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# Population and Activities of Peatland Microorganisms on Oil Palm Plantation based on Soil Depth and Age of Plant

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## Abstract

Population and activity of soil microorganisms can be used as indicators in soil management. This research aimed to examine the population and activity of peatland microorganisms based on the soil depth and age of oil palm plants in the plantations. This research was located in Katapiang, Batang Anai Subdistrict, Padang Pariaman District, which peatland is used for oil palm plantations and it gets minimal plantation management. The research used the survey method in four stages: preparation, pre-survey, main survey and sampling, and laboratory analysis and data processing. Soil samples were taken from peatland that is planted with oil palm from ages 0-5 years, 5-10 years, 10-15 years, and soil samples from natural peatlands. Sampling was taken at depths of 0-20 cm, 20-40 cm, and 40-60 cm. Data analysis showed that the soil microorganisms population decreases with the increase of oil palm plantations age. The bacterial and fungal populations mostly are found on the surface layer. Meanwhile, the highest activity of the microorganisms is on 5-10 years of oil palm soil. Phosphate solubilizing bacteria are mostly found in 5-10 years of oil palm soil. Groundwater level, water content, and soil pH also affect the population and activity of soil microorganisms.

Keywords: microorganism population, oil palm, peatland, phosphate solubilizing bacteria, soil characteristics

## 1. Introduction

West Sumatera has an area of around 140,000 ha of peatlands spreading across the South Coastal Districts, Agam, Padang, Padang Pariaman, and Pasaman (BPS, 1995). Padang Pariaman district has an area of peatlands around 11,000 ha and which has been utilized as an oil palm plantation in Batang Anai. The plantation in the area reaches 90,00 ha with oil palm productivity of 67.75 tons in 2017 and 60.50 tons in 2015 (BPS Padang Pariaman, 2018). Management carried out by farmers during oil palm cultivation has caused damage to the peatlands, as well as damage that can occur in the biological properties of the soil.

The purpose of this study is to determine the population and to assess bacterial activity on peatlands that have been converted into oil palm plantations at various soil depths and ages of oil palm plants.

## 2. Materials and Methods

This research was conducted from June to October 2019 using survey methods. Sampling location is in Ketaping, Batang Anai District, Padang Pariaman Regency, West Sumatera. Soil analysis was carried out in the Soil Biology Laboratory, Faculty of Agriculture, Andalas University.

Soil sampling was done by using a purposive random sampling technique on the peatland planted with oil palm plants aged 0-5 years, 5-10 years, 10-15 years, and natural peat soils which were used as control. Samples were taken with a depth of 0-20 cm, 20-40 cm, and 40-60 cm. Laboratory analysis was carried out on the population of bacteria and fungi, the activity of microorganisms, phosphate solubilizing bacteria, water content, and soil pH.

## 3. Results and Discussion

### A. Population of Bacteria

In Table 1, it can be seen that the aging of the plants causes a decrease in the number of bacteria. The smallest amount of soil bacteria is found in plants aged 10-15 years and soil depths of 40-60 cm. Cultivating old peatlands for oil palm plantations has caused the peatlands to change from their natural state. This is related to the existing cultivation process on the peatlands. The longer peatland opening will cause a decrease in peatland water content and thickness of the peatland (Suwondo, *et al.* 2012).

Overall, the largest population of soil bacteria was found at the ground surface (0-20 cm) compared to a soil depth of 20-40 and 40-60 cm. The high population of bacteria on the surface of the soil is caused by the plant's root system. Plant root metabolites will increase nutrients in the soil that allows the availability of substrates and food supply for the bacteria, so which affects the increase of soil bacteria population. Also, the lower bacterial population at a depth of 20-60 cm is probably caused by decreasing oxygen level which is caused by the existence of groundwater at 40 cm soil depth.

**Table 1.** Soil's bacteria population found in different oil palm ages and soil depth

| Oil palm age (year) | Soil depth (cm) | Bacteria population (CFU) |
|---|---|---|
| 0-5 | 0-20 | $5.2 \times 10^7$ |
| | 20-40 | $1.7 \times 10^7$ |
| | 40-60 | $10.6 \times 10^6$ |
| 5 - 10 | 0-20 | $2.3 \times 10^7$ |
| | 20-40 | $9.0 \times 10^6$ |
| | 40-60 | $6.0 \times 10^6$ |
| 10 - 15 | 0-20 | $2.5 \times 10^7$ |
| | 20-40 | $1.8 \times 10^7$ |
| | 40-60 | $1.1 \times 10^6$ |
| Natural | 0-20 | $1.4 \times 10^6$ |
| | 20-40 | $1.1 \times 10^6$ |
| | 40-60 | $6.0 \times 10^5$ |

## B. Population of Fungi

**Table 2.** Soil's fungi population from different oil palm ages and soil depth

| Oil palm age (year) | Soil depth (cm) | Fungi population (CFU) |
|---|---|---|
| 0-5 | 0-20 | $3.0 \times 10^5$ |
| | 20-40 | $4.0 \times 10^5$ |
| | 40-60 | $3.0 \times 10^5$ |
| 5 - 10 | 0-20 | $3.0 \times 10^5$ |
| | 20-40 | $2.0 \times 10^5$ |
| | 40-60 | $2.0 \times 10^5$ |
| 10 - 15 | 0-20 | $2.0 \times 10^5$ |
| | 20-40 | $3.0 \times 10^4$ |
| | 40-60 | $2.0 \times 10^4$ |
| Natural | 0-20 | $7.0 \times 10^4$ |
| | 20-40 | $3.0 \times 10^3$ |
| | 40-60 | $2.0 \times 10^3$ |

Table 2 shows that the older the oil palms on peatlands, the less the fungi population on that land. Early drainage causes changes in peatlands from anaerobic to aerobic conditions. Lignin, cellulose, and hemicellulose compounds that are still a lot cause the fungi population to increase. However, the longer the land used will cause a decrease in the fungi population because these materials have broken down into simpler materials. So that the population and activity of fungi in peatlands will decrease.

The soil depth also affects the fungi population. Generally, the population of fungi is mostly found on the soil surface with a depth of 0-20 cm compared to the soil with a 20-40 cm and a 40-60 cm depth. Besides, the low population of fungi found at depth of 40-60 cm is caused by groundwater level that found at depth of 40-50 cm, causing oxygen supply to be reduced. According to Utomo (2008), the condition of peatland which is always flooded and gets a few light intensity causes lower soil's oxygen condition.

## C. Respiration of Microorganism

The $CO_2$ production of microorganisms is directly proportional to the activity of microorganisms in the soil. The data in Figure 1 indicates that the increasing soil depth causes the decrease of the respiration activity of microorganisms.

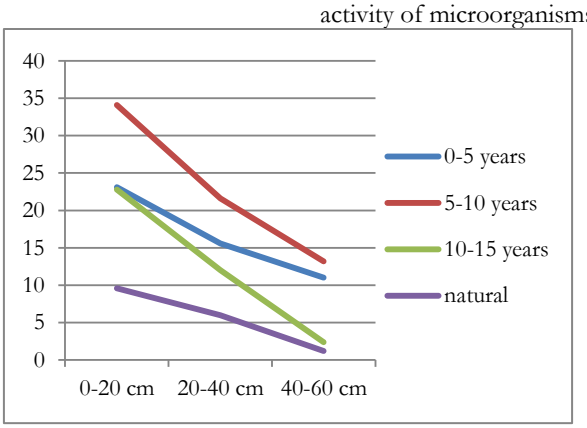


**Figure 1.** Relation of microorganism respiration (mg $CO_2$/100 gr soil/day) with oil palm ages and soil depth.

### D. Carbon (C) Biomass of Microorganism

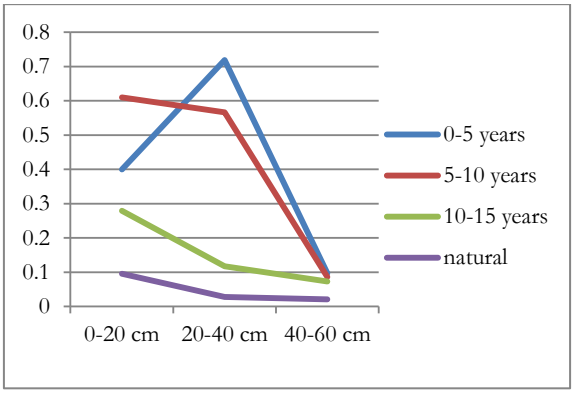


**Figure 2.** Relation of microorganism C biomass (mg C/g soil) with oil palm ages and soil depth.

The highest carbon (C) biomass from microorganisms is found in oil palm plants aged 5-10 years and 0-20 cm soil depth (Figure 2.). This is presumably because oil palm aged 5-10 years produce roots exudate more than oil palm aged 0-5 years or 10-15 years. On the other side, oil palm aged 5-10 years stand in a state that has been long enough to dry, so that in such conditions a good decomposition process on the land has occurred. According to Zul *et. al.* (2013), the microbial biomass is strongly influenced by the availability of soil organic matter which is a source of nutrition for microbes in carrying out metabolic processes.

### E. Phosphate Solubilizing Bacteria

The presence of phosphate solubilizing bacteria is more influenced by the presence of the substrate, soil pH, air temperature, soil temperature, soil moisture, and the state of the soil texture. The data was shown in Table 3 below.

**Table 3.** Number of phosphate solubilizing bacteria on peatland

| Oil palm age (year) | Soil depth (cm) | Phosphate solubilizing bacteria population (CFU) |
|---|---|---|
| 0-5 | 0-20 | $2.0x10^3$ |
| | 20-40 | - |
| | 40-60 | - |
| 5 - 10 | 0-20 | $4.0x10^3$ |
| | 20-40 | $2.0x10^3$ |
| | 40-60 | $1.0x10^3$ |
| 10 - 15 | 0-20 | $2.0x10^3$ |
| | 20-40 | $2.0x10^3$ |
| | 40-60 | - |
| Natural | 0-20 | - |
| | 20-40 | - |
| | 40-60 | - |

### F. Relation of Soil Water Content with Microorganism Activity

The soil water content of oil palm plantations can be seen in Table 4. Water content significantly influences the activity of microorganisms in the peatlands. Due to the high water content, the condition of the peatland

becomes anaerobic so that the oxygen supply will decrease and cause the decline of microorganisms activity.

**Table 4.** Soil water content on each oil palm ages and soil depth

| Oil palm age (year) | Soil depth (cm) | Water Content (%) |
|---|---|---|
| 0-5 | 0-20 | 162.46 |
| | 20-40 | 169.54 |
| | 40-60 | 301.61 |
| 5 - 10 | 0-20 | 157.60 |
| | 20-40 | 415.46 |
| | 40-60 | 491.71 |
| 10 - 15 | 0-20 | 202.11 |
| | 20-40 | 262.31 |
| | 40-60 | 599.30 |
| Natural | 0-20 | 208.64 |
| | 20-40 | 165.95 |
| | 40-60 | 234.49 |

Figures 3, Figure 4, and Figure 5 show clearly that with each increase in water content, the activity of microorganisms decreases. The depth of the groundwater-surface of each soil is 40-50 cm. So that at that depth, the $O_2$ supply has begun to decrease. This anaerobic condition causes microorganism activity is reduced. The surface layer which has low water content has a high activity of microorganisms, meaning that the water content is inversely proportional to the activity of microorganisms on peatlands.

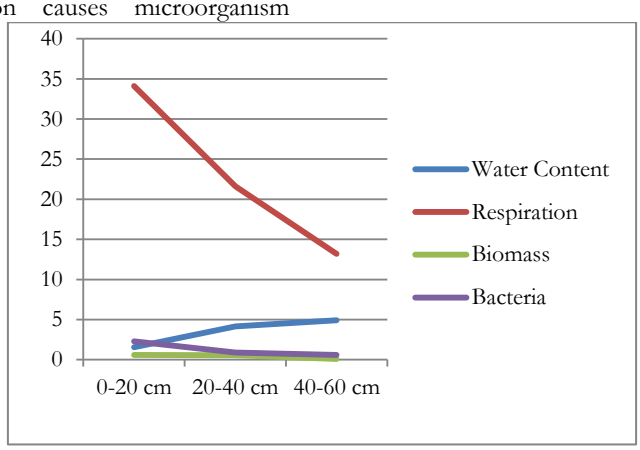


**Figure 3.** Relation of water content with microorganism activity on oil palm age 0-5 years.

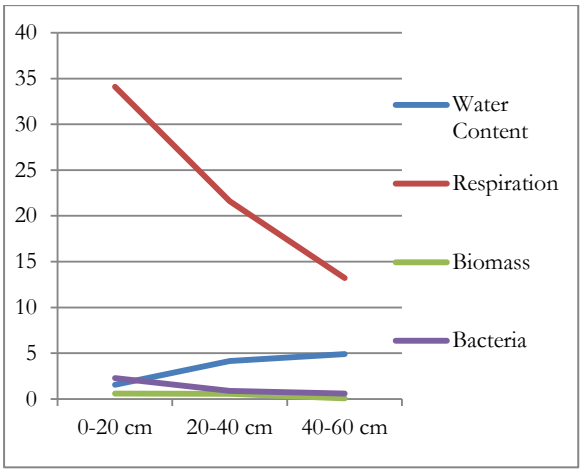


**Figure 4.** Relation of water content with microorganism activity on oil palm age 5-10 years

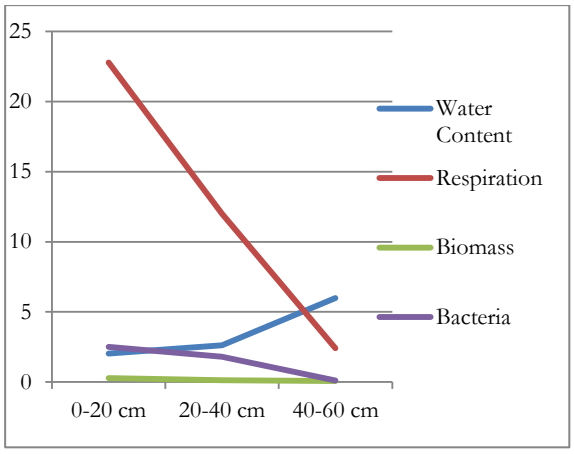


**Figure 5.** Relation of water content with microorganism activity on oil palm age 10-15 years

### G. Relation of Microorganism Activity with Soil pH

Soil pH condition of oil palm plantation soil can be seen in Table 5. The state of soil pH can also affect the activity of microorganisms. Soil pH plays important role in the availability of nutrients for soil microorganisms and also in the working power of enzymes produced by microorganisms. At a very acidic pH, not all microorganisms can survive so that only a few species of bacteria or fungi can adapt to that acidic pH.

Figure 6 is about oil palm aged 0-5 years, shows that a decrease in pH causes a decrease in the number of bacterial and fungal populations, respiration, and microorganisms biomass. This data shows that peatlands recently opened for plantations experience increasing in soil pH, but are still in the category which is very acid and not much different from the natural pH of peatland.

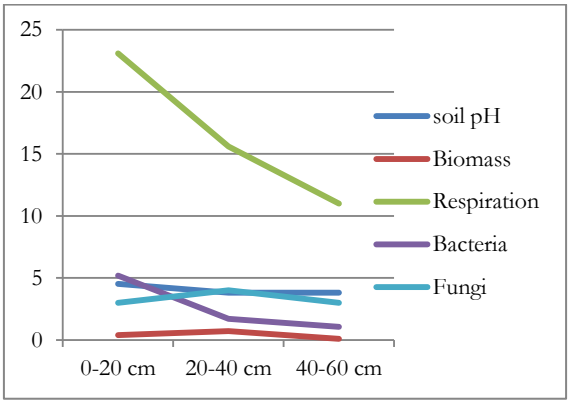


**Figure 6.** Relation of soil pH with population and microorganism activity on oil palm age 0-5 years.

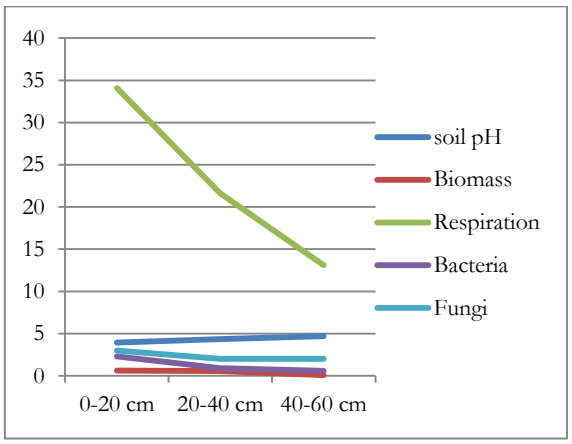


**Figure 7.** Relation of soil pH with population and microorganism activity on oil palm age 5-10 years

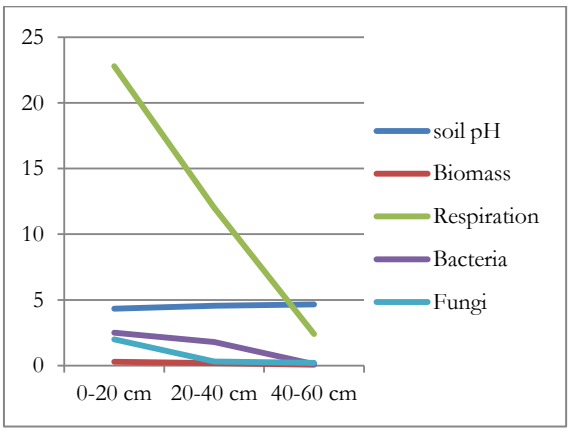


**Figure 8.** Relation of soil pH with population and microorganism activity on oil palm age 10-15 years

Figure 7 (oil palm aged 5-10 years) and Figure 8 (oil palm aged 10-15 years) show that the pH at the soil surface (0-20 cm) is lower than the pH at depths of 20-40 cm and 40-60 cm. Because in the oil palm aged 5-10 years and 10-15 years the surface of the soil has undergone a process of decomposition by microorganisms from the layers of 20-40 cm and 40-60 cm. This decomposition process will produce acidic organic acids so that it will affect the acidity of the soil layer.

**Table 5.** Soil pH on each oil palm ages and soil depth

| Oil palm age (year) | Soil depth (cm) | Soil pH |
|---|---|---|
| 0-5 | 0-20 | 4.52 |
| | 20-40 | 3.81 |
| | 40-60 | 3.82 |
| 5 - 10 | 0-20 | 3.94 |
| | 20-40 | 4.34 |
| | 40-60 | 4.71 |
| 10 - 15 | 0-20 | 4.33 |
| | 20-40 | 4.55 |
| | 40-60 | 4.66 |
| Natural | 0-20 | 3.26 |
| | 20-40 | 3.01 |
| | 40-60 | 3.34 |

## 4. Conclusions

From the results of the study, it can be concluded that with the older age of the oil palm plant and the increasing depth of the soil, the microorganism population of the soil will also decrease. Then, the highest activity of soil microorganisms was found in oil palm plants aged 5-10 years at a soil depth of about 0-20 cm and 20-40 cm. Phosphate solubilizing bacteria are commonly found in oil palm plantations aged 5-10 years and also in oil palm plantations aged 10-15 years.

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