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Impact of Water Hyacinth Compost and Compound Fertilizers on Soil Chemistry, Nutrient Uptake, and Shallot Yield

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Abstract

Water hyacinth (*Eichhornia crassipes*) compost provides a sustainable opportunity to improve soil fertility while managing an invasive aquatic weed. This study evaluated the optimal combination of water hyacinth compost and NPKS fertilizers for enhancing soil chemical properties, nutrient uptake, and shallot (*Allium ascalonicum* L.) yield on Inceptisols. The experiment was conducted from July to October 2023 using a Randomized Complete Block Design with seven fertilization treatments, including a control treatment without compost or NPKS, a compost-only treatment, a full NPKS treatment, and four combined treatments consisting of compost at ¼, ½, ¾, and 1 dosage levels each paired with ¾ of the recommended N, P, K, and S fertilizers. Results showed substantial improvements in soil chemistry, particularly in treatments combining compost with reduced mineral fertilizer rates. Soil pH increased toward neutral conditions, total nitrogen rose from 0.10% in the control to 0.32%, and available phosphorus and potassium increased more than fourfold compared with unfertilized soil. The treatment of ¾ compost dose (18.75 t ha^{-1}) + ¾ recommended NPKS consistently produced the highest soil nutrient availability, reflecting enhanced mineralization and nutrient retention. Nutrient uptake by shallot plants also improved markedly, with nitrogen, phosphorus, and potassium absorption increasing two- to threefold relative to the control. These improvements corresponded with clear gains in crop performance: the number of bulbs increased from 5 in the control to 9, and fresh bulb weight rose from 92.89 g to 132.26 g. Integrated treatments outperformed both compost-alone and full mineral fertilization. These findings indicate that combining water hyacinth compost with reduced NPKS fertilization can maintain high shallot productivity while decreasing reliance on chemical fertilizers, enhancing soil fertility, and providing an environmentally beneficial use for invasive aquatic biomass—supporting sustainable and circular nutrient management in low-fertility tropical soils

INTRODUCTION

The consumption of shallots by the Indonesian population from 2019 to 2023 has shown fluctuating but relatively increasing trends (Indonesian Ministry of Agriculture, 2023). A crucial aspect of optimizing shallot production is the use of synthetic and organic fertilizers. Currently, the most commonly utilized organic fertilizers are animal manure. Applying cow manure at a dose of 20 t ha^{-1}, combined with liquid organic fertilizer at a concentration of 15 mL L^{-1}, yielded the highest shallot production compared to other treatments (Lasmini et al., 2024). While animal manure is beneficial for enhancing shallot yields, water hyacinth compost offers several advantages as well.

Water hyacinth ranks among the world's ten worst

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invasive aquatic plants, disrupting local ecosystems and livelihoods (Churko et al., 2024). It significantly affects water flow, blocks sunlight from reaching aquatic plants, and serves as a bioindicator of polluted water (Pendse and Deshmukh, 2024). The highest biomass of water hyacinth recorded was 408.1 t ha^{-1} in a wetland ecosystem of the Brahmaputra floodplain in India om September 2021 (Lahon et al., 2023). Composting the water offers an effective strategy for controlling its spread while repurposing it as a valuable agricultural input. Once converted into compost, water hyacinth can provide organic carbon (C) at 28.73%, nitrogen (N) at 1.85%, phosphorus (P) at 4.06%, and potassium (K) at 2.75% (Sofyan, 2023). Compost produced with cow dung and cassava peel waste showed total nitrogen, phosphorus, and potassium of 1.37%, 0.48%, and 0.25%, respectively (Sebayang et al., 2023). Another study using cow rumen contents as a starter solution reported phosphorus and potassium content of 0.37% and 2.21%, consecutively (Nurdiansyah et al., 2023). Compared to cow manure, water hyacinth compost has demonstrated superior effectiveness in enhancing soil's physical, chemical, and biological properties, making it a promising alternative for sustainable agriculture (Begum et al., 2022).

Applying water hyacinth compost has been shown to increase soil pH by up to 0.69 units, soil organic carbon by 24.3%, total nitrogen (N) by 28.6%, available phosphorus (P) by 80.2%, and exchangeable potassium (K) by 112.7% (Gezahegn et al., 2024). This increase in pH occurs because water hyacinth compost releases organic acids that can bind with H^+ ions, effectively reducing soil acidity and raising pH levels (Jutakanoke et al., 2023). Additionally, a significant reduction in soil bulk density (24.8%) was observed in land supplied with compost over three consecutive growing seasons compared to treatments without fertilizers (Chen et al., 2022).

Water hyacinth compost also enhances soil nitrogen by supplying organic matter and stimulating microbial decomposition, releasing ammonium (NH_4^+) and nitrate (NO_3^-) for plant absorption (Lewoyehu et al., 2024). This compost boosts microbial activity, facilitating the nitrogen cycle and enabling bacteria to fix atmospheric nitrogen into usable forms. The shift toward neutral pH further enhances phosphorus, where orthophosphate ions may convert from PO_4^{3-} to HPO_4^{2-} or $H_2PO_4^-$ (phosphate ions) for plant uptake (Hardjowigeno, 2010). The use of water hyacinth compost not only improves soil chemistry but also enhances nutrient uptake and overall plant health, resulting in higher yields and better-quality shallots (Remona et al., 2020).

Applying N, P, and K fertilizers alongside organic fertilizers significantly improves shallot yield and increases disease resistance. A combination of organic and synthetic fertilizers increased the dry weight of shallots by 40.79% or 16.89 t.ha^{-1} compared to plots without organic fertilizers (Ramadhan et al., 2018). Fertilizers applied at optimal doses also promote the number of offshoots and plant height, which in turn improve the fresh weight of shallots (Soenyoto, 2016). Studies show that higher doses of solid organic fertilizers, such as 3.5 kg per plot or 20 t.ha^{-1}, improve plant height and bulb yield (Hakim and Sulardi, 2023).

A treatment of ½ compost combined with ¾ doses of N, P, K, and S fertilizers resulted in the highest sulfur availability and uptake, which in turn improved the aroma, color, and yield of shallot bulbs (Sofyan et al., 2023). Another study in Bangalore found that 45 kg S per hectare, combined with recommended fertilizers, resulted in the highest bulb yield (61.96 t ha-1) under drip irrigation (Haris et al., 2021). Furthermore, potassium is a key player in ATP synthesis, which is essential for energy transfer within plant cells. This energy is crucial for various metabolic processes, including those involved in bulb development (Singh et al., 2024).

With these advantages, additional studies should further explore how water hyacinth compost contributes to improving soil N, P, and K levels, nutrient uptake efficiency, and shallot yield. Previous research has primarily focused on the use of water hyacinth compost as a single organic amendment, with limited evaluation of its interaction with synthetic fertilizers under field conditions. This experiment addresses that gap by investigating the combined application of water hyacinth compost and reduced N, P, K, and S fertilizer doses. The findings provide new insight into optimizing nutrient management and enhancing shallot productivity on nutrient-deficient Inceptisols. This study aimed to determine the optimal dose of water hyacinth compost for improving soil chemical properties, nutrient assimilation, and productivity of shallot (*Allium ascalonicum* L.).

MATERIALS AND METHODS

Study Area

This study was conducted experimentally in a greenhouse at the Soil Chemistry and Plant Nutrition Laboratory, Faculty of Agriculture, Universitas Padjadjaran, in Jatinangor District, Sumedang Regency, Indonesia from July to October 2023. The site is located at an altitude of 725 meters above sea level, with an average rainfall of 4.075 mm per month. Soil and plant analyses were performed at the Soil Chemistry and Plant Nutrition Laboratory in the university. The materials used in this experiment were Inceptisols soil from Jatinangor, classified under the subgroup Fluventic Eutrudepts. Based on laboratory analysis results, Inceptisols from Jatinangor have a slightly acidic pH of 6.48; low organic carbon content of 1.25%; a moderate C/N ratio of 13; very low total nitrogen of 0.10%; moderate P2O5 (HCl 25%) of 20.84 $mg.100g^{-1}$; very high K2O (HCl 25%) of 78.42 $mg.100g^{-1}$; and low SO_4^{2-} of 41.42 $mg.kg^{-1}$. The shallot seeds used were of the Batu Ijo variety due to their superior performance in previous local trials, demonstrating higher growth rates and yields compared to other varieties. The fertilizers applied included compost made from water hyacinth, urea containing 46% N, SP-36 containing 36% P_2O_5, KCl containing 60% K_2O, and ZA (ammonium sulfate) containing 21% N and 24% S.

Production of Water Hyacinth Compost

The material used for compost production was 70 kg of water hyacinth (Figure 1) from Jatiluhur Reservoir, Purwakarta, Indonesia. The water hyacinth was first chopped into small pieces measuring 3-5 cm. This aims to increase the surface area for decomposition by the microorganisms added, thereby accelerating the decomposition process of the water hyacinth. The chopped water hyacinth was then treated with Orgadec bio-activator, added to the compost pile at a dose of 350 g, and evenly mixed using a hoe (Sofyan, 2023). Composting was carried out anaerobically to reduce water evaporation and maintain the stability of the compost temperature.

Figure 1. Fresh water hyacinth from Jatiluhur Reservoir, Purwakarta, Indonesia

The maintenance of the compost involves turning and watering to regulate temperature, humidity, and oxygen levels. Turning and watering were performed weekly. Temperature measurements were taken by inserting a thermometer into the compost pile. When the temperature in the compost pile drops to 27°C, the compost is ready to be applied in the field (Remona, 2020). Samples for laboratory analysis were taken at four weeks of composting by collecting compost samples from five points on each side of the compost pile, each about a tablespoon, and then compositing the samples. The samples were subsequently placed in zip-lock bags to avoid contamination. Based on laboratory test, water hyacinth compost contains 16.94% organic carbon (C), 1.25% nitrogen (N), a C/N ratio of 14, 1.31% phosphorus (P), and 0.39% potassium (K), along with a moisture content of 11.66% and a pH of 7.77. The compost used meets the quality standards based on SNI 19-7030-2004.

Experimental Design

The experiment was arranged in a Randomized Complete Block Design (RCBD) consisting of seven treatments with three replications. The treatments included: (A) control (without water hyacinth compost or NPKS fertilizers), (B) ¾ of the recommended N, P, K, and S doses, (C) 1 dose of water hyacinth compost, (D) ¼ dose of water hyacinth compost + ¾ of the N, P, K, and S doses, (E) ½ dose of water hyacinth compost + ¾ of the N, P, K, and S doses, (F) ¾ dose of water hyacinth compost + ¾ of the N, P, K, and S doses, and (G) 1 dose of water hyacinth compost + ¾ of the N, P, K, and S doses. Water hyacinth compost was incorporated into the soil two weeks before transplanting, while mineral fertilizers were applied according to shallot growth stages—half at planting and the remainder at 30 days after planting. Detailed treatment combinations are presented in Table 1.

Variables of Observation and Statistical Analysis

Observations consisted of analysis of pH, total N, P, and K, and the yield component including the number of shoots, the number of bulbs, and the fresh weight of the bulbs. The tested parameters were analyzed according to the technical guidelines for the analysis of fertilizers, water, soil, and plants from Balai Penelitian Tanah (2009). Sampling was conducted when the shallot plants were 42 days after planting (DAP) or had reached

Table 1. Arrangement of water hyacinth compost and N, P, K, S fertilizers treatments on shallot

Treatment		Fertilizer Dose				
		Water hyacinth compost	Urea	SP-36	KCl	ZA
		t.ha^{-1}	kg.ha^{-1}			
A	Control	0	0	0	0	0
B	¾ of the recommended N, P, K, and S doses	0	150	225	150	375
C	1 dose of compost	25.00	0	0	0	0
D	¼ dose of compost + ¾ of the N, P, K, and S doses	6.25	150	225	150	375
E	½ dose of compost + ¾ of the N, P, K, and S doses	12.50	150	225	150	375
F	¾ dose of compost + ¾ of the N, P, K, and S doses	18.75	150	225	150	375
G	1 dose of compost + ¾ of the N, P, K, and S doses	25.00	150	225	200	375

maximum vegetative growth, characterized by the appearance of flowers, with a total weight of 500 g.

Polybag measuring 30 × 30 cm was filled with eight kilograms of soil. Next, water hyacinth compost was mixed into the soil according to the treatment and incubated for two weeks. Planting was carried out by placing one shallot bulb (Batu Ijo variety) in the polybag, with half of the bulb buried in the soil and half above the surface. Before planting, the outer skin of the bulb and any remaining roots were cleaned, and the tip was cut off by approximately ¼. The application of SP-36 and KCl fertilizers was performed at the time of planting, while urea and ZA fertilizers were applied at 7 and 21 DAP.

Plant maintenance included watering in the morning or evening, which was stopped approximately 7–10 days before harvest to allow proper bulb maturation and prevent rot. Weeding was done manually by pulling out the weeds growing around the planting medium by hand. Weeds were collected into a trash bag and disposed of in the waste bin. Plant pests was carried out preventively by applying Furadan before planting. Harvesting was conducted at 67 DAP when the stem bases were soft, 80% of the leaves turned yellow and dried, fully filled bulbs with dark reddish-purple color emerged above the soil surface.

The resultant data were statistically analyzed using analysis of variance (ANOVA) with SPSS version 16.0. When significant differences were detected, mean separation was performed using Duncan's Multiple Range Test (DMRT) at a 5% significance level. Figures presented in this paper are editable to ensure clarity; any nonessential figures not discussed in the text were removed to maintain conciseness.

RESULTS AND DISCUSSION

Soil Chemical Properties

Based on the data in Table 2, water hyacinth compost can enhance the levels of pH, total nitrogen

Table 2. Effects of water hyacinth compost and N, P, K, S fertilizers on soil chemical properties in Inceptisols

Treatment		pH	Total Nitrogen	Available phosphorus	Available potassium
			(%)	(mg kg^{-1})	(cmol kg^{-1})
A	Control	6.97 a	0.10 a	7.21 a	2.09 a
B	¾ of the recommended N, P, K, and S doses	7.29 b	0.24 bc	19.12 b	4.22 b
C	1 dose of compost	7.28 b	0.22 b	20.74 b	4.46 b
D	¼ dose of compost + ¾ of the N, P, K, and S doses	7.21 b	0.26 bc	25.85 c	4.28 b
E	½ dose of compost + ¾ of the N, P, K, and S doses	7.54 c	0.26 bc	24.00 c	4.30 b
F	¾ dose of compost + ¾ of the N, P, K, and S doses	7.41 c	0.29 cd	32.12 d	5.48 c
G	1 dose of compost + ¾ of the N, P, K, and S doses	7.50 c	0.32 d	31.19 d	4.62 b
CV (%)		1.67	2.19	9.15	6.92

Note: Means followed by the same letters in the same column are not significantly different according to Duncan's multiple range test at a 5% significance level. CV = Coefficient of Variation.

(N), available phosphorus (P), and available potassium (K) in Inceptisols. The control treatment showed significantly different results compared to all other test treatments. The treatment with ½ dose of compost + ¾ dose of N, P, K, and S produced a higher pH value of 7.54 compared to other treatments, but did not significantly differ from the treatments with ¾ dose of compost + ¾ dose of N, P, K, and S and 1 dose of compost + ¾ dose of N, P, K, and S. This increase in pH occurs because water hyacinth compost releases organic acids that can bind with H^+ ions, effectively reducing soil acidity and raising pH levels (Jutakanoke et al., 2023).

In the observation of total soil nitrogen, the treatment with ¾ dose of compost + ¾ dose of N, P, K, and S showed significantly different results compared to the control treatment and the treatment with 1 dose of compost. The treatment with 1 dose of compost + ¾ dose of N, P, K, and S yielded total soil nitrogen of 0.32% and did not significantly differ from the treatment with ¾ dose of compost + ¾ dose of N, P, K, and S. The increase in total nitrogen in the soil due to the use of water hyacinth compost can occur for several reasons. First, water hyacinth compost is a rich source of nitrogen, which is released into the soil during the decomposition process. During this process, microorganisms break down organic matter, producing nitrogen in the form of ammonium (NH_4^+) and nitrate (NO_3^-) that can be absorbed by plants (Lewoyehu et al., 2024). Additionally, this compost enhances soil microbial activity, which plays a role in the nitrogen cycle, including nitrogen fixation by bacteria that convert atmospheric nitrogen into usable forms. The stability of nitrogen in the soil is also improved because the organic matter in the compost helps reduce nitrogen loss due to volatilization or leaching (Begum et al., 2022).

According to Table 2, the available phosphorus content showed an increase in value with the application of both compost and synthetic fertilizers. The treatment with ¾ dose of compost + ¾ dose of N, P, K, and S exhibited results that were not significantly different from the treatment with 1 dose of compost + ¾ dose of N, P, K, and S, yielding available phosphorus content of 32.12 mg/kg and 31.19 mg/kg, respectively. This increase is attributed to the phosphorus content, one of the essential nutrients in water hyacinth compost, which contributes to the increase of available P in the soil. Compost derived from nutrient-rich organic materials releases these nutrients into the soil after the decomposition process, making them available for plant absorption (Hardjowigeno, 2010).

In terms of available potassium content, the treatment with ¾ dose of compost + ¾ dose of all the element could directly increase the K_2O levels in the soil. The total potassium content in the studied water hyacinth compost was found to be 1.37%, which can enhance the K_2O content in the soil through decomposition by microorganisms that release potassium as K_2O. The subsequent reduction in extractable K observed in treatment G (1 dose of compost + ¾ dose of N, P, K, and S) may be explained by several interacting mechanisms in the Inceptisols studied. A higher dose of compost may have stimulated microbial activity, leading to temporary immobilization of potassium within organic complexes during the decomposition process (Wolf et al., 2021). Moreover, depending on the clay mineralogy of the Inceptisol, the increased concentration of cations resulting

Table 3. Effects of water hyacinth compost and N, P, K, S fertilizers on nutrient uptake by shallots in Inceptisols

Treatment		Total Nitrogen	Total P_2O_5	Total K_2O
			(mg/plant)	
A	Control	6.86a	6.38a	8.82a
B	¾ of the recommended N, P, K, and S doses	16.49bc	16.14b	9.43a
C	1 dose of compost	15.42b	18.64c	11.02b
D	¼ dose of compost + ¾ of the N, P, K, and S doses	18.63bc	19.66cd	11.36b
E	½ dose of compost + ¾ of the N, P, K, and S doses	21.45cd	19.74cd	14.57c
F	¾ dose of compost + ¾ of the N, P, K, and S doses	21.95cd	22.29e	14.82c
G	1 dose of compost + ¾ of the N, P, K, and S doses	24.94d	21.86de	11.51b
CV (%)		6.91	9.55	3.31

Note: Means followed by the same letters in the same column are not significantly different according to Duncan's multiple range test at a 5% significance level. CV = Coefficient of Variation.

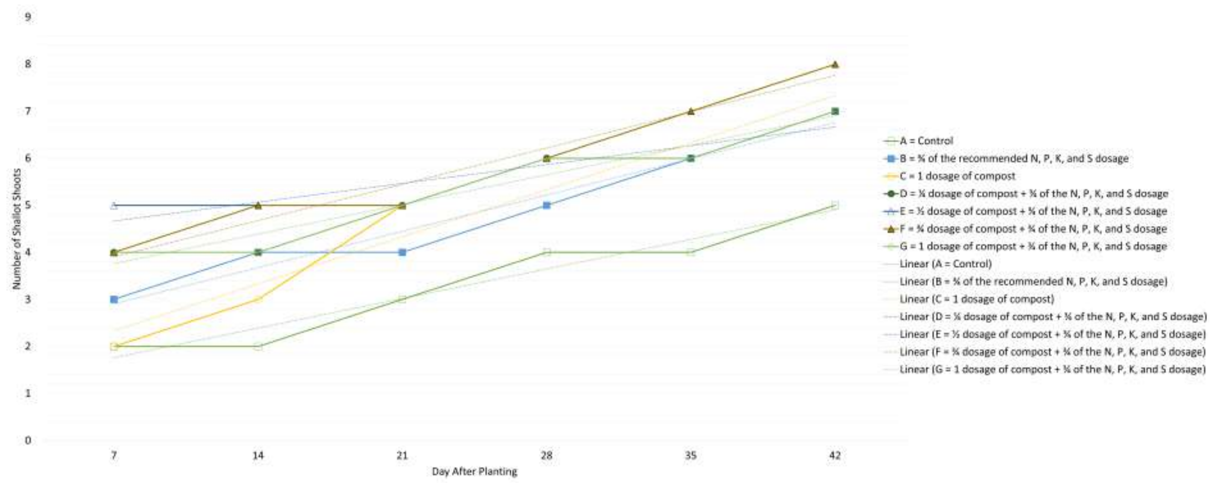

Figure 2. The number of shallot offshoots as affected by the application of water hyacinth compost and N, P, K, S fertilizers

from compost mineralization could have enhanced K fixation or adsorption onto interlayer sites of certain clay minerals, thereby reducing the extractable K measured by standard methods (Annapurna et al., 2016).

Testing the chemical properties of the soil plays a crucial role in determining nutrient availability. Additionally, chemical testing helps monitor changes in soil quality over time, including the impacts of agricultural practices and resource management. According to Begum et al. (2022), organic fertilizers based on water hyacinth demonstrate advantages over manure, as they have a more significant impact on soil properties, particularly in terms of pH value, cation exchange capacity (CEC), and primary nutrients (N, P, and K).

Nutrient Uptake

Pursuant to the data showcased in Table 3, it is perceivable that the confluence of water hyacinth compost and N, P, K, S fertilizers substantially enhanced the assimilation of nitrogen, phosphorus, and potassium by plants compared to the control treatment. Increased nutrient uptake by the plants correlates with the availability of nutrients in the soil (Hardjowigeno, 2010). The control treatment exhibited the lowest nitrogen absorption value, which was 6.86 mg per plant. The treatment with 1 dose of compost + ¾ dose of N, P, K, S fertilizers yielded a significantly different result compared to the control treatment, ¾ dose of recommended N, P, K, S, 1 dose of compost, and ¼ dose of compost + ¾ dose of N, P, K, S fertilizers, with a value of 24.94 mg per plant. This phenomenon can be attributed to the equipoise between organic fertilizers derived from it, which facilitates quicker nutrient availability for the plants. This condition enables nutrients such as nitrogen to be more readily assimilated by the plants.

This salutary change enhances the solubility of various nutrients, especially phosphorus, in the soil. The form of orthophosphate ions may have transmogrified from PO_4^{3-} to HPO_4^{2-} or even $H_2PO_4^-$ (phosphate ions) in a short time, leading to an increase in phosphorus concentration in the plants (Hardjowigeno, 2010). Regarding potassium absorption, the treatment with ¾ dose of compost + ¾ dose of N, P, K, S fertilizers yielded results that were not significantly different from the treatment with ½ dose of compost + ¾ dose of N, P, K, S fertilizers, with values of 14.82 and 14.57 mg per plant, respectively. Result indicates that the synergy of water hyacinth compost and synthetic fertilizers enhance potassium uptake by the plants. Yatoo et al. (2025) reported that compost derived from aquatic plants, including water hyacinth, significantly enhanced soil nutrient status and microbial activity, demonstrating its potential as an eco-friendly soil amendment. Similarly, Kelbesa (2021) found that the application of organic composts in tropical soils increased the availability of nitrogen, phosphorus, and potassium, leading to higher vegetable crop yields.

Shallot Yield Results

Pursuant to the data showcased in Figure 2, it is discernible that shallots subjected to 1 dose of compost

Table 4. Effects of water hyacinth compost and N, P, K, S fertilizers on the number of bulbs and fresh weight of shallots on Inceptisols

	Treatment	Number of Bulbs		Fresh Weight of Shallots (g)	
A	Control	5	a	92.89	a
B	¾ of the recommended N, P, K, and S doses	7	b	107.27	b
C	1 dose of compost	7	b	98.09	a
D	¼ dose of compost + ¾ of the N, P, K, and S doses	8	bc	115.14	c
E	½ dose of compost + ¾ of the N, P, K, and S doses	8	bc	121.93	cd
F	¾ dose of compost + ¾ of the N, P, K, and S doses	8	bc	124.82	de
G	1 dose of compost + ¾ of the N, P, K, and S doses	9	c	132.26	e
	CV (%)	8.82		3	

Note: Means followed by the same letters in the same column are not significantly different according to Duncan's multiple range test at a 5% significance level. CV = Coefficient of Variation.

+ ¾ dose of N, P, K, S and ¾ dose of compost + ¾ dose of N, P, K, S engendered 8 offshoots at 42 days subsequent to planting. Conversely, the control treatment resulted in the lowest number of offshoots, with merely 4. The quantity of offshoots is influenced by nitrogen availability, as nitrogen plays a pivotal role in the rate of photosynthesis and enhances protein synthesis, which is essential for cell formation and optimizing vegetative growth (Begum et al., 2022). The number of offshoots directly impacts the quantity of shallot bulbs produced. An increase in the number of offshoots leads to a higher bulb yield. Nutrient availability plays a vital role in affecting the number of offshoots in plants. The addition of N, P, K, S fertilizers and water hyacinth compost contributes to higher plant yields, increasing the number of offshoots, fresh weight, dry weight, and the weight of shallot plant shoots compared to treatments without fertilization (Suwandi et al., 2016; Supadma et al., 2020).

According to Table 4, the control treatment (without the application of water hyacinth compost nor N, P, K, S fertilizers) had the lowest average number of bulbs, which was 5. This occurs because the nutrient requirements of the plants were not met, hindering their growth and development. The treatment with 1 dose of compost + ¾ dose of N, P, K, S produced a higher average number of bulbs, reaching 9; however, this was not significantly different from the treatments of ¼ dose of compost + ¾ dose of N, P, K, S, ½ dose of compost + ¾ dose of N, P, K, S, and ¾ dose of compost + ¾ dose of N, P, K, S. The treatment using only ¾ of the recommended N, P, K, S dose resulted in an average number of bulbs of 7, which was significantly different from the control treatment and the treatment with 1 dose of compost + ¾ dose.

The application of water hyacinth compost can provide a balanced nutrient profile in the soil. Providing balanced sulfur will improve onion bulb harvests (Shiferaw et al., 2015). However, excessive sulfur application can hinder the growth of shallot plants, leading to reduced yields. In addition, the application of water hyacinth compost significantly affects the

Figure 3. a) Shallot plants one week after planting; b) Shallot plants five weeks after planting

fresh weight of bulbs compared to using N, P, K, S fertilizers only.

The treatment with 1 dose of compost + ¾ dose of N, P, K, S yielded a higher fresh bulb weight of 132.26 g, but did not show a significant difference from the treatment of ¾ dose of compost + ¾ dose of N, P, K, S, which produced 124.82 g. This aligns with the findings of Lasmini et al. (2024), which showed that the use of both organic and synthetic fertilizers can improve shallot yield, shallot bulb quality, soil quality, and the efficiency of synthetic fertilization.

Figure 3 illustrates the growth condition of shallot plants at one and five weeks after planting. High shallot yields are influenced by the availability of essential nutrients N, P, K, and S, whose roles cannot be replaced by other nutrients. Nitrogen plays a crucial role in chlorophyll formation, photosynthetic rate, and protein synthesis for cell development. Nitrogen optimizes vegetative growth and the photosynthesis process in shallot plants, thereby promoting both the quantity and the fresh and dry weight of the bulbs (Supriyatna et al., 2016). Phosphorus also plays a role in photosynthesis, particularly in chlorophyll formation and energy transport from metabolism, which can stimulate bulb growth. Additionally, potassium is a key player in ATP synthesis, which is essential for energy transfer within plant cells. This energy is crucial for various metabolic processes, including those involved in bulb development (Singh et al., 2024). A positive relationship was observed between soil nutrient availability (N, P, K) and nutrient uptake by shallot plants, which was reflected in the corresponding increase in bulb yield. This indicates that improvements in soil fertility directly enhance plant performance.

CONCLUSIONS

Compost derived from water hyacinth exhibited considerable promise in ameliorating the edaphic attributes, nutrient assimilation, and productivity of shallot cultivars cultivated in Inceptisol soil. The concomitant application of water hyacinth compost and ¾ of the recommended N, P, K, and S fertilizer doses improved plant growth and yield compared to synthetic fertilizers alone. The treatment combining ¾ compost (18.75 t ha^{-1}) with ¾ of the recommended N, P, K, and S fertilizer doses (150 kg ha^{-1}; 225 kg ha^{-1}; 150 kg ha^{-1}; and 375 kg ha^{-1}, respectively) resulted in the most significant enhancement in soil chemical properties, nutrient uptake, and shallot yield in Inceptisols. This approach underscores the potential of utilizing water hyacinth, an abundant aquatic macrophyte, as an eco-friendly compost material to support sustainable agriculture on soils with low fertility, such as Inceptisols.

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