

**Research Article**

## **The potential of biochar and compost from sugarcane bagasse on growth, yield, nutrient uptake of shallot, and properties of an Inceptisol**

**Hidayatuz Zu'amah<sup>1</sup>, Cicik O. Handayani<sup>1</sup>, Triyani Dewi<sup>1\*</sup>, Forita D. Arianti<sup>2</sup>, Jajuk A. Beti<sup>1</sup>, Akhmad Jufri<sup>3</sup>, Mochamad Rosjidi<sup>4</sup>, Dewi Sahara<sup>5</sup>, Siti Maro'ah<sup>6</sup>, Jauhari Syamsiyah<sup>6</sup>**

<sup>1</sup> Research Center for Horticulture, National Research and Innovation Agency, Soekarno Science and Technology Area, Jl. Raya Jakarta-Bogor KM 46, Cibinong, Bogor 16915, West Java, Indonesia

<sup>2</sup> Research Center for Sustainable Production System and Life Cycle Assessment, Research Organization for Energy and Manufacture, National Research and Innovation Agency, Gedung Teknologi 2, Kawasan Puspiptek, Serpong, Tangerang Selatan 15314, Indonesia

<sup>3</sup> Research Center for Estate Crops, National Research and Innovation Agency, Soekarno Science and Technology Area, Jl. Raya Jakarta-Bogor KM 46, Cibinong, Bogor 16915, West Java, Indonesia

<sup>4</sup> Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency, Gedung Teknologi 2, Kawasan Puspiptek, Serpong, Tangerang Selatan 15314, Indonesia

<sup>5</sup> Research Center for Behavioral and Circular Economics, Research Organization for Governance, Economy and Community Welfare, National Research and Innovation Agency, Jl. Gatot Subroto No.10 Jakarta 12170, Indonesia

<sup>6</sup> Department of Soil Science, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta 57126, Central Java, Indonesia

\*corresponding author: triy021@brin.go.id

### **Abstract**

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Excessive pesticide use and intensive shallot farming to satisfy high market demand can degrade soil quality and harm environmental sustainability. Sustainable agricultural practices, such as biochar and compost, are alternatives to ensure long-term soil productivity and fertility. This study investigated the ability of biochar and compost made from bagasse waste to improve shallot growth, yield, nutrient absorption, and soil quality. The research used a factorial randomized block design in a greenhouse. The first factor was the application of biochar and compost (K1 = compost, K2 = biochar, K3 = biochar-compost (1:4/w:w) and K4 = biochar-compost (1:2/w:w), and the second factor was the dose of NPK fertilizer (0%, 50%, and 100% of the recommended dose). The planting medium used was an Inceptisol from shallot fields in Sukaharjo, Central Java. The variables measured included plant growth, yield components, soil chemical properties, and levels of N, P, and K in plants. The results showed that the combination of compost with 100% NPK fertilizer gave better plant growth, fresh and dry weight of plants and tubers, increased organic C, total N, and CEC of the soil, and increased the uptake of N, P, and K by plants.

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### **Introduction**

Inceptisol soil is immature soil that still resembles the properties of its parent material. Low fertility levels characterized by low organic C content, low soil pH,

and relatively low levels of N, P, and K nutrients are limiting factors that can inhibit plant growth (Rizwan and Harahap, 2021; Rahmayuni et al., 2023). If appropriately managed, this soil has excellent potential for cultivating food crops and horticulture. To improve

soil quality, individuals can provide organic matter, use balanced inorganic fertilizers, and apply soil conditioners like biochar and dolomite to enhance the soil's physical, chemical, and biological properties (Islamiati et al., 2024; Sara et al., 2024; Wiskandar and Ajidirman, 2024). This approach is important to maintain soil productivity, especially on land that has the potential for soil damage due to intensive management, such as shallot fields.

Shallots are one of the important commodities that support food self-sufficiency in Indonesia. The high demand for shallots has also encouraged intensive shallot cultivation practices using excessive agrochemicals such as synthetic fertilizers and chemical pesticides to increase yields (López-Felices et al., 2023). Using these agrochemicals can increase productivity in the short term but has long-term adverse impacts on soil health and environmental sustainability if used excessively and continuously (Sharma and Singhvi, 2017). The decline in land quality in intensive shallot farming occurs due to reduced soil nutrient content such as organic carbon, nitrogen (N), phosphorus (P), potassium (K), and other micronutrients caused by excessive use of agrochemicals (de Sousa et al., 2024; Córdova et al., 2025).

Sustainable agricultural approaches aim to mitigate the effects of intensive cultivation of shallots. These techniques enhance productivity while preserving soil health by promoting biodiversity, reducing dependence on synthetic inputs, and increasing soil fertility (Dewi et al., 2024a). The integration of organic amendments, including biochar and compost, into the agricultural system is an effective approach to achieving this equilibrium (Dewi et al., 2024b).

An effective approach to waste management and soil health enhancement is the utilization of agricultural waste, such as sugarcane bagasse, to generate biochar and compost. Biochar is recognized for its numerous advantages, such as improving soil structure, augmenting water retention (Lu et al., 2024), providing a stable habitat for beneficial soil microorganisms (Bolan et al., 2024), minimizing nutrient loss from leaching, and enhancing nutrient use efficiency (Tran et al., 2023). On the other hand, compost enhances soil quality by improving soil structure, augmenting moisture retention, and providing a consistent release of essential nutrients (Wang et al., 2022). The integration of biochar and compost offers an effective method for enhancing soil fertility, augmenting microbial activity, and improving agricultural productivity, all while supporting environmental sustainability (Qian et al., 2023).

The potential application of biochar and compost derived from sugarcane bagasse residue in horticultural cultivation has been demonstrated in numerous prior studies. In particular, the application of biochar and compost derived from sugarcane bagasse can increase the bacterial population and reduce the

concentration of heavy metal cadmium (Cd) in the soil used for shallot cultivation (Zu'amah et al., 2024). Furthermore, these amendments significantly enhance soil properties, including pH, organic matter content, and total nitrogen (Farid et al., 2022; Liu et al., 2023). Enhancing soil quality through the application of biochar and compost from sugarcane bagasse positively impacts the growth and yield of various horticultural crops, including strawberries (Aali et al., 2024), tomatoes (Gnanamani and Vijayalakshmi, 2023), broccoli (Dhatt et al., 2023), and chilies (Swari et al., 2022).

The utilization of biochar and compost derived from sugarcane bagasse has demonstrated substantial advantages in sustainable agriculture, particularly in the context of various horticultural commodities. This emphasizes the potential for using sugarcane bagasse as biochar and compost, particularly in regions experiencing soil degradation and declining productivity. In addition, manufacturing biochar and compost from sugarcane bagasse is consistent with the principles of a circular economy, as it converts agricultural refuse into valuable resources that improve soil health.

This study aimed to determine the potential of biochar and compost derived from sugarcane bagasse waste to increase shallot growth, yield, nutrient absorption, and soil quality. This research was also anticipated to offer insights that can facilitate the implementation of more sustainable cultivation practices for shallots and other horticultural commodities.

## Materials and Methods

The pot research was conducted in the greenhouse, Faculty of Agriculture, Universitas Sebelas Maret, from February to September 2024. The soil for the planting medium was taken from the shallot fields in Mancasan Village, Baki District, Sukoharjo Regency, Central Java, with coordinates 7°38'13.1" S-110°46'19.6" E with an altitude of 105 m above sea level. This research included the manufacture of compost and biochar from sugarcane bagasse and planting the Bima Brebes variety of shallots.

### *The pyrolysis process for preparing biochar*

Biochar from bagasse was produced thermally through pyrolysis, low or no oxygen combustion at around 300 °C. Initially, the bagasse was sun-dried to reduce its moisture content, ensuring efficient carbonization. The process involved placing the dried bagasse into a tightly sealed drum container to limit oxygen exposure and prevent combustion. External heat was applied to the drum, causing the bagasse to undergo carbonization - a process where volatile compounds are released, and the remaining material transforms into biochar. This reaction occurred without air to minimize gas evaporation and maximize carbon

retention. After the bagasse had fully converted to charcoal, water was sprayed on the material to cool it and extinguish residual embers. Once cooled, the charcoal was removed, dried under sunlight, and inspected for quality. Properly processed biochar was identified by its black color, lightweight texture, and retention of the bagasse's original structure, signaling a successful pyrolysis outcome.

#### ***Production of compost from sugarcane bagasse***

To prepare the compost, 10 kg of dried sugarcane bagasse waste was chopped into smaller pieces to facilitate the decomposition process and mixed with 5 kg of cow manure. The mixture was then combined with 200 mL of EM-4 solution and 50 mL of molasses, which had been dissolved in 10 liters of water. These ingredients were stirred to ensure thorough mixing. The compost materials were tightly covered with plastic or tarpaulin to promote fermentation. The mixture was stirred once a week to maintain homogeneity.

The compost is ready for use after one month of decomposition, which is characterized by its dry, smooth, and crumbly texture. It should also be odorless and have a blackish-brown color.

#### ***Characteristic compost and biochar from sugarcane bagasse***

The overall characteristics of the compost have met the criteria based on the Minister of Agriculture, Republic of Indonesia Regulation No. 261/KPTS/SR.310/M/4/2019 (Table 1). Parameters such as pH, water content, organic C, and C/N ratio of compost from sugarcane bagasse are in a good range according to the Ministry of Agriculture No. 261/2019 regulation. The compost is neutral, has a relatively high organic carbon content (26.72%), and the C/N ratio (17.71) is within the recommended range. The content of macronutrients (nitrogen, phosphorus, and potassium) in the compost is still low (<2%), and the content of humic and fulvic acids in the compost is 6.79% and 8.08%, respectively.

Table 1. Characteristics of compost from sugarcane bagasse.

Parameter	Unit	Methods*	Value	Quality standard**
pH H <sub>2</sub> O	-	pH meter	6.80	4-9
Water content	%	Gravimetry	8.02	8-20
Organic carbon	%	Walkley and Black	27.62	min 15
C/N ratio	-	-	17.71	≤25
Total N	%	Kjeldahl	1.56	min 2
P <sub>2</sub> O <sub>5</sub>	%	HNO <sub>3</sub> : HClO <sub>4</sub>	0.29	min 2
K <sub>2</sub> O	%	HNO <sub>3</sub> : HClO <sub>4</sub>	0.23	min 2
Humic acid	%	Spectrophotometry	6.79	-
Fulvic acid	%	Spectrophotometry	8.08	-

\*Sulaeman et al. (2005), \*\*Quality standards according to Minister of Agriculture, Republic of Indonesia Regulation No. 261/KPTS/SR.310/M/4/2019, 2019.

A comparison of the morphology of the pore shape of the upper surface of the bagasse biochar sample from the results of SEM (Scanning Electron Microscope) measurements can be seen in Figure 1. The pore measurements on bagasse biochar show that the surface does not show any pore distribution. The pores in a material act as regular cavities that can absorb water, nutrients, and metal elements such as N, P, K, and Mg, as well as other compounds that support soil fertility (Sharma et al., 2021). Bagasse biochar shows distinctive functional groups, smoother surface morphology, and significant specific surface area, increasing its potential for application in soil amendment and carbon sequestration (Emenike et al., 2023). The bagasse biochar contains a water content of 1.31%, pH 7.68, and cation exchange capacity (CEC) 34.5%. Biochar's CEC value significantly affects its quality and effectiveness as a soil amendment. Increasing CEC increases nutrient retention, which is important for soil fertility and plant growth (Domingues et al., 2020; Dey et al., 2023).

The results of EDX (Energy Dispersive X-ray Spectroscopy) characterization have a mass

percentage composition of carbon (C) 50.02%, oxygen (O) 35.68%, silica (Si) 3.15%, potassium (K) 4.42%, and aluminum (Al) 0.86%. The high oxygen content is due to the low pyrolysis temperature during combustion. Biochar processed at low pyrolysis temperatures can retain more groups, functions such as oxygen-containing groups that increase reactivity (Valenga et al., 2024).

#### ***Experimental site and design***

This study utilized a factorial randomized block design. The first factor examined was the type of organic amendment, which included four treatments: K1 = compost, K2 = biochar, K3 = a mixture of biochar and compost (biocompost) in a 1:4 weight-to-weight ratio (w:w), and K4 = a mixture of biochar and compost (biocompost) in a 1:2 weight-to-weight ratio (w:w). The second factor was the application level of NPK fertilizer, consisting of three levels: A0 = no NPK, A1 = 50% of the recommended NPK dosage, and A2 = 100% of the recommended NPK dosage. In total, there were 12 treatment combinations, with each treatment replicated three times.

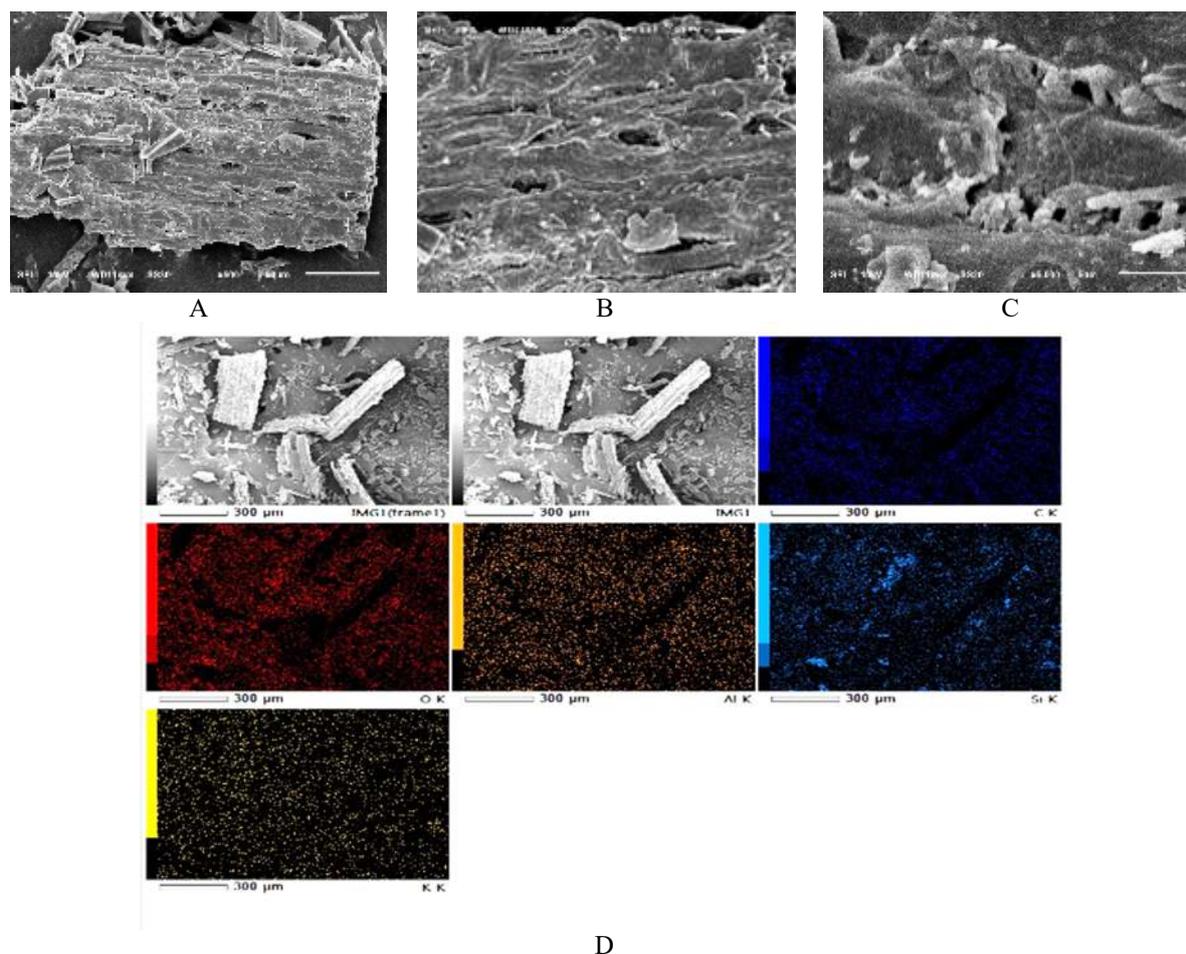


Figure 1. SEM images (A, B, and C captured at 100, 1,000, and 5,000 magnifications) and EDX mapping image (D) of bagasse biochar.

The planting medium used was an Inceptisol obtained from shallot fields in Mancasan Village, Baki District, Sukoharjo. Each pot contained 5 kg of soil. The application of compost and biochar followed the specific treatments, with a recommended dose of 10 t/ha for both. According to ISRI (2021), the recommended doses for NPK (15-10-12) and ZA fertilizers are 525 kg/ha and 185 kg/ha, respectively. To prepare the Bima Brebes variety shallot seeds, the tips of the bulbs were cut off by about one-third. One seed was then planted in each prepared pot. NPK fertilizer was applied at the time of planting and again 14 days after planting (DAP). ZA fertilizer was applied at a specified growth stage. Maintenance activities for the shallot plants included watering in the mornings and evenings, weeding, replanting any seedlings that died or exhibited disturbed growth, and applying pesticides as necessary if symptoms of pest or disease attacks were observed, following the recommended dosages. The shallots were harvested 60 days after planting by pulling the plants out of the soil.

The variables observed in this study included plant growth measurements, yield and its components, plant nutrient uptake, and soil chemical properties such as pH, organic carbon, total nitrogen, available

phosphorus, available potassium, and soil cation exchange capacity (CEC). Plant nutrient uptake was calculated using the formula provided by Arifiyatun et al. (2016):

$$\text{Nutrient uptake} = \text{Plant dry weight} \times \text{nutrient concentration (\%)} \text{ in plant tissue}$$

#### *Physical and chemical soil properties*

The method for chemical parameter analysis of soil samples referred to the Technical Guidelines for Chemical Analysis of Soil, Plants, Water, and Fertilizers by Sulaeman et al. (2005). The soil properties parameters observed included pH (pH meter), organic C (Walkley and Black), total N (Kjeldahl), available P (Olsen extract), available K (Morgan Wolf extract), and CEC (NH<sub>4</sub>OAc extract pH 7). According to the Soil Texture Triangle (USDA, 2018), the soil examined in this study was classified as Inceptisol and falls within the silt texture category. The soil comprises clay (8.79%), silt (85.94%), and sand fractions. Additionally, it has a moderate total nitrogen content of 0.38%, low available phosphorus at

8.94 mg/kg, and very low available potassium at 0.64 mg/kg. These macronutrients are crucial for plant growth. The CEC of the soil is relatively high at 28.25 cmol(+)/kg, indicating that it has a good ability to retain nutrients, making them available for plant uptake (Mishra et al., 2023). The higher soil CEC indicates a greater capacity for nutrient retention (Purnamasari et al., 2021; Nel et al., 2023). However, the soil's organic carbon content is relatively low at 1.63%, suggesting that organic amendments, such as compost, are necessary to enhance its structure and nutrient content.

### Data analysis

Data processing was conducted using the Minitab 16.0 software. An analysis of variance (ANOVA) was performed to assess the impact of different doses of compost, biochar, and inorganic fertilizer on the observed variables. If the effect was significant ( $p < 0.05$ ), a Tukey's post hoc test was then conducted at the 5% level.

## Results and Discussion

### Change in soil chemical properties

The chemical properties of the soil after harvest from each treatment are presented in Table 2. The combination of compost, biochar, and biocompost with NPK fertilizer application showed a significant variation in soil pH values. The application of NPK fertilizer at 50% and 100% of the recommended dose resulted in a decrease in soil pH compared to soil

without NPK fertilizer, which had a slightly alkaline pH range of 8.1 to 8.3. This reduction in pH can enhance nutrient availability, particularly for micronutrients like iron and manganese, which become more accessible at lower pH levels (Rengel, 2015; Khoshru et al., 2023). The combination of compost, biochar, and biocompost treatments with NPK fertilizer applied at the recommended dose (100% NPK) resulted in a soil pH that approached the optimal condition for shallot growth, which ranged from 6.7 to 7.2. Shallot plants prefer slightly acidic to neutral soil pH (Girsang et al., 2021). According to Kurnianingsih et al. (2019), shallots thrive in fertile soil with a crumbly structure, medium to clay texture, a pH of around 5.6 to 6.5, and effective drainage and aeration.

The compost treatment with 100% NPK exhibited the highest organic carbon content at 3.62%, followed closely by biocompost (1:4) without NPK, which had an organic carbon content of 3.44%. This aligns with the characteristics of bagasse compost, which is known for its high organic carbon levels. In comparison, biochar contributes less to soil organic carbon than compost because it is more stable and decomposes at a slower rate (Gross et al., 2024; Yang et al., 2024). Compost significantly enhanced the total nitrogen (N) content in the soil, especially when combined with NPK fertilizer, achieving up to 0.43% total N at 100% NPK. Conversely, biochar had a limited impact on increasing total N due to its lower nitrogen content. However, the combination of biocompost showed promising synergy, raising total N content by up to 0.41% in treatments without NPK.

Table 2. Effect of interaction between compost, biochar, biocompost, and NPK fertilizer on soil chemical properties.

Treatment		Soil Chemical Properties					
Biochar, compost and biocompost	NPK Fertilizer Dosage	pH	Organic C (%)	Total N (%)	Available P (mg/kg)	Available K (mg/kg)	CEC (cmol(+)/kg)
Compost (K1)	Without NPK (A0)	8.4 a	3.25 ab	0.35 bc	4.53 bcd	0.34 a	25.02 bc
	50% NPK (A1)	7.3 def	3.06 abc	0.35 bc	3.73 cde	0.28 a	23.66 c
	100% NPK (A2)	6.8 fg	3.62 a	0.43 a	3.04 ef	0.39 a	35.05 a
Biochar (K2)	Without NPK (A0)	8.1 ab	2.40 d	0.30 cd	1.88 f	0.37 a	27.41 bc
	50% NPK (A1)	7.7 bc	2.93 abcd	0.35 bc	5.87 ab	0.31 a	30.02 abc
	100% NPK (A2)	7.2 def	3.17 ab	0.34 bc	3.55 cde	0.37 a	29.49 abc
Biocompost (1:4) (K3)	Without NPK (A0)	8.2 ab	3.44 a	0.41 ab	1.97 f	0.34 a	30.45 ab
	50% NPK (A1)	7.4 cde	2.82 bcd	0.40 ab	4.77 bc	0.35 a	34.36 a
	100% NPK (A2)	6.9 efg	2.69 bcd	0.27 d	7.06 a	0.29 a	26.29 bc
Biocompost (2:4) (K4)	Without NPK (A0)	8.2 ab	2.48 cd	0.36 abc	3.58 cde	0.49 a	26.44 bc
	50% NPK (A1)	7.4 cd	3.03 abc	0.38 ab	4.82 bc	0.38 a	27.34 bc
	100% NPK (A2)	6.7 g	2.71 bcd	0.36 abc	3.35 de	0.34 a	26.35 bc

Remarks: Numbers in the same column followed by different letters indicate significant differences in the 5% Tukey test.

The study found that biocompost (1:4) and 100% NPK combination resulted in the highest available phosphorus at 7.06 mg/kg, suggesting a synergistic effect. Biochar treatment with 50% NPK also increased available phosphorus by 5.87 mg/kg,

indicating that biochar improves soil chemical properties. Biochar increases phosphate retention, lowers leaching, and makes phosphorus more available to plants (Yang et al., 2021; Ahmed et al., 2024; Deng et al., 2024). While available potassium

(K) did not show significant differences between the treatments, the combination of biocompost (2:4) without NPK exhibited a higher K content compared to compost or biochar alone, as well as biocompost (1:4). This indicates that biochar is more effective in maintaining K levels in the soil, although its role in increasing available K remains limited.

The highest CEC was observed in the compost treatment with 100% NPK (35.05 cmol(+)/kg), corresponding with the high organic carbon content found in the compost. Additionally, biochar increased the CEC, particularly when combined with compost. The combination of biocompost (1:4) with 50% NPK also showed a high CEC of 34.36 cmol(+)/kg. This indicates that biochar enhances CEC through its porous structure, which improves nutrient retention. When using biocompost (1:4 ratio) without NPK, there was still an increase in CEC, but the effect was more pronounced with NPK. This suggests a synergistic relationship between organic amendments and chemical fertilizers.

Incorporating organic fertilizers like compost and biochar alongside a reduced NPK dose (50%) can improve soil quality while decreasing reliance on inorganic fertilizers. However, to achieve optimal yields regarding nitrogen and phosphorus contents, complete NPK application may still be necessary. Therefore, the most effective approach is the use of organic fertilizers together with NPK in a balanced manner, which can provide long-term benefits for soil quality and crop productivity (Wang et al., 2024).

Overall, combining biochar and compost, especially with 50%-100% NPK application, significantly improved soil properties important for shallot cultivation. A previous study conducted over 3 years in sub-Saharan Africa found that compost or inorganic NPK fertilizer alone or in combination with biochar improved soil quality such as reduced bulk density, increased porosity, moisture retention, organic matter content, nitrogen, phosphorus, and cation exchange capacity, thereby increasing crop production (Phares and Akaba, 2022).

#### Growth of shallots

The interaction between compost, biochar, and biocompost with NPK fertilizer significantly affected the growth of shallot plant height at 14, 28, 42, and 56 DAP (Table 3). Applying compost alone, biochar alone, and combined biochar and compost with NPK fertilizer at the recommended dosage yielded higher plants than treatments without NPK or with only 50% NPK. This indicates that compost alone does not provide sufficient availability of the essential nutrients for shallot plants, necessitating the addition of NPK fertilizer at the recommended dosage. NPK fertilizer supplies nutrients more rapidly, while the nutrients from compost are released slowly, thereby supporting the long-term growth of shallot plants. Furthermore, compost enhances microbial activity, which aids in plant nutrient absorption, whereas biochar efficiently maintains nutrient retention and release (Singh, 2022; Permana et al., 2023).

Table 3. Effect of Interaction between compost, biochar, biocompost, and NPK on plant height.

Treatment		Plant Height (cm)			
Biochar, compost and biocompost	NPK Fertilizer Dosage	14 DAP	28 DAP	42 DAP	56 DAP
Compost (K1)	Without NPK (A0)	20.0 ab	31.3 a	34.7 bc	37.0 ab
	50% NPK (A1)	21.7 ab	31.0 a	35.7 bc	36.7 ab
	100% NPK (A2)	26.0 a	34.7 a	41.7 a	42.3 a
Biochar (K2)	Without NPK (A0)	25.0 a	32.7 a	37.3 abc	38.0 ab
	50% NPK (A1)	24.7 a	31.3 a	36.3 abc	37.3 ab
	100% NPK (A2)	21.7 ab	32.0 a	35.3 bc	38.3 ab
Biocompost (1:4) (K3)	Without NPK (A0)	17.3 b	28.7 ab	33.2 c	34.3 bc
	50% NPK (A1)	19.3 ab	32.0 a	36.0 abc	36.7 ab
	100% NPK (A2)	20.7 ab	32.3 a	39.7 ab	40.7 a
Biocompost (2:4) (K4)	Without NPK (A0)	15.3 b	23.0 b	27.3 d	30.0 c
	50% NPK (A1)	20.7 ab	31.0 a	37.7 abc	38.7 ab
	100% NPK (A2)	22.0 ab	32.3 a	37.3 abc	36.7 ab

Remarks: Numbers in the same column followed by different letters indicate significant differences in the 5% Tukey test, DAP = days after planting.

The effect of biochar, compost, and NPK on the number of leaves can be seen in Figure 2. Data on the number of leaves at the observation time (14 to 56 DAP) showed a significant increase in the number of leaves over the observation time. The provision of compost (K1) significantly affected the number of leaves at the 42 DAP compared to other treatments

(Figure 2a). The treatment of giving 50% NPK fertilizer (A1) and 100% NPK (A2) had a significant effect compared to not giving NPK fertilizer at the age of 42 HST (Figure 2b). At 42 DAP, the shallot plants had passed the peak of the vegetative phase, and in this condition, the growth activity had reached its peak, and the process of forming and enlarging the bulbs began.

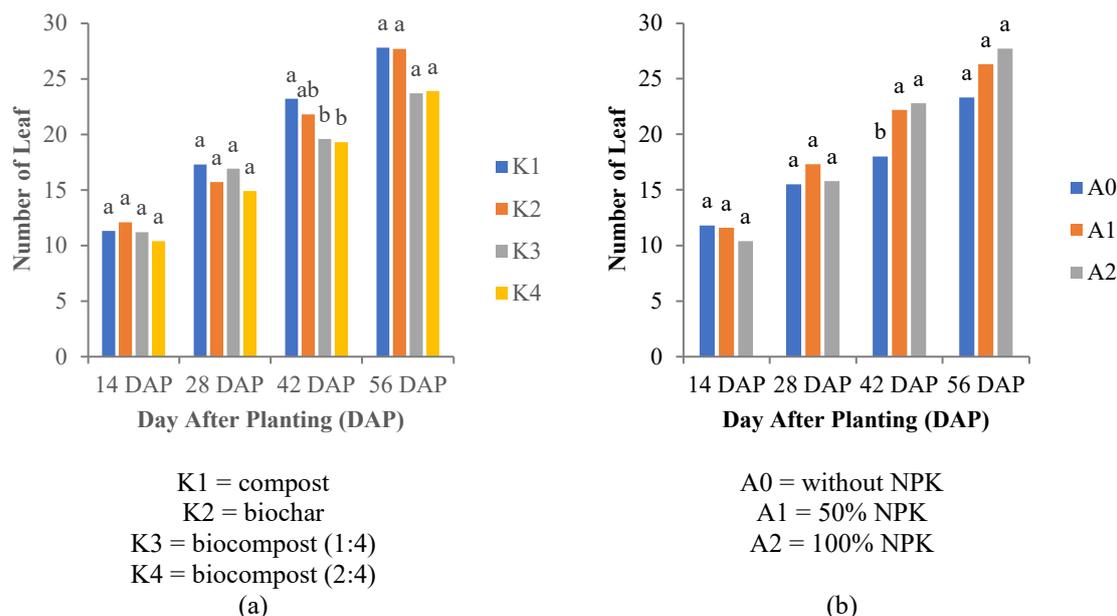


Figure 2. Effect of compost, biochar, biocompost (a), and NPK fertilizer (b) on the leaf number of shallot.

**Yield and yield component of shallot**

The combination of biochar and/or compost treatment with NPK fertilizer at three dosage levels significantly affected harvest weight, dry plant weight, bulb harvest weight, dry bulb weight, and shallot bulb diameter (Table 4). The provision of compost, biochar, biocompost, and NPK fertilizer provides complementary benefits; each has its role in creating optimal growth in environmental conditions, thereby

increasing the yield and components of shallot yields. The provision of compost and 50% NPK fertilizer dose provided better harvest yield, such as adding 100% NPK fertilizer dose to save the input of NPK fertilizer given to shallots. A significant increase in harvest yields from the combination of compost, biochar, and NPK fertilizer was also obtained in other plants such as rice, corn, cabbage, and pineapple (Situmeang et al., 2018; McDonald et al., 2019; Phares and Akaba, 2022; Hanyabui et al., 2024).

Table 4. Effect of interaction between compost, biochar, biocompost, and NPK fertilizer on yield and yield component of shallot.

Treatment		Yield and yield component of shallot				
Biochar, compost and biocompost	NPK Fertilizer Dosage	Fresh weight (g/plant)	Dry weight (g/plant)	Fresh weight of bulb (g/plant)	Dry weight of bulb (g/plant)	Bulb diameter (cm)
Compost (K1)	Without NPK (A0)	12.7 cd	3.7 cd	4.7 b	2.3 d	1.0 b
	50% NPK (A1)	31.3 a	16.3 a	16.3 a	14.0 ab	1.8 a
	100% NPK (A2)	28.0 abc	16.7 a	16.7 a	17.0 a	1.9 a
Biochar (K2)	Without NPK (A0)	28.7 ab	10.7 abc	12.0 ab	8.7 bcd	1.4 ab
	50% NPK (A1)	24.3 abcd	11.3 abc	12.0 ab	9.3 abcd	1.5 ab
	100% NPK (A2)	27.0 abc	10.3 abc	12.0 ab	8.0 bcd	1.4 ab
Biocompost (1:4) (K3)	Without NPK (A0)	13.0 bcd	3.7 cd	11.3 ab	2.7 cd	1.3 ab
	50% NPK (A1)	24.7 abcd	10.0 abcd	10.0 ab	8.0 bcd	1.5 ab
	100% NPK (A2)	25.7 abcd	14.0 ab	12.0 ab	10.3 abc	1.6 ab
Biocompost (2:4) (K4)	Without NPK (A0)	10.0 d	2.3 d	4.0 b	2.3 d	1.7 ab
	50% NPK (A1)	27.3 abc	11.7 ab	13.0 ab	10.3 abc	1.8 a
	100% NPK (A2)	18.3 abcd	7.3 bcd	8.7 ab	6.3 bcd	1.6 ab

Remarks: Numbers in the same column followed by different letters indicate significant differences in the 5% Tukey test.

Biochar and compost from bagasse played an important role in increasing plant growth and yielding components through synergistic mechanisms. Biochar

from bagasse has high porosity and good adsorption capacity, increasing water retention capacity, nutrient availability, and carbon stability in the soil and

supporting microbial activity (Farid et al., 2022). Compost from bagasse can provide organic nutrients directly to plants, improve soil structure, increase microbial activity, and accelerate nutrient release (Alabi et al., 2022). The combination of biochar and compost from bagasse is a sustainable innovation in synergistic soil management because biochar can absorb and retain nutrients released by compost, reduce nutrient loss, and create a stable microenvironment so that it can increase nutrient absorption efficiency, support optimal growth, and increase yields sustainably (Qian et al., 2023).

### Nutrients in plant tissue and nutrient uptake

The highest potassium (K) content in plant tissue was achieved when compost was combined with a 100% NPK fertilizer dose, as demonstrated in Table 5. This indicates that this combination is the most effective for increasing K levels. Conversely, treatments that did not include NPK, regardless of the combinations of biocompost and biochar used, yielded lower K levels. This highlights the significance of NPK application for enhancing potassium absorption in shallot plant tissue, particularly when paired with compost. While the combination of biochar and compost also showed some variations in yields, it was not as effective as using compost alone with a 100% NPK dose.

Nutrient uptake in shallot plants was influenced significantly by treatments involving biocompost, various doses of NPK fertilizer, and their combinations, as indicated in Table 5. The interactions among these treatments also yielded significant nutrient uptake in the shallots. Applying compost without NPK resulted in the lowest nutrient uptake. However, the addition of NPK, at both 50% and 100% doses, significantly enhanced the uptake of nitrogen (N), phosphorus (P), and potassium (K) nutrients, with the highest uptake observed at the 100% NPK dosage. Specifically, the maximum uptake for N, P, and K was recorded at 14.6 mg/plant, 9.0 mg/plant, and 9.0 mg/plant, respectively. This indicates that the combination of compost and 100% NPK is highly effective in increasing nutrient uptake in shallots. Moreover, the application of biochar alone without NPK fertilizer resulted in higher nutrient uptake compared to the application of compost without NPK. However, adding NPK to biochar did not lead to as significant an increase in nutrient uptake as it did when combined with compost. Biocompost (in ratios of 1:4 and 2:4) yielded better nutrient uptake than using biochar or compost separately without NPK. A notable increase in nutrient uptake was observed when NPK was added, though this increase was not as pronounced as that achieved with compost plus NPK.

Table 5. Effect of interaction between compost, biochar, and biocompost with NPK fertilizer on nutrient content in plant tissue and nutrient uptake.

Treatment		Nutrient content in plant tissue (%)			Nutrient uptake (g/plant)		
Biochar, compost and biocompost	NPK Fertilizer Dosage	N	P	K	N	P	K
Compost (K1)	Without NPK (A0)	0.7 a	0.4 a	0.3 b	1.6 d	0.9 d	0.6 d
	50% NPK (A1)	0.7 a	0.5 a	0.3 b	9.4 b	5.6 ab	3.6 b
	100% NPK (A2)	0.8 a	0.5 a	0.5 a	14.6 a	9.0 a	9.0 a
Biochar (K2)	Without NPK (A0)	0.6 a	0.4 a	0.3 b	4.9 cd	3.3 bcd	2.1 bcd
	50% NPK (A1)	0.7 a	0.4 a	0.4 ab	6.6 bc	4.1 bcd	3.6 b
	100% NPK (A2)	0.7 a	0.5 a	0.4 ab	5.5 c	4.2 bcd	3.2 bc
Biocompost (1:4) (K3)	Without NPK (A0)	0.6 a	0.5 a	0.4 ab	1.9 d	1.4 cd	1.3 cd
	50% NPK (A1)	0.7 a	0.5 a	0.5 a	5.6 c	3.9 bcd	3.7 b
	100% NPK (A2)	0.7 a	0.4 a	0.4 ab	7.3 bc	5.1 abc	3.9 b
Biocompost (2:4) (K4)	Without NPK (A0)	0.7 a	0.4 a	0.4 ab	1.5 d	0.9 d	0.8 d
	50% NPK (A1)	0.7 a	0.4 a	0.4 ab	6.8 bc	3.8 bcd	3.1 bc
	100% NPK (A2)	0.7 a	0.4 a	0.3 b	7.6 bc	4.3 bcd	3.5 bc

Remarks: Numbers in the same column followed by different letters indicate significant differences in the 5% Tukey test.

Overall, compost with 100% NPK is the most effective combination to increase nutrient uptake, while biochar can increase nutrient availability but may require a combination with other organic materials for optimal yields. Biochar is a rich source of essential plant nutrients, improves plant performance, and has the potential to replace chemical fertilizers, increasing nutrient uptake and crop yields and thereby improving plant performance (Hou et al., 2022). Sugarcane bagasse compost, rich in micro and macronutrients and plant carbon, promotes nutrient absorption through

increased microbial activity, reducing the C:N ratio, regulating porosity, and increasing water holding capacity (Alabi et al., 2022).

### Conclusion

The combination of bagasse compost and a full dose of 100% NPK fertilizer consistently generated the highest plant height, leaf number, overall yield, and shallot yield components. This treatment also raised soil organic carbon, total nitrogen, and cation

exchange capacity (CEC) by 3.62%, 0.43%, and 35.05 cmol(+)/kg, respectively. In addition, it increased nitrogen (N), phosphorus (P), and potassium (K) absorption by 14.6 g/plant, 9.0 g/plant, and 9.0 g/plant, respectively, as compared to other treatments. Although using bagasse compost with a 50% NPK fertilizer dose gave slightly lower plant yields than 100% NPK fertilizer, the combination was cheaper. Using NPK fertilizer and organic materials like compost from sugarcane waste can improve plant nutrient absorption and reduce environmental loss. At the same time, biochar from bagasse can enhance fertilizer efficiency and soil quality.

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