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Effect of *Pleurotus ostreatus* substrates compost on the chemical properties of acid sulfate soils

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Abstract. The common problem of acid sulfate soils is their acidity, which affects the availability of nutrients. Soil pH is an important factor because interval pH defined the availability of nutrients in the soil. Amelioration could improved soils pH, and techniques that are often used is liming. However, Ramsar convention lime's application is not recommended because of its potential harm to the environment. Due to that reason, this study was conducted to identify the effect of *Pleurotus ostreatus* substrates compost on the chemical properties of acid sulfate soils. The greenhouse experiment was arranged in completely randomized design (CDR) with five treatments, i.e. 0 (b₀), 5 (b₁), 10 (b₂), 15 (b₃), and 20 (b₄) ton ha⁻¹. The highest value of pH (5.05), available N (1.70 ppm and 2.13 ppm, ammonium (NH₄⁺) and nitrate (NO₃⁻), respectively), and organic carbon (C) (3.45%) was found in the b₄ treatment, compared to control, the b₄ treatment improved about 40.50%, 77.50%, and 40.82% for NH₄⁺, NO₃⁻, and organic-C, respectively. While, the highest available phosphorus (P) (16.36 ppm) was found in the b₃ treatment, which improved about 166.88% compared to control (b₀). Application of *Pleurotus ostreatus* substrates compost was able to ameliorate the chemical properties of acid sulfate soils.

1. Introduction

Natural sediments that contain iron sulfides, commonly called acid sulfate soils [1], are one of the marginal lands. When disturbed or exposed to air in the area, these soils can release their acidity, affecting damaging soil structures and vegetation near the site [2]. Due to severe acidification, acid sulfate soils are dynamic systems with continuous chemical degradation processes [3]. Acid sulfate soils divided into two categories, potential acid sulfate soils and actual acid sulfate soils. Potential acid sulfate soils contain iron sulfides that have not been exposed to the air and are thus not oxidised. The other one is the actual acid sulfate soils, which contain iron sulfides that have already been oxidised [4].

The most important factor of acid sulfate soils is soil pH [5]. Soil pH determines the availability and toxicity of nutrients, i.e. available N, available P, and organic-C content [6, 7]. Acid sulfate soils become strongly acidic (pH < 3.5) [8], thus acidic pH made soils lack the availability of P and N because those nutrients processes are only depending on pH intervals [9]. Soil pH and organic-C content are positively correlated with each other because organic-C also increased soil pH using humic acid to bind the nutrient as metal elements, i.e. aluminium (Al) and iron (Fe) [10]. In increasing soil pH, several treatments are required. Techniques such as inundation and repair could theoretically increase soil pH [11]. Special techniques in cultivating the soil also need to be done to avoid oxidizing the soil.



Acid sulfate soils need special treatments because of the oxidation of pyrites. One of the treatment is amelioration, and techniques that are often used are liming [12]. However, Ramsar convention lime's application is not recommended because of its potential harm to the environment [13]. Besides liming, organic matter is often used as an ameliorant. The incorporation of organic matter into the acid sulfate soils increased the soil pH because the aerobic decomposition of the organic matter dilutes oxygen and then converts sulfates into sulfides [14]. Organic matter that used in this study is *Pleurotus ostreatus* (oyster mushrooms) as substrates compost. Oyster mushroom is an edible mushroom, which is profitable for agribusiness [15]. It can be cultivated in a medium called baglog derived from wood powder that has been weathered and wrapped in plastic, and sterilized [16]. However, the increase in oyster mushroom productions generates an increase in its wastes. Oyster mushroom substrates contain organic-N (1.65%), organic-C (36.67%), humic acid (2.44%) and the other macro and micronutrients, as well as having alkaline pH (8.10) [17]. Due to that reason, the oyster mushroom substrates hypothetically could help to improve soil pH and nutrients in acid sulfate soils.

The purpose of this study was to measure the effect of *Pleurotus ostreatus* substrates compost on the chemical properties of acid sulfate soils and obtain the best treatment of *Pleurotus ostreatus* substrate compost to improve the chemical properties of acid sulfate soils.

2. Methods

2.1. Acid sulfate soils picking up

Acid sulfate soils were taken from the experimental field of Agriculture Faculty of Lambung Mangkurat University, Sungai Rangas in Banjar Regency, South Kalimantan (-3.3493 S, 114.76774 E). Paddy field usually cultivates in the experimental area. The location is 48.5 m above sea level. The air temperature when the soil was collected was 54 °C.

2.2. Composting *Pleurotus ostreatus* substrate

This study formula of the compost consisted of 30 kg of *Pleurotus ostreatus* substrates, 12 kg of manure, 6 kg of husk charcoal, and 1.2 kg of brans. All of the components were mixing in the box, then added 42 mL of EM4 as the source of activator for decomposing. The compost was stirring every two days and incubated for 14 days.

2.3. Treatments and soil sampling

This research was greenhouse experiment that arranged in completely randomized design (CDR) with five treatments, i.e. 0 (b_0) (control), 5 (b_1), 10 (b_2), 15 (b_3), and 20 (b_4) ton.ha⁻¹. Soils transferred to a bucket are then inundated for one week with an inundation height of 10 cm. After that, the composts were applied to acid sulfate soils. Soils samples were collected 14 days after applying compost using spuit, and each treatment was taken about 200 g for chemical properties analysis.

2.4. Chemistry properties analysis

In this experiment, the soil chemical properties were analyzed at the Soil Laboratory of Soil Department, Agriculture Faculty, Lambung Mangkurat University. Some of the soil chemical properties analyzed were pH KCl and pH H₂O using the electrometric method, available N (NH₄⁺ and NO₃⁻) using the colorimetric method, P available using the Bray-1 method, and organic-C analysis using the Walkley and Black methods [27].

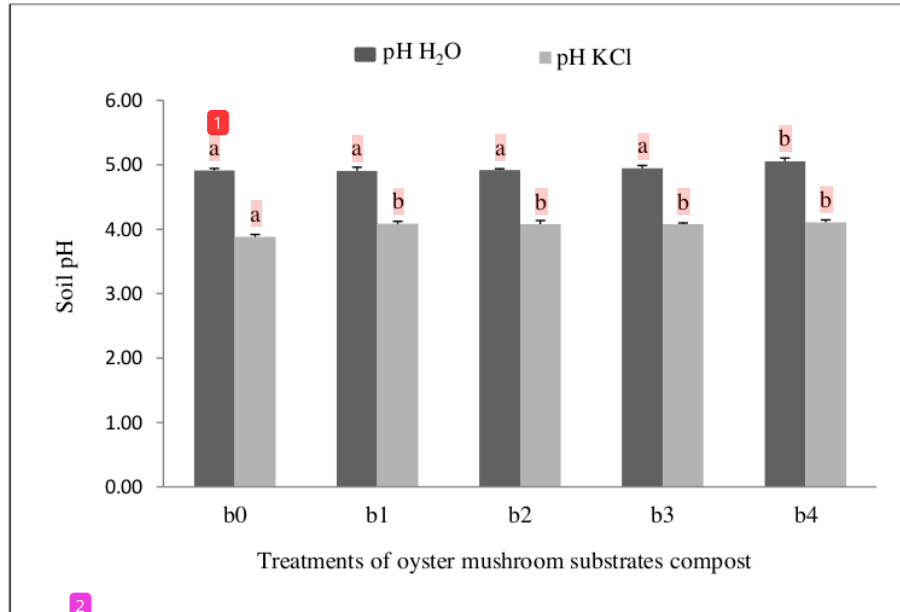
2.5. Data analysis

The data obtained from laboratory analysis were analyzed with a 95% confidence level variance. If there is an influence on the treatment, then continue with The Duncan Multiple Range Test (DMRT) with a 95% confidence level [28].

3. Results and discussion

3.1. Changes in soil pH

The changes of acid sulfate soils pH applied to oyster mushroom substrates compost obtained in the following figure 1.



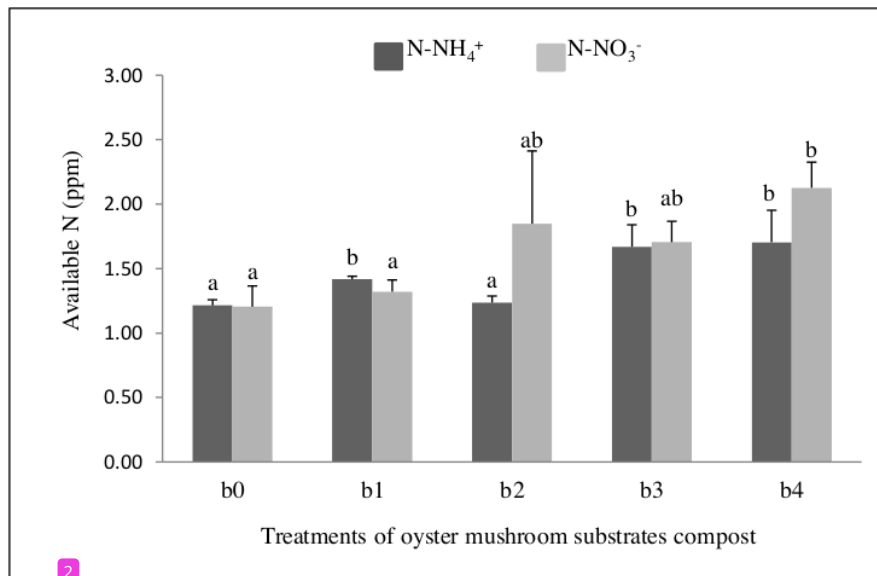
Note: b₀= 0 ton ha⁻¹; b₁= 5 ton ha⁻¹; b₂= 10 ton ha⁻¹; b₃=15 ton ha⁻¹; b₄= 20 ton ha⁻¹.

Figure 1. Changes of acid sulfate soils pH applied to oyster mushroom substrates compost. The line above the bar chart represents the standard error of the treatment (n = 5). The different letters between the columns above the line indicate that the treatment has a significantly different effect based on Duncan's Multiple Range Test (DMRT) at the α 5% level.

Soil acidity is an indicator of soil fertility because it can detect nutrient availability in the soil. Soil acidity is expressed in pH values. The data shown in figure 1 depicts the changes in soil pH, which showed that the application of oyster mushroom substrates compost on acid sulfate soils gives different results among the treatments for changes in soil pH. The figure shows that only the treatment of b₄ (20 ton ha⁻¹) had the highest pH H₂O in 5.05, which differed significantly with b₀ treatment (control). However, all treatments tested with pH KCl showed statistically different from the control treatment (figure 1). Generally, pH KCl of soil can be a better indicator for soil acidity than pH H₂O because pH KCl not only to figured acidity in soil solution but also reserve acidity in the colloids [18]. In addition, it is because the oyster mushroom substrates compost has a very high pH (alkaline), which is 8.19. The increasing OH⁻ causes high alkaline levels in sulfate soils, acid increased the pH value. Compared to the acid sulfate soils the compost intensify pH on heat soils and tidal swamps as much as 30% and 40%, respectively [29]. In contrast, in the treatment of b₁ (5 ton.ha⁻¹), b₂ (10 ton.ha⁻¹), and b₃ (15 ton.ha⁻¹) had no significant effect compared to b₀ (control) on changes in pH H₂O. However, the b₁, b₂, and b₃ treatments had a significant effect compared to b₀ (control) on the pH KCl.

3.2. Changes of available N

The changes of available N in acid sulfate soils applied to oyster mushroom substrates compost obtained in the following figure 2.



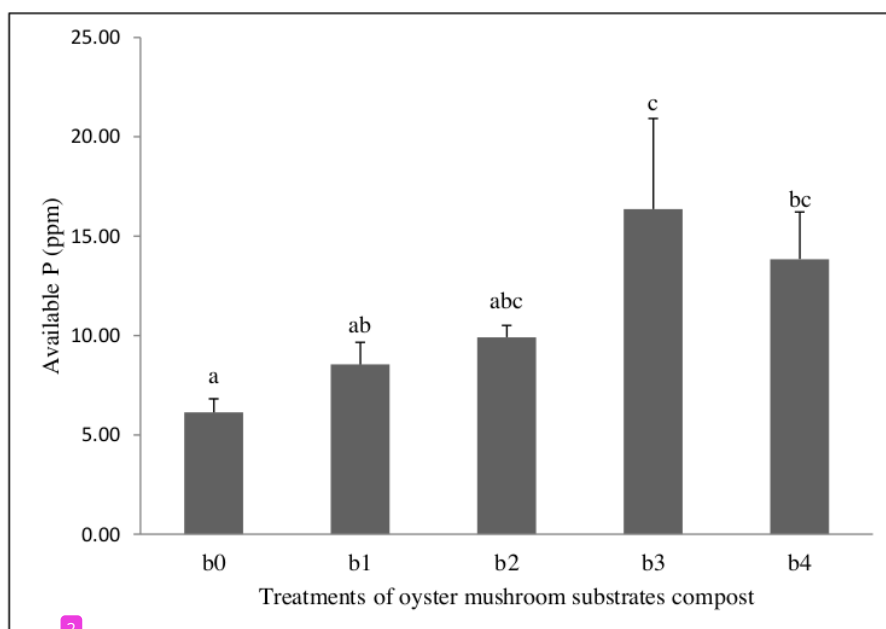
Note: b₀= 0 ton ha⁻¹; b₁= 5 ton ha⁻¹; b₂= 10 ton ha⁻¹; b₃=15 ton ha⁻¹; b₄= 20 ton ha⁻¹.

Figure 2. Changes of available N in acid sulfate soils applied to oyster mushroom substrates compost. The line above the bar chart represents the standard error of the treatment ($n = 5$). The different letters between the columns above the line indicate that the treatment has a significantly different effect based on Duncan's Multiple Range Test (DMRT) at the α 5% level.

Oyster mushroom substrates compost on acid sulfate soils affected available N in the soil (figure 2). Almost all of the treatments had higher available N than control because they have a higher organic matter from the oyster mushroom substrates compost. Nitrogen in the soil comes from the binding of N in the air by microorganisms, rainwater, fertilization, and soil organic matter. Available N in the soil, such as NH₄⁺ is usually absorbed by minerals in the form of illite and NO₃⁻ which are highly volatile so that plants cannot absorb n. The addition of organic matter to the soils could cause the soils to get a supply of N. NH₄⁺ content in b₁ was higher than NO₃⁻ content, but in b₂, b₃, and b₄ treatment, the amount of NO₃⁻ the content was higher than NH₄⁺ content. The highest available N (1.70 ppm and 2.13 ppm, NH₄⁺ and NO₃⁻ content, respectively) were found in b₄ treatment. It occurs due to the process of changing N form in the soil. N changes in the soil through the process of aminization, ammonification, and nitrification [19]. A high NO₃⁻ the content was due to the nitrification process, which is the process of changing NH₄⁺ to NO₃⁻. The nitrification process, to run properly, must have good soil aeration condition [20]. Soils containing high organic matter usually consist of macrofauna in the form of earthworms that play a key role in preventing soil compaction and making soil aeration better [21].

3.3. Changes of available P

The changes of available P in acid sulfate soils applied to oyster mushroom substrates compost obtained in the following figure 3.



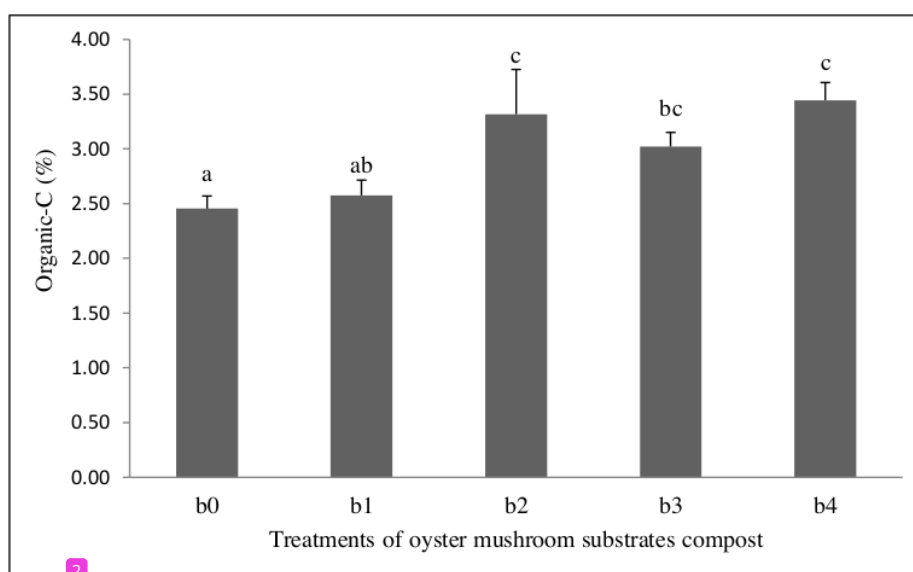
Note: b₀= 0 ton ha⁻¹; b₁= 5 ton ha⁻¹; b₂= 10 ton ha⁻¹; b₃=15 ton ha⁻¹; b₄= 20 ton ha⁻¹.

Figure 3. Changes of available P in acid sulfate soils applied to oyster mushroom substrates compost. The line above the bar chart represents the standard error of the treatment (n = 5). The different letters between the columns above the line indicate that the treatment has a significantly different effect based on Duncan's Multiple Range Test (DMRT) at the α 5% level.

The application of oyster mushroom substrate compost affected available P in acid sulfate soils (figure 3). Control (b₀) treatment was significantly different from b₃ and b₄, but not significantly different from b₁ and b₂. The highest available P (16.36 ppm) was found in the b₃ treatment, which was improved by about 166.88% compared to control (b₀). The availability of P in the soils will affect the sustainability of the next crop phase. The characteristics of acid sulphate soil itself affect the low availability of phosphate (PO₄³⁻). The low availability of PO₄³⁻ is influenced by Fe and Al, which bind the PO₄³⁻ to iron phosphate or aluminium phosphate [22]. High soil acidity causes the dissolution of toxic elements and deficiency of macro and micronutrients. The application of organic matter will affect the availability of P in the soil as in figure 3. The application of organic matter to the soil can increase the available P. Increasing the availability of P in the soil can be done by adding organic matter [6]. Organic material will undergo mineralization and release mineral P (PO₄³⁻), organic acids or other chelating compounds from the decomposition results will release PO₄³⁻ that bind to Al and Fe from insoluble to dissolved form, the presence of humic and fulvic acids which reduce PO₄³⁻ uptake [23].

3.4 Changes of organic-C

The changes of organic-C in acid sulfate soils applied to oyster mushroom substrates compost obtained in the following figure 4.



Note: $b_0=0 \text{ ton ha}^{-1}$; $b_1=5 \text{ ton ha}^{-1}$; $b_2=10 \text{ ton ha}^{-1}$; $b_3=15 \text{ ton ha}^{-1}$; $b_4=20 \text{ ton ha}^{-1}$.

Figure 4 Changes of organic-C in acid sulfate soils applied to oyster mushroom substrates compost. The line above the bar chart represents the standard error of the treatment ($n = 5$). The different letters between the columns above the line indicate that the treatment has a significantly different effect based on Duncan's Multiple Range Test (DMRT) at the α 5% level.

Observations on soil organic-C showed that the soil-applied oyster mushroom substrates compost had higher organic-C content (figure 4). Control (b_0) treatment was significantly different from b_2 , b_3 , and b_4 but not significantly different from b_1 . The highest organic-C (40.82%) were found in b_4 treatment. The addition of organic matter to the soil increases the organic-C content. Organic matter such as oyster mushroom substrates added to the soil will increase organic-C, as known soil organic-C will affect soil physical, chemical, and biology properties [24]. Inherent factors affecting soil organic matter were climate, soil texture and clay mineralogy. The quantity of soil organic matter depends on the determination of soil organic-C, which is 58% soil organic matter was formed by C [25]. C itself is a source of energy for microorganisms in the soil, and this is because the soil organic-C content will stimulate soil microorganisms to decompose organic matter [24]. Treatment b_3 was not significantly different from b_2 , lower than b_2 , but b_4 also gave the best results, same as b_2 , which means that b_2 gave a better result than b_3 . Hypothetically, this phenomenon occurred because of the decomposition of organic matter that is overhauled into inorganic compounds. Thus levels of organic-C were decreasing [26].

4. Conclusion

Application of *Pleurotus ostreatus* substrate compost affects the chemical properties of acid sulfate soils. The highest pH value can see it (5.05), available N (1.70 ppm and 2.13 ppm, NH_4^+ and NO_3^- respectively) and C-organic (3.45%) were found in treatment b_4 . Compared with the control, b_4 treatment increased by about 40.50%, 77.50% and 40.82%, respectively, for NH_4^+ , NO_3^- , and organic-C content. At the same time, the highest available P (16.36 ppm) was found in treatment b_3 , an increase of 166.88% compared to the control (b_0). Therefore, it can be concluded that the b_4 treatment is the best treatment for reamending acid sulfate soils. Application of *Pleurotus ostreatus* substrates compost was able to ameliorate the chemical properties of acid sulfate soils.

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