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Effect of Vermicompost and Liquid Organic Fertilizer on Growth and Yield of Shallot (*Allium ascalonicum* L.) from True Shallot Seed

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ABSTRACT

*This study evaluated the effects of vermicompost and liquid organic fertilizer (LOF) on the growth and yield of shallots (*Allium ascalonicum *L.) cultivated from true shallot seeds (TSS). The experiment was conducted from October 2023 to February 2024 at the Teaching Farm of the Faculty of Agriculture, Hasanuddin University, Makassar, Indonesia. A factorial experiment arranged in a randomized complete block design was conducted using different vermicompost and LOF levels in the substrate. The first factor was vermicompost dosage (0.0, 7.5, and 15.0 t ha $^{-1}$), and the second was LOF concentration (0, 2.5, 5, and 7.5 mL L $^{-1}$). The results showed that both vermicompost and LOF significantly improved plant growth and yield parameters ($p < 0.05$). Increasing the vermicompost dosage enhanced biomass accumulation and bulb development, whereas higher LOF concentrations promoted plant growth and improved the yield performance. However, no significant interaction was observed between vermicompost and LOF ($p > 0.05$), indicating that each factor acted independently of the other. In conclusion, vermicompost and LOF are effective organic inputs for improving the productivity of shallots. This study highlights the potential of these treatments as sustainable nutrient management strategies to support efficient and environmentally friendly cultivation of shallots in the future.*

Keywords:
Bulb yield; liquid organic fertilizer; organic fertilization; true shallot seeds; vermicompost.

1. Introduction

In Indonesia, agriculture is a significant sector that plays a crucial role in the community and should not be overlooked by policymakers. The demand for agricultural products within the community is increasing; however, shallot production has fluctuated annually. Many farmers continue to rely on traditional farming methods, including the use of synthetic fertilizers, which leave residues that contribute to the decline in soil fertility and crop yield. To enhance and sustain soil fertility and agricultural output, there has been a shift towards more eco-friendly farming practices, such as converting livestock manure and crop residues into organic fertilizers.

In shallot farming, the use of bulbs faces challenges owing to the limited availability of high-quality, high-yield seed bulbs, which are often expensive and disease-prone. The use of botanical seeds from shallots (TSS) offers several advantages, including lower costs, easier transport, extended storage life, consistent seed quality, minimal pathogen contamination, and high productivity (Syam'un et al., 2017). In addition, the use of true shallot seeds (TSS) offers a more efficient alternative to conventional bulb-based propagation methods. TSS requires only 2–3 kg ha^{-1} of seed, with an estimated cost of Rp 4–6 million per hectare, compared to 1.5–2 t ha^{-1} of seed bulbs, costing approximately Rp60–80 million per hectare (Saidah et al., 2020). This substantial difference highlights the economic advantage of TSS; however, these comparisons should be interpreted carefully because costs may vary depending on the location and production conditions. Moreover, TSS provides additional benefits such as easier storage, more efficient transportation, and lower risk of pathogens. According to Darwis et al. (2023), the reduction in shallot production is also attributed to the prolonged and excessive use of inorganic fertilizers, which leads to soil compaction, decreased soil aggregate stability, and reduced soil fertility, ultimately resulting in low nutrient availability in the soil.

Implementing organic farming systems based on sustainable principles is essential for maintaining land productivity by preserving the soil’s physical, chemical, and biological properties (Nugroho & Khoyriyah, 2023). However, the adoption of organic farming remains limited due to insufficient knowledge and low interest among farmers, as well as the relatively long processing time required to produce organic fertilizers. Consequently, many farmers continue to rely on inorganic fertilizers for immediate results. Therefore, more efficient processing technologies are needed to accelerate the decomposition of organic materials into forms that are readily available for plant uptake (Risal & Mukhlishah, 2019). Organic matter enhances soil fertility by improving its physical, chemical, and biological characteristics. Organic fertilizers are crucial for supplying macro-and microelements to plants.

Vermicompost is a solid organic fertilizer derived from the excreta of earthworms. As organic matter passes through the worm's digestive system, it is processed with the aid of vitamins and enzymes. Vermicompost enhances soil physical properties, including structure, porosity, permeability, and water retention (Abduli et al., 2013; Hasanudin et al., 2021). Vermicompost contains essential elements for plant development, including organic C, N, P, K, Ca, Mg, Na, Zn, Cu, Fe, and Mn, as well as Azotobacter sp., a nitrogen-fixing bacterium that enhances the nitrogen content of compost. The levels of macro-and micronutrients in vermicompost increase when applied to soil (Pereira et al., 2014; Nurrizky et al., 2023). Vermicompost also acts as an absorbent, helping to retain moisture in sandy soils by boosting the soil's water retention capacity and minimizing evaporation, thereby reducing the risk of drought (Pujiwati et al., 2021). According to Faried et al. (2021), using vermicompost at a rate of 15 t ha^{-1} yielded optimal results in shallot growth and production, with plant height at 20 HST reaching 19.27 cm, bulb count at 1.46, fresh bulb weight at 24.01 g, dry bulb weight at 18.91 g, and fresh bulb diameter at 27.19 mm.

Liquid organic fertilizer is a nutrient-rich solution derived from fermented organic matter that is easily absorbed by plants. LOF provides nutrients to fulfill plant requirements, enhances soil structure, and increases soil organic matter content. They can be applied by spraying on leaves or directly onto the soil (Ramarao et al., 2024). LOF is frequently used to address nutrient deficiencies because it rapidly supplies nutrients without harming the soil or plants. LOF is designed to minimize waste and reduce the expense and usage of costly inorganic fertilizers in agricultural production systems. It contains nutrients that have been broken down, making them more accessible to plants, although the nutrient content is lower (Sitepu, 2019). Ramadhan et al. (2018) indicated that the optimal growth and yield of shallot plants were achieved with a LOF concentration of 5 mL L^{-1}, as evidenced by various parameters, including wet shoot weight of 23.32 g, dry shoot weight of 15.52 g, dry bulb weight of 14.64 g, number of bulbs at 1.09, bulb diameter at 2.88 cm, and potential yield of shallots.

Although numerous studies have reported the individual effects of vermicompost and liquid organic fertilizer (LOF) on shallot growth and yield, their combined effects, particularly in shallot cultivation using true shallot seeds (TSS), remain unknown. Previous studies have largely focused on single-input applications, leaving unclear how the integration of vermicompost as a slow-release nutrient source and LOF as a readily available nutrient supply may interact to influence plant growth, nutrient uptake, and yield performance of plants. Therefore, the synergistic potential of these two organic inputs in TSS-based shallot production systems remains an important knowledge gap that must be addressed in future studies.

This study aimed to explore and evaluate the effects of vermicompost and liquid organic fertilizer on the growth and production of shallot plants originating from botanical seeds.

2. Materials and Methods

2.1 Research Site

The study was conducted at the Teaching Farm, Faculty of Agriculture, Universitas Hasanuddin, located in Tamalanrea District, Makassar City, South Sulawesi Province, at coordinates 5°7′40.07″ S and 119°28′48.94″ E, at an altitude of 9 m above sea level (ASL) with a pH of 6.65. The study was conducted from October 2023 to February 2024.

2.2 Study Site Experimental Design

The experiment was arranged in a factorial randomized complete block design (RCBD) consisting of two factors with three replications.

The first factor was vermicompost dosage, consisting of three levels:

- v0 = 0 t ha^{-1}
- v1 = 7.5 t ha^{-1}
- v2 = 15 t ha^{-1}

The second factor was liquid organic fertilizer (LOF) concentration, consisting of four levels:

- p0 = 0 mL L^{-1}
- p1 = 2.5 mL L^{-1}
- p2 = 5 mL L^{-1}
- p3 = 7.5 mL L^{-1}

2.3 Plant Materials

The plant material used in this study was true shallot seeds (TSS) of the Lokananta variety. Other materials included vermicompost fertilizer, liquid organic fertilizer (CAM Plus), NPK Mutiara fertilizer (16:16:16), plastic mulch, and several crop protection products such as Curacron insecticide, Golma 240 EC and Gramoxone herbicides, Antracol 70 WP, and Dithane M-45 fungicides.

A total of 36 plots were prepared, each measuring 1 m × 1 m, with 70 planting holes per plot at a spacing of 15 cm × 10 cm. True shallot seeds were first sown in seedbeds located in a greenhouse at the experimental farm of the Faculty of Agriculture, Hasanuddin University, Makassar, Indonesia. The seedbeds measured 6 m × 1 m in size. Before sowing, the seeds were treated with Antracol 70 WP fungicide at a rate of 2 g to prevent fungal infections.

The seedlings were transplanted into field plots after reaching the appropriate growth stage. Standard crop management practices, including irrigation, weed control, pest management, and fertilization, were uniformly performed across all the treatments throughout the growing period.

Harvesting was conducted when plants reached 65–75 days after planting (DAP), as indicated by the yellowing and lodging of leaves. Plants were harvested manually by carefully pulling the plants from the soil and cleaning off adhering soil particles

2.4 Fertilizer Treatments

Vermicompost was applied one week before transplanting according to the treatment dosage and was evenly distributed in each experimental plot. Liquid organic fertilizer (LOF) was applied via foliar spraying using a knapsack sprayer. Fertilizer was applied five times at 7-day intervals when plants were 14, 21, 28, 35, and 42 days after planting (DAP). Spray volumes were gradually increased according to plant growth stages, starting from 800 mL, 900 mL, 1,000 mL, 1,100 mL, and 1,200 mL per application.

The following growth and yield parameters were observed:

1. Plant height was measured from the base of the pseudostem to the tip of the longest leaf at 14, 21, 28, 35, and 42 days after planting.
2. The number of leaves per plant was counted at each observation interval.
3. The number of bulbs per clump was recorded at harvest by counting the bulbs produced by each sampled plant per clump.
4. Fresh shoot weight was measured immediately after harvest using a digital scale. Dry shoot and bulb weights were measured after natural drying for ten days following harvest.
5. Bulb diameter was measured at the widest part using calipers.
6. Bulb shrinkage was determined after drying by comparing the weights of the fresh and dried bulbs.
7. Bulb production per plot (kg m^{-2}) was calculated based on the dry bulb weight obtained from each plot.
8. Yield per hectare (t ha^{-1}) was estimated by converting the bulb production per square meter to hectares.
9. The harvest index was calculated as the ratio of bulb weight to total plant biomass.

2.5 Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) according to a randomized complete block design (RCBD). When significant differences among treatments were detected, mean comparisons were made using the Honestly Significant Difference (HSD) test at the 5% probability level.

3. Results and Discussion

3.1 Plant Growth

3.1.1. Plant Height (cm)

The application of vermicompost and liquid organic fertilizer influenced the early vegetative growth of shallot plants, as reflected by the differences in plant height at 14 days after planting (DAP). The detailed results are listed in Table 1.

Table 1. Effect of vermicompost and liquid organic fertilizer on plant height at 14 DAP

Vermicompost	Liquid Organic Fertilizer				Average	HSD 5%
	0 mL L^{-1} (p0)	2.5 mL L^{-1} (p1)	5 mL L^{-1} (p2)	7.5 mL L^{-1} (p3)		
0 t ha^{-1} (v0)	19.02	19.90	20.33	22.45	20.43^{b}	
7.5 t ha^{-1} (v1)	22.48	21.74	24.67	22.45	22.83^{ab}	3.25
15 t ha^{-1} (v2)	24.26	22.31	25.40	24.69	24.17^{a}	
Average	21.92	21.32	23.47	23.20		

Note: v0 = 0 t ha^{-1} vermicompost; v1 = 7.5 t ha^{-1} vermicompost; v2 = 15 t ha^{-1} vermicompost. p0 = 0 mL L^{-1} liquid organic fertilizer; p1 = 2.5 mL L^{-1} liquid organic fertilizer; p2 = 5 mL L^{-1} liquid organic fertilizer; p3 = 7.5 mL L^{-1} liquid organic fertilizer. Values followed by different letters within the same column indicate significant differences according to the HSD test at the 5% significance level.

Table 1 shows the plant heights at 14 DAP under different vermicompost and liquid organic fertilizer treatments. The highest average plant height (24.17 cm) was obtained with the application of 15 t ha^{-1} vermicompost (v2), whereas the lowest average plant height (20.43 cm) was observed in plants without vermicompost (v0). In the liquid organic fertilizer treatments, the highest average plant height was observed at 5 mL L^{-1} (p2).

Figure 1 shows the plant height and leaf number of shallot plants at 42 DAP under different vermicompost and liquid organic fertilizer treatments. The tallest plants (43.95 cm) were observed in the treatment combination of 15 t ha^{-1} vermicompost (v2) and 5 mL L^{-1} liquid organic fertilizer (p2), whereas the shortest plants (37.93 cm) were recorded in the treatment without vermicompost and liquid organic fertilizer (v0p0).

The highest leaf number (6.43 leaves per plant) was obtained in plants treated with 15 t ha^{-1} vermicompost (v2) combined with 7.5 mL L^{-1} liquid organic fertilizer (p3), whereas the lowest leaf number (5.19 leaves per plant) was observed in the treatment without vermicompost or liquid organic fertilizer (v0p0).

3.1.2 Fresh Shoot Weight (g) and Dry Shoot Weight (g)

The application of vermicompost and liquid organic fertilizer significantly influenced biomass production in shallot plants. The variations in fresh and dry shoot weights under different treatment combinations are shown in Table 2.

The highest fresh shoot weight (27.24 g) was obtained with the application of 15 t ha^{-1} vermicompost (v2), whereas the lowest value (21.59 g) was recorded in plants without vermicompost (v0). Similarly, the dry shoot weight with the highest value (14.89 g) was observed in the 15 t ha^{-1} vermicompost treatment (v2), and the lowest value (11.50 g) was recorded in the 0 t ha^{-1} vermicompost treatment (v0). In the liquid organic fertilizer treatments, the fresh shoot weight. The highest fresh shoot weight (28.71 g) was obtained at a concentration of 7.5 mL L^{-1} (p3), whereas the lowest value (18.31 g) was observed in plants without liquid organic fertilizer (p0). Dry shoot weight ranged from 9.65 to 15.60 g, with the highest value (15.60 g) obtained at 7.5 mL L⁻¹ (p3) and the lowest value (9.65 g) recorded in the treatment without liquid organic fertilizer (p0).

Table 2. Effect of vermicompost and liquid organic fertilizer on fresh and dry shoot weights of shallot plants.

	Fresh Shoot Weight	Dry Shoot Weight
Vermicompost		
v0 (0 t ha^{-1})	21.59**b**	11.50**b**
v1 (7.5 t ha^{-1})	22.38**b**	11.69**b**
v2 (15 t ha^{-1})	27.24**a**	14.89**a**
HSD (5%)	2.99	1.80
Liquid Organic Fertilizer		
p0 (0 mL L^{-1})	18.31**q**	9.65**q**
p1 (2.5 mL L^{-1})	21.96**q**	11.19**q**
p2 (5 mL L^{-1})	26.51**p**	14.32**p**
p3 (7.5 mL L^{-1})	28.71**p**	15.60**p**
HSD (5%)	3.82	2.99

Note: v0 = 0 t ha^{-1} vermicompost; v1 = 7.5 t ha^{-1} vermicompost; v2 = 15 t ha^{-1} vermicompost. p0 = 0 mL L^{-1} liquid organic fertilizer; p1 = 2.5 mL L^{-1}; p2 = 5 mL L^{-1}; p3 = 7.5 mL L^{-1}. Means followed by different letters within the same column indicate significant differences according to the HSD test at the 5% significance level.

3.1.3 Leaf Number

As shown in Figure 1, both vermicompost and liquid organic fertilizer increased the leaf production of the shallot plants. The highest leaf number (6.43 leaves per plant) was obtained in plants treated with 15 t ha^{-1} vermicompost (v2) combined with 7.5 mL L^{-1} liquid organic fertilizer (p3), whereas the lowest value (5.19 leaves per plant) was observed in plants without vermicompost or liquid organic fertilizer (v0p0) (Figure 1).

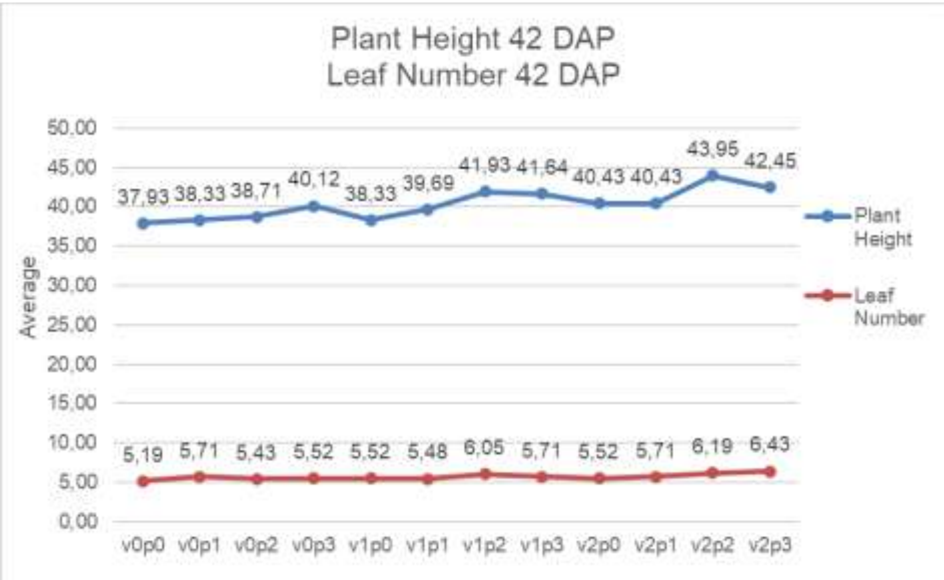

Figure 1. Plant height (cm) and leaf number of shallot plants 42 days after planting (DAP) under different vermicompost and liquid organic fertilizer treatments.

3.2 Yield Components

3.2.1 Bulb per Clump

The number of bulbs per clump is an important yield component that reflects the productivity of shallot plants. The effects of vermicompost and liquid organic fertilizer application on these parameters are summarized in Table 3.

Table 3. Effect of vermicompost and liquid organic fertilizer on the number of bulbs per clump of shallot plants

Vermicompost	Liquid Organic Fertilizer				Average
	0 mL L^{-1} (p0)	2.5 mL L^{-1} (p1)	5 mL L^{-1} (p2)	7.5 mL L^{-1} (p3)	
0 t ha^{-1} (v0)	1.38	1.33	1.43	1.48	1.40
7.5 t ha^{-1} (v1)	1.10	1.29	1.57	1.57	1.38
15 t ha^{-1} (v2)	1.29	1.38	2.00	1.33	1.50
Average	1.25q	1.33q	1.67p	1.46pq	
HSD (5%)			0.30		

Note: v0 = 0 t ha^{-1} vermicompost; v1 = 7.5 t ha^{-1} vermicompost; v2 = 15 t ha^{-1} vermicompost. p0 = 0 mL L^{-1} liquid organic fertilizer; p1 = 2.5 mL L^{-1}; p2 = 5 mL L^{-1}; p3 = 7.5 mL L^{-1}. Means followed by different letters within the same column indicate significant differences according to the HSD test at the 5% level of significance.

The highest average number of bulbs (1.67 bulbs per clump) was obtained at a liquid organic fertilizer concentration of 5 mL L^{-1} (p2), whereas the lowest average number (1.25 bulbs per clump) was recorded in plants that did not receive any liquid organic fertilizer (p0). Across the vermicompost treatments, the number of bulbs per clump ranged from 1.38 to 1.50. The highest average number of bulbs (1.50 bulbs per clump) was observed in the 15 t ha^{-1} vermicompost treatment (v2), while the lowest value (1.38 bulbs per clump) was observed in the 7.5 t ha^{-1} vermicompost treatment (v1).

3.2.3 Bulb Weight (g) and Bulb Diameter (cm)

Bulb weight and diameter are key indicators of shallot yield and quality. The effects of vermicompost and liquid organic fertilizer on these parameters are shown in Table 4.

The effects of vermicompost and liquid organic fertilizer on the bulb weight and diameter of shallot plants are presented in Table 4. The highest bulb weight (13.55 g) was obtained with the application of 15 t ha^{-1} vermicompost (v2), whereas the lowest value (10.28 g) was recorded for the treatment without vermicompost (v0). The largest bulb diameter (2.64 cm) was observed in the 15 t ha^{-1} vermicompost treatment (v2), whereas the smallest diameter (2.43 cm) was observed in plants without vermicompost (v0). Among the liquid organic fertilizer treatments, the highest bulb weight (14.24 g) was obtained at a concentration of 7.5 mL L^{-1} (p3), whereas the lowest value (8.57 g) was observed in the treatment without liquid organic fertilizer (p0). The bulb diameter under the liquid organic fertilizer treatments ranged from 2.40 to 2.77 cm. The largest diameter (2.77 cm) was obtained at a concentration of 7.5 mL L^{-1} (p3), while the smallest diameter (2.40 cm) was recorded for plants without liquid organic fertilizer (p0).

Bulb weight reflects the accumulation of assimilates produced during photosynthesis and stored in the bulb tissues. The increase in bulb weight was associated with improved soil fertility resulting from vermicompost application. Vermicompost enhances soil structure, increases microbial activity, and improves the availability of essential nutrients such as nitrogen, phosphorus, and potassium.

Table 4. Effect of vermicompost and liquid organic fertilizer on bulb weight and bulb diameter of shallot plants

	Bulb Weight (g)	Bulb Diameter (cm)
Vermicompost		
v0 (0 t ha^{-1})	10.28**b**	2.43
v1 (7.5 t ha^{-1})	10.58**b**	2.49
v2 (15 t ha^{-1})	13.55**a**	2.64
HSD (5%)	1.53	
Liquid Organic Fertilizer		
p0 (0 mL L^{-1})	8.57**q**	2.40**q**
p1 (2.5 mL L^{-1})	10.09**q**	2.51**pq**
p2 (5 mL L^{-1})	12.97**p**	2.41**q**
p3 (7.5 mL L^{-1})	14.24**p**	2.77**p**
HSD (5%)	1.95	0.34

Note: v0 = 0 t ha^{-1} vermicompost; v1 = 7.5 t ha^{-1} vermicompost; v2 = 15 t ha^{-1} vermicompost. p0 = 0 mL L^{-1} liquid organic fertilizer; p1 = 2.5 mL L^{-1}; p2 = 5 mL L^{-1}; p3 = 7.5 mL L^{-1}. Means followed by different letters within the same column indicate significant differences according to the HSD test at the 5% significance level.

These nutrients are required for plant growth, photosynthesis, and assimilate translocation to storage organs. Plants receiving higher vermicompost doses produced heavier bulbs than those grown without vermicompost. Previous studies have also demonstrated that vermicompost significantly improves bulb yield and quality in shallot cultivation because of its ability to enhance nutrient availability and soil biological activity (Hidayatullah et al., 2020).

3.2.3 Bulb Shrinkage (%)

The application of vermicompost and liquid organic fertilizer influenced bulb shrinkage in shallot plants, as reflected by variations in the percentage of bulb shrinkage among the different treatments. The detailed results are presented in Figure 2.

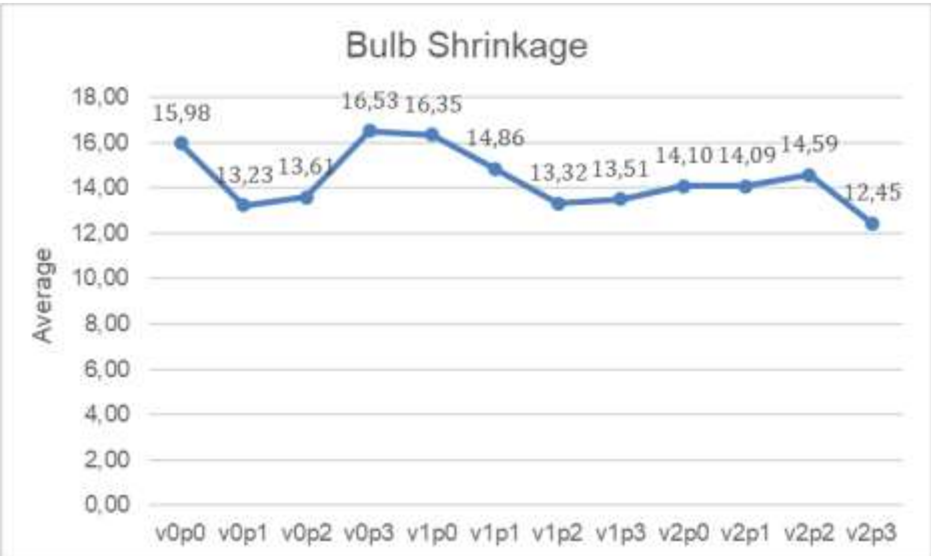

Figure 2. Bulb shrinkage (%) in shallot organic fertilizer treatments.

The application of vermicompost and liquid organic fertilizer influenced bulb shrinkage in shallot plants, as indicated by variations in the percentage of bulb shrinkage among the different treatments. The lowest bulb shrinkage (12.45%) was recorded in the treatment combination of 15 t ha^{-1} vermicompost and 7.5 mL L^{-1} organic liquid fertilizer (v2p3). The other treatment combinations showed intermediate bulb shrinkage values, ranging from 13.23% to 15.98%.

3.2.4 Bulb–Shoot Ratio and Harvest Index

The bulb-to-shoot ratio and harvest index of the shallot plants under different vermicompost and liquid organic fertilizer treatments are presented in Figure 3.

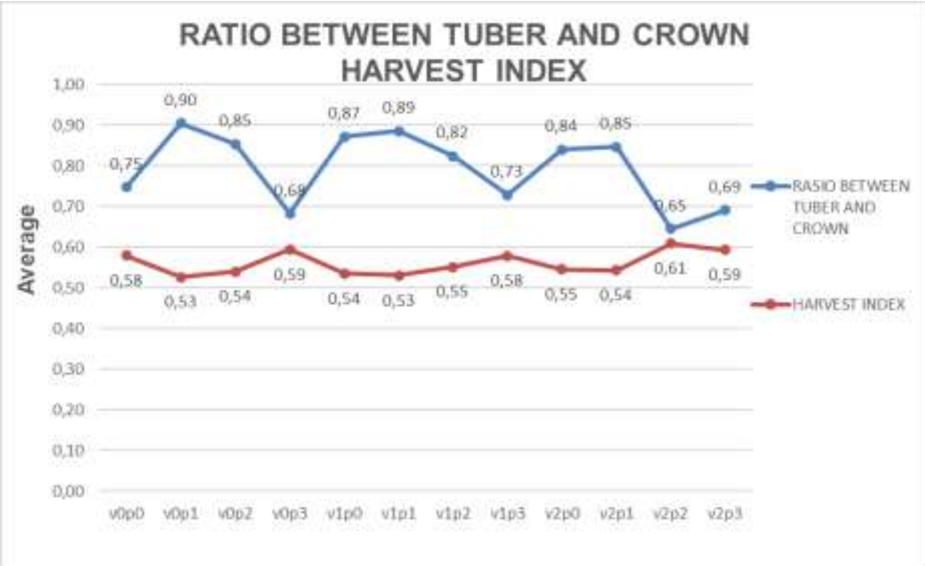

Figure 3. Bulb–shoot ratio and harvest index of shallot plants under different vermicompost and liquid organic fertilizer treatments.

The highest bulb–shoot ratio (0.90) was observed in the treatment combination of 0 t ha^{-1} vermicompost and 2.5 mL L^{-1} liquid organic fertilizer (v0p1), whereas the lowest value (0.65) was recorded in the treatment combination of 15 t ha^{-1} vermicompost and 5 mL L^{-1} liquid organic fertilizer (v2p2).

Similarly, the harvest index ranged from 0.53–0.61. The highest harvest index (0.61) was obtained in the treatment combination of 15 t ha^{-1} vermicompost and 5 mL L^{-1} liquid organic fertilizer (v2p2), while the lowest value (0.53) was observed in the treatment combinations v0p1 and v1p1.

3.2.5 Yield Production

The effects of vermicompost and liquid organic fertilizer on shallot bulb yield per plot and per hectare are presented in Table 5.

Vermicompost significantly increased the bulb yield. The highest yield per plot (0.95 kg m^{-2}) and per hectare (9.49 t ha^{-1}) was obtained with the application of 15 t ha^{-1} vermicompost (v2), whereas the lowest yield (0.72 kg m^{-2} or 7.19 t ha^{-1}) was recorded in plants that were not treated with vermicompost (v0).

Liquid organic fertilizer also significantly affected the bulb yield. The highest yield per plot (1.00 kg m^{-2}) and per hectare (9.97 t ha^{-1}) was achieved at a concentration of 7.5 mL L^{-1} (p3), while the lowest yield (0.60 kg m^{-2} or 6.00 t ha^{-1}) occurred in plants without liquid organic fertilizer application (p0). These results indicate that increasing the vermicompost dosage and liquid organic fertilizer concentration improved the shallot bulb yield.

Table 5. Effect of vermicompost and liquid organic fertilizer on shallot bulb yield per plot and per hectare

	Bulb Yield per Plot (kg)	Bulb Yield per Hectare (ton)
Vermicompost		
v0 (0 t ha^{-1})	**0.72b**	**7.19b**
v1 (7.5 t ha^{-1})	**0.74b**	**7.40b**
v2 (15 t ha^{-1})	**0.95a**	**9.49a**
HSD (5%)	0.11	1.07
Liquid Organic Fertilizer		
p0 (0 mL L^{-1})	**0.60q**	**6.00q**
p1 (2.5 mL L^{-1})	**0.71q**	**7.06q**
p2 (5 mL L^{-1})	**0.91p**	**9.08p**
p3 (7.5 mL L^{-1})	**1.00p**	**9.97p**
HSD (5%)	0.14	1.37

Note: Means followed by different letters within the same column differ significantly at the 5% HSD test. Values represent the treatment means.

The results of the analysis of variance indicated that the interaction between vermicompost and LOF fertilizer treatments did not significantly affect any of the observed parameters. Vermicompost and LOF fertilizers exerted individual effects on certain observed parameters and did not directly influence plant growth. Low levels of soil N, P, and K nutrients after analysis, along with the doses of manure and KCl fertilizer, did not directly affect plants because each treatment in the experiment had only a singular impact on several observed parameters, resulting in a lack of mutual support between manure and KCl fertilizer. This view is also supported by Manullang et al. (2019), who noted that the two-factor treatment has not been able to influence plants because the treatments do not support each other, and optimal plant growth can be achieved when the growth-affecting factors are balanced and favorable to the plant. If the interaction effect is not significantly different, the treatments operate independently of each other.

The results showed that increasing the vermicompost dose improved plant growth and yield. The application of vermicompost to soil can supply nutrients to support the initial phase of plant growth. According to Asgele et al. (2018), organic fertilizers provide all the essential nutrients for growth, thereby enhancing plant height. Vermicompost boosts the availability of crucial macronutrients, micronutrients, and microbial populations, facilitating sustainable plant growth. Faried et al. (2021) stated that higher doses of vermicompost increase nitrogen (N) content and aid in the metabolic processes of plant cells. Consequently, higher vermicompost doses enhanced N availability, resulting in the formation of chlorophyll and better plant growth compared to lower doses.

A similar trend was observed for the LOF treatments. Higher concentrations resulted in greater improvements in plant growth and yield. Each plant reacts differently and thrives if the dosage provided aligns with its requirements. This was corroborated by Diaz-Perez et al. (2018), who suggested that the growth of shallot plants improves with increased concentrations of organic fertilizer, thereby enhancing nutrient availability. Administering LOF according to plant needs had a more pronounced effect than lower

LOF treatments. However, a higher dosage does not necessarily ensure better growth, as each plant has unique nutrient absorption needs, and excessive amounts may not yield significant benefits for plant growth. It is crucial to consider the appropriate dosage based on the plant and soil conditions to achieve optimal results.

The results also revealed Table 2 that the 15 t ha^{-1} vermicompost fertilizer treatment yielded the best results in terms of fresh and dry bran weights. The application of vermicompost enhances nutrient availability, allowing plants to grow optimally. According to Adam et al. (2019), vermicompost can increase soil nitrogen levels, which in turn boosts carbohydrate production and food reserves, thereby increasing the fresh weight. Martins et al. (2018) and Fauzi et al. (2018) noted that nitrogen is vital for protein synthesis, chlorophyll production, and photosynthetic rates. A greater number of leaves and a larger leaf area improve the leaves' ability to capture light during photosynthesis, facilitating carbohydrate translocation to the bulbs and affecting the dry weight of shallot plants. Adequate nutrient availability boosts chlorophyll production, which is crucial for determining plant dry weight.

The findings in Table 4 indicate that the application of 15 t ha^{-1} of vermicompost fertilizer yielded the most favorable outcomes for the dry tuber weight parameter. Vermicompost fertilizer enhances soil potassium content, making it more accessible for plant absorption. Absorbed potassium plays a crucial role in improving tuber quality by aiding tuber formation and growth. As noted by Hidayatullah et al. (2020), vermicompost use boosts nutrient uptake in plants, particularly in shallots, facilitating bulb formation. Shallots can effectively form bulbs when there is adequate potassium uptake by the root system. This was corroborated by Jiku et al. (2020), who asserted that K enhances plant efficiency in sugar and starch production and translocation. The presence of potassium ions (K+) helps retain water within the plant and accelerates photosynthesis, leading to starch production and its translocation to various plant parts, particularly during tuber development. An increased photosynthetic output can stimulate tuber formation, thereby boosting tuber weight.

The results in Table 4 also demonstrate that applying LOF at a concentration of 7.5 mL L^{-1} yielded the best results for the dry bulb weight parameters. The formation and development of shallot bulbs are influenced by photosynthates stored in the bulbs, a process that is dependent on nutrient availability. LOF cam plus contained organic C (6.84%), nitrogen (3.69%), P (3.43%), K (3.58%), and microelements Mn (301.50 mg L^{-1}), Cu (295 mg L^{-1}), Zn (369.20 mg L^{-1}), B (152.50 mg L^{-1}), Co (7.05 mg L^{-1}), and Mo (4.10 mg L^{-1}). According to Maulida (2023), the components of LOF include N, P, K, Ca, and Fe, which serve as nutrients for plants and enhance the soil structure. As noted by Abdissa et al. (2011) and Samawati et al. (2022), the weight of dry bulbs is linked to an increase in photosynthesis and a plant's response to fertilization that boosts the production of assimilates transported to various plant parts. Shallots store food reserves in their bulbs. Photosynthate outcomes influence bulb weight during development, with the weight of shallot bulbs indicating the accumulation of organic compounds synthesized from inorganic substances such as water and carbon dioxide.

The findings in Table 4 revealed that applying LOF at a concentration of 7.5 mL L^{-1} had the most significant impact on bulb diameter. This is likely due to the adequate supply of phosphorus, which is crucial for root development, as roots are essential for nutrient absorption. Potassium plays a role in cell elongation and division, thereby affecting the size of the shallot bulbs. Fatirahma and Kastono (2020) reported that the diameter of shallot bulbs can reach optimal growth with sufficient phosphorus, which is vital as an energy source and stimulates root development. The transport of photosynthetic products and healthy root growth influence the uptake of other nutrients, which are important for cell elongation and division, resulting in optimal shallot bulb growth. This was supported by Diriba-Shiferaw et al. (2013) and Mutia et al. (2023), who stated that phosphorus is crucial for aiding assimilation, fruit and flower formation, and supporting root development, which is responsible for nutrient absorption by the soil. Proper root formation enhances the uptake of nutrients such as N, K, and other essential elements. When nutrient needs are met, plant growth is maximized, ensuring efficient photosynthesis and promoting tuber growth.

The findings, as shown in Table 5, indicate that applying vermicompost fertilizer at a rate of 15 t ha^{-1} resulted in the highest average yield per plot and per hectare. Achieving optimal production involves meeting the nutritional requirements of plants, as supplying sufficient nutrients aids in the transport of assimilates from leaves to tubers and in the expansion of plant cells. Vermicompost enhances the availability of potassium and other elements for plant absorption, thereby influencing shallot growth and yield. Wang et al. (2013) and Hayati et al. (2021) noted that K is crucial for protein synthesis, photosynthesis, and the distribution of photosynthetic products throughout the plant. Furthermore, potassium encourages root development, increases plant size, and boosts tuber number and production. It plays a vital role in synthesizing proteins and carbohydrates and facilitates the translocation and enlargement of shallot bulbs.

The results also demonstrated in Table 5 that using LOF at a concentration of 7.5 mL L^{-1} had the most favorable impact on production parameters per plot and per hectare. LOF enhances and maintains soil structure, improving air aeration and water movement, which, in turn, boosts plant growth and productivity. According to Maryati and Idham (2022), the application of LOF increases the levels of N, P, and K. Moreover, LOF positively affects soil structure by enhancing aeration and water movement, leading to better soil absorption and increased plant growth and production. Asadi et al. (2021) and Tuhuteru et al. (2023) support this, noting that LOF can transform compact soil into a loose structure due to the presence of microorganisms that supply nutrients to the plant vicinity, thereby enriching the nutrient content around the roots. Improved soil physical properties, such as a looser structure, increased porosity, and adequate water retention capacity, make the shallot root system more effective in absorbing water and nutrients, thereby enhancing shallot growth and yield. Provided that the plants' nutrient needs are met and there is no competition among plants, the photosynthetic rate during growth remains relatively consistent.

4. Conclusion

Vermicompost and liquid organic fertilizer (LOF) independently enhanced the growth and yield performance of shallots derived from true shallot seeds. The higher performance observed at 15 t ha^{-1} vermicompost and 7.5 mL L^{-1} LOF indicates that optimizing organic nutrient inputs can substantially improve biomass accumulation and bulb development. These findings suggest that organic-based nutrient management is a viable strategy for improving productivity in true shallot seed systems while maintaining soil health. From a practical perspective, the application of 15 t ha^{-1} vermicompost combined with 7.5 mL L^{-1} LOF can be recommended to farmers as an effective and sustainable fertilization approach to enhance shallot yields. Future research should focus on evaluating long-term soil fertility dynamics, optimizing application timing and frequency, and assessing the economic feasibility of these practices under different agroecological conditions to support their wider adoption.

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