

Effect of Coconut Shell Biochar Application on the Effectivity of NPK Fertilizer in Red Onion (*Allium ascalonicum* L.) Cultivation

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ABSTRACT

Shallot cultivation in Lampung faces challenges because the land is dominated by ultisol soils, which have low nutrients. Therefore, soil improvement materials such as biochar and fertilizers are needed. This study aims to determine the effect of coconut shell biochar addition on the effectiveness of NPK fertilizer in the production of shallots. The study was arranged in a Factorial Completely Randomized Design consisting of 2 factors, namely the dose of biochar (0, 40, 80, and 120 g/pot) and the dose of NPK fertilizer (0, 0.8, 1.6, and 2.4 g/pot). Each treatment combination was repeated 3 times. Parameters included soil characteristics (pH, soil volume shrinkage) and plant parameters (plant height, number of leaves, canopy area, bulb number and diameter, evapotranspiration, fresh root weight, bulb air dry weight, and water productivity). The results showed that coconut shell biochar had a significant effect ($\alpha = 0.05$) in increasing soil pH and decreasing soil shrinkage. The dose of biochar 80 g/pot (B2) with a dose of NPK 1.6 g/pot (N3) was the best treatment. In this treatment combination, shallots produced an average weight of 120.54 g/pot of fresh stover, 14 bulbs with diameter of 2.05 cm and air dry bulb weight of 70.17 g/pot, and the water productivity of 18.22 kg/m³.

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1. INTRODUCTION

Red onion or shallot (*Allium Ascalonicum* L.) is one of the plants that are widely cultivated in Indonesia. Tuber or bulb is the portion of the shallot that are used in daily life. Shallot bulbs are often used as kitchen ingredient for delicious taste on cuisine. In addition, shallots can be used as herbal medicines to overcome various health problems including unwell, fever, diabetes mellitus, dysentery, and injuries due to insect bites. Shallots require high organic materials during their cultivation (Nani & Hidayat, 2005). For this reason, shallots need fertile land for growth. However, the condition of land in Lampung is dominated by ultisol soils. Ultisols are red to yellow because it has a high content of Al, Fe and Mn with low level of organic material due to their thin surface layer (horizon A), limited water storage, and low aggression degrees

and weak aggregate stability (Notohadiprawiro, 1973).

The way to overcome these obstacles is to provide soil enhancing materials such as compost and biochar. One type of compost that can be used is trichocompost. Trichocompost is compost that has undergone a decomposition process due to the interaction between microorganisms, namely *Trichoderma* sp that work in it. The advantages of trichocompost fertilizer compared to ordinary compost, among other are its ability to protects plants from attack by plant-disturbing organisms, its function as a disease biological controller for horticultural and food crops, and its ability in destroying disease-causing pathogens in the soil.

In addition to compost, biochar is an effective soil enhancer to reduce leaching of nutrients in the soil so that fertilizer use is more efficient. Biochar is a product from the pyrolysis of abundant biomass such as agricultural wastes and wood wastes. Biochar is now produced not only for fuel purposes, but also for applications as a soil enhancer (Haryanto *et al.*, 2021). The application of biochar has a significant effect on the chemical, physical, and biological properties of soil. Regarding to soil chemical properties, biochar is able to increase soil pH, cation exchange capacity (CEC), and increase C-organic compounds, N-total, Fe, Al, and available P (Nigussie *et al.*, 2012). Relating to the physical properties of soil, biochar is able to hold water so that it can reduce the level of leaching of nutrients in the soil, improve soil structure, improve soil porosity, and improve soil aggregate formation (Southavong, 2012). As for soil biological properties, biochar can stimulate the population of microorganisms such as rhizobacteria which are beneficial for plants (Graber *et al.*, 2010). The application of biochar at a rate of 5,000 kg/ha showed that the respiration rate of soil and soil microbial biomass was higher than that of soil without biochar (Triyono *et al.*, 2019).

One of the abundant agricultural wastes that can be utilized as biochar feedstock is coconut shell. The use of biochar from coconut shells can help in suppressing the excessive use of chemical fertilizers and is expected to increase the productivity of horticultural crops such as shallots. This study aims to determine the effect of coconut shell biochar on the effectiveness of NPK fertilizer in onion cultivation.

2. MATERIALS AND METHODS

2.1. Experimental Location

This research was conducted from October 2020 to January 2021 at a green house within the Integrated Field Laboratory, Faculty of Agriculture, University of Lampung (Latitude: -5.4064931; Longitude: 105.2429555).

2.2. Materials

Shallot cultivation is carried out using a pot with a media content of 3 kg of soil. Shallot seeds of Bima Brebes variety were purchased from farmers in Tanggamus area, Lampung. NPK fertilizer was purchased from a farm shop in Bandar Lampung. The ultisol subsoil was taken from Rajabasa area, Bandar Lampung. The soil was dried under the sun for 3 days to a moisture content of about 10%, after that it was crushed and sieved with a 3 mm soil sieve. The soil that passes the sieve was then used for planting media.

Biochar was made from coconut shells by pyrolysis using a tin barrel heated externally for two hours until it becomes charcoal. The biochar was then ground and sieved with a 2 mm sieve. Trichocompost fertilizer was obtained from the Food Crops and Horticulture Protection Laboratory, Gadingrejo, Lampung. Table 1 showed the characteristics of the growing media used in this study.

Table 1. Characterisitic of soil, biochar, and trichocompost

Characterisitic	Parameters	Value
Soil	N-Total (%)	0.04
	P-available (ppm)	11.85
	K-dd (me/100g)	0.09
	C-organic (%)	0.38
Biochar	Ash content (%)	5
	Moisture content (%)	6.56
	pH	10
Trichocompost	Bulk density (g/cm ³)	0.6
	N-Total (%)	0.14
	P-Total(%)	024
	K-Total (%)	0.72
	C-organik (%)	5.05

2.3. Experimental Design

This research was arranged in a completely randomized design with two factors and three replications. The first factor is the dose of biochar (0, 40, 80, and 120 g/pot) and the second factor is the dose of NPK fertilizer (0, 0.8, 1.6, and 2.4 g/pot). The total weight of the growing media was 3000 g/pot with the composition given in Table 2.

Table 2. Composition of growing media (grams) based on biochar dose treatment

Treatment	Trichocompost	Biochar	Soil	Total
B1	500	0	2500	3000
B2	500	40	2460	3000
B3	500	80	2420	3000
B4	500	120	2380	3000

After being evenly mixed, the planting media was irrigated up to field capacity which was approximated by draining the growing media that had been saturated for 48 hours. The amount of water to reach field capacity is the difference of soil weight at field capacity minus 3000 g. Onion bulb seeds were sliced about a quarter and then planted in the center of the pot by turning and pressing them into the soil to a depth of about 3 cm or until the bulbs were were at the same level as the soil surface. One tuber was planted in each pot. To determine the change in soil shrinkage during plant growth, a measuring tape is attached to the wall of the pot. Fertilization was carried out in stages (3 times), namely when the shallots are 7, 14, and 28 DAP by immersing the fertilizer in the soil around the plants and close to the plant roots. Plant maintenance involved watering in the afternoon around 16.00 PM by weighing the pot and adding water loss to return it to its original condition (field capacity). Control of

plant pests and weeding was performed manually as necessary. Harvesting was carried out after the shallots were 65 days old. The arrangement of the experimental pots before harvesting was shown in Figure 1.



Figure 1. Experimental arrangement of the interaction effect of coconut shell biochar and NPK fertilizer on shallot cultivation.

2.4. Observations and Measurements

Parameters to be observed at the end of the study included pH, soil shrinkage, fresh root weight, dry bulb weight, bulb number, bulb diameter, water productivity, and fertilizer productivity. The parameter that was monitored daily involved plant's water requirement which was measured by weighing the pot. Parameters of plant height and number of leaves were observed weekly, while the canopy area was measured three times, namely at the age of 30, 45, and 60 DAP. The canopy area was measured using the Canopy Cover application available freely on android. The image of the leaves was taken from above position with the help of a 60x60 cm frame with a hole in the middle so that the frame can be placed parallel to the ground and fits right on the smartphone screen. After the leaf image is cleaned, the canopy area will be displayed in % of the frame area (Figure 2).

Water productivity (PA) of shallots was calculated from the yield of shallot production (HP) divided by water consumption (JKA) based on Equation (Mboyerwa *et al.*, 2021):

$$PA = \frac{HP \text{ (g/pot)}}{JKA \text{ (cm}^3\text{/pot)}} \quad (1)$$

2.5. Analysis

The collected data was analyzed using ANNOVA followed by a further test of least significant difference (LSD) test using the SAS University software.

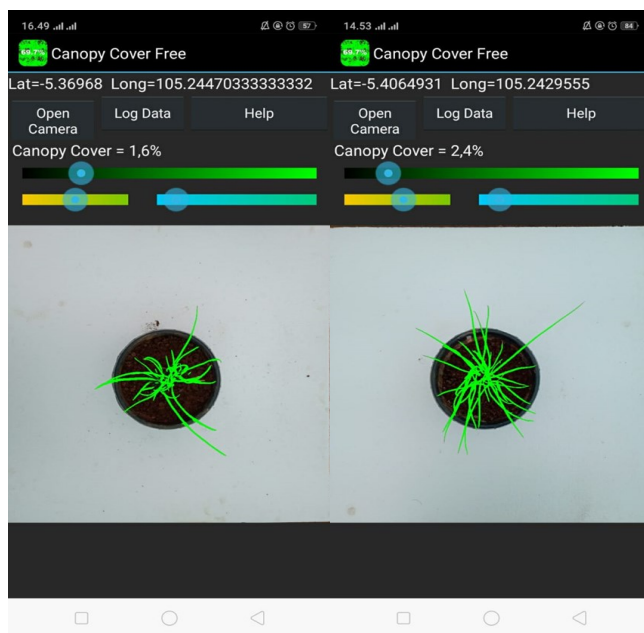


Figure 2. An example of an image from the Canopy Cover application after being filtered

3. RESULTS AND DISCUSSION

3.1. Soil Characteristics

One of the important soil properties in agriculture is soil pH. Plants do not grow well if the soil is too acidic or too alkaline. In this study, the soil used initially had a pH of 5 and was classified as acidic. Observations on the soil after harvest showed that there was no significant effect of the dose of NPK fertilizer on soil pH. This may be due to the very large ratio between fertilizer doses and growing media, (between 1÷37,500 and 1÷12,500). However, the application of biochar can significantly increase the soil pH at a level of $\alpha = 5\%$. According to [Rahayu *et al.* \(2019\)](#), shell biochar with a pH of around 10 can neutralize acidic soil pH. The increase in soil pH due to the application of biochar may be due to the release of alkaline cations ([Nurida *et al.*, 2015](#)). The results of other studies also state that biochar can significantly increase the pH of acidic mineral soils ([Yuan *et al.*, 2011](#)). Our results showed that the higher the dose of biochar given, the more neutral the soil pH (Figure 3). At the highest dose of biochar (120 g/ pot) it was able to increase the pH up to an average of 7, while in the treatment without biochar the pH of the soil only increased slightly to an average of 5.3.

Soil compaction is another problem in agricultural cultivation. Dense soil has low air aeration and water infiltration capacity, which inhibits plant root development. Dense soil will also inhibit the absorption of nutrients and water from the soil by roots to other parts of the plant ([Rusdiana *et al.*, 2000](#)). Biochar is a lightweight material because it has a large pore space ([Soemeinaboedhy & Tejowulan, 2007](#)). One of the expected effects of giving biochar is to reduce soil compaction. This can be seen from the soil shrinkage after shallots harvesting (Figure 4). Observations showed that the dose of biochar had a significant effect ($\alpha = 5\%$) on soil shrinkage. Soil that was not given biochar experienced a shrinkage up to 1.63 cm thick. Giving biochar can reduce soil shrinkage which means reducing soil density. [Nurida *et al.* \(2012\)](#) stated that biochar can reduce soil bulk density, increase rapid drainage pores and available water pores, both in acid dry land and dry land with dry climates. From Figure 3, it can be

seen that the higher the dose of biochar resulted in decreased soil shrinkage with the lowest shrinkage thickness of 1.10 cm occurring at a biochar dose of 120 g/pot. There was no significant effect of the dose of NPK fertilizer on soil shrinkage. The very small NPK dose as compared to the weight of the planting medium is likely provides an explanation why the fertilizer dose has no significant effect on soil shrinkage.

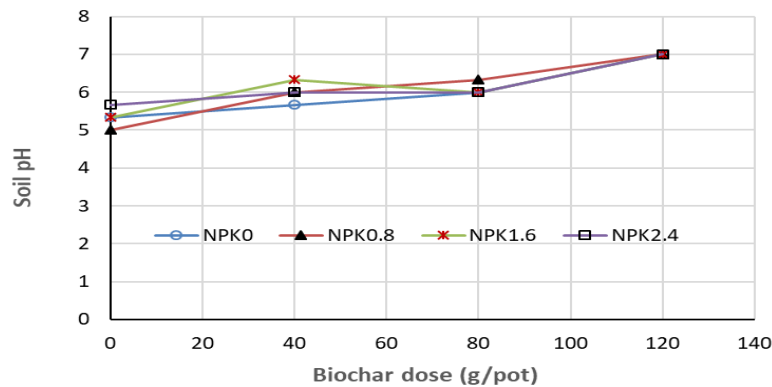


Figure 3. Effect of treatments on the soil pH

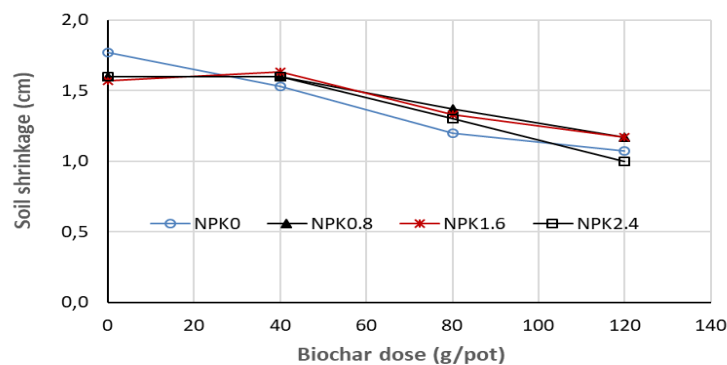


Figure 4. Effect of treatment on soil shrinkage

3.2. Plant Height

The results showed that the interaction of coconut shell biochar and NPK fertilizer had a significant effect ($\alpha = 5\%$) on plant height starting at 4 week after planting (WAP). The results also showed that without the application of NPK fertilizer, shallot plants could still grow well (Figure 5). This is thought to be caused by the addition of biochar and trichocompost which are sufficient for the nutrient requirements of shallot plants. However, from the graph in Figure 5 it can also be seen that the addition of biochar resulted in almost the same plant height, namely 41–45 cm (B1), 39–49 (B2), and 43–49 (B3). The application of NPK fertilizer also resulted in good growth even without biochar, which was 45–48 cm (B0). However, in the control treatment (without biochar and without fertilizer) the plants only reached an average height of 37 cm. This means that biochar has a positive effect on the growth of shallot plants.

Figure 5 shows that initially the shallot plants had relatively the same growth. But at the age of 4 WAP the treatment began to demonstrate different effects on onion growth. Shallots enter the vegetative growth phase from 11 DAP to 35 DAP (Saputra, 2016). In this phase, shallots need N element to support plant photosynthesis. Good

photosynthesis will support plant height growth (Tania *et al.*, 2012). The graph in Figure 5 shows that at the early of 8 WAP plants began to enter the generative phase which was characterized by slowing growth. This is in accordance with Hirsyad (2019) observation that the generative phase of shallot plants starts at 36 DAP or early 6 WAP. In this phase, shallot plants begin to focus on the formation of tubers, so that the plant height does not show significant growth. In the final phase, which was 9 WAP, the height of the shallots began to decrease because in this phase some of the plant leaves began to wilt and dry, and were ready to be harvested.

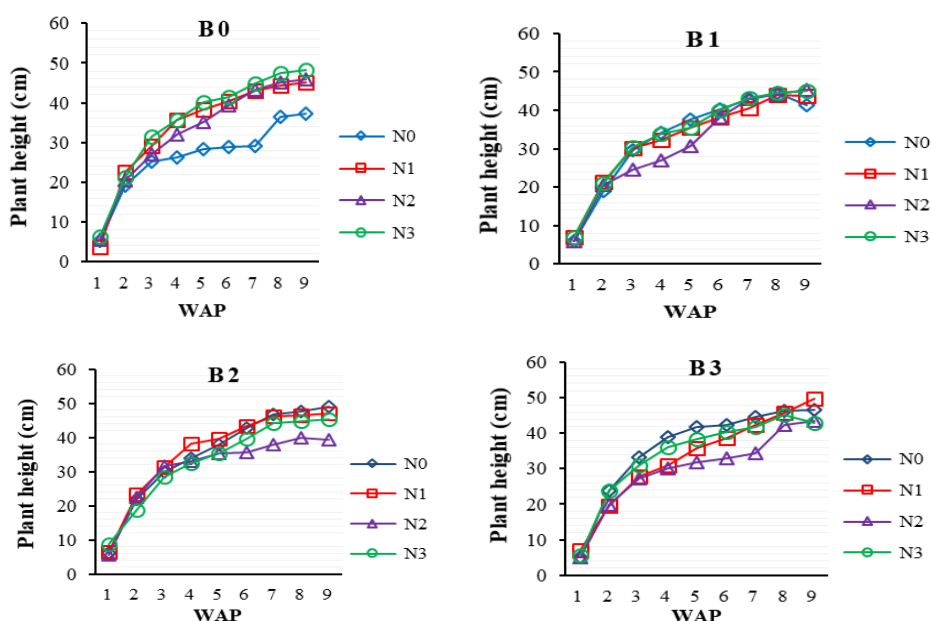


Figure 5. Effect of treatments on the growth of shallot plant height

3.3. Leaves Number

Figure 6 shows that the number of leaves of the shallot plant increases with the age of the plant. However, starting at 8 WAP the number of leaves began to fall because some of the leaves began to wither. The interaction of coconut shell biochar treatment and NPK fertilizer had a significant effect ($\alpha = 5\%$) on the number of leaves of shallots. The leaves number of shallot in the control treatment (B0N0) reached an average of 36 leaves at most. The application of biochar and/or fertilizer gave inconsistent effects on the leaves number. For example, the application of NPK fertilizer in treatment B0 (without biochar) resulted in 47–55 leaves for all doses of fertilizer. But in other treatments, for example B1N2, the average number of leaves was only 25. Similarly, B2N3 treatment resulted 33 leaves, and B3N2 treatment only 32 leaves. This may be related to genetic factors from the seeds used.

3.4. Canopy Area

Figure 7 portrays canopy area development of shallot for different treatment. It is expected that the more the number of leaves, the greater the canopy area of the shallot plant. Plant height is also expected to affect the canopy area. Onion is a leafy plant. The taller the plant, the heavier the leaves so that they bend sideways and result in an increase in the canopy area. However, ANOVA analysis showed that the interaction effect of coconut shell biochar dose and NPK fertilizer was not significant ($\alpha = 5\%$). In the treatment with biochar, the average canopy area was 199.36–401.74

cm² (B1), 249.20–348.88 cm² (B2), and 190.30–376.07 cm² (B3). In the treatment without biochar, the canopy area was also not much different, with an average of 122.34–379.09 cm² (B0). This insignificant difference may be caused by the shape of the red onion leaves which are small and elongated resembling a stick. With an almost upright position, the canopy area of the leaves will not vary much even though the height is different.

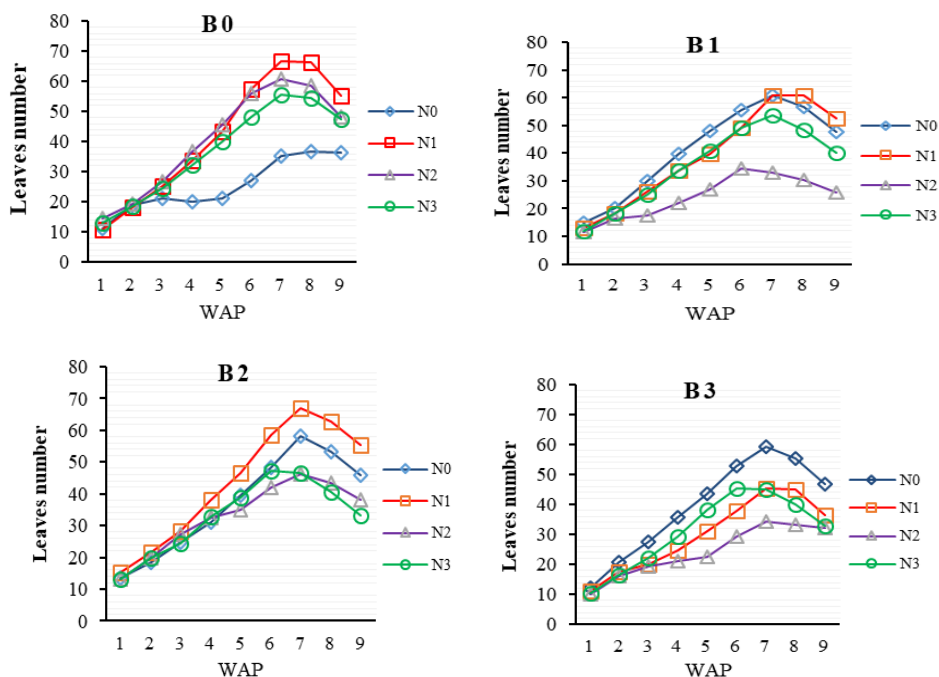


Figure 6. Effect of treatments on the development of leaves number

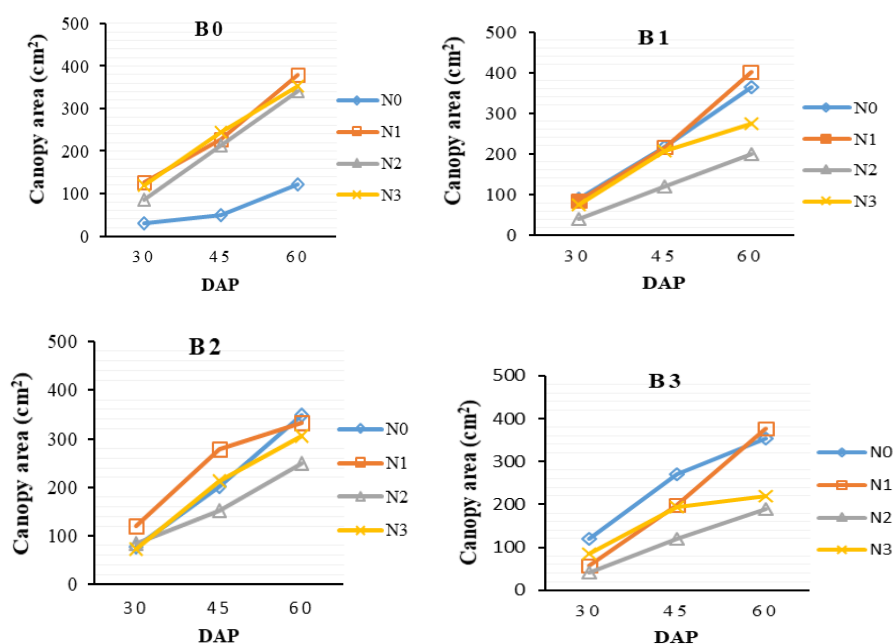


Figure 7. Effect of treatment on the development of the canopy area of shallots

3.5. Weight of Fresh and Air-Dried Bulbs

The results showed that shell biochar dose had a significant effect ($\alpha = 5\%$) on the fresh green onion weight. According to [Rahayu *et al.* \(2019\)](#), coconut shell biochar can hold nutrients in the soil so that it helps plants to absorb nutrients in the soil which can then increase plant fresh weight. The results of our study showed that the effect of biochar dose on the yield of fresh stover was not very strong. Treatments B0 and B1 did not show a significant difference with the results of the average fresh stover weight of 83.27 g and 90.24 g, respectively (Figure 8). Meanwhile, treatment B2 produced 111.33 g, but it was still not significantly different from B1 even though it was different from B0. Biochar treatment with the highest dose (120 g/pot) actually resulted in the lowest weight of fresh stover, which was 78.65 g. According to [Verheijen *et al.* \(2010\)](#), the application of biochar to soil has the potential to be positive for crop yields, but also negative effects can occur related to crop yields and there is no clear mechanism for the positive effect on crop yields to be negative related to the threshold of biochar dose applied.

The results of our study also showed that the effect of the dose of NPK fertilizer was significant ($\alpha = 5\%$) on the weight of fresh bean curd. In this case, the N0 treatment resulted in the lowest fresh stover weight, which was an average of 67.95 g. Treatment with fertilizer application (N1–N3) did not significantly differ on the yield of fresh stover, namely 105.93 g (N1), 95.83 g (N2), and 93.77 g (N3). This shows that the influence of the NPK fertilizer factor is more dominant than the biochar factor.

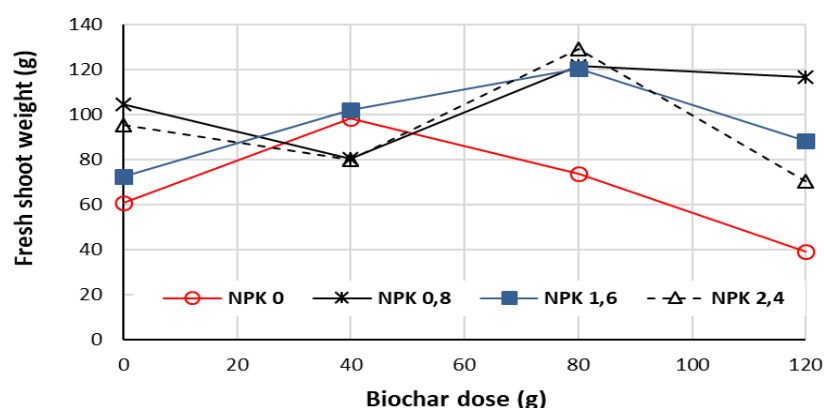


Figure 8. Effect of treatment on the weight of fresh red onion

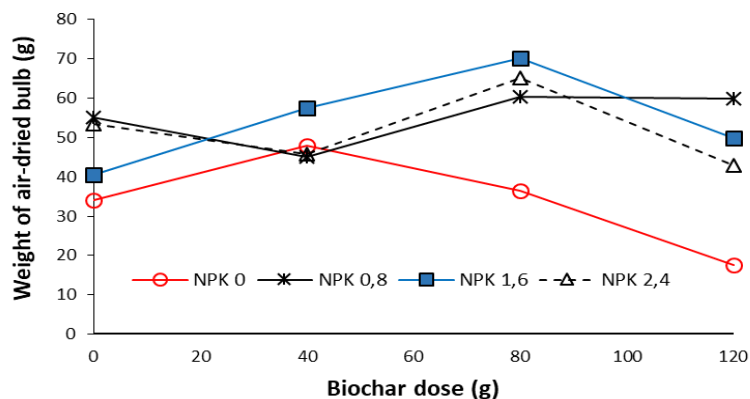


Figure 9. Effect of treatment on dry weight of shallot bulbs

The results of our study showed that the fertilizer dose factor had a significant effect ($\alpha = 5\%$), but the biochar factor had no significant effect ($\alpha = 5\%$) on bulb dry weight. In this case, the N0 treatment (without fertilizer) resulted in the lowest bulb dry weight, which was an average of 33.99 g. As shown in Figure 9, treatment with fertilizer application (N1-N2-N3) resulted in average bulb weights of 55.11 g (N1), 54.54 g (N2), and 51.84 g (N3) and were not different significantly. This shows that the influence of NPK factor is more dominant than the biochar factor. In the process of bulb formation, shallot plants require P and K nutrients which play a role in the formation of protein for bulb formation and improve bulb quality.

3.6. Number of Bulbs and Bulb Diameter

The results showed that the dose of biochar and NPK fertilizer had no significant effect ($\alpha = 5\%$) on the number of bulbs (tubers). Treatments with or without using biochar on average had the same number of bulbs, namely 10–11 (B0), 11–12 (B1), 10–15 (B2), and 10–15 (B3) as presented in Figure 10. The insignificant effect was because the number of bulbs of the shallot plants are influenced among others by the genetic factors of the seed planted. This is in accordance with [Azmi et al. \(2011\)](#) which states that the number of shallot bulbs is influenced mostly by genetic factors and only a small part by environmental factors.

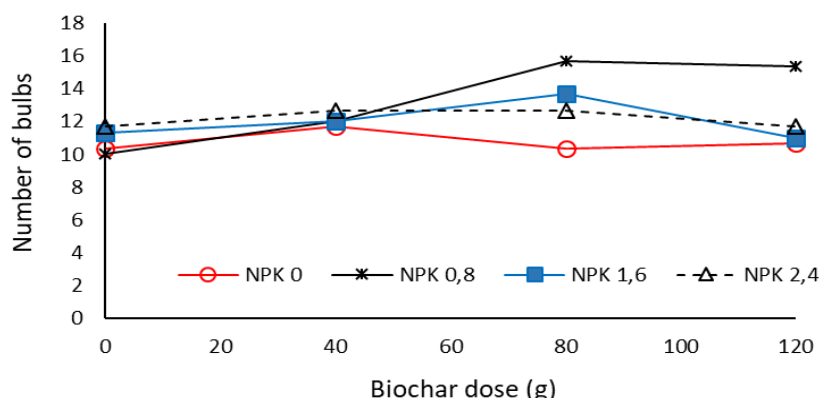


Figure 10. Effect of treatments on the number of shallot bulbs

The interaction of coconut shell biochar factor and NPK fertilizer, however, had a significant effect ($\alpha = 5\%$) on the diameter of shallot bulbs. As revealed in Figure 11 in the treatment given biochar, the average diameter was almost the same, namely 1.67–1.96 cm (B1), 1.58–2.05 cm (B2), and 1.02–1.84 cm (B3). The application of biochar without NPK (N0) fertilizer resulted in low average bulb diameters of 1.70 (B1), 1.58 cm (B2), and 1.02 cm (B3). Likewise, the treatment without biochar and without fertilizer (B0N0) resulted in a low average diameter of 1.61 cm. Thus, the NPK fertilizer factor is more dominant than the biochar factor. In addition to environmental influences, the diameter or size of shallot bulbs is influenced by genetic factors originating from the parent variety ([Putrasamedja & Soedomo, 2007](#)).

3.7. Water Consumption

The results showed that the interaction of coconut shell biochar factor and NPK fertilizer had a significant effect ($\alpha = 5\%$) on plant evapotranspiration starting at 5 WAP. The results also showed that in all treatments with the addition of biochar, shallot plants still used high water levels even without the application of NPK fertilizer (Figure

12). It is suspected that the addition of biochar has an effect on increasing the ability of shallot plants to absorb water even without the role of NPK fertilizer. Figure 12 shows that the addition of biochar resulted in almost the same average weekly evapotranspiration, namely 673.5–1078.5 ml (B1), 682.5–1095 ml (B2), and 797.5–1074 ml (B3). Our results also showed that plant evapotranspiration increased with the age of the shallot plant. This shows that the water requirement of shallot plants increases as the plants get bigger. This evapotranspiration affects plant productivity. The higher the plant absorbs water, the better it grows. Plant evapotranspiration is influenced by several factors such as temperature, relative humidity, wind speed, solar radiation, and latitude (Fuadi *et al.*, 2016).

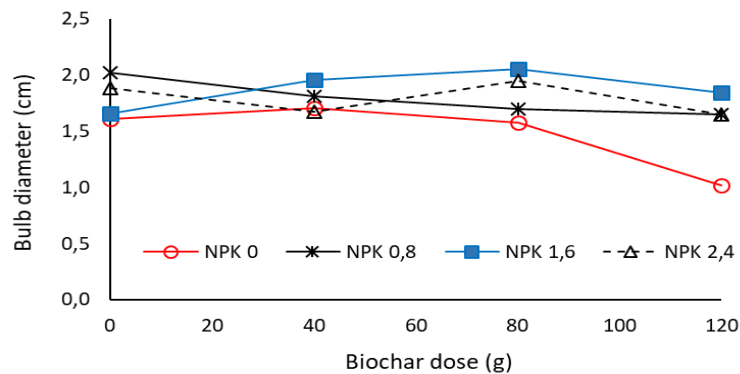


Figure 11. Effect of treatments on the diameter of shallot bulbs

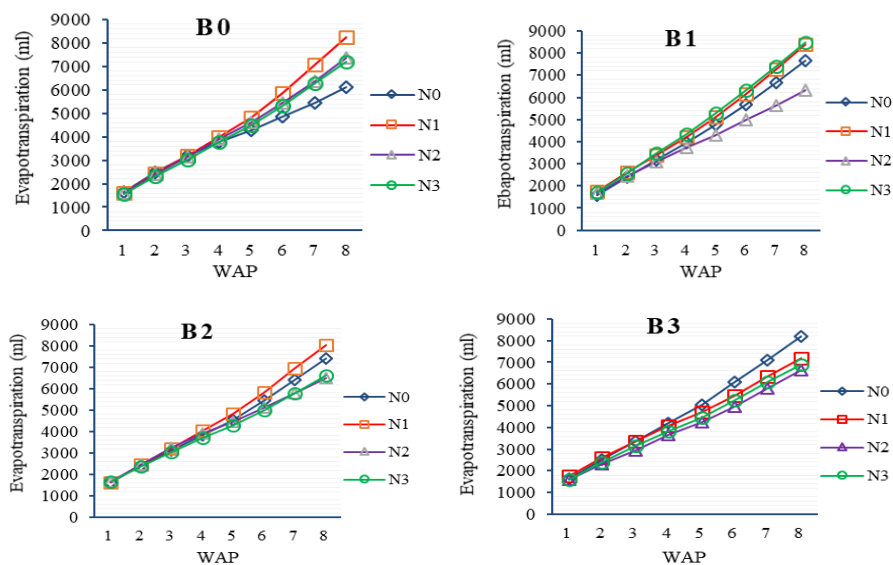


Figure 12. Effect of treatment on the cumulative evapotranspiration of shallots

The results also showed that the dose of NPK fertilizer had a significant effect ($\alpha = 5\%$) on the water productivity of shallot plants. The evapotranspiration of onion plants is high when the plants grow well. In Figure 13, it can be seen that at a dose of 80 g/pot biochar, water productivity was higher for plants that were given NPK fertilizer than plants without NPK fertilizer. For all doses of NPK water productivity was not significantly different, namely 15.52 kg/m³ (NPK dose 0.8 g/pot), 18.22 kg/m³ (1.6 g/pot

NPK), and 18.35 kg/m³ (NPK up to 2.4 g/pot). In plants that were not given NPK (B0) fertilizer, the average water productivity was only 9.51 kg/m³.

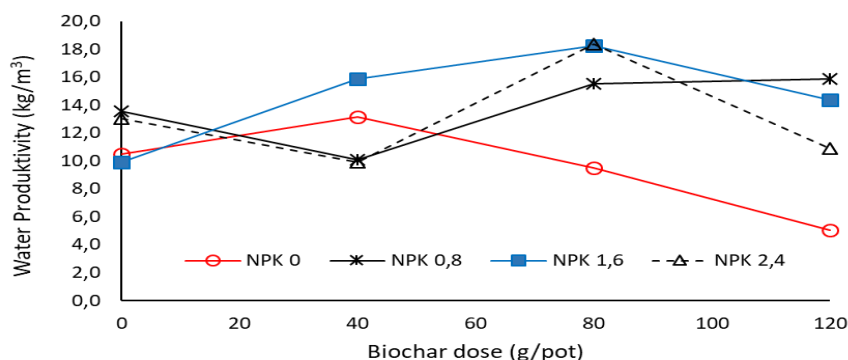


Figure 13. Effect of treatment on water productivity of shallots

4. CONCLUSION

The conclusions from the results of research that have been carried out are:

1. Addition of coconut shell biochar had a significant effect on the increasing soil pH and decreasing soil shrinkage at the level of $\alpha = 0.05$.
2. The biochar dose of 80 g/pot with NPK fertilizer gave higher fresh stover weight, bulb dry weight, and water productivity of shallot plants than without fertilizer for all doses of NPK fertilizer.
3. The biochar dose of 80 g/pot (B2) combined with a dose of NPK 1.6 g/pot (N3) was the best treatment. In this treatment combination, shallots produced an average weight of 120.54 g/pot of fresh stover, the number of bulbs was 14, the diameter of the bulbs was 2.05 cm, the bulb dry weight was 70.17 g/pot, and the water productivity was 18.22 g/l.
4. The application of biochar increases the effectiveness of the use of NPK fertilizers. This can be seen from the treatment with a fertilizer dose of 1.6 g/pot which resulted in a greater stover dry weight and tuber diameter than that of fertilizer dose of 2.4 g/pot for all doses of biochar.

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