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Growth and yield responses of shallot (*Allium cepa* L.) to goat manure and ammonium sulfate fertilizer rates

Nugraheni Hadiyanti^{1*}, Gita Maulina¹, and Edy Kustiani¹¹Department of Agriculture,
Universitas Kadiiri, Kediri, East Java,
Indonesia**Correspondence**Nugraheni Hadiyanti, Department of
Agriculture, Universitas Kadiiri,
Kediri, East Java, Indonesia
Email: nugraheni@unik-kediri.ac.idThis is an open-access article distributed
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Attribution 4.0 International License**Abstract**

Balanced integration of organic and inorganic fertilizers is important for improving shallot productivity while maintaining soil fertility. This study evaluated the effects of goat manure and ammonium sulfate fertilizer rates on the growth and yield of shallot (*Allium cepa* L. Aggregatum Group) under alluvial soil conditions. A field experiment was conducted in Mlorah Village, Rejoso District, Nganjuk Regency, East Java, Indonesia, from April to June 2024 using a factorial randomized block design with three replications. Goat manure was applied at 3, 4, and 5 kg plot⁻¹ (15, 20, and 25 t ha⁻¹), while ammonium sulfate was applied at 10, 20, and 30 g plot⁻¹ application⁻¹ (50, 100, and 150 kg ha⁻¹ application⁻¹). Plant height, leaf number, tiller number, fresh and dry biomass weights, and consumable bulb weight were evaluated. Significant interactions between goat manure and ammonium sulfate were observed for plant height at 35 days after planting and fresh biomass weight. Goat manure independently increased leaf number at 25 and 35 days after planting and consumable bulb weight, whereas ammonium sulfate affected leaf number only at 35 days. Neither treatment significantly affected dry biomass weight or tiller number. The K5Z30 combination produced the highest plant height and fresh biomass weight, while 5 kg plot⁻¹ goat manure produced the highest consumable bulb weight. Overall, goat manure showed a more consistent contribution than ammonium sulfate to shallot growth and bulb yield under the tested alluvial soil conditions.

KEYWORDS

shallot, organic fertilizer, productivity

1. INTRODUCTION

Shallot (*Allium cepa* L.) is an important horticultural commodity widely used as a culinary spice and functional food ingredient. Besides its role in daily food consumption, shallot contains bioactive compounds, vitamins, minerals, and potassium that support human nutrition and metabolic functions (Moldovan et al., 2022; Prabawati et al., 2026; Sagar et al., 2022). Indonesia

remains one of the major shallot-producing countries, with national production reported at 1.82 million tonnes in 2020 and approximately 1.97 million tonnes in 2022. East Java contributed substantially to national production, indicating the strategic importance of improving shallot productivity in this region (Ilmiah et al., 2023). Sustainable improvement of shallot productivity requires appropriate nutrient management because bulb formation is highly dependent on nutrient

availability, soil physical condition, and balanced vegetative growth. Intensive shallot cultivation often relies heavily on inorganic fertilizers, which can rapidly supply nutrients but may not fully improve soil structure, organic matter content, water retention, or microbial activity. Continuous dependence on inorganic fertilization without sufficient organic matter input may reduce soil fertility and limit long-term crop productivity. Balanced fertilization through the integration of organic and inorganic nutrient sources has therefore become an important strategy for improving crop yield while maintaining soil health (Aulakh et al., 2022; Gelaye & Mengistu, 2025).

Goat manure is a potential organic fertilizer for shallot cultivation because it contributes organic matter and essential nutrients while improving soil structure, cation exchange capacity, water-holding capacity, and microbial activity. These improvements can enhance root growth and nutrient uptake, particularly in soils with low organic matter content. Goat manure contains macro- and micronutrients, including nitrogen, phosphorus, and potassium, which are gradually released during decomposition. Previous findings showed that goat manure application improved shallot growth and dry matter accumulation, indicating its potential role as a basal organic fertilizer for bulb crops (Haryanta & Widya, 2024). Ammonium sulfate fertilizer (ZA) is commonly used by shallot farmers as an inorganic source of nitrogen and sulfur. This fertilizer contains approximately 21% nitrogen and 23% sulfur, both of which are important for vegetative growth, chlorophyll formation, protein synthesis, and the development of sulfur-containing compounds in *Allium* crops (Firmada et al., 2023). Nitrogen supports leaf development and photosynthetic capacity, whereas sulfur is associated with plant metabolism, bulb quality, and the characteristic aroma of *Allium* species. Nevertheless, the effectiveness of ammonium sulfate depends on soil fertility status, organic matter availability, fertilizer rate, and crop growth stage.

Previous studies have discussed the benefits of organic fertilization, inorganic fertilization, and integrated nutrient management for improving crop productivity (Aulakh et al., 2022; Gelaye & Mengistu, 2025; Paramesh et al., 2023). However, limited information is available on the combined use of goat manure and ammonium sulfate fertilizer for shallot cultivation under alluvial soil conditions, particularly regarding their interaction effects on vegetative growth, biomass accumulation, and consumable bulb weight. This knowledge gap is important because alluvial soils may differ in nutrient retention, organic matter content, and response to fertilizer inputs. Understanding the combined response of shallot to goat manure and ammonium sulfate fertilizer can support more precise and balanced fertilization recommendations for local production systems.

This study hypothesized that the combined application of goat manure and ammonium sulfate fertilizer would improve shallot growth and yield more effectively than lower fertilizer-rate combinations because goat manure can improve soil conditions and nutrient retention, while ammonium sulfate can provide readily available nitrogen and sulfur. Therefore, this study aimed to evaluate the effects of different goat manure and ammonium sulfate fertilizer rates on the growth and yield of shallot grown under alluvial soil conditions.

2. MATERIALS AND METHODS

2.1 Experimental site

The field experiment was conducted from April to June 2024 in a paddy field located in Mlorah Village, Rejos District, Nganjuk Regency, East Java, Indonesia. The experimental site was classified as alluvial soil and had been used for seasonal crop cultivation before the experiment. Composite soil samples were collected before treatment application from the 0–20 cm soil layer to determine the initial physicochemical properties of the soil. The samples were air-dried, gently crushed, passed through a 2-mm sieve, and analyzed for soil pH, organic C, total N, available P, available K,

cation exchange capacity (CEC), soil texture, and available S. These baseline soil properties were used to characterize the fertility status of the experimental site before fertilizer application.

2.2 Planting material and fertilizer sources

Shallot bulbs of the Thailand variety were used as planting material. The bulbs had been stored for two months before planting to ensure suitable physiological maturity and uniform sprouting ability. The fertilizer materials consisted of goat manure and ammonium sulfate fertilizer, locally known as ZA. Goat manure was used as the organic fertilizer source, whereas ammonium sulfate was used as the inorganic source of nitrogen and sulfur. The goat manure was composted before application and had a dark brown color, crumbly texture, and no strong odor, indicating that it was sufficiently mature for field application. Chemical analysis of the manure was conducted before application to determine its nutrient composition and maturity status.

2.3 Experimental design and treatments

The experiment was arranged using a factorial randomized block design with two factors and three replications. The first factor was goat manure rate, consisting of three levels: 3 kg plot⁻¹ (K3), 4 kg plot⁻¹ (K4), and 5 kg plot⁻¹ (K5). The second factor was ammonium sulfate rate, consisting of three levels: 10 g plot⁻¹ application⁻¹ (Z10), 20 g plot⁻¹ application⁻¹ (Z20), and 30 g plot⁻¹ application⁻¹ (Z30). The combination of both factors resulted in nine treatments, and each treatment was replicated three times, producing 27 experimental plots. Each plot measured 2 m × 1 m, equivalent to 2 m². The goat manure rates of 3, 4, and 5 kg plot⁻¹ were equivalent to 15, 20, and 25 t ha⁻¹, respectively. Ammonium sulfate was applied three times during the growing season. The rates of 10, 20, and 30 g plot⁻¹ application⁻¹ were equivalent to 50, 100, and 150 kg ha⁻¹ application⁻¹, respectively, or 150, 300, and 450 kg ha⁻¹ season⁻¹. Because ammonium sulfate contains approximately 21% N and 23% S, these rates supplied 31.5, 63.0, and 94.5 kg N ha⁻¹

season⁻¹ and 34.5, 69.0, and 103.5 kg S ha⁻¹ season⁻¹, respectively.

2.4 Field preparation and crop management

The experimental field was plowed, leveled, and divided into plots according to the treatment layout. The distance between plots was 0.3 m, whereas the distance between blocks was 0.5 m. Shallot bulbs were planted at a spacing of 15 cm × 20 cm, with approximately 60 plants per plot. The central ten plants in each plot were selected as sample plants, while border plants were excluded from measurement to minimize edge effects.

Goat manure was incorporated into the soil during land preparation according to the assigned treatment rates. Ammonium sulfate was applied by broadcasting at 10, 20, and 30 days after planting (DAP), according to the assigned treatment rates. No additional fertilizer was applied outside the experimental treatments. Irrigation was carried out once daily or adjusted according to field moisture conditions to maintain adequate water availability during plant growth. Replanting was conducted at 7–12 DAP to replace non-growing plants. Weed control was performed manually three times: during tiller formation at 10–21 DAP, during bulb development at 30–35 DAP, and during bulb maturation at 50–55 DAP. Pest and disease incidence was monitored regularly, and control measures were applied uniformly across all plots when symptoms appeared to avoid treatment bias.

2.5 Growth and yield measurements

Plant growth was evaluated based on plant height, number of leaves, and number of tillers. Plant height was measured from the soil surface to the tip of the longest leaf using a ruler and was recorded at 15, 25, and 35 DAP. Leaf number was counted as the total number of fully emerged green leaves per sampled plant at 15, 25, and 35 DAP. Tiller number was counted at 60 DAP by recording the number of tillers formed per sampled plant. Yield-related variables included fresh biomass weight, dry biomass weight, and consumable bulb weight. Fresh biomass weight was determined

immediately after harvest by weighing the whole plant, including bulbs and aboveground biomass, before drying. Dry biomass weight was determined after oven-drying the plant material at 70°C until constant weight. Consumable bulb weight was measured after removing roots, dry leaves, damaged tissues, and non-marketable parts. Healthy, mature, undamaged, and disease-free bulbs were classified as consumable bulbs. All growth and yield measurements were conducted using the central ten sample plants from each plot.

2.6 Harvesting and postharvest handling

Shallots were harvested at 65 DAP when the plants reached physiological maturity. Harvest maturity was determined based on visual indicators, including leaf yellowing, partial leaf lodging, bulb enlargement, and the formation of outer bulb skin. Harvested plants were tied to facilitate handling, and the bulbs were sun-dried for 1–2 weeks under direct sunlight. Dried bulbs were then cleaned and used for measuring consumable bulb weight according to the defined criteria.

Harvest maturity was determined based on visual indicators, including leaf yellowing, partial leaf lodging, bulb enlargement, and the formation of outer bulb skin

2.7 Statistical analysis

The observed data were analyzed using analysis of variance for a two-factor randomized block design. When the interaction effect was not significant but the main effect was significant, mean separation was performed for the corresponding main factor. Data normality and homogeneity of variance were evaluated using the Shapiro–Wilk and Levene’s tests, respectively. Statistical analyses were performed using SPSS version 26.0. The coefficient of variation was calculated for each variable to evaluate experimental precision.

3. RESULT AND DISCUSSION

3.1 Plant height

Plant height represents an important vegetative growth indicator because it reflects cell division, cell elongation, and canopy development during early crop establishment. The analysis of variance indicated that the interaction between goat manure and ammonium sulfate rates significantly affected shallot plant height at 35 days after planting (DAP), whereas no significant interaction was observed at 15 and 25 DAP. Mean plant height under different treatment combinations is summarized in [Table 1](#).

Table 1. Mean shallot plant height under different goat manure and ammonium sulfate fertilizer rates

Treatment	Plant height (cm) at 15 DAP	Plant height (cm) at 25 DAP	Plant height (cm) at 35 DAP
K3Z10	14.07	22.67	36.73a
K3Z20	14.60	22.20	37.53bc
K3Z30	15.87	22.73	39.13f
K4Z10	14.93	22.47	39.00e
K4Z20	15.00	22.40	38.67de
K4Z30	15.60	22.00	36.47a
K5Z10	15.73	22.27	37.73cd
K5Z20	15.40	22.07	40.13g
K5Z30	16.53	22.60	41.40h
LSD 5%	ns	ns	0.30

Note: Values followed by the same letter within the same column are not significantly different according to the least significant difference test at the 5% level; ns = not significant.

The 15 and 25 DAP observations showed relatively similar plant height among treatment combinations. This response may be associated with the early growth stage of shallot, during which sprouting and initial leaf emergence still depend partly on nutrient reserves stored in the planting bulb. Fertilizer effects became more distinct at 35 DAP, when plant nutrient demand increased and root activity became more important for supporting vegetative growth. The interaction pattern between goat manure and ammonium sulfate fertilizer rates is illustrated in [Figure 1](#), which shows that the plant-height response varied across ammonium sulfate rates and became most pronounced at the highest goat manure rate.

The highest plant height at 35 DAP was recorded under K5Z30, reaching 41.40 cm,

followed by K5Z20 with 40.13 cm. The significant interaction indicates that the effect of ammonium sulfate depended on the goat manure rate. Higher goat manure input likely improved soil structure, moisture retention, and nutrient-holding capacity, thereby increasing the efficiency of readily available nitrogen and sulfur supplied by ammonium sulfate. Nitrogen contributes to chlorophyll formation, protein synthesis, and leaf expansion, whereas sulfur supports plant metabolism and the formation of sulfur-containing compounds in *Allium* crops. The interaction pattern between goat manure and ammonium sulfate fertilizer rates should be visualized using an interaction plot to clarify the treatment response across fertilizer combinations.

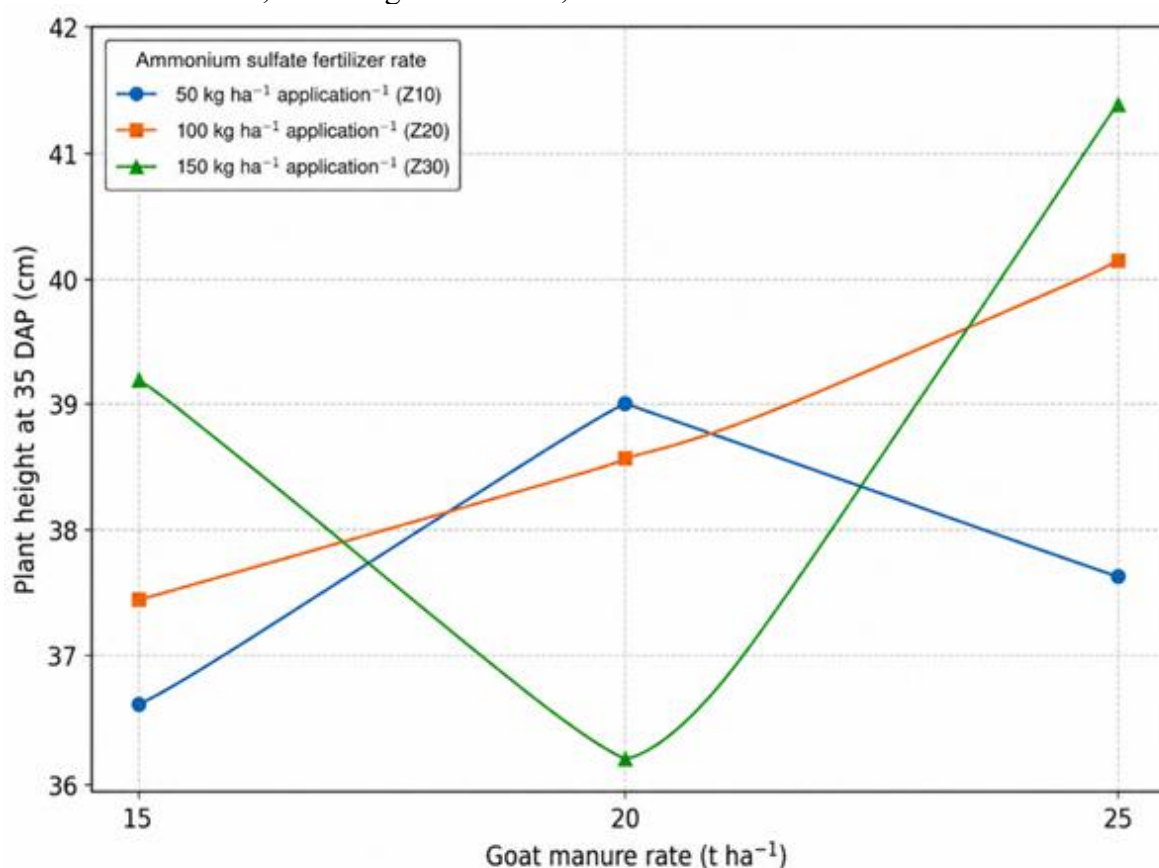


Figure 1. Interaction plot of goat manure and ammonium sulfate fertilizer rates on shallot plant height at 35 DAP.

The improved plant height under higher combined fertilizer rates supports the concept that integrated nutrient management can enhance crop growth by combining the immediate nutrient supply of inorganic fertilizer with the soil-improving effects of organic inputs. Paramesh et al. (2023) reported that integrated nutrient management can improve crop growth and soil properties by enhancing nutrient availability and supporting a more favorable root environment. The present result suggests that the combined use of goat manure and ammonium sulfate was more effective for plant height than lower fertilizer-rate combinations under the tested alluvial soil condition. Sulfur uptake was associated with increased nitrogen uptake and higher yield, indicating the close relationship between N and S nutrition in bulb crops (Vigneault et al., 2024).

The present result suggests that the combined use of goat manure and ammonium sulfate was more effective for plant height than lower fertilizer-rate combinations under the tested alluvial soil

condition. Sulfur uptake was associated with increased nitrogen uptake and higher yield, indicating the close relationship between N and S nutrition in bulb crops

3.2 Number of leaves

Leaf number is closely related to photosynthetic capacity because leaves are the main organs responsible for light interception and assimilate production. The analysis of variance showed no significant interaction between goat manure and ammonium sulfate rates for the number of leaves. Goat manure significantly affected leaf number at 25 and 35 DAP, whereas ammonium sulfate significantly affected leaf number only at 35 DAP. Mean leaf number under the main effects of goat manure and ammonium sulfate is presented in [Table 2](#).

Goat manure significantly affected leaf number at 25 and 35 DAP, whereas ammonium sulfate significantly affected leaf number only at 35 DAP

Table 2. Mean number of shallot leaves under different goat manure and ammonium sulfate fertilizer rates

Treatment	Number of leaves	Number of leaves	Number of leaves at 35
	at 15 DAP	at 25 DAP	DAP
K3	2.51	3.80a	5.78a
K4	2.60	4.29a	6.13a
K5	3.53	4.69b	7.29b
LSD 5%	ns	0.10	0.18
Z10	2.60	4.07	6.00a
Z20	2.80	4.29	6.44b
Z30	2.96	4.42	6.76b
LSD 5%	ns	ns	0.18

Note: Values followed by the same letter within the same column are not significantly different according to the least significant difference test at the 5% level; ns = not significant.

The goat manure rate of 5 kg plot⁻¹ consistently increased leaf number, particularly at 25 and 35 DAP. This response indicates that the contribution of goat manure became more evident as crop growth progressed. Goat manure supplies organic matter and gradually releases nutrients during decomposition, which can support leaf development after the early establishment stage. Improved soil physical conditions may also enhance root growth and nutrient uptake, allowing plants to maintain better canopy development. The effect of ammonium sulfate was significant only at 35 DAP, with Z20 and Z30 producing higher leaf numbers than Z10. This result suggests that nitrogen and sulfur supplied by ammonium sulfate became more influential during the active vegetative growth phase. Nitrogen availability supports leaf initiation and expansion, while sulfur contributes to enzymatic activity and protein metabolism. Ahmadi et al. (2024) reported that organic and inorganic nutrient sources can support plant growth through different nutrient-release patterns. The present results indicate that goat manure exerted a more consistent effect on leaf development than ammonium sulfate, although both fertilizer sources contributed to vegetative performance at the later growth stage.

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3.3 Number of tillers per plant

Tiller formation contributes to shallot yield potential because each tiller can support bulb development. The analysis of variance showed that goat manure, ammonium sulfate, and their interaction did not significantly affect the number of tillers per plant at 60 DAP. Mean tiller number under the main effects of goat manure and ammonium sulfate is presented in [Table 3](#).

Table 3. Mean number of shallot tillers per plant under different goat manure and ammonium sulfate fertilizer rates

Treatment	Number of tillers per plant
K3	4.31
K4	4.51
K5	4.87
LSD 5%	ns
Z10	4.60
Z20	4.62
Z30	4.47
LSD 5%	ns

Note: ns = not significant.

The numerical increase in tiller number under K5 indicates a tendency toward improved vegetative development with higher goat manure input, but this difference was not statistically significant. Therefore, the result should not be interpreted as a strong treatment effect. Tiller formation is influenced not only by nutrient availability but also by genetic characteristics, planting material quality, environmental conditions, and plant population density. Haryanta and Widya (2024) stated that fertilizer type, cultivation practice, soil condition, and environmental factors can influence shallot growth. The absence of significant treatment effects in this study suggests that the tested fertilizer-rate range was not sufficient to induce a clear change in tiller formation, or that tiller number was more strongly regulated by variety and field conditions than by fertilizer treatment.

3.4 Fresh biomass weight

Fresh biomass weight reflects total plant mass at harvest before water removal and is influenced by both structural biomass accumulation and tissue water content. The analysis of variance showed a significant interaction between goat manure and

ammonium sulfate rates on fresh biomass weight. Mean fresh biomass weight under different treatment combinations is summarized in [Table 4](#).

Table 4. Mean fresh biomass weight of shallot under different goat manure and ammonium sulfate fertilizer rates

Treatment	Fresh biomass weight (g)
K3Z10	41.33a
K3Z20	42.40ab
K3Z30	45.87bc
K4Z10	47.43de
K4Z20	50.87f
K4Z30	46.67cd
K5Z10	49.27e
K5Z20	58.23g
K5Z30	61.40h
LSD 5%	1.16

Note: Values followed by the same letter within the same column are not significantly different according to the least significant difference test at the 5% level.

The K5Z30 treatment produced the highest fresh biomass weight, reaching 61.40 g, followed by K5Z20 with 58.23 g. The significant interaction indicates that higher ammonium sulfate rates were more effective when combined with the highest goat manure rate. Goat manure likely improved soil water retention, aggregation, and nutrient-holding capacity, whereas ammonium sulfate supplied readily available nitrogen and sulfur for vegetative growth. These complementary functions may explain the higher fresh biomass accumulation

under K5Z30. The interpretation of fresh biomass should consider both biomass formation and tissue water content. Martelli et al. (2025) emphasized that fresh biomass includes the water contained in plant tissues, making it useful for estimating total harvestable mass but less specific for dry matter accumulation. The present study showed that fresh biomass increased significantly under combined fertilizer application, whereas dry biomass did not show a significant response. This contrast suggests that the increase in fresh biomass may have been partly associated with improved tissue hydration and water retention rather than only with increased dry matter accumulation. The interaction response for fresh biomass should be displayed using an interaction plot to clarify the pattern across goat manure and ammonium sulfate rates. The interaction response is presented in Figure 2, which shows a clear increase in fresh biomass weight when higher ammonium sulfate rates were combined with higher goat manure input.

However, fresh biomass should be interpreted carefully because it reflects both dry matter accumulation and tissue water content. The significant increase in fresh biomass, together with the non-significant response of dry biomass, suggests that the treatment effect may have partly reflected improved water retention or tissue hydration rather than only increased structural dry matter. This interpretation is important because fresh weight alone may overestimate yield improvement if it is not supported by dry matter or marketable bulb weight. Organic fertilization studies in onion have shown that organic nutrient sources can maintain or improve yield performance compared with mineral fertilization, but the response may vary depending on soil condition, nutrient availability, and production system (Qin et al., 2023).

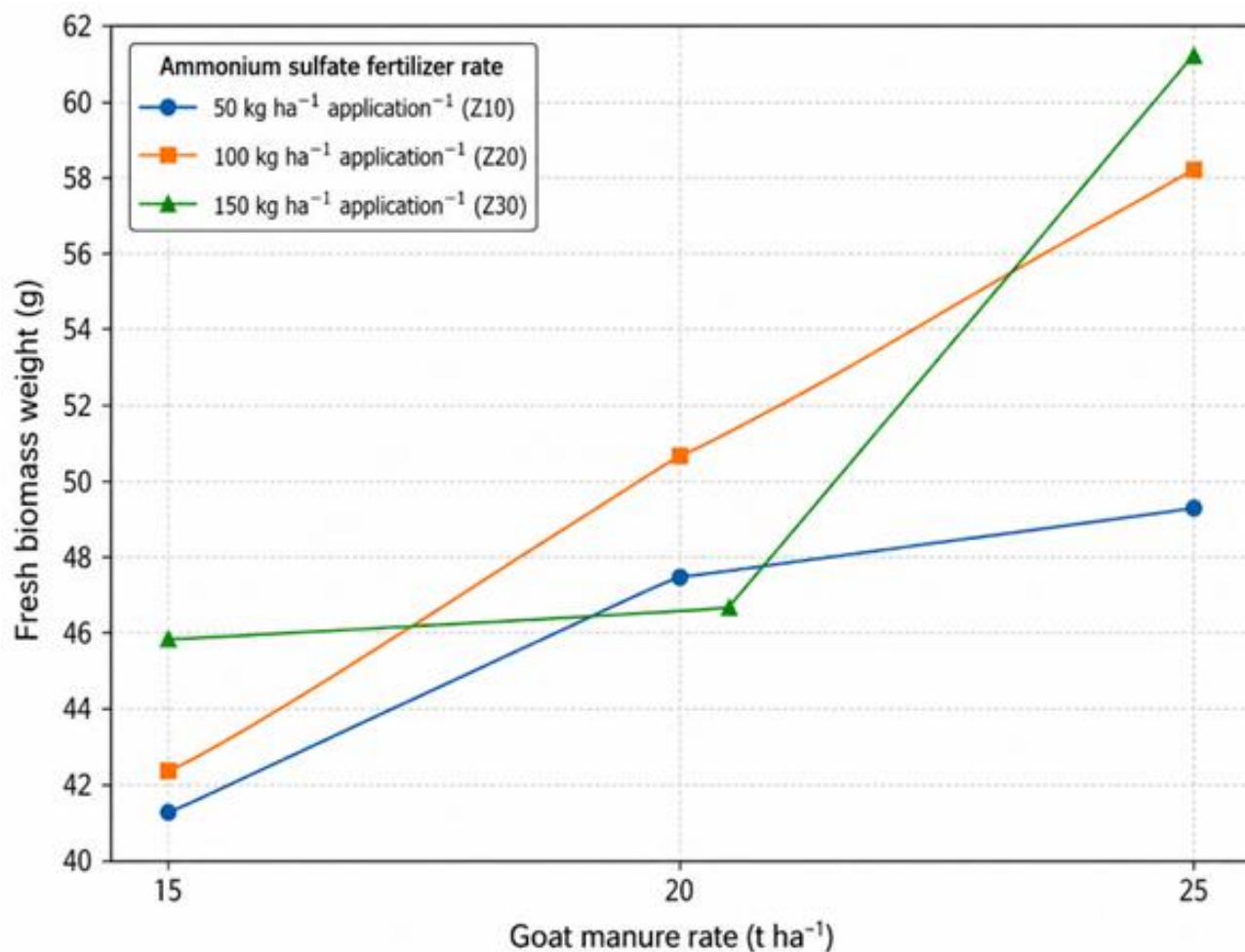


Figure 2. Interaction plot of goat manure and ammonium sulfate fertilizer rates on shallot fresh biomass weight.

3.5 Dry biomass weight and consumable bulb weight

Dry biomass weight represents the non-water fraction of plant tissues and provides a better indication of dry matter accumulation than fresh biomass. Consumable bulb weight represents the marketable portion of the harvested shallot and is directly related to crop productivity. The analysis of variance showed no significant interaction between goat manure and ammonium sulfate rates for dry biomass weight or consumable bulb weight. Goat manure and ammonium sulfate also did not

significantly affect dry biomass weight. Goat manure significantly affected consumable bulb weight, whereas ammonium sulfate did not show a significant effect. Mean dry biomass weight and consumable bulb weight are presented in [Table 5](#).

The analysis of variance showed no significant interaction between goat manure and ammonium sulfate rates for dry biomass weight or consumable bulb weight

Table 5. Mean dry biomass weight and consumable bulb weight of shallot under different goat manure and ammonium sulfate fertilizer rates

Treatment	Dry biomass weight (g)	Consumable bulb weight (g)
K3	35.84	33.31a
K4	35.62	34.44a
K5	37.96	38.43b
LSD 5%	ns	1.15
Z10	36.51	33.84
Z20	35.78	35.23
Z30	37.13	37.11
LSD 5%	ns	Ns

Note: Values followed by the same letter within the same column are not significantly different according to the least significant difference test at the 5% level; ns = not significant.

Goat manure significantly increased consumable bulb weight, whereas ammonium sulfate showed only a numerical trend. This result indicates that organic matter input played a more consistent role in improving marketable yield under the tested alluvial soil conditions. Goat manure may have supported bulb development by improving soil structure, nutrient retention, microbial activity, and root-zone conditions. Better root growth and nutrient uptake can enhance assimilate partitioning to bulbs, which is essential for increasing consumable yield. Previous studies on shallot and onion have shown that organic and integrated nutrient management can improve bulb yield by enhancing both nutrient supply and soil quality (Paramesh et al., 2023).

The non-significant effect of ammonium sulfate on consumable bulb weight may indicate that N and S supply alone was not sufficient to significantly improve bulb yield under the experimental conditions. Excessive or poorly synchronized mineral fertilization can also reduce fertilizer-use efficiency and may not always increase marketable yield. Recent onion fertilization research emphasized that optimizing fertilizer rates

is important because excessive fertilization can reduce fertilizer productivity and marketable yield (Sagar et al., 2022). Therefore, the present findings suggest that ammonium sulfate should be applied as part of an integrated nutrient strategy rather than as the sole determinant of shallot yield.

4. CONCLUSION

Goat manure and ammonium sulfate fertilizer interacted significantly in affecting shallot plant height at 35 DAP and fresh biomass weight. Goat manure showed a more consistent effect than ammonium sulfate fertilizer, particularly by increasing leaf number at 25 and 35 DAP and consumable bulb weight. Ammonium sulfate fertilizer significantly affected leaf number only at 35 DAP and did not significantly improve dry biomass weight or consumable bulb weight. The K5Z30 treatment combination produced the highest plant height and fresh biomass weight, whereas goat manure at 5 kg plot⁻¹, equivalent to 25 t ha⁻¹, was the most effective rate for improving consumable bulb weight. These findings indicate that goat manure plays an important role in supporting shallot growth and bulb yield under the tested alluvial soil

condition. The interpretation of these results should be limited to the specific location, growing season, shallot variety, and fertilizer-rate range used in this study; further multi-location and multi-season studies are required to validate broader fertilization recommendations.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Nugraheni Hadiyanti: Funding acquisition, Conceptualization. Gita Maulina: Conceptualization, Funding acquisition, Writing – original draft, Supervision. Edy Kustiani: Writing – original draft, Writing – review & editing.

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CONFLICT OF INTEREST

The author declares no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data available by request.

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