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The Use of Rice Harvest Residue as Soil Amendment for Growth and Yield of Rice (*Oryza sativa* L.) on Acid Sulfate Soil

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ABSTRACT

The area of rice fields in Indonesia decreased every year. Acid sulfate soil, which was sub-marginal land, had the potential to be converted into rice fields, but it needed improvement, one of which was by using organic materials as ameliorants. This research aimed to obtain the best composition of applying rice harvest residue as an ameliorant on acid sulfate soil in improving the growth and yield of rice. The research was conducted at the greenhouse of Panca Bhakti University Pontianak from January to April 2022. This study used a Completely Randomized Design (CRD). The treatments consisted of: p0: Control, p1: Rice straw = 40 gr/polybag, p2: Rice husk = 40 gr/polybag, p3: Rice husk charcoal = 40 gr/polybag, p4: Rice husk ash = 40 gr/polybag, p5: Rice straw + rice husk, p6: Rice straw + rice husk charcoal, p7: Rice straw + rice husk ash, p8: Rice husk + rice husk charcoal, p9: Rice husk + rice husk ash, p10: Rice husk charcoal + rice husk ash, with each material weighing 20 gr/polybag. The observation variables were plant height, number of tillers, number of productive tillers, dry weight of grains per hill, and 100-grain weight. Analysis of variance used F-test and continued with Least Significant Difference (LSD) test at the 5% level. The application of rice harvest residue had a better effect on the growth and yield of rice than the treatment without the application of rice harvest residue. Treatment p6 had the best effect on the dry weight of grains per hill, which was 65.67 grams.

1. INTRODUCTION

The area of rice fields in Indonesia is decreasing every year. The decreasing of land is due to the conversion of rice fields to housing or industry. The conversion of national rice fields varies between 60,000-80,000 hectares per year. If the harvest index for rice that has changed its function is between 2.5-3% with an average productivity of 6 tons of dry milled grain/hectare, then in five years the rice fields that have changed its function will be between 300,000-400,000 hectares with a loss of rice yield reaching 1.8 million tons-

2.4 million tons of GKG (Kementerian Pertanian, 2022). The narrowing of rice fields requires farmers to look for alternative land locations for rice cultivation. Land that has the potential to be used as paddy fields is acid sulphate soil.

Acid sulfate soil is often found in swamp land. The swamp land in West Kalimantan itself is very extensive and still not widely used. The potential land area in West Kalimantan is 4,969,824 ha and 110,894 ha is tidal swamp land (BPS Provinsi Kalimantan Barat, 2014). The development of acid sulphate tidal land for agriculture is faced with low availability of essential macro nutrients such as N, P and K, and high solubility of elements that can poison plants such as Fe, Al and Mn, as well as soil acidity which is generally acid to very acid (Masulili *et al*., 2014). Acid sulfate soil contains pyrite which, when oxidized, will increase soil acidity which can reduce soil fertility (Annisa & Purwanto, 2010). Low soil fertility on tidal land results in low rice productivity on this land, so it is necessary to improve soil quality. One of the efforts to improve the quality of acid sulfate soil is using ameliorant. One of the ameliorants that can be used is one that comes from rice harvest waste. Paddy fields produce around 4-6 t ha-1 of straw in each planting season, even if farmers plant local varieties they will produce more straw, namely around 7-9 t ha-1. This large amount of straw has the potential to be used as organic material after undergoing a composting process or processed into biochar (Maghdalena *et al*., 2017). Straw compost contains C-organic nutrients (35.11%), N (1.86%), P (0.21%), K (5.35%) and water content (55%) (Hendra *et al*., 2014). Rice husk ash contains the nutrients Ca (15.20%), Mg (8.16%), N (0.018%), P (0.28%), K (6.40%) (Farni, 1998), while straw ash contains the nutrient Ca (0.59%) , Mg (0.51%), N (0.31%), P (0.80%), K (3.81%) and Si (37.81%) (Hendra, 2000).

Research on the use of rice harvest waste as an ameliorant has been widely carried out, including rice husk and straw waste in peat soil as a growth medium for soybeans and green beans (Hendra *et al*., 2014; Riono & Apriyanto, 2020), rice husk ash as an ameliorant in soil. ultisol (Kurniawan & Widodo, 2009), rice straw compost and biochar in paddy field soil (Avifah *et al*., 2022), and rice straw residue in acid sulfate soil (Susilawati & Nursyamsi, 2013). Additionally, Lucky *et al*. (2020) combined rice husk biochar with straw compost and Tithonia diversifolia to improve nutrient uptake in intensified rice fields. This research aims to obtain the best composition for the application of straw ameliorant and rice husk charcoal on acid sulphate soil to increase rice growth and production.

2. MATERIALS AND METHODS

The research was carried out in the greenhouse at Panca Bhakti University, Pontianak, starting from January 2022 to April 2022. The rice seeds used were the Ciherang variety. The type of soil used was acid sulfate soil taken from Pal Sembilan Village, Sungai Kakap District. The polybags used have a size of (40 x 50) cm. The basic fertilizer was Urea, SP36, KCl fertilizer at the recommended dose. The rice wastes (straw, husks, husk charcoal, husk ash) were taken in Pal Sembilan Village, Sungai Kakap District. The stra was chopped before application. The tools used in this research included hoes, shovels, meters, buckets, scales, raffia plastic ropes, cutter knives, documentation tools, thermometer, hygrometer, pH meter, raining bucket, stationery, and other supporting tools.

2.1. Experimental Design and Data Analysis

This research used a Completely Randomized Design (CRD), with eleven treatments and repeated three times. Planting was performed using polibag and a total of 33 polibags was provided as experimental units. The addition of organic wastes from the rice harvest was given based on the general recommended dose, namely 10 tonnes/ha which is equivalent to 40 g/polybag. The treatments used in this research was presented in Table 1.

Table 1. Details of research treatment

Treatment	Material dose (g/polybag)			
	Straw	Husk	Husk charcoal	Husk ash
p_0 (Control)	0	0	0	0
p_1	40	0	0	0
p_2	0	40	0	0
p_3	0	0	40	0
p_4	0	0	0	40
p_5	20	20	0	0
p_6	20	0	20	0
p_7	20	0	0	20
p_8	0	20	20	0
p_9	0	20	0	20
p_{10}	0	0	20	20

2.2. Research Steps

2.2.1. Nursery

Before sowing the seeds were soaked in the water for ± 24 hours. Seeding was performed using a wet seeding method were seeds were sown in a basin with acid sulfate soil mixed with manure at a 1:1 ratio. After the seeds were ± 14 days old, they were transplanted into polybags.

2.2.2. Preparation of Planting Media

The type of soil used as a planting medium was acid sulfate soil. Before use, the soil was first cleaned by sieving, then air-dried. As much as 8 kg soil was prepared for each polybag. The soil was first mixed evenly with rice wastes at respected dose as in Table 1. The prepared soil media was then filled into the polybag using a shovel. The planting medium that has been prepared in polybags, then incubated for ± 14 days before the seeds are transferred to polybags.

2.2.3. Maintenance

The basic fertilizer was given at the recommended dose for rice. The need for urea fertilizer for rice plants = 100 kg/ha, SP36 = 200 kg/ha, and KCl = 50 kg/ha. For this study, the dosages were equivalent to 0.4 g urea, 0.8 g SP36, and 0.2 g KCL per polybag. Watering in polybags was carried out just after planting. The inundation depth was 5 - 10 cm during the vegetative phase before the primordia period. When the rice entered the primordia until harvest the inundation depth in the polybags was set up at around 2-5 cm. Weeding was done as required by removing the weeds. Pest control was also carried out as required when symptoms of attack by pests are seen (the dominant pest in this study was the stink bug). This pest control is carried out using furadan pesticide at a dose of 1 ml/liter of water. Other pest control was done by fencing off the research area using transparent nets to prevent pests entering the research area.

2.2.4. Harvesting

The harvesting process was carried out after the rice plants starting to fall or have reached the dead ripe stage marked by hard grain contents. The harvesting process was carried out with scissors to cut the rice panicles.

2.3. Data Analysis

The response variables included plant height, number of tillers, number of productive tillers, dry grain weight per pot, and weight of 100 dry grains. Rice plant height was measured from the base of the stem to the tip of the growing point 50 days after transplanting (DAT). The number of tillers was calculated after the rice plant reached the primordia phase and did not produce any more tillers at 50 days after planting. The number of productive tillers was calculated from the tillers that produce panicles during the rice harvesting process. The weight of dry grain was measured from the grain produced by each clump after the grain was dried. The weight of 100 grains of dry grain was calculated from 100 grains in each treatment and then weighed.

Data were analyzed using ANOVA to determine if the treatments resulted in different responses. If there is a significant difference, then to determine the difference between treatments, analysis was continued with the Tukey test at the 5% level.

3. RESULTS AND DISCUSSION

3.1. Soil Properties

Results of chemical analysis of the chemical properties of acid sulfate land is listed in Table 2. Based on Table 2, it can be seen that the soil texture is silty loamy clay. The penetration ability of plant roots and soil water retention is largely determined by soil texture. In addition, soil texture can also influence the chemical and biological properties of the soil (Pusparani, 2018). Soil that has low clay will cause the Cation Exchange Capacity (CEC) of the soil to be low (Puja & Atmaja, 2018). Soil with low clay also tends to have low organic matter which will affect the presence of microorganisms in the soil (Gupta, 2011). Based on Table 2, the soil pH in this study was 4.32, which is classified as very acidic. Soil pH can influence the supply of plant nutrient levels due to chemical reactions in soil colloids which are regulated by the electrochemical properties of the soil (Rahmah *et al*., 2014). Soil acidification occurs as a result of the presence of a layer of pyrite (FeS_2) which undergoes oxidation (Khairullah & Noor, 2018). A number of nutrients will be less available in very acidic conditions. Iron phosphate which cannot dissolve at acid condition will fix the P element, causing the availability of P to be very limited (Manurung *et al*., 2017). Rice really needs the availability of macro and micro nutrients during the growth process (Zahrah, 2011). Apart from nutrient unavailability, plants can also experience Al and Fe poisoning as a result of the pyrite oxidation process, which can affect rice growth (Shamshuddin *et al*., 2014). Soil ameliorant such as organic materials, biochar, and biomas ash is known to improve soil pH, reduce the toxicity of aluminum and iron, improve water content and soil permeability and increase nutrient availability (Gonzalo *et al*., 2013).

The C-Organic parameter shows a value of 0.19% (very low). The C-Organic content is an important factor determining the quality of mineral soil, the higher the total C-Organic content, the better the soil quality (Siregar, 2017). Base saturation and CEC values in the soil are also classified as very low. This implies that the availability of nutrients in the soil is low (Sembiring *et al*., 2015).

Table 2. Chemical properties of soil used in the experiment

Parameters	Value	Criteria
pH H_2O	4,32	Highly acid
pH KCl	3,60	
C-Organic (%)	0,19	Very low
Extraction Bray I		
P_2O_5 (ppm)	10,59	Adequate
Extraction NH_4OAC 1N pH : 7		
Calsium (cmol (+) kg^{-1})	0,62	Very low
Mangnesium (cmol (+) kg^{-1})	0,27	Very low
Kalium (cmol (+) kg^{-1})	0,22	Low
Natrium (cmol (+) kg^{-1})	0,23	Low
CEC (cmol (+) kg^{-1})	12,76	Low
Base saturation (%)	10,50	Very low
Extraction KCl 1N		
Alumunium (cmol (+) kg^{-1})	0.90	
Hidrogen (cmol (+) kg^{-1})	0,09	
Texture		Silty Loamy Clay
Sand (%)	11,38	
Silt (%)	63,06	
Clay (%)	25,56	

3.2. Growth and Yield of Rice Plants

The results of the ANOVA analysis showed that there were significant differences for all observation parameters. A recapitulation of the 5% Tukey test results on growth and yield parameters of rice plants is presented in Table 3.

Table 3. Effect of rice wastes addition on the average rice growth and yield in acid sulfate soil

Treatment	Plant heigh (cm)	Number of tiller	Number of Productive tiller	Dry grain weight per pot (g)	Weight of 100 dry grains (g)
p_0 (Control)	84.33 a	10.33 a	9.66 a	30.14 a	2.50 a
p_1 (straw)	106.33 bc	22.33 b	20.66 b	63.44 b	2.67 a
p_2 (husk)	105.33 bc	21.33 b	19.00 ab	62.08 b	2.60 a
p_3 (husk charcoal)	108.66 c	24.33 b	21.33 b	63.70 b	2.64 a
p_4 (husk ash)	94.66 ab	18.66 b	17.66 ab	53.22 ab	2.55 a
p_5 (straw+husk)	100.00 bc	20.00 b	18.33 ab	57.70 b	2.67 a
p_6 (straw+husk charcoal)	109.00 c	24.33 b	22.66 b	65.67 b	2.69 a
p_7 (straw+husk ash)	102.16 bc	20.33 b	18.66 ab	59.30 b	2.61 a
p_8 (husk+husk charcoal)	103.33 bc	21.00 b	18.66 ab	60.62 b	2.61 a
p_9 (husk+husk ash)	106.16 bc	21.66 b	19.66 b	62.69 b	2.60 a
p_{10} (husk charcoal +husk ash)	99.00 bc	18.66 b	18.00 ab	56.25 b	2.55 a

Note: Numbers followed by the same letter are not significantly different in the 5% Tukey test.

The results of the ANOVA analysis of plant height data showed that soil amendment treatment using rice harvest wastes had a significant effect on rice plant height as compared to the control. The results of the Tukey test at the 5% level on the average rice plant height resulted that all treatments using rice wastes are not significant; the exception is for p4 treatment which produce the lowest plant height and not significantly different from the p0 (control). The p6 treatment showed that the average plant height was relatively higher than the other treatments, although statistically is not different. This is in line with research by Andayani & Hayat (2019) and Abdillah & Widiyastuti (2022). Research by Andayani & Hayat (2019) shows that the use of oil palm empty fruit bunches and rice husk charcoal can increase the height of rice plants in acid sulphate soil. Research by Abdillah & Widyastuti (2022) shows that the combined application of rice straw compost and solid decanter can reduce dissolved Fe^{-} and Al^{-}. Rice straw undergoes a decomposition process of organic material into mineral compounds through abiotic and biotic processes (Nurlaila *et al*., 2021). The breakdown of organic material in the soil will cause mineralization of nutrients, so that nutrients that were initially unavailable become available to plants so that the plant growth process runs well (Ifansyah & Saidy, 2019). Suriani *et al*. (2020) also reported that straw compost can increase soil pH and reduce Fe concentration.

The results of ANOVA analysis on the number of tillers show that soil amendment treatment using rice harvest wastes has a very significant effect. The results of the Tukey test at the 5% level reveals that all treatment using rice harvest wastes are significant on the average number of rice tillers (Table 3). Again, the p6 treatment produced the highest average of number of tillers than the other treatments, although statistically is not different.

The results of the ANOVA analysis on the number of productive tillers show that the treatment of soil amendments from p3, p6, and p9 has resulted the highest effect on the number of productive tillers of rice plants. Whereas the other treatments (p2, p4, p5, p7, p8, p10), although resulted in are much higher productive tillers than control, but statistically are not different to the control and to those of the highest treatments (Table 3). The p6 treatment showed that the average number of tillers and productive tillers of the plants was relatively higher than the other treatments. According to (Barus, 2011), the number of tillers is greatly influenced by the availability of nitrogen and phosphorus nutrients in the soil. The availability of nitrogen and phosphorus nutrients might be a result of the mineralization process of organic material in the soil (Saputra & Sari, 2021). Research by Gharieb *et al*. (2015) showed that the application of compost can increase nitrogen and P-available in paddy fields. High availability of the nutrient N will cause an increase in the rate of photosynthesis, while the addition of the nutrient P will strengthen the plant root system so that more tillers are produced (Syahrudin *et al*., 2021). The P element also plays a role in cell division so that if enough P nutrients are available it will stimulate rice plants to produce more tillers (Sunadi *et al*., 2019).

The results of the ANOVA analysis of the dry grain weight data showed that the soil amendment treatment using rice harvest wastes had a significant effect on the dry grain weight of rice as compared to control. Only treatment p4 (husk ash) that is not statistically not different to control, though numerically is considerably higher. The results of the AOVA analysis of the weight of 100 grains, however, showed that the soil amendment treatment of rice harvest waste had no significant effect as compared to control. As can be observed from Table 3, the effect of all treatments using rice wastes on the dry grain weight are not statistically different. It is suspected that the provision of rice harvest wastes is able to create a conducive environment for growth and provide additional nutrients, especially Si, organic C, total Mg, and K in the formation of the number of panicles which can influence the number of grains. This is in line with research by Abdillah & Widiyastuti (2022) which showed that the use of rice straw compost and crumb rubber solid waste resulted in a higher weight of unhusked dry grain as compared to the control. If plant tissue in the soil is decomposed due to the activities of various organisms, various organic and inorganic compounds will be produced. Carbohydrates and proteins are easily decomposed into phosphate (PO_4), sulfate (SO_4), nitrate (NO_3), ammonia (NH_4), carbon dioxide (CO_2), and several other elements (Kurnia *et al*., 2021).

Overall, treatment p6 (straw + husk charcoal) showed relatively higher growth and yield of rice plants compared to other treatments. Rice straw is known to contain 0.35% N, 0.1% P and S, 0.1% K, 5% Si and 33.4% C, and contains microelements such as Zn, Si, and Fe so it has the potential to be a source of nutrients in acid sulfate soil (Masulili *et al*., 2014; Fahmi *et al*., 2009). Nutrient availability from rice straw residues is a result of mineralization and immobilization processes as well as soil microbial activity. Mineralization will release a number of plant nutrients (N, P, K, Ca, Mg, Fe, Cu, Zn, Mn, etc.), while immobilization will bind nutrients (especially N, P, and S) that were previously available into the form temporarily immobilized and the process depends on the C/N, C/P, and C/S ratios (Susilawati & Nursyamsi, 2013).

Rice straw can also reduce iron toxicity in acid sulfate soils. The application of organic material can increase the concentration of Fe_2^+ or reduce the concentration of Fe_2^+ in the soil depending on the maturity level of the organic material (Duckworth *et al*., 2009; Fahmi *et al*., 2009). Providing relatively raw organic material tends to increase the concentration of $Fe2^+$ because it encourages the reduction of Fe_3^+ to Fe_2^+. Apart from that, straw compost also contains organic acids such as humic and fulvic acids which have the ability to chelate toxic elements so they are not harmful to plants. Organic acids resulting from the decomposition of organic materials are able to release P which is fixed by Fe and Al into a soluble form, causing plants to grow well that increase nutrient uptake and plant production (Susilawati & Nursyamsi, 2013).

Rice husk charcoal is also known to increase the productivity of acid sulfate soils. Research by Masulili *et al*. (2014) using rice husk charcoal combined with *Chromolaena odorata* and rice straw at 6 weeks after incubation, can increase pH, organic C, available P and CEC, and reduce exchangeable Al and soluble Fe in the acid sulfate soil. Increasing soil pH after applying rice husk straw and charcoal indirectly increases the solubility of nutrients. The increase of soil pH can be resulted from the reduction of Fe_3^+ to Fe_2^+ by organic materials which can presented as the following (Fahmi *et al*., 2009):

$$Fe(OH)_3 + 2\,H^+ + \tfrac{1}{4}CHO_3^- \rightarrow Fe^{2+} + 11/4\,H_2O + \tfrac{1}{4}\,CO_2 \quad (1)$$

Soils that are rich in organic matter have relatively few nutrients that are fixed in soil minerals so that are more available to plants. Plant residues that are returned to the soil can also increase plant growth and development, and also have an effect on increasing the activity of microorganisms that play an important role in the decomposition process, so that nutrient elements become available and can be utilized by plants. Organic matter plays a physical, chemical and biological role in determining the fertility status of the soil. In soil that lacks of organic matter, more nutrients are fixed in soil minerals so that they become relatively unavailable, causing plant to unoptimally grow (Santoso *et al*., 2013).

Addition of organic matter to the soil has a good impact on the soil for plants to grow. Plants will respond positively if the place where they grow provides good conditions for their growth and development (Ohorella & Hilmanto, 2011). Organic material added to the soil provides plant growth regulators that provide benefits for plant growth such as vitamins, amino acids, auxins and gibberellins which are formed through the decomposition of organic material. Organic material added to the soil contains high carbon. Regulating the amount of carbon in the soil increases plant productivity and the sustainability of plant life because it can increase soil fertility and efficient use of nutrients. It can be concluded that plants that lack of organic material will have stunted growth because the plants experience a deficiency of nutrient elements. According to Hanafiah (2007), nutrient translocation will be disrupted if the nutrient supply is disrupted, so that plants experience deficiencies marked by abnormal growth. This is proven by the p0 treatment (control) which produces the lowest number of tillers.

According to Adiningsih & Rochayati (1988), soil organic matter management is an action to improve the plant growing environment which, among other things, can increase fertilization efficiency. Organic materials can also increase the availability of several nutrients and increase the efficiency of P fertilization (Suhartatik & Sismiyati, 2000). Therefore, by improving the CEC, increasing nutrient availability and increasing the efficiency of P nutrient uptake, the treatment of addition organic materials synergistically can have an effect on improving plant growth and increasing components. The function of plant nutrients cannot be replaced by other elements. If plants lack of nutrients, metabolic processes will be disrupted or stop completely. In addition, plants that lack of nutrients will show symptoms in certain organs. Plants that lack of nutrients show their growth and results are not optimal, and this is proven by the p0 treatment (control), which gives the lowest value of grain weight.

4. CONCLUSION

Addition of different types of rice wastes to rice plants had no significant effect between each treatment, but all treatments had a significant effect as compared to the control (without rice waste addition). The p6 treatment (a combination of 20 g of straw and 20 g of husk charcoal) resulted the best effect on the grain weight of rice plants, even though statistically is not different to other treatments. The average dry grain weight result for the p6 treatment was 65.67 g per pot. Addition of waste from rice harvests had a better effect than treatment without rice waste, both in terms of growth and yield of rice plants. Local rice is recommended for use in future research so that the rice yields obtained are expected to be more optimal.

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