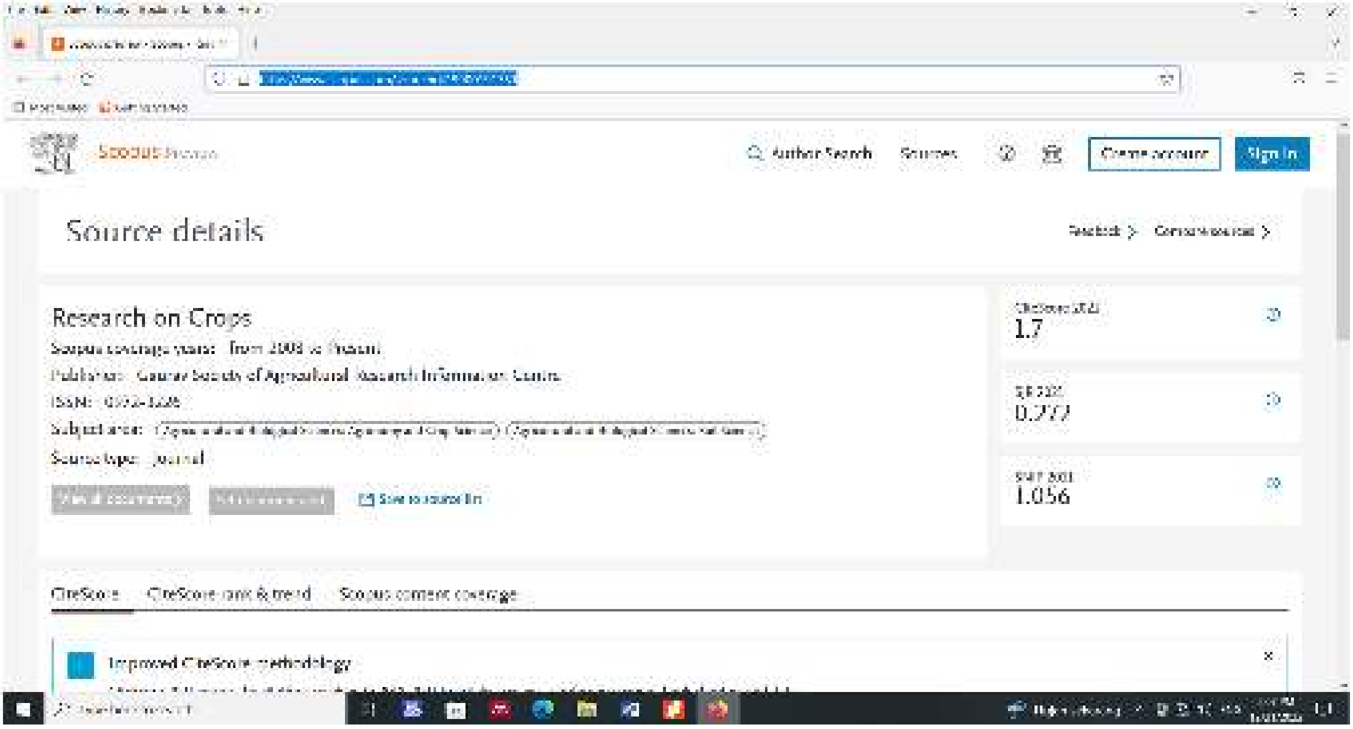
MANUSCRIPT HISTORY
Published in
Research on Crops (Q3)

Publisher: Gaurav Society of Agricultural Research Information Centre

https://www.scopus.com/sourceid/19900191751



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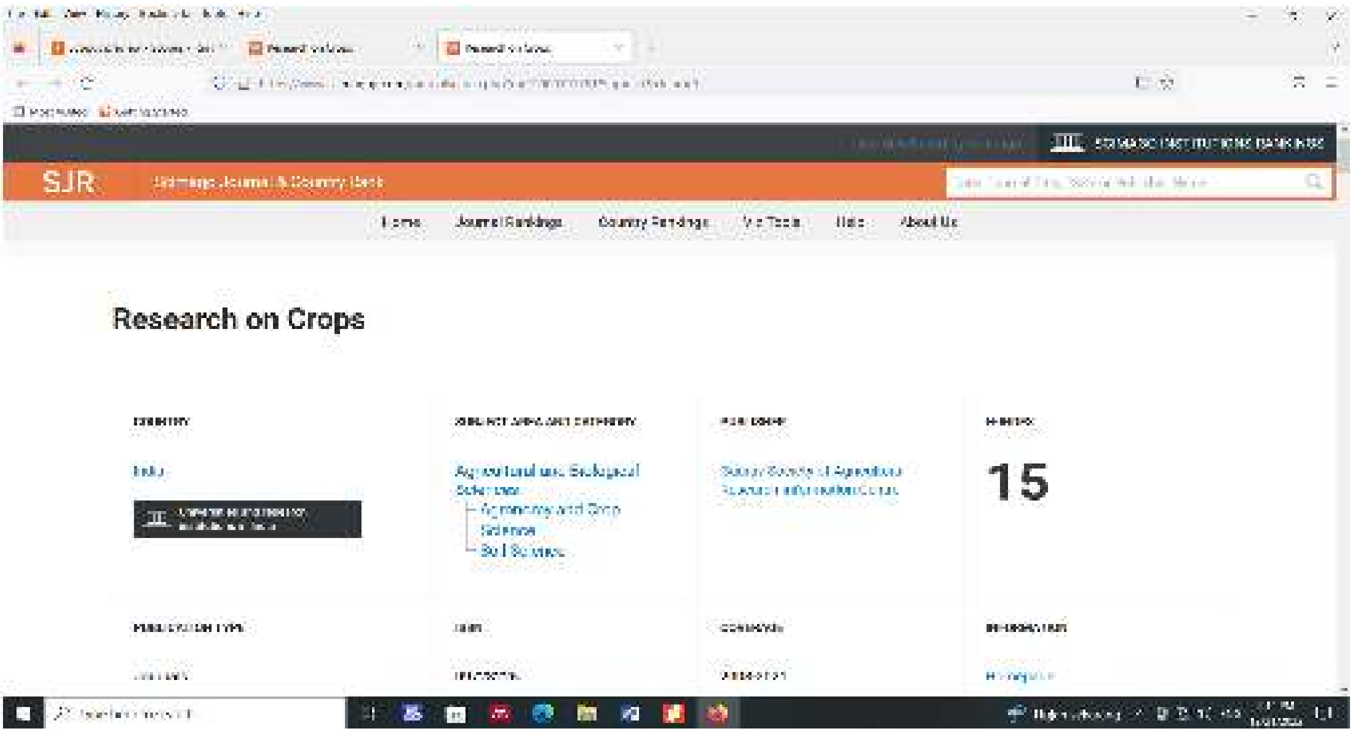

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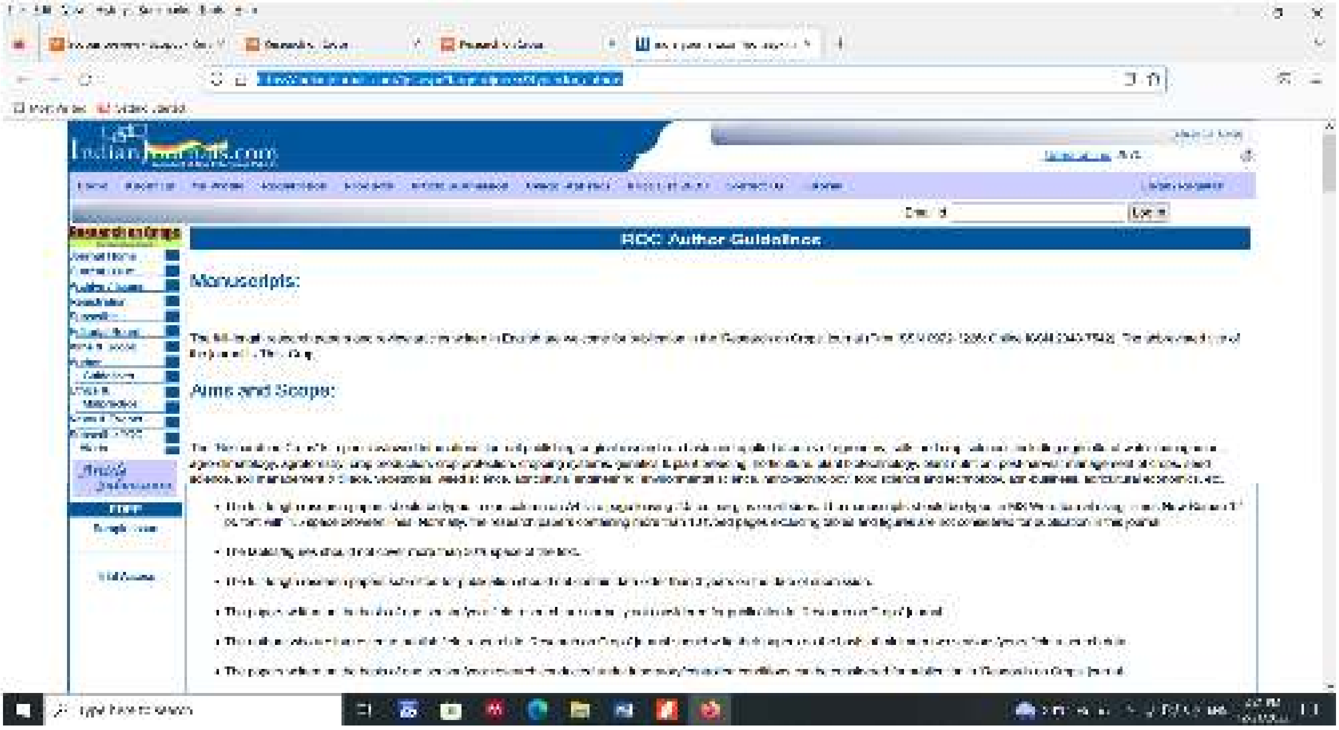

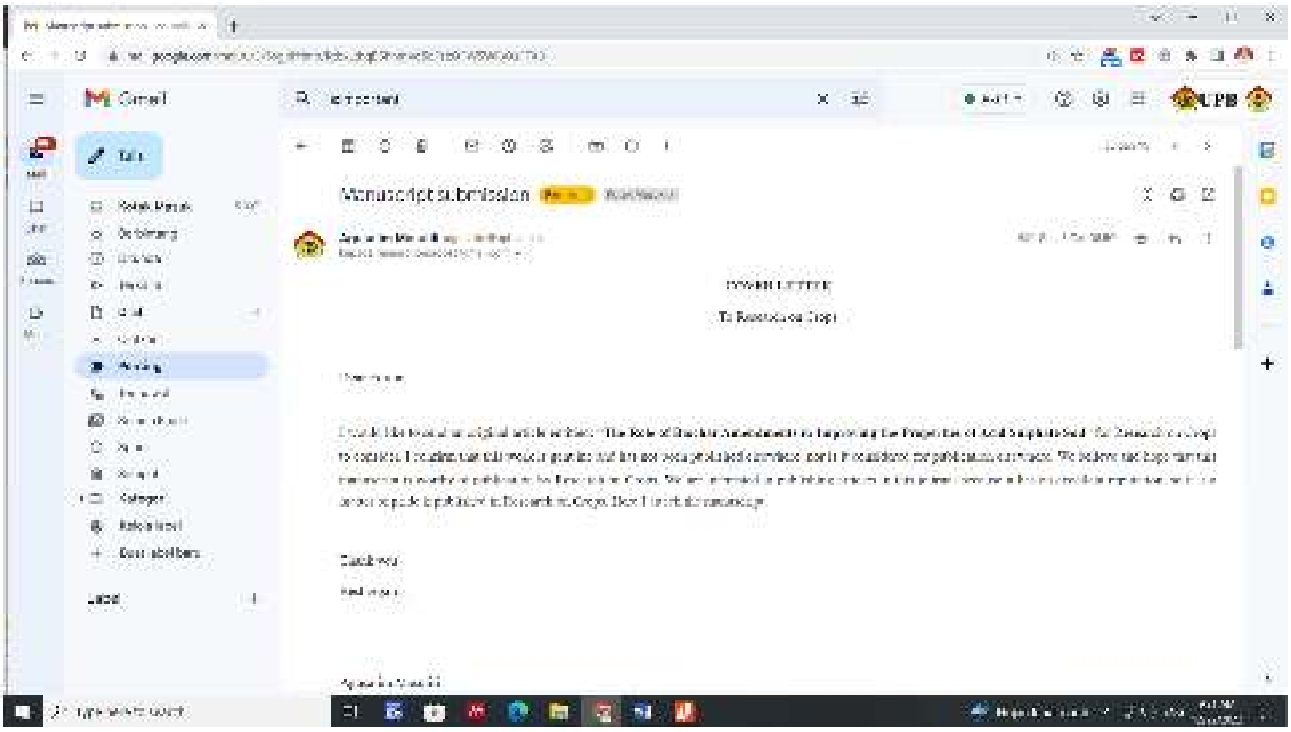

Manuscript submission : 3 Oktober 2022

COVER LETTER

To Research on Crops

Dear Editor,

I would like to send an original article entitled: "**The Role of Biochar Amendments in Improving the Properties of Acid Sulphate Soil"** for Research on Crops to consider. I confirm that this work is genuine and has not been published elsewhere, nor is it considered for publication elsewhere. We believe and hope that this manuscript is worthy of publication by Research on Crops. We are interested in publishing articles in this journal because it has an excellent reputation, so it is a matter of pride if published in Research on Crops. Here I attach the manuscript.

Thank you
Best regards,

Agusalim Masulili
Panca Bhakti University, Pontianak, West Kalimantan, Indonesia

The Role of Biochar Amendments in Improving the Properties of Acid Sulphate Soil

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ABSTRACT

Acid sulphate soil has the potential for agricultural development. Nevertheless, this soil has various soil properties problems that can inhibit plant growth. The granting of amendments can improve the properties of the soil. The study aimed to know the role of rice husk biochar combined with amendments to *Chromolaena odorata*, rice straw, and rice husk ash to improve the properties of acid sulphate soil. The study was conducted in a greenhouse and arranged in a complete randomized design (CRD) with three replications. Biochar amendments consisted of nine kinds, namely: without amendments (control), *Chromolaena odorata* (10 t/ha), rice straw (10 t/ha), rice husk biochar (10 t/ha), rice husk

ash (10 t/ha), *Chromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha), rice straw (10 t/ha) + rice husk biochar (5 t/ha), *Chromolaena odorata* (10 t/ha) + rice husk ash (5 t/ha), and rice straw (10 t/ha) + rice husk ash (5 t/ha). The results showed that the amendment of rice husk biochar combined with amendments to *Chromolaena odorata* and rice straw, respectively, had a good effect on improving soil physical properties, namely total soil pores, reducing soil content weight and soil strength. Its effect on soil chemical properties is that it can increase pH, C-organic, P-available, cation exchange capacity (CEC), and lower Al-dd and Fe soluble. The research findings show that applying biochar and organic amendments to *Chromolaena odorata* and rice straw can potentially improve the properties of acid sulphate soil. In future research, we recommend increasing the carrying capacity of acid sulphate soil against plant growth, and it can be done by improving soil properties through the organic amendments application of *Chromolaena odorata* or straw enriched with rice husk biochar.
Key words: *Chromolaena odorata*, rice husk ash, rice husk biochar, rice straw, soil properties
Running headline: Improving the properties of acid sulphate soil

INTRODUCTION

Acidic sulphate soils are the common name for soils and sediments containing iron sulfide, namely pyrite (Das and Das, 2015). In agricultural development, efforts to reclaim acid sulphate soils do not always result in soil productivity since improvements in soil properties after reclamation are not achieved. So far, efforts have been encouraged to overcome existing obstacles after reclamation, including inorganic fertilizers (urea, TSP, KCl) and liming (dolomite). However, rice crop productivity in this field has not been optimal.

Inorganic fertilizers increase over time and can even decrease land quality if inputs are high and intensive. Liming can only cope with short-term pH and is often done repeatedly. As a result, high costs are needed, which becomes a burden for farmers and will threaten the sustainability of land productivity. Therefore, it is necessary to manage land based on land amendments that can improve the nature of sustainable soils.

Reclamation can result in changes in soil properties and is related to the potential for pyrite oxidation, affecting the increase in soil packaging and the solubility of ions such as Al, Fe, Mn, and sulphate. On the other hand, this soil has a high clay content which affects the increased weight of the contents. Therefore, the development of acid sulphate soil for agriculture after reclamation requires proper management of soil amendments to achieve the formation of steady cultivated land and sustainable farming. Das and Das (2015) suggested that acid sulphate soil having a high pH can inhibit plant growth. In addition, when this soil is drained, it can affect an increase in sulfuric acid and the release of iron, aluminum, and other heavy metals. Shamshuddin *et al.* (2014), stated that plants grown in acidic sulphate soils could not grow well due to low pH and high Al content.

Biochar is one of the soil amendment materials with the long-term potential to maintain soil fertility. The results of experts' investigations into the phenomenon of terra preta show that soil fertility is stable in the Amazon basin due to the presence of black carbon, the result of the management of the Amerindian nation 500–2,500 years ago. This carbon black is nothing but biochar immersed in the soil. Murtaza *et al.* (2021) found that 4.0 t/ha cotton biochar improves physical, chemical, soil biological, and soil fertility properties and peanut productivity in Alfisol. Zhang *et al.* (2022) have proven that biochar provides effects such as liming and providing nutrients that lead to soil improvement. Kocsis *et al.* (2022) stated that biochar has a high porosity and can improve the physicochemical and biological properties of the soil. In line, Sovova *et al.* (2021) found biochar had a good influence on improving the soil properties of regosol. Further afield, Das *et al.* (2021) suggest the application of biochar to the soil can provide agronomic benefits, support crop yield improvement, and improve soil quality and health. In addition, biochar has been shown to act as a fertilizer and soil conditioner.

Nutrient retention and higher nutrient availability were found in the soil after biochar addition, associated with higher CEC, surface acreage, and direct nutrient addition (Glaser *et al*., 2002). In line with opinions, Murtaza *et al*. (2021) suggested that biochar is a recalcitrant carbon product of biomass produced through the pyrolysis process. The recalcitrant properties of biochar are distinctive and important to the long-term improvement of soil properties through the effects of their residues that can persist for a long time in the soil. Beusch (2021), biochar can contribute to soil fertility and crop productivity, and Kalu *et al*. (2021) increase water availability and lower soil BD.

Applying biochar can improve soil properties and long-term crop productivity compared to other organic amendments. In other organic amendments, research results by Suri and Yudono (2020) showed that giving *Cromolaena odorata* as compost can increase plants' nutrition and nutrient uptake. Agustina *et al*. (2019) argued that using *Chromolaena odorata* and rice straw can maintain soil quality. Mahmoud *et al*. (2009) also showed rice straw compost could improve soil quality. The same was discovered by Gewaily (2019), that straw compost can increase potassium availability.

Furthermore, the results of the study by Yin *et al*. (2022) showed the weight of the soil contents decreased, and the water-holding capacity and total porosity increased in the soil with rising rice husk ash. Adding rice husk ash neutralizes soil acidity and increases plant nutrient availability. Research by Lestari and Rachmawati (2020) showed that applying rice husk ash (4 t/ha) can increase rice growth and reduce salinity stress.

Previously, several studies on the effect of biochar singularly have been carried out, including on the P-availability (Zhang *et al*., 2022), improvement of soil physical properties (Aslam *et al*., 2014), chemical properties of the soil (Bista *et al*., 2019), and some soil characteristics (Yadav *et al*., 2018), soil aggregate stability (Ebido *et al*., 2021), and to the development of rice roots (Kartika *et al*., 2021). However, no research has been found on how the role of biochar was given together with other organic amendments in acid sulphate soil. Therefore, it is necessary to study how the effect of biochar is given together with organic amendments to *Chromolaena odorata* and rice straw. This research is expected to contribute to improving the nature of acid sulphate soil in West Kalimantan, which has been one of the types of soil widely used as an agricultural activity for rice crops. In connection with this hah, this study aimed to know the role of rice husk biochar combined with amendments to *Chromolaena odorata*, rice straw, and rice husk ash in improving the properties of acid sulphate soil.

MATERIALS AND METHODS

Study Area

This research was conducted from September to November 2021. The research site was carried out at the Laboratory of the Faculty of Agriculture, Universitas Panca Bhakti, Pontianak, West Kalimantan Province, Indonesia. The height of the study site is one m from above sea level, with an average temperature and humidity of 27.6 ºC and 82.8%, respectively. The research position is located at a latitude of 2º05' N–3º 05' S and longitude of 108º30' E–144º10' W.

Experimental Design

The study was conducted in a greenhouse and arranged in a complete randomized design (CRD) with three replications. Biochar amendments consisted of nine kinds, namely: without amendments (control), *Chromolaena odorata* (10 t/ha), rice straw (10 t/ha), rice husk biochar (10 t/ha), rice husk ash (10 t/ha), *Chromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha), rice straw (10 t/ha) + rice husk biochar (5 t/ha), *Chromolaena odorata* (10 t/ha) + rice husk ash (5 t/ha), and rice straw (10 t/ha) + rice husk ash (5 t/ha). In all, 27 polybags are needed.

Research Procedures

The material in this study used acid sulphate soil taken on the experimental land of the West Kalimantan, Sungai Kakap, Agricultural Technology Assessment Center, and land farmers' work on rice crops. This area included the development of swampland agriculture which has built irrigation canals since 1980 and was currently designated as an Integrated Farmer Business Area. Soil picking was carried out randomly at a soil depth of 0-20 cm, then mixed, air-dried, and cleaned. Then put in polybags was as much as 8 kg.

Biochar was made by taking rice husk from grain harvested from rice plants grown directly in the acid sulphate soil of the Kakap River, West Kalimantan, Indonesia. First, the rice mill was taken the grain to obtain rice husk. Furthermore, the rice husk was placed on the pyrolysis device to be processed into biochar by incomplete combustion (limited air) in a reactor made of Pertamina drums.

Organic amendments to *Chromolaena odorata* were taken from around the field, then chopped to a size of 1-2 cm. Rice straw was taken from waste harvested rice grown and grown by farmers in acid sulphate soil and chopped within 1–2 cm. Rice husks were taken from waste from rice milling, then used as ash through burning in open areas to produce grayish-white ash.

Prepared acid sulphate soil introduced into 27 polybags until it reached 8 kg. Further, the dose of soil amendment was calculated based on the soil weight in the polybag area, mixed with the soil in each polybag to a soil depth of 20 cm, after which it was incubated with moisture content until it was closed to the field capacity for 30 days.

At 30 days after incubation, from each study unit, soil sampling of about 50 g was undisturbed to determine the weight of the soil moisture content accident. In addition, a disturbed soil sample of 100 g was taken from each research unit for analysis of chemical properties.

Observation parameters

The soil bulk density (BD) was determined by the clod method described by Blake & Harke. The total pore was calculated from the soil moisture content (v/v) at the matrix potential of 0 kPa. The available groundwater was estimated by reducing the soil moisture content in the matrix potential by -33 kPa (field capacity) with the soil moisture content in the matrix potential, which was -15 Mpa (wilting point). The soil moisture content at this potential matrix was determined using a pressure plate device. The strength of the soil was measured with a hand penetrometer (Daikie) at a soil depth of 15 cm.

The pH level was measured in a soil solution at a ratio of 1:2.5 (with deionized water), using a pH meter (Jenway 3305). Walkley and Black's wet oxidation method was used to determining organic C levels (Soil Survey Laboratory Staff). Total N levels were measured by the Kjeldhal (Bremner and Mulvaney) method. Al_3 + and Fe_2+ were extracted with 1 M KCl (Barnhisel and Bertsch). CEC was extracted with 1 M NH_4Oac (buffer at pH 7.0), and the concentration of alkaline cations was measured using AAS (Shimadzu), P-available with Bray I.

Statistical Analysis

Statistical analysis was carried out on each observation parameter data to determine the effect of the amendments on the nature of acid sulphate soil. The data obtained were analyzed by analysis of variance (ANOVA) at 5% significant level. In addition, the test of least significant difference (LSD) at 5% significant level was used to determine the average value between treatments.

RESULTS AND DISCUSSION

Effect of various soil amendments on some physical soil properties

Applying biochar improved the soil's physical properties (Aslam *et al*., 2014). Applying biochar and organic amendments influenced the changes in some of the observed soil physical properties. The statistical test is shown in Table 1. The soil BD was lower on all amendments granted. For example, in soils fed a single rice husk biochar (10 t/ha), soil BD decreased from 1.27 mg/m^3 in the control soil to 1.15 mg/cm^3. However, not significantly different from soils was given straw (10 t/ha) and a combination of straw + biochar, *Chromolaena odorata* + rice husk ash, and straw + rice husk ash. Furthermore, in the combination of *Cromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha), a BD of 1.13 mg/m^3 was obtained and was the lowest soil BD. Still, it was not significantly different from the soil, given a combination of straw (10 t/ha) + rice husk biochar 5 (t/ha) produced soil BD of 1.14 mg/m^3. These results indicate an improvement in the physical soil properties if biochar was given together with organic amendments to *Chromolaena odorata*.

Table 1. Effect of rice husk biochar with soil amendments on some physical properties of acid sulphate soil at one month after incubation

Soil amendments	BD (mg/m^3)	Total pores (%)	Penetration resistance (N/cm^2)		
			pF 0	pF 2	pF 2.5
Control	1.24 e	44.43 a	36.67 b	310.00 e	500.00 d
C. odorata (10 t/ha)	1.16 c	52.17 e	20.00 a	230.00 abc	403.33 bc
Rice straw (10 t/ha)	1.17 bc	53.27 f	16.67 a	243.33 bc	393.33 b
Rice husk biochar (10 t/ha)	1.15 b	54.21 g	14.33 a	223.33 ab	390.00 b
Rice husk ash (10 t/ha)	1.19 d	47.30 b	20.00 a	270.00 d	403.33 bc
C. odorata (10 t/ha) + biochar (5 t/ha)	1.13 a	56.73 i	10.00 a	220.00 a	340.00 a
Rice straw (10 t/ha) + rice husk biochar (5 t/ha)	1.14 ab	55.57 h	13.33 a	223.00 ab	360.00 a
C. odorata (10 t/ha) + rice husk ash (5 t/ha)	1.15 b	48.90 c	16.67 a	240.00 bc	420.00 c
Rice straw (10 t/ha) + rice husk ash (5 t/ha)	1.16 bc	50.30 d	20.00 a	246.67 c	403.33 bc

Remarks: The average numbers followed by the same letter in the same column show no significant difference in the LSD test at 5% significant level.

Applying various biochar amendments and their combinations increased the soil's total pore. The statistical test results are shown in Table 1. There was a significant difference in the total pore of the soil between the various amendments. Control soils had the lowest total pore (44.43%), contrasting with soils that provided various amendments. On soils fed with rice husk biochar (10 t/ha), the total soil pore increased to 54.21%, significantly different from other single amendments. Furthermore, a combination of *Cromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha) caused the total pore to increase to 56.73% and was the highest total pore.

The application of various amendments, both single and combined, affected the decrease in soil strength as measured as soil penetration resistance (N/cm^2) at conditions of pF 0, pF 2, and pF 2.5, where the higher the soil matric suction (pF), the higher the soil penetration resistance. The results of statistical tests (Table 1) show that under saturated conditions (pF 0), the various soil amendments do not offer a noticeable difference. In pF 2 shows that the application of rice husk biochar (10 t/ha) can reduce soil penetration resistance from 310.00 N/cm^2 (control soil) to 223.33 N/cm^2. No significant difference between soils fed with *Chromolaena odorata* and rice straw or a combination of straw (10 t/ha) + rice husk biochar (5 t/ha). Furthermore, soils given a combination of *Cromolaena odorata* (10 t/ha) + biochar (5 t/ha) obtained the lowest penetration resistance (220.00 N/cm^2). Still, it was not significantly different from soils have given *Chromolaena odorata* (10 t/ha), rice husk biochar (10 t/ha), and a combination of straw (10 t/ha) + biochar (5 t/ha).

Similarly, at pF 2.5, the application of rice husk biochar (10 t/ha) was single. It could reduce the value of soil penetration resistance from 500.00 N/cm^2 on control soil to 390.00 N/cm^2. Still, it was not significantly different from soils have given *Chromolaena odorata* (10 t/ha), straw (10 t/ha), rice husk ash (10 t/ha), and a combination of rice straw (10 t/ha) + rice husk ash (5 t/ha). Furthermore, the combination of *Cromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha) achieved the lowest penetration resistance (340.00 N/cm^2). Still, it was not significantly different from the combination of rice straw (10 t/ha) + biochar (5 t/ha) (360.00 N/cm^2). It indicated that rice husk biochar had the potential to control soil strength. In line with Das *et al*. (2021), applying biochar into the soil could reduce soil strength.

Effect of rice husk biochar on some soil chemical properties

The application of several soil amendments and their combinations could influence some chemical properties of acid sulphate soil. The results of statistical tests in Table 2 show that soil reaction (pH) of the soil increased in all treatments given compared to controls. For example, in the application of rice husk biochar showed an increase in pH from 3.36 (control soil) to 4.40 on soils given biochar (10 t/ha) but did not significantly different from other single amendments. Furthermore, the combined application of *Cromolaena odorata* (10 t/ha) + biochar (5 t/ha) obtained the highest increase in soil pH (4.58), in marked contrast to soils given rice husk ash but not significantly different from single amendments or other combinations.

Applying single and combined soil amendments affected to increase in soil C-organics. The statistical test results in Table 2 show that the control soil had the lowest C-organic (1.94%), in stark contrast to other amended soils, except that the soils have given rice husk ash (10 t/ha) was not significantly different. The soil given a single amendment of rice straw (10 t/ha) obtained 4.58% C-organic, in stark contrast to the control soil and the soil given rice husk ash, but not significantly different from other soil amendments. Similarly, soils given a combination of *Chromolaena odorata* (10 t/ha) + biochar husk (5 t/ha) achieved the highest soil C-organic (4.93%) in marked contrast to control soils and soils fed with rice husk ash but did not significantly different from other soil amendments.

Table 2. Effect of rice husk biochar with soil amendments on some chemical properties of acid sulphate soil at one month after incubation

Soil amendments	pH H_2O	C-organic (%)	P-available (%)	Al-dd (me/100 g)	Soluble Fe (%)	CEC (me/100 g)
Control	3.36 a	1.94 a	0.21 a	3.84 e	3.61 d	6.64 a
C. odorata (10 t/ha)	4.06 bc	4.22 b	0.29 bc	3.31 c	3.28 c	7.15 ab
Rice straw (10 t/ha)	4.28 bc	4.58 b	0.30 bc	3.42 cd	3.34 cd	7.32 abc
Rice husk biochar (10 t/ha)	4.40 bc	4.09 b	0.32 cd	3.16 b	3.10 abc	8.03 c
Rice husk ash (10 t/ha)	3.98 b	2.78 a	0.28 b	3.51 d	3.34 cd	7.76 bc
C. odorata (10 t/ha) + biochar (5 t/ha)	4.58 c	4.93 b	0.34 d	3.02 a	2.94 ab	10.04 e
Rice straw (10 t/ha) + rice husk biochar (5 t/ha)	4.48 bc	4.75 b	0.33 d	3.08 ab	2.91 a	9.67 de
C. odorata (10 t/ha) + rice husk ash (5 t/ha)	4.26 bc	4.70 b	0.31 cd	3.37 c	3.25 c	9.17 d
Rice straw (10 t/ha) + rice husk ash (5 t/ha)	4.26 bc	4.73 b	0.31 cd	3.47 d	3.22 bc	9.20 d

Remarks: The average numbers followed by the same letter in the same column show no significant difference in the LSD test at 5% significant level.

Applying various amendments and combinations to acid sulphate soil generally affected the increase in P-available. The results of statistical tests (Table 2) showed that control soils had the lowest P-available content (0.21%), significantly different from soils given various amendments. In soils fed with a rice husk biochar (10 t/ha), the P-available increased to 0.32%. Still, it was not significantly different from other combined or single-amended soils, except with soils that were given rice husk ash with a lower P-available (0.27%). The highest P-available was obtained on soils given a combination of *Chromolaena odorata* (10 t/ha) + biochar (5 t/ha) (0.34%), in stark contrast to control soils and those topped with rice husk ash but not significantly different from single amendments or other combinations.

The decrease in Al-dd and Fe-dissolve in acid sulphate soil also occurs due to applying various soil amendments and their combinations. Statistical tests (Table 2) show that the highest Al-dd was obtained on control soils (3.84%), further decreasing and differing markedly from soils given various single and combined amendments. On single-amendment soils of rice husk biochar (10 t/ha), Al-dd decreased to 3.16%, significantly different from other single-amended soils. Furthermore, the soil given the combination of *Chromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha) obtained the lowest Al-dd content (3.02%). It was not significantly different from the soil given a combination of rice straw (10 t/ha) + biochar (5 t/ha), but it was significantly different from other amended soils. In soluble Fe content, the application of rice husk biochar (10 t/ha) could reduce soluble Fe from 3.61% on control soils to 3.10% and was significantly different from other single amendments. And when the soil was given a combination of rice straw (10 t/ha) + rice husk biochar (5 t/ha) caused the lowest decrease in Al-dd (2.91%). Still, it was not significantly different from soil that was given a combination of *Chromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha).

The CEC of land has also increased due to the application of various land amendments and their combinations. The statistical test is shown in Table 2 show that the control soil had the lowest CEC (6.64 Cmol/kg), not significantly different from soils fed with *Chromolaena odorata* and rice straw. On the other hand, on soils provided with rice husk biochar (10 t/ha), the soil CEC increased to 8.03 Cmol/kg, but it was not significantly different from soil given rice straw and rice husk ash.

In line with the results that have been put forward, Yamato *et al*. (2006) found that the application of biochar from *Acacia mangium* bark into the soil in Sumatra led to changes in soil chemical properties through increased pH, N-total and P-available, CEC, and lowered interchangeable Al. Liang *et al.* (2006) found that two mechanisms could create a larger CEC. First, a higher charged density per unit of surface acreage means a higher degree of oxidation of soil organic matter. Second, the presence of a higher surface area for cation absorption or the combined effect of both. Glaser *et al.* (2002) posit that oxidation of aromatic C and carboxyl formation are the main reasons for the high CEC. Liang *et al*. (2006) also found that the CEC per unit C was higher, and the load density was higher in carbon-black-rich Anthrosol compared to soils that were poor in carbon black. In addition, Anthrosol showed a higher surface acreage due to its higher carbon black concentration.

From the results, the great potential of rice husk biochar against improving soil properties increased when given together with the biomass *Chromolaena odorata*. It could happen because *Chromolaena odorata* contains higher humate and fulvic organic acids, so that it could encourage the complex mechanisms of organo-mineral organs and soil aggregation. In addition, *Chromolaena odorata* can highly suppress Al and Fe, thereby increasing the P availability in the soil due to the presence of organic acids released during decomposition. Research results by Suri and Yudono (2020) also found that using *Chromolaena odorata* compost could improve soil quality and nutrient uptake of lettuce plants.

Chromolaena odorata can contribute to the care of soil C-organic and physical properties due to a reasonably high polyphenol content that could inhibit the decomposition and mineralization of N organic matter, even though it had a low C/N ratio.

CONCLUSIONS

In conclusion, the amendment of rice husk biochar combined with amendments to *Chromolaena odorata* and rice straw improved soil physical properties, namely total soil pores, reducing soil content weight and strength. Its impact on soil chemical properties was that it could increase pH, C-organic, P-available, CEC, lower Al-dd, and Fe soluble. Therefore, applying biochar and organic amendments to *Chromolaena odorata* and rice straw could improve the properties of acid sulphate soil. Consequently, we recommend increasing the carrying capacity of acid sulphate soil against plant growth. It can be done by enhancing soil properties through the organic amendments application of *Chromolaena odorata* or straw enriched with rice husk biochar.

ACKNOWLEDGEMENTS

We thank the Institute for Research and Community Service, Universitas Panca Bhakti, which has given support for research funds. In addition, we thank the Faculty of Agriculture, Universitas Panca Bhakti, which has provided loans for facilities in the form of equipment for research.

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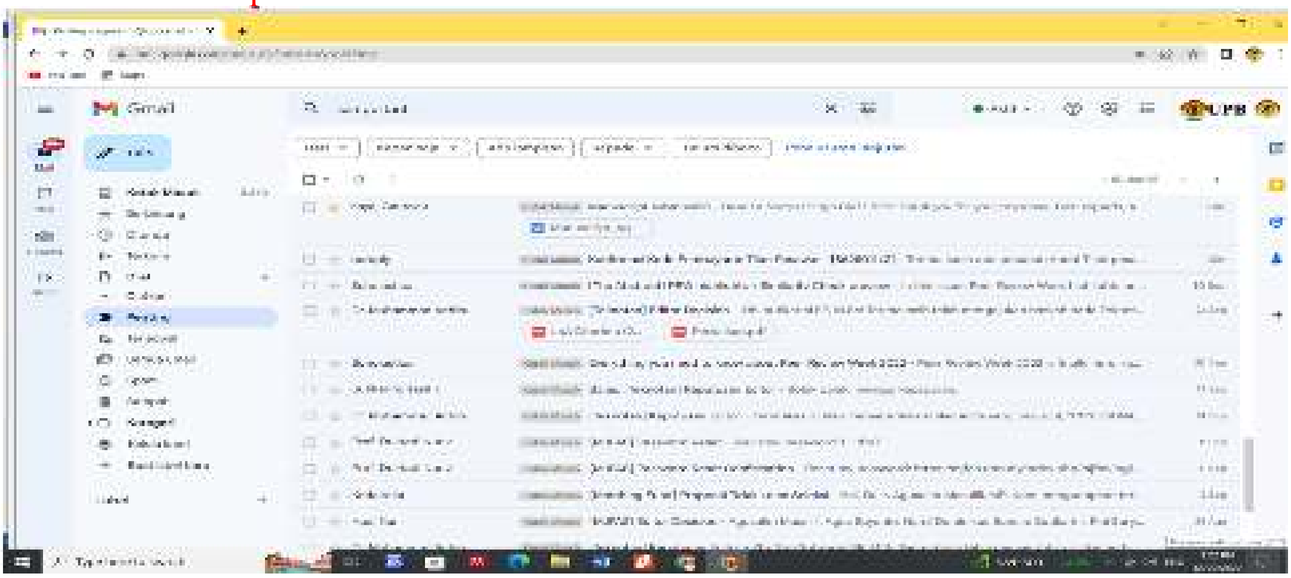
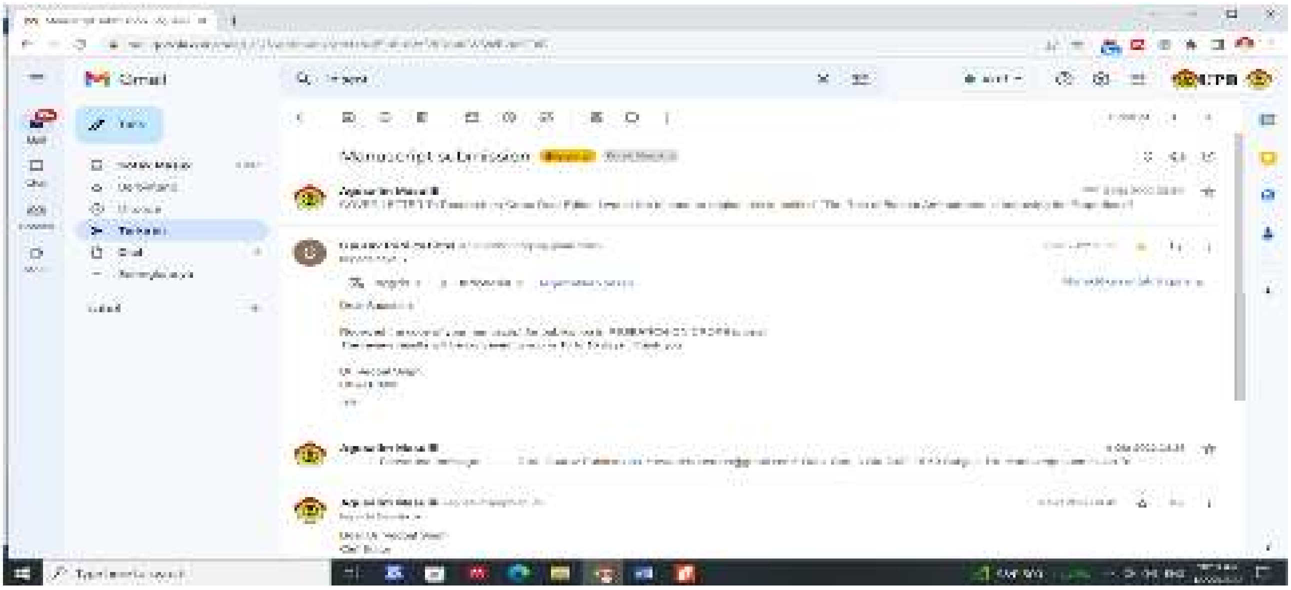
Online manuscript submission : 3 Oktober 2022

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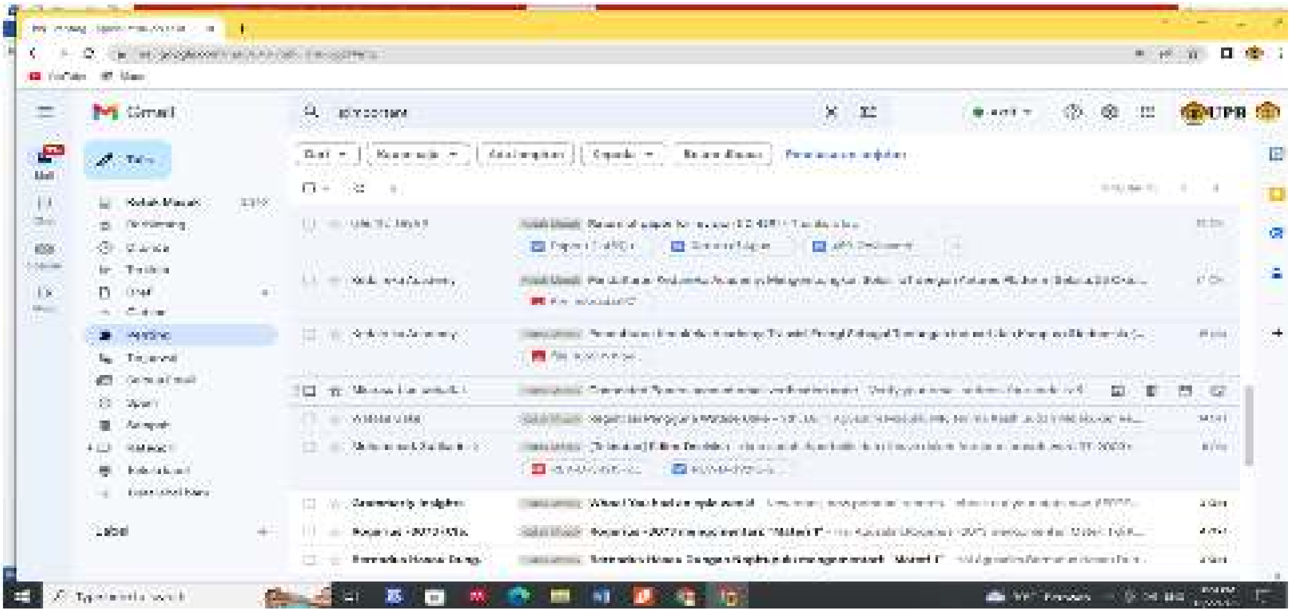
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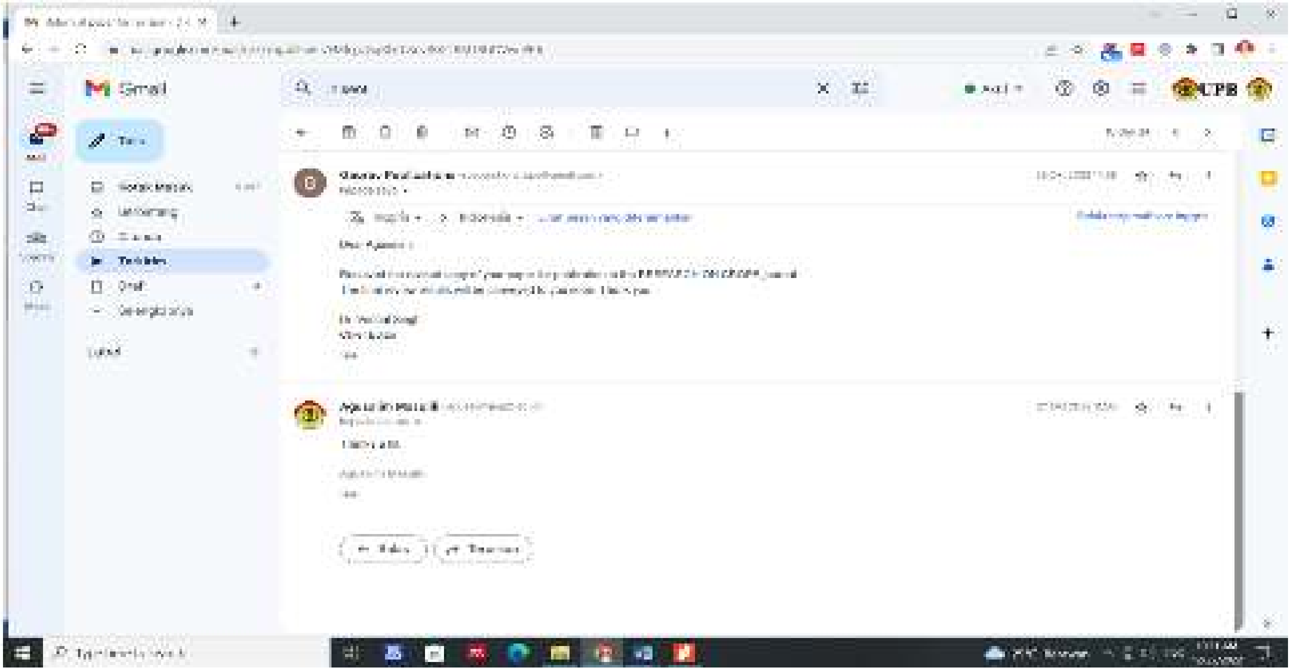
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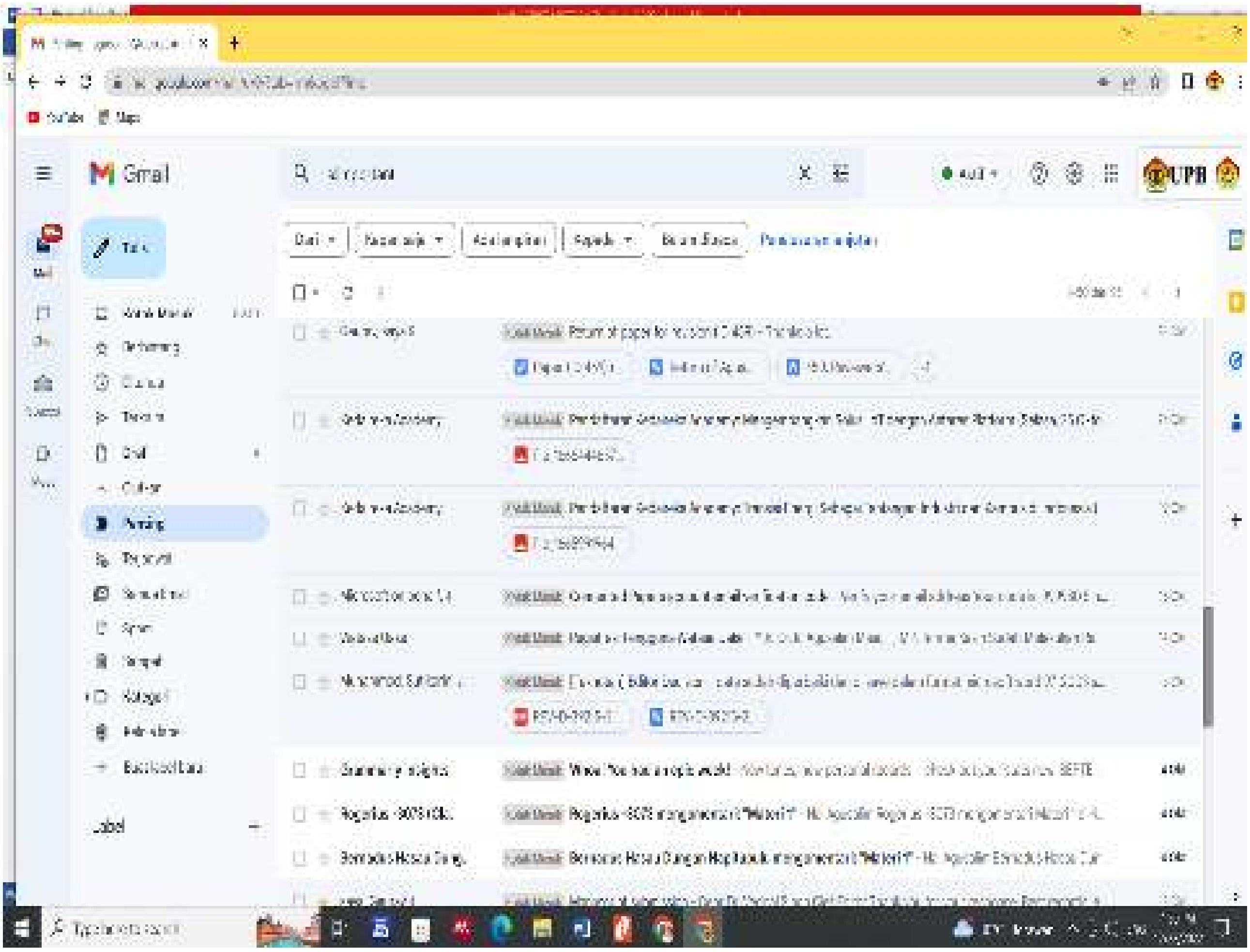
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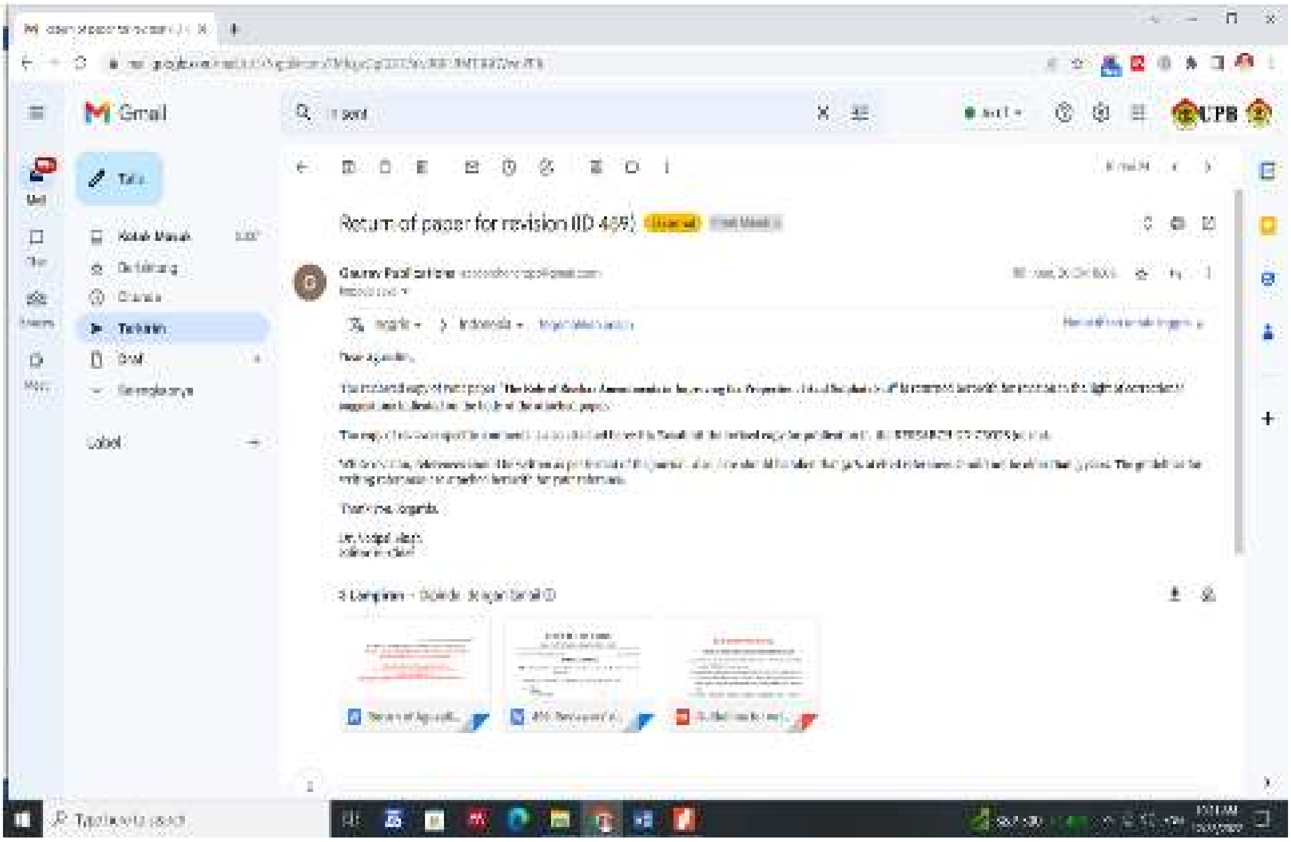

Role of biochar amendments in improving the properties of acid sulphate soil

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ABSTRACT

Acid sulfate soils have potential for agricultural development. However, this soil has various properties problems that can inhibit plant growth. One way to improve soil properties is through the application of biochar amendments. The study aimed to know the role of rice husk biochar combined with amendments to *Chromolaena odorata*, rice straw, and rice husk ash to improve the properties of acid sulphate soil. The study was conducted in a greenhouse and arranged in a complete randomized design (CRD) with three replications. Biochar amendments consisted of nine kinds, namely: without amendments (control), *Chromolaena odorata* (10 t/ha), rice straw (10 t/ha), rice husk biochar (10 t/ha), rice husk ash (10 t/ha), *Chromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha), rice

straw (10 t/ha) + rice husk biochar (5 t/ha), *Chromolaena odorata* (10 t/ha) + rice husk ash (5 t/ha), and rice straw (10 t/ha) + rice husk ash (5 t/ha). The results showed that the amendment of rice husk biochar combined with amendments to *Chromolaena odorata* and rice straw, respectively, had a good effect on improving soil physical properties, namely total soil pores, reducing soil content weight and soil strength. Its effect on soil chemical properties is that it can increase pH, C-organic, P-available, cation exchange capacity (CEC), and lower Al-dd and Fe soluble. The research findings show that applying biochar and organic amendments to *Chromolaena odorata* and rice straw can potentially improve the properties of acid sulphate soil. In future research, we recommend increasing the carrying capacity of acid sulphate soil against plant growth, and it can be done by improving soil properties through the organic amendments application of *Chromolaena odorata* or straw enriched with rice husk biochar.
Key words: *Chromolaena odorata*, rice husk ash, rice husk biochar, rice straw, soil properties

INTRODUCTION

Acidic sulphate soils are the common name for soils and sediments containing iron sulfide, namely pyrite (Das and Das, 2015). In agricultural development, efforts to reclaim acid sulphate soils do not always result in soil productivity since improvements in soil properties after reclamation are not achieved. So far, efforts have been encouraged to overcome existing obstacles after reclamation, including inorganic fertilizers (urea, TSP, KCl) and liming (dolomite). However, rice crop productivity in this field has not been optimal.

Inorganic fertilizers increase over time and can even decrease land quality if inputs are high and intensive. Liming can only cope with short-term pH and is often done repeatedly. As a result, high costs are needed, which becomes a burden for farmers and will threaten the sustainability of land productivity. Therefore, it is necessary to manage land based on land amendments that can improve the nature of sustainable soils.

Reclamation can result in changes in soil properties and is related to the potential for pyrite oxidation, affecting the increase in soil packaging and the solubility of ions such as Al, Fe, Mn, and sulphate. On the other hand, this soil has a high clay content which affects the increased weight of the contents. Therefore, the development of acid sulphate soil for agriculture after reclamation requires proper management of soil amendments to achieve the formation of steady cultivated land and sustainable farming. Das and Das (2015) suggested that acid sulphate soil having a high pH can inhibit plant growth. In addition, when this soil is drained, it can affect an increase in sulfuric acid and the release of iron, aluminum, and other heavy metals. Shamshuddin *et al*. (2014), stated that plants grown in acidic sulphate soils could not grow well due to low pH and high Al content.

Biochar is one of the soil amendment materials with the long-term potential to maintain soil fertility. The results of experts' investigations into the phenomenon of terra preta show that soil fertility is stable in the Amazon basin due to the presence of black carbon, the result of the management of the Amerindian nation 500–2,500 years ago. This carbon black is nothing but biochar immersed in the soil. Murtaza *et al*. (2021) found that 4.0 t/ha cotton biochar improves physical, chemical, soil biological, and soil fertility properties and peanut productivity in Alfisol. Zhang *et al*. (2022) have proven that biochar provides effects such as liming and providing nutrients that lead to soil improvement. Kocsis *et al*. (2022) stated that biochar has a high porosity and can improve the physicochemical and biological properties of the soil. In line, Sovova *et al*. (2021) found biochar had a good influence on improving the soil properties of regosol. Further afield, Das *et al*. (2021) suggest the application of biochar to the soil can provide agronomic benefits, support crop yield improvement, and improve soil quality and health. In addition, biochar has been shown to act as a fertilizer and soil conditioner.

Nutrient retention and higher nutrient availability were found in the soil after biochar addition, associated with higher CEC, surface acreage, and direct nutrient addition (Glaser *et al*., 2002). In line with opinions, Murtaza *et al*. (2021) suggested that biochar is a recalcitrant carbon product of biomass produced through the pyrolysis process. The recalcitrant properties of biochar are distinctive and important to the long-term improvement of soil properties through the effects of their residues that can persist for a long time in the soil. Beusch (2021), biochar can contribute to soil fertility and crop productivity, and Kalu *et al*. (2021) increase water availability and lower soil BD.

Applying biochar can improve soil properties and long-term crop productivity compared to other organic amendments. In other organic amendments, research results by Suri and Yudono (2020) showed that giving *Cromolaena odorata* as compost can increase plants' nutrition and nutrient uptake. Agustina *et al*. (2019) argued that using *Chromolaena odorata* and rice straw can maintain soil quality. Mahmoud *et al*. (2009) also showed rice straw compost could improve soil quality. The same was discovered by Gewaily (2019), that straw compost can increase potassium availability.

Furthermore, the results of the study by Yin *et al*. (2022) showed the weight of the soil contents decreased, and the water-holding capacity and total porosity increased in the soil with rising rice husk ash. Adding rice husk ash neutralizes soil acidity and increases plant nutrient availability. Research by Lestari and Rachmawati (2020) showed that applying rice husk ash (4 t/ha) can increase rice growth and reduce salinity stress.

Previously, several studies on the effect of biochar singularly have been carried out, including on the P-availability (Zhang *et al*., 2022), improvement of soil physical properties (Aslam *et al*., 2014), chemical properties of the soil (Bista *et al*., 2019), and some soil characteristics (Yadav *et al*., 2018), soil aggregate stability (Ebido *et al*., 2021), and to the development of rice roots (Kartika *et al*., 2021). However, no research has been found on how the role of biochar was given together with other organic amendments in acid sulphate soil. Therefore, it is necessary to study how the effect of biochar is given together with organic amendments to *Chromolaena odorata* and rice straw. This research is expected to contribute to improving the nature of acid sulphate soil in West Kalimantan, which has been one of the types of soil widely used as an agricultural activity for rice crops. In connection with this background and literature review above, this study aimed to know the role of rice husk biochar combined with amendments to *Chromolaena odorata*, rice straw, and rice husk ash in improving the properties of acid sulphate soil.

MATERIALS AND METHODS

Study Area

This research was conducted from September to November, 2021. The research site was carried out at the Laboratory of the Faculty of Agriculture, Universitas Panca Bhakti, Pontianak, West Kalimantan Province, Indonesia. The height of the study site is one m from above sea level, with an average temperature and humidity of 27.6 ºC and 82.8%, respectively. The research position is located at a latitude of 2º05' N–3º 05' S and longitude of 108º30' E–144º10' W.

Experimental Design

The study was conducted in a greenhouse and arranged in a complete randomized design (CRD) with three replications. Biochar amendments consisted of nine kinds, namely: without amendments (control), *Chromolaena odorata* (10 t/ha), rice straw (10 t/ha), rice husk biochar (10 t/ha), rice husk ash (10 t/ha), *Chromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha), rice straw (10 t/ha) + rice husk biochar (5 t/ha), *Chromolaena odorata* (10 t/ha) + rice husk ash (5 t/ha), and rice straw (10 t/ha) + rice husk ash (5 t/ha). In all, 27 polybags are needed.

Research Procedures

The material in this study used acid sulphate soil taken on the experimental land of the West Kalimantan, Sungai Kakap, Agricultural Technology Assessment Center, and land farmers' work on rice crops. This area included the development of swampland agriculture which has built irrigation canals since 1980 and was currently designated as an Integrated Farmer Business Area. Soil picking was carried out randomly at a soil depth of 0-20 cm, then mixed, air-dried, and cleaned. Then put in polybags was as much as 8 kg.

Biochar was made by taking rice husk from grain harvested from rice plants grown directly in the acid sulphate soil of the Kakap River, West Kalimantan, Indonesia. First, the rice mill was taken the grain to obtain rice husk. Furthermore, the rice husk was placed on the pyrolysis device to be processed into biochar by incomplete combustion (limited air) in a reactor made of Pertamina drums.

Organic amendments to *Chromolaena odorata* were taken from around the field, then chopped to a size of 1-2 cm. Rice straw was taken from waste harvested rice grown and grown by farmers in acid sulphate soil and chopped within 1–2 cm. Rice husks were taken from waste from rice milling, then used as ash through burning in open areas to produce grayish-white ash.

Prepared acid sulphate soil introduced into 27 polybags until it reached 8 kg. Further, the dose of soil amendment was calculated based on the soil weight in the polybag area, mixed with the soil in each polybag to a soil depth of 20 cm, after which it was incubated with moisture content until it was closed to the field capacity for 30 days.

At 30 days after incubation, from each study unit, soil sampling of about 50 g was undisturbed to determine the weight of the soil moisture content accident. In addition, a disturbed soil sample of 100 g was taken from each research unit for analysis of chemical properties.

Observation parameters

The soil bulk density (BD) was determined by the clod method described by Blake & Harke. The total pore was calculated from the soil moisture content (v/v) at the matrix potential of 0 kPa. The available groundwater was estimated by reducing the soil moisture content in the matrix potential by -33 kPa (field capacity) with the soil moisture content in the matrix potential, which was -15 Mpa (wilting point). The soil moisture content at this potential matrix was determined using a pressure plate device. The strength of the soil was measured with a hand penetrometer (Daikie) at a soil depth of 15 cm.

The pH level was measured in a soil solution at a ratio of 1:2.5 (with deionized water), using a pH meter (Jenway 3305). Walkley and Black's wet oxidation method was used to determining organic C levels (Soil Survey Laboratory Staff). Total N levels were measured by the Kjeldhal (Bremner and Mulvaney) method. Al_3 + and Fe_2+ were extracted with 1 M KCl (Barnhisel and Bertsch). CEC was extracted with 1 M NH_4Oac (buffer at pH 7.0), and the concentration of alkaline cations was measured using AAS (Shimadzu), P-available with Bray I.

Statistical Analysis

Statistical analysis was carried out on each observation parameter data to determine the effect of the amendments on the nature of acid sulphate soil. The data obtained were analyzed by analysis of variance (ANOVA) at 5% significant level. In addition, the test of least significant difference (LSD) at 5% significant level was used to determine the average value between treatments.

RESULTS AND DISCUSSION

Effect of various soil amendments on some physical soil properties

Applying biochar improved the soil's physical properties (Aslam *et al*., 2014). Applying biochar and organic amendments influenced the changes in some of the observed soil physical properties. The statistical test is shown in Table 1. The soil BD was lower on all amendments granted. For example, in soils fed a single rice husk biochar (10 t/ha), soil BD decreased from 1.27 mg/m^3 in the control soil to 1.15 mg/cm^3. However, not significantly different from soils was given straw (10 t/ha) and a combination of straw + biochar, *Chromolaena odorata* + rice husk ash, and straw + rice husk ash. Furthermore, in the combination of *Cromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha), a BD of 1.13 mg/m^3 was obtained and was the lowest soil BD. Still, it was not significantly different from the soil, given a combination of straw (10 t/ha) + rice husk biochar 5 (t/ha) produced soil BD of 1.14 mg/m^3. These results indicate an improvement in the physical soil properties if biochar was given together with organic amendments to *Chromolaena odorata*.

Applying various biochar amendments and their combinations increased the soil's total pore. The statistical test results are shown in Table 1. There was a significant difference in the total pore of the soil between the various amendments. Control soils had the lowest total pore (44.43%), contrasting with soils that provided various amendments. On soils with rice husk biochar (10 t/ha), the total soil pore increased to 54.21%, significantly different from other single amendments. Furthermore, a combination of *Cromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha) caused the total pore to increase to 56.73% and was the highest total pore.

The application of various amendments, both single and combined, affected the decrease in soil strength as measured as soil penetration resistance (N/cm^2) at conditions of pF 0, pF 2, and pF 2.5, where the higher the soil matric suction (pF), the higher the soil penetration resistance. The that under saturated conditions (pF 0), the various soil amendments do not offer a noticeable difference. In pF 2 showed that the application of rice husk biochar (10 t/ha) can reduce soil penetration resistance from 310.00 N/cm^2 (control soil) to 223.33 N/cm^2, but not significant difference between *Chromolaena odorata* (10 t/ha) + rice straw or a combination of straw (10 t/ha) + rice husk biochar (5 t/ha). Furthermore, soils given a combination of *Cromolaena odorata* (10 t/ha) + biochar (5 t/ha) obtained the lowest penetration resistance (220.00 N/cm^2), and this treatment was not significantly different from soils have given *Chromolaena odorata* (10 t/ha), rice husk biochar (10 t/ha), and a combination of rice straw (10 t/ha) + rice husk biochar (5 t/ha).

Similarly, in pF 2.5, the application of rice husk biochar (10 t/ha) could reduce the value of soil penetration resistance from 500.00 N/cm^2 (control soil) to 390.00 N/cm^2, and this treatment not significantly different from soils have given *Chromolaena odorata* (10 t/ha), rice straw (10 t/ha), rice husk ash (10 t/ha), and a combination of rice straw (10 t/ha) + rice husk ash (5 t/ha). Furthermore, the combination of *Cromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha) achieved the lowest penetration resistance (340.00 N/cm^2). Also, it was not significantly different from the combination of rice straw (10 t/ha) + biochar (5 t/ha) (360.00 N/cm^2). It indicated that rice husk biochar had the potential to control soil strength. In line with Das *et al*. (2021), applying biochar into the soil could reduce soil strength.

Effect of rice husk biochar on some soil chemical properties

The application of several soil amendments and their combinations could influence some chemical properties of acid sulphate soil. The results of statistical tests in Table 2 showed that soil reaction (pH) of the soil increased in all treatments given compared to controls. For example, in the application of rice husk biochar showed an increase in pH from 3.36 (control soil) to 4.40 on soils given biochar (10 t/ha) but did not significantly different from other single amendments. Furthermore, the combined application of *Cromolaena odorata* (10 t/ha) + biochar (5 t/ha) obtained the highest increase in soil pH (4.58), in marked contrast to soils given rice husk ash but not significantly different from single amendments or other combinations.

Applying single and combined soil amendments affected to increase in soil C-organics. The statistical test results in Table 2 showed that the control soil had the lowest C-organic (1.94%), in stark contrast to other amended soils, except that the soils have given rice husk ash (10 t/ha) was not significantly different. The soil given a single amendment of rice straw (10 t/ha) obtained 4.58% C-organic, in stark contrast to the control soil and the soil given rice husk ash, but not significantly different from other soil amendments. Similarly, soils given a combination of *Chromolaena odorata* (10 t/ha) + biochar husk (5 t/ha) achieved the highest soil C-organic (4.93%) in marked contrast to control soils and soils fed with rice husk ash but did not significantly different from other soil amendments.

Applying various amendments and combinations to acid sulphate soil generally affected the increase in P-available. The results of statistical tests (Table 2) showed that control soils had the lowest P-available content (0.21%), significantly different from soils given various amendments. In soils fed with a rice husk biochar (10 t/ha), the P-available increased to 0.32%. Still, it was not significantly different from other combined or single-amended soils, except with soils that were given rice husk ash with a lower P-available (0.27%). The highest P-available was obtained on soils given a combination of *Chromolaena odorata* (10 t/ha) + biochar (5 t/ha) (0.34%), in stark contrast to control soils and those topped with rice husk ash but not significantly different from single amendments or other combinations.

The decrease in Al-dd and Fe-dissolve in acid sulphate soil also occurs due to applying various soil amendments and their combinations. Statistical tests (Table 2) showed that the highest Al-dd was obtained on control soil (3.84%), further decreasing and differing markedly from soils given various single and combined amendments. On single-amendment soils of rice husk biochar (10 t/ha), Al-dd decreased to 3.16%, significantly different from other single-amended soils. Furthermore, the soil given the combination of *Chromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha) obtained the lowest Al-dd content (3.02%). It was not significantly different from the soil given a combination of rice straw (10 t/ha) + rice husk biochar (5 t/ha), but it was significantly different from other amended soils. In soluble Fe content, the application of rice husk biochar (10 t/ha) could reduce soluble Fe from 3.61% on control soil to 3.10% and was significantly different from other single amendments. And when the soil was given a combination of rice straw (10 t/ha) + rice husk biochar (5 t/ha) caused the lowest decrease in Al-dd (2.91%). Still, it was not significantly different from soil that was given a combination of *Chromolaena odorata* (10 t/ha) + rice husk biochar (5 t/ha).

The CEC of land has also increased due to the application of various land amendments and their combinations. The statistical test is shown in Table 2 show that the control soil had the lowest CEC (6.64 Cmol/kg), not significantly different from soils fed with *Chromolaena odorata* and rice straw. On the other hand, on soils provided with rice husk biochar (10 t/ha), the soil CEC increased to 8.03 Cmol/kg, but it was not significantly different from soil given rice straw and rice husk ash.

In line with the results that have been put forward, Yamato *et al*. (2006) found that the application of biochar from *Acacia mangium* bark into the soil in Sumatra led to changes in soil chemical properties through increased pH, N-total and P-available, CEC, and lowered interchangeable Al. Liang *et al.* (2006) found that two mechanisms could create a larger CEC. First, a higher charged density per unit of surface acreage means a higher degree of oxidation of soil organic matter. Second, the presence of a higher surface area for cation absorption or the combined effect of both. Glaser *et al.* (2002) posit that oxidation of aromatic C and carboxyl formation are the main reasons for the high CEC. Liang *et al*. (2006) also found that the CEC per unit C was higher, and the load density was higher in carbon-black-rich Anthrosol compared to soils that were poor in carbon black. In addition, Anthrosol showed a higher surface acreage due to its higher carbon black concentration.

From the results, the great potential of rice husk biochar against improving soil properties increased when given together with the biomass *Chromolaena odorata*. It could happen because *Chromolaena odorata* contains higher humate and fulvic organic acids, so that it could encourage the complex mechanisms of organo-mineral organs and soil aggregation. In addition, *Chromolaena odorata* can highly suppress Al and Fe, thereby increasing the P availability in the soil due to the presence of organic acids released during decomposition. Research results by Suri and Yudono (2020) also found that using *Chromolaena odorata* compost could improve soil quality and nutrient uptake of lettuce plants.

Chromolaena odorata can contribute to the care of soil C-organic and physical properties due to a reasonably high polyphenol content that could inhibit the decomposition and mineralization of N organic matter, even though it had a low C/N ratio.

CONCLUSIONS

In conclusion, the amendment of rice husk biochar combined with amendments to *Chromolaena odorata* and rice straw improved soil physical properties, namely total soil pores, reducing soil content weight and strength. Its impact on soil chemical properties was that it could increase pH, C-organic, P-available, CEC, lower Al-dd, and Fe soluble. Therefore, applying biochar and organic amendments to *Chromolaena odorata* and rice straw could improve the properties of acid sulphate soil. Consequently, we recommend increasing the carrying capacity of acid sulphate soil against plant growth. It can be done by enhancing soil properties through the organic amendments application of *Chromolaena odorata* or straw enriched with rice husk biochar.

ACKNOWLEDGEMENTS

We thank the Institute for Research and Community Service, Universitas Panca Bhakti, which has given support for research funds. In addition, we thank the Faculty of Agriculture, Universitas Panca Bhakti, which has provided loans for facilities in the form of equipment for research.

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Table 1. Effect of rice husk biochar with soil amendments on some physical properties of acid sulphate soil at one month after incubation.

Soil amendments	BD (mg/m^3)	Total pores (%)	Penetration resistance (N/cm^2)		
			pF 0	pF 2	pF 2.5
Control	1.24 e	44.43 a	36.67 b	310.00 e	500.00 d
C. odorata (10 t/ha)	1.16 c	52.17 e	20.00 a	230.00 abc	403.33 bc
Rice straw (10 t/ha)	1.17 bc	53.27 f	16.67 a	243.33 bc	393.33 b
Rice husk biochar (10 t/ha)	1.15 b	54.21 g	14.33 a	223.33 ab	390.00 b
Rice husk ash (10 t/ha)	1.19 d	47.30 b	20.00 a	270.00 d	403.33 bc
C. odorata (10 t/ha) + biochar (5 t/ha)	1.13 a	56.73 i	10.00 a	220.00 a	340.00 a

Rice straw (10 t/ha) + rice husk biochar (5 t/ha)	1.14 ab	55.57 h	13.33 a	223.00 ab	360.00 a
C. odorata (10 t/ha) + rice husk ash (5 t/ha)	1.15 b	48.90 c	16.67 a	240.00 bc	420.00 c
Rice straw (10 t/ha) + rice husk ash (5 t/ha)	1.16 bc	50.30 d	20.00 a	246.67 c	403.33 bc

Remarks: The average numbers followed by the same letter in the same column show no significant difference in the LSD test at 5% significant level.

Table 2. Effect of rice husk biochar with soil amendments on some chemical properties of acid sulphate soil at one month after incubation.

Soil amendments	pH H_2O	C-organic (%)	P-available (%)	Al-dd (me/100 g)	Soluble Fe (%)	CEC (me/100 g)
Control	3.36 a	1.94 a	0.21 a	3.84 e	3.61 d	6.64 a
C. odorata (10 t/ha)	4.06 bc	4.22 b	0.29 bc	3.31 c	3.28 c	7.15 ab
Rice straw (10 t/ha)	4.28 bc	4.58 b	0.30 bc	3.42 cd	3.34 cd	7.32 abc
Rice husk biochar (10 t/ha)	4.40 bc	4.09 b	0.32 cd	3.16 b	3.10 abc	8.03 c
Rice husk ash (10 t/ha)	3.98 b	2.78 a	0.28 b	3.51 d	3.34 cd	7.76 bc
C. odorata (10 t/ha) + rice husk biochar (5 t/ha)	4.58 c	4.93 b	0.34 d	3.02 a	2.94 ab	10.04 e
Rice straw (10 t/ha) + rice husk biochar (5 t/ha)	4.48 bc	4.75 b	0.33 d	3.08 ab	2.91 a	9.67 de
C. odorata (10 t/ha) + rice husk ash (5 t/ha)	4.26 bc	4.70 b	0.31 cd	3.37 c	3.25 c	9.17 d
Rice straw (10 t/ha) + rice husk ash (5 t/ha)	4.26 bc	4.73 b	0.31 cd	3.47 d	3.22 bc	9.20 d

Remarks: The average numbers followed by the same letter in the same column show no significant difference in the LSD test at 5% significant level.

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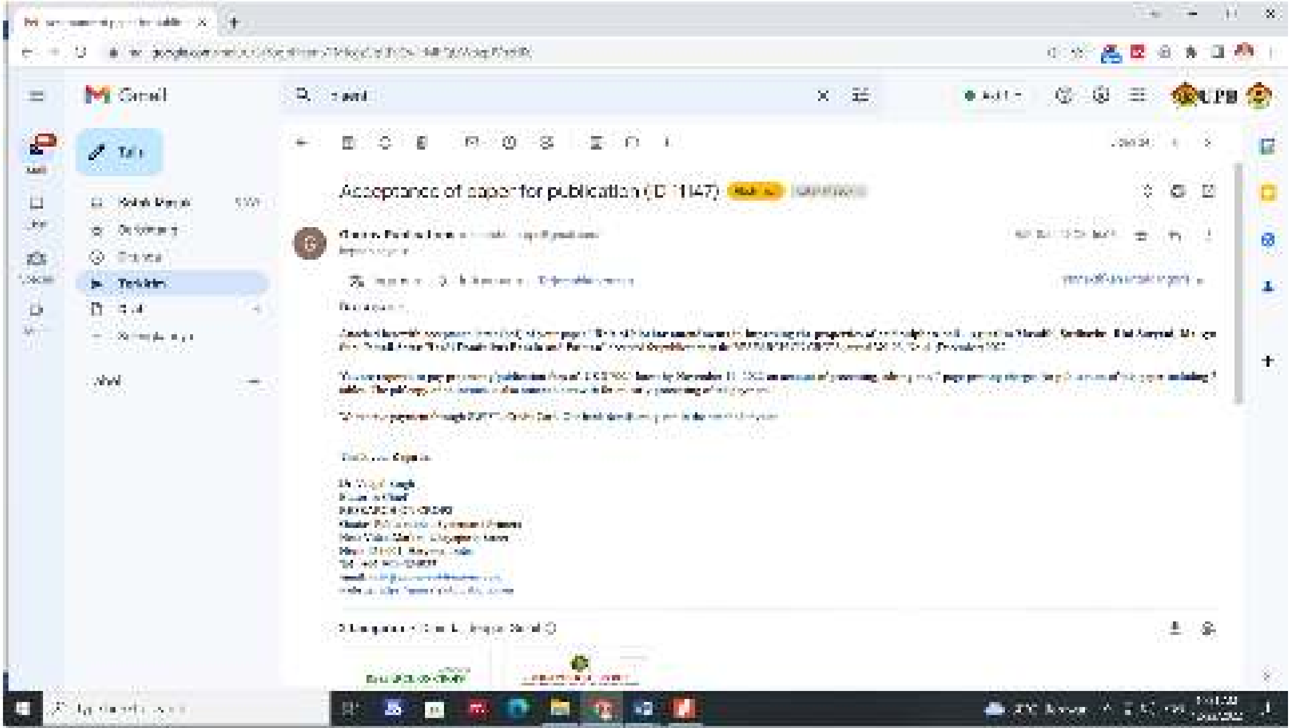

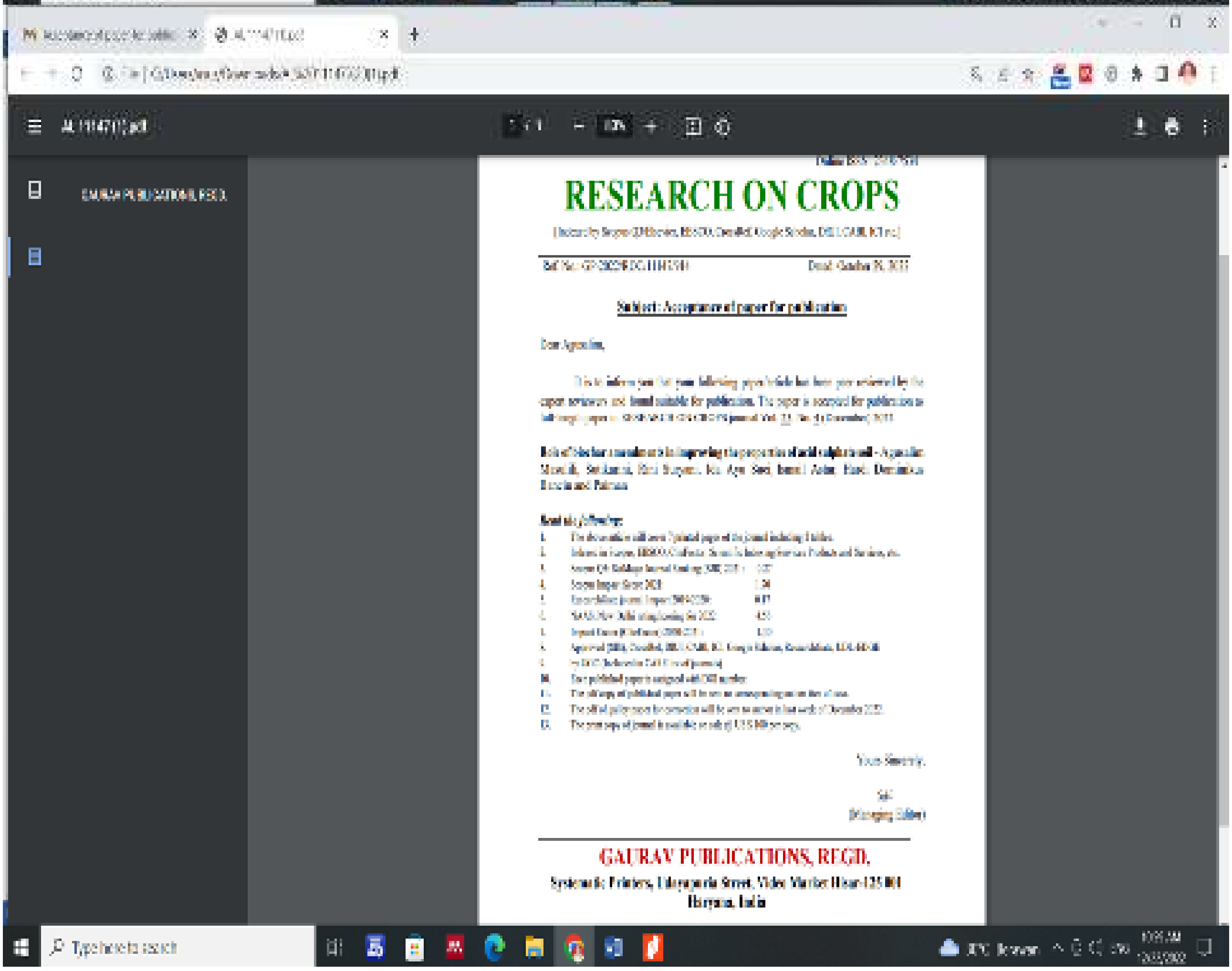

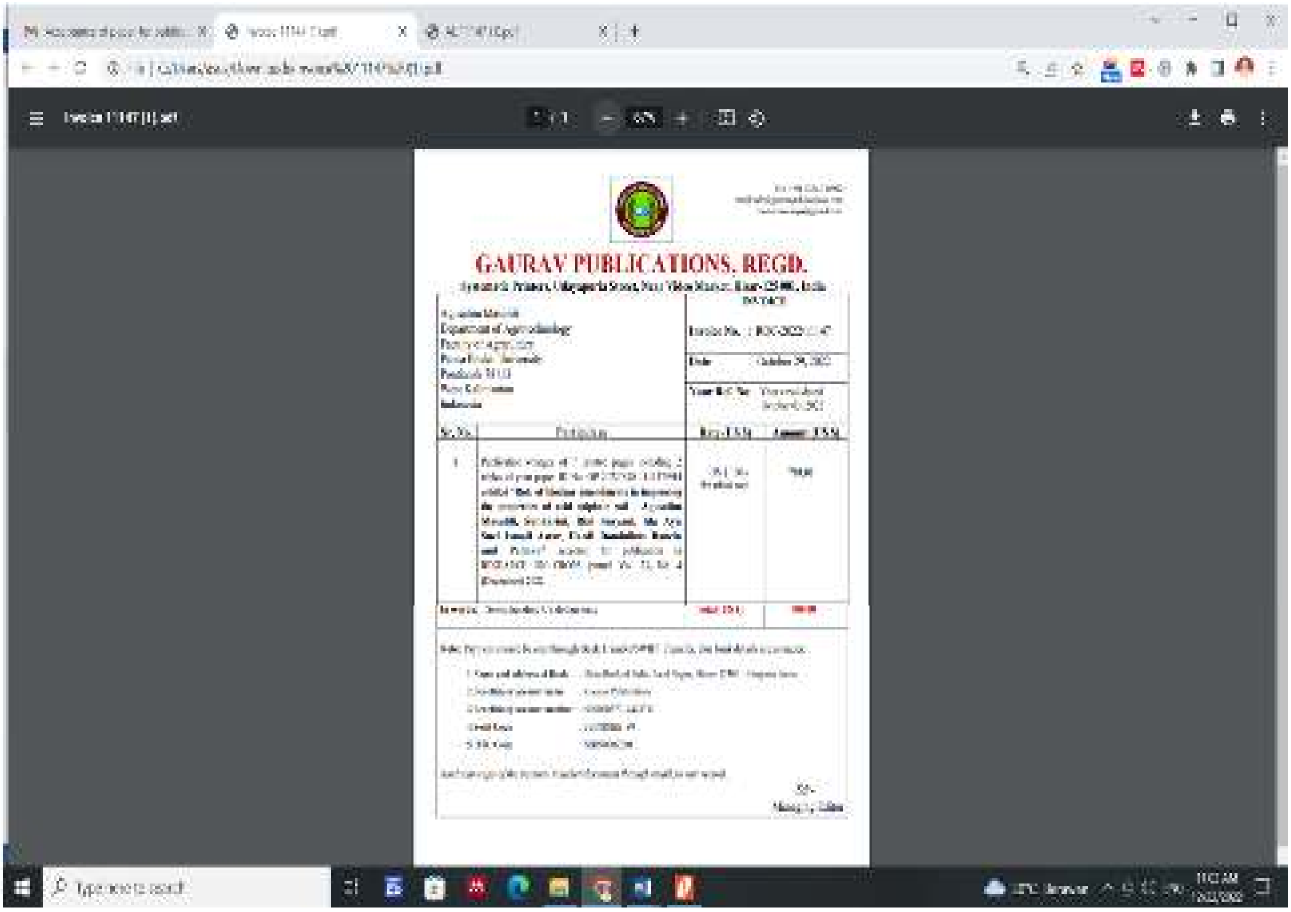

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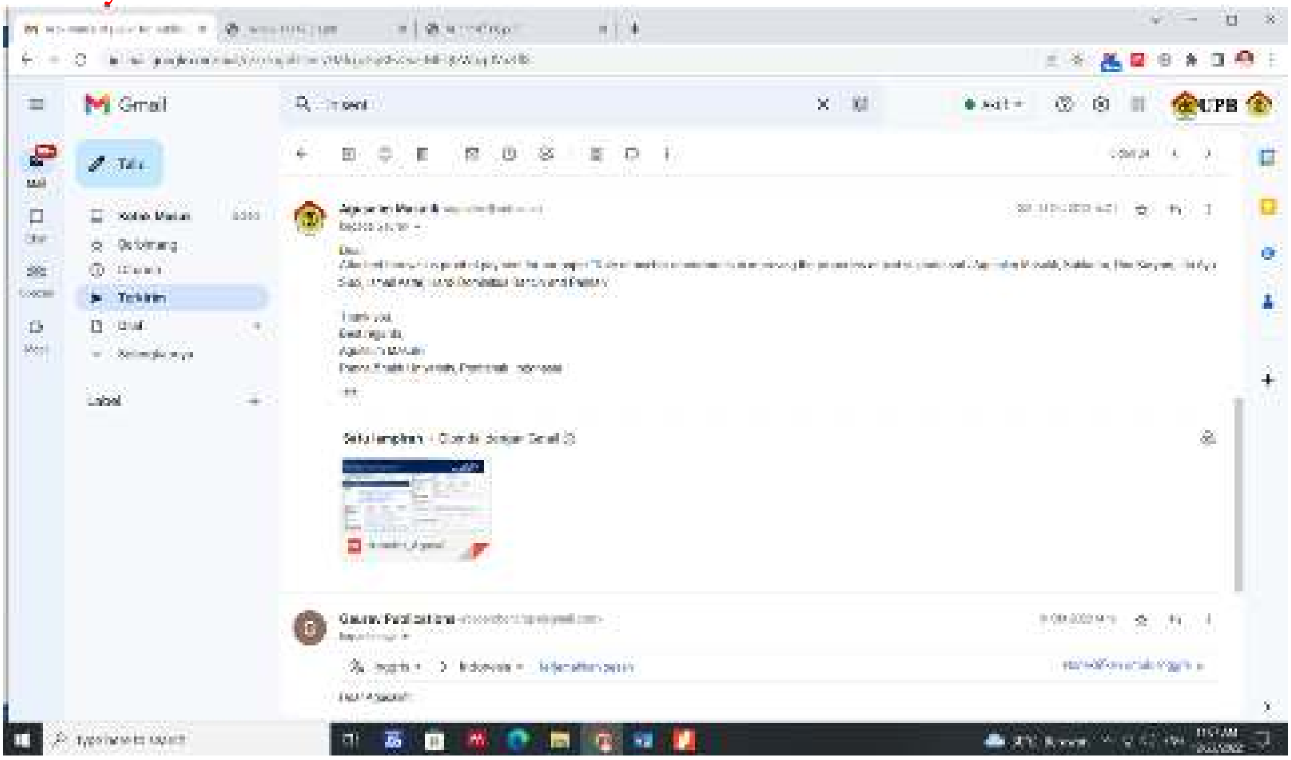

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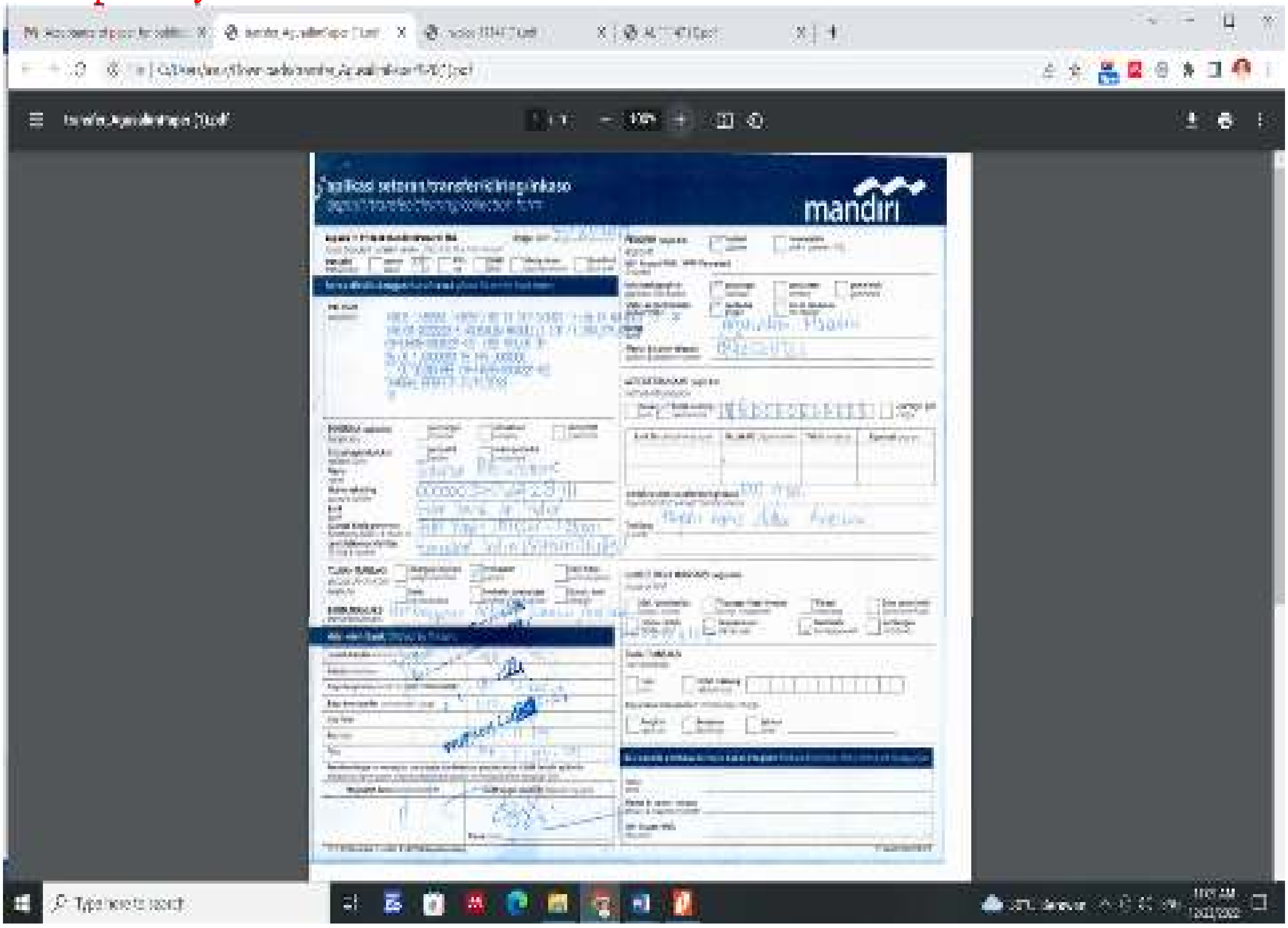
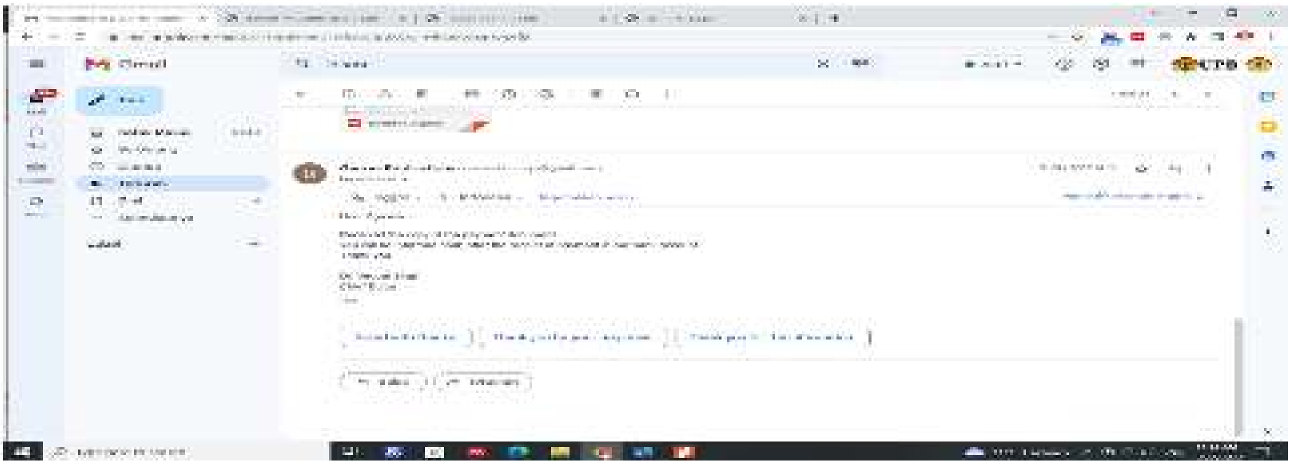


Pemberitahuan penerimaan pembayaran biaya publikasi: 31 Oktober 2022



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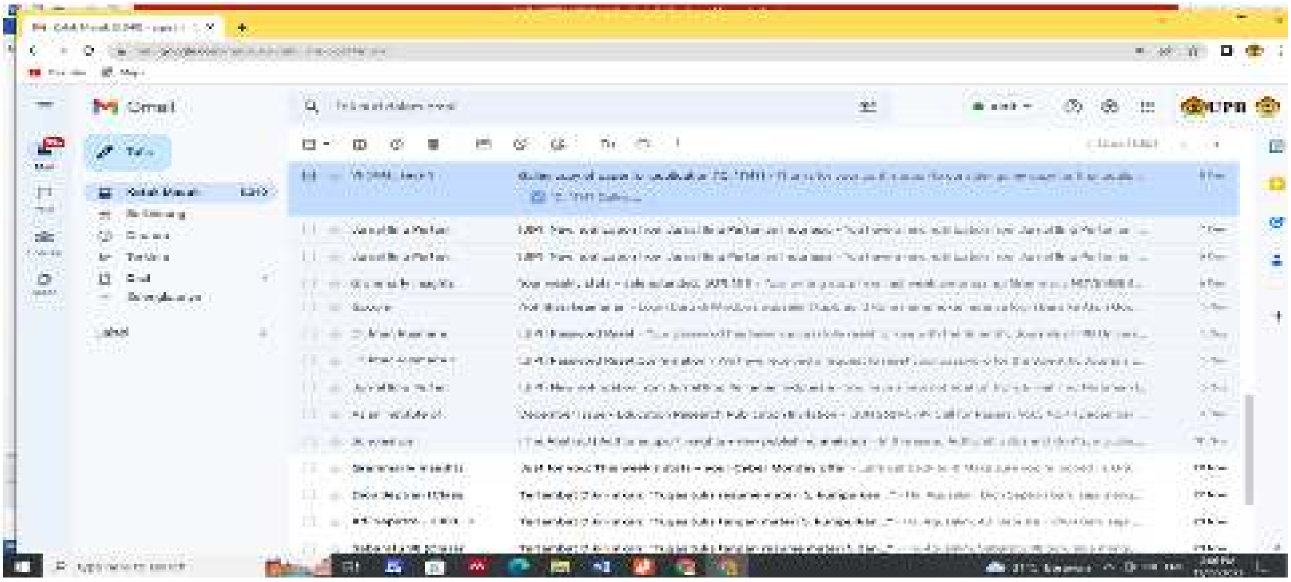

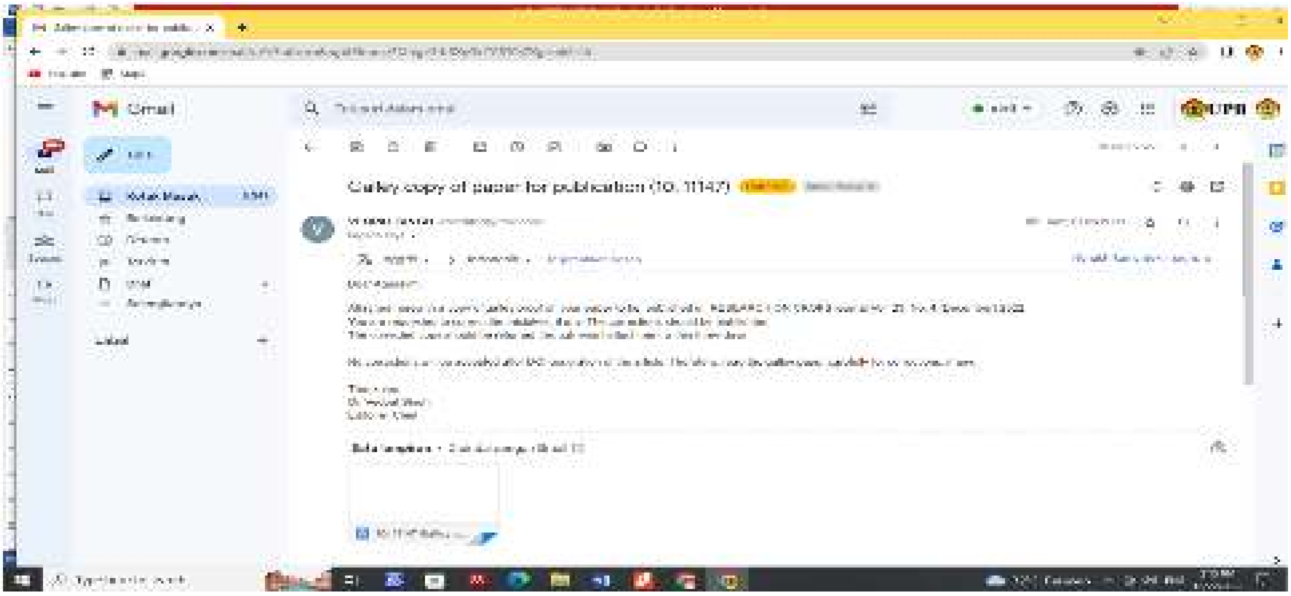

Res. Crop. **23** (4): (2022)
Printed in India

Role of biochar amendments in improving the properties of acid sulphate soil

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(Received: October 03, 2022 / Accepted: November 28, 2022)

ABSTRACT

Acid sulfate soils have potential for agricultural development. However, this soil has various properties problems that can inhibit plant growth. One way to improve soil properties is through the application of biochar amendments. The study aimed at knowing the role of rice husk biochar combined with amendments to *Chromolaena odorata*, rice straw, and rice husk ash to improve the properties of acid sulphate soil. The study was conducted in a greenhouse and arranged in a complete randomized design (CRD) with three replications. Biochar amendments consisted of nine kinds, namely, without amendments (control), *C. odorata* (10 t/ha), rice straw (10 t/ha), rice husk biochar (10 t/ha), rice husk ash (10 t/ha), *C. odorata* (10 t/ha)+rice husk biochar (5 t/ha), rice straw (10 t/ha)+rice husk biochar (5 t/ha), *C. odorata* (10 t/ha)+rice husk ash (5 t/ha), and rice straw (10 t/ha)+rice husk ash (5 t/ha). The results showed that the amendment of rice husk biochar combined with amendments to *C. odorata* and rice straw, respectively, had a good effect on improving soil physical properties, namely, total soil pores, reducing soil content weight and soil strength. Its effect on soil chemical properties was that it could increase pH, C-organic, P-available, cation exchange capacity (CEC), lower Al-dd and Fe soluble. The research findings showed that applying biochar and organic amendments to *Chromolaena odorata* and rice straw could potentially improve the

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properties of acid sulphate soil. In future research, we recommend increasing the carrying capacity of acid sulphate soil against plant growth, and it can be done by improving soil properties through the organic amendments application of *C. odorata* or straw enriched with rice husk biochar.

Key words: *Chromolaena odorata*, rice husk ash, rice husk biochar, rice straw, soil properties

INTRODUCTION

Acidic sulphate soils are the common name for soils and sediments containing iron sulfide, namely, pyrite (Das and Das, 2015). In agricultural development, efforts to reclaim acid sulphate soils do not always result in soil productivity since improvements in soil properties after reclamation are not achieved. So far, efforts have been encouraged to overcome existing obstacles after reclamation, including inorganic fertilizers (urea, TSP and KCl) and liming (dolomite). However, rice crop productivity in this field has not been optimal.

Inorganic fertilizers increase over time and can even decrease land quality if inputs are high and intensive. Liming can only cope with short-term pH and is often done repeatedly. As a result, high costs are needed, which becomes a burden for farmers and will threaten the sustainability of land productivity. Therefore, it is necessary to manage land based on land amendments that can improve the nature of sustainable soils.

Reclamation can result in changes in soil properties and is related to the potential for pyrite oxidation, affecting the increase in soil packaging and the solubility of ions such as Al, Fe, Mn and sulphate. On the other hand, this soil has a high clay content which affects the increased weight of the contents. Therefore, the development of acid sulphate soil for agriculture after reclamation requires proper management of soil amendments to achieve the formation of steady cultivated land and sustainable farming. Das and Das (2015) suggested that acid sulphate soil having a high pH could inhibit plant growth. In addition, when this soil is drained, it can affect an increase in sulfuric acid and the release of iron, aluminum, and other heavy metals. Shamshuddin *et al*. (2014) stated that plants grown in acidic sulphate soils could not grow well due to low pH and high Al content.

Biochar is one of the soil amendment materials with the long-term potential to maintain soil fertility (Ogunleye *et al*., 2019; Jaswal *et al*., 2022). The results of experts' investigations into the phenomenon of terra preta show that soil fertility is stable in the Amazon basin due to the presence of black carbon, the result of the management of the Amerindian nation 500-2,500 years ago. This carbon black is nothing but biochar immersed in the soil. Murtaza *et al*. (2021) found that 4.0 t/ha cotton biochar improved physical, chemical, soil biological soil fertility properties and peanut productivity in Alfisol. Zhang *et al*. (2022) have proven that biochar provides effects such as liming and providing nutrients that lead to soil improvement. Kocsis *et al*. (2022) stated that biochar had a high porosity and could improve the physico-chemical and biological properties of the soil. In line, Sovova *et al*. (2021) found that biochar had a good influence on improving the soil properties of regosol. Further, Das *et al*. (2021) suggest the application of biochar to the soil can provide agronomic benefits, support crop yield improvement, and improve soil quality and health. In addition, biochar has been shown to act as a fertilizer and soil conditioner.

Nutrient retention and higher nutrient availability were found in the soil after biochar addition, associated with higher CEC, surface acreage and direct nutrient addition (Glaser *et al*., 2002). In line with opinions, Murtaza *et al*. (2021) suggested that biochar was a recalcitrant carbon product of biomass produced through the pyrolysis process. The recalcitrant properties of biochar are distinctive and important to the long-term improvement of soil properties through the effects of their residues that can persist for a long time in the soil. Beusch (2021), biochar can contribute to soil fertility and crop productivity, and Kalu *et al*. (2021) increase water availability and lower soil BD.

Applying biochar can improve soil properties and long-term crop productivity compared to other organic amendments. In other organic amendments, research results by Suri and Yudono (2020) showed that giving *C. odorata* as compost can increase plants' nutrition and nutrient uptake. Agustina *et al*. (2019) argued that using *C. odorata* and rice straw could maintain soil quality. Mahmoud *et al*.

(2009) also showed rice straw compost could improve soil quality. The same was discovered by Gewaily (2019), that straw compost can increase potassium availability.

Furthermore, the results of the study by Yin *et al*. (2022) showed the weight of the soil contents decreased, and the water-holding capacity and total porosity increased in the soil with rising rice husk ash. Adding rice husk ash neutralizes soil acidity and increases plant nutrient availability. Research by Lestari and Rachmawati (2020) showed that applying rice husk ash (4 t/ha) could increase rice growth and reduce salinity stress.

Previously, several studies on the effect of biochar singularly have been carried out, including on the P-availability (Zhang *et al*., 2022), improvement of soil physical properties (Aslam *et al*., 2014; Yin *et al*., 2018), chemical properties of the soil (Bista *et al*., 2019), some soil characteristics (Yadav *et al*., 2018), soil aggregate stability (Ebido *et al*., 2021) and to the development of rice roots (Kartika *et al*., 2021). However, no research has been found on how the role of biochar was given together with other organic amendments in acid sulphate soil. Therefore, it is necessary to study how the effect of biochar is given together with organic amendments to *C. odorata* and rice straw. This research is expected to contribute to improving the nature of acid sulphate soil in West Kalimantan, which has been one of the types of soil widely used as an agricultural activity for rice crop. In connection with this background and literature review above, this study aimed at knowing the role of rice husk biochar combined with amendments to *C. odorata*, rice straw and rice husk ash in improving the properties of acid sulphate soil.

MATERIALS AND METHODS

Study Area

This research was conducted from September to November 2021. The research site was carried out at the Laboratory of the Faculty of Agriculture, Universitas Panca Bhakti, Pontianak, West Kalimantan Province, Indonesia. The height of the study site is one m from above sea level, with an average temperature and humidity of 27.6ºC and 82.8%, respectively. The research position is located at a latitude of 2º05' N-3º 05'S and longitude of 108º30' E-144º10' W.

Experimental Design

The study was conducted in a greenhouse and arranged in a complete randomized design (CRD) with three replications. Biochar amendments consisted of nine kinds, namely, without amendments (control), *C. odorata* (10 t/ha), rice straw (10 t/ha), rice husk biochar (10 t/ha), rice husk ash (10 t/ha), *C. odorata* (10 t/ha)+rice husk biochar (5 t/ha), rice straw (10 t/ha)+rice husk biochar (5 t/ha), *C. odorata* (10 t/ha)+rice husk ash (5 t/ha), and rice straw (10 t/ha)+rice husk ash (5 t/ha). In all, 27 polybags were needed.

Research Procedures

The material in this study used acid sulphate soil taken on the experimental land of the West Kalimantan, Sungai Kakap, Agricultural Technology Assessment Center, and land farmers' work on rice crops. This area included the development of swampland agriculture which had built irrigation canals since 1980 and was currently designated as an Integrated Farmer Business Area. Soil picking was carried out randomly at a soil depth of 0-20 cm, then mixed, air-dried, and cleaned. Then put in polybags was as much as 8 kg.

Biochar was made by taking rice husk from grain harvested from rice plants grown directly in the acid sulphate soil of the Kakap River, West Kalimantan, Indonesia. First, the rice mill was taken the grain to obtain rice husk. Furthermore, the rice husk was placed on the pyrolysis device to be processed into biochar by incomplete combustion (limited air) in a reactor made of Pertamina drums.

Organic amendments to *C. odorata* were taken from around the field, then chopped to a size of 1-2 cm. Rice straw was taken from waste harvested rice grown and grown by farmers in acid sulphate soil and chopped within 1–2 cm. Rice husks were taken from waste from rice milling, then used as ash through burning in open areas to produce grayish-white ash.

Prepared acid sulphate soil introduced into 27 polybags until it reached 8 kg. Further, the dose of soil amendment was calculated based on the soil weight in the polybag area, mixed with the soil in each polybag to a soil depth of 20 cm, after which it was incubated with moisture content until it was closed to the field capacity for 30 days.

At 30 days after incubation, from each study unit, soil sampling of about 50 g was undisturbed to determine the weight of the soil moisture content accident. In addition, a disturbed soil sample of 100 g was taken from each research unit for analysis of chemical properties.

Observation Parameters

The soil bulk density (BD) was determined by the clod method described by Blake & Harke. The total pore was calculated from the soil moisture content (v/v) at the matrix potential of 0 kPa. The available groundwater was estimated by reducing the soil moisture content in the matrix potential by -33 kPa (field capacity) with the soil moisture content in the matrix potential, which was -15 Mpa (wilting point). The soil moisture content at this potential matrix was determined using a pressure plate device. The strength of the soil was measured with a hand penetrometer (Daikie) at a soil depth of 15 cm.

The pH level was measured in a soil solution at a ratio of 1 : 2.5 (with deionized water), using a pH meter (Jenway 3305). Walkley and Black's wet oxidation method was used to determine organic C levels (Soil Survey Laboratory Staff). Total N levels were measured by the Kjeldhal (Bremner and Mulvaney) method. Al_3+and Fe_2+were extracted with 1 M

KCl (Barnhisel and Bertsch). CEC was extracted with 1 M NH_4Oac (buffer at pH 7.0), and the concentration of alkaline cations was measured using AAS (Shimadzu), P-available with Bray I.

Statistical Analysis

Statistical analysis was carried out on each observation parameter data to determine the effect of the amendments on the nature of acid sulphate soil. The data obtained were analyzed by analysis of variance (ANOVA) at 5% significant level. In addition, the test of least significant difference (LSD) at 5% significant level was used to determine the average value between treatments.

RESULTS AND DISCUSSION

Effect of Various Soil Amendments on Some Physical Soil Properties

Applying biochar improved the soil's physical properties (Aslam *et al*., 2014). Applying biochar and organic amendments influenced the changes in some of the observed soil physical properties. The statistical test is shown in Table 1. The soil BD was lower on all amendments granted. For example, in soils fed a single rice husk biochar (10 t/ha), soil BD decreased from 1.27 mg/m^3 in the control soil to 1.15 mg/cm^3. However, not significantly different from soils was given straw (10 t/ha) and a combination of straw+biochar, *C. odorata*+rice husk ash, and straw+rice husk ash. Furthermore, in the combination of *C. odorata* (10 t/ha)+rice husk biochar (5 t/ha), a BD of 1.13 mg/m^3 was obtained and was the lowest soil BD. Still, it was not significantly different from the soil, given a combination of straw (10 t/ha) + rice husk biochar (5 t/ha) produced soil BD of 1.14 mg/m^3. These results indicated an improvement in the physical soil properties if biochar was given together with organic amendments to *C. odorata*.

Applying various biochar amendments and their combinations increased the soil's total pore. The statistical test results are shown in Table 1. There was a significant difference in the total pore of the soil between the various amendments. Control soils had the lowest total pore (44.43%), contrasting with soils that provided various amendments. On soils with rice husk biochar (10 t/ha), the total soil pore increased to 54.21%, significantly different from other single amendments. Furthermore, a combination of *C. odorata* (10 t/ha)+rice husk biochar (5 t/ha) caused the total pore to increase to 56.73% and was the highest total pore.

The application of various amendments, both single and combined, affected the decrease in soil strength as measured as soil penetration resistance (N/cm^2) at conditions of pF 0, pF 2 and pF 2.5, where the higher the soil matric suction (pF), the higher the soil penetration resistance. The under saturated conditions (pF 0), the various soil amendments did not offer a noticeable difference. In pF 2 showed that the application of rice husk biochar (10 t/ha) could reduce soil penetration resistance from 310.00 N/cm^2 (control soil) to 223.33 N/cm^2, but not significant difference between *C. odorata* (10 t/ha)+rice straw or a combination of straw (10 t/ha)+rice husk biochar (5 t/ha). Furthermore, soils given a combination of *Cromolaena odorata* (10 t/ha)+biochar (5 t/ha) obtained the lowest penetration resistance (220.00 N/cm^2), and this treatment was not significantly different from soils have given *C. odorata* (10 t/ha), rice husk biochar (10 t/ha), and a combination of rice straw (10 t/ha)+rice husk biochar (5 t/ha).

Similarly, in pF 2.5, the application of rice husk biochar (10 t/ha) could reduce the value of soil penetration resistance from 500.00 N/cm^2 (control soil) to 390.00 N/cm^2, and this treatment not significantly different from soils had given *C. odorata* (10 t/ha), rice straw (10 t/ha), rice husk ash (10 t/ha), and a combination of rice straw (10 t/ha)+rice husk ash (5 t/ha). Furthermore, the combination of *C. odorata* (10 t/ha)+rice husk biochar (5 t/ha) achieved the lowest penetration resistance (340.00 N/cm^2). Also, it was not significantly different from the combination of rice straw (10 t/ha)+biochar (5 t/ha) (360.00 N/cm^2). It indicated that rice husk biochar had the potential to control soil strength. In line with Das *et al*. (2021), applying biochar into the soil could reduce soil strength.

Effect of Rice Husk Biochar on Some Soil Chemical Properties

The application of several soil amendments and their combinations could influence some chemical properties of acid sulphate soil. The results of statistical tests in Table 2 show that soil reaction (pH) of the soil increased in all treatments given compared to controls. For example, in the application of rice husk biochar showed an increase in pH from 3.36 (control soil) to 4.40 on soils given biochar (10 t/ha) but did not significantly differ from other single amendments. Furthermore, the combined application of *C. odorata* (10 t/ha)+biochar (5 t/ha) obtained the highest increase in soil pH (4.58), in marked contrast to soils given rice husk ash but not significantly different from single amendments or other combinations.

Applying single and combined soil amendments affected the increase in soil C-organics. The statistical test results in Table 2 show that the control soil had the lowest C-organic (1.94%), in stark contrast to other amended soils, except that the soil had given rice husk ash (10 t/ha) was not significantly different. The soil given a single amendment of rice straw (10 t/ha) obtained 4.58% C-organic, in stark contrast to the control soil and the soil given rice husk ash, but not significantly different from other soil amendments. Similarly, soils given a combination of *C. odorata* (10 t/ha)+biochar husk (5 t/ha) achieved the highest soil C-organic (4.93%) in marked contrast to control soils and soils fed with rice husk ash but did not significantly differ from other soil amendments.

Applying various amendments and combinations to acid sulphate soil generally affected the increase in P-available. The results of statistical tests (Table 2) show that control soils had the lowest P-available content (0.21%), significantly different from soils given various amendments. In soils fed with a rice husk biochar (10 t/ha), the P-available increased to 0.32%. Still, it was not significantly different from other combined or single-amended soils, except with soils that were given rice husk ash with a lower P-available (0.27%). The highest P-available was obtained on soils given a combination of *C. odorata* (10 t/ha)+biochar (5 t/ha) (0.34%), in stark contrast to control soils and those topped with rice husk ash but not significantly different from single amendments or other combinations.

The decrease in Al-dd and Fe-dissolve in acid sulphate soil also occured due to applying various soil amendments and their combinations. Statistical tests (Table 2) showed that the highest Al-dd was obtained on control soil (3.84%), further decreasing and differing markedly from soils given various single and combined amendments. On single-amendment soils of rice husk biochar (10 t/ha), Al-dd decreased to 3.16%, significantly different from other single-amended soils. Furthermore, the soil given the combination of *C. odorata* (10 t/ha)+rice husk biochar (5 t/ha) obtained the lowest Al-dd content (3.02%). It was not significantly different from the soil given a combination of rice straw (10 t/ha)+rice husk biochar (5 t/ha), but it was significantly different from other amended soils. In soluble Fe content, the application of rice husk biochar (10 t/ha) could reduce soluble Fe from 3.61% on control soil to 3.10% and was significantly different from other single amendments. And when the soil was given a combination of rice straw (10 t/ha)+rice husk biochar (5 t/ha) caused the lowest decrease in Al-dd (2.91%). Still, it was not significantly different from soil that was given a combination of *C. odorata* (10 t/ha)+rice husk biochar (5 t/ha).

The CEC of land has also increased due to the application of various land amendments and their combinations. The statistical test shown in Table 2 shows that the control soil had the lowest CEC (6.64 Cmol/kg), not significantly different from soils fed with *C. odorata* and rice straw. On the other hand, on soils provided with rice husk biochar (10 t/ha), the soil CEC increased to 8.03 Cmol/kg, but it was not significantly different from soil given rice straw and rice husk ash.

In line with the results that have been put forward, Yamato *et al*. (2006) found that the application of biochar from *Acacia mangium* bark into the soil in Sumatra led to changes in soil chemical properties through increased pH, N-total and P-available, CEC and lowered interchangeable Al. Liang *et al.* (2006) found that two mechanisms could create a larger CEC. First, a higher charged density per unit of surface acreage means a higher degree of oxidation of soil organic matter. Second, the presence of a higher surface area for cation absorption or the combined effect of both. Glaser *et al.* (2002) posit that oxidation of aromatic C and carboxyl formation were the main reasons for the high CEC. Liang *et al*. (2006) also found that the CEC per unit C was higher, and the load density was higher in carbon-black-rich Anthrosol compared to soils that were poor in carbon black. In addition, Anthrosol showed a higher surface acreage due to its higher carbon black concentration.

From the results, the great potential of rice husk biochar against improving soil properties increased when given together with the biomass *C. odorata*. It could happen because *C. odorata* contained higher humate and fulvic organic acids, so that it could encourage the complex mechanisms of organo-mineral organs and soil aggregation. In addition, *C. odorata* can highly suppress Al and Fe, thereby increasing the P availability in the soil due to the presence of organic acids released during decomposition. Research results by Suri and Yudono (2020) also found that using *C. odorata* compost could improve soil quality and nutrient uptake of lettuce plants.

C. odorata can contribute to the care of soil C-organic and physical properties due to a reasonably high polyphenol content that could inhibit the decomposition and mineralization of N organic matter, even though it had a low C/N ratio.

CONCLUSION

In conclusion, the amendment of rice husk biochar combined with amendments to *C. odorata* and rice straw improved soil physical properties, namely, total soil pores, reducing soil content weight and strength. Its impact on soil chemical properties was that it could increase pH, C-organic, P-available, CEC, lower Al-dd and Fe soluble. Therefore, applying biochar and organic amendments to *C. odorata* and rice straw could improve the properties of acid sulphate soil. Consequently, we recommend increasing the carrying capacity of acid sulphate soil against plant growth. It can be done by enhancing soil properties through the organic amendments application of *C. odorata* or straw enriched with rice husk biochar.

ACKNOWLEDGEMENTS

The authors thank the Institute for Research and Community Service, Universitas Panca Bhakti, which has given support for research funds. In addition, they thank the Faculty of Agriculture, Universitas Panca Bhakti, which has provided loans for facilities in the form of equipment for research.

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Table 1. Effect of rice husk biochar with soil amendments on some physical properties of acid sulphate soil at one month after incubation.

Soil amendments	BD (mg/m^3)	Total pores (%)	Penetration resistance (N/cm^2)		
			pF 0	pF 2	pF 2.5
Control	1.24 e	44.43 a	36.67 b	310.00 e	500.00 d
C. odorata (10 t/ha)	1.16 c	52.17 e	20.00 a	230.00 abc	403.33 bc
Rice straw (10 t/ha)	1.17 bc	53.27 f	16.67 a	243.33 bc	393.33 b
Rice husk biochar (10 t/ha)	1.15 b	54.21 g	14.33 a	223.33 ab	390.00 b
Rice husk ash (10 t/ha)	1.19 d	47.30 b	20.00 a	270.00 d	403.33 bc
C. odorata (10 t/ha) + biochar (5 t/ha)	1.13 a	56.73 i	10.00 a	220.00 a	340.00 a

Rice straw (10 t/ha) + rice husk biochar (5 t/ha)	1.14 ab	55.57 h	13.33 a	223.00 ab	360.00 a
C. odorata (10 t/ha) + rice husk ash (5 t/ha)	1.15 b	48.90 c	16.67 a	240.00 bc	420.00 c
Rice straw (10 t/ha) + rice husk ash (5 t/ha)	1.16 bc	50.30 d	20.00 a	246.67 c	403.33 bc

Remarks: The average numbers followed by the same letter in the same column show no significant difference in the LSD test at 5% significant level.

Table 2. Effect of rice husk biochar with soil amendments on some chemical properties of acid sulphate soil at one month after incubation.

Soil amendments	pH H_2O	C-organic (%)	P-available (%)	Al-dd (me/100 g)	Soluble Fe (%)	CEC (me/100 g)
Control	3.36 a	1.94 a	0.21 a	3.84 e	3.61 d	6.64 a
C. odorata (10 t/ha)	4.06 bc	4.22 b	0.29 bc	3.31 c	3.28 c	7.15 ab
Rice straw (10 t/ha)	4.28 bc	4.58 b	0.30 bc	3.42 cd	3.34 cd	7.32 abc
Rice husk biochar (10 t/ha)	4.40 bc	4.09 b	0.32 cd	3.16 b	3.10 abc	8.03 c
Rice husk ash (10 t/ha)	3.98 b	2.78 a	0.28 b	3.51 d	3.34 cd	7.76 bc
C. odorata (10 t/ha) + rice husk biochar (5 t/ha)	4.58 c	4.93 b	0.34 d	3.02 a	2.94 ab	10.04 e
Rice straw (10 t/ha) + rice husk biochar (5 t/ha)	4.48 bc	4.75 b	0.33 d	3.08 ab	2.91 a	9.67 de
C. odorata (10 t/ha) + rice husk ash (5 t/ha)	4.26 bc	4.70 b	0.31 cd	3.37 c	3.25 c	9.17 d
Rice straw (10 t/ha) + rice husk ash (5 t/ha)	4.26 bc	4.73 b	0.31 cd	3.47 d	3.22 bc	9.20 d

Remarks: The average numbers followed by the same letter in the same column show no significant difference in the LSD test at 5% significant level.

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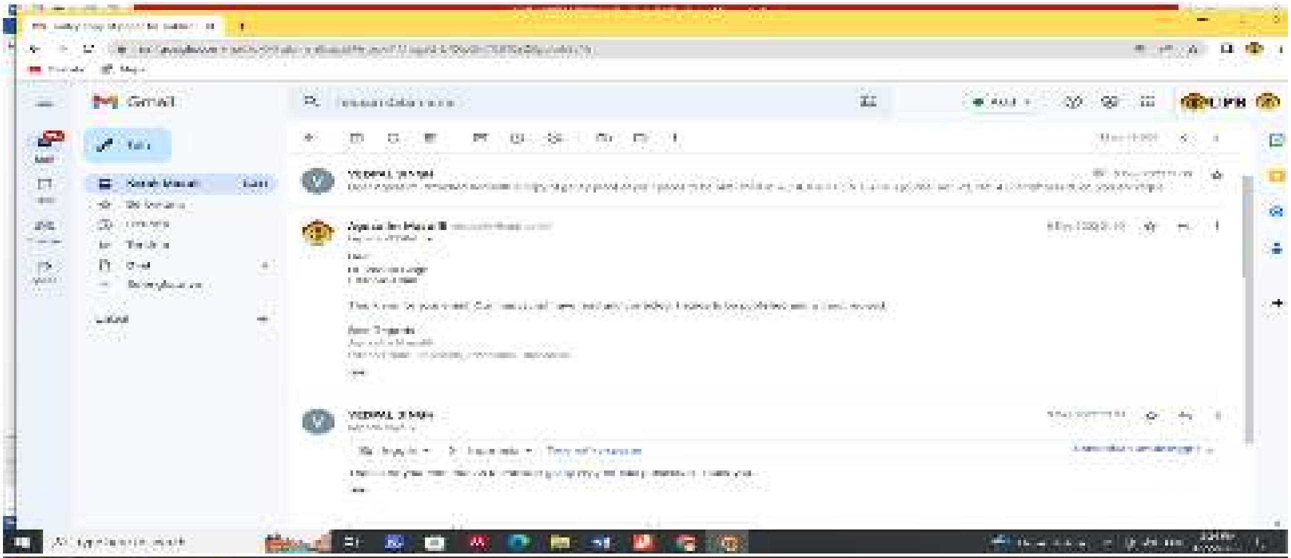

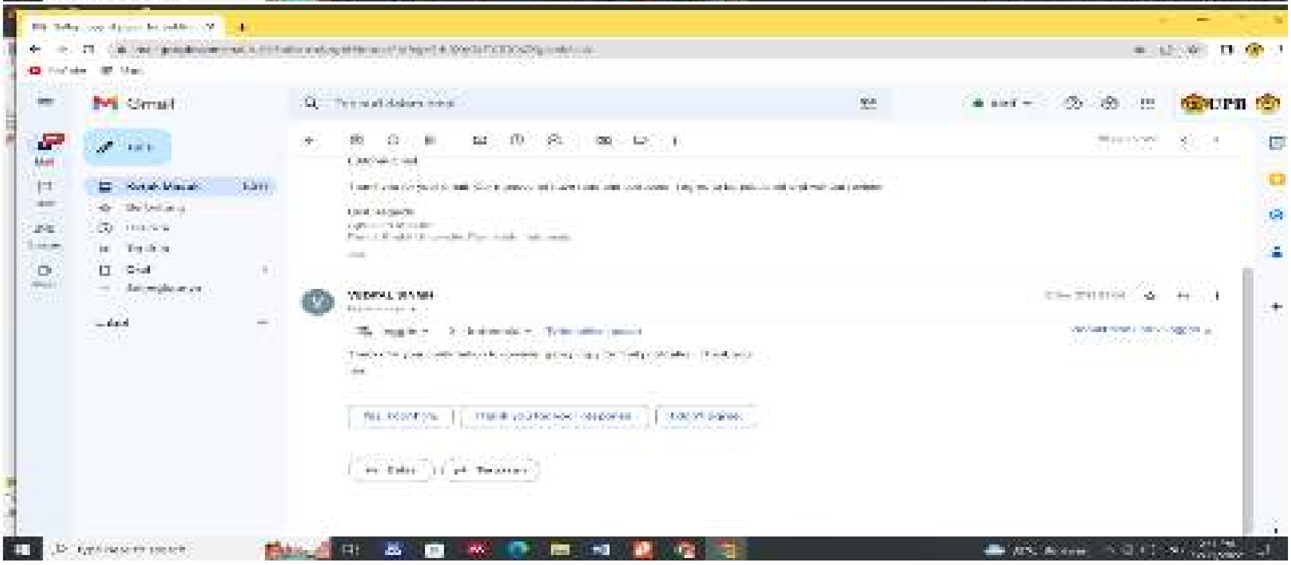

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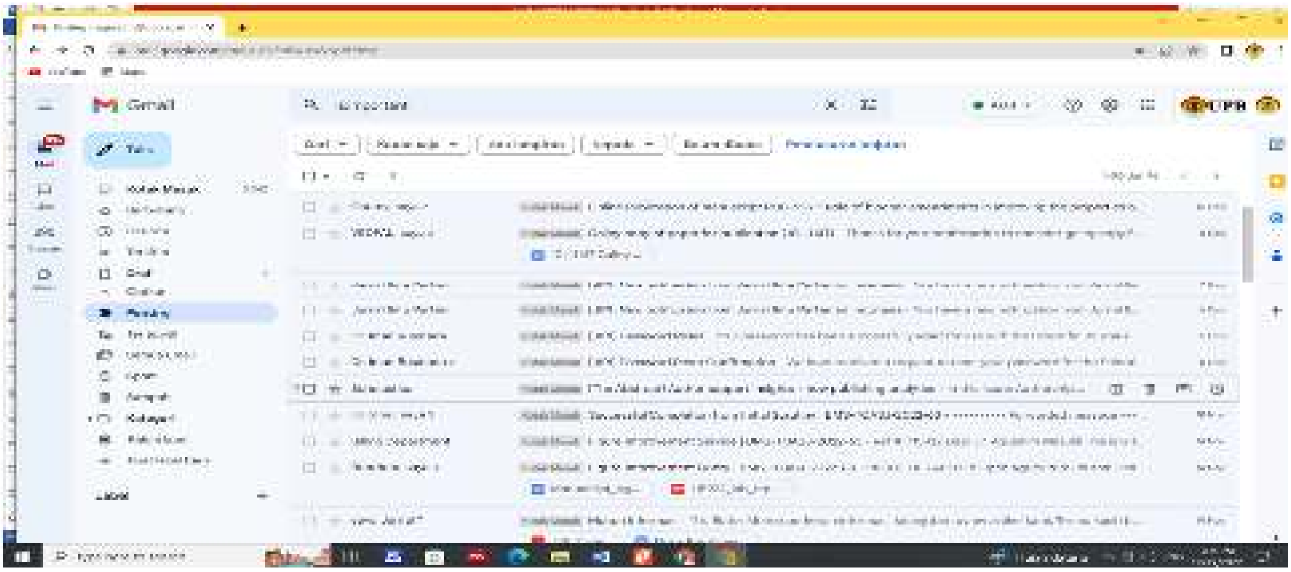

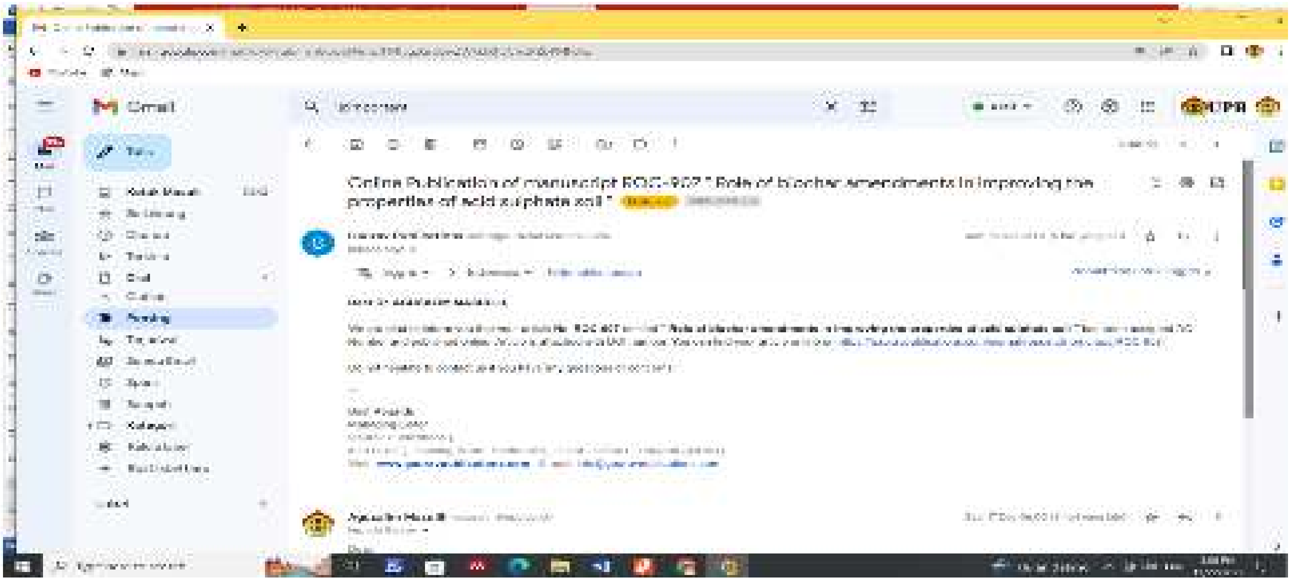

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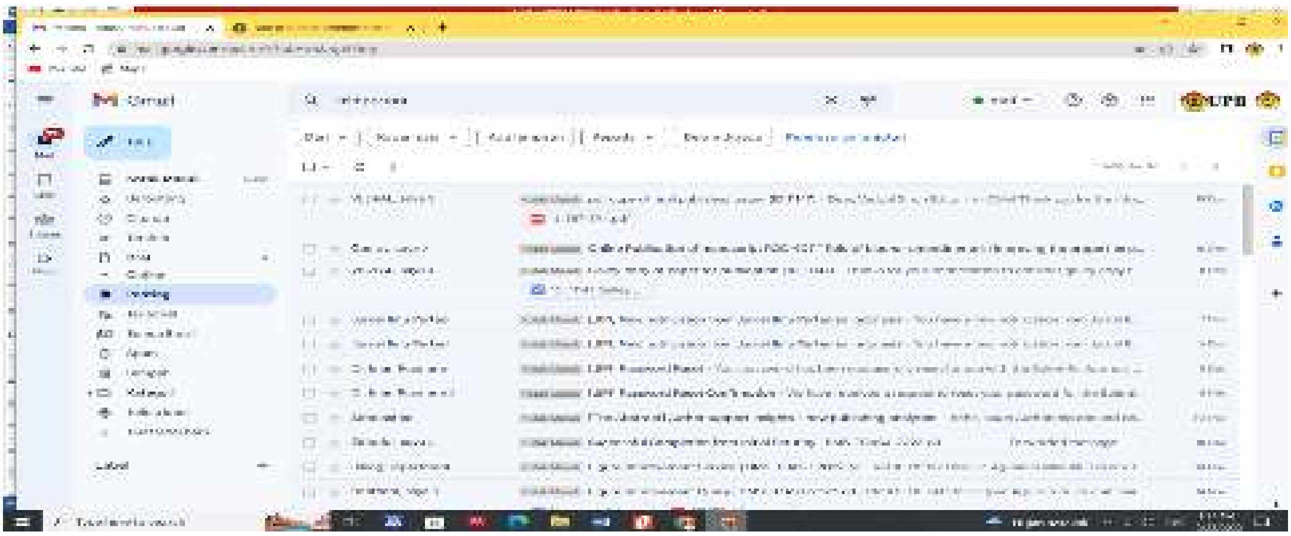

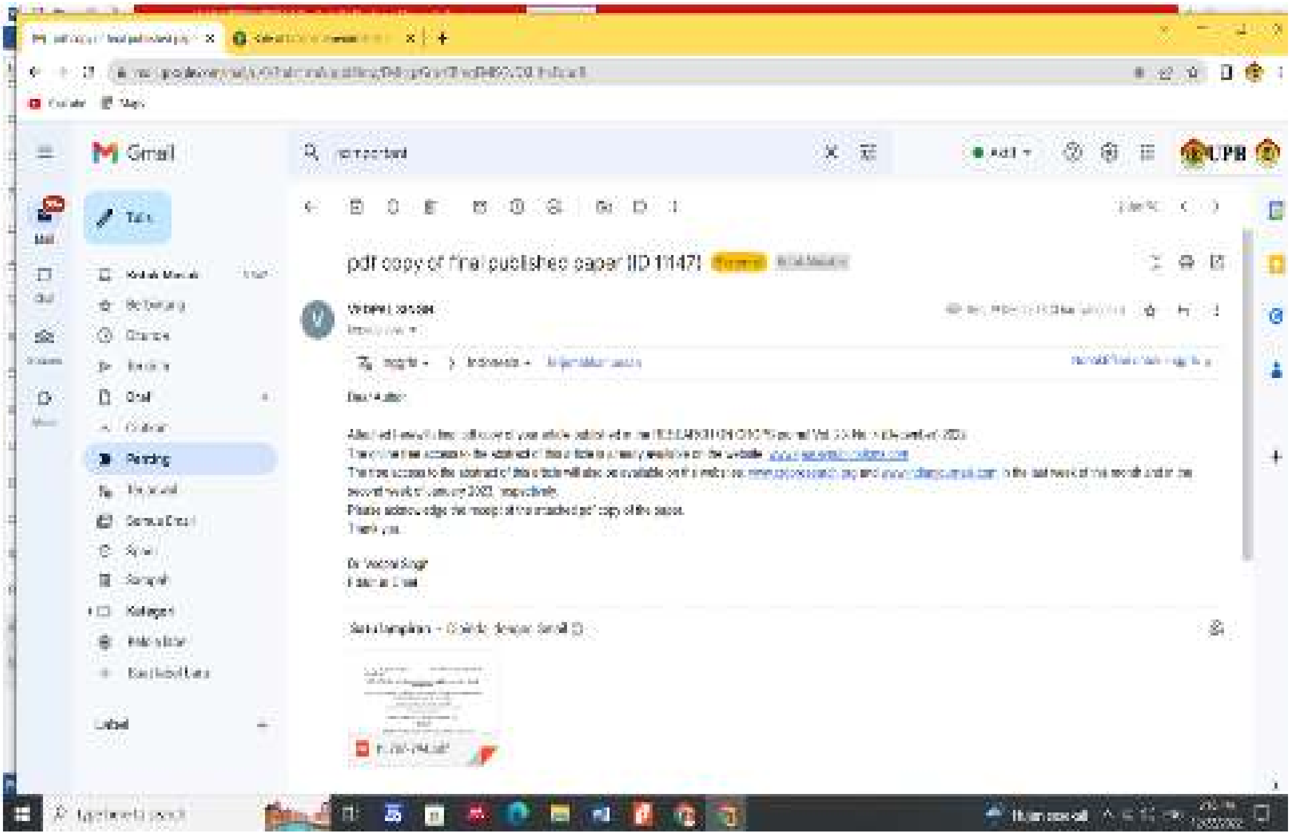

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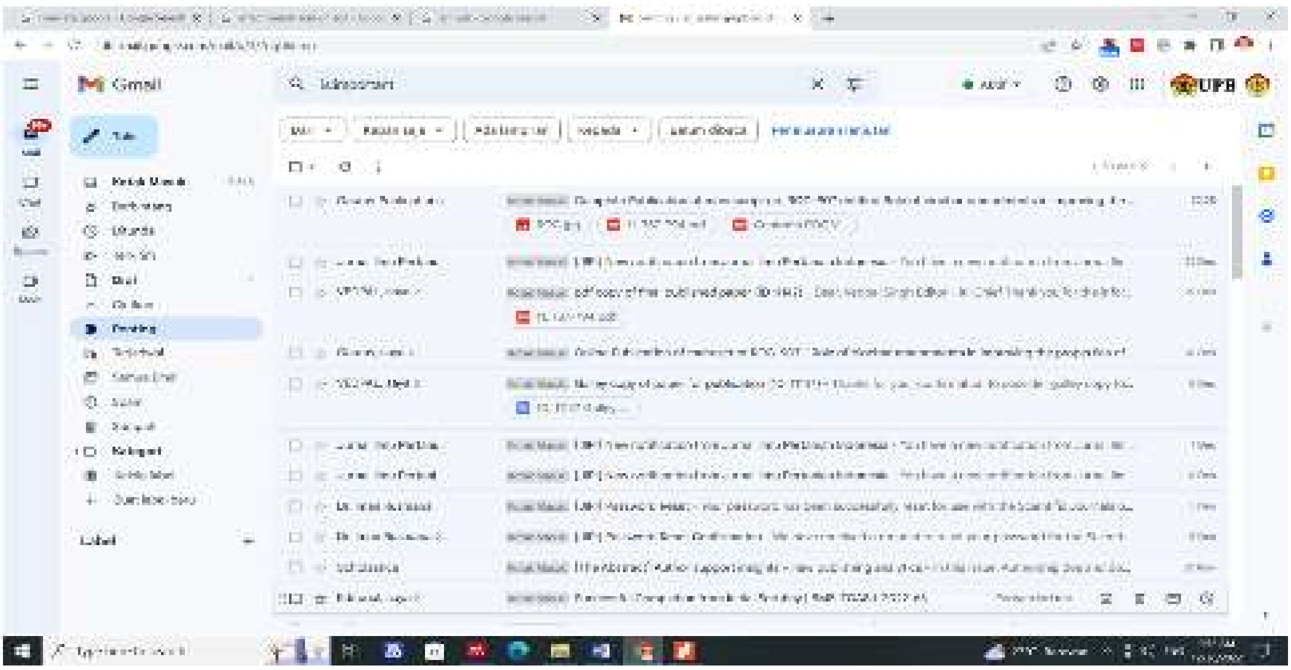

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Citation :- Role of biochar amendments in improving the properties of acid sulphate soil. Res. Crop. 23: 787-794

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Online Published: 10-12-2022

Abstract

Acid sulfate soils have potential for agricultural development. However, this soil has various properties problems that can inhibit plant growth. One way to improve soil properties is through the application of biochar amendments. The study aimed at knowing the role of rice husk biochar combined with amendments to Chromolaena odorata, rice straw, and rice husk ash to improve the properties of acid sulphate soil. The study was conducted in a greenhouse and arranged in a complete randomized design (CRD) with three replications. Biochar amendments consisted of nine kinds, namely, without amendments (control), C. odorata (10 t/ha), rice straw (10 t/ha), rice husk biochar (10 t/ha), rice husk ash (10 t/ha), C. odorata (10 t/ha)+rice husk biochar (5 t/ha), rice straw (10 t/ha)+rice husk biochar (5 t/ha), C. odorata (10 t/ha)+rice husk ash (5 t/ha), and rice straw (10 t/ha)+rice husk ash (5 t/ha). The results showed that the amendment of rice husk biochar combined with amendments to C. odorata and rice straw, respectively, had a good effect on improving soil physical properties, namely, total soil pores, reducing soil content weight and soil strength. Its effect on soil chemical properties was that it could increase pH, C-organic, P-available, cation exchange capacity (CEC), lower Al-dd and Fe soluble. The research findings showed that applying biochar and organic amendments to Chromolaena odorata and rice straw could potentially improve the properties of acid sulphate soil. In future

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