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The exploration and utilization of functional microorganisms isolated from the tropical peatlands

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Abstract. The utilization of peatlands may decline the ecological functions of peatlands as carbon sink, water storage and biodiversity source. Therefore, different scientific approaches are required to increase peat productivity and inhibit decline in the ecological functions of peatlands. This article is aimed to provide information on researches that have been carried out in tropical peats in the South Kalimantan Province. The exploration and the potential utilization of microbes was reviewed from several studies conducted in the Desa Landasan Ulin Utara (LaURa), Kota Banjarbaru, South Kalimantan Province. Peat research carried out in the Desa LaURa during the dry season after peat fires in 2015 showed that microbial SRBM (mixture of N fixing, solubilizing P and cellulolytic microorganisms) from the modified recharge bio-pore system was able to improve the growth of roots, stems, and leaves, nutrient uptake, and increase production and biomass of soybean. In another research in 2018, the use of commercial biofertilizers containing *Azotobacter* sp and *Lactobacillus* sp applied to the LaURa peats significantly increased the total N and pH of peats but did not accelerate the decomposition of peat materials. In subsequent study on the exploration of nitrogen fixing microorganisms from the LaURa peats (sapric peats) which amounted to $10^{3.75}$ - $10^{5.00}$ cells g^{-1} , the total N-fixing microbial population was correlated positively to the pH and EC of peats, and correlated negatively to the contents of peat organic C. Combining the results, the total N_2 fixing microbial (NFM) population was significantly affected by organic C and peat EC (total NFM population = $-154.052 + 33.126 \text{ pH} + 607.117 \text{ EC}$, $R^2 = 51.63\%$). Results obtained from these studies demonstrated that the functional microbes of peatlands are able to maintain ecological functions of the peats.

1. Introduction

Indonesia is the country that has the largest tropical peatland in the world, in where 47% of the area of tropical peat in the world (21 million ha) was situated in Indonesia [1] and [2]. Peatlands are generally developed from the accumulation of organic matter, which the decomposition rate was slower than the accumulation rate in the wet environment for thousands years. Peatland in Indonesia has an important role as a storage of 30 percent carbon, water storage/providers that may prevent drought, and function as a habitat for the biodiversity of various types of flora and fauna that are only found in this ecosystem.

Increasing population growth has resulted in the conversion of peatlands into agricultural and plantation lands. This condition occurs because of increasing food demands. On the other hand, the



conversion of peatlands may cause land damage, such as increasing greenhouse gas emissions, peat subsidence and the loss of the ability of peats for water storage. Given the importance of the role of peats for the environment, the government has issued a Government Regulation on the protection and management of peat ecosystems, namely Government Regulation No.71 of 2014 and No.57 of 2015.

From the aspect of protection and management of the peat ecosystem in Indonesia, peatland is divided into two main functions, namely ecological functions and cultivation functions. Even though peatland has a cultivation function, management must pay attention to the ecological aspects of the peats. Based on the level of fertility and nutrient status of the soil, most of the peatlands in Kalimantan was classified as oligotopic peats which have a low fertility and nutrient status, and a high level of acidity [3]. Therefore, fertilizer and lime inputs are required as ameliorant material for improving peat productivity. However, this practice will accelerate the process of decomposition and mineralization of peat material which ultimately causes land damage.

Beneficial microbes are capable of increasing fertility and suppressing or slowing down the processes of decomposition, mineralization and loss of peat may apply as an alternative in the peatland management. This article presents the results of research on the exploration and utilization of beneficial microorganisms on tropical peat management in the South Kalimantan Province.

2. Methods

Authors, you seem to have mixed the materials and methods in result and discussion section. This will confuse the readers. Please relocate the highlighted text and add some narration in the materials and methods. This article resumed three studies on the use and exploration of beneficial microorganisms to support agricultural activities on tropical peat, which carried out in the Desa Landasan Ulin Utara (LaURa) Banjarbaru, the South Kalimantan Province. The three studies are: (1) The use of beneficial microbes isolated from the modified recharge bio-pore system on dry lands applied to support the growth and production of soybean on peatlands. This research was carried out after peat fires occurred in 2015 [4]; (2) the application of commercial biofertilizers in improving the chemical properties of tropical peats. This research was carried out in 2018 [5]; and (3) The exploration of atmospheric N₂ fixing microorganisms of tropical peatlands. This research was completed in 2018 [6].

3. Result and discussion

3.1. Functional Microbe in Increasing Soybean Growth and Yields

Peatland fires occurred in the dry season in 2015 led to thickness depletion and inability in holding water of peats in the LaURa, Banjarbaru City, South Kalimantan Province. Recovery efforts are required to increase the ability of peats to hold water and to provide essential nutrients required for plants growth for utilizing peatland as productive agricultural lands. Ameliorant application is an alternative management to improve fertility and productivity of peatlands. In the study conducted in the dry season after peat fire in 2015, the combination of compost and biological agent was applied to peatlands for improving the growth and production of soybean.

This study was conducted using a randomized block design (RBD) with four treatments: (a) control (peatlands without treatment); (b) Kompostar and IMR; (c) Kompostar and SRBMi; (d) Bokhasi and SRBMi. The Kompostar and the IMR are a compost and a functional microbe from BATAN which were used as comparative products, while the SRBMi is consortium of microorganisms (i.e. N fixing, P solubilizing and cellulolytic microorganism) originating from oil palm waste composts (i.e. empty bunches, shells and fibers) produced by modified biopore recharge systems. Soybean Gamasugen c.v. was used as indicator plants obtained from the National Atomic Energy Agency (BATAN)..

Total nitrogen contents of peatland was classified as moderate (0.21 - 0.27% N). Results of the study showed that the application of bokhasi and the SRBMi to peats at the depth of 10-20 cm was able to supply nutrients compared to other combination packages (Fig. 1). Phosphorous status in this

peatlands was classified very low to low (9.30 - 20.31 ppm). The application of the Kompostar and the IMR to peats at the depth of 0-10 cm increased the supply of total P compared to other treatments.

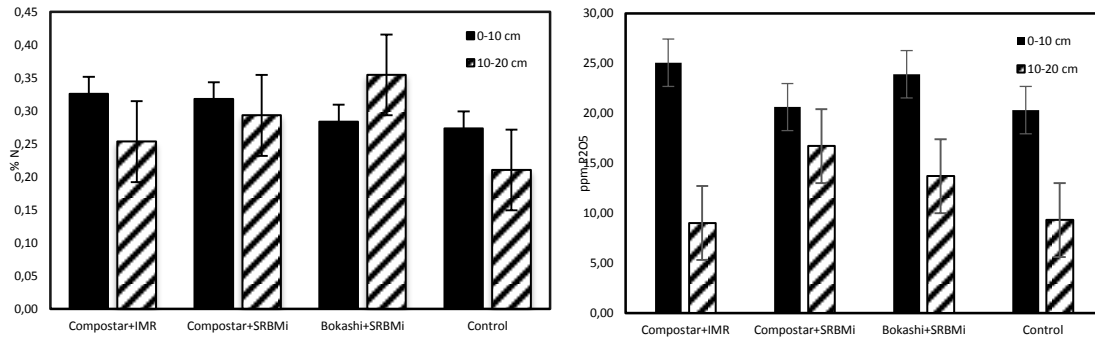


Figure 1. Status of nutrients N and P peatlands in the LaURa Village, Banjarbaru City.

The amounts of N, P and K absorbed by soybeans cultivated on peatlands ranged 1.50-1.82%, 0.66-0.83% and 0.33-0.81%, respectively (Table 1). This result is in agreement with the result obtained by [7] who reported that the uptake of N, P and K nutrient by soybeans applied with beneficial microorganisms and organic fertilizers were in the range of 0.82-1.72%, 0.17-0.70%, and 0.42-0.80%, respectively. The application of the combination of the Bokashi and the SRBmi improved the availability of N, P and K nutrients for soybean growth compared to other treatments (Table 1). The ability of microbes to colonize the rhizosphere greatly determines its role in nutrient uptake, a study conducted by [8] explained that N uptake soybeans significantly increased by *A. chroococcum* inoculation. Increased plant N uptake originated from two sources, namely N fixation activity by exogenous *Azotobacter* which successfully colonized rhizosphere and *Bradyrhizobium* in soybean root nodules.

Table 1. N, P and K nutrient uptake by soybeans in LaURa Village Banjarbaru city

Treatments	N	P	K
	----- % -----		
Compostar+IMR	1.61	0.69	0.54
Compostar+SRBmi	1.54	0.70	0.33
Bokashi+SRBM	1.82	0.83	0.81
Kontrol	1.50	0.66	0.35

The functional microbial adaptability of the SRBmi in peatlands was better than other functional microbes as indicated by their ability to promote soybean roots, stems, and leaves growth, and nutrient uptake of plant (Fig. 2). The SRBmi microbes also have the higher ability to increase the production and biomass of soybean compared to the control and the IMR functional microbes.

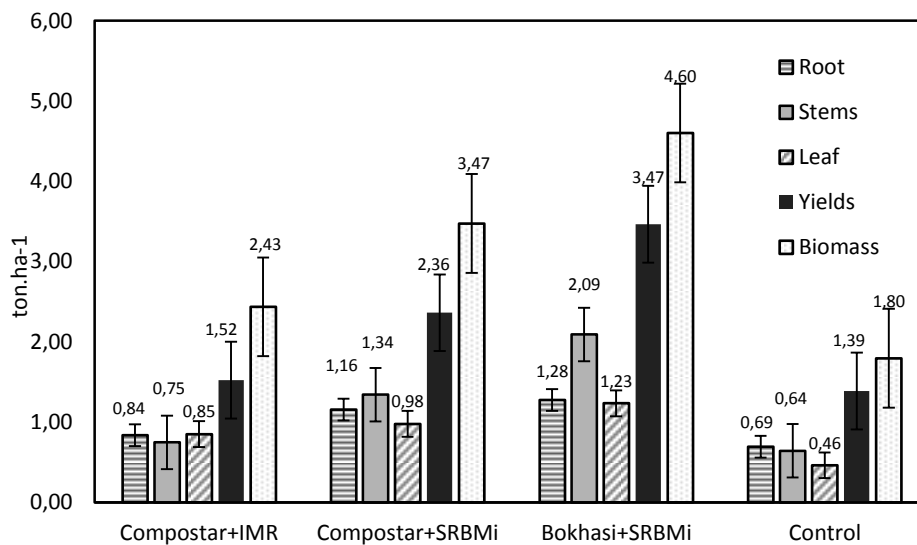


Figure 2. Soybean root, stems, leaf, yields and biomass in the LaURA village Banjarbaru City

The SRBMi functional microbes not only have ability to support soybean growth and production, but may also adapt well in peatlands (Table 2). The Bokhasi and the SRBMi combination on peatlands have a higher viability and persistency when compared to the combination of compost and the IMR. The condition of peatlands which is always wet with the moisture content of 51.98 - 91.60% is the main barrier to microorganisms that live in the environment.

Table 2. Viability and persistence of beneficial microbes on soybean cultivation area in the LaURA Village, Banjarbaru City

Treatment	Cellulolytic	Rhizobium	N fixing (free living)	P Solubilizing
	Log population			
Compostar+IMR	2.42	4.82	5.66	2.21
Persistence (%)	33.33	66.66	83.33	33.33
Compostar+SRBMi	2.32	4.76	5.54	2.07
Persistence (%)	33.33	66.66	83.33	33.33
Bokhasi+SRBMi	6.33	6.40	7.45	5.97
Persistence (%)	83.33	83.33	100.00	83.33

3.2. Commercial Biofertilizers Use for Improving the Chemical Properties of Peats

Peatlands are natural unrennewable resources, therefore improper peatland management will accelerate environmental damages. Application of inorganic fertilizers may improve the decomposition process of organic matter (peat), so that the application of biological fertilizers becomes an alternative to reduce the loss of peat throughout peat decomposition. However, the application of biological fertilizers should consider the environmental conditions so that microorganisms contained in the biological fertilizers are able to adapt to their environments. This research was aimed to determine the effect of several biofertilizers types on peat decomposition. This research where carried out in laboratory was using Completely Randomized Design (CRD) with four commercial biofertilizers (i.e. Control, H1, H2 and H3) as treatments. The amounts of biofertilizers applied in this experiment was equal to 50 ml per 500 g of peat material.

The use of biofertilizers significantly affected the total N contents and the acidity of peat, but did not significantly affect the C/N ratio of peats (Fig. 3). The biofertilizers of H1 increased peat N contents, whereas H2 and H3 biofertilizers significantly reduced the total N contents of peats.

However, the H2 and H3 fertilizers significantly increased peat pH. Increasing the pH of peats (decreases in H^+ ions) may occur when $R-NH_2$ or even NH_3 hold H^+ ions through the covalent coordination. The carboxyl and ammoniac groups can get out of their environment due to leaching or nutrient uptake by plants, so the environment will have more OH^- ions. This causes an increase in pH and a decrease in the contents of N.

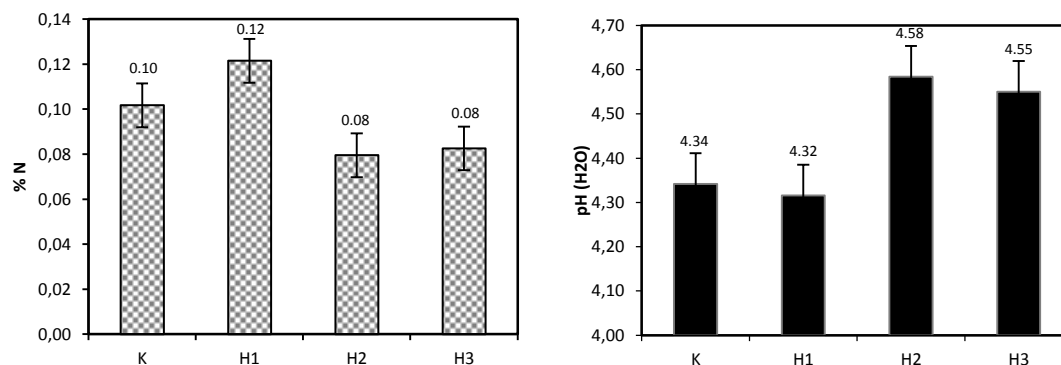


Figure 3. Total nitrogen contents and peat soil acidity from the LaURa Village Banjarbaru city

3.3. Exploration of Nitrogen Fixing Microbes (NFM) from Tropical Peatlands

The losses of peat ecological function as water storage and carbon sources could be reduced by the use of indigenous microbes that are capable of providing nutrients and promoting plant growth for agricultural practices on tropical peatlands in the future. The utilization of indigenous microbes is able to reduce the mineralization and the emission of peatlands, which ultimately avoiding the subsidence and loss of peat materials. The aim of this study was to explore the nitrogen fixing microbes (NFM) and to assess relationship between the NFM and chemical properties of sapric peats in the LaURa peats.

This study started with a field survey to obtain sources of isolates on the LaURa peats. The isolates was obtained from three different land conditions, namely non-reclaimed peatlands, reclaimed peatlands and reclaimed and managed peatland at a depth of 0-40 cm. Six sources of isolates were taken in each land condition, so that 18 sources of isolates were collected. Furthermore, isolation of NFM and some soil chemical properties was carried out.

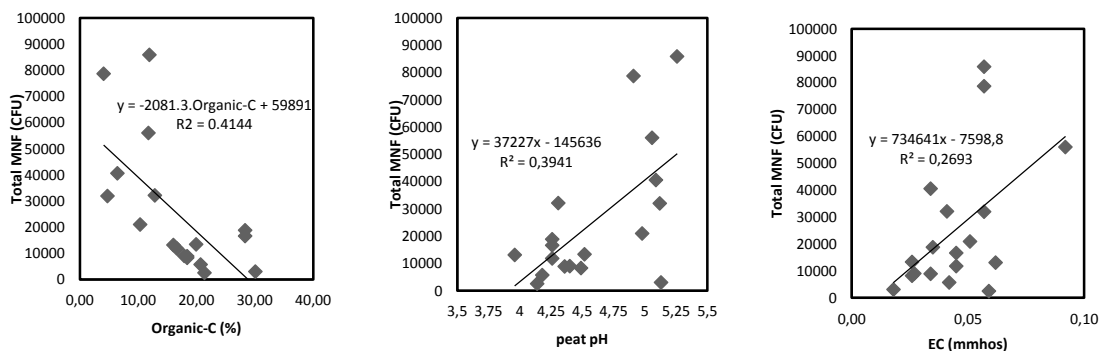
The NFM isolated from the LaURa peats were in the range of 2,479 - 85,899 cells g^{-1} peat material. The total microbial population in the LaURa peats material are relatively lower when compared to the microbes found in the fertile soils. Wet peatland condition and peat burned during the dry season of 2015 and low quality of soil chemical properties of peats causes low total microbial population of the peatlands.

The total population of NFM was positively correlated with peat pH and EC, and negatively correlates with peat organic C (Table 3 and Fig. 4). Several soil chemical properties of the peats influenced the total NFM as indicated by the multiple regression equations of the total population of NFM correlated with soil chemical properties of peats total population of NFM = $-154,052 + 33,126 \text{ pH} + 607,117 \text{ EC}$ ($R^2 = 51.63\%$).

Table 3. Correlation between total population and soil chemical properties of peats

	Total Population	Peat pH	Organic-C	Total-N	Peat EC
Peat pH	0.628 0.005				
Organic-C	-0.644 0.004	-0.491 0.039			
Total-N	-0.307 0.215	-0.155 0.540	0.366 0.135		
Peat EC	0.519 0.027	0.161 0.523	-0.459 0.055	-0.301 0.224	
Fiber content	-0.142 0.573	-0.640 0.004	0.151 0.551	0.208 0.408	-0.052 0.839

Cell Contents
Pearson correlation
P-Value

**Figure 4.** Simple regression between the total population of NFM and the contents of peat organic C, peat pH and peat EC.

4. Conclusion

Beneficial microorganisms such as SRB Mi and biological fertilizers and indigenous microorganisms from the LaURA peats have demonstrated their ability to support agricultural activities and reduce the effects of peatland damages. The SRB Mi functional microbes adapt well to the LaURA peats and demonstrate its ability to provide nutrients and support the growth and production of soybeans. Commercial biofertilizers significantly increase total N and pH of peats, but do not significantly reduce C/N ratio of the peats. The indigenous NFM population was positively correlated with peat pH and EC, and negatively correlated with organic C. The indigenous microbes were significantly affected by pH and EC of peat and multiple regression equations: the total population of NFM = $-154,052 + 33,126 \text{ pH} + 607,117 \text{ EC}$, $R^2 = 51.63\%$). Results of these studies concluded that the use of functional microorganisms is an alternative management of peatlands for agriculture practices.

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