Jurnal Ilmu Pertanian Indonesia (JIPI), July 2026
(Indonesian Journal of Agricultural Sciences)
ISSN 0853-4217 EISSN 2443-3462

Vol. 31 (3): 474–485
http://journal.ipb.ac.id/index.php/JIPI
DOI: 10.18343/jipi.31.3.474

Optimization of the Growing Environment Through Applying Mulch and Liquid Organic Fertilizer on The Growth and Yield of Shallots (*Allium ascalonicum* L.)

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(Received September 2025/Accepted May 2026)

ABSTRACT

Shallots (*Allium ascalonicum* L.) are widely consumed, but their productivity remains inconsistent due to various factors, including the long-term reliance on chemical fertilizers, which negatively impact soil and water quality. Therefore, sustainable cultivation strategies, including the application of liquid organic fertilizers (LOF) and plastic mulch are needed. This study aimed to evaluate the interactive effects of different LOF concentrations (0, 20 mL/-1) and black silver plastic mulch on the growth and yield of shallot plants. The research was conducted from Nover Jan 2024 in the dry land of Dusun K Sin, Amp Villa e, Karang oso Sub district, alang Regency. This study employed a factorial randomized block design RE method. In terms of growth parameters, mulch treatment (M1) at the LOF 20 concentration can increase 33.33% of shoot weight, 12% of p y weight, 6.73% of leaf area and 6.86% of plant height compared to that without mulch. The results showed that mulch treatment at the LOF P20 concentration increased tuber fresh weight, 30.85% of tuber dry weight per clump, 14.16% of tuber shrinkage weight, and harvest yield by 24.13, 30.85, 14.16, and 19.44%, respectively. LOF P20 provided significantly higher yields than P0 in all treatments.

Keywords: Black silver plastic mulch, liquid organic fertilizer, shallots

INTRODUCTION

Shallot consumption in Indonesia has increased annually. Based on BPS 2023, the predicted data on shallot consumption between 2023 and 2027 is estimated to increase by an average of 860,620 tons per year. Shallot production in Indonesia in 2021 was 2,004,590 tons per year, then decreased to 1,982,360 tons in 2022, and increased slightly to 1,985,233 tons in 2023. This fluctuation indicates a challenge for farmers due to the high demand for shallots. One of the main challenges in shallot cultivation is the use of chemical fertilizers. A 2023 study by Liu *et al.* showed that the use of inorganic fertilizers causes a decrease in soil pH to 4.4, which leads to a decline in the soil microbiome and a decrease in the soil's ability to bind nutrients. Therefore, it is important to identify sustainable alternatives.

One alternative that can be used to increase shallot yields is the application of liquid organic fertilizer and mulch. Liquid organic fertilizer is a fertilizer made from organic materials such as livestock manure, crop residues, and other organic materials that undergo a fermentation process to contain macro- and micro-nutrients that can support plant growth (Marpaung *et al.* 2023). Mulch is a material that covers the soil surface and can help improve the quality of the microclimate in the soil. Black and silver plastic mulch is more effective in increasing crop yields because it can cover the soil surface better, thereby maintaining soil moisture and preventing weed growth (Zhao *et al.* 2023). The use of mulch can significantly increase the absorption of liquid organic fertilizer because it creates more optimal soil conditions for plant growth. Mulch helps maintain soil moisture by reducing air evaporation, so that nutrients from liquid organic fertilizers remain available and are easily absorbed by plant roots (Lasmini *et al.* 2021). The use of plastic mulch in the study by Reza *et al.* in (2020) was proven to be able to significantly increase plant growth, as evidenced by the parameter of plant height reaching 58.02 cm compared to 41.58 cm without mulch. A research gap and the problem faced by farmers in the use of liquid organic fertilizers in previous studies was determining the optimal concentration of liquid organic fertilizers. Based on this information, with the goal of increasing shallot growth and yield, this study aimed to optimize the concentration of liquid organic fertilizer combined with black and silver plastic mulch.

METHODS

Materials and Instruments

The tools used include the Nict Voor PS 1200 analytical scale to measure the weight of the shallot

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yield, manual knapsack sprayer for fertilization, soil water content to measure soil humidity, pH meter to measure soil pH, Memmert oven type 21037 FNR for drying, and Leaf Area Meter type LI-3100 to measure leaf area. The materials used in this study included shallot seeds of the canopy variety, liquid manure brand "Kilat", urea, ZA, KCL, and black silver plastic mulch.

Research Location

The research was conducted from November to January 2024 in the dry fields of Kasin Hamlet, Ampeldento Village, Karangploso, Malang Regency. The location is at an altitude of 600 m above sea level. The climate in Malang Regency has an average humidity of 70-90%, an average temperature of 25-31°C, and an average rainfall of 1,250 mm/year (BPS 2019).

Research Stages

- Land preparation

Land preparation is carried out by clearing weeds and previous crop residue. Soil cultivation was loosened to a depth of 20-30 cm. 32 beds of 4 m × 1 m were made, the distance between replications was 0.5 m, and the distance between each bed was 0.4 m. Mulch was installed with a hole of 6 cm in diameter.

- Planting

The selected shallot seeds were cleaned and 1/3 of the tip was cut off. One seed was planted in each hole, with a plant spacing of 20 × 20 cm.

- Maintenance

Fertilization using the Liquid Organic Fertilizer "KILAT" was carried out 4 times at 10, 20, 30, and 40 Days After Planting (DAP) with a variation of concentrations such as 10 ml l^{-1} (5,6 ml/plot) 15 ml l^{-1}(8,4 ml/plot) 20 ml l^{-1} (11,2 ml/plot) applied by manual spray. Fertilization using inorganic urea fertilizer at a dose of 75 kg ha^{-1}, ZA 150 kg ha^{-1}, and KCl 75 kg ha^{-1} was carried out at 15 and 35 DAP for all treatments. Weeding was performed when the plants were 14 and 35 DAP. Irrigation is performed using a surface irrigation method that circulates air between the beds. Pesticide application was performed using a sprayer once every 10 days.

- Harvesting

Harvesting was carried out when the shallot leaves turned yellow and 60% of the stem neck was soft. The shallots were harvested at 52 - 59 DAP. Shallots are harvested when they appear to be lying down, the leaves are starting to turn yellow, and the stem neck is 60% soft. The stem neck of the shallot plant is located above the bulb and connects the stem and bulb. When the shallots are ready to be harvested, the stem neck begins to loosen and becomes more flexible.

Experimental Design

The experimental design was using a RCBD factorial, with two factors, mulch (M1) and liquid organic fertilizer concentration (LOF).

M0 : Without Mulch
M1: Black Silver Plastic Mulch
P0: Without LOF
P10: 10 mL L^{-1}
P15: 15 mL L^{-1}
P20: 20 mL L^{-1}

Therefore, the following treatment combinations were obtained (Table 1): There are 8 treatment combinations, each treatment combination repeated 4 times, resulting in 32 combination units. There were 100 plants in each combination unit. Total plants were used in this study were 3,200 plants.

Observation Parameters

- **Growth parameters**

Growth parameters included non-destructive parameters such as plant length (cm), measured with a ruler from the base of the plant to the tip of the plant, and destructive parameters included leaf area (cm2/clump), measured with a leaf area meter, total dry weight of plants (g/clump), measured with an analytical balance after being oven-dried with an Iven type 21037 FNR until it reached a constant weight, and fresh weight of roots (g/clump), measured with an analytical balance. The N content (%) in the plant tissue was measured using the Kjeldahl method. The P content (%) in plant tissue was measured using a spectrophotometer, and the K content (%) in plant tissue was measured using an Atomic Absorption Spectrophotometer (AAS).

- **Yield Parameters**

1. Fresh weight of bulbs per clump (g clump-1). The bulbs were weighed after separating them from the leaves and roots. Fifteen plants were sampled from each plot.
2. Sun-dried weight of bulbs per clump (g clump-1). Observations were made after the plants were separated from the leaves and roots and dried in the

Table 1 Treatment combinations

Mulch	liquid organic fertilizer concentration			
	P_0	P_{10}	P_{15}	P_{20}
M_0	M_0P_0	M_0P_{10}	M_0P_{15}	M_0P_{20}
M_1	M_1P_0	M_1P_{10}	M_1P_{15}	M_1P_{20}

Note: M_0 =.....

sun for approximately 7 days until the weight was constant to determine the dry weight of the bulbs.

3. Bulb weight loss (%). Bulb weight loss was calculated using the following formula:

$$\text{Bulb weight loss} = \frac{a - b}{a} \times 100\%$$

Where:
a = Fresh weight of bulbs per plot (kg m-2)
b = Sun-dried weight of bulbs (kg m-2)

4. Yield per hectare (t ha-1). Observations were made by weighing the shallot yield per plot and then converting the total production of each plot to hectares using the following formula:

Tuber yield × 71.5% × dry tuber weight per harvest plot

Where:
10,000 m^2 = 1 ha of land area
4 m^2 = Harvest plot area
71.5% = Effective land area per hectare

Data Analytics

The observation data were obtained and processed in Microsoft Excel, then calculated manually with formula without software, and analyzed using ANOVA (α = 0,05). If the test obtained a significant effect, it was continued with a comparison test between treatments using the Tukey Honest Significant Difference (HSD) test at 5% significance level and 5% degree of freedom to calculate the differences between treatments.

RESULTS AND DISCUSSION

The Interaction Effect of Mulch and LOF Concentration on the Growth of Shallots

The mulch treatment (M1) at a LOF concentration of P20 increased plant height by 6.86% compared to the unmulched treatment. In contrast, in the non-mulching treatment, P20 increased plant height by 19.08% compared to the P0 control treatment. This is in line with the results of Bahri *et al.* (2022). Although there was no interaction between mulch treatment and LOF concentration (Rosyadi 2022), the data indicate that increasing P20 concentration increases the nutrient supply required for plant growth, which aligns with Simatupang (2020) research, which demonstrated that mulching significantly improved plant vegetative growth compared to non-mulching. The results of stable NPK levels measured during the rainy season in this study prove that black and silver plastic mulch also slows the loss of fertilizer and other important nutrients due to water loss, both during rain and irrigation, and is more effective in absorbing nutrients (Adnan 2023).

The average yield of shallot plant length per plant in all treatments increased at 15–45 DAP and decreased at 60 DAP (Figure 1) (Table 2). The period between 15 and 35 DAP is the vegetative growth phase that focuses on increasing plant size; therefore, in this period, there will be an increase in plant length. The greatest plant length was obtained at 45 DAP with a combination of 20 mL L^{-1} of LOF and mulch (M1). The decrease in plant length at 60 days after planting in both treatments with mulch (M1) and without mulch (M0) was because of–51-65 days after planting is the generative phase of shallot bulb maturation, leading to decreased vegetative growth and more focus on bulb development (Amanda and Yuniarti, 2020). These results were also similar to those of Adnan (2023), who showed a decrease in shallot plant length during the generative phase at 50 days after planting.

The mulch treatment (M1) at a LOF concentration of P20 increased leaf area by 6.73% compared to the treatment without mulch. Meanwhile, in the treatment without mulch, there was an increase of 19.59% at P20 compared with the control P0. ANOVA also showed an interaction between mulch treatment and LOF at 15 DAP (Figure 2). This is in line with Surajudin *et al.* (2015). Increased nutrient content by LOF to a

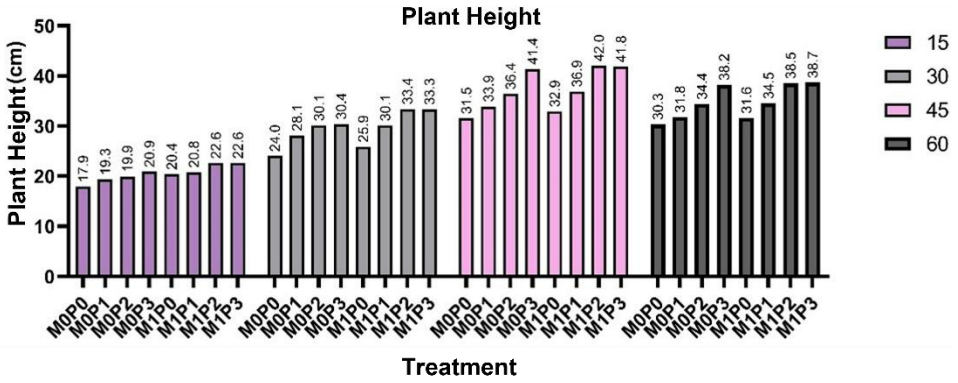

Figure 1 Shallot's height parameters at the treatment combinations of mulch M1, without mulch M0 with the liquid organic fertilizer concentration (LOF) concentration at 15 to 60 days after planting (DAP).

Table 2 Average height of shallot plants with mulch and LOF concentration treatments at 45 and 60 DAP (harvest age)

Treatments	Height of shallot (cm) DAP	
	45	60
Mulch		
M0 (without mulch)	55^{A}	33.41^{A}
M1 (mulch)	38.17^{B}	36.02^{B}
HSD 5%	0.53	0.56
LOF concentration		
P0	32.44^{A}	30.94^{A}
P10	35.44^{B}	32.91^{B}
P15	38.97^{C}	36.69^{C}
P20	40.09^{D}	38.31^{D}
HSD 5%	1.43	1.50
CV%	8.27	8.83

Note: Numbers accompanied by the same capital letters in the same column and the same lowercase letters in the same row indicate no significant difference based on the Honest Significant Difference (HSD) 5% test. CV = Coefficient of Variation; DAP = Days after planting; and LOF = Liquid organic fertilizer.

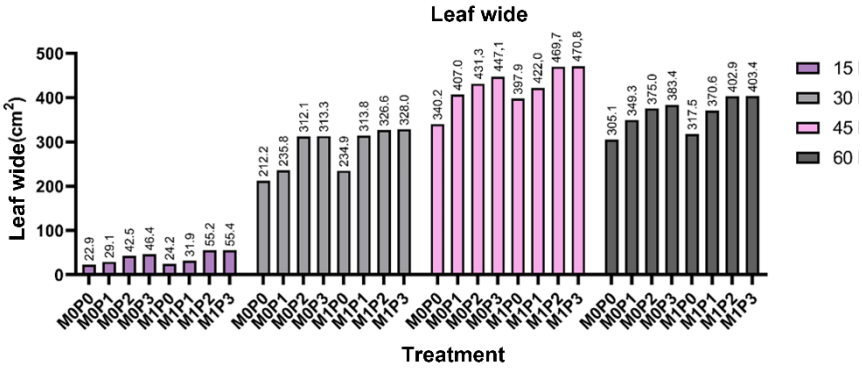

Figure 2 Shallot's leaves wide parameters at the treatment combinations of mulch (M1), without mulch (M0) with the concentration variation of liquid organic fertilizer (LOF) concentration at at 15 to 60 days after planting (DAP).

concentration of 20 ml/L^{-1} triggered an increase in leaf area and supported shallot growth. The largest average leaf width was obtained in the mulch treatment (M1) with a combination of 20 mL L^{-1}liquid organic fertilizer (LOF), which was 470.8 cm2 at 45 DAP (Figure 2) (Table 3).

No interaction was observed between mulch (M) and LOF concentration (P) on the dry weight of shallots at 30 and 45 days after planting (Figure 3). However, an interaction was observed at 15 and 60 days after planting. This is because at 15 days after planting, the soil pH was optimal for shallots (Figure 4), this condition of pH allowing for optimal nutrient absorption, and at 60 days after planting, plant growth and development had reached their maximum limits.

The findings of this study revealed a 12% increase in dry plant weight in the M1P20 treatment, which was significantly different from the treatment without mulch (M0) (Figure 3) (Table 4). This indicates that the nutrients provided by LOF can be absorbed better with the help of mulch, supported by data on increased NPK nutrient absorption that supports plant growth and increased plant dry weight data. This optimal growth and development can be achieved due to the fulfillment of nutrients, especially optimum and balanced macronutrients, especially provided by LOF (Dirgantari 2016). Increased assimilate accumulation supports a high dry weight in plants (Maulana 2023).

Therefore, it can be concluded that the application of mulch and LOF significantly affected the dry weight of shallots 15 and 60 days after planting. At 60 days after planting, root development reached its maximum, along with an increase in the number of bulbs. Plastic mulch can increase root volume at harvest age, as evidenced by Zuliati (2020) research, which found that root weight increased significantly due to mulch 8 days after planting. Root weight supports the increase in the dry weight of plants.

The results of this study are supported by moisture and pH data (Figure 4), which indicate that mulch can improve soil quality through physical and microclimatic mechanisms that indirectly improve the ability of plants to absorb nutrients. Mulch covers the soil surface, protecting it from erosion and rain splashes that can damage the soil structure. This coverage also reduces air evaporation, resulting in more stable soil moisture, which is crucial for nutrient mobility in the soil solution and efficient root absorption. With more humid and temperature-stable soil conditions (Figure 4), plant

Table 3 The effect of mulch treatments and liquid organic fertilizer (LOF) concentration on the leaf area of shallots plants at 45 and 60 days after planting (DAP)

Treatment	Leaf area (cm^2/clump) DAP	
	45	60
Mulch		
M0 (without mulch)	406.41[a]	359,43
M1 (mulch)	435.73[b]	377,35
HSD 5%	5.54	tn
LOF concentration		
P0	369.05[a]	323,77[a]
P10	405.78[b]	359,96[b]
P15	450.52[c]	388,93[C]
P20	458.94[c]	400,89[C]
HSD 5%	14.90	13.20
CV%	7.08	7.16

Note: Numbers accompanied by the same capital letters in the same column and the same lowercase letters in the same row indicate no significant difference based on the Honest Significant Difference (HSD) 5% test. CV = Coefficient of Variation; DAP = Days after planting; and LOF = Liquid organic fertilizer.

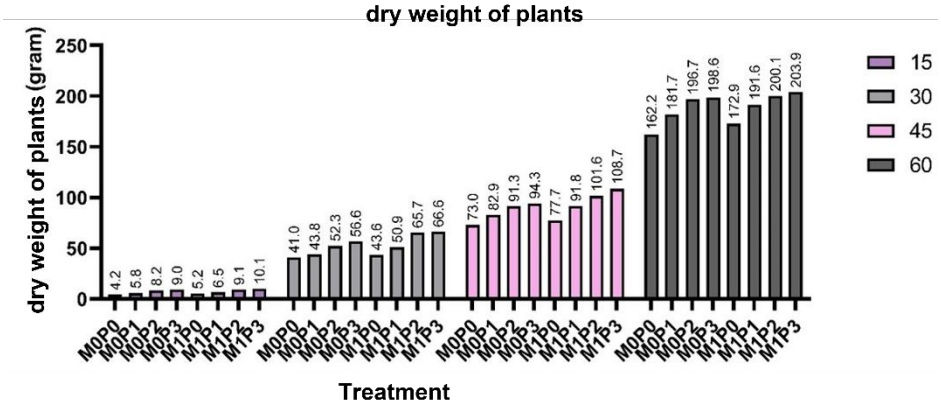

Figure 3 Shallot's dry weight parameters at the treatment combinations of mulch (M1), without mulch (M0) with the liquid organic fertilizer concentration (LOF) concentration at 15 to 60 days after planting (DAP).

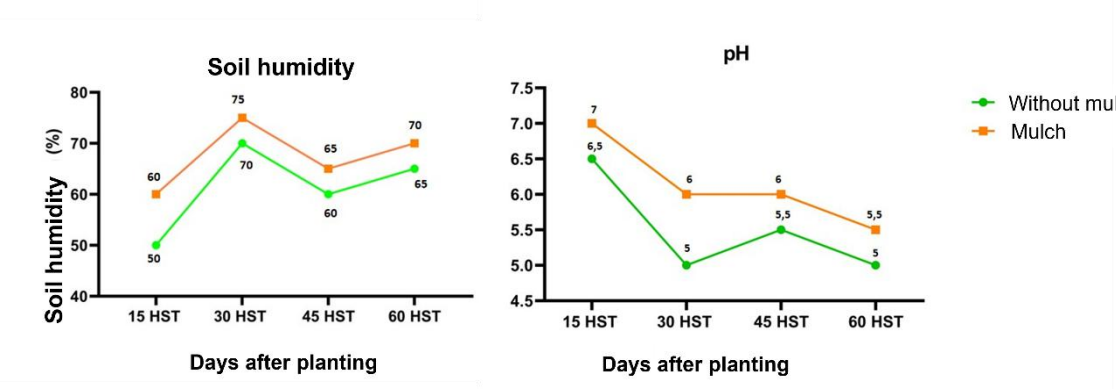

Figure 4 Soil humidity dan pH at 15 to 60 days after planting (DAP).

roots can grow deeper and wider, thereby increasing the volume of soil explored. This allows roots to absorb more nutrients, even though plastic mulch does not directly add nutrients. Moisture stability also improves fertilizer dissolution around the root zone, resulting in more efficient nutrient uptake (Gaitanis 2023).

The root fresh weight increased by 33.33% compared to that of the control without mulch at P20. Meanwhile, in the treatment without mulch, root fresh weight increased by 43.94% compared with that in the control P0. There was no interaction between LOF and M on the fresh weight of shallot roots per clump at 15

and 30 days after planting (DAP) but an interaction was observed at 45 and 60 days after planting (Figure 5) (Table 5) (Table 6). This is because, at 15 days after planting, the plants had not yet optimally absorbed nutrients. Meanwhile, 30 days after planting, they are still in the vegetative growth stage towards generative growth (Amanda and Yuniarti, 2020). Therefore, this transition period also requires plants to adapt and organize the distribution of nutrients required for growth and development. The same results were obtained by Zuliati (2020), who found that roots reached their highest weight when entering the harvest age. The average fresh weight of shallot roots per plant in all treatments at 15–60 days after planting increased with increasing LOF concentration.

The growth of roots due to auxin hormones such as Indole Acetyl Acid (IAA) in KILAT LOF, a growth stimulant, can optimize tissue formation in various plant organs and systems, such as shoots and roots, and enhance plant physiological processes and nutrient uptake (Hidayati 2022). These results are also supported by the continued increase in phosphorus

Table 4 The Effect of mulch treatments and LOF concentrations on the dry weight of shallots at harvest age (60 DAP)

Mulch (M)	Dry weight of shallots (g/clump)			
	LOF Concentration (P)			
	P0	P10	P15	P20
M0	v a A	12,9[a] A	15,6[B] A	17,6[b] A
M1	12.3[a] A	16,9[b] B	19,1[Bc] B	20,0[c] B
HSD 5%	2.34			
CV (%)	6.26			

Note: Numbers accompanied by the same capital letters in the same column and the same lowercase letters in the same row indicate no significant difference based on the Honest Significant Difference (HSD) 5% test. CV = Coefficient of Variation; DAP = Days after planting; and LOF = Liquid organic fertilizer.

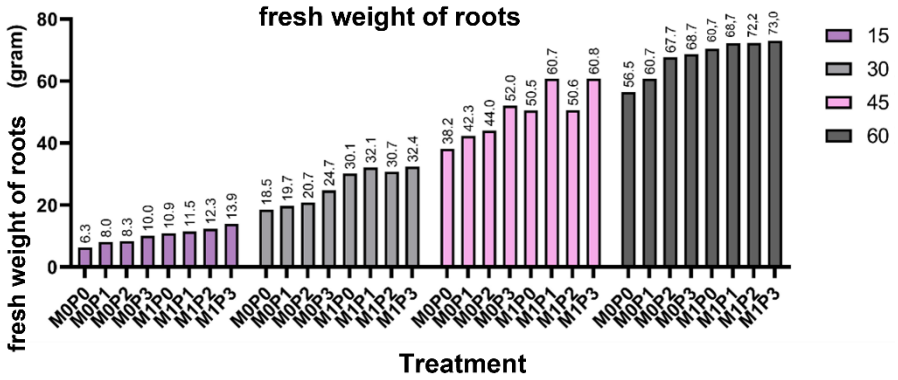

Figure 5 The results of shallot's root fresh weight parameters at the treatment combinations of mulch (M1), without mulch (M0) with the liquid organic fertilizer concentration (LOF) concentration at 15 to 60 days after planting (DAP).

Table 5 Effect of mulch treatments and LOF concentrations on fresh weight of roots of shallot plants aged 45 DAP

Mulch (M)	Fresh weight of roots (g/clump)			
	LOF concentration (P)			
	P0	P10	P15	P20
M0	3.6[A] A	3.7[a] A	3,8[A] A	4,3[a] A
M1	3.7[A] A	4.7[ab] A	6,1[Bc] B	6,6[C] B
HSD 5%	1.76			
CV (%)	16.36			

Note: Numbers accompanied by the same capital letters in the same column and the same lowercase letters in the same row indicate no significant difference based on the Honest Significant Difference (HSD) 5% test. CV = Coefficient of Variation; DAP = Days after planting; and LOF = Liquid organic fertilizer.

nutrient uptake data in line with the increasing LOF concentration, as phosphorus plays a crucial role in root growth.

Nitrogen plays a role in the formation of enzymes and chlorophyll, which are required for photosynthesis. The results of the LOF treatment in this study showed a 16% increase in N nutrient uptake as the LOF dose increased. However, both mulch (M1) and non-mulch (M0) treatments at each LOF dose showed similar absorption results. In the P10 and P20 treatments, absorption with mulch (M1) was slightly higher than that in the non-mulch (M0) treatment. According to Firmansyah and Sumarni (2013), nitrogen nutrients in the form of ammonia and others can be converted into nitrate molecules and cause a decrease in soil pH because the nitrification process produces hydrogen ions that have the potential to increase soil acidity (Figure 6). Although N uptake was suboptimal, it still increased with the addition of LOF, which is also in line with the results of leaf development, which became wider with increasing LOF concentration, especially in the P20 treatment.

The results of P nutrient absorption showed that mulching (M1) can increase 76,03% P nutrient absorption in shallot plants compared to the treatment without mulch (M0) at each LOF concentration. Even at a low LOF concentration (10 ml), the highest absorption occurred in the LOF P20 treatment with mulch (M1), which was 1.95% (Figure 6). This proves that the application of liquid organic fertilizer can increase the ability of shallots to absorb phosphorus nutrients in the soil. Phosphorus contributes to cell division and root development. P nutrients can encourage the formation of flowers and lateral roots, trigger the differentiation process, and form fruit and seed albumin (Kurniawan 2025). The highest potassium uptake was found in the 20 mL L^{-1} LOF treatment with mulch (M1) at 1.31%. The application of mulch and LOF in this study increased potassium uptake (Figure 6).

Table 6 The effect of mulch treatments and LOF concentration on the fresh weight of shallot's roots at harvest age (60 DAP).

Mulch (M)	Fresh weight of roots (g/clump)			
	LOF concentration (P)			
	P0	P10	P15	P20
M0	3.6^{A} A	3.7^{a} A	3,8^{a} A	4,4^{a} A
M1	3.7^{A} A	4.8^{ab} A	6,1^{bc} B	6,6^{c} B
HSD 5%	1.64			
CV (%)	15.06			

Note: Numbers accompanied by the same capital letters in the same column and the same lowercase letters in the same row indicate no significant difference based on the Honest Significant Difference (HSD) 5% test. CV = Coefficient of Variation; DAP = Days after planting; and LOF = Liquid organic fertilizer.

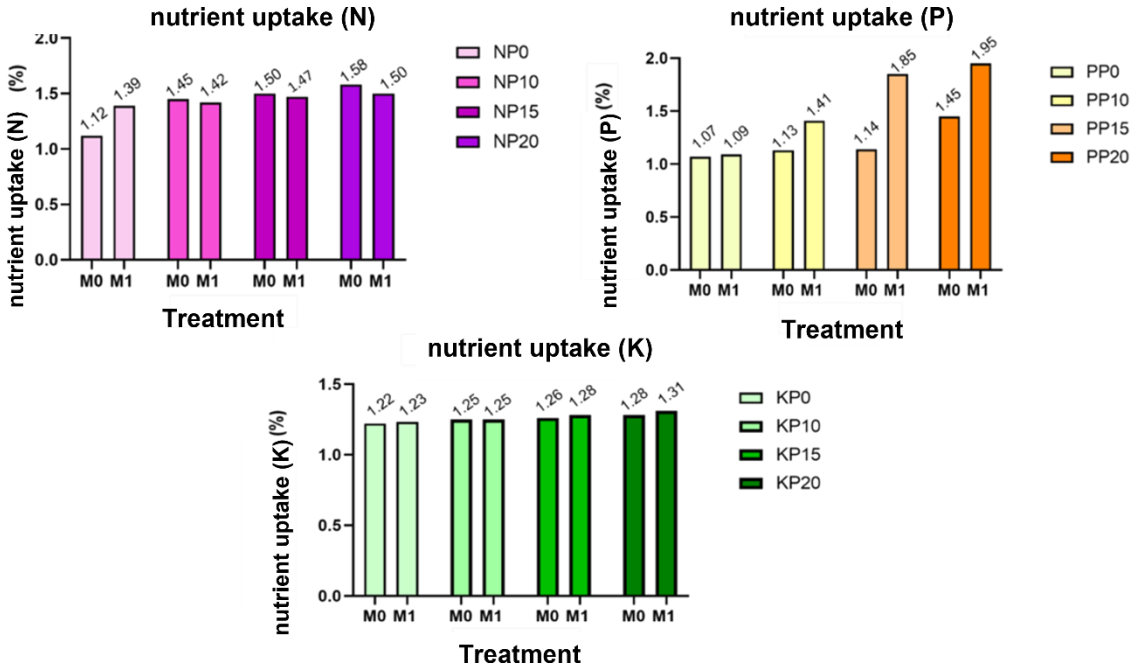

Figure 6 Absorption N, P, and K of shallots parameters at the treatment combinations of mulch (M1), without mulch (M0) with the concentration variation of Liquid organic fertilizer concentration (LOF).

Optimal phosphorus absorption can support root weight. Although neither treatment significantly affected fresh weight at 15 and 30 days after planting, there was a significant interaction between the two treatments at 45 and 60 days after planting. This shows that a higher concentration of LOF results in a higher nutrient uptake capability by the roots and increases growth parameters, such as plant length, leaf development, and plant dry weight. Furthermore, these results prove that the use of mulch can increase phosphorus nutrient uptake in shallots. Potassium plays a role in many plant metabolic processes, such as respiration, photosynthesis, stomatal regulation, sugar translocation in protein and starch synthesis, enzyme cofactor, and resistance to pests and diseases.

In tuber crops such as shallots, potassium is needed at higher levels than other nutrients and can help tissue growth and produce bulbs (Kurniawan, 2025). According to Alfian *et al.* (2015), potassium can increase bulb diameter, number of bulbs per clump, and fresh weight of shallot bulbs. The results of K nutrient uptake measurements at 50 days after planting with mulch (M1) were higher 1,81% than without mulch (M0) at each LOF concentration. These data indicate that mulch plays an important role in increasing Kalium uptake by shallots.

The Interaction Effect of Mulch and LOF Concentration on Shallot Yields

The LOF concentration of P20 increased the tuber fresh weight by 24.13%. Meanwhile, the treatment without mulch (M0) at P20 showed a 29.10% increase in tuber fresh weight per clump compared to P0. ANOVA also showed an interaction at 60 DAP. In the LOF P15 and P20 treatments using mulch (M1), no significant differences were observed. Overall, the data showed that the higher the LOF content, the greater the fresh weight of the shallot bulbs.

According to Napitulu (2010), the large amount of water stored in all plant organs, including bulbs, is due to the optimal absorption of nitrogen nutrients. These results are also supported by data on N absorption, which increased with the use of 10 mL L^{-1} LOF and further increased with the use of 20 mL L^{-1}LOF. Therefore, the greater the number of leaves formed and the wider the leaves, the higher the fresh weight of the bulb (Novatriana and Hariyono 2020). This data supports the results of bulb weight, which is directly proportional to the number of leaves formed. These results were similar to those of Arham (2012), who showed an effect and interaction between the use of LOF and mulch on the fresh weight of shallot bulbs.

Dry tuber weight per hill increased by 30.85% in the P20 treatment compared to the non-mulching treatment. In contrast, in the non-mulching treatment, P20 resulted in a 44.61% increase in dry tuber weight per hill compared to the P0 control. ANOVA showed an interaction at 60 DAP (Figure 7). The formation of shallot bulbs is made from the union's leaf to form stems, which then undergo changes in function and shape to become larger. Shallot bulbs are formed from layers of enlarged leaves (Uke *et al.* 2015). LOF contains potassium, which is important for bulb enlargement. According to Napitulu (2010), potassium is essential for the formation, elongation, and enlargement of bulbs. Shalihah's (2024) research also showed that the use of organic fertilizer significantly affected the dry weight of shallot bulbs and also their fresh weight.

The highest dry weight of shallot bulbs was obtained from the 20 mL L^{-1}LOF treatment (P20) with mulch (M1), which was 82.7 g. The treatment without mulch showed no significant difference between the LOF P15 and P20 treatments (Table 7) (Table 8) because every plant has an optimal nutrient dose required for its growth. Overall, the dry weight of shallot bulbs continued to increase with increasing LOF concentration. Weight loss represents the amount of water lost due to the drying process or transpiration and the decomposition of glucose into CO2 and H2O in small amounts that evaporate into the air (David 2022).

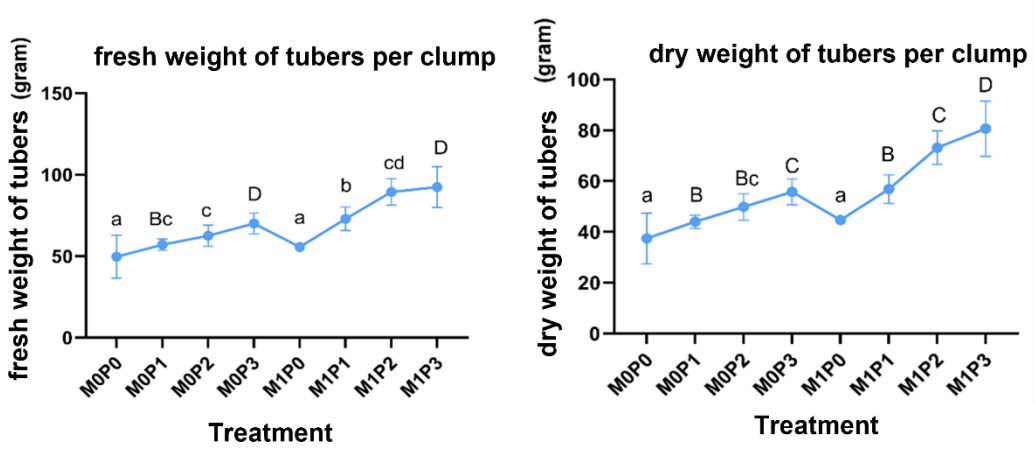

Figure 7 The effect of interaction between M and P on the weight and fresh weight at 60 days after planting (DAP).

Table 7 Effect of mulch treatments and LOF concentrations on fresh weight of bulbs per clump of shallot bulbs at harvest age (60 DAP)

Mulch (M)	Fresh weight of bulbs per clump (g/clump)			
	LOF concentration (P)			
	P0	P10	P15	P20
M0	49.7[a] A	57.1[ab] A	62,5[ab] A	70,1[b] A
M1	55.6[a] A	73.0[ab] A	89,5[bc] B	92,4[c] B
HSD 5%	17.43			
CV (%)	10.69			

Note: Numbers accompanied by the same capital letters in the same column and the same lowercase letters in the same row indicate no significant difference based on the Honest Significant Difference (HSD) 5% test. CV = Coefficient of Variation; DAP = Days after planting; and LOF = Liquid organic fertilizer.

Table 8 Effect of mulch treatments and LOF concentration on bulb dry weight per clump of shallots at harvest age (60 DAP)

Mulch (M)	Bulb dry weight per clump (g/clump)			
	LOF concentration (P)			
	P0	P10	P15	P20
M0	37.4[A] A	44.0[Ab] A	49.8[ab] A	55,8[b] A
M1	44.7[A] A	56.8[A] A	73.2[b] B	80,7[B] B
HSD 5%	14.03			
CV (%)	10.69			

Note: Numbers accompanied by the same capital letters in the same column and the same lowercase letters in the same row indicate no significant difference based on the Honest Significant Difference (HSD) 5% test. CV = Coefficient of Variation; DAP = Days after planting; and LOF = Liquid organic fertilizer.

Tuber weight loss decreased by 14.16% in the mulch treatment compared to the unmulched treatment. In the M0 treatment, the P20 concentration reduced weight loss by 21.48% compared to the P0 co ntrol. The lowest percentage of bulb weight loss was not significantly different between the P15 and P20 treatments (Figure 8). In P15, the use of mulch successfully reduced the percentage of bulb weight loss from 20.4% to 16.4%. The effect of mulch was greatest in the P20 treatment, with the percentage of bulb weight loss decreasing from 20.2% to 15.7%. Overall tuber weight is also significantly influenced by early plant growth factors during the vegetative phase. Therefore, to achieve maximum yield, optimal maintenance should begin during the vegetative growth period. When the generative phase is entered, the nutrients and energy used during the vegetative phase are reduced (Kharolina 2023).

This result is supported by the fact that potassium and nitrogen are essential elements in plant metabolism, which support bulb formation and yield. Potassium acts as a catalyst in the breakdown of proteins into small amino acid molecules, as a carbohydrate constituent, regulator of carbohydrate accumulation and translocation, and enzyme activator during photosynthesis. It can also increase the size and quality of fruits and vegetables (Uke *et al.* 2015). Furthermore, LOF contains gibberellins that stimulate embryo development and germination. Cytokinin hormones play a role in cytokinesis or cell division (Hidayati 2022).

The production yield with the P20 concentration increased by 19.44% compared to that of the unmulched treatment. In the M0 treatment, the P20 concentration increased the yield by 39.65% compared to the P0 control with the interaction at 60 days after planting (DAP). Shallot production at LOF concentrations P15 and P20 was not significantly different (Figure 9). The highest yield of 14.4 tons was obtained from the 20 ml LOF treatment using mulch (M1). The results of the mulch treatment are in line with the theory that the *crown variety* of shallots has a total production potential of 12-16 tons/ha (Rjiman *et al.* 2022). The lowest weight was obtained from the control without mulch (M0) and without LOF (P0), which was 8.3 tons (Table 9). This production result is supported by the dry weight of the bulb, fresh weight of the bulb, and percentage of bulb shrinkage. Higher fresh and dry weights of the bulb increased the production yield. A lower bulb shrinkage weight indicates a decrease in the percentage of water content lost, suggesting that the tissue of the bulb has a high density. High density resulted in high bulb weight and increased shallot yield. In addition, other factors that determine the yield include cytological, morphological, physiological, chemical, and other individual factors, as well as environmental factors (Jasmin *et al.* 2013).

Treatments with and without mulch showed a significant increase in shallot production yield. However, the unmulched treatment resulted in lower shallot yields than the mulched treatment. Overall plant growth and yield are closely related to nutrient availability to support plant metabolism, as increased

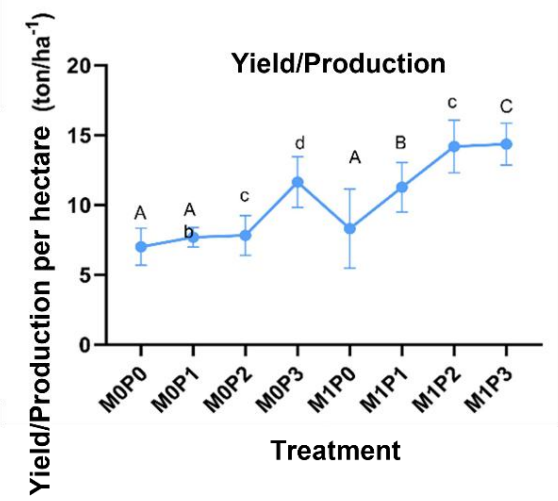

Figure 8 The effect of interaction between M and P on shallot production.

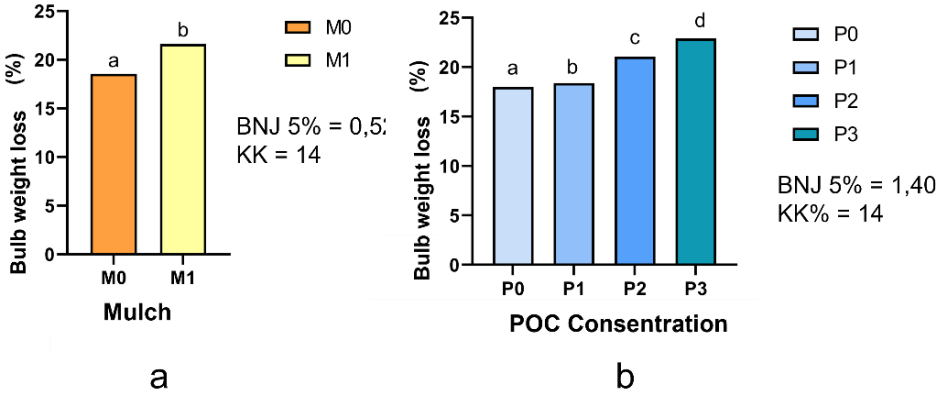

Figure 9 The effect of mulch treatment and LOF concentration on the percentage of bulb weight loss per clump of shallots at 60 Days after planting (DAP).

Table 9 The effect of mulch treatments and LOF concentration on the yield of shallots aged 60 DAP

Mulch (M)	Yield (t/ha)			
	LOF concentration (P)			
	P0	P10	P15	P20
M0	7.0^{A} A	7.7^{Ab} A	7.8^{ab} A	11.6^{B} A
M1	8.3^{A} A	11.3^{Ab} A	14.2^{b} B	14.4^{B} A
HSD 5%	4.07			
CV (%)	10.86			

Note: Numbers accompanied by the same capital letters in the same column and the same lowercase letters in the same row indicate no significant difference based on the Honest Significant Difference (HSD) 5% test. CV = Coefficient of Variation; DAP = Days after planting; and LOF = Liquid organic fertilizer.

plant metabolism positively impacts the formation of shallot bulbs (Afrita *et al.* 2025). Future research should focus on optimizing higher concentrations of LOF and exploring the use of other types of mulch to enhance growth and yield.

CONCLUSION

In terms of growth parameters, mulch treatment (M1) at the LOF P20 concentration can increase 33.33% fresh root weight, 12% dry plant weight, 6.73% leaf area, and 6.86% plant height compared to without mulch. The use of mulch increased phosphorus

absorption by 76.03% and potassium absorption by 1.18%. The P0 treatment with mulch could increase the absorption of N nutrients by 19.42% higher than the treatment without mulch, but in other LOF treatments, there was a decrease in nitrogen absorption.

The yield parameters showed that mulch treatment at the LOF P20 concentration can increase 24.13% fresh tuber weight, 30.85% dry tuber weight per clump, 14.16% tuber shrinkage weight and 19.44% harvest yield. LOF P20 provided significantly higher results than P0 for all treatments. Therefore, it can be concluded that the use of mulch can optimize the nutrient absorption provided by LOF. The recommended concentration for further research to increase shallot growth and yield is above 20 ml. Using plastic mulch in hot weather can increase plant temperature; therefore, organic mulch is recommended for summer planting.

ACKNOWLEDGMENTS

We thank all the research team members involved, as well as the Agronomy Research Program, Department of Agricultural Cultivation, Brawijaya University, which facilitated this research process.

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