



Effectiveness of Coconut Shell Biochar Soaking Duration and Phonska Plus Dosage (15 15 15) in Increasing Soil Fertility, Growth, and Yield of Shallots

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ABSTRACT

This study investigated the effect of compost tea soaking duration in biochar and Phonska Plus fertilizer dosage on soil fertility and shallot growth. A greenhouse experiment using a factorial Completely Randomized Design was conducted with four soaking durations (0, 12, 24, and 36 hours) and four fertilizer doses (100, 200, 300, and 400 kg/ha). Results showed that soaking duration significantly improved plant growth, yield components, soil pH, organic carbon, available N, P, K, and fungal colonies. Fertilizer dosage also significantly affected growth, yield, and soil fertility. While no interaction effects were observed on yield and fungal colonies, interactions occurred for growth and some soil parameters.

INTRODUCTION

Shallots are a vegetable commodity with high economic value, important for national consumption, as a source of income for farmers, and export potential (Sialagan, 2024; Beja, 2020). Demand continues to increase along with population growth (Palupi, 2019). BPS data (2024) shows that national production of shallots in 2020-2024 tends to increase, reaching 2,085,979 tons in 2024. In NTB Province, increasing the production and productivity of shallots has the potential to boost regional economic growth (Iswandi et al., 2023). NTB is the third largest shallot production center in Indonesia after East Java and Central Java (Ayu et al., 2023), with a production of 188,740.4 tons from 17,570 hectares of land (BPS, 2021). Its cultivation is spread across various districts on the islands of Sumbawa and Lombok, including marginal land use (Firmansyah et al., 2014).

Currently, the increase in onion production still depends on inorganic fertilizers, but its excessive use has negative impacts on the soil, such as increased acidity, decreased microbial activity, and micronutrient deficiencies, which decrease land productivity (Luta et al., 2023). Soil fertility is very important for crop yields, but many lands in NTB have been degraded, such as low organic matter and nutrient imbalance (Kusnadi et al., 2020). One of the efforts to improve soil fertility is the use of organic matter and soil ameliorant (Nabila, 2025).

Behind the advantages of compostable tea, there are weaknesses found, especially in the application method. Berek (2017) in his research reported that the weakness of compost tea is that some nutrients will be lost. Compost tea is liquid, so the nutrients in compost tea wash away easily from the soil surface and are not always optimally available to plants in the long term. Lost nutrients are very important because they are related to the nutrient content, especially N and P that undergo leaching or evaporating into the air from composted tea that will be used as fertilizer. One of the efforts that can be made is the addition of biochar with chemical characteristics, namely high content of lignin, cellulose and hemicellulose such as coconut shells. Saturation of biochar with compost tea will have the opportunity to capture the nutrients present in composted tea into biochar.

Based on the advantages and disadvantages of biochar and compost tea above, it can be ascertained that there is potential to be developed into nutrient-saturated biochar from composted tea. According to Fretis et al., (2019) Biochar added to composted tea functions as a water and nutrient binder so that it is not easily lost due to too high evaporation. Research conducted by Adrien et al., (2023) revealed that soaking biochar using composted tea for 24 hours can increase corn yields by 210% compared to the control treatment (without soaking compost tea). In previous studies, there have not been many specific studies related to the effectiveness of soaking so that in this study there is a variation of the treatment of the length of soaking coconut shell biochar using compost tea, namely no soaking, 12 hours soaking, 24 hours soaking and 36 hours soaking which is then combined with various doses of Phonska Plus fertilizer (15 15 15) which is 100 g/ha, 200 g/ha, 300 g/ha and 400 g/ha in an effort to reduce

dependence on inorganic fertilizers (Phonska) for the growth and yield of shallot plants (*Allium ascalonicum* L.) and to improve soil fertility.

THEORETICAL REVIEW

Biochar is a soil ameliorant in the form of a porous solid material, rich in carbon content, with a high surface area and cation exchange capacity (KTK). Biochar is produced from the pyrolysis process in an oxygen-limited environment (Hussain et al., 2017). Biochar is highly resistant to decomposition, thus being able to provide long-term habitat for microorganisms, the stability of biochar in soil allows for consistent and sustainable habitat support for microbial communities (Spokas et al., 2012). Apart from the great benefits of biochar as a soil improver, biochar only contains a small amount of nutrients, especially nitrogen, so it needs to be modified by mixing other nutrients so that plants can grow and have optimal production results (Hasibuan, 2017). To add nutrients to biochar, it can be done by saturation using nutrient-rich organic materials.

Compost tea is the extraction of compost using water by the stirring method (addition of oxygen) obtained through the process of air conditioning (aeration) in the liquid phase (Farisi et al., 2024). Solid organic fertilizers processed into liquid compost tea generally provide nutrients and hormones that are dissolved and are more quickly absorbed by plant roots and leaves, so that they can be applied directly to the soil or sprayed on the leaves (Farisi et al., 2024). Abubaker et al., (2024) in their research reported that the application of compost tea in soil and leaves can significantly increase the number of stem area, plant height, number of leaves and weight of tomatoes. Other crop types also show significant yields namely okra (Siddiqui et al., 2008), pakchoi (Pant et al., 2012) and sweet corn (Kim et al., 2015). The advantage of compost tea is that it provides nutrients that are faster and ready to be absorbed by plants both through roots and leaves (Berek, 2017).

METHODOLOGY

This experiment will be carried out in February-June 2025, located in the Greenhouse of the Faculty of Agriculture, University of Mataram. Soil and microbial analysis activities were carried out at the Soil Chemistry Laboratory and Agricultural Microbiology Laboratory, Faculty of Agriculture, University of Mataram. The tools used in this experiment are roll meters, analytical scales, gems, plastic buckets, hoes, aerators, stationery and other supporting tools. Furthermore, the ingredients used in this experiment are shallot seeds of the Tapas variety, coconut shell biochar, Phonska Plus fertilizer (15 15 15), aquades, Trichocompos, and other supporting materials.

This experiment was arranged using a Factorial Random Design (RAL) consisting of 2 Factors. The first factor is the variation in the length of soaking coconut shell biochar using compost tea (B) and the second factor is the dose of phonska plus fertilizer which each consists of four levels, including:

1. Bo = No soaking of Biochar (Control)
 2. B1 = Perendaman biochar 12 jam
 3. B2 = Perendaman biochar 24 jam
 4. B3 = Perendaman biochar 36 jam
-
1. P0= Phonska Plus Fertilizer (15 15 15) dose 100 kg/ha
 2. P1= Phonska Plus Fertilizer (15 15 15) dosage 200 kg/ha
 3. P2= Phonska Plus Fertilizer (15 15 15) dosage 300 kg/ha
 4. P3= Phonska Plus Fertilizer (15 15 15) dosage 400 kg/ha

Each treatment was combined so that 16 treatment combinations were obtained, namely B0P0, B0P1, B0P2, B0P3, B1P0, B1P1, B1P2, B1P3, B2P0, B2P1, B2P2, B2P3, B3P, B3P1, B3P2, B3P3 each treatment combination was repeated 3 times, so that as many as 48 experimental pots were obtained.

Making compostable tea is done by preparing a plastic bucket with a capacity of 20 liters, then filled with 8 liters of aquades. Furthermore, as much as 2 kg of Trichocompost is prepared and wrapped in a clean cloth so that solid particles do not spread into the solution. The compost packet is then put into a bucket that has been filled with aquades. To increase the oxygen level in the solution, an aerator is installed and run during the soaking process. This oxygenation aims to accelerate the release of nutrients from the compost into the solution, so that the quality of the composted tea produced becomes more optimal. The soaking process is carried out for 24 hours. Once finished, composted tea can be used as a soaking solution for coconut shell biochar (Adopted from Berek., 2017 & Madjen, 2018)

The process of soaking biochar using composted tea is carried out by preparing a 12 liter compost tea solution and 6 kg of coconut shell biochar which is divided into 3 parts, namely for 12 hours, 24 hours, and 36 hours of soaking. Each part of biochar is then put into a bag (cloth) then tied up and put in a compost tea solution. Next, aeration is given using an aerator.

The observation data was analyzed using Fingerprint Variety analysis (ANOVA) using the Minitab for Windows ver application. 16. At the real level of 5%. Treatments that showed significance were further tested with the honest real difference test (BNJ) at the same real level.

RESULTS AND DISCUSSION

Soil analysis activities are carried out twice, namely before the soil is given treatment and after the shallot plants are harvested. The chemical properties of the soil before the experiment are varied. The initial soil pH value of 6.6 is included in the neutral category. The C-organic content is only 0.31% which is classified as very low and shows indications of organic matter deficiency (Sanchez, 2019). Organic carbon is an important indicator of soil fertility because it is a source of energy for microorganisms that play a role in the decomposition of organic matter and nutrient cycling (Lehmann & Kleber, 2015). In addition, the N-Available content is also very low, which is 0.19 ppm. Although phosphorus (12.76 ppm), and potassium (2.00 me/100g) are relatively high, the effectiveness

of the utilization of these nutrients is still limited by the low organic matter. Without the presence of sufficient humus, nutrients are easily lost through leaching or volatilization, especially nitrogen (Weil & Brady, 2017). These results show that the soil is very poor in nutrients, especially C-Organic and Nitrogen.

In addition to the initial soil analysis, a test of the number of mushroom colonies was also carried out on biochar saturated with compost tea. The test results are presented in Table 1. Under.

Table 1. Number of Fungal Colonies on Biochar Various Soaking Lengths

Treatment	Number of Mushroom Colonies (108CFU/g Soil)
B0 (Biochar without Soaking)	5,6
B1 (12-hour Soaking Biochar)	7
B2 (24-hour Soaking Biochar)	11,6
B3 (36-hour Soaking Biochar)	17

Source: Primary Data (Agricultural Microbiology Laboratory UNRAM), 2025

Based on Table 1. It is known that the longer the soaking time, the more the number of mushroom colonies increases. This increase can be explained by the ability of the soaked biochar to absorb organic compounds and microorganisms from the composted tea, which then provides a microenvironment that supports the growth of soil fungi. Biochar functions as a stable place to live, provides organic carbon that is easy to utilize and improves soil aeration and moisture (Evizal & Prasmatiw, 2021; Antonius et al., 2018). The longer soaking duration allows biochar to absorb more nutrients and active microbes, making it not only a soil improver, but also a carrier agent of microorganisms that enrich soil microbial communities. This is in line with the findings that biochar enriched with organic matter can increase soil microbial diversity and activity, which ultimately positively impacts soil fertility and crop productivity (Lesmana, 2023; Liu et al., 2024).

Growth of Shallot Plants

The results of the observations in Table 2. show that both treatments have a significant influence on plant growth. In the treatment of the duration of biochar soaking, soaking for 24 hours gives the most optimal results on plant *height*, especially in the vegetative phase (14–42 hst). Plants treated with biochar soaked in 24-hour compost tea reached a height of 38.1 cm at 42 hst, higher than the treatment without soaking (37.1 cm) although there was no statistically significant effect between treatments. This shows that soaking biochar with a nutrient solution can gradually and sustainably increase nutrient availability (Purbalisa et al., 2020). Soaked biochar has the potential to increase cation exchange capacity (KTK) and nutrient retention efficiency. Previous research has shown that biochar pre-loading techniques can reduce the risk of nutrient binding by biochar and accelerate the availability of nitrogen and phosphorus to plants (Mukherjee & Lal, 2014; Glaser et al., 2015).

An increase in the dose of phonska plus fertilizer from 100 to 400 kg/ha indicates a positive response to the height of the plant. In 42 hst, plants given 400 kg/ha reached a height of 38.7 cm, higher and significantly different from the dose of 100 kg/ha (35.6 cm) and not significantly different in the treatment of 200 kg/ha (37.6 cm) and 300 kg/ha (38.2 cm). The nitrogen, phosphorus, and potassium content in these fertilizers supports vegetative tissue formation, root growth, and photosynthesis efficiency (Fageria et al., 2014). However, previous research has shown that increasing the dose of NPK fertilizer above 300 kg/ha does not necessarily provide a significant increase in yield, as plants can reach a saturation point against nutrient intake (Rachmawati et al., 2022). Therefore, the fertilizer dosage should be adjusted to the growth phase and absorption capacity of the plant.

The combination of nutrient-saturated biochar and phonska plus fertilizer in optimal doses has the potential to have a synergistic effect on plant growth. In addition, previous research revealed that the use of soaked biochar can reduce fertilizer needs by up to 25% without reducing the productivity of horticultural crops (Yusuf & Hartono, 2018). Therefore, there is a potential efficiency in the use of phonska plus fertilizer up to the level of 200 kg/ha.

Table 2. Average growth parameters (plant height and number of leaves) at the long treatment of biochar saturation and the dose of phonska plus fertilizer

Treatment	Plant Height (cm)			Number of Leaves (strands)		
	14 hst	28 hst	42 hst	14 hst	28 hst	42 hst
Biochar (B)						
B0	22,4 a	32,9 a	37,1 a	13,3 a	21,3 a	30 a
B1	23,1 ab	34,5 ab	37,3 a	15,3 ab	22,8 a	32,8 b
B2	24,1 b	35 b	38,1 a	15,8 b	23,5 a	34,9 b
B3	22,3 a	35,3 b	37,6 a	14,3 ab	22 a	33,4 b
BNJ 5%	1,22	1,81	Ns	2,20	Ns	2,29
Phonska Plus (P)						
P0	21,8 a	33,1 a	35,6 a	12,8 a	20,9 a	30,4 a
P1	23,2 b	34,9 ab	37,6 b	14,6 ab	22,9 ab	32,8 b
P2	23,5 b	34,6 ab	38,2 b	15,7 b	21,3 a	33,5 b
P3	23,3 b	35,1 b	38,7 b	15,8 b	24,3 b	34,3 b
BNJ 5%	1,22	1,81	1,50	2,20	2,74	2,29

Remarks: The number followed by the same letter in the same column shows no significant difference in the BNJ level of 5%.

The number of leaves is an important indicator in the vegetative growth of shallots because it is directly related to the photosynthesis capacity and metabolic efficiency of the plant (Fageria et al., 2014). The results showed that both the duration of the biochar soaking and the dose of Phonska Plus fertilizer (15-15-15) had a significant effect on the increase in the number of leaves in all phases of plant growth.

In the biochar treatment, the 24-hour soaking resulted in a higher leaf count and was significantly different from the non-soaking treatment (B0) and

did not differ significantly at the 12-hour (B1) and 36-hour (B3) immersions, especially at the age of 42 hst. This suggests that the soaking process allows the biochar to absorb nutrients from the composted tea solution, which is then gradually released into the root zone (Purbalisa et al., 2020). The micro-pore structure and large surface area of biochar support the adsorption capacity of nutrient ions, thereby increasing the efficiency of nutrient absorption by plants (Glaser et al., 2015). Research by Yusuf & Hartono (2018) also shows that soaked biochar is able to significantly increase the number of leaves and fresh weight of shallot plants compared to fresh biochar.

An increase in the number of leaves was also observed in the treatment of the dose of phonska plus fertilizer, where a dose of 400 kg/ha resulted in the highest number of leaves and a real difference, namely 34.3 leaves at the age of 42 hst, compared to the dose of 100 kg/ha which only reached 30.4 leaves. This suggests that adequate availability of nitrogen, phosphorus, and potassium is essential in supporting vegetative tissue formation, energy metabolism, and photosynthetic efficiency (Baronti et al., 2014; Sarijan, 2011). However, the continuous use of high doses of chemical fertilizers can have negative impacts on the environment, such as nutrient leaching, decreased soil microbial populations, and increased greenhouse gas emissions (Lehmann et al., 2021). Therefore, the combination of inorganic fertilizers and organic materials such as biochar is a more sustainable strategy. Research by Rachmawati et al., (2022) shows that the combination can significantly increase the leaf area index and yield of horticultural crops, while reducing the need for chemical fertilizers by up to 30% (Safitri & Rosnita, 2016).

Shallot Crop Yield

Based on the results of the BNJ analysis of the 5% level in Table 3. The parameters of the number of bulbs of the onion plant did not show any noticeable difference due to the long treatment of biochar soaking. The highest average number of tubers was obtained at the 12-hour biochar saturation treatment (8.2 tubers), while the lowest number of tubers was recorded at 36-hour immersion (7.4 tubers) although statistically insignificant. Although not statistically significant, trends suggest that soaking biochar for 12–24 hours tends to increase the number of bulbs compared to no soaking. However, too long soaking duration can lead to ionic saturation that disrupts the nutrient balance around the plant's roots (Mukherjee & Lal, 2014). In this case, it is likely that what occurs when soaking for a long period of time causes an imbalance of ions in the soil solution that inhibits the development of roots and the initiation of bulbs. However, the treatment of the dose of Phonska Plus fertilizer has a significant effect between treatments on the number of bulbs. The Phonska Plus dose of 400 kg/ha yields the highest number of bulbs (8.4 bulbs), which is significantly different from the dose of 100 kg/ha (7.1 bulbs) and is not significantly different from the 200 kg/ha and 300 kg/ha treatments. This indicates that there is a potential for the dose of Phonska Plus to be gradually reduced in field application. In general, Phonska Plus fertilizer contains nitrogen, phosphorus, and potassium which play an important role in the formation and enlargement of tubers. Nitrogen supports

early vegetative growth, phosphorus stimulates root formation and bulb initiation, while potassium strengthens tissues and increases bulb filling (Fageria et al., 2014; Yusuf & Hartono, 2018). Previous research has also shown that increasing the dose of NPK fertilizer to optimal levels can significantly increase the number and weight of bulbs (Rachmawati et al., 2022).

Table 3. Average Yield Parameters (Tuber Size, Tuber Diameter, Wet Tuber Weight, Dry Tuber Weight) at the long treatment of biochar soaking and the dosage of Phonska Plus fertilizer

Treatment	Results Observation Parameters			
	Number of Tubers (tubers)	Diameter Tubers (cm)	Weight of Wet Tubers (g)	Dry Tuber Weight (g)
Biochar (B)				
B0	8,1 a	3,2 a	7,4 a	5 a
B1	8,2 a	3,3 ab	9,2 a	5,3 a
B2	7,5 a	3,6 bc	9,3 a	6,4 a
B3	7,4 a	3,8 c	12,6 b	9 b
BNJ 5% 2,21	1,10	0,34		2,63
Phonska Plus (P)				
P0	7,1 a	3,3 a	7,9 a	4,9 a
P1	7,7 ab	3,4 a	9,8 a	6,4 ab
P2	8,1 ab	3,6 a	10,5 a	7,4 b
P3	8,4 b	3,6 a	10,3 a	7,2 b
BNJ 5% 2,21	1,10			

Remarks: The number followed by the same letter in the same column shows no significant difference in the BNJ level of 5%.

The diameter of the tuber is an important indicator in determining the quality and economic value of shallots, because it is closely related to its weight and shelf life (Baronti et al., 2014). The results of the observation showed a significant effect of the long treatment of biochar soaking on the diameter of the onion bulbs. Biochar treatment with 36 hours of immersion resulted in the largest tuber diameter (3.8 cm), followed by 24-hour immersion (3.6 cm), while without saturation had the smallest tuber diameter (3.2 cm). In contrast, the dose of phonska plus fertilizer did not have a significant effect on the diameter of the bulbs, although there was a trend of increasing diameter at doses of 300 and 400 kg/ha (3.6 cm).

The increase in the diameter of the bulbs in the biochar treatment shows that biochar acts as a buffer for nutrients and water, as well as improves soil structure. Soaked biochar is able to absorb and release nutrients such as potassium gradually, which are important in the formation and filling of tubers (Mukherjee & Lal, 2014; Fageria et al., 2014). Potassium plays a role in maintaining osmotic pressure, strengthening cell walls, and supporting plant metabolism related to tuber enlargement (Yusuf & Hartono, 2018). In addition,

biochar also increases cation exchange capacity (KTK) and provides habitat for soil microorganisms that play a role in mineralization and dissolution of nutrients, including phosphorus and other important micronutrients (Jeffery et al., 2015; Ahmad et al., 2018). The soaking process allows the biochar to absorb organic compounds and microbes from the composted tea, which are then released sustainably into the root zone (Glaser et al., 2015).

The weight of wet tubers is one of the indicators of measuring the level of shallot production. The results showed a significant effect of the long treatment of biochar immersion on the weight parameters of wet tubers. Biochar soaked for 36 hours yielded the highest wet tuber weight (12.6 g), followed by 24-hour (9.3 g) and 12-hour (9.2 g) soaks, while non-soaking biochar achieved only 7.4 g. Furthermore, the treatment of the dose of phonska plus fertilizer has a insignificant effect on the increase in the weight of wet tubers

This increase in wet tuber weight reflects the plant's ability to accumulate biomass, which is influenced by soil quality improvement through the application of nutrient-saturated biochar. Biochar increases water and nutrient retention capacity, as well as improves soil structure that supports root growth (Evizal & Prasmatiwi, 2021). In addition, soaked biochar can store nutrients that gradually release nutrients into the root zone, supporting the nutrient needs of shallots during the bulb formation phase (Glaser et al., 2015). Furthermore, soaked biochar can also act as a reservoir of nutrients that slowly release nutrients into the root zone. In line with the opinion of Jeffery et al. (2015), that biochar is able to retain and release as well as reduce nutrient loss due to *leaching*. This is important for shallot plants that require a continuous supply of nutrients during the bulb formation and filling period.

The weight of dried tubers is an important parameter in evaluating the quality of the onion crop because it reflects a stable accumulation of biomass and is not affected by moisture content (Baronti et al., 2014). The results showed that the soaked biochar treatment gave a significant result on the weight of the dried tubers. Biochar soaked for 36 hours produced the highest dry tuber weight (9.0 g), followed by 24-hour (6.4 g) and 12-hour (5.3 g) soaks, while non-soaking biochar only reached 5.0 g, which was the lowest of any other treatment. The treatment dose of Phonska Plus fertilizer exerted a significant effect between treatments on the weight of dry tubers, the doses of phonska 300 and 400 kg/ha gave higher dry tuber weight results (7.4 and 7.2 g), although they did not always differ statistically. This increase in tuber weight suggests that biochar saturation helps improve nutrient and water utilization efficiency through gradual release of nutrients, supporting carbohydrate accumulation and protein synthesis in tuber tissue (Mukherjee & Lal, 2014; Glaser et al., 2015).

The weight of dry tubers is highly dependent on the plant's ability to convert photosynthates into durable and stable biomass. Phonska plus fertilizer also shows an important role in increasing the weight of dry tubers. Nitrogen in fertilizers supports protein formation, phosphorus helps in energy metabolism, and potassium plays a role in tuber enlargement and cell pressure regulation (Fageria et al., 2014; Taiz & Zeiger, 2015).

Analysis of Chemical and Biological Properties of Soil

Table 4. Interaction Long treatment of soaking biochar in compost tea and the dose of phonska plus fertilizer (15, 15, 15) on soil pH and C-Organic

Treatment	pH Soil				C-Organic (%)			
	B0	B1	B2	B3	B0	B1	B2	B3
P0	7,1 a A	6,8 a B	6,98a B	7,05 a B	0,11a A	0,18a AB	0,22a B	0,35b C
P1	6,7 b A	6,7 b A	6,55 bc B	7,1 a C	0,35c B	0,41b B	0,31b AB	0,26a A
P2	6,6 c A	6,4 d B	6,6 b A	6,3 b C	0,21b A	0,53c C	0,27ab A	0,36b B
P3	6,4 d A	6,6 c B	7 c D	6,1 c C	0,37c B	0,79d C	0,34b B	0,25a A

Information:

- Lowercase letters (a, b, c, d) indicate the apparent effect of the biochar (B) treatment on each dose of fertilizer (P).
- The capital letters (A, B, C, D) indicate the apparent effect of the dose of Phonska Plus fertilizer (P) on the respective soaking duration of biochar (B).
- The values followed by the same letter were not significantly different according to the BNJ 5% follow-up test.

Soil acidity is an important factor that affects soil fertility. The results of statistical analysis (Table 4) show that soaking biochar using composted tea has a real effect on improving soil pH. In general, biochar soaked for 24–36 hours (B2 and B3) tends to increase soil pH compared to biochar without soaking (B0) or short soaking for 12 hours (B1). This is likely due to the increased alkaline content (such as K, Ca, and Mg) that is absorbed into the biochar pores during the soaking process with composted tea, thus strengthening the alkaline properties of biochar when applied to the soil (Lehmann & Joseph, 2015; Zhang et al., 2021). Composted tea itself contains microorganisms and dissolved compounds that are alkaline, such as humic acid, fulva, and nutrient minerals that are able to neutralize soil acidity (Ingham, 2019).

The dosage of Phonska Plus fertilizer also has a noticeable effect on soil pH. It was observed that in the treatment without fertilizer (P0), the soil pH was generally higher, while increasing the fertilizer dose (up to P3 = 400 kg/ha) tended to lower the pH. This is thought to be due to the characteristics of Phonska Plus fertilizer (15-15-15) which contains nitrogen in the form of ammonium (NH₄⁺) which is acidic when oxidized into nitrates in the soil (Zhao et al., 2020). A significant decrease in soil pH was seen in the combination of high doses of Phonska Plus (P3) and non-immersion biochar (B0), which resulted in the lowest pH of 6.1. This supports previous findings that high-formulated inorganic

fertilizers can shift the pH balance of the soil towards more acidic if not balanced with organic matter or alkaline buffers (Rengel, 2003)

The interaction between the soaking time of the biochar and the dose of Phonska Plus fertilizer has a significant effect on the pH of the soil. The combination of P1B3 (200 kg/ha fertilizer and 36-hour soaking biochar) and P3B2 (400 kg/ha fertilizer and 24-hour soaking biochar) treatment yielded the highest pH, which was 7.1 and 7.0. This suggests that biochar soaked in compost tea can act as a soil acidity counterbalance due to moderate to high doses of NPK fertilizer application. This phenomenon can be explained by the ability of biochar that has been enriched with alkaline elements from compost tea to neutralize excess H⁺ ions in the soil produced by the nitrification reaction of NPK fertilizers. These results are in line with research conducted by Ding et al. (2016), which stated that biochar soaked by organic solutions can reduce the acidity effects of soil due to the use of intensive inorganic fertilizers.

C-Organic is one of the main indicators in assessing soil fertility. C-organic plays an important role in improving the physical, chemical, and biological properties of soils. This study showed a real interaction between the soaking time of biochar and the dose of Phonska Plus fertilizer on soil C-organic levels. The highest C-organic value was obtained in the P3B1 treatment (400 kg/ha fertilizer + 12 hours of biochar immersion) of 0.79%, which was significantly different from other treatments. In contrast, the lowest C-organic value was found in the P0B0 treatment (100 kg/ha fertilizer + without biochar immersion) with a value of only 0.11%. This shows that the combination of high fertilizer doses and proper biochar soaking time is able to significantly increase the C-organic content of the soil. In line with the findings from Agegnehu et al. (2017) which stated that the use of inorganic fertilizers combined with organic materials such as biochar is able to improve the chemical properties of the soil, especially the content of organic matter and the capacity of cation exchange.

Biochar soaked in composted tea for 12 hours (B1) is thought to have absorbed the soluble organic compounds and microorganisms contained in the composted tea. When applied to soil, these compounds can increase microbial activity and soil organic matter accumulation (Zhang et al., 2022). However, if the immersion time is too long (e.g. 36 hours), as in P3B3 treatment, the C-organic value decreases to 0.25%, likely due to elemental rotation or microbial population imbalances. Interestingly, at lower fertilizer doses (P0–P2), an upward trend of C-organic is still seen but not as high as at P3, suggesting that higher fertilizer doses tend to improve the efficiency of carbon uptake and retention of biochar. In contrast, without fertilizers and soaking biochar (P0B0), the accumulation of C-organic is very low due to the lack of nutrient inputs and organic matter.

Table 5. Interaction of the treatment of the length of immersion of biochar in compost tea and the dose of Phonska Plus fertilizer (15 15 15) on Available N and Available P

Parameter	N-Available (ppm)				P-Available (ppm)			
	B0	B1	B2	B3	B0	B1	B2	B3
Treatment	B0	B1	B2	B3	B0	B1	B2	B3

P0	16,33a	20,33a	19,33a	18,33a	20,89	17,09	22,88 a	17,89
	A	A	A	A	a	a	B	a
P1	17,33a	21,67a	19,33a	18,33a	20,06	23,46	27,19	21,8
	A	A	A	A	a	b	B	ab
P2	18,33a	17,33a	26,33b	20,67a	28,88	27,95	25,37	33,42
	A	A	B	A	b	b	ab	c
P3	18,33a	20a	19a	23,33a	32,79	35,72	40,52 c	31,88
	A	A	A	A	b	c	B	c

Information:

- Lowercase letters (a, b, c, d) indicate the apparent effect of the biochar (B) treatment on each dose of fertilizer (P).
- The capital letters (A, B, C, D) indicate the apparent effect of the dose of Phonska Plus fertilizer (P) on the respective soaking duration of biochar (B).
- The values followed by the same letter were not significantly different according to the BNJ 5% follow-up test.

N-Available is a fraction of soil nitrogen that can be absorbed directly by plants, especially in the form of ammonium (NH_4^+) and nitrates (NO_3^-) (Gao et al., 2024; Hutapea & Aprilia, 2020). Nitrogen (N) is an essential macronutrient that is essential for soil fertility and plant growth. The results showed that the interaction between the dose of Phonska Plus fertilizer and the duration of soaking of biochar in composted tea had a varied effect on the level of available nitrogen (N-available) in the soil. Data showed that the combination treatment of P2B2, i.e. the application of 300 kg/ha of Phonska Plus fertilizer with biochar soaked for 24 hours in composted tea, produced the highest available N-level of 26.33 ppm and was significantly different from other treatments ($p < 0.05$). This shows that there is a synergy between nitrogen input from inorganic fertilizers and the ability of biochar to and release nutrients from organic solutions (composted tea). Biochar that has been soaked for 24 hours is believed to be able to absorb nitrogen-rich organic compounds and improve the soil's cation exchange capacity (KTK), as well as increase microbial activity that plays a role in nitrogen mineralization (Zhang et al., 2022). In contrast, treatment without fertilizer and without soaking biochar (P0B0) showed the lowest levels of N-available (16.33 ppm), reflecting the lack of nutrient contribution from both organic and inorganic sources. These results are in line with the findings of Fatharani et al. (2021), who stated that the combination of nutrient-saturated biochar with fertilizer inputs can improve the efficiency of nitrogen use and extend its availability in the soil.

P-Available is one of the essential macronutrients that is very important for soil fertility and plant growth. P-available refers to the phosphorus fraction that can be directly absorbed by plant roots in the form of orthophosphate ions

(H_2PO_4^- and HPO_4^{2-}). The sufficient availability of phosphorus in the soil supports a wide range of plant physiological and biochemical processes, including energy formation (ATP), DNA and RNA synthesis, and root development and flowering (Havlin et al., 2017).

The results of this study show that the interaction between the dose of Phonska Plus fertilizer and the soaking time of biochar in compost tea is proven to have a significant effect on the availability of phosphorus (P-available) in the soil. The combination of P3B2 treatment (Phonska Plus fertilizer 400 kg/ha and biochar soaked for 24 hours) resulted in the highest available P-level of 40.52 ppm, significantly different from other treatments. This increase is suspected to be due to the synergy between nutrients from fertilizers and the role of saturated biochar in composting tea in improving fertilization efficiency and improving soil chemical properties. Biochar that has been saturated is able to slowly adsorb and release organic compounds and phosphates, reduce fixation by Al and Fe, and increase the activity of phosphate-solvent microorganisms (Yuan et al., 2023; Mukherjee et al., 2022). In contrast, P0B1 treatment (100 kg/ha and 12-hour immersion) showed the lowest P-available value of 17.09 ppm, indicating that low fertilizer doses without optimal biochar support have not sufficiently increased phosphorus availability.

Table 6. Interaction Long treatment of soaking biochar in compost tea and dose of Phonska Plus fertilizer (15, 15, 15) against K-Available soil

Parameter	K-Available (ppm)			
	B0	B1	B2	B3
P0	2,33 a A	1,77 a B	2,17 a B	2,61 a A
P1	2,00 a A	1,99 a A	2,74 b B	2,03 b A
P2	2,12 a BA	2,05 a A	2,57 a B	2,57 a B
P3	2,14 a A	2,31 b A	2,18 a A	3,13 c B

Information:

- Lowercase letters (a, b, c, d) indicate the apparent effect of the biochar (B) treatment on each dose of fertilizer (P).
- The capital letters (A, B, C, D) indicate the apparent effect of the dose of Phonska Plus fertilizer (P) on the respective soaking duration of biochar (B).
- The values followed by the same letter were not significantly different according to the BNJ 5% follow-up test.

Potassium (K) is an essential macronutrient that plays an important role in various physiological processes of plants, such as the regulation of osmotic pressure, the opening and closing of stomata, and the distribution of photosynthetic results throughout plant tissues (Hutapea & Apriliya, 2020; Zörb

et al., 2014). K-Available in soil is strongly influenced by the form of K used, soil cation exchange capacity, as well as interactions between organic matter and nutrient inputs such as compound fertilizers and biochar (Sparks, 1987; Wicaksono et al., 2015).

The results of this study show that the interaction between the dose of Phonska Plus fertilizer and the length of soaking of biochar in composted tea has a significant effect on the content of potassium (K) available in the soil. The best treatment was obtained in a combination of P3B3, namely a fertilizer dose of 400 kg/ha and a 36-hour biochar immersion, which resulted in the highest K-available value of 3.13 ppm. This value differed markedly from other treatments in the same soaking group, suggesting that an increased dose of fertilizer combined with longer-activated biochar was able to optimally increase the release of K-available. This is in line with the findings of Agegnehu et al. (2017), who stated that activated biochar can improve fertilizer efficiency as well as stabilize nutrient availability through increased cation exchange capacity and microbial activity.

In contrast, the lowest K-available value was found in the combination of P1B1, which was a dose of 200 kg/ha and a 12-hour biochar immersion, with a value of only 1.77 ppm. These results indicate that biochar that is only soaked for 12 hours has not undergone enough biological and chemical activation to increase the release of nutrients in the soil. Biochar that has not been optimally activated has an active surface and porosity that is still limited, so its ability to hold and release K ions is low (Lehmann & Joseph, 2015). Thus, the duration of soaking is an important factor in maximizing the function of biochar as a storage and provider of soil nutrients.

Overall, the results of this study show that the effectiveness of biochar in increasing K-availability is greatly influenced by the length of soaking in composted tea and the dose of fertilizer administered. The use of bioactivated biochar in combination with appropriate inorganic fertilizers can be an integrated strategy to improve soil fertility, improve fertilization efficiency, and support sustainable plant growth. A combination of P3B3 treatments is recommended as the best treatment for increasing the availability of potassium in the soil, which is essential for metabolic processes, protein formation, and osmotic pressure regulation of plants (Römheld & Kirkby, 2010).

Table 7. Average number of fungal colonies at long treatments, soaking biochar in compost tea and dosage of Phonska Plus fertilizer (15, 15, 15)

Treatment	Number of Fungal Colonies (10 ⁴ CFU/ g Soil)
Biochar (B)	
B0	21,9 b
B1	22,8 b
B2	23,6 b
B3	31,3 a
Phonska Plus (P)	
P0	31,0 a
P1	26,4 a

P2	23,9 ab
P3	18,3 b
BNJ 5 %	7,14

Remarks: The numbers in each column followed by the same letter in each treatment were not significantly different in the 5% BNJ test

The number of Mushroom Colonies is one of the important indicators of soil biological activity and health. The results showed that the treatment of biochar and Phonska Plus fertilizer single-handedly affected the number of soil mushroom colonies, with a significant difference in the BNJ test level of 5%. The biochar treatment with a soaking time of 36 hours in composted tea (B3) resulted in the highest number of fungal colonies of 31.3×10^4 CFU/g soil, which was significantly different from other treatments. Meanwhile, the lowest number of mushroom colonies was found in the non-soaking biochar treatment (B0), which was 21.9×10^4 CFU/g soil. The increase in the mushroom population in B3 shows that the process of soaking biochar in compost tea for 36 hours is able to increase the content of microorganisms and organic compounds available to soil microbes. Compost tea acts as a bio-inoculant that enriches biochar with microbial populations, while biochar pore structures provide a stable habitat for microbial growth, including saprophytic fungi (Lehmann & Joseph, 2015; Sun et al., 2022).

In contrast, in the Phonska Plus fertilizer treatment, the highest number of fungal colonies was found at the lowest dose ($P_0 = 100$ kg/ha) of 31.0×10^4 CFU/g of soil, which was not significantly different from the P_1 and P_2 doses, but significantly different from the highest dose ($P_3 = 400$ kg/ha), which resulted in the lowest number of fungal colonies of 18.3×10^4 CFU/g of soil. A decrease in fungal populations at high doses of fertilizer indicates the potential negative effects of the accumulation of salts or certain ions from inorganic fertilizers on soil microorganisms. High ion concentrations can cause osmotic stress and decrease microbial activity, especially in soil conditions with low buffer capacity (Yin et al., 2020; Nannipieri et al., 2020). In addition, the imbalance of the carbon and nitrogen ratio caused by high inorganic fertilizer inputs can inhibit the growth of soil fungi that are more sensitive to changes in the chemical environment. The best combination to support the presence of soil fungi is the B3 and P_0 treatments, which are biochar soaking for 36 hours and the use of a dose of Phonska Plus fertilizer of 100 kg/ha. This combination results in the highest mushroom population (about $31.3\text{--}31.0 \times 10^4$ CFU/g), which reflects biologically healthier soil conditions.

CONCLUSION AND RECOMMENDATION

The results showed that the soaking time had a significant effect on plant height, number of leaves, tuber diameter, wet tuber weight and dry tuber weight as well as soil fertility parameters such as pH, C-organic, N-available, P-tertsdia, K-available and increased number of fungal colonies. Furthermore, the dosage of Phonska Plus fertilizer (15 15 15) had a noticeable effect on plant height, number of leaves, number of bulbs, weight of dry bulbs, Ph of soil, C-Organic, P-

Available, K-available and increase in the number of fungal colonies. There was no effect of treatment interactions on shallot yield parameters and increased number of fungal colonies. However, it has a noticeable effect on plant growth, increasing soil pH, C-Organic, N-available, P-available, and K-available.

FURTHER STUDY

Future studies could focus on exploring the long-term effects of soaking time and Phonska Plus fertilizer dosage on shallot productivity and soil health sustainability. It would also be valuable to examine different combinations of organic and inorganic fertilizers to determine whether synergistic interactions could further enhance yield and soil fertility. In addition, investigating the role of microbial diversity beyond fungal colonies could provide deeper insights into soil biological activity and its contribution to shallot growth and productivity.

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