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ORIGINAL RESEARCH

Effect of mulch and liquid organic fertilizer on shallot production (*Allium cepa*)

NASRULLAH[1], RINA SRIWATI [2*], SUGIANTO[3], SAMADI[4], SAID MIRZA PRATAMA[4], KEVIN RIZQULLAH EL-RYIAD[2]

[1]Department of Agrotechnology, Faculty of Agriculture, Universitas Syiah Kuala. Banda Aceh, Aceh, Indonesia.
[2]Department of Plant Protection, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh, Indonesia.
[3]Department of Soil Science, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh, Indonesia.
[4]Department of Animal Science, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh, Indonesia.

*Corresponding Author:
rinasriwati@usk.ac.id

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Abstract. Shallot (*Allium cepa*) is an economically valuable and highly nutritious crop whose productivity can be increased through optimal cultivation practices. This study investigated the combined effects of mulch and liquid organic fertilizer (LOF) on onion yield and performance. A factorial randomized block design (RCBD) was used consisting of two factors, namely mulch type (no mulch, black and silver plastic mulch, rice husk mulch, and shallot skin mulch) and LOF dosage (no LOF, 1,000 L/ha, and 1,500 L/ha). Data were analyzed using Least Significant Difference (LSD) and Duncan's Multiple Range Test (DMRT) at $\alpha = 5\%$. The application of rice husk mulch and LOF at a dose of 1,500 L/ha resulted in the highest number of bulbs, bulb diameter, wet weight, dry weight, soil microbial population, and peroxidase enzyme activity among all treatments. This study demonstrates that rice husk mulch and LOF at a dose of 1,500 L/ha can significantly enhance shallot production. Additionally, the findings indicate that the use of rice husk mulch and LOF at a dose of 1,500 L/ha can boost soil microbial population and increase peroxidase enzyme activity.

Keywords: *Liquid Organic Fertilizer, Mulch, Shallots*

INTRODUCTION

Shallot production is a crucial aspect of the agricultural sector in Indonesia, as shallots are a vital commodity used in various daily local dishes. However, shallot production often faces challenges such as pest attacks that damage the plants, unpredictable weather conditions leading to unstable growth, and poor soil quality [1]. Therefore, technological innovations and effective cultivation methods are needed to enhance the yield of this crop.

The use of mulch has been shown to significantly improve onion growth and yield by increasing soil moisture retention, regulating temperature, and suppressing weed competition. For example, black silver plastic mulch was found to optimize root development and nutrient decomposition, resulting in greater bulb diameter and biomass accumulation [2]. On the other hand, the application of liquid organic fertilizer (LOF) can provide essential nutrients for shallot plants, enhance soil fertility, and reduce dependence on synthetic chemical fertilizers that can harm the environment [3]. There is a linear relationship between the combination of mulch and the dosage of liquid organic fertilizer on shallot bulb yield. Local LOF typically contains essential macronutrients such as nitrogen (N), phosphorus (P), potassium (K), and calcium (Ca), along with organic matter and beneficial microbes. Coconut husk-based LOF, for instance, contains 1.58% N, 0.79% P_2O_5, and 1.68% K_2O, which contribute to improved plant height, leaf number, bulb diameter, and soil microbial activity. The higher the dosage, the higher the yield obtained [4]. However, the effects of using a combination of different types of mulch and local LOF dosages on shallot production still need to be analyzed.

This study aims to assess the effectiveness of a combination of mulch use and liquid organic fertilizer (LOF) dosage in increasing shallot crop production. Higher yield and quality, as well as supporting more environmentally friendly farming practices are the main suggestions of this study and serve as a reference for farmers and researchers in developing more efficient and sustainable shallot cultivation strategies.

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Figure 1. Shallot Nganjuk (Bauji), classified as *Allium cepa*

METHODOLOGY

This research was conducted from August to November 2024 in Paloh Batee Village, Lhokseumawe City, Aceh Province, Indonesia. Paloh Batee Village, Muara Dua Sub-district, Lhokseumawe City, is located at coordinates 5.16°N and 97.13°E, with an elevation of about 16 meters above sea level. Soil microbial population observations were carried out in the Plant Pathology Laboratory, Faculty of Agriculture, Universitas Syiah Kuala, while peroxidase enzyme activity was analyzed in the Seed Science and Technology Laboratory and the Food and Agricultural Product Analysis Laboratory.

Research design

The research used a factorial randomized group design. The two factors evaluated were the type of mulch, which consisted of four levels: no mulch, black and silver plastic mulch, rice husk mulch, and onion skin mulch. The second factor was the dose of NASA liquid fertilizer, which consisted of three levels: no LOF, LOF at a dose of 1,000 L/ha, and LOF at a dose of 1,500 L/ha. These two factors resulted in twelve treatment combinations with three replications, resulting in a total of 36 experimental units. Plastic mulching materials have a greater importance than the organic ones to control soil environment and increase crop yield [5],[6]. Meanwhile, NASA POC rich in nitrogen, phosphorus, potassium, calcium, and beneficial microbes at doses (3 ml L-1 dose) is able to accelerate the generative phase of plants [7]. These references informed the selection of mulch varieties and LOF doses in our factorial design to assess their synergistic impact under field conditions. The shallot variety used in this study is Nganjuk (Bauji), classified as *Allium cepa*.

Before planting, beds with a height of 30 cm were prepared. Two weeks before planting, manure was applied at a dose of 10 t/ha as base fertilizer. Mulch was applied one week before planting. Shallots were planted in the experimental plots with a spacing of 15 cm x 20 cm. NASA Liquid organic fertilizer was applied to shallot plants three times, at the age of 15, 30, and 45 days after planting with the dosage according to the treatment.

The Parameters observed included plant wet and dry weight, soil microbial population, and peroxidase enzyme activity. These measurements were taken at harvest time, which was at the age of 90 days after planting, when the shallot shoots began to turn yellow and fall off. Wet and dry weights were determined using a digital analytical balance, while the soil microbial population was measured using serial dilution and petri dish methods. Peroxidase enzyme activity was assessed using spectrophotometric analysis at 470 nm**.**

Data analysis

Observation data were analyzed with the F test. If the analysis of variance (ANOVA) test shows a real effect, further tests are carried out with the smallest real difference (BNT) 5% and Duncan Multiple Range Test (DMRT) at the 5% level.

RESULTS AND DISCUSSION

Onion Production

Based on the ANOVA results, there was no interaction between mulch type and LOF dosage on shallot production. However, individually, both factors had a very significant effect on the wet weight and dry weight of shallot plants, which showed clear differences between treatments (Table 1).

Rice husk mulch treatment gives the best effect on the number of bulbs, bulb diameter, wet weight and dry weight of shallot bulbs which are significantly different from other mulch types and control (Table 1). The application of rice husk mulch is believed to reduce soil water evaporation, thereby maintaining soil moisture and water availability. This practice also provides additional nutrients and prevents weed growth, which can help increase the diameter of shallot bulbs. The use of rice husk mulch improves infiltration and moisture retention, creating an environment conducive to optimal nutrient uptake through transpiration and enhancing the rate of photosynthesis [5],[8]. Adequate water availability allows shallot bulbs to develop optimally, resulting in higher wet weight. The use of rice husk mulch in shallot cultivation not only contributes organic matter to the soil, but also effectively suppresses weed growth, thereby enhancing crop development [9]. When compared with other shallot varieties, such as Allium cepa cv. Nasik Red, mulching also showed the same positive effects. For example, white plastic mulch significantly increased bulb diameter (7 mm), bulb weight (117.5 g), and overall yield (27 tons/ha) in Nasik Red onion under winter conditions in Nepal [10].

In addition, the use of rice husk mulch can also provide additional organic matter to the soil [11] and can also inhibit weed growth so that plants can grow and develop optimally [5]. Rice husk contains carbohydrates (37.04%), crude protein (1.85%), fiber (25.74%), ash (23.39%), and essential minerals such as calcium, magnesium, potassium, phosphorus, iron, zinc, and manganese. These nutrients contribute to soil fertility and plant health when rice husk is used as mulch [12]. Moreover, their high lignin content contributes to slow decomposition, ensuring a sustained release of nutrients and improved soil structure over time. Research results [13] reported that the use of organic mulch of Jatropha leaves at a dose of 5 tons ha-1 before planting in the field

Table 1. Effect of mulch and liquid organic fertilizer (LOF) on shallot production

Treatments	Number of Bulbs	Diameter of bulbs (mm)	Wet weight (g)	Dry weight (g)
Without mulch	3.92+0.67 d	14.30+2.70 d	19.32+2.11 d	18.61+5.78 d
Black and silver plastic mulch	4.42+0.84 c	16.07+2.32 c	21.61+4.05 c	12.74+3.04 c
Rice husk mulch	7.28+1.15 a	22.90+2.63 a	40.13+7.28 a	31.33+6.75 a
Shallot skin mulch	6.19+0.63 b	21.08+2.45 b	32.42+3.92 b	26.62+4.44 b
LSD 5%	**0.39**	**0.95**	**2.88**	**2.29**
Without LOF	4.65+1.38 c	16.03+4.32 c	23.95+6.49 c	16.44+6.46 c
LOF 1,000 L/ha	5.56+1,41 b	19.38+3.68 b	29.33+10.18 b	23.87+9.03 b
LOF 1,500 L/ha	6.15+1.71a	20.35+3.96 a	31.83+10.72 a	26.66+7.89 a
LSD 5%	**0.34**	**2.49**	**2.49**	**1.99**

Note: Numbers followed by different letters in the same column indicate significantly different based on the Least Significant Difference (LSD) test at the 5% level.

prevented the adverse effects of water stress on wheat by maintaining the moisture and water status of plants. The use of mulching with organic matter on agricultural land is the oldest method of soil water conservation that helps maintain soil temperature within the root zone by improving thermal and moisture conditions around the plant [14]. Meanwhile, another research report states that plastic mulching systems have drawbacks, such as reduction of soil organic matter and microplastic pollution, which hinder the widespread adoption of cultivation using plastic mulch in China [15].

Research findings indicate that rice husk mulch had a significant effect on the number of bulbs, bulb diameter, wet weight, and dry weight of shallot bulbs compared to other types of mulch. This is supported by the results of research [16] which reported that rice husk mulch was most effective in increasing the growth and yield of *Ocimum sanctum* plants compared to sawdust mulch. The improvement in growth and yield was attributed to the ability in growth and yield is due to the ability of rice husk mulch to improve the physico-chemical properties of the soil as it decomposes, thus making nutrients more readily available to plants.

This study showed that mulching significantly affected the dry weight of onion bulbs. Organic and plastic mulches improved soil moisture retention and temperature regulation, creating optimal conditions for photosynthesis and nutrient uptake. This increases biomass accumulation and bulb development. Other studies reported, silver black plastic mulch combined with NPK fertilizer at a dose of 30 g/plot produced the highest dry bulb weight of 225.25 g per sample [17]. Similarly, rice straw mulch paired with chicken manure at a dose of 20 tons/ha can increase dry tuber weight and tuber volume [18]. These findings confirm that mulch type plays an important role in increasing shallot productivity under field conditions. The size of the bulbs, development, and all agronomic parameters of shallots are enhanced by organic mulch[19]. With an optimal environment, plants can be more efficient in the process of photosynthesis and nutrient absorption, which ultimately increases the dry weight of the bulbs. The application of mulch from various types of organic materials, such as chopped grass and clover materials, improves plant development, growth, and also increases the yield of shallot bulbs [20].

Furthermore, the addition of organic waste such as shallot skin has not been widely studied. Considering the safer effects of this waste, further research is needed. The application of LOF significantly affected the yield and production of shallots compared to the control (without LOF). The LOF treatment at 1,500 L/ha had the best influence on the number of bulbs, bulb diameter, fresh weight, and dry weight of shallots, thus showing a significant difference with other LOF dose treatments and the control (Table 1). This is presumably because LOF contains macro and micro nutrients needed by plants. Macro nutrients such as nitrogen, phosphorus, and potassium, as well as micro nutrients such as boron, manganese, and zinc, all play a role in various physiological processes in plants, such as photosynthesis, protein formation, and root growth [21].

LOF generally contains macro and micro nutrients. The main macronutrients are nitrogen, phosphorus, and potassium which are needed in large amounts by plants to carry out important physiological processes such as photosynthesis, respiration, and growth. Maintaining a balanced nutrient supply in the soil is crucial for healthy plant growth [22].

The application of LOF results in an increase in dry weight biomass and nutrient uptake of N, P, Zn, Cu, and Fe in corn plants under water deficit conditions [23]. Liquid organic fertilization results in increased absorption of macro and micro nutrients compared to plants given mineral fertilizers [24].

The addition of LOF can improve soil quality. Research results [23] show that the application of LOF leads to an increase in soil biological properties (soil microbial respiration, soil microbial biomass, dehydrogenase activity, and the number of aerobic heterotrophic bacteria) and improvement of soil physical conditions, such as aggregate stability, hydrophobicity, and total porosity. In general, LOF improves soil conditions by improving soil physical and biological properties and reducing the negative effects of air stress [23].

Rice husk decomposes very slowly by it self, rice husk prevents weed seeds from growing on it for a long time. The hard surface of rice husk with high silicon content makes it difficult to be decomposed by bacteria [25] making rice husk an excellent choice as an organic mulch in controlling weeds. However, when the rice husk used as mulch finally decomposes, it can maintain soil moisture for a long time and protect the soil from direct sunlight. The use of rice husk has been considered as a mulch in fruit plantations that can prevent surface runoff (surface erosion), regulate soil temperature, maintain moisture, and prevent unwanted plant growth due to lack of light [26].

Rice husk mulch can improve plant growth and yield by improving soil quality including decreasing soil bulk density, increasing soil pH, adding organic carbon, increasing accessible nutrients, and removing heavy metals from the system [27]. Additionally, recycling rice husks as mulch contributes to waste reduction and promotes environmental sustainability.

Nutrients are one of the critical factors in supporting plant growth [28]. LOF is a source of nutrients and plant growth regulators (PGRs) that plants can utilize to support their growth. LOF is one source of nutrients and ZPT that can be utilized by plants to support their growth. LOF contains nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulfur (S) and magnesium (Mg). In addition, LOF also contains growth stimulants (ZPT) such as auxin, gibberellin and cytokinin. Liquid organic fertilizer (LOF) contains more varied nutrients, namely macro nutrients such as N, P and K and micro nutrients. Liquid organic fertilizers (LOF) contain a more varied array of nutrients, including macro elements such as N, P, and K, and microelements. Liquid fertilizers are more readily absorbed by plants because the compounds within them are already decomposed. It is also mentioned that liquid organic fertilizers have binding agents, allowing the fertilizer solution applied to the soil surface to be immediately utilized by plants [29].

[30] reported that the results of the analysis of liquid organic fertilizer nutrients were in accordance with the quality standards for liquid organic fertilizers, namely containing macro nutrients such as N, P and K, although sometimes the levels of N, P and K are still below the standards of the Minister of Agriculture Regulation Number 28/Regulation of the Minister of Agriculture/OT.140/2/2000, namely levels> 2%. Complete Liquid Fertilizers (PPC) or LOF are sourced from plant extracts or animal manure[31]. According to research [32], the highest nitrogen (N) content is found in vegetable liquid waste, phosphorus (P) in vegetable and fruit waste, and potassium (K) in fruit waste. As for microelements, calcium (Ca) is found in both fruit and vegetable waste, magnesium (Mg) in fruit waste, iron (Fe) in vegetable and fruit waste, zinc (Zn) in cow urine, and ammonia (NH_4) in a mixture of vegetable and fruit liquid fertilizer waste.

Complete Liquid Fertilizers (PPC) or LOF are sourced from plant extracts or animal manure [31]. Plant- and animal-based liquid organic fertilizers enhance biomass production and nutrient concentrations in citrus plants. The data presented supports the idea that liquid organic fertilizers can be successfully used as a substitute for mineral fertilizers in nutrient management of citrus trees under drip irrigation, as they improve soil chemical fertility, prevent excessive nitrate-N concentrations, enhance plant growth, and carbon fixation in plants.

Research results indicate that plants fertilized with animal liquid fertilizers exhibit higher total biomass with the development of more new organs (leaves and fibrous roots). Liquid organic fertilization increases the absorption of macro and micronutrients compared to trees given mineral fertilizers. Additionally, organic fertilization positively impacts carbohydrate content (fructose, glucose, and sucrose), especially in summer leaves. Liquid organic fertilization also increases soil organic matter content [31].

Liquid biofertilizers can reduce the use of chemical fertilizers by 15–40%. Liquid biofertilizers contain hormones that are beneficial to plants [33]. Hormones such as gibberellins, and acids such as acetic acid that increase root growth and nutrient absorption by inhibiting some harmful microorganisms and disease-causing agents [35] and indole-3-acetic acid (IAA) mainly controls plant cells [33].

These nutrients and plant growth regulators play a role in improving root development and carbohydrate content in plants [34], increasing the formation of fibrous roots and lateral roots, elongating stems, and increasing the number of internodes. They can also enhance the weight and size of plants [35].

On the other hand, shallot plants without using mulch and LOF had the lowest yield compared to other treatments. This is suspected to be due to the absence of additional materials that can maintain soil moisture, water, sufficient nutrients, and organic matter. Moreover, the high number of weeds that grow is also suspected to have a direct and indirect negative impact on the plants. The competition between the plants and weeds for resources used in production, such as water, light, nutrients, and carbon dioxide [36], is one factor. Furthermore, weeds have an indirect effect by creating a microclimate that supports the spread of diseases to the plants, and can serve as hosts for pest insects, and possess allelopathic compounds that can inhibit the growth of surrounding plants [37].

Soil microbial population

Based on the results of ANOVA, there was no interaction between the factors of mulch type and LOF dose on soil microbial population. But individually, both factors showed a significant effect on the wet weight and dry weight of shallot plants and showed significant differences between treatments (Table 2).

Rice husk mulch was the treatment with the highest microbial population (bacteria and fungi) among all treatments. his is likely because rice husk mulch affects the presence of soil microbes by creating a suitable environment for them to thrive. The use of rice husk mulch can reduce soil temperature by more than 10°C compared to bare soil, so that soil moisture and soil moisture content are maintained [38]. Optimal soil moisture affects the continuity of the soil microbial respiration process and has an impact on the soil microbial population [39]. Additionally, the use of organic materials can also affect the presence of soil microbes [40].

LOF contains organic matter and nutrients, which cause soil microbes to gather and utilize the available organic material and nutrients for their metabolic processes. This

Table 2. Effect of mulch and liquid organic fertilizer (LOF) on soil microbial population

Treatments	Soil microbial population (CFU/mL)	
	Fungi x10^5	Bacteria x10^5
Without mulch	15.92±2.59 c	39.91±10.38 c
Black and silver plastic mulch	13.92+2.41 d	24.60±8.35 d
Rice husk mulch	20.74±2.14 a	54.46±10.11 a
Shallot skin mulch	18.59±1.21 b	46.72±7.54 b
LSD 5%	**1.06**	**4.28**
Without LOF	15.13±3.06 c	30.99±11.99 c
LOF 1,000 L/ha	17.57±2.90 b	42.12±13.32 b
LOF 1,500 L/ha	19.17±2.93 a	47.41±13.90 a
LSD 5%	**0.92**	**3.70**

Note: Numbers followed by different letters in the same column indicate significantly different based on the Least Significant Difference (LSD) test at the 5% level.

Table 3. Effect of mulch and liquid organic fertilizer (LOF) on enzyme activity peroxidase activity of shallot plants

Treatments	Absorbance value (U/g)
Without mulch and without LOF	0.733±0.001 k
Without mulch and LOF 1,000 L/ha	1.526±0.003 h
Without mulch and LOF 1,500 L/ha	2.195±0.002 e
Black and silver plastic mulch and without LOF	0.37±0.001 l
Black and silver plastic mulch and LOF 1,000 L/ha	1.172±0.001 j
Black and silver plastic mulch and LOF 2,00 L/ha	1.412±0.010 i
Rice husk mulch and without LOF	2.104±0.005 f
Rice husk mulch and LOF 1,000 L/ha	2.234±0.010 b
Rice husk mulch and LOF 1,500 L/ha	2.496±0.009 a
Shallot skin mulch and without LOF	1.644±0.006 g
Shallot skin mulch and LOF 1,000 L/ha	2.212±0.012 d
Shallot skin mulch and LOF 1,500 L/ha	2.218±0.010 c

Note: Numbers followed by different letters in the same column indicate significant differences based on the Duncan's Multiple Range Test (DMRT) at the 5% level.

is in line with the statement by [41], that the use of LOF can alter the structure of the soil microbial community and increase the soil microbial population.

Peroxidase enzyme activity

According to the ANOVA results, there is an interaction between the factors of mulch type and LOF dosage on peroxidase enzyme activity. Additionally, both the mulch type and LOF dosage factors show significant differences between treatments (Table 3).

Peroxidase is an enzyme that has an important role in various processes in the plant body, such as oxidizing phenolic compounds, lignification and other metabolites to support plant resistance to pathogens and auxin metabolism [42]. The use of rice husk mulch and LOF dose of 1,500 L/ha showed the highest peroxidase results among all treatments. The high peroxidase enzyme activity in this treatment is thought to be related to the addition of organic matter to the plants. The addition of organic matter can enhance physiological, chemical, and biological processes within plant cells and the formation of proteins, leading to an increase in peroxidase enzyme concentration [43]. One example of this process is the increase in bulb diameter through cell wall thickening (lignification). Peroxidase activity is associated with the production of phenolic compounds and the lignification mechanism in plant cell walls [42]. Strong cell walls can prevent pathogen entry during infection [44]. Simultaneously, the use of rice husk mulch and LOF at 1,500 L/ha resulted in the largest shallot bulb diameters. At the same time, the use of rice husk mulch and LOF 1,500 L/ha had the highest shallot bulb diameter. This indicates that the lignification process occurred in the shallot bulbs and is related to the high peroxidase activity. Peroxidase enzymes play a vital role in plant biology by helping plants manage oxidative stress and protect against cell damage.

CONCLUSION

Individually, mulch and LOF dosages have a significant effect on the number of bulbs, bulb diameter, bulbs wet weight, bulbs dry weight, and soil microbial population, while the combination of mulch and LOF doses gave a very significant effect on peroxidase enzyme activity. Specifically, the combination of rice husk mulch and LOF at a dosage of 1,500 L/ha resulted in the highest peroxidase activity. The results of this research indicate that cultivating shallots using organic mulch and LOF can improve the quality and quantity of shallots and enhance disease resistance. The synergistic effect of LOF and organic mulch may stimulate peroxidase activity, leading to improved systemic resistance and stress tolerance in shallots. In other words, using rice husk waste as mulch provides numerous benefits for shallot cultivation .In other words, using rice husk waste as mulch provides numerous benefits for shallot cultivation.

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