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Diversity of Cellulolytic Microbes from Several Depth in Peat Soil Planted with Oil Palm

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Abstract

Present research was carried out to elucidate the diversity diversity of cellulolytic microbes from several depth in peat soil planted with oil palm. Soil samples were taken from wetlands cultivated to 2 years, 6 years, and 10 years old oil palm, as well as secondary forest, in Landasan Ulin Utara village, South Kalimantan. Soil samples were transported to the laboratory and used for determination of population of cellulolytic microbes, microbial C, soil pH, and water content. Correlation test was employed to assess the relationship between population of cellulolytic decomposer with microbial C, soil pH, and water content. The results showed that the largest cellulolytic bacterial population was found at a depth of 0-40 cm from 10 years old oil palms, followed by a depth of >40 cm from 10 years old oil palms. There was no difference between cellulolytic bacterial populations from 6 and 2 years old palms at all depths. The lowest population of cellulolytic bacteria was found at a depth of >40 cm from forest soil. There were positive correlations between population of cellulotic decomposer with all parameter measured, except soil water content that were logistic negatively correlated. The relationship between water content (Y, mm/day) and the population of cellulolytic decomposer (x, cfu/g soil) can be described with equation $Y = \log(-0.0051x + 162.65)$. These findings suggested that the organic matters supplied by oil palm, especially the 10 years old oil palm) enhance the diversity of cellulolytic microbes. These results may also suggest that the cellulolytic microbes were mostly from aerobic type.

Keywords: microbial diversity, oil palm, wetland.

INTRODUCTION

Peatlands in Indonesia are spread over three large islands, namely Sumatra with a peat area of 5.8 million hectares, Kalimantan with a peat area of 4.5 million hectares and Papua with a peat area of 3 million hectares. Indonesia has an area of tropical peat as large as13.43 million hectares and is the country with the largest area of tropical peat in the world. Peatlands can be used for agricultural businesses, one of which uses a lot of peatlands is the oil palm farming industry. This is due to the high national and global market demand for this industry which has resulted in massive land expansion to increase plantation product production (Anonymous, 2023).

The expansion of oil palm plantations in Indonesia has occurred very rapidly in the past (e.g., around 200,000 ha in 1980 to 7.2 million ha in 2010). Although Indonesian government has released regulations to limit the use of peatlands for oil palm plantation, about one million ha of oil palm plantation presently exist. People still choose to expand on peatlands even though the management level is quite difficult. Mistakes in peat management that have occurred have resulted in degradation of the peat ecosystem. In addition, degraded peatlands have lower water holding capacity (Nugroho and Widodo, 2001), so that in the rainy season it is easy to flood and in the dry season it is easy to dry out and burn and the efficiency and effectiveness of fertilization is low. This choice was taken because the availability of mineral land is increasingly limited.

The decrease in soil water content and the accompanying decrease in ground water levels due to the use of peat land for oil palm causes the peat to be in an aerobic condition. The activity of decomposing microorganisms, one of which is cellulolytic microbes, process in aerobic condition is higher than under anaerobic conditions (Hajoeningtijas, 2012). There has been no study on the relationship between groundwater level and the population and

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activity of cellulolytic microorganisms, so it needs to be studied as a basis for peatland management.

This research aims to determine the effect of peatland development for oil palm plantations on decomposition rates and determine the relationship between cellulolytic bacterial populations and pH, decomposition rate, c-microorganisms and water content of peat soils from different depths.

METHODOLOGY

Time and Location of Research

Soil samples were taken in oil palm field owed by small holding oil palm farmer at Jalan Kampung Baru, Landasan Ulin Utara village, Banjarbaru city, South Kalimantan. The soil analyses were carried out at the Soil Department Laboratory, Faculty of Agriculture, Lambung Mangkurat University. The research was carried out from April to June 2023.

Research Methods

This research used a nested experimental design with soil depths nested in plant ages. The research was carried out on oil palm plantations owned by farmers which consisted of four stages of development (plant age as treatment/main plot), namely:

1. Unplanted peat soil, as control (K)
2. Peat soil planted with 2 year old oil palms (S2)
3. Peat soil planted with 6 year old oil palms (S6)
4. Peat soil planted with 10 year old oil palm (S10)

Research Implementation

Implementation in the field

Implementation begins by drawing boundaries between four stages of development (not yet planted, 2 years old, 6 years old, 10 years old). Next, soil samples were taken using a peat drill at two depths, namely 0-20 cm and 20-40 cm. The soil samples were then put in plastic bags and taken to the laboratory for cellulolytic microbial isolation and other parameters. Soil samples were stored in a cooler until use.

Implementation in the laboratory

Parameters determined included population of cellulolytic microbes, decomposition rate, soil pH, microbial C content, and water content. Population of cellulolytic bacteria was determined following method described by Khairiah el al. (2013). According to this method, 0.01% congo red was poured over the bacterial colony and allow to reach in 15 minutes. The diameters of cleared zone were measured after NaCl application. The diameters of clear zone were used as indicator of decomposition rate.

Soil pH was quantified using pH meter (TOA, Japan) after 30 minutes extraction in water with soil: water ratio was 1:5. The microbial C content was determined using incubation induction method, while water content was determined gravimetrically following procedure described by Page et al. (1982).

RESULTS

Cellulolytic Bacterial Populations

Results analysis using a nested design showed that the land development stage (S) and depth (D) affected the population of cellulolytic bacteria. Further tests using the LSD test showed that the largest cellulolytic bacterial population was found at a depth of 0-40 cm (Da) from 10 year old oil palms (S10), followed by a depth of >40 cm (Db) from 10 year old oil palms (S10). There was no difference between cellulolytic bacterial populations from 6 and 2 years old palms at all depths. The lowest population of cellulolytic bacteria was found at a depth of >40 cm from forest land (Fig. 1).

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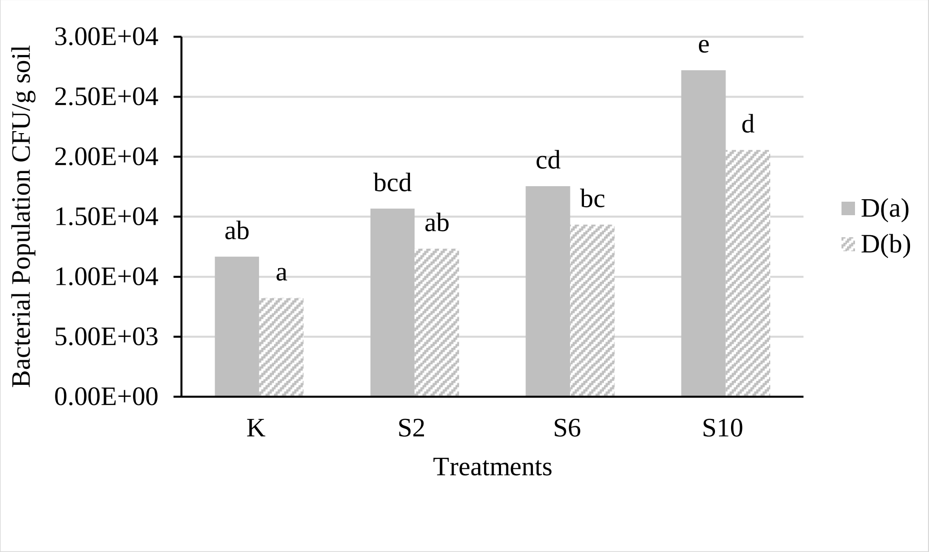

Figure 1. Cellulolytic bacterial population. K = Control, S2 = 2 years old oil palm, S6 = 6 years old oil palm, S10 = 10 years old oil palm, D(a) =0-40 cm soil depth, D(b) = >40 cm soil depth. Means followed by the same latter are not different according to least significant test at 95% confidence level.

Decomposition Rate

Results analysis using a nested design showed that the treatment stage of land development (S) and depth (D) had an effect on the rate of decomposition (which was predicted by measuring the clear zone at 3 and 7 days after incubation). Further tests using the LSD test/least significant difference in decomposition rate showed that the highest decomposition rate occurred at a depth of 0-40 cm (Da) from 10 year old oil palms (S10), followed by a depth of > 40 cm (Db) from 10 year old oil palms (S10) and a depth of 0-40 cm (Da) from 6 year old oil palms (S6) and a depth of > 40 cm (Db) from 6 year old oil palms (S6). There was no difference between decomposition rates in 6 and 2 year oil palm fields at all depths. The lowest decomposition rate was found at a depth of >40 cm from forest land (Fig. 2).

Soil pH

The results of analysis using a nested design show that the treatment of land development stage (S) and depth (D) has an effect on pH. Further tests using the LSD test/smallest significant difference in pH showed that the highest pH was found at a depth of 0-40 cm (Da) from 10 year old oil palms (S10), followed by a depth of > 40 cm (Db) from 10 year old oil palms (S10) and a depth of 0-40 cm (Da) from 6 year old oil palms (S6) and a depth of > 40 cm (Db) from 6 year old oil palms (S6). There was no difference between decomposition rates in 6 and 2 year oil palm fields at all depths, while the lowest pH was found at a depth of >40 cm from forest land (Fig. 3).

Water content

The results of the analysis using a nested design show that the treatment of land development stage (S) and depth (D) has an effect on soil water content. Further tests using the LSD test/smallest real difference in water content showed that the highest water content was found at a depth of 0-40 cm (Da) from forest land, followed by a depth of > 40 cm (Db) from forest land. There was no difference between water content on land. 10, 6, and 2 year old palms at all depths (Fig. 4).

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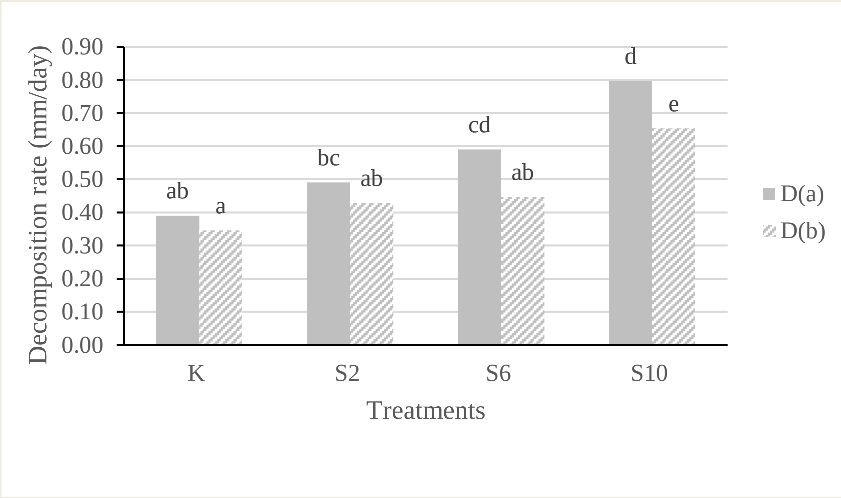

Figure 2. Decomposition rate. K = Control, S2 = 2 years old oil palm, S6 = 6 years old oil palm, S10 = 10 years old oil palm, D(a) =0-40 cm soil depth, D(b) = >40 cm soil depth. Means followed by the same latter are not different according to least significant test at 95% confidence level.

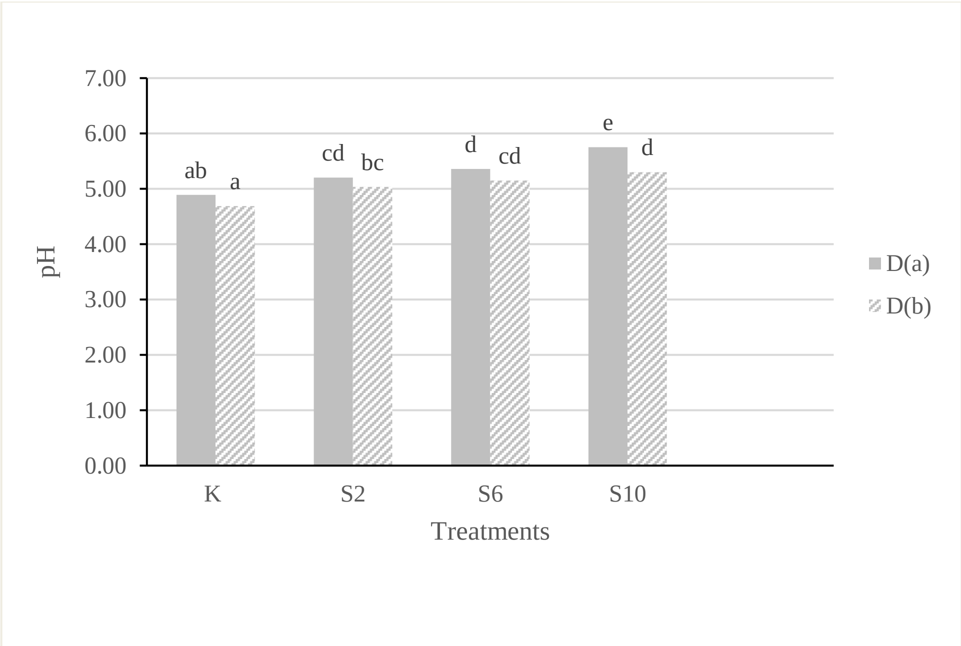

Figure 3. Soil pH. K = Control, S2 = 2 years old oil palm, S6 = 6 years old oil palm, S10 = 10 years old oil palm, D(a) =0-40 cm soil depth, D(b) = >40 cm soil depth. Means followed by the same latter are not different according to least significant test at 95% confidence level

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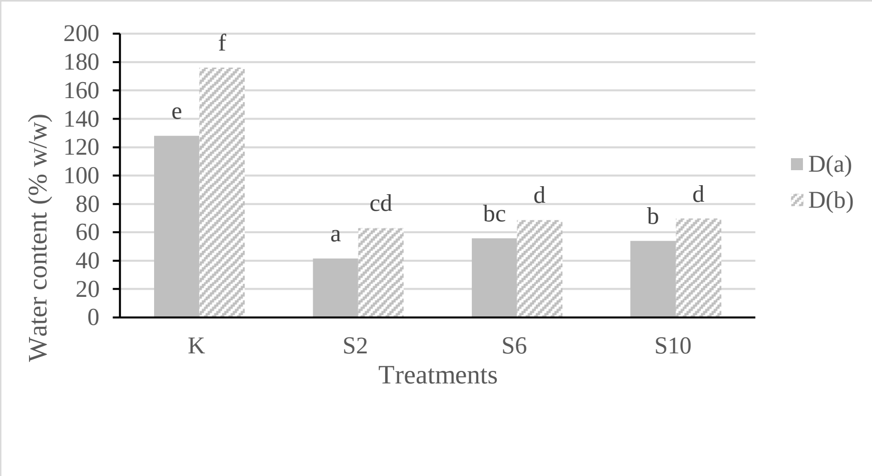

Figure 4. Water content. K = Control, S2 = 2 years old oil palm, S6 = 6 years old oil palm, S10 = 10 years old oil palm, D(a) =0-40 cm soil depth, D(b) = >40 cm soil depth. Means followed by the same latter are not different according to least significant test at 95% confidence level.

Relationship between Bacterial Population with Soil pH, Decomposition Rate, and Water Content

The correlation test showed that there was a very real positive correlation between the population of cellulolytic bacteria and pH (R^2 = 0.942). Based on the results of this research, it is known that increasing the pH value in the soil can increase the population of cellulolytic bacteria and vice versa. The relationship between the population of cellulolytic bacteria and pH can be expressed by the equation: $Y=5 \times 10^5 + 4.33$.

The correlation test showed that there was a very significant positive correlation between the population of cellulolytic bacteria and the decomposition rate (R^2 = 0.9197). Based on the results of this research, it is known that increasing the decomposition rate value in soil can increase the population of cellulolytic bacteria and vice versa. The relationship between the population of cellulolytic bacteria and the decomposition rate can be expressed by the equation: $Y=3 \times 10^5 + 0.1147$.

The correlation test shows that there is a logarithmic relationship between the dependent variable of bacterial population and the independent variable of water content as indicated by the results of the correlation test which obtains a coefficient of determination (R^2) = 0.5843. Based on the results of this research, it is known that increasing water content in the soil can reduce the population of cellulolytic bacteria and vice versa. The relationship between cellulolytic bacterial populations and water content can be expressed with the equation: $y = \log(-0.0051x + 162.65)$.

DISCUSSION

Population levels are influenced by many factors, especially the environment and energy sources Saibi and Tolangara (2017). Based on the results obtained from the average cellulolytic microbial population, the highest was found in peatlands that had been developed for oil palm for ten years and the lowest was found in peatlands that had not been developed for oil palm. Land developed for oil palm, especially around the rhizosphere or root area at depth a, has the highest average population (Fig. 1). This is thought to be because at depth a there were suitable environmental conditions and energy source for cellulolytic microbes. This is in accordance with research by Ali et al. (2016). The high population of bacteria on the soil surface is caused by the plant root system which allows the availability of substrate and food sources so that plant root metabolites provide

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additional nutrients in the soil which affects the microbial population in the soil. Apart from root exudates, 10 years old oil palm also accumulate branch, empty bunch, etc. which will be additional substrate for microbes, leading to the enhanced the diversity of cellulolytic microbes.

This phenomenon is also shown by decomposition rate data where land developed for oil palm at two different depths has a significant influence on the decomposition rate (Fig. 2). This is because the deeper the soil, the more limited the availability of oxygen for aerobic microorganisms. Wijoyono (2009) reported that the decomposition process by bacteria is greatly influenced by environmental conditions, especially the availability of dissolved oxygen, especially for aerobic bacteria. This is also proven by the correlation test between the population of cellulolytic bacteria and the rate of decomposition, showing a real correlation, where the higher the population of cellulolytic bacteria, the higher the rate of decomposition in the soil.

pH is one of the chemical factors that influences bacterial populations (Wijoyono, 2009; Noor, 2001). Based on the results of the nested design analysis, peatlands developed for oil palm have a pH that tends to be more neutral compared to undeveloped land and slightly more acidic at depth b in each land. In addition, soil pH plays a major role in the availability of nutrients for soil microorganisms. and also plays a role in the working power of enzymes produced by microorganisms. The optimum pH for most bacteria is a minimum of 4 and a maximum of 9, but some species can grow in acidic or basic (alkaline) conditions (Wijoyono. 2009). This is in accordance with the results of the correlation test between the population of cellulolytic bacteria and soil pH, showing a significant correlation, where the higher the population of cellulolytic bacteria, the more neutral the soil pH is.

Peatlands are synonymous with their ability to hold water (Noor, 2001). Simatupang et al. (2018) and Susandi et al. (2015) reported that peat soil has a relatively high capacity to bind or hold water on a dry weight basis. Besides that, in accordance with research by Susandi et al. (2015) which states that the depth of the solum or soil layer determines the volume of groundwater storage; the deeper the soil layer, the higher the ground water content. Water content also influences the presence of microorganisms in the soil as shown by the results of the correlation test between the population of cellulolytic bacteria and water content, where the lower the water content in the soil, the higher the population of cellulolytic bacteria. The high population of cellulolytic bacteria is due to the low water content so that oxygen circulation is smoother and bacteria that are classified as aerobic grow better. Apart from that, water also influences the activity of microorganisms because water is the main component of protoplasm. Excess water will limit gas exchange thereby reducing the supply of O_2, so that the environment will become anaerobic (Saibi and Tolangara, 2017).

CONCLUSIONS

Thus, there are differences in bacterial populations in peatlands that have been developed for oil palm for ten years and peatlands that have not been developed for oil palm. Land developed for oil palm, especially around the rhizosphere or root area, has the highest average population. The longer peatlands are developed for oil palm, the more the population of cellulolytic bacteria increases.

Decomposition rate and pH were correlated with cellulolytic bacterial populations. The higher the decomposition rate and the more neutral the pH, the more cellulolytic bacterial populations will grow.

Water content was logarithmically correlated with the population of cellulolytic bacteria. The higher the water content, the smaller the population of cellulolytic bacteria that will grow.

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