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RESEARCH ARTICLE

Effect of Mixture of Water Hyacinth Compost and Rice Husk Biochar on the Improvement of Alluvial Soil Properties and the Growth of Red Ginger (*Zingiber Officinale* L.)

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Abstract:

Background:

Alluvial is the potential soil for agricultural development. However, this soil can inhibit plant growth. One of the ways to improve the physical properties of this soil is through the application of soil amendments.

Objective:

This study aimed to determine the optimum dose of a mixture of water hyacinth compost and rice husk biochar for improving alluvial soil properties and the growth of red ginger.

Methods:

This study was arranged in a completely randomized design (CRD) with four replications. The treatment consisted of a mixture of water hyacinth compost and rice husk biochar (volume ratio of 2:1), which consisted of six doses: 0, 40, 60, 80, 100, and 120 g polybag^{-1}. Then, each replication consisted of three samples. As many as 72 polybags were needed in this study. The observed physical properties of the soil were the bulk density (BD) and the soil pore space. The plant growth parameters included plant height, leaf numbers, tiller numbers, and fresh weight.

Results:

The results showed that applying a mixture of water hyacinth compost and rice husk biochar at a dose of 120 g polybag^{-1} caused the lowest BD and the most pore space in the soil. However, a dose of 80 g polybag^{-1} can provide maximum plant height, leaf numbers, tiller numbers, and fresh weight.

Conclusion:

The study findings show that mixing water hyacinth compost and rice husk biochar at 80 g polybag^{-1} is the optimum dose to support the maximum red ginger growth. However, we recommend that future research is needed to investigate the causes of decreasing BD and increasing soil pores.

Keywords: Bulk density, Soil pore, Red ginger, Alluvial, Water hyacinth, Rice husk biochar.

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1. INTRODUCTION

The red ginger plant (*Zingiber officinale* var. *rubrum*.) is one of the important medicinal plants and is widely used by the people of Indonesia. Jabborova *et al.* [1] reported that ginger is important for maintaining health and is effective against some symptoms or diseases, including headaches, nausea, vomiting, and motion sickness. In addition, ginger is associated with anti-tumorigenic and immunomodulatory effects as an anti-microbial, anti-viral agent, a powerful analgesic, and a stimulant that controls various diseases, such as cholesterol and high blood pressure. Azizah *et al.* [2] stated that cultivation techniques and growing media help determine the production standards of red ginger. A good growing medium for red ginger is loose and fertile soil. Hagner *et al.* [3] explained that compost could improve ex-mining soils. Hafez *et al.* [4] added

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that the substance of humates and vermicompost can improve nutrition, plant growth, and water use efficiency. Research results by Perdigão *et al.* [5] stated that tanning waste compost could increase nitrogen and ryegrass crop production on a laboratory scale.

One type of soil that has the potential for ginger development is alluvial soil, which constitutes an area of 15,111,870 km^2 or 10.29% of the total province of West Kalimantan. The soil type belongs to the immature group with slow profile development compared to mature soil and still resembles much of the parent material. Alluvial soil will provide a productive land for the development of red ginger plants. According to Yatno *et al.* [6], these soils belong to marginal soils and are rich in clay. Hikmatullah and Al-Jabri [7] stated that these soils are formed from deposits on flat to nearly flat slopes by fluvial or colluvial processes through water flow and gravitational forces, causing physical, chemical, and mineralogical variations, as well as nutrient accumulation.

Yahya *et al.* [8] argued that an important problem of alluvial soils is soil compaction, which causes obstacles to developing plant roots. It is related to the soil's high BD and low pore space. Widodo and Kusuma [9] stated the problem to be associated with the low content of soil organic matter. Thus, efforts can be made to overcome alluvial soil problems in order to make it a good growing medium by providing soil-improving treatment. One type of soil dressing that can be used is compost. The application was expected to improve the physical properties of the soil, including BD and soil pores. Cahyono *et al.* [10] stated that compost contains organic compounds that can improve the chemical and physical properties of the soil, especially marginal soils. Widodo and Kusuma [9] stated that compost can loosen the soil and enhance the pore space.

One of the materials that can potentially be composted is water hyacinth. These plants can absorb heavy metals and have a very high growth speed. This growing speed causes water hyacinths to be considered a weed or nuisance plant. In large quantities, water hyacinths will have negative impacts in the form of disturbances in the use of water, namely accelerating silting of irrigation canals, enlarging evapotranspiration, making it difficult to transport water, and reducing fishery products. To minimize the negative impact, water hyacinths can be used as compost. Research results by Birnadi *et al.* [11] stated that water hyacinth compost significantly influenced the increase in the peanuts' growth. Mashavira *et al.* [12] said that using water hyacinth compost could increase the growth rate and yield of healthy tomatoes. Water hyacinth compost has the potential to be a source of nutrients, increasing soil organic matter, soil particle aggregation, porosity, water holding capacity, cation exchange capacity, pH, and soil microorganisms [13].

Adding rice husk biochar can increase the role of water hyacinth compost in improving the soil's physical properties, especially BD and pore space. Beusch [14] stated that adding rice husk biochar to the soil contributes to soil fertility, where rice husk biochar can improve the soil's physical, chemical, and biological properties. Karthik *et al.* [15] reported that biochar could increase soil pores and lower BD. In line with this, Glaser *et al.* [16] also suggested that biochar could increase soil productivity. According to Nyasapoh [17], biochar application can improve water use efficiency.

So far, many studies have reported compost and rice husk biochar to improve soil properties and plant growth. However, further research is still needed to use water hyacinth compost mixed with biochar to improve the properties of BD and soil pores. In addition, research on improving the physical properties of alluvial soils could increase red ginger growth. Therefore, based on the background and literature review above, this study aimed to determine the optimum dose of a mixture of water hyacinth compost and rice husk biochar for improving alluvial soil properties and the growth of red ginger.

2. MATERIALS AND METHODS

2.1. Study Site

The study was done in March-June 2021. The research location was the Faculty of Agriculture, Panca Bhakti University, Pontianak, Indonesia. Topographic contours were flat, with an average soil surface height of 1 m above the sea level (ASL). The average temperature and humidity of the air were 27.6 ºC and 82.8%, respectively. The location of the study was at 2º05' North Latitude – 3°05' South Latitude and 108°30'–144°10' East Longitude.

2.2. Experimental Design

The study was arranged in a completely randomized design (CRD) with four replications. The treatment was a mixture of water hyacinth compost and rice husk biochar (volume ratio of 2:1, v/v), which consisted of six doses: 0, 40, 60, 80, 100, and 120 g polybag^{-1}. Each replication consisted of three samples, so 72 polybags were needed.

2.3. Research Procedures

In this study, an alluvial type of soil was used. The soil sample was taken from a depth of 20 cm. The soil was dried for a week and cleared of dirt, root residues, wood, and twigs. The soil was crushed to a size of about 0.2 cm. Then, the soil was put into a polybag (plastic pot) of 40 × 40 cm with a weight of 8 kg. The plant material was local red ginger from Poring Village, Pinoh District, Melawi Regency, West Kalimantan Province, Indonesia.

The compost material was taken from water hyacinth growing in the farmers' land primary channels. Water hyacinths were taken from all parts of the plant and chopped to a size of 1–2 cm. And then, 10 kg of water hyacinth, 5 kg of rice bran, 5 kg of goat manure, and 5 L water were mixed well. Next, the compost was watered with a solution of 6 tablespoons of Tricogreen, and stirred again until evenly mixed. Then, it was tightly covered with a plastic tarp and stored in a place protected from direct sunlight. The material was allowed to stand for four weeks for incubation and stirred once weekly.

Rice husk biochar was made from rice milling waste and was produced by pyrolysis. Next, the water hyacinth compost was mixed with the rice husk biochar in a volume ratio of 2:1 (v/v). Then, the dosage level of treatment was incubated into the polybag for a week before for the stability of soil organic matter. Then, the red ginger seedlings were planted. Dolomite powder (liming agent) was used as a soil amelioration material at 7.7 g polybag^{-1}. NPK Mutiara fertilizer (16:16:16) was used for basal fertilization at 1.2 g polybag^{-1}.

2.4. Parameters

The parameters observed in the study were the soil's physical properties and red ginger growth. Specifically, the alluvial soil properties observed included BD and soil porosity. BD was measured by the clod method described by Blake and Harke. Soil pores were total pores calculated from the moisture content of the soil (v/v) at a matrix potential of 0 kPa. In addition, observations of red ginger growth were carried out 90 days after planting (DAP), including plant height, leaf numbers, tiller numbers, and fresh weight of the plant.

2.5. Statistical Analysis

The data were analyzed using analysis of variance (ANOVA) at the significance level (α: 0.05) [18] with IBM SPSS Statistic 23. In addition, the treatment means were compared using the least significance difference (LSD) at the significance level (α: 0.05).

3. RESULTS

3.1. Changes in Bulk Density and Soil Pores

A mixture of water hyacinth compost and rice husk biochar could improve the physical properties of alluvial soils. The higher dose of a mixture of water hyacinth compost and rice husk biochar caused a decrease in BD, but increased soil pore at 90 days after treatment (DAT). The results of the $LSD_{α: 0.05}$ on BD and soil porosity at 90 DAP are shown in Table **1**.

Table **1** shows that the lowest BD obtained at doses of 100 and 120 g polybag^{-1} was not significantly different, but different at the dose of 0-80 g polybag^{-1}. The total pore also increased at the dose of water hyacinth compost and the rice husk biochar. The highest total pores were achieved with a mixture of water hyacinth compost and rice husk biochar at a dose of 120 g polybag^{-1}. It was not significantly different from the dose of 100 g polybag^{-1}, but significantly different from the dose of 0-80 g polybag^{-1}. This suggests that soil's physical properties with BD indicators and alluvial soil pores can be improved by increasing the mixture of water hyacinth compost and rice husk biochar.

Changes in BD and total pores at various dose treatments of water hyacinth compost and rice husk biochar at 90 DAT can be seen in Fig. (**1**).

Table 1. Effect of mixing water hyacinth compost with rice husk biochar on bulk density and soil pores.

Mixture of Water Hyacinth Compost and Rice Husk Biochar (g polybag^{-1})	Bulk Density (mg m^{-3})	Total Porosity (%)
0	1.23 d	44.43 a
40	1.19 c	52.17 b
60	1.18 bc	53.27 bc
80	1.17 b	54.21 bc
100	1.02 a	55.30 cd
120	0.72 a	58.00 d
$LSD_{α: 0.05}$	0.02	2.75

Note: Values are the mean of four replicates (n= 4). Different letters in the same column are significantly different according to the LSD at the significant level (α: 0.05).

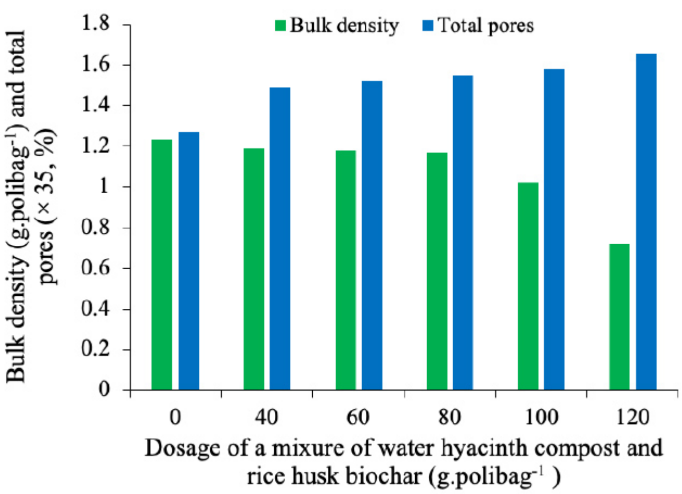

Fig. (1). Effect of a mixture of water hyacinth compost and rice husk biochar on bulk density and total soil porosity.

Fig. (**1**) shows that the highest BD was obtained on the 0 g polybag^{-1} (as control), and it decreased further when the treatment dose of a mixture of water hyacinth compost and rice husk biochar was increased. The lowest decrease in BD at the dose treatment was 120 g polybag^{-1}. Fig. (**1**) shows that an increase in the dose of a mixture of water hyacinth compost and rice husk biochar caused an increase in total soil porosity. Again, the lowest total soil pores were obtained at 0 g polybag^{-1} and the highest at a dose of 120 g polybag^{-1}.

3.2. Growth of Red Ginger Plants

Changes in soil fertility have a good effect on the growth of red ginger plants. The results of the $LSD_{\alpha: 0.05}$ on plant height, leaf numbers, tiller numbers, and fresh weight of plant at 90 DAP can be seen in Table **2**.

Table **2** shows that the dose treatment of a mixture of water hyacinth compost and rice husk biochar significantly influenced all observed growth parameters. Furthermore, the highest values for plant height, leaf number, tiller numbers, and fresh weight of plants were obtained at a dose treatment of 80 g polybag^{-1}, in stark contrast to the control doses of 40, 60, 100, and 120 g polybag^{-1}, respectively.

For more details, the effect of a mixture of water hyacinth compost with rice husk biochar on the red ginger growth at 90 DAP can be seen in Fig. (**2**).

Fig. (**2**) shows that all parameters' observations of red ginger growth were highest at a dose of 80 g polybag^{-1}. However, when the treatment dose was increased to 100 or 120 g polybag^{-1}, there was a decrease in plant growth. Therefore, it indicates that inhibition of red ginger growth could occur in a mixed dose of water hyacinth compost with rice husk biochar after a dose of 80 g polybag^{-1}.

Table 2. Effect of a mixture of water hyacinth compost with rice husk biochar on the growth of red ginger plants.

Mixed of Water Hyacinth Compost and Rice Husk Biochar (g polybag^{-1})	Plant Height (cm)	Leaf Numbers (sheets)	Tiller Numbers (sproud)	Fresh Weight of Plant (g)
0	44.63 a	54.92 a	7.50 a	128.84 a
40	49.67 a	62.33 a	6.92 a	128.06 a
60	48.31 a	59.42 a	7.25 a	145.66 a
80	56.80 b	97.08 b	11.42 b	267.47 b
100	46.52 a	54.08 a	7.17 a	150.11 a
120	48.05 a	58.08 a	7.42 a	154.77 a
$LSD_{\alpha: 0.05}$	6.45	23.52	2.24	84.40

Note: Values are the mean of four replicates (n= 4). Different letters in the same column are significantly different according to the LSD at the significant level (α: 0.05).

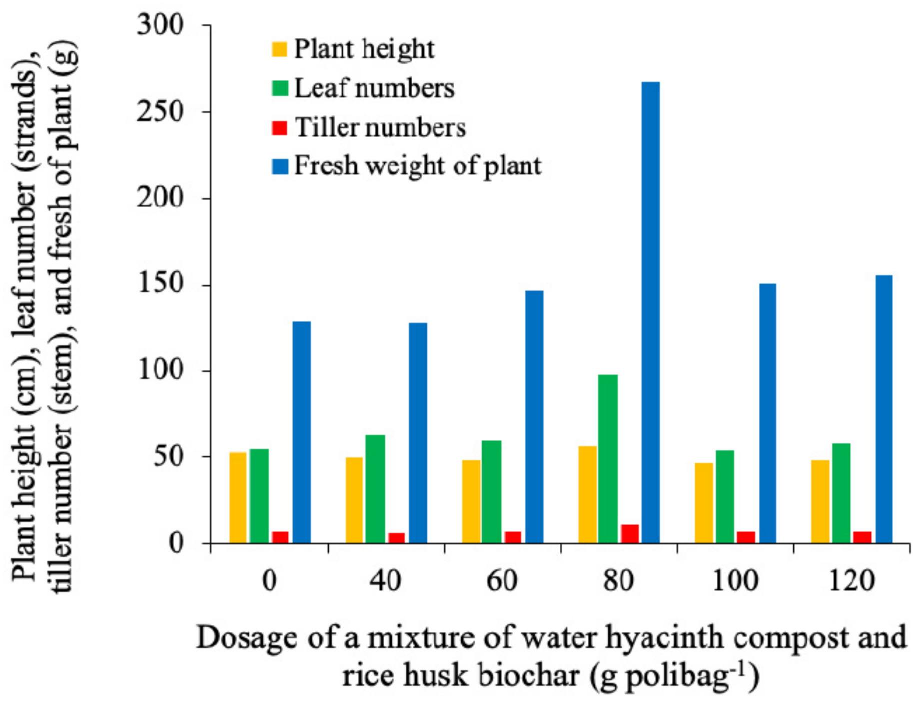

Fig. (2). Growth of red ginger plants on various doses of a mixture of water hyacinth compost and rice husk biochar.

4. DISCUSSION

4.1. Changes in Bulk Density and Soil Pores

Organic amendments to the soil will undergo a further decomposition process and produce organic acids. Furthermore, the resulting organic substance will affect the soil's physical, chemical, and biological properties. In line with this, the study results (Table **1**) show that the higher dose of the mixture of water hyacinth compost and rice husk biochar had a good impact on improving BD and soil pores. Adding organic matter to the soil will influence the formation of soil granulation due to the presence of organic matter that can produce organic acids to form clay-organic complexes. The soil aggregation leads to decreasing BD and increasing soil pores. The treatment, thus, showed an inverse relationship between BD and soil pores, where BD decreased and total pores increased, and vice versa.

Soil aggregation is closely related to BD and soil pores. In connection with Cincotta *et al.* [19], soil aggregation is related to organic matter content and would affect BD and soil pores. Furthermore, research conducted by D'Hose *et al.* [20] showed biochar mixed with compost to improve the soil's chemical properties. As reinforced by Zhang *et al.* [21], humic substances play an important role in the formation and stability of soil aggregates. Based on the research by Šimanský *et al.* [22], humic substances also play a role in soil structure. Humic acids can improve soil properties [23]. The humic substance is a component of organic matter of the most active humus fraction and can interact with soil particles by binding with its active group. This compound has a functional group that can bond with soil minerals. The reaction between soil minerals and humic materials will encourage aggregation and the formation of stable aggregates. Thus, applying soil reformers as a mixture of water hyacinth compost and biochar will affect the content and stability of organic C in the soil aggregate, and will further affect the increase in soil pores.

4.2. Growth of Red Ginger Plants

Water hyacinth compost and rice husk biochar in alluvial soils, including a certain amount of organic soil dressing, can increase plant growth due to improving the soil's chemical, physical, and biological properties. The study results (Table **2**) show that a decrease in soil BD and an increase in soil pores occur with an increase in the dose of a mixture of hyacinth compost and rice husk biochar. The best results were obtained at a dose treatment of 120 g polybag^{-1}. However, the red ginger growth was best achieved at a dose of 80 g polybag^{-1}, and it decreased when the treatment dose was increased. It indicates that too high a dose can inhibit red ginger growth. This phenomenon hints that aspects of soil fertility to support red ginger growth require a balance between various soil properties, both physical and chemical soil.

Various studies have found that organic reformers improve soil quality and cause an increase in plant growth. Cahyono *et al.* [10] showed that compost could improve acidic soil properties. According to Frimpong *et al.* [24], N-rich compost mixture + carbon + biochar-rich compost could enhance soil quality, including cation exchange capacity and soil pH. Organic amendments could improve soil fertility, carbon sequestration, and crop productivity [25]. Finally, using organic amendments can increase crop yields and reduce the use of inorganic fertilizers by up to 50% [26]. Applying a mixture of water hyacinth compost and rice husk biochar can improve the soil properties (physical, chemical, and biological).

CONCLUSION AND FUTURE RECOMMENDATION

Based on the results of research and discussion, it can be concluded that applying a mixture of water hyacinth compost and rice husk biochar at a dose of 120 g polybag^{-1} caused the lowest BD and the most pore space in the soil. However, a dose of 80 g polybag^{-1} could provide maximum plant height, leaf numbers, tiller numbers, and fresh weight. Therefore, the study findings show that mixing water hyacinth compost and rice husk biochar at 80 g polybag^{-1} is the optimum dose to support the maximum red ginger growth. However, we recommend that future research is needed to investigate the causes of decreasing BD and increasing soil pores.

LIST OF ABBREVIATIONS

ANOVA	=	Analysis of Variance
ASL	=	Above Sea Level
BD	=	Bulk Density
CRD	=	Completely Randomized Design
DAP	=	Days After Planting
DAT	=	Days After Treatment
LSD	=	Least Significant Difference
NPK	=	Nitrogen, Phosphate, and Kalium

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

All the data and supportive information are provided within the article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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