence of soil macrofauna is strongly influenced by soil moisture because the soil macrofauna body is generally not resistant to drought. That is, soil moisture has a positive effect on soil macrofauna [4,5].

3.3. Presence frequency of soil macrofauna in Sei Liput oil palm plantation

The most frequently found soil macrofauna species were: *Pontoscolex corethrurus*, *Odontoponera denticulata* and *Vostax apicedentatus* in all generations of Sei Liput oil palm plantation with Absoluteee, constant and accidental presence categorization. List of species with their presence frequency and categorization is presented in Table 5.

Table 5. Presence frequency (%) of soil macrofauna in Sei Liput oil palm plantation

Species	Local Name	Location/Generation							
		II		III		IV		V	
		PF (%)	Category	PF (%)	Category	PF (%)	Category	PF (%)	Category
1. *Pontoscolex corethrurus*	Cacing tanah	**100,00**	**Absolutee**	**100,00**	**Absolutee**	**100,00**	**Absolutee**	**100,00**	**Absolutee**
2. *Tapinopa bilineata*	Laba-laba	**14,28**	**Accidental**	-	-	**14,28**	**Accidental**	**28,57**	**Accessory**
3. *Pardosa amentata*	Laba-laba	**14,28**	**Accidental**	-	-	**14,28**	**Accidental**	**28,57**	**Accessory**
4. *Pardosa glacialis*	Laba-laba	**14,28**	**Accidental**	-	-	**14,28**	**Accidental**	**42,86**	**Accessory**
5. *Paraphrynus mexicanus*	Laba-laba	**14,28**	**Accidental**	-	-	**14,28**	**Accidental**	**42,86**	**Accessory**
6. *Loxosceles laeta*	Laba-laba	**14,28**	**Accidental**	-	-	**14,28**	**Accidental**	**42,86**	**Accessory**
7. *Loxosceles taino*	Laba-laba	**14,28**	**Accidental**	-	-	**14,28**	**Accidental**	**42,86**	**Accessory**
8. *Geophilus flavus.*	Lipan/Kelabang	-	-	**100,00**	**Absolutee**	**100,00**	**Absolutee**	**100,00**	**Absolutee**
9. *Scolopendra morsitans*	Lipan/kelabang	**14,28**	**Accidental**	-	-	**57,14**	**Constant**	-	-
10. *Polydesmus collaris*	Keluwing	-	-	-	-	**14,28**	**Accidental**	-	-
11. *Blatta orientalis*	Kecoak tanah	**71,43**	**Constant**	-	-	-	-	**14,28**	**Accidental**
12. *Blattella germanica*	Kecoak jerman	**57,14**	**Constant**	-	-	-	-	**14,28**	**Accidental**
13. *Dynastes granti*	Kumbang badak	**14,28**	**Accidental**	-	-	-	-	-	-
14. *Melanophthalma americana*	Kumbang	-	-	-	-	**14,28**	**Accidental**	-	-
15. *Catharsius pithecius*	Kumbang	-	-	**14,28**	**Accidental**	-	-	-	-
16. *Vostax apicedentatus*	Cecopet kecil	**71,43**	**Constant**	**100,00**	**Absolutee**	**14,28**	**Accidental**	**57,14**	**Constant**
17. *Syrphus vittafrons*	Larva Lalat	-	-	-	-	-	-	**28,57**	**Accessory**
18. *Odontoponera denticulata*	Semut hitam	**100,00**	**Absolutee**	**100,00**	**Absolutee**	**14,28**	**Accidental**	**57,14**	**Constant**
19. *Oecophylla longinoda*	Semut merah	**14,28**	**Accidental**	-	-	**57,14**	**Constant**	**14,28**	**Accidental**
20. *Solenopsis fugax*	Semut hitam	**14,28**	**Accidental**	-	-	**14,28**	**Accidental**	**14,28**	**Accidental**
21. *Gryllotalpa brachyptera*	Anjing tanah	**14,28**	**Accidental**	-	-	-	-	-	-
22. *Gryllus pennsylvanicus*	Jangkrik	-	-	-	-	-	-	**28,57**	**Accessory**
23. *Gryllus asimilis*	Jangkrik	-	-	-	-	-	-	**14,28**	**Accidental**
24. *Macrotermes gilvus*	Rayap	**100,00**	**Absolutee**	**100,00**	**Absolutee**	**100,00**	**Absolutee**	-	-
25. *Philoscia muscorum*	Kutu Kayu	-	-	**14,28**	**Accidental**	-	-	**100,00**	**Absolutee**

Note: PF = Presence Frequency (%)

Earthworms from species *Pontoscolex corethrurus* are found with the frequency of absolute presence (very often). This shows that the species is a species that has a broad tolerance range to environmental conditions. *Pontoscolex corethrurus* is an earthworm species that has extensive adaptability and tolerance to various environmental conditions, besides that this earthworm has the ability to consume soil with low quality organic matter [21].

Ants of *Odontoponera denticulata* species were found with a frequency of absolute presence (very often) in the locations of generation II and III plantation areas, and had a frequency of constant presence (often) in generation V, and had a frequency of accidental presence (very rare) in generation IV. The presence of ants from the *Odontoponera denticulata* species shows that this species has a high adaptability to environmental conditions, and has a fairly wide spread in the plantation area. *Odontoponera denticulata* are adaptable species and there are many activities in disturbed areas, such as agricultural and plantation areas [23].

Ants from the species Odontoponera denticulata have a high abundance in agricultural areas because these species are adaptable and move in disturbed areas adjacent to human activities [23].

Furthermore *Odontoponera denticulata* can reach 70% of the land macrofauna population, so that this family can be found in large numbers and wide spread [4].

Vostax apicedentatus species (small earwigs) are found with the frequency of absolute presence (very often) in the location of generation III garden areas, and have a constant frequency (often) in generation II and V, and have a frequency of accidental presence (very rare) in generation IV. The presence of cecopet from the *Vostax apicedentatus* species shows that this species has a high ability to adapt to environmental conditions, and has a wide spread in the plantation area, and is omnivorous. Earwigs has a wide geographical distribution from temperate to tropical regions [24]. The distribution of earwigs in Indonesia included Sumatra, Java, Sulawesi, Kalimantan, and Papua Furthermore ocopet is commonly found in areas with high rainfall and humidity [25].

Earwigs from the species *Vostax apicedentatus* is an omnivorous insect that can act as a predator. Feed habits of earwigs by consuming decaying leaf litter, sometimes living plants, and some species as predators or other insectivors [10,26]. Soil macrofauna from other species has a frequency of attendance that is classified as accidental (very rare) to accessory (rare), this condition is caused by having poor ability to adapt to environmental conditions, and having a wide spread in this area of oil palm plantations. Each of the soil macrofauna species has a different dependence on the environmental conditions of the soil in terms of energy supply and nutrition for its growth. The life of soil fauna is highly dependent on their habitat, because the presence / frequency of the presence of a population of a type of soil fauna in an area is largely determined by environmental factors, and a land management system [6,27].

3.4. Soil macrofauna species as bioindicators

Soil macrofauna that lived and reproduced well, can be used as bioindicator of soil quality in the Sei Liput oil palm plantation. We obtained 6 species namely *Pontoscolex corethrurus, Geophilus flavus, Vostax apicedentatus, Odontoponera denticulata, Macrotermes gilvus* and *Philoscia muscorum*. Of the six species found in 4 generations, *Pontoscolex corethrurus*, followed by *Geophilus flavus* and *Macrotermes gilvus* existed for 3 generations, then species of *Odontoponera denticulata* for 2 generations and *Vostax apicedentatus* and *Philoscia muscorum* species which only existed in one generation.

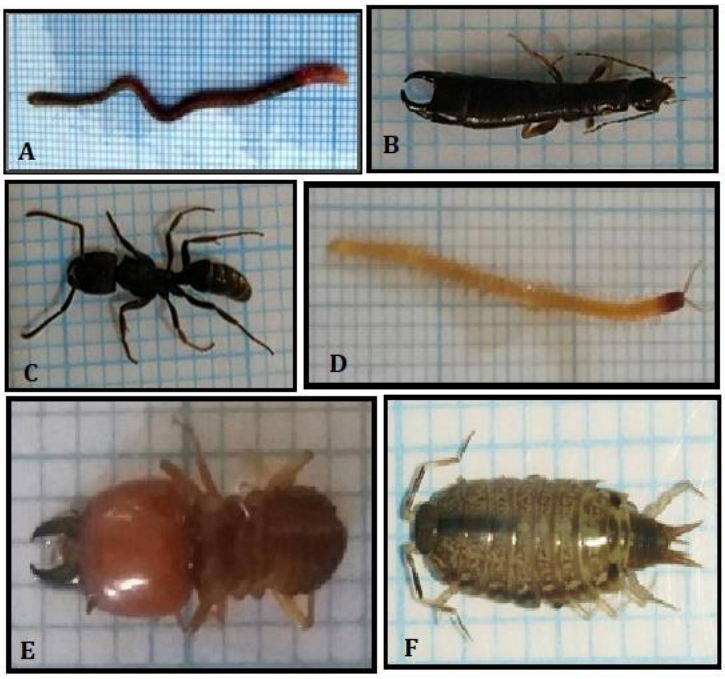

Figure 1. Soil macrofauna as bioindicators: **A.** *Pontoscolex corethrurus*, **B.** *Vostax apicedentatus*, **C.** *Odontoponera denticulata*, **D.** *Geophilus flavus*, **E.** *Macrotermes gilvus*, **F.** *Philoscia muscorum*

3.5. Correlation of ecological and physico-chemical parameters in Sei Liput oil palm plantation

From the Pearson correlation test between ecological (abundance) and physico-chemical parameters (temperature, soil humidity, soil acidity/ pH, soil organic-C), abundance (ind/m^2) is positively influenced by soil acidity and humidity while negatively influenced by temperature and soil organic-C as shown by the positive (+) and negative (-) correlation value (r) (Table 6).

Table 6. Pearson's product moment correlation result between abundance and physico-chemical of Sei Liput oil palm plantation

Correlation test (r)	**Parameters**			
	Temperature	**Soil Humidity**	**Soil pH**	**Soil Organic Carbon**
Abundance	-0,648	+0,480	+0,891	-0,201

From the correlation value obtained, the higher temperature in soil will reduce the abundance of soil macrofauna in the oil palm plantation area, even though the value is in the medium category. The species and abundance of soil macrofauna in the Sei Liput oil palm plantation area are mostly from Annelids and Arthropods. Earthworms have an ideal temperature tolerance range between 15-25^{o}C for life and growth [27]. While arthropods generally have wider tolerance range to soil temperature, although different in each species. Soil arthropods, especially from groups of insects, have a certain temperature range, generally the appropriate or effective soil temperature is at a minimum temperature of 15^{o}C, optimum 25^{o}C, and a maximum of 45^{o}C [20].

The results of the correlation analysis between soil humidity and abundance of soil macrofauna in Sei Liput showed the correlation results + (positive) or unidirectional + 0.480. This value includes the category of correlation values rather low. From these results it can be stated that if soil humidity rises (higher) then the abundance of soil macrofauna will also increase, and if the humidity drops (too low) or rises too high then the abundance of soil macrofauna will decrease. The soil macrofauna have different tolerance range for soil humidity, such as the Annelids, especially earthworms, Arthropods, such as centipedes and earwigs. Decreasing soil humidity will lead those soil macrofauna groups to decease. Earthworms and most arthropods prefer more humid soil while to some arthropods, are more resistant to extreme temperatures ($\geq 45^0$C) with low humidity ($\leq$ 50%) [6,20].

The results of the correlation analysis between soil pH and abundance of soil macrofauna in Sei Liput showed the correlation + (positive) or unidirectional, ie + 0.891. However, the increase and decrease in pH cannot directly indicate an increase and decrease in the number of soil macrofauna species. This is because the pH scale is not linear and limited. There are soil macrofauna that prefer acid pH (pH <6.0), neutral pH (pH 6.0-7.0), and alkaline pH (pH> 7). Annelids especially earthworms have an ideal pH between 6.5-8.6 for their survival and are able to neutralize the soil pH they occupy [22]. Arthropods generally have a very variable pH and usually depend on the availability of food. With exception to phytophagous insects generally prefer alkaline pH than carnivore insects [21].

The results of the correlation analysis between soil organic-C and abundance of soil macrofauna in the Sei Liput area showed the correlation results which were negative (-) or opposite, that is, the value -0.201 . This value belongs to the category of low correlation value and indicate that each increase in the value of soil organic-C may reduce the abundance of soil macrofauna in Sei Liput.

Soil macrofauna from the Annelids group, such as earthworms, and arthropods, such as centipedes, leaflets, earwigs, cockroaches basically prefer fertile soil with high organic matter content, because they contain a lot of food and nutrients for these organisms. Soil macrofauna extracts nutrients from these soil organic matter, so that the availability of soil organic matter which is sufficient will affect the survival of soil macrofauna [1]. Furthermore, the more organic material available, the more the number of individual macrofauna soils [14,15].

Soil organic matter is a collection of a variety of complex organic compounds that are being or have undergone a decomposition process, in the form of humification humus or mineralized inorganic compounds and including heterotrophic and muscrophic microbes involved and in the soil [28].

Furthermore, soil fauna plays an important role in decomposition of plant residues from animal activity and microorganisms, namely through fragmentation of soil organic matter [29].

4. Conclusions

Twenty-five soil macrofauna species grouped into 2 phyla, 6 classes, 12 orders, 20 families, and 25 genera / species are found in this study. The highest abundance is found in the Generation II plantation area of 217.46 ind/m^2 and the lowest in the Generation III of 125.38 ind/m^2. The highest presence frequency (%) of soil macrofauna in the four generations consisted of 3 species, namely *Pontoscolex corethrurus*, *Odontoponera denticulata*, and *Vostax apicedentatus*. There are negative correlations between temperature and soil organic-C to the population of soil macrofauna, and positive correlations between soil pH and humidity to soil macrofauna abundance.

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