Journal of Smart Agriculture and Environmental Technology
e-ISSN:3021-8802
Vol. 1, No. 3, December 2023
https://josaet.com | https://doi.org/10.60105/josaet.2023.1.3.73-77

Research Paper

Micro-remediation Experiments of Acid Sulphate Soils

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Article History: Received: August 28, 2023, Accepted: October 12, 2023

Abstract

Soils that are acid sulfuric have low productivity, because the physical and chemical conditions of this land are characterized by high acidity. Based on the problem of acid sulphate soil, micro remediation research is carried out to fulfill objectives such as the formation of good and sustainable cultivation land. Acid sulphate soil was taken from at Mesuji Ogan Komering Ilir in January 2023. The method in this study was field observation by taking samples using a belgi drill at several points of the land. The study used a pot with a size of $12\,\text{cm} \times 15\,\text{cm}$ which was washed 5 times to remove the acid content in the soil. The pot contains 40% soil, 40% sugarcane husk and 20% rice husk biochar. The object used in this study is the ginger plant. High levels of soil acidity can trigger the dissolution of toxic elements and increase the cause of nutrient deficiencies. Adsorption of complexes in the soil will offer sufficient nutrients for plant development if the soil is rich in soluble bases. Conversely, the soil will tend toward acid if Al and H dominate the adsorption complex. The results of this study can be concluded that micro remediation using sugarcane pulp and biochar has a very real impact. The use of sugarcane bag and biochar in this study helped reduce the initial Al of $9.97\,\text{Cmol}^+/\text{kg}$ to $1.65\,\text{Cmol}^+/\text{kg}$ in the soil and lowered the soil acidity level in the initial soil with a pH of 3.26 to a soil pH of 4.94.

Keywords

Acid Sulphate Soil, Biochar, Sugarcane husk

1. INTRODUCTION

Soils that are acid sulfuric have low productivity, because the physical, chemical, and biological conditions of this land are characterized by high acidity. High concentrations of Al and Fe elements are potentially toxic, limiting the main nutrients such as phosphorus. This causes the soil's ability to support plant growth to be limited (Fahmi and Khairullah, 2018). The material, which contains high levels of pyrite (FeS_2), develops into acid sulphate soils. In soils that are often flooded and contain a lot of organic matter and dissolved sulfates, they generally come from seawater, resulting in pyrite accumulation. When oxygen drains into the stagnant soil, pyrite oxidizes and turns into sulfuric acid.

Nopriani et al. (2023) stated that acid sulphate soils are usually found in coastal lowlands. Some of these lands are planted with agricultural crops, but productivity is low and this has been associated with soil infertility related to Al toxicity. In these acid sulphate soil conditions, usually liming to remove Al poisoning is impractical. The application of organic materials to overcome Al poisoning is considered a better choice. Efforts to improve the quality of this acid sulfate soil by adding organic matter from waste of sugarcane blotong and rice husk biochar which contains $CaCO_3$. The higher the dose given, the higher the C-organic (Purba et al., 2015).

Blotong comes from sugar factory waste which has a very large opportunity to be used as a soil amendment, one of which is a source of organic matter and does not interfere with the vegetative and generative phases (Rajiman et al., 2008). Meanwhile, rice husk biochar is also a soil enhancer which has the function of improving soil fertility. The use of these soil amendments is one of the ways to utilize agricultural waste such as sugar cane husks, corn cobs, rice husks, tofu dregs, rice washing water, and so on. The raw material for this soil enhancer is organic, so it will have an impact on the soil and the environment. However, this soil enhancer is difficult to decompose.

Based on the problem of acid sulphate soil, many studies have been carried out to improve soil quality, especially to be managed as agricultural land. The purpose of this research is to experiment with microremediation of acid sulphate soils to fulfill objectives such as establishing good and sustainable cultivation areas using organic matter.

2. EXPERIMENTAL SECTION

2.1 Research Location, Biomaterial Use, and Cultivation Procedures

Acid sulphate soil was taken from the Mesuji Ogan Komering Ilir, South Sumatra, Indonesia in January 2023. The method in this study was field observation by taking samples using a belgi drill at several points of the land. Soil sampling was taken randomly.

The study used pots with a size of 12 cm × 15 cm which were washed 5 times to remove the acid content in the soil. Under these conditions the soil water content is maintained at field capacity. Because the drainage process has stopped or almost stopped flowing due to gravity before the soil is fully saturated. Applying organic matter also helps in retaining water and keeping the soil moist. This is in line with Saxton and Rawls (2006) that organic matter is capable of retaining groundwater. The pot contains 40% soil, 40% sugarcane husk and 20% rice husk biochar. The object used in this study is the ginger crop. Observations of plant adaptation were carried out by looking at plant growth for 4 weeks from 7 April to 7 May 2023. Observations were made on the number of leaves. Analysis of soil chemical parameters carried out in the laboratory includes pH, organic C, available phosphorus, potassium and exchangeable aluminum.

Ginger is a commodity that has high economic value and is used as a cooking spice and raw material for traditional medicine. Ginger plant is one of the plants that can adapt to temperature differences. Ginger plants can also grow in lowland or highland areas. Based on Utara (2012) stated that market demand could not be fulfilled due to land problems which hampered commodity production.

3. RESULT

Soils in South Sumatra on average have low soil fertility which is a factor in crop productivity. With this to meet food needs there are efforts to improve the land to be productive. So, this micro experiment will be very impactful if there are significant changes and will certainly optimize crop production in a farm. Table 1. Below are the results of analysis of acid sulfate soils.

3.1 Sugarcane Blotong, Rice Husk Biochar and Liquid Organic Fertilizer

Blotong and biochar are one of the raw materials for soil amendments that help improve soil physical and chemical properties such as water retention, low unit weight, porous and high cation exchange capacity. Blotong and biochar can also supply organic matter and provide nutrients. This research utilizes sugar cane and rice husk waste. The content of sugarcane blotong and rice husk biochar can increase the C-organic content in acid sulfate soils and help reduce soil acidity. Based on the results of the analysis carried out, the soil pH is still relatively acidic, if the soil amendment is carried out in an active way, the soil pH will increase (neutral). Soil acidity is bad for plant growth because it causes toxins. Therefore, the use of sugar cane bag and rice husk biochar is an option in improving the soil, as well as in utilizing waste.

The soil supplement used is liquid organic fertilizer. The liquid organic fertilizer has the availability of nutrients that can support plant growth. However, the nutrient content in liquid organic fertilizer cannot replace chemical fertilizers. Because nutrient levels in liquid organic fertilizers are very small compared to chemical fertilizers. The use of chemical fertilizers can accelerate plant growth processes such as plant height, leaf growth, accelerate flowering to the fruit formation process. This is in line with Dhani et al. (2014) stating that sufficient nutrients can help encourage and accelerate the process of plant growth. Therefore the use of liquid organic fertilizer can be a supplement or vitamin for soil and plant growth.

3.2 pH

The results of the analysis have found that the pH of the soil before remediation is 3.26 which is very acid. This experiment did not provide agricultural lime, but only used ameliorants or soil enhancers such as sugar cane pulp and rice husk biochar. This is supported by Nopriani et al. (2023) who stated that applying agricultural lime is impractical for acid sulfate soils, but can be replaced by adding organic matter.

The pH content has increased to 4.94 (acid). This happened as a result of applying sugarcane blotong and rice husk biochar to the land planted with ginger for two months. P elements bound by Al and Fe can cause soil acidity. The high level of soil acidity can trigger the dissolution of toxic elements and cause an increase in nutrient deficiencies, resulting in a decrease in soil productivity (Ramadhan et al., 2018).

The effect of providing organic matter is that it can maintain soil moisture, improve physical and chemical properties such as soil structure, increase pH and reduce Al and Fe (Iyus et al., 2021). There is a relationship between soil pH and Al. A low soil pH value will create a high Al content.

3.3 C-Organic

C-organic is the carbon content in soil organic matter. Based on the results of c-organic analysis, the effect was due to the addition of organic matter from sugarcane blotong and rice husk biochar. The c-organic content of sugarcane husks was 26.51% while the 12.6% c-organic content was in the husk biochar.

The c-organic content in the yield was 5.06% before treatment while the % c-organic in the soil after treatment was 6.57%. The increase experienced occurred due to the supply of organic matter from sugarcane blotong and rice husk biochar.

Table 1. Analysis of Chemical Characteristic of Acid Sulphate Soil

Parameter	Analysis Method	Before Treatment	After Treatment
pH H2O	Electrometry	3.26	4.94
Total-Organic Carbon (%)	Kjeldahl-titrimetry	5.06	6.57
Total-N (%)	Walkey & Black	0.25	0.36
Available P-Bray I (mg kg-1)	Spectrophotometry	28.09	63.61
K2O in 25% HCL (cmol kg-1)	Flamephotometry	126.24	103.64
Al-dd (Cmol(+) kg-1)	Titrimetry	9.97	1.65

Source: Integrated Laboratory Research and Development Departement PT. Binasawit Makmur – Sampoerna Agro, Tbk.

Organic matter is one of the important factors in the soil because it determines the yield of agriculture. Organic matter can also lower soil pH levels which causes high Al levels in the soil. The danger of Al levels in soil causes toxicity as a result of oxidation in acid sulphate soils.

3.4 N-Total, P-Available and K2O

Based on Table 1, low levels of N can be associated with low soil organic matter because the N element comes from soil organic matter. The element nitrogen includes macro nutrients such as phosphorus and potassium. The third content in the soil determines the managed plant growth. The results of laboratory analysis showed that the N level increased by 0.11% before the treatment the N level was 0.25% and after the treatment the N level increased to 0.36%.

3.5 Phosphorus (P)

Phosphorus (P) is an element needed by microorganisms to remodel cells. All the amount of phosphorus (P) in the soil, including those that are accessible, not available, or bound by other components (Nazella, 2023). The supply of phosphorus (P) which tends to be limited to acid sulfate soils in tidal lands is caused by two other factors, namely the level of acidity (pH) and the level of solubility of metals in the soil. This is the main reason why the P content in the soil is low (Selviya, 2023).

The available P content in the initial soil was 28.09 ppm which increased to 63.61 ppm. A characteristic feature of acid sulphate soils is the presence of a layer of sulfidic material (such as sulfur clay) which contains a lot of pyrite (FeS_2). The reaction between pyrite compounds and oxygen in the soil produces hydroxide iron ($Fe(OH)_3$), sulfate (SO_4^{2-}), and hydrogen ions (H^+), which in turn significantly increases soil acidity. As a result, ions such as Fe^{2+}, Al^{3+}, and Mn^{2+} become more soluble in the soil and can be potentially harmful to plants. In addition, phosphates also bond to iron or aluminum to form compounds such as iron phosphate or aluminum phosphate. As a result, the availability of phosphate in the soil will also be affected and reduced (Emi, 2022).

3.6 Potassium (K)

Some of the K (potassium) cannot be easily exchanged and is usually converted to the form K-dd (potassium which is difficult to exchange) or K solution. The weathering characteristics of minerals have an influence on the rate and amount of potassium (K) released in the soil. This release of K usually occurs at varying rates depending on the type of mineral and environmental conditions. K can be lost through the leaching process, in which water removes K from the soil layer. K can also change its form in the soil, for example into compounds that are less available to plants. The K content in the initial soil was 126.24 and the final soil was 103.64.

Potassium content in the research samples is related to soil pH. The more acidic the soil pH, the lower the potassium content in the soil and vice versa. H^+ ion activity or pH in soil solution has a significant influence on nutrient availability. As mentioned by Triharto et al. (2014), soil can become acidic due to a decrease in cations such as calcium, magnesium, potassium, or sodium in the soil.

Potassium (K) has a high tendency to dissolve from soil under conditions of low pH and low base saturation. However, aluminum (Al) can bind K under neutral pH conditions and high base saturation. pH and soil base saturation have an impact on the availability of elemental K. When soil pH increases, Al^{3+} ions will precipitate as $Al(OH)_3$, which causes an increase in K uptake by the soil and reduces K loss through the leaching process.

3.7 Sugarcane fruit cake

Sugarcane fruit cake is one of the raw materials for soil improvement because sugarcane fruit cake contains 26.51% Carbon (C), 1.04% Nitrogen (N), 6.142% Phosphate (P), 0.485% Potassium (K), and 0.485% Sodium (Na), 0.082%, Calcium (Ca) 5.785%, Magnesium (Mg) 0.419%, Iron (Fe) 0.191%, Manganese (Mn) 0.115% (Aidil et al., 2023). Therefore, the parameters analyzed in the initial soil underwent changes due to the addition of sugarcane blotong and rice husk biochar.

3.8 Liquid Organic Fertilizer

This study also used liquid organic fertilizer as a soil supplement to support nutrient availability for ginger plants.

Figure 1. Growth performance of ginger plants after treatment

Using organic matter can help improve the soil in the long term.

3.9 The Exchangeable Aluminium (Exch. Al)

Exchangeable aluminum in the initial soil has a very high value of 9.97 Cmol/kg and the final soil has decreased to 1.65 Cmol/kg. This also has an effect because of the input given. Al-dd is related to soil acidity because Al. High Al content in the soil can absorb P nutrients in the soil.

The initial soil has a very high aluminum content. This has the potential for plant poisoning by high Al and the availability of nutrients such as phosphorus is also low because it is bound by aluminum. According to Emi (2022), adsorption complexes in the soil will offer sufficient nutrients for plant development if the soil is rich in dissolved bases. Conversely, the soil will tend toward acid if Al and H dominate the adsorption complex.

In this condition, the saturation values of Al and H will increase, while the values of Fe and Mn will also increase. This can cause plants to experience Al, Fe, and Mn poisoning. It should be remembered that the level of base saturation in the soil is always opposite to the value of Al and H saturation.

3.10 Growth performance of crop adaptation

Crop growth was observed for two months from April 7 to May 7. The condition of the ginger plant shows good growth (Figure 1). The number of leaves on April 7 was 7, and on May 7 there were 9. The condition of plants that grow well is an indicator that acid sulphate soil that has been oxidized can recover so that it can be planted with cultivated plants.

4. CONCLUSION

The results of this study can be concluded that micro remediation using sugarcane pulp and biochar has a very real impact. The acidity of the soil in acid sulphate affects the fertility and availability of elements in the soil. The use of sugarcane blotting and biochar in this study helped to reduce the initial Al of 9.97 $Cmol^{+}/kg$ to 1.65 $Cmol^{+}/kg$ in the soil and reduce the acidity of the soil in initial soil with a pH of 3.26 to a pH of 4.94.

5. ACKNOWLEDGEMENT

I would like to express my gratitude to Sugarcane Plantation PT Pratama Nusantara Sakti (PNS), Ogan Komering District, South Sumatra, Indonesia, for their assistance in providing soil samples and Blotong material.

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