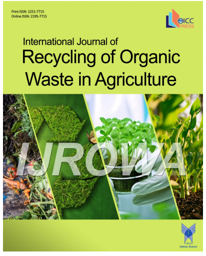

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Effect of the combination tanks biochar and chicken manure on availability of nutrients and yields of purple eggplant

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Original Research

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Abstract:

Purpose: Alluvial soil poses challenges for eggplant cultivation due to deficiencies in nutrients (N, P, K) and high Al/Fe content. This study aims to address these challenges by utilizing biochar from tank waste and chicken manure.

Methods: Biochar materials, specifically from tanks and chicken manure, were pyrolyzed at 400 °C for 4 hours. The resulting biochar was weighed to achieve the desired proportion and sieved through a 60-mesh sieve. It underwent analysis for pH, organic C, total-N, total-P, total-K, and Scanning Electron Microscopy (SEM). The tank's biochar was enriched with chicken manure biochar and NPK compound fertilizer at 75% of the recommended dose. The research involved two main components: 1) Planting purple eggplant seeds in polybags with varying treatments based on dosage, and 2) Chemical characterization of biochar, assessing soil N, P, K availability, and eggplant production up to the second harvest.

Results: The combination of tanks biochar and chicken manure significantly increased soil N, P, and K availability: N by 73.68%, P by 35.36%, and K by 92.78% compared to the control. Harvest 1 yielded 90% of production, while Harvest 2 reached 16.50% compared to the control.

Conclusion: Palm oil waste in the form of tanks biochar, enriched with chicken manure biochar and NPK compound fertilizer at 75% of the recommendation, has the potential to enhance alluvial soil fertility and promote growth and yield in purple eggplant plants.

Keywords: Alluvial soil; Tanks biochar; Chicken manure; Available NPK; Purple eggplant

1. Introduction

Alluvial soil as agricultural land has many problems such as poor fertility levels, low pH, low alkali saturation, and low N, P, and K content, besides toxic levels of Al, Fe, and Mn with varying C/N. (Hanafiah, 2010). The organic fertilizer such as tanks biochar and chicken manure that leaves residual effects help in providing organic C for a long period and improving soil fertility, and can help the growth and yield of purple eggplant plants. The quality of biochar depends on the raw materials and manufacturing process (pyrolysis). Pyrolysis carried out in low, or no oxygen conditions usually produces high-quality biochar, both in terms of C content, ash content, and other chemical elements; because in this pyrolysis the charcoal formation process is high, the loss of C and volatiles is low, and little ash is formed (Brown, 2009). This is closely related to the aim of providing ameliorant materials for agricultural soils. In soils of poor fertility, the application of high-quality biochar can improve the soil chemical environment (pH, CEC, macro, and microelements), water availability, aeration besides reducing, the rate of nutrient loss to the environment, and enhancing soil nutrient availability which in turn leads to good crop yields.

Application of biochar to soil has been proven to efficiently retain ammonium (NH_4^+) through cation exchange (Liang et al., 2006) and fresh biochar applied to soil can retain anions such as nitrate (NO_3^-) (Cheng et al., 2006). Increased fertility due to the addition of biochar to the soil has been proven by increasing pH, organic C, and soil water holding capacity because organic ameliorants generally increase water holding capacity and biochar has a great ability to hold

water because it has a high number of macro and micropores (Major et al., 2009). The addition of biochar also increases the total N content of the soil (Zhang et al., 2012).
In previous studies, Yulies et al. (2022) stated that the use of organic material such as tanks biochar + chicken manure in a ratio of 25:50, and 50:50 after 4 weeks of incubation with alluvial soil had sufficient weathering for the tank's biochar and chicken manure (the C/N ratio was lower) to release nutrients into the soil (CEC) cation exchange capacity (and BS) Base Saturation (are increasing). The difference can be seen in Table 1.
From Table 1, the C/N ratio for 4 weeks of incubation was low, indicating that the longer the incubation period, the more complete the weathering process. The CEC and BS values were also getting higher. After incubation treatment between soil, tanks biochar, and chicken manure for 4 weeks, it was found that the C/N ratio for 4 weeks of incubation was low, indicating that the longer the incubation period, the more complete the weathering process. The CEC and BS values were also getting higher, indicating that incubation for 4 weeks has occurred with sufficient weathering for tanks biochar and chicken manure (C/N ratio was getting lower) to release nutrients into the soil (CEC and BS are increasing).
The use of organic fertilizer tanks biochar and chicken manure is expected to reduce the application of compound NPK fertilizer to eggplant plants. Chicken manure is an organic fertilizer that has advantages over other animal manure, including chicken manure can improve soil fertility and improve soil physics, soil chemistry, and soil biology, in addition to that it also has more macronutrient content such as elements N, P, and K than other animal manure (Ernawati et al., 2024).
These properties make biochar a unique substance, retain nutrients that are exchangeable and therefore available to plants in the soil, and are likely to increase crop yields while reducing environmental pollution by nutrients. The role of biochar is as a vessel to bind nutrients around it, as a source of water, and as a home for soil microorganisms due to the large number of pore spaces. Soil that is given biochar will supply more nutrients (Indrawati et al., 2023).
Alluvial soil, a sedimentary soil, formed from mud and fine sand that has experienced soil erosion. These are found in the lowlands, around river estuaries, swamps, valleys, and on either side of large rivers. This soil contains a lot of sand and clay and does not contain many nutrients. These soils are gray in colour soil with a slightly loose structure and are sensitive to erosion. Fertility levels are moderate to high depending on the parent material and climate. In Indonesia, alluvial soils are good and used for the cultivation of seasonal to annual food crops (rice fields and secondary crops) (Hakim et al., 1986).

2. Material and methods

The research was conducted on alluvial soil in Pal IX Village, Kubu Raya Regency, West Kalimantan Province, Indonesia, and at the Soil Chemistry and Fertility Laboratory, Faculty of Agriculture, Tanjungpura University, West Kalimantan. The research materials used were oil palm empty fruit bunch biochar, chicken manure, and Alluvial soil, and the tools used were Scanning Electron Microscopy (SEM), pyrolyzer (Retort), muffle, sieve, digital scales, atomic absorption spectrophotometry (AAS), pH meter, flame photometer, chemical cylinder, percolator, spray flask, etc.
The biochar material, namely empty fruit bunches, was pyrolyzed using a Kontiki Kiln for 4 hours at a temperature of 400 °C. The desired quantity of biochar was obtained, after sieving through a 60-mesh sieve and analyzed for pH (1:20 biochar: water), ash content, organic matter using the Walkey and Black method, total N using the Kjeldhal method, total-P using spectrophotometry, total -K with AAS, and structural analysis using SEM. The research implementation consisted of 2 activities, namely 1) Planting purple eggplant seeds in polybags with treatment according to the dosage and 2) Chemical characterization of biochar, availability of N, P, and K elements in the soil, and eggplant production until the 2nd harvest.
The design used was a Completely Randomized Design (CRD) with a combination treatment of doses of tanks of biochar organic fertilizer and chicken manure, namely B0 = control, B1 = 5 t/ha fertilizer combination, B2 = 10 t/ha fertilizer combination, B3 = fertilizer combination 15 t/ha and B4 = fertilizer combination 20 t/ha. Each treatment was given the same dose of compound NPK fertilizer, namely 75% of the recommended purple eggplant fertilizer. The

Table 1. Incubate tanks (empty palm bunches) biochar, chicken manure, Alluvial soil after 4 weeks of treatment.

CODE (TB:CM)	H_2O	KCl	mS	C %	N %	C/N	P_2O_5
Kakap (25:75)	4.88	4.27	0	3.73	0.45	8.33	22.20
Kakap (50:50)	4.77	4.20	0	3.77	0.45	8.46	16.41
Kakap (75:25)	4.65	4.14	0	3.73	0.46	8.19	17.39

CODE (TB: CM)	Av-Ca	Av-Mg	Av-K	Av-Na	C E C	BS %
Kakap (25:75)	2.99	2.09	0.65	1.10	16.09	44.84
Kakap (50:50)	2.95	1.90	0.61	1.02	16.24	40.87
Kakap (75:25)	2.81	1.67	0.55	0.93	16.07	37.88

*Source: (Yulies et al., 2022).

control treatment (P0) in this study did not use tanks biochar and chicken manure. The parameters observed were: chemical properties of chicken manure incubated for 1 month, chemical properties of fresh tanks and tanks biochar, chemical properties of soil incubated with tanks biochar and chicken manure after 4 weeks of treatment, N, P, K available after incubation and weight of purple eggplant in harvest 1 and harvest 2. This research uses Anova statistical analysis with the F test. If there are significant differences between treatments, comparisons were made using the Duncan Multiple Range Test (DMRT) with a confidence level of 5%.

3. Results and discussion

Chemical and physical properties of soil

Before the research, a preliminary analysis of the chemical properties of alluvial soil as a planting medium was carried out, and can be seen in Table 2.

Chemical properties of chicken manure that have been incubated for 1 month

The chemical properties of chicken manure that have been incubated for 1 month can be seen in Table 3 below:
From Table 3 it can be seen that chicken manure was ready to be used as a soil conditioner to be mixed with biochar. Chicken manure that has been incubated for 1 month had a pH of 7.33 and a C/N ratio of 12.76.

Chicken manure biochar pores

The pores of chicken manure biochar that were pyrolyzed for 4 hours at 400 °C appeared solid and regular. Some of them turned to ash because the C/N of chicken manure was < 20%, This is because:
1. Composition: Chicken manure biochar has a relatively low carbon content compared to other types of manure. Chicken manure is rich in nitrogen (N), resulting in a low C/N ratio.
2. Carbonization Process: During the carbonization process, organic components (carbon) in biochar undergo decomposition, producing gases such as CO_2 and CH_4. If the C/N ratio is low, more carbon is likely to decompose into gas, increasing the likelihood of biochar turning into ash (Steiner et al., 2008).
With 1000x magnification it can be seen in Fig. 1 below.
Sturdy pores can function as water storage, housing microorganisms in the decomposition process so that they can provide nutrients for soil and plants (Indrawati et al., 2017).

Table 3. Chemical properties of chicken manure.

Parameter Analysis		Chicken Manure
pH	-	7.33
Organik-C	(%)	46.11
Total-N	(%)	3.6
C/N ratio		12.76
Potassium Chloride Extraction		
Phosphorus	(%)	0.41
Potassium	(%)	0.44
Calsium	(%)	0.16
Magnesium	(%)	0.16

Source: Soil Chemistry Laboratory, Faperta, Untan (2020).

Table 2. Alluvial soil characteristics of Sei Kakap District.

Parameter Analysis	Value	Information
pH H_2O	4.32	acid
pH KCl	4.12	
Organic Carbon (%)	3.73	high
Total-N (%)	0.56	high
Phosphorus Extraction		
P_2O_5 (ppm)	106.58	Very high
Ammonium Acetate Extraction		
Calcium (cmol (+) kg^{-1})	2.24	low
Magnesium (cmol (+) kg^{-1})	0.55	low
Potassium (cmol(+) kg^{-1})	0.34	Very low
Sodium (cmol(+)kg^{-1})	0.57	Very low
CEC (cmol(+)kg^{-1})	19.65	
Base Saturation (%)	18.83	low
Potassium Chlorite Extraction		
Aluminium (cmol(+) kg^{-1})	0.51	Very low
Hydrogen (cmol(+) kg^{-1})	1.87	high
Texture		
Sand (%)	0	
Loam (%)	62.94	Clay loam
Clay (%)	37.06	

Source: Soil Chemistry Laboratory, Faperta, Untan (2020). CEC: Capacity of Exchange; BS: Base Saturation
From Table 2, data is obtained that Alluvial soil has a pH that was still in the acidic category, and CEC and BS were low. The C and N content was also low.

Chemical characterization of fresh tanks

Before being used for research, fresh tanks must be analyzed for their chemical properties, and can be seen in Table 4 below.
From Table 4, fresh tanks had a fairly high pH. The C/N ratio was high so it can be a carbon source if pyrolyzed at a temperature of 400 °C, it had nutrient content even though

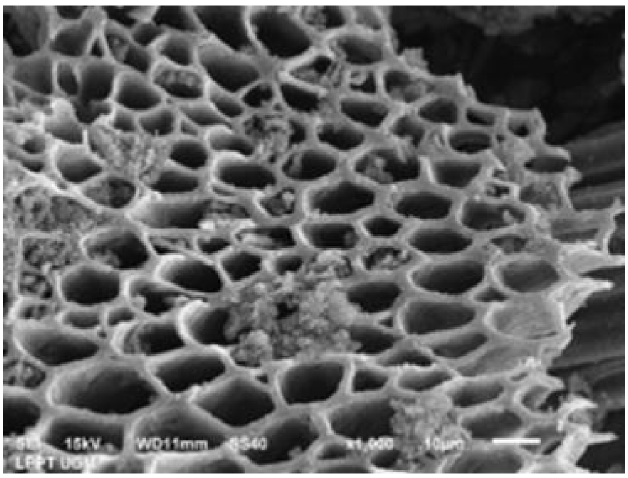

Figure 1. Chicken manure biochar magnified 1000x
Source: Results of Indrawati analysis (2022) through LPPT UGM (2022).

Table 4. Chemical characteristics of fresh tanks.

Parameter Analysis		Tanks
pH	-	9.43
Oganic-C	%	55.87
Total-N	%	2.07
C/N Ratio		26.99
Total-P	%	0.08
Total-K	%	1.28
Total-Ca	%	0.16
Total-Mg	%	0.21

Source: Results of Laboratory Analysis of Soil Department, Faperta UNTAN (2020)

it was in low levels (P, K, Ca, and total Mg). The raw tanks analyzed showed a high C/N ratio of 26.99. Tanks had a high cellulose and lignin content (C/N $>$ 20%), this is very profitable because it contained high carbon and low ash content, and did not break down easily (Schmidt and Noack, 2000).

Chemical characterization of Tanks' biochar

Tanks which have been pyrolyzed for 4 hours into biochar were then analyzed for its chemical properties at the Soil Chemistry and Fertility Laboratory and the results can be seen in Table 5.

After becoming biochar, it turned out that it had a neutral pH, had Ca and Mg due to the small amount of ash from the carbonation process. The increase in pH was only momentary. The K content was high because K was still present when heated to 400 °C. The CEC value was high because: 1) there was a contribution from the presence of the nutrients Ca, Mg, and K available during carbonation, 2) Micropore Structure: Biochar had a micro-porous structure that allowed for the absorption and exchange of cations. These pores provided a large surface area for interacting with ions in the soil, 3) Activated Carbon Surface: Biochar contained activated carbon, which exhibited strong adsorption properties toward cations. The carbon surface can retain and release ions such as K^+, Ca^{2+}, and Mg^{2+}, 4) Functional Groups Presence: Biochar contained functional groups such as hydroxyl, carboxyl, and phenolic groups. These groups play a role in enhancing cation exchange capacity by chemically interacting with ions in the soil. Biochar made from tanks like this can be used as an ameliorant for long-term restoration and improvement of soil quality (Indrawati et al., 2017).

Pore tanks biochar and chicken manure

Tank biochar combined with chicken manure has the potential to be used as an ameliorant in alluvial soil, because it can provide nutrients due to the availability of functional groups in biochar, besides that the pores of tanks biochar are still intact with the arrangement neat and regular, as a microbial home to mineralize the nutrients provided by chicken manure biochar. (Indrawati et al., 2017)

Next, to see the arrangement of the pores, see Fig. 2 below. The surface morphology of the macro- and micropores of the tank biochar burned using Kontiki Kiln pyrolysis was strong and regular in arrangement. The large and neatly arranged arrangement and shape of the pores increased the role of biochar as an ameliorant in the soil. Lehmann and Joseph (2009) stated that in the formation of biochar surface pores at a pyrolysis temperature of 250 – 500 °C, the pore arrangement is not yet regular, the biochar pores begin to have an orderly arrangement at a pyrolysis temperature of 800 – 2500 °C, but the pores formed easily collapse so they are vulnerable to destruction. As a result, the pore structure is messy. This will reduce the role of biochar as a soil ameliorant (Brown, 2009).

One of the roles of biochar considered as a soil ameliorant is its ability to improve soil macro- and micropores. Air and water balance is needed to improve soil fertility and to support the life and viability of microbes in the soil for a long time. This is confirmed by the results of SEM analysis (Fig. 2), the micropore structure of biochar with a magnification of 1000 times shows relatively regular pores; in some pores, it appears as a single whole, and several parts of the pore are located side by side. This formation of intact pores makes biochar better in terms of lind density, particle density, and aeration. The high surface area, volume, and pore size of biochar influence the water retention ability of biochar.

NPK available after incubation

From the results of the diversity analysis (ANOVA), all treatments for the parameters N total, P available, K available, and crop production had no real effect, but there were differences in values for each other's treatments, so what emerges is a picture of the difference in values between the

Table 5. Summary of average characteristics of tanks biochar chemical properties.

Biochar	pH H_2O	DHL mS	Av-Ca	Av-Mg	K- av cmol(+)kg^{-1}	CEC
tanks 4 hour	6.74	0.43	1.26	0.43	3.65	10.00

Source: Indrawati et al. (2017).

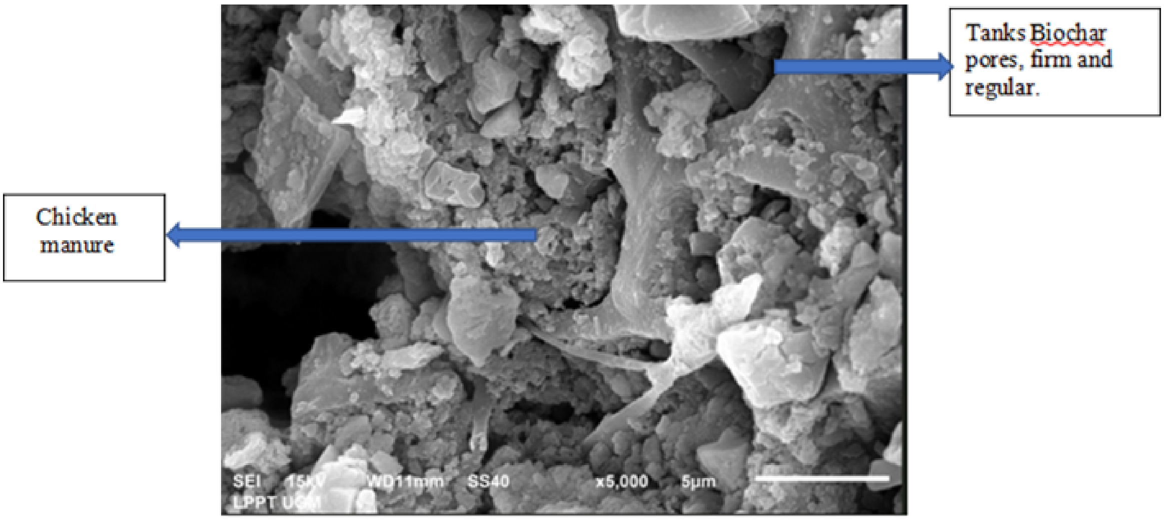

Figure 2. Macro and micropores at 5000x magnification, a combination of organic tanks biochar fertilizer and chicken manure with a composition of 25% tanks biochar: 75% chicken manure.
Source: Results of Indrawati analysis (2022) through LPPT UGM (2022).

following treatments with respect to the parameters. and will be discussed one by one below:

Total – N (%)

Nitrogen is an element that is in short supply in the soil because it is mostly transported by plants. Natural nitrogen derived from free air cannot be used directly by plants; However, it must go through a mineralization process carried out by microorganisms. The results of the Total-N analysis can be seen in Fig. 3.

Based on Fig. 3, the total N content in each treatment was included in the very high category. The total N content contained in the soil, where treatment B0 (0 g biochar) was categorized as very high, namely 0.57%, treatment B1 (5 t/ha biochar) was 0.78% with a very high category, treatment B2 (10 t/ha biochar) was in the very high category at 0.86%, treatments B4 (15 t/ha biochar) and B5 (20 t/ha biochar) showed a very high category where soil N was 0.98% and 0.99%. It can be seen from each treatment by administering doses of tanks of biochar and chicken manure to the alluvial soil that the N element in the soil increased, although not significantly, where the results of soil analysis before the incubation period were 0.56%, including the high category.

According to Hardjowigeno (2003), organic matter is the main source of N in the soil, the process of loss of N in the soil can be caused by being absorbed by plants and used by microorganisms, the N is still in the form of N. NH_4^+ is bound by the clay mineral illite so it cannot be utilized by plants, N is still in the form of NO_3^- which is easily leached by rainwater, and land conditions that are still flooded and excessive fertilization can also cause denitrification and volatilization processes in the form of NH_3^+ (ammonia).

Phosphorus (P) available (ppm)

Phosphorus is a macronutrient that plants need in large quantities and its role cannot be replaced by other nutrients (Rosmarkam and Yuwono, 2002). The amount of available phosphorus in the soil is less than the nutrients nitrogen and potassium. The results of soil available P analysis (ppm) in each treatment can be seen in Fig. 4.

Based on Fig. 4, the available P content (ppm) in the soil in each treatment was in the high to very high category. The available P content in the soil, treatment B0 (0 g biochar) was categorized as very high, namely 106.57 ppm, treatment B1 (5 t/ha biochar) was 120.21 ppm in the very high category, treatment B2 (10 t/ha biochar) was in the very high category at 125.32 ppm, treatments B3 (15 t/ha biochar) and B4 (20 t/ha biochar) showed a very high category where

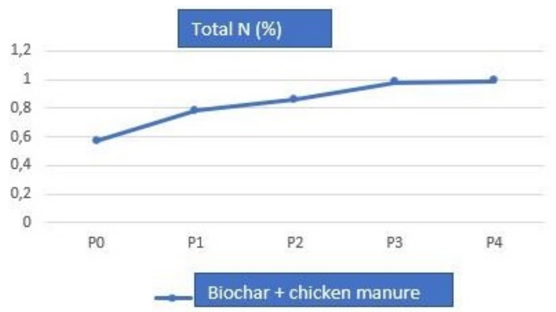

Figure 3. Graph of soil total-N analysis results after incubation.

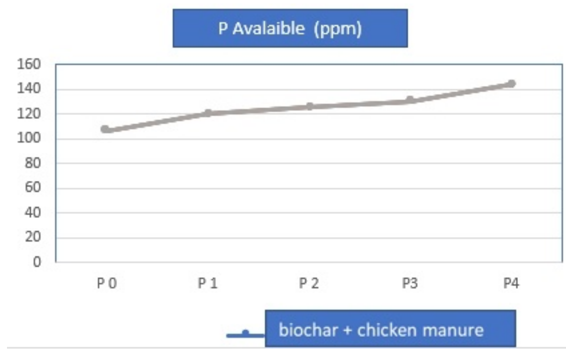

Figure 4. Graph of soil P-available analysis results after incubation.

soil P was 130.11 ppm and 144.25 ppm. It can be seen from each treatment by administering doses of tanks biochar and chicken manure to the alluvial soil that the P element in the soil increased, although not significantly, where the results of soil analysis before the incubation period were 106.58%, including the high category.

It can be seen from each treatment by administering doses of tanks biochar and chicken manure to the alluvial soil that the P element in the soil increases very significantly, where the results of the available P analysis (ppm) of the soil before the incubation period was 106.58% ppm, which was in the very high category. The addition of organic matter can increase the availability of P in the soil.

The effect of organic matter on P availability can be directly through the mineralization process or indirectly by helping the release of fixed P. The results of decomposition of organic materials in the form of organic acids can form chelation bonds with Al and Fe ions so that they can reduce the solubility of Al and Fe ions so that the availability of P increases. Organic acids produced from the decomposition of organic materials can also release P which adsorbed so that P availability increases. (Fox et al., 1990)

Simple organic acids such as oxalic acid are one of the important compounds in the process release of P. The mechanism of oxalic acid in increasing P availability can be done by: replacing the adsorbed P through ligand exchange on the Al and Fe oxide surfaces. Besides That, can also be done by dissolving the metal oxide surface and releasing the adsorbed P, can This can also be done by complexing Al and Fe in solution, then preventing re-precipitation of the metal compound and adsorption of P by Al and Fe (Bhatti et al., 1998).

K available (cmol (+)kg^{-1})

Potassium is very important in metabolic processes and has a special influence on nutrient absorption, regulation of respiration, transpiration, enzyme work and functions to increase soil resistance to pest and disease attacks. (Hakim et al., 1986).

The results of the K-available analysis (cmol(+)kg^{-1}) of soil in each treatment can be seen in Fig. 5.

Based on the results of research using tanks of biochar and chicken manure on alluvial soil, increasing the dose given to each treatment showed that adding organic material to the soil can increase K in the soil. Where the results of soil analysis before treatment were around 0.34 cmol(+)kg^{-1} based on the criteria for assessing soil chemical properties were classified as low. The available K content in the soil, treatment B0 (0 g biochar) was categorized as medium, namely 22.01 cmol(+)kg^{-1}, treatment B1 (5 t/ha biochar) was 25.03 cmol(+)kg^{-1} in the medium category, treatment B2 (10 t/ha biochar) was in the medium category at 30.41 cmol(+)kg^{-1}, treatments B3 (15 t/ha biochar) and B4 (20 t/ha biochar) showed a very high category where soil K was 32.33 and 42.43 cmol(+)kg^{-1}. in the medium and high categories. The higher the dose of tanks biochar and chicken manure given, the higher the available K. The size of the K content in the soil was because the nutrient K in the soil was formed more stable than the nutrient N, and was more mobile than the nutrient P so that it was easily moved by rainwater and temperature can accelerate the release and weathering of minerals in leaching potassium. Providing biochar also contributes to the presence of K in the soil (Indrawati et al., 2017). Potassium levels available in the soil can decrease due to absorption by plants. The nutrient potassium plays a role in plant vegetative growth, such as strengthening stem stands and also increasing carbohydrate levels (Rosmarkam and Yuwono, 2002).

Purple eggplant production at harvest 1

The size of the fruit was longer, reaching 27 cm with a diameter of 5 cm. Hard fruit reached 2.8 kg. High production with potential yields of more than 4.6 kg per plant. Vigor plant, cylindrical fruit shape, dark purple-shiny fruit colour with a smooth fruit surface texture.

The production results of purple eggplant (g/treatment) in each treatment can be seen in Fig. 6.

Purple eggplant production per treatment from the picture can be seen where treatment B0 (0 g biochar) was 110 g, treatment B1 (5 t/ha biochar) was 125 g, treatment B2 (10 t/ha biochar was 138.7 g, treatment B3 (15 t/ha biochar) and B4 (20 t/ha biochar) amounted to 145 g and 209 g per treatment. Production in the 1st harvest was a total of 1835 g. The higher the dose of biochar + chicken manure enriched with 75% NPK fertilizer, it shows that production was increasing, there has been no decline in production in Harvest 1.

Purple eggplant production at harvest 2

The second harvest was carried out a week after the first harvest.

The production results of purple eggplant (g/treatment) in each treatment can be seen in Fig. 7.

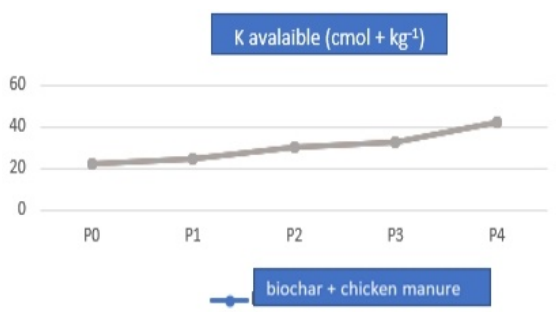

Figure 5. Graph of soil K-excangable analysis results after incubation.

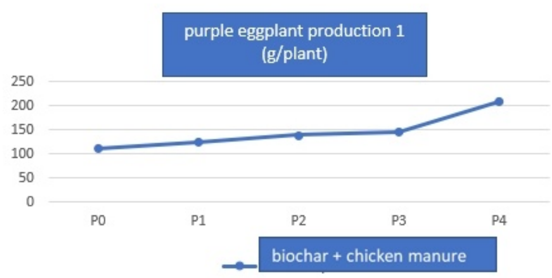

Figure 6. Production graph of purple eggplant in Harvest 1.

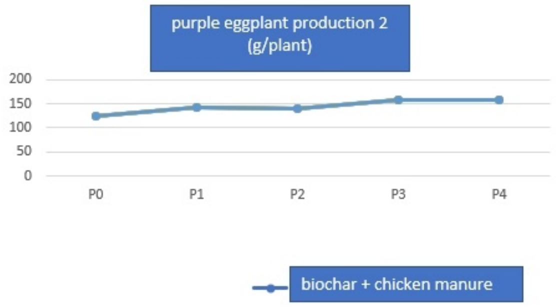

Figure 7. Production graph of purple eggplant in Harvest 2.

Figure 8. Production of purple eggplant in each treatment until the second Harvest.

Figure 9. The plants and production of purple eggplant.

Purple eggplant production per treatment from the picture can be seen where treatment B0 (0 g biochar) was 123.6 g, treatment B1 (5 t/ha biochar) was 142.25 g, treatment B2 (10 t/ha biochar was 141 g, treatment B3 (15 t/ha biochar) and B4 (20 t/ha biochar) amounted to 157.5 g and 144 g per treatment. Production in harvest 2 totaled 2,711 g. The higher the dose of biochar + chicken manure enriched with 75% NPK fertilizer, it shows that production was increasing, there has been no decline in production in Harvest 2 (Fig. 8). The plants and production of purple eggplant can be seen in Fig. 9.

4. Conclusion

The combination of tank biochar and chicken manure enriched with 75% NPK can help increasing the availability of N, P, and K available in the soil, whereas the dose of organic fertilizer increased, the availability of N, P, and K in the soil also increased, namely N by 73.68%, P 35 .36%, and K 92.78% compared to controls.

2. The combination of tanks biochar + chicken manure enriched with 75% NPK can help increasing purple eggplant production, whereas the dose of organic fertilizer increased, purple eggplant production will also increase, namely in Harvest 1 by 90% and Harvest 2 by 16.50% compared to the control.

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Author contribution
This research was conducted, analyzed, and discussed by Urai Suci Yulies Vitri Indrawati since 2022.

Availability of data and materials
The authors declare that the data supporting the findings of this study are available within the paper.

Conflict of interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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