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Research Paper

Agronomic Characteristics, Physiology, and Antioxidant Activity of Shallots (*Allium ascalonicum L.*) in Response to Application of Chicken Manure and ZA Fertilizer in Floating Cultivation

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Abstract

Floating cultivation is an innovative techniques that enables optimal plant growth on flooded land. This system is particularly suitable for shallot plants, which are susceptible to waterlogging, as it can prevent root asphyxiation, improve aeration, and optimize yields in flood-prone areas. This study aimed to examine the effect of chicken manure and ZA fertilizer on the agronomic characteristics, physiological responses, and antioxidant activity of shallots (*Allium ascalonicum L.*) grown using a floating cultivation system. The research was conducted from July to September 2024 in the Kertapati District, Palembang, South Sumatra. A Factorial Randomized Block Design (FRBD) was used, with two factors : chicken manure (0, 1, 2, and 3 kg/plant) and ZA fertilizer (0, 2.00, 5.00, and 7.00 g/plant). Observed parameters included leaf length, number of leaves, number of tillers, wet stover weight, wind-dried tuber weight, fresh tuber weight, tuber diameter, chlorophyll content, and flavonoid content. The results showed that the application of 2 kg chicken manure and 5.00 g/plant of ZA fertilizer significantly improved leaf length, number of leaves, tiller formation, tuber yield, biomass production, and flavonoid content. Additionally, chicken manure enhanced soil fertility and nutrient uptake, while ZA fertilizer supported chlorophyll synthesis and antioxidant activity. In the floating cultivation system, the combination of these two treatments produced synergistic effects that optimized shallot growth and quality.

Keywords

Chicken Manure; ZA Fertilizer; Shallot; Floating Cultivation

1. INTRODUCTION

Shallots (*Allium ascalonium L.*) are an essential horticulture crop commonly used as a staple culinary ingredient (Susilawati et al., 2023b). Known for their distinctive aroma, shallot are widely used as a kitchen spice due to their content of alliin compounds (S-Allyl Cysteine) found in the tubers (Juwanda et al., 2023). According to Hartoyo (2020) shallots are unique herbal plants with medicinal value, containing natural compounds and nutrients that benefit human health. Various active chemical compounds in shallots, such as sulfur compounds, contribute to pharmacological effects that support wellness. These include alliin, allicin, flavonoids, polyphenols, adenosine, diallyl disulfide, diallyl trisulfide, ajoene, prostaglandin A-1, diallyl sulfide, floroglusinol, kaemferol, cycloaliin, and diphenylamine (Aryanta, 2019). Flavonoids, such as quercetin, anthocyanins, and kaempferol, act as antioxidant (Yovita et al., 2021), with pharmacological benefits for conditions such as cataracts, cardiovascular diseases, and cancer (Arora et al., 2017), Prabowo and Noer (2020) also noted that flavonoids contribute to plant regulation, photosynthesis, and have antimicrobial and antiviral properties. The antibacterial properties of onion flavonoids are attributed to protein denaturation and bacterial cell membrane lysis (Edy et al., 2022).

Shallot consumption in Indonesia fluctuates but has shows an increasing trend annually due to rising public demand and the growth of the food industry (Sulistiowati et al., 2021). According to data from the Central Bureau of Statistics of South Sumatra Province (2023), shallot production in the region has fluctuations-dropping from 1,390 tons in 2019 to 934 tons in 2020, then increasing again to 1,125 tons in 2021. Hendarto et al. (2024) reported that shallot production remains insufficient to meet the growing demand, which increases by approximately 5% each year. One strategy to ensure consistent supply is the utilization of underused swamp land for cultivation. South Sumatra has significant potential for shallot development on swamp land (Irwandi, 2015). Swamp land is defined as land that is periodically or permanently flooded due to rainfall or river overflow (Siaga and Lakitan, 2021), According to Syafrullah (2014) floating cultivation in swamp makes use of natural or artificial waterlogging, while artificial pond systems offer controlled environments with better regulation of water and nutrients. These systems provide advantages such as water stability, enhanced pest and disease management, and potentially higher yieds. Improvement of shallot varieties is key increasing productivity, considering phenotypic diversity, such as tuber size, color, and environmental adaptability (Irawan et al., 2021). The Bauji variety from Nganjuk, a local Indonesian variety, is known for its pests and diseases resistance, high productivity, and short flowering period (Siswadi et al., 2020). Ideal shallots should possesss traits such as disease resistance, appropriate plant height, balanced tillers numbers, short growth duration, large tuber size, dark red color, and round shape (Marlin et al., 2021). Research by Susilawati et al. (2023a) found that the Bauji variety exhibits strong correlation between tuber diameter length, weight, and volume.

In addition to appropriate cultivation techniques, productivity is also influenced by mineral and nutrient availability. One effective approach is the application of sulfur, which is essential in metabolic processes, amino acid and protein synthesis, and improving nutritional quality (Hasanah et al., 2021a). Sulfur can be supplied through fertilizers such as ZA (Ammonium sulfate), which increase sulfate levels in the soil (Sakhidin et al., 2022). Sulfur also plays a role in chlorophyll formation, which supports photosynthesis in shallots, promoting better growth and increasing yield (Mustikawati et al., 2020). A lack of sulfur can inhibit plant growth and cause leaf chlorosis. ZA fertilizer contains sulfur, calcium, and magnesium, and is highly soluble and readily absorbed by plants (Mawardiana et al., 2021). The application of 400 $kg\,ha^{-1}$ ZA fertilizer has been shown to affect various growth aspects, including plant height, number of leaves, tubers per clump, and tuber weight-ultimately increasing yield (Saptorini et al., 2019). Manure application enhances microbial activity, adds nutrients and humus, and improves soil cation exchange capacity. Chicken manure, in paticular is rich in nitrogen, phosphorus, and potassium, with a C/N ratio of 8.3 (Susikawati et al., 2018). However, the moist growing media in floating cultivation may inhibit oxygen diffusion to the roots and impair physiological processes. Therefore, combining chicken manure with ZA fertilizer is expected to enhance nutrient uptake and crop productivity (Susilawati et al., 2022). Chicken manure helps balance soil nutrients often lower in chemical fertilizers (Asri et al., 2019). Application of 2 kg chicken manure per plant significant increases plant height, number of shoots, and fresh weight (Baka et al., 2020). The study aims to evaluate the effect of sulfur and chicken manure on agronomic traits, physiology, and flavonoid content of the Bauji shallot variety. Understanding the relationship between antioxidant activity and plant physiology is vital, as it offers insights into plant health, growth potential, and stress tolerance. This knowledge supports the optimization of cultivation practices, enhances nutritional value and improves crop resilience-especially in the face of increasing environmental challenges.

2. RESEARCH METHODOLOGY

2.1 Place and Time

This research was conducted in June 2024, located in Kemasrindo Village, Kertapati District, Palembang, South Sumatra Province.

2.2 Tools anda Materials

The Tools used in this study include: a 250 mL measuring cup, vernier digital, filter paper, planting pond, memmert UN 55 I oven, 30 x 30 cm polybag, floating raft made from bottles, UV-Vis spetrophotometer, and analytical balance.

The materials used included: ethanol, pesticides, chicken manure, ZA fertilizer, SP-36 fertilizer, KCl, NPK (16:16:16), soil, Bauji variety Shallot, and Trichoderma sp.

2.3 Research Methods

This studt used a Factorial Randomized Block Design (FRBD) with two factors and three replications. Each replication consisted of 3 plants, totaling 144 treatment units. The treatments were:
Factor 1 : Chicken Manure (A),which are A0 = 0 kg/plant (Control), A1 = 1 kg/plant, A2 = 2 kg/plant, A3 = 3 kg/plant and Factor 2: ZA Fertilizer (Z), which are Z0 = 0 g/plant (Control), Z1 = 2.00 g/plant (equivalent to 200 kg/ha), Z2 = 5.00 g/plant (equivalent to 400 kg/ha), Z3 = 7.00 g/plant (equivalent to 600 kg/ha).

The collected data were analyzed using analysis of variance (ANOVA) with orthogonal polynomial regression in R studio and Microsoft Excel. Further analysis was performed using Tukey's Honestly Significant Difference (HSD) test.

2.4 Floating Raft Contruction

The raft was contructed using 128 mineral water bottles (1.5 L each). Buoyancy calculating were based on Archimedes' principke: Bottle Volume × Water Density × Gravity > Mass × Gravity (Idly et al., 2024). The bottles were tied together with string and assembled on a PVC frame measuring 2.5 m x 1.5 m. Before planting, shallot tubers are planted by cutting first about 1/3 part, this is done to accelerate the growth of shoots and stimulate the growth of side tubers. Next, the shallot tubers were soaked in a solution of fungicide made from Mancozeb 80% at a dose of 3 $g\,L^{-1}$ water for 5 minutes. Planting is done by inserting the shallot tuber into the planting hole with a movement like turning a screw, so that the tip of the seed tuber appears flat with the soil surface (Nazirah and Maulana, 2020).

2.5 Observed Parameters

Parameters observed included : leaf length, number of leaves, number of tillers, wet stover weight, wind-dried tuber weight, fresh tuber weight, tuber diameter, Chlorophyll Content, Flavonoid content.

Chlorophyll Content Chlorophyll content was analyzed in the physiology laboratory. Using the Wintermans and De Mots method. About 0.25 g of shallot leaves was ground with mortar and extracted with absolute ethanol to a volume of 1.5 mL. The extract was mixed using a vortex mixer and incubated at 4°C in the dark for 30 minutes. The supernatant was transferred to a 5mL cuvette, and absorbance was measured at wavelengths of nm 649 nm and 665 nm using a UV-Vis. spectrophotometer. Ethanol (96%) was used as a blank. The formulas used were Wintermans and De Mots (1965) calculation in Pratama and Laily (2015)

Chlorophyll a = (13.7 x A665) - (5.76 x A649)
Chlorophyll b = (25.8 x A649) - (7.60 x A665)
Total Chlorophyll = Chlorophyll a + Chlorophyll b.

Flavonoid Content Total flavonoid content was measured using the method described by Amelia et al. (2023), using quercetin as a standard. Standard solution were prepared at concentrations of 10, 20, 30, 40 and 50 ppm. A Thick extract of 60 mg was diluted with 96% ethanol to a final volume of 10 mL. A 500 µL aliquot was mixed with 1.5 mL ethanol p.a, 0.1 mL of 10% AlCl3, 0.1 mL of 1 M sodium acetate, and 2.8 mL of distilled water. The solution was allowed to stand for 30 minutes, and absorbance was measured using a UV-Vis Spectrophotometer at 435 nm. The test was performed in triplicate.

3. RESULTS AND DISCUSSION

3.1 Leaf length (cm)

The results of the analysis of variance showed that chicken manure had a highly significant effect at each week of observation, while ZA fertilizer had a significant affect on leaf length at 5 and 6 weeks after planting (WAP). The longest leaf lengths were observed with the application of 2k g chicken manure (36.16 cm average) and 5.00 gr/plant of ZA fertilizer (32.68 cm avarage) (Table 1).

The application of chicken manure and ZA fertilizer-significantly influenced shallot leaf length in the floating cultivation system. As shown in Table 1, the 2 kg chicken manure treatment (A2) resulted in the greatest leaf length, particularly at 5-7 WAP, with values of 35.83 cm, 36.07 cm, and 36.16 cm, respectively. This suggests that the 2 kg dose provided optimal nutrient availability for leaf development. These findings are in line with (Nadiah et al., 2024), who reported that the nitrogen, phosphorus, and potassium contents in chicken manure plays a vital role in vegetative growth, including leaf elongation. In contrast, the 3 kg chicken manure (A3) resulted in shorter leaf length, likely due to nutrient excess, which may have inhibited nutrient absorption. Regarding f ZA fertilizer, the 5.00 g/plant dose (ZA) yielded the longest leaves at 5 WAP (31.56 cm) and 6 WAP. (32.68). Agustine et al. (2021) noted that ZA fertilizer contains nitrogen and sulfur, which are crucial for protein synthesis, enzymes activity, and chlorophyll production-all essential for photosynthesis and leaf growth. After 6 WAP, leaf length began to decrease in most treatments, indicating the transition from the vegetative to the generative phase, where energy and photosynthates are redirected toward tuber formation rather than leaf development. This decline was especially evident in the A2 treatment, where the leaf length drecreased from 36.16 cm at 7 WAP to 31.02 cm at 8 WAP. Similarly, in the Z2 treatment, leaf length dropped from 31.13 to 27.45 cm (Souminar and Fajriani, 2018), resported that during the generative phase (35-50 day after planting), shallot plants allocate more resources tuber formation than vegetative growth. This stage is also characterized by increased senescence of older leaves. The interaction between chicken manure and ZA fertilizer emphasizes the importance of combining organic and inorganic nutrient sources. Chicken manure provides a gradual release of nutrients, while ZA fertilizer supplies readily available nitrogen and sulfur. Together, they create a synergistic effect that enhances vegetative growth prior to the generative phase.

3.2 Number of Leaves (strands)

The number of leaves in shallot plants treated with chicken manure was significantly affected at every observation week. Meanwhile, the ZA fertilizer treatment had a highly significant effect at 2 WAP, a significant effect at 3-4 and 6-7 WAP. The highest number of leaves was observed in the treatment with 2kg of chicken manure, with an average of 23.88 leaves, and 5.00 gr/plant of ZA fertilizer, with an average of 21.11 leaves (Table 2).

Chicken manure, particularly at 2 kg/plant dose, led to the highest number of leaves. This is attributed to the macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as micronutrients needed for vegetative growth. Nitrogen, as a key component of chlorophyll and proteins, plays a critical role in increasing leaf number. In addition, manure improve soil structure, enhance water-holding capacity, and gradually releases nutrients that support consistent plant development (Harbing et al., 2022). The 5.00 g/plant ZA fertilizer dose also significantly increased leaf number, average 21.11 leaves per plant. Sulfur, a secondary nutrient contained in ZA, contributes to the synthesis of sulfur-containing amino acids such as cysteine and methionine, which are essential for protein production and tissue development . Sulfur also supports chloroplast formation, increasing photosynthetic activity (Hasanah et al., 2021b). The significant effect of ZA fertilizer was observed at 2 WAP and continued to have a strong influence at 3-4 and 6-7 WAP, indicating its importance during early to mid-stages of vegetative growth. The combination of chicken manure and sulfur-based fertilizer created a synergistic effect, enhancing leaf development. Sulfur also functions in the photosynthesis process and the

Table 1. Average leaf length of shallot plants aged 2 - 8 weeks after planting in the treatment of chicken manure and fertilizer ZA

Treatment	Leaf length (cm)						
	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
A0 (0 kg/plant)	12.33 bc	18.82 bc	25.19 b	31.58 a	33.08 a	28.91 c	27.53 a
A1 (1 kg/plant)	15.14 ab	21.64 b	30.12 a	31.64 a	34.21 a	33.05 b	28.55 a
A2 (2 kg/plant)	17.40 a	25.84 a	32.82 a	35.83 a	36.07 a	36.16 a	31.02 a
A3 (3 kg/plant)	11.72 c	15.72 c	18.05 c	19.71 b	20.90 b	22.25 d	18.29 b
Z0 (0 g/plant)	12.67 a	19.24 a	25.00 a	29.04 ab	32.02 a	29.41 a	25.15 a
Z1 (2.00 g/plant)	14.22 a	20.65 a	27.89 a	31.46 a	32.14 a	30.97 a	27.32 a
Z2 (5.00 g/plant)	15.11 a	21.26 a	27.47 a	31.56 a	32.68 a	31.13 a	27.45 a
Z3 (7.00 g/plant)	14.59 a	20.87 a	25.84 a	26.71 ab	27.42 a	28.50 a	25.47 a

Description: Numbers followed by different letters in the same column are significantly different based on the 5% HSD test.

electron transport system, and contributes to the formation of ceonzymes and prosthetic groups such as ferredoxin (Abadie and Tcherkez, 2019). Agustin et al. (2020) emphasized the importance of balanced fertilization during the vegetative phase to support optimal plant development. Overall, the increase in leaf number was closely associated with the availability and efficiency of nutrient uptake, which is vital for optimizing physiological processes in shallot plants.

3.3 Number of Tillers (clumps)

The number of tillers in shallots plants treated with chicken manure showed a highly significant effect at every week of observation. ZA fertilizer significantly affected the number of tillers at 4, 6 and 7 weeks after planting (WAP). The application of 2 kg chicken manure (average: 4.99 tillers) and 5.00 g/plant ZA fertilizer (average: 4.59 tillers) resulted in highest number of tillers compared to other treatments (Table 3).

The 2 kg chicken manure treatment produced the highest tillers count due to its rich nitrogen (N), phosphorus (P), and potassium (K), which support vegetative growth and stimulate the emergence of new shoots. Additionally, chicken manure enhanced soil fertility by improving structure, water-holding capacity, and gradual nutrient release, thus facilitating tiller development (Amelia et al., 2023). ZA Fertilizer at a dose of 5.00 g/plant influenced tiller formation at 4, 6, and 7 WAP, with an average of 4.59 tillers per plant. The sulfur in ZA fertilizer promotes protein synthesis and the production of growth hormones such as auxin, which are important for cell division and tiller initiation (Idly et al., 2024). Sulfur also increases photosynthetic efficiency by supporting chloroplast formation. The combination application of chicken manure and ZA fertilizer provided the best results for tiller production. Chicken manure supplies essential macronutrients that support basic vegetative growth, while ZA fertilizer fulfills metabolic needs, particularly during the tillering stage. Sulfur plays a role in enhancing the availability of other nutrients and contributes to nitrogen fixation processes and environmental stress-especially under conditions of limited water availability (Chan et al., 2019). According to Triadiawarman et al. (2022) the number of tillers is strongly influenced by the dose and composition of fertilizer. Proper nutrient management stimulates the formation of new tillers, while over- or under- fertilization man inhibit their growth.

3.4 Wet Stover Weight (g)

The application of chicken manure and ZA fertilizer in floating shallot cultivation significantly ($P<0.001$) affected wet stover weight. The 2 kg chicken manure treatment results in the highest average weigh (46.84 g), which was significantly different from other treatments. The lowest weight was observed in the 3kg chicken manure treatment (20.15 g). Similarly, the 5.00 g/plant ZA fertilizer treatment produced the highest wer stover weight (38.18 g), while the control (no ZA fertilizer) yielded the lowest (28.99 g).

The regression analysis showed that chicken manure application had a strong predictive relationship with wet stover weight (R^2: 0.9241). The resulting quadratic equation was: $y = -10.212x^2 + 29.637x + 24.464$, with an estimated optimum dose 1.45 kg of chicken manure yielding 45.9 g of wet stover. Likewise, ZA fertilizer application showed a high predictive correction (R^2: 0.9773), with the quadratic equation: $y = -0.7936x^2 + 5.7145x + 28.653$, and an estimated optimum dose of 3.60 g producing 38.9 g of wet stover. The increase in wet stover weight with 2 kg chicken manure can be attributed to the high levels of nitrogen (N), phosphorus (P), and potassium (K) , which support vigorous vegetative growth, root development, improved soil structure.

Table 2. Average number of leaves of shallot plants aged 2 - 8 weeks after planting in the treatment of chicken manure and fertilizer ZA

Treatment	Number of Leaves (strands)						
	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
A0 (0 kg/plant)	7.11 b	9.92 b	16.83 b	17.91 b	17.38 b	15.52 a	14.11 b
A1 (1 kg/plant)	8.11 a	11.94 a	20.88 a	19.13 b	21.63 a	16.58 a	15.61 ab
A2 (2 kg/plant)	8.81 a	12.82 a	21.59 a	22.83 a	23.88 a	17.75 a	17.75 a
A3 (3 kg/plant)	6.77 b	8.18 c	11.05 c	10.94 c	14.41 b	11.47 b	10.86 c
Z0 (0 g/plant)	7.08 b	9.91 b	16.16 b	15.97 a	17.61 b	14.77 ab	14.69 a
Z1 (2.00 g/plant)	7.97 a	11.12 ab	17.85 ab	18.25 a	19.97 ab	15.88 ab	15.16 a
Z2 (5.00 g/plant)	8.04 a	11.31 a	18.77 a	19.00 a	21.11 a	16.86 a	15.50 a
Z3 (7.00 g/plant)	7.71 ab	10.51 ab	17.57 ab	17.61 a	18.63 ab	13.80 b	12.97 a

Description: Numbers followed by different letters in the same column are significantly different based on the 5% HSD test.

These factors increase water and nutrient retention capacity, resulting in enhanced plant biomass (Riono, 2019). However, the 3 kg dose showed a decrease in wet stover weight, likely due to nutrient excess or imbalance that may have led to toxicity, inhibiting plant growth. For ZA fertilizer 5.00 g/plant dose significantly improved wet stover production. Sulfur enhanced amino acid and protein synthesis and activities enzymes essential for metabolic processes. Furthermore, sulfur contributes to the formation of volatile compounds responsible for shallot aroma. Charoenchai et al. (2018) demonstrated that sulfur facilitates the synthesis of key amino acids, promotes tuber development, and contributes to characteristic aroma compounds through sulfoxide formation. This finding was also supported (Idly et al., 2024).

3.5 Fresh Tuber Weight (g) and Wind-Dried Tuber Weight (g)

The application of chicken manure and ZA fertilizer in floating shallot cultivation had a significant effect ($P < 0.001$) on both fresh tuber weight and wind-dried tuber weight. The 2 kg chicken manure treatment produced the highest fresh tuber weight (39.49 g), while the 3 kg dose resulted in the lowest (18.85 g). Similarly, the 5.00 gr/plant ZA fertilizer treatment yielded the highest fresh tuber weight (30.49 g), whereas the control (0 g/plant) produced the lowest (21.42 g). For wind-dried tubers weight, the 2 kg chicken manure treatment again resulted in the highest yield (33.72 g), and the 3 kg treatment the lowest (15.38 g). The highest wind-dried tuber weight from ZA fertilizer application was observed at 5.00 gr/plant (23.57 g), with the at the control (16.27 g) (Figure 2).

Chicken manure plays a critical role in supplying essential macronutrients-particularly nitrogen (N), phosphorus (P), and potassium (K), in balanced amounts, which support metabolic processes and stimulate tuber formation. Favorable environmental conditions, including high temperatures at the study site (average 29.89°C-30.35°C), also contributed optimal shallot growth, as shallots prefer lowland areas with sunny climates. nitrogen increases biomass and accelerates carbohydrate accumulation, which contributes to increase tuber weight (Susikawati et al., 2018). Sulfur is an essential element absorbed in large quantities from the vegetative to flowering stages, with the highest accumulation occurring in young leaves before being transported in the form of sucrose to the tuber (Mustikawati et al., 2020). During this process, sulfur absorbed as sulfate (SO4-2) is converted into the amino acids cysteine and methionine, which are vital for enzyme synthesis and the formation of lignin and pectin that support cell wall integrity and elasticity. Sulfur is also a key component of ferredoxin, an Fe and S compound that plays an essential role in carbohydrate metabolism within chloroplasts, thus supporting photosynthate production and distribution (Slameto, 2023). According to Mawardiana et al. (2021), sulfur requiremey in plants are almost equal to phosphorus, due to its role in protein formation nitrate reduction. A deficiency in sulfur can inhibit photosynthesis by damaging Photosystem II (PSII), negatively affects growth and development (Riffat et al., 2020). Optimal sulfur availability is crucial during the generative phase, and proper fertilizer management is essential for maximizing (Slameto, 2023). The results indicate that moderate doses (2 kg chicken manure and 5.00 g/plant ZA fertilizer) were most effective, as higher doses tended to reduce tuber yield likely due to over fertilization and nutrient imbalance (Nadiah et al., 2024). The improvements in wind-dried tuber weight with sulfur application may be attributed to enhanced root growth and chlorophyll formation, leading to more efficient photosynthesis. Sul-

Table 3. Average number of tillers of shallot plants aged 2 - 8 weeks after planting in the treatment of chicken manure and fertilizer ZA

Treatment	Number of Leaves (strands)						
	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
A0 (0 kg/plant)	2.61 a	2.86 a	3.44 b	3.81 b	4.36 a	4.36 a	4.53 a
A1 (1 kg/plant)	2.81 a	2.88 a	3.50 ab	3.83 ab	4.44 a	4.45 a	4.72 a
A2 (2 kg/plant)	2.86 a	3.08 a	4.02 a	4.56 a	4.58 a	4.58 a	4.99 a
A3 (3 kg/plant)	2.31 b	2.47 b	2.80 c	3.03 c	3.05 b	3.06 b	3.33 b
Z0 (0 g/plant)	2.61 a	2.69 a	3.47 ab	3.75 a	4.05 ab	4.05 ab	4.47 a
Z1 (2.00 g/plant)	2.64 a	2.86 a	3.50 ab	3.86 a	4.28 ab	4.28 ab	4.58 a
Z2 (5.00 g/plant)	2.69 a	2.93 a	3.69 a	3.94 a	4.45 a	4.45 a	4.59 a
Z3 (7.00 g/plant)	2.64 a	2.80 a	3.11 b	3.69 a	3.67 b	3.67 b	3.95 a

Description: Numbers followed by different letters in the same column are significantly different based on the 5% HSD test.

fur supports the synthesis of coenzyme A and amino acids necessary for protein and disulfide bond formation, which are linked to tuber diameter and weight increases (Lacerda et al., 2022). According to (Li et al., 2020) the relationship between sulfur and phosphorus metabolism in plants is also important. under phosphorus deficiency, plants synthesize sulfolipids to replace phospholipids, and vice versa, indicating the significance of sulfur in maintaining metabolic balance and productivity. conditions.

3.6 Tuber Diameter (mm)

The application of chicken manure and ZA fertilizer in floating shallot cultivation had a significant effect (P<0.001) on tuber diameter. The 2 kg chicken manure treatment resulted in the highest average tuber diameter (2.99 mm/plant), significantly different from other treatments. The lowest average was found in the treatment of 3 kg chicken manure treatment (1.84 mm/plant). Similarly, the 5.00 g/plant ZA fertilizer treatment produced the largest tuber diameter (2.58 mm m/plant), while the control (no ZA fertilizer) resulted in smallest (2.39 mm/plant).

The regression analysis showed a strong relationship between chicken manure application and tuber diameter (R^2: 0.8369), with the following quadratic equation : $y = -0.3509x^2 + 0.9106x + 2.3456$, yielding an estimated optimal dose of 1.29 kg for a predicted diameter of 2.54 cm. ZA fertilizer application also showed a strong predictive relationship (R^2: 0.9712), with the equation: $y = -0.012x^2 + 0.0952x + 2.385$, with an estimated optimum dose of 3.96 g and a predicted diameter of 2.57 cm. The significant increase in tuber diameter from the application of 2 kg chicken manure and 5.00 g/plant ZA fertilizer suggests that moderate doses optimal nutrient balance to support tuber development. In contrast, excessive doses such as 3 kg of chicken manure or 7.00 g/plant of ZA fertilizer led to reduce growth likely due to nutrient toxicity or interference with nutrient uptake. Optimizing fertilizer dosage crucial for improving productivity without negatively affecting plant physiology or the environment (Nadiah et al., 2024). According to Setiawati et al. (2024), the presence of organic matter in the soil can reduce the bulk density and form more stable soil aggregates, improving porosity and aeration, which supports better root development. Sejati et al. (2017) also reported that manure application improves shallot tuber quality, resulting in larger tuber and clove sizes. More efficient sulfur use contributes to increased tuber diameter (Salim et al., 2023). As an essential nutrient, sulfur plays a vital role in protoplasm formation and supports the photosynthesis process (Abadie and Tcherkez, 2019). During the generative phase, increased photosynthetic activity is focused on tuber development and filling (Mustikawati et al., 2020). Moreover , sulfur influences various plant quality traits , including vegetative and generative growth, chemical composition, and plant mechanisms (Skwierawska et al., 2016).

3.7 Chlorophyll Analysis ($\mathrm{mg\,L^{-1}}$)

The application of chicken manure and ZA fertilizer in floating shallot cultivation significant effected (P<0.001). The 2 kg chicken manure treatment yielded the highest chlorophyll content (11.97 $\mathrm{mg\,L^{-1}}$), while the lowest was observed in the control (no manure, 9.99 $\mathrm{mg\,L^{-1}}$). Similarly, the 5.00 g/plant ZA fertilizertm treatment resulted in the highest chlorophyll level (12.82 $\mathrm{mg\,L^{-1}}$),and the lowest was found in the control without ZA fertilizer (8.95 $\mathrm{mg\,L^{-1}}$).

Regression analysis showed that chicken manure application had a very strong predictable relationship with chlorophyll content (R^2: 0.9979), resulting in the following quadratic equation: $y = -0.3303x^2 + 1.6676x + 10.01$, with the estimated optimal dose at 2.52 kg yielded 12.11 $\mathrm{mg\,L^{-1}}$ chlorophyll. ZA fertilizer also demonstrated a very strong

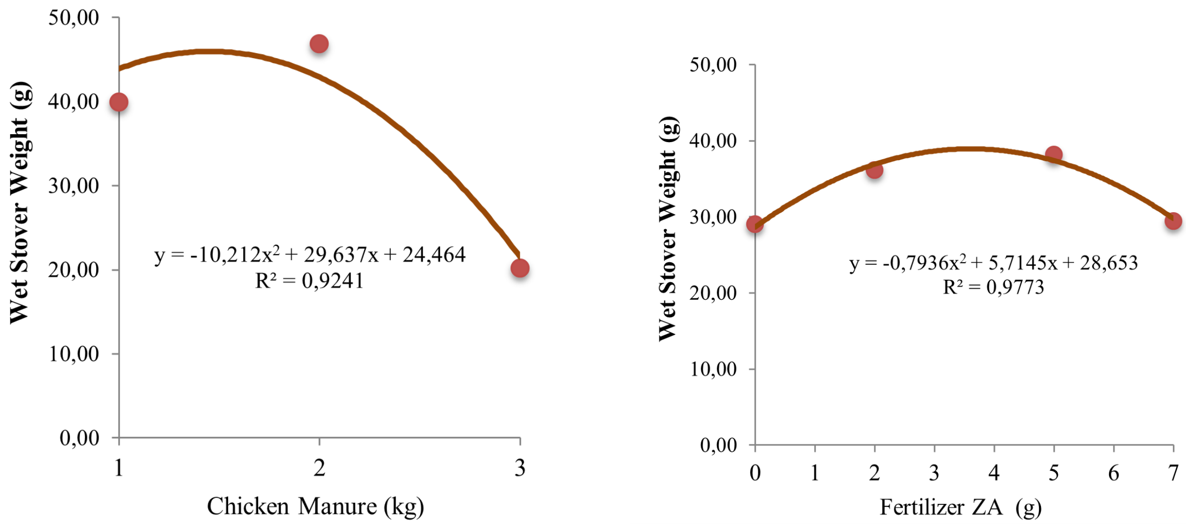

Figure 1. Results of orthogonal polynomial regression test of wet stover weight as influenced by chicken manure (A) and fertilizer ZA (B).

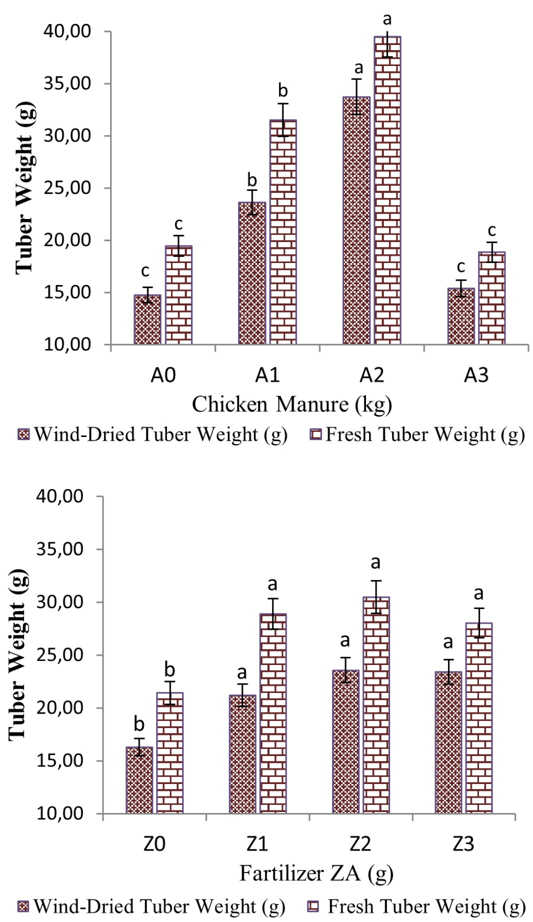

Figure 2. Results of orthogonal polynomial regression test of wind-dried tuber weight and fresh tuber weight as influenced by chicken manure (A) and fertilizer ZA (B).

relationship (R^2: 0.9996), with the equation: $y = -0.1355x^2 + 1.4478x + 8.9304$, giving an estimated optimum dose of 5.34 g and 12.79 mg L^{-1} chlorophyll content. The significant increase in chlorophyll content frim the application of chicken manure , the interaction between chicken manure and ZA fertilizer highlights in enhancing photosynthetic capacity. Sulfur, as contained in ZA fertilizer, supports chloroplasts formation, thereby increasing photosynthetic efficiency (Hasanah et al., 2021a). Sulfur also enhances the activity of glutathione reductase and glutathione peroxidase enzymes, which are essential in the formation of photosynthetic pigments and in protecting chlorophyll from oxidative damage (Riffat et al., 2020). Additionally , sulfur is a key element in preventing chlorosis and is involved in the structural development of chloroplasts, directly influencing the amount of chlorophyll in plant tissues (Li et al., 2020), these findings indicate that the right balance of organic and inorganic nutrients not only supports plant growth but also improves physiological functions like photosynthesis crucial for productivity in floating cultivation systems.

3.8 Flavonoid

The application of chicken manure and ZA fertilizer in floating shallot cultivation significantly (P<0.001). The highest flavonoid level was found in the 2kg chicken manure treatment (143.78 mg/g), while the lowest was observed in the control without manure (106.74 mg/g). Similarly, the 5.00 g/plant ZA fertilizer treatment resulted in a high flavonoid content (140.38 mg/g), and the control (no ZA fertilizer) had the lowest(85.53 mg/g).

Regression analysis showed that chicken manure application had a strong predictable effect on flavonoid content (R^2: 0.9232), with the quadratic equation: $y = -14.215x^2 +$

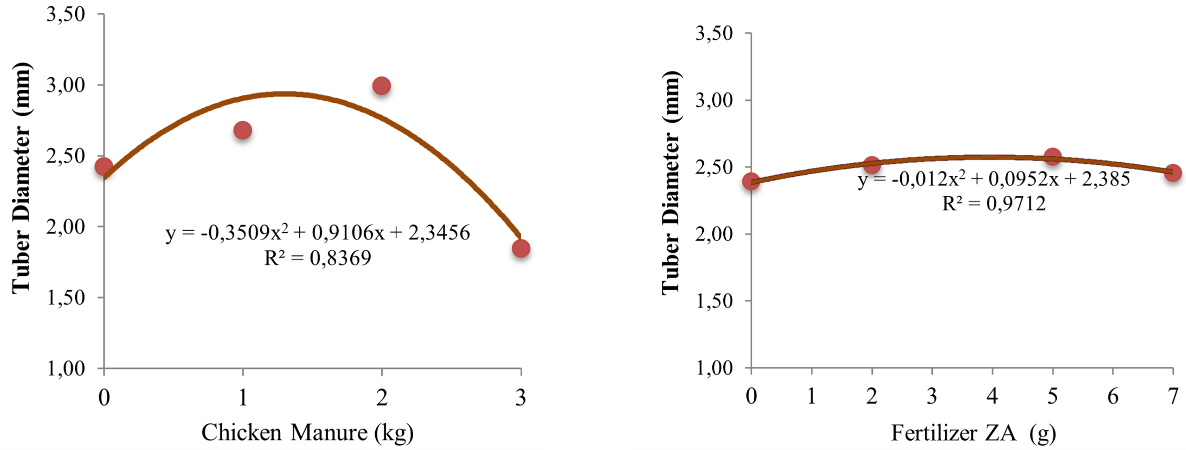

Figure 3. Results of orthogonal polynomial regression test of tuber diameter as influenced by chicken manure (A) and fertilizer ZA (B).

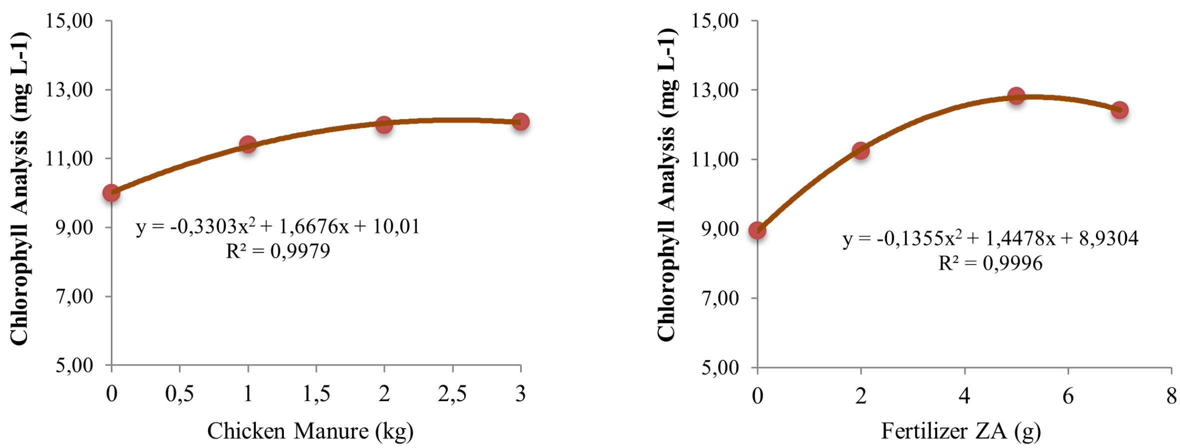

Figure 4. Results of orthogonal polynomial regression test of chlorophyll analysis as influenced by chicken manure (A) and fertilizer ZA (B).

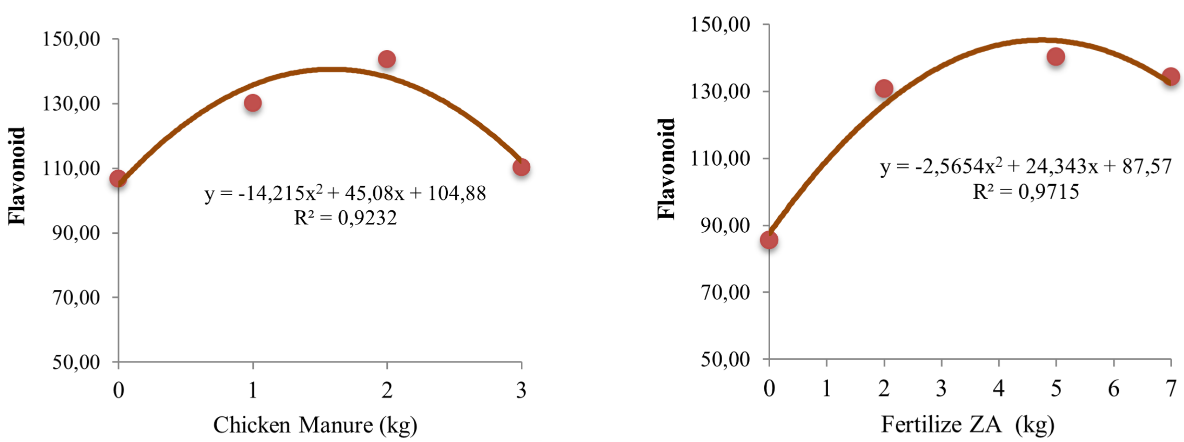

Figure 5. Results of orthogonal polynomial regression test of flavonoid as influenced by chicken manure (A) and fertilizer ZA (B).

45.08x + 104.88, resulting in an estimated optimum dose of 1.58 kg for a predicted flavonoid content of 140.61 mg/g. ZA fertilizer also had a strong effect (R^2: 0.9715), with the equation : $y = -2.5654x^2 + 24.343x + 87.57$, giving an optimum dose of 4.74 g and a predicted content of 145.31 mg/g. The increase in flavonoid content due to the applicationof 2 kg chicken manure indicates that organic fertilizer plays a crucial role in stimulating secondary metabolite production. Flavonoids function as antioxidants and are involved in the plant's defense system against environmental stress Ningsih et al. (2023) . The control treatment (without chicken manure) showed a clear reduction in flavonoids levels, highlighting the importance of organic inputs for biochemical processes. Likewise, sulfur in ZA fertilizer enhances the synthesis of secondary metabolite, including flavonoids. Sulfur plays a key role in plant metabolism, particularly in the biosynthesis of phenolic compounds that act antioxidants and contribute to plant resistance (Ayu et al., 2024). Overall, combination of 2 kg chicken manure and 5 g/plant ZA fertilizer proved most effective in increasing flavonoid content, showing that the integration of organic and inorganic nutrients enhances the biochemical quality of shallot plants cultivated in floating systems.

4. CONCLUSIONS

The results of this conclude that application of 2 kg/plant chicken manure and 5.00 g/plant ZA fertilizer significantly enhances the growth, quality and yield of shallots cultivated in a floating system. Chicken manure supports vegetative growth by improving soil structure and nutrient availability, while ZA fertilizer plays an essential role in protein synthesis, chlorophyll formation, and flavonoid production. However, excessive application particularly 3kg of chicken manure may lead to nutrient imbalances that reduce yield. Therefore, the correct dosage is crucial to achieve optimal productivity.

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