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Changes in the chemical characteristics of acid sulfate soils applied to oyster mushroom baglog waste compost

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ABSTRACT

Acid sulfate soils are one of the potential lands for agriculture with appropriate treatment. The main problem in these soils is the chemical properties, which is high in acidity and limited nutrients availability and Fe and Al toxicity. Amelioration techniques are needed to improve the chemical properties of the soil, which is oyster mushroom baglog waste compost. This research aims to study the effect of oyster mushroom baglog waste (OMBW) compost to soil chemical properties, also to know the best dosage which affects chemical properties. The research was conducted at the greenhouse of the Agroecotechnology Department and the Laboratory of the Soil Department, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru. The research was started from August-October 2020. One-factor completely randomized design (CRD) with five treatments and five replications was used, the b_0 treatment was not OMBW compost, b_1 was 5 t ha^{-1}, b_2 was 10 t ha^{-1}, b_3 was 15 t ha^{-1}, and b_4 was 20 t ha^{-1}. The application of the OMBW compost significantly affected the soil pH and decreased soluble-Fe and Al, but did not significantly affect the Eh value at 2 WAA (Week After Application). The best concentration of dose of OMBW compost was 10 t ha^{-1} which improved soil pH, decreased soluble-Fe and Al.

Keywords: Amelioration, organic matter, suboptimal wetlands, soil acidity.

1. Introduction

In recent years, the rate of depreciation of agricultural land has been correlated with a reduction in food production area. The development of housing and industrial estates, especially in the South Kalimantan area has a significant impact on the conversion of productive agricultural land. Based on data from The Statistics of Kalimantan Selatan Province (2018), it shows that the agricultural land declined from 1,238,573 ha and in 2017 to 1,099,264 ha in 2018. The data shows the number of agricultural productive reduction area which was 139,309 ha in 11 years. The reduced agricultural land will have a positive correlation with food availability. There was a moderate relationship between these two factors with a value of 0.62 in several provinces (Arotaa et al. 2016).

According to Agricultural Office of South Kalimantan (2013), South Kalimantan has 3,849,541 ha potential land. About 5.25% of land area in South Kalimantan is acid sulfate soils, or around 202,100 ha. Acid sulfate soils are soils with iron sulfide content. The most common is pyrite (FeS_2). Proper management of agricultural and non-agricultural planning on these soils requires not only knowledge of the physical, chemical, and biological properties of the soil, but also knowledge of the climate, in its current land uses. It is very important that it is necessary to know the soils first before being managed (Das & Das, 2015).

The development of acid sulfate soils still faces many problems. One of the obstacles is the high soil acidity (pH <4). This very acidic pH condition will directly affect plant growth due to increased solubility of Fe and Al, and indirectly reduce the availability of P and other nutrients (Agegnehu et al., 2019). Nozoe et al. (2008) found that the critical limit for food plants is 500-2,000 ppm. While the critical limit for Al tolerance ranges from 4-10 ppm (Wijanarko & Taufiq, 2004).

The development of acid sulfate soils needs to apply technology that can improve soil properties, while still paying attention to the surrounding environmental conditions. One technology that can be applied is land amelioration. Land amelioration is an effort to provide materials to improve soil properties which are expected to increase growth and production (Fahmi & Khairullah, 2018). Many studies have been carried out regarding amelioration technology to improve the properties of acidic soil, some of which are lime, livestock manure, ash, charcoal, and compost (Saputra, 2016). However, research on the use of OMBW as an ameliorant is still not widely published. So, this research needs to be verified with actual data.

OMBW is waste produced from baglog or post-production oyster mushroom media that is not used and has the potential to become waste that pollutes the environment (Susilowati & Raharjo, 2010). Jumar et al. (2020) reports that the nutrients contained in OMBW compost are N, P, K, and C with successive values of 0.74%, 0.50%, 0.30%, and 14.38%. The pH of OMBW compost was classified as alkaline (pH 8.19), so it has the potential to increase soil pH in acid sulfate soils. OMBW compost in this study qualified the criteria for quality compost according to SNI No.19-7030-2004 (Putri et al., 2022).

Based on data from The Statistics of Kalimantan Selatan Province (2013), the production of oyster mushrooms in South Kalimantan reaches 27,403 kg m^{-2} with a production area of 1,815 m^2. If the production is optimal, it can produce 49 t at once. If it is assumed that the mushrooms produced are about 40% of the total baglog weight, then the waste will reach 73.5 t. Therefore, it is necessary to manage the waste from the oyster mushroom cultivation. The research that can change chemical properties on acid sulfate soils with oyster mushroom compost needs to be carried out.

2. Materials and Methods

The research started from August to October 2020 in the Greenhouse of the Agroecotechnology Department and the Physics, Chemistry, and Biology Laboratory of the Soil Department, Faculty of Agriculture, Lambung Mangkurat University (ULM), Banjarbaru. The research used single factor in completely randomized design (CRD) consisting of five levels of treatment. Each treatment was repeated five times in order to obtain 25 experimental units. The treatments were 0, 5, 10, 15, and 20 t ha^{-1} or 0.00, 21.36, 42.74, 64.10, and 85.47 g $bucket^{-1}$.

OMBW were taken from the mushroom cultivation on Mistar Cokrokusumo Street, North Loktabat, Banjarbaru City, South Kalimantan. Composting was used a formula adapted from Hunaepi et al. (2018). A total of 30 kg of OMBW evenly distributed with other ingredients, among others: 12 kg of cow manures, 5 kg of husk charcoal, 5 kg of topsoil and 1.2 kg of bran. The decomposer solution was 42 mL EM4 to which 30 g of brown sugar was added. Then poured on the compost raw material mixture while stirring. Decomposition was carried out for 14 days, with stirring every two days. Ripe compost had physical characteristics, such as no soil odor, breaks easily, and in black-colored. It has chemical properties, which contains nutrients for plants (Setyorini et al., 2006).

Acid Sulfate soil was taken from the ULM experimental field at Sungai Rangas, Banjar Regency, South Kalimantan (-3.3493 S. 114.76774 E). 270 kg of soil was taken using *sundak* at a depth of 0-30 cm. The soils were transferred to 25 buckets measuring 10 L each 10 kg of soils. The Soil was submerged as high as 3 cm for one week before treatment.

The OMBW compost was applied with a predetermined treatment and the layout has been randomized first. Incubation was carried out for two weeks after application. After incubation for 2 weeks, 200 g $bucket^{-1}$ of soil samples were taken back for laboratory tests with the observation variables i.e., soil pH, soil Eh, soluble-Fe and Al using squib syringes. The analysis was carried out at the Laboratory of Physics, Chemistry, and Biology, Department of Soil, Faculty of Agriculture, Lambung Mangkurat University. Soil pH and Eh were analyzed using the electrometric method (Neves et al., 2021; Rabenhorst et al., 2009), soluble-Fe were measured with the ammonium acetate extracts method (Ure et al., 1993), and soluble-Al were measured with the colorimetric method (aluminon plus ascorbic acid) (Abreu Jr. et al., 2003).

The data obtained on the observed variables were tested for their homogeneity. If the data is not homogeneous, it is necessary to transform the data. As is homogeneous, it is continued with the analysis of variance with a 95% confidence interval using GenStat 11th edition. If the data states that the results are influential, a further DMRT (Duncan Multiple Range Test) was applied (Duncan, 1995).

3. Results and Discussion

Change in the pH value

The application of OMBW compost increased soil pH values, both H_2O and KCl pH. The effect can be seen in Figure 1.

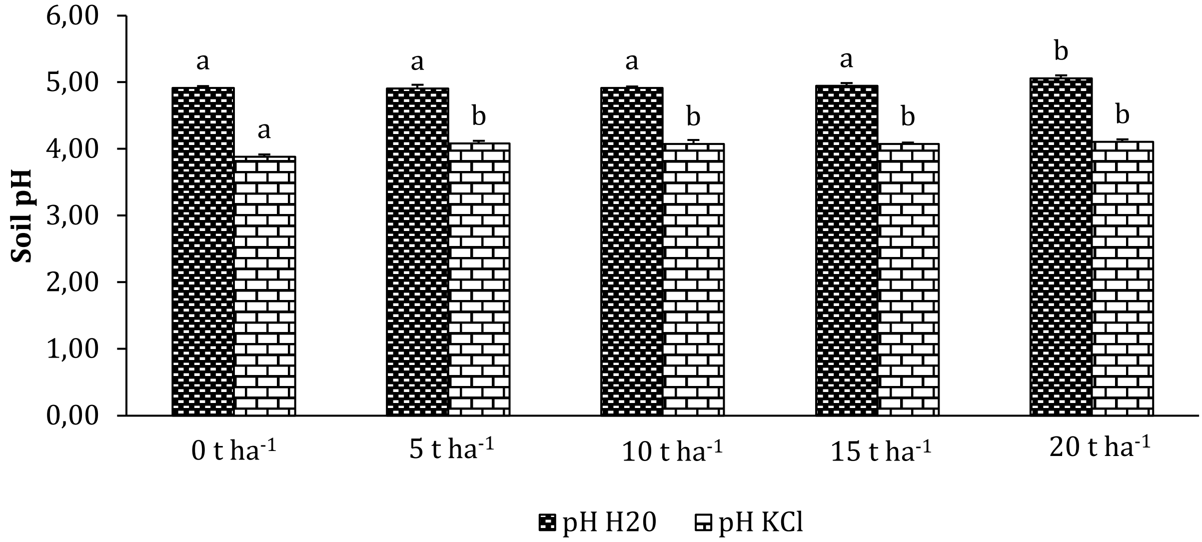

Figure 1. Changes in the pH value of acid sulfate soils at 2 WAA. b_0= 0 t ha^{-1}; b_1= 5 t ha^{-1}; b_2= 10 t ha^{-1}; b_3= 15 t ha^{-1}; b_4= 20 t ha^{-1}. The line above the bar chart represents the standard error of the treatment (n=5). The different letters between the columns above the line indicate that the treatment has a significantly different effect based on Duncan's Multiple Range Test (DMRT) at the α 5% level.

Based on the picture above, it shows that only 20 t ha^{-1} showed the difference from the control. The increased recorded for all treatments from control. This was because OMBW compost had a high pH (alkaline) according to the results of research by Jumar & Saputra (2020), that the pH of OMBW compost ranges from 8.19. Soil acidity is the most important indicator to determine soil fertility because it can be an early detection of nutrient availability in the soil. Soil acidity is expressed in pH values. Yuniarti et al. (2020) also reported that this high alkaline level was due to the increased concentration of OH^- in the soils due to the OMBW compost addition. Compared to the acid sulfate soils the OMBW compost intensify pH on peat soils and tidal swamps as much as 30% and 40%, respectively (Saputra & Sari, 2021).

The best concentration of OMBW compost for soil pH was 10 t ha^{-1} or converted to 42.74 g bucket^{-1}, although it was only significantly different from the b_0 treatment at KCl pH. Basically, the pH of KCl is more acceptable to researchers than the pH of H_2O because it not only determines the acidity in soil solutions, but also determines the acidity in colloids (Wright et al., 1991). This consentration used fewer ingredients than the others but resulted in no difference from the others as it was more efficient in the cost of making compost.

Change in the Eh value

The application of OMBW compost did not have a significant effect on changes in the Eh value of the soil. The effect of the application of OMBW compost can be seen in Figure 2.

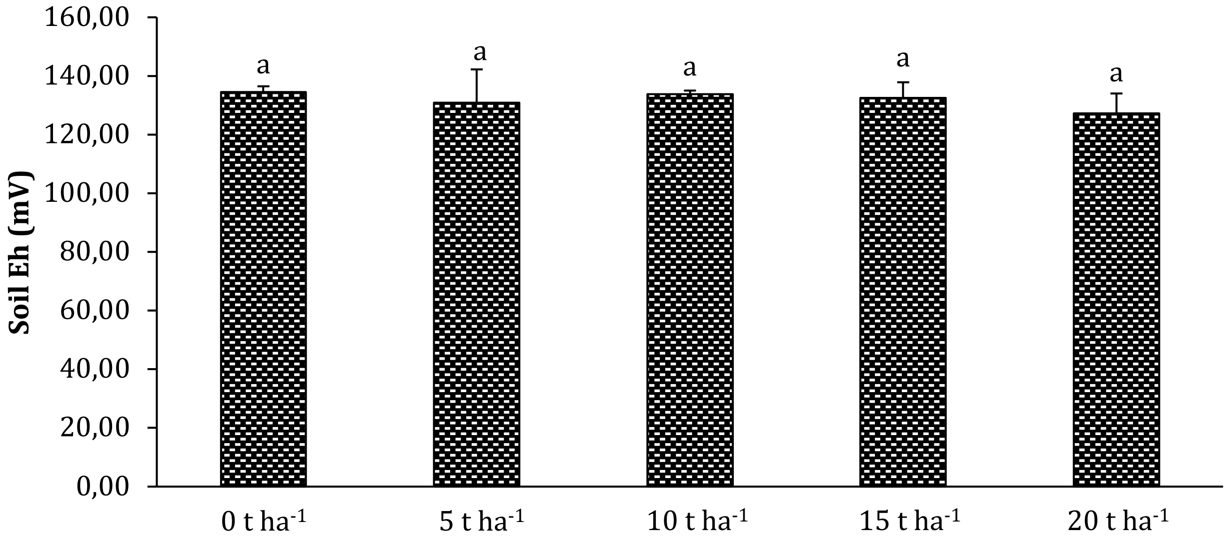

Figure 2. Changes in the Eh value of acid sulfate soils at 2 WAA. b_0= 0 t ha^{-1}; b_1= 5 t ha^{-1}; b_2= 10 t ha^{-1}; b_3= 15 t ha^{-1}; b_4= 20 t ha^{-1}. The line above the bar chart represents the standard error of the treatment (n=5). The different letters between the columns above the line indicate that the treatment has a significantly different effect based on Duncan's Multiple Range Test (DMRT) at the α 5% level.

Based on the figure above, it shows that all treatments were not significantly different from control. ANOVA test results found that the application of OMBW compost did not have a significant effect on changes in soil Eh value. The Eh value is a quantitative unit to show the availability of oxidation and reduction electrons in a chemical system (Tan, 2011). Based on the chart shown in Figure 2, all treatments were not significantly different from b_0 (control) on the change in the value of Eh 2 WAA.

This is probably due to the activity of the H^+ in acid sulphate soils. Although it can increase soil pH with a significant difference with the control, application of OMBW compost only slightly reduces H^+ ion activity which is usually found in acid soils such as acid sulfate soils. Based on the opinion of Tan (2011), the Eh value of soil states oxidation and reduction activity in the soil, the Eh value will decrease if the reduction process takes place and will increase if the oxidation process takes place. According to Cyio (2008), organic matter can contribute to the decline in Eh value because it releases OH^- ions which will later undergo a reduction process thereby reducing the Eh value of the soil, but in this study, it shows that organic matter applied even at the highest dose does not cause a reduction in the number of electrons significantly on acid sulfate soils.

Decrease in soluble-Fe

The application of OMBW compost had a significant effect on reducing the soluble-Fe. The effect of the application of OMBW compost can be seen in Figure 3.

Based on the figure above, it states that the b_2 and b_3 treatments are significantly different from the b_0 treatment in decreasing the soluble-Fe of acid sulfate soils 2 WAA. Fe toxicity is a common thing in acid sulfate tidal lands, Fe toxicity is caused by high levels of soluble-Fe in the soil (Audebert, 2006). The results of the analysis of variance showed that the application of OMBW compost had a significant effect on reducing the soluble-Fe of acid sulfate soils. The effect of the application of OMBW compost can be seen in Figure 3. Based on the picture above, it shows that the b_2 and b_3 treatments were significantly different from b_0 (control) in reducing the Fe-soluble of acid sulfate soil 2 WAA.

According to Eusterhues et al. (2014) giving the amount of organic material such as compost reduces iron (III) (Fe^{3+}) ions to iron (II) (Fe^{2+}) ions, then Fe^{2+} has high reactivity to organic matter so that the organic material contained in the compost covers the toxicity of binding Fe important nutrients for the soil. This will also increase the pH value indirectly because when the reduction of Fe takes place it requires a number of H^+ ions, so that the pH value increases (Audebert, 2006). This is also strengthened based on the research of Dada & Aminu (2013), the application of organic matter accelerates the process of iron reduction. The source of electrons and energy for Fe-reducing microbes is obtained through organic matter. The things mentioned above are in accordance with the results of the research which showed that the application of OMBW compost had a significant effect on increasing the pH value of acid sulfate soils.

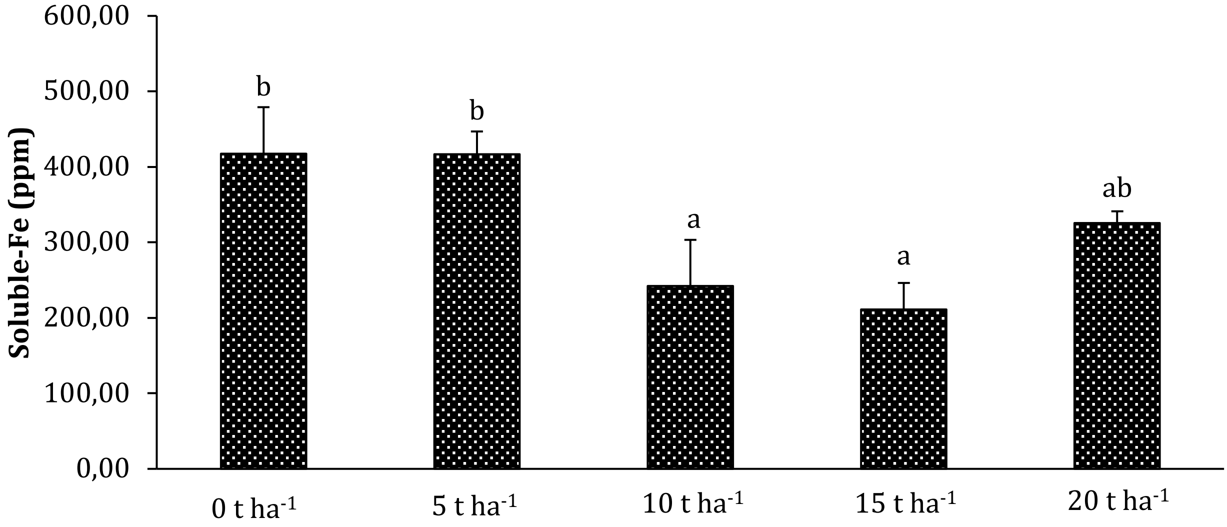

Figure 3. Decrease in soluble-Fe of acid sulfate soils at 2 WAA. b_0= 0 t ha^{-1}; b_1= 5 t ha^{-1}; b_2= 10 t ha^{-1}; b_3= 15 t ha^{-1}; b_4= 20 t ha^{-1}. The line above the bar chart represents the standard error of the treatment (n=5). The different letters between the columns above the line indicate that the treatment has a significantly different effect based on Duncan's Multiple Range Test (DMRT) at the α 5% level.

However, the results of the study also found that the correct dosage was needed in application of OMBW compost, this could be seen because the b_4 treatment which was the treatment with the highest dose did not have a significant effect on the b_0 treatment. This is presumably because there is a limit in increasing the pH value by giving acids or bases which is known as soil refractory. Soil buffering capacity is the ability of the soil to maintain a balance of nutrient levels contained in the soil solution. The exchange of soil cations creates the development of active and potential acidity. Active acidity is the acidity caused by H^+ ions in the soil solution, while the potential acidity is caused by H^+ and aluminum (III) (Al^{3+}) ions which are absorbed on the surface of the absorption complex. If H^+ ions are neutralized with alkalis (bases that come from compost), the potential acidity will release H^+ ions which can be exchanged into soil solution to restore soil equilibrium. No change in soil reaction occurs until the H^+ ion reserves run out because the H^+ ions released make the Fe reduction process inhibited (Tan, 2011). This was also confirmed by the lowest average Eh value found in the b_4 treatment due to the increased oxidation of H^+ ions.

Based on the data above, the best application of OMBW compost to reduce the soluble-Fe of acid sulfate soils was found in the b_2 treatment at a dose of 10 t ha^{-1} or converted to 42.74 g bucket^{-1} which is less than the b_3 treatment and gives results that are not much different from the b_3 treatment, so it is more efficient.

Decrease in soluble-Al

The application of OMBW compost had a significant effect on reducing soluble-Al of acid sulfate soils. The effect of the application of OMBW compost can be seen in Figure 4.

Based on the picture above shows that only b_2 treatment is significantly different from b_0 (control) in reducing soluble-Al acid sulfate soil 2 WAA. ANOVA test showed that OMBW compost had a significant effect on reducing the soluble-Al of acid sulfate soils. According to Tan (2011), soluble-Al is still the main problem with low soil pH. The effect of OMBW compost application can be seen in Figure 4. Only the b_2 treatment was significantly different from the b_0 treatment in reducing soluble-Al of acid sulfate soils 2 WAA.

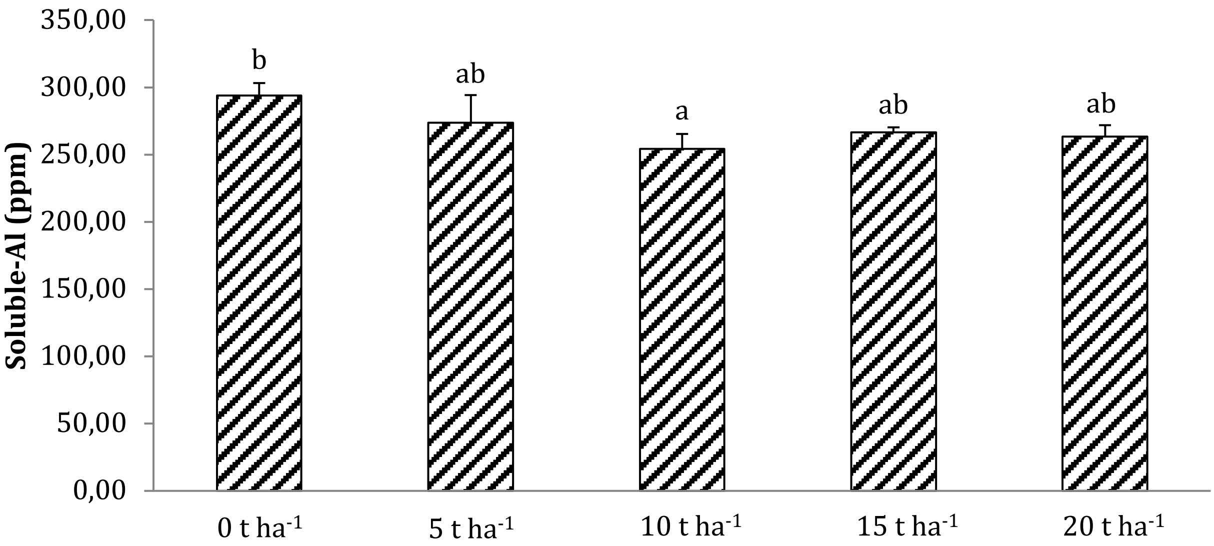

Figure 4. Decrease in soluble-Al of acid sulfate soils at 2 WAA. b_0= 0 t ha^{-1}; b_1= 5 t ha^{-1}; b_2= 10 t ha^{-1}; b_3= 15 t ha^{-1}; b_4= 20 t ha^{-1}. The line above the bar chart represents the standard error of the treatment (n=5). The different letters between the columns above the line indicate that the treatment has a significantly different effect based on Duncan's Multiple Range Test (DMRT) at the α 5% level.

This is because soluble-Al can be neutralized by adding organic matter to the soil due to the binding of Al^{3+} ions by the functional groups of organic acids, for example humic acid. Based on the report of Salim (2015), OMBW compost contains 2.44% humic acid. Humic acid contains functional groups that can bind Al-soluble, the activity of functional groups will reduce the hydrolysis process and will decrease H^+ ions and increase the pH value. This is also consistent with what was reported by Ifansyah (2013), humic acid showed a positive correlation with an increase in pH and a decrease in soluble-Al. This is also reinforced by research data which shows that the treatment has a significant effect on the pH value.

However, the results of the study also found that the correct dosage was needed in application of OMBW compost, this could be seen because the b_4 treatment which was the treatment with the highest dose did not have a significant effect on the b_0 treatment. This is presumably because there is a limit in increasing the pH value by giving acids or bases which is known as soil refractory. Soil buffering capacity is the ability of the soil to maintain a balance of nutrient levels contained in the soil solution. The exchange of soil cations creates the development of active and potential acidity. Active acidity is the acidity caused by H^+ ions in the soil solution, while the potential acidity is caused by H^+ and aluminum (III) (Al^{3+}) ions which are absorbed on the surface of the absorption complex. If H^+ ions are neutralized with alkalis (bases that come from compost), the potential acidity will release H^+ ions which can be exchanged into soil solution to restore soil equilibrium. No change in soil reaction occurs until the H^+ ion reserves run out because the H^+ ions released make the Fe reduction process inhibited (Tan, 2011). This was also confirmed by the lowest average Eh value found in the b_4 treatment due to the increased oxidation of H^+ ions. Based on the data above, the best application of OMBW compost to reduce soluble-Al of acid sulfate soils was found in b_2 treatment at a dose of 10 t ha^{-1} or converted to 42.74 g bucket^{-1} because it was significantly different from treatment b_0.

4. Conclusions

The application of OMBW compost increased the soil pH, but it did not decrease the Eh value of the soils. The application reduced the soluble-Fe and Al in acid sulfate soils. The best dosage of OMBW compost to changes in some chemical properties of acid sulfate soils was 10 t ha^{-1} because it significantly affected the pH, especially the KCl pH (potential), decreased soluble-Fe and Al.

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