

Improving Shallot Yield Performace through Applications of Vermicompost and Mycorrhiza with Low Doses of Synthetic Fertilizer

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Abstract: The objective of this study was to reduce the use of synthetic fertilizers on shallot production by application of vermicompost and mycorrhiza. The study was arranged by using a factorial Randomized Completely Block Design. The factors of vermicompost dose viz. 0, 20 and 40 t ha⁻¹, the dose of mycorrhiza viz. 0, 10, and 20 g plant⁻¹ and the dose of synthetic fertilizer based on recommendation dose viz. 100% (138 kg N ha⁻¹, 72 kg P₂O₅ ha⁻¹ 180 kg K₂O ha⁻¹), 75% (103 kg N ha⁻¹, 54 kg P₂O₅ ha⁻¹, 135 kg K₂O ha⁻¹) and 50% (69 kg N ha⁻¹, 36 kg P₂O₅ ha⁻¹, 90 kg K₂O ha⁻¹) were tested. The variables observed included the number of bulbs, fresh weight of bulbs and bulbs diameter. All variables were observed at harvest time. The use of 50% synthetic fertilizer along with 40 t ha⁻¹ of vermicompost and 20 g plant⁻¹ of mycorrhiza gained equal number of bulbs, fresh weight of bulbs and diameter of shallot bulbs compared to application of 100% synthetic fertilizer only. Therefore, the reduction of 50% synthetic fertilizer with application of vermicompost and mycorrhiza could support sustainable of agriculture on the production of shallot.

Keywords: mycorrhiza; shallot; synthetic fertilizer; vermicompost

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1. Introduction

Shallot is one of the main commodities as the priority for vegetable development in Indonesia. The demand for shallot increases due to the increasing needs of society, the shallot processing product industry, and market developments (Arrofiq et al., 2021; Central Bureau of Statistics, 2021). In 2019, Indonesia's shallot consumption reached 27.72 kg/capita/year, so with a population of 270.20 million people, Indonesia's shallot demand reached around 7.48 million tons per year. Meanwhile, Indonesia's shallot production in 2020 reached 1.8 million tons only (Central Bureau of Statistics, 2019, 2021). Therefore, shallot production in Indonesia must be increased to fulfill consumers demand.

Effort to increase shallot production have triggered increasingly by intensive use of synthetic fertilizers. The continuous use of synthetic fertilizers cause land degradation. According to Agbede

(2010), excessive use of synthetic fertilizers causes soil, air, and water pollution, damage to the physical properties of soil, accumulation of toxic chemicals in waterways, and loss of biodiversity. Continuous application of synthetic fertilizers causes absorb and accumulate heavy metals in plant tissue (Abdiani et al., 2020; Maqbool et al., 2022). Synthetic fertilizers causing degradation of soil structure and decreased soil aggregation (Islam et al., 2017). Excessive use of synthetic fertilizers causes environmental damage and a decline in beneficial organisms (Kakar et al., 2019) and impact on environmental pollution and threatens human health (Sharma, Singhvi, 2017).

Some efforts have been conducted to reduce synthetic fertilizers, including adding vermicompost and mycorrhiza. Vermicompost is an environmentally friendly organic fertilizer (Aritonang, Sidauruk, 2020), rich in nutrients and soil amendments (Nahar et al., 2021) and improve the physical, chemical, and biological properties of soil (Purnawanto et al., 2021), as well as increase water-holding capacity (Mahmoud, Gad, 2020). Mycorrhiza is an endophytic fungus that can absorb nutrients for plants through the formation of hyphae networks in the soil (Fall et al., 2022) so that plants can increase their uptake of nitrogen, phosphorus, and potassium (Anderson et al., 2018).

Many studies have been carried out on the use of vermicompost and mycorrhiza in shallot cultivation. Arifah et al. (2021) reported that the use of vermicompost made from soybean hulls at 15 t ha⁻¹ increased shallot yields. Application a 15% vermicompost tea increased the number and weight of shallot bulbs (Guzman, Gonzales, 2023). Hasanudin et al. (2021) also reported that vermicompost combined with cow biourine increased the growth and yield of shallots. Application of vermicompost of 40 t ha⁻¹ at 10 days before planting increased the number and weight of shallot bulbs (Setyowati et al., 2023). Meanwhile, Siregar and Ulpah (2024) mentioned that 50 t ha⁻¹ vermicompost combined with 300 kg ha⁻¹ NPK 16:16:16 fertilizer produced 14.23 bulbs. The use of mycorrhiza 2.5 g plant⁻¹ in shallot cultivation reduced the use of N, P, and K fertilizer by 50% (Hazra et al., 2021). Application of mycorrhiza in soil+organic fertilizer media (50:50 ratio) increased the growth of shallot by 48.9% compared to soil+tailings (50:50 ratio) (Natawijaya et al., 2022), while mycorrhiza combined with *Trichoderma* sp showed shallot growth that was no different from application of mycorrhiza only (Hidayat et al., 2019).

While many studies have explored the individual benefits of vermicompost and mycorrhiza in shallot cultivation, there remains a significant knowledge gap regarding their combined effects. Specifically, there is a need to understand how applying both can reduce the reliance on synthetic fertilizers without compromising crop yields. Addressing this gap presents an opportunity to develop a more sustainable approach to enhancing shallot productivity while preserving soil quality and health. The aim of this study is to evaluate the impact of using vermicompost and mycorrhiza in conjunction with low doses of synthetic fertilizers on shallot yields. It is hoped that the findings will contribute to the development of more environmentally friendly agricultural practices and support long-term agricultural resilience.

2. Materials and Methods

The study was conducted at the Experimental Garden of the Faculty of Agriculture and Fisheries, the Universitas Muhammadiyah Purwokerto, located in Karangasari Village, Kembaran District, Banyumas Regency. The research was arranged using a Randomized Complete Block Design with three replications. The treatments given consisted of three factors. The first factor was the vermicompost dose viz. 0 t ha⁻¹ (V0), 20 t ha⁻¹ (V1) and 40 t ha⁻¹ (V2). The second factor was the dose of mycorrhiza viz. 0 g plant⁻¹ (M0), 10 g plant⁻¹ (M1), and 20 g plant⁻¹ (M2). The third factor was the dose of synthetic fertilizer based on recommendation viz. 100% (P1), 75% (P2) and 50% (P3) were tested. The synthetic fertilizer recommendation was 138 kg N ha⁻¹, 72 kg P₂O₅ ha⁻¹ and 180 kg K₂O ha⁻¹. The vermicompost used in this study was mushroom substrate waste, which contained 1.36% nitrogen (N), 1.61% phosphorus (P₂O), 3.06% potassium (K₂O), 1.77 × 10⁶ N-fixing bacteria and 1.05 × 10⁶ phosphate-solubilizing bacteria.

Seven kilograms of soil (30% soil water content) mixed with vermicompost and mycorrhiza (according to treatment) then put into a polybag with size of 35 cm x 35 cm and then kept for seven days. Shallot seeds (Bima variety) were selected as uniform in size and weight in average. Each

polybag was planted with one shallot bulb. Before planting, the ends of the onion bulbs were cut by 1/3 part and then air-dried for 24 hours. Next, the cutted bulb were planted in polybag. Synthetic fertilizers of phosphorus and potassium fertilizers were applied once at sowing time, while nitrogen was applied at sowing time and 30 days after sowing. The dose of fertilizers were applied according to the treatment.

The components of shallot yield were observed at the end of the research, consisting of the number of bulbs, fresh weight of the bulbs, and diameter of the bulbs. The number of bulbs is calculated based on all the shallot bulbs formed. Observation of the fresh weight of bulbs was carried out by weighing all the tubers formed using a digital scale. Diameter of bulbs was measured using a caliper at the largest diameter of bulbs. All observations were made at harvest. Harvesting of shallots was taken at 60 days after sowing (das), with the characteristics of the leaves being 70-80% drooping, yellowing, and the neck of the stem drooping, the bulbs looking densely filled, some of which are sticking out of the ground with the color of the skin shiny and red.

The effect of treatment on shallot yield was analyzed using analysis of variance ($\alpha \leq 0.05$) with the Statistical Product and Service Solutions (SPSS) 25 program. Multiple comparisons for treatments with a significant effect were using Duncan's Multiple Range Test (DMRT) with $\alpha \leq 0.05$.

3. Results (or Results and Discussion)

Based on the analysis of variance, it shows that the application of vermicompost, mycorrhiza, and synthetic fertilizers had a significant effect on the number of shallot bulbs. Shallots that were given 50% synthetic fertilizer without being followed by vermicompost and mycorrhiza only produced 5.8 bulbs. Meanwhile, if given 40 t ha⁻¹ of vermicompost and 20 g of plant⁻¹ mycorrhiza, it can produce 8.9 bulbs. There was an increase in the number of bulbs by 53,4%. These results are not significantly different from the use of 100% synthetic fertilizer accompanied by the addition of vermicompost as much as 40 t ha⁻¹ and mycorrhiza as much as 20 g plant⁻¹ (Fig. 1).

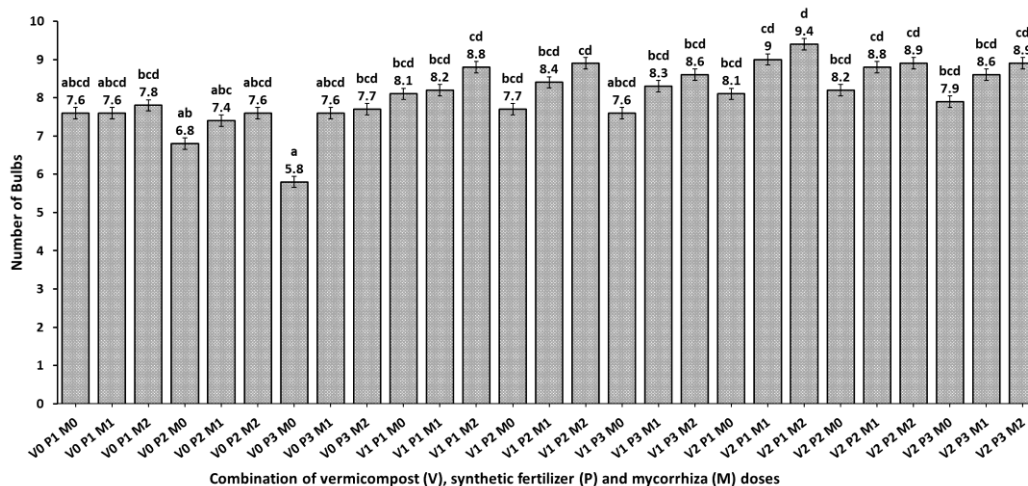


Figure 1. Effect of doses of vermicompost, mycorrhiza, and synthetic fertilizer on the number of shallot bulbs

The addition of 40 t ha⁻¹ of vermicompost and 20 g of plant⁻¹ of mycorrhiza to shallots given 50% synthetic fertilizer can produce a fresh bulbs weight of 77.6 grams, an increase of 49,2% compared to if shallots were only given synthetic fertilizer as much as 50%. The largest fresh bulbs weight (89.2 grams) was obtained from the application of 100% synthetic fertilizer followed by the addition of 40 t ha⁻¹ of vermicompost and 20 g of plant⁻¹ of mycorrhiza (Fig. 2).

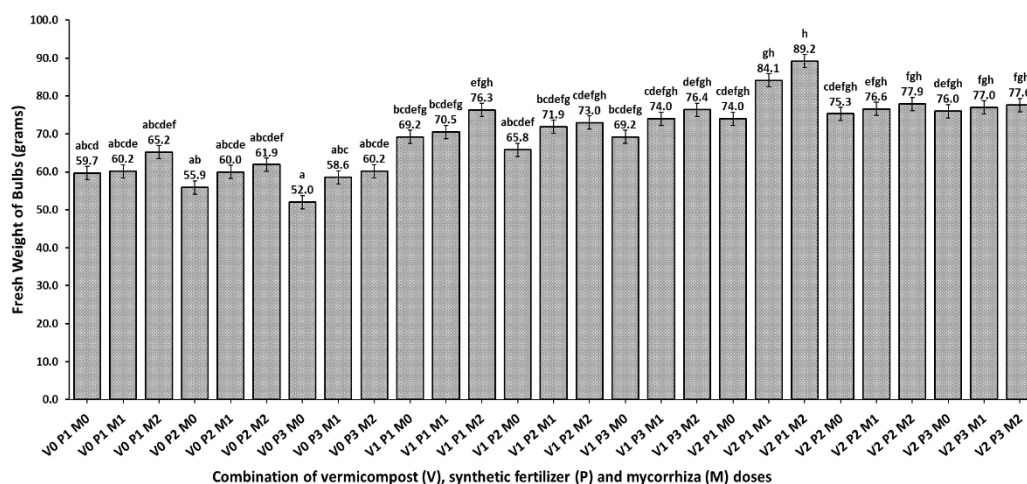


Figure 2. Effect of doses of vermicompost, mycorrhiza, and synthetic fertilizer on fresh weight of shallot bulbs

Bulb diameter was significantly influenced by the application of vermicompost combined with mycorrhiza and synthetic fertilizer. The smallest bulbs diameter was obtained in the treatment of giving 50% synthetic fertilizer without adding vermicompost and mycorrhiza. Meanwhile, if 40 t ha⁻¹ of vermicompost and 20 g of mycorrhiza plant⁻¹ are added, the tuber diameter increases by 34.8%, this is not significantly different from the application of 100% synthetic fertilizer followed by the addition of 40 t ha⁻¹ vermicompost and mycorrhiza as much as 20 g of plant⁻¹ (Fig. 3).

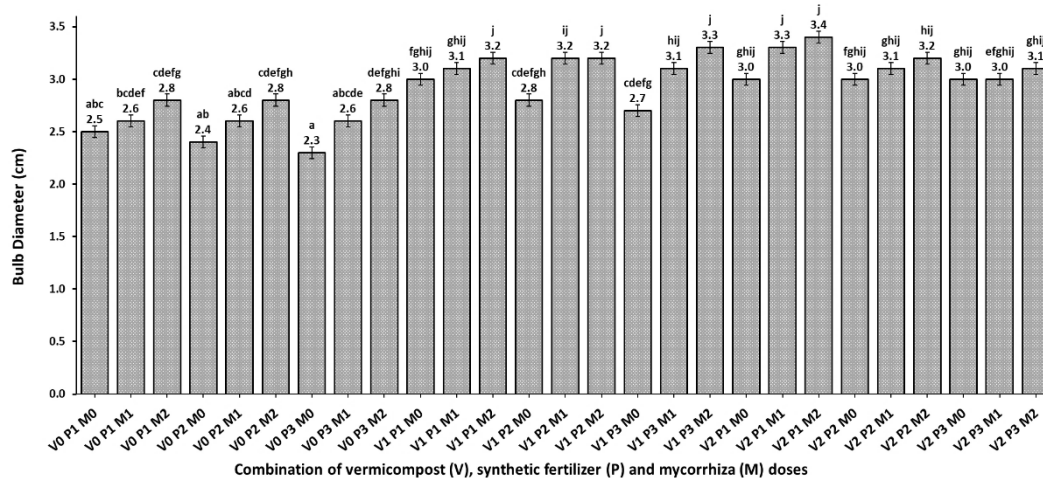


Figure 3. Effect of doses of vermicompost, mycorrhiza, and synthetic fertilizer on bulb diameter of shallots

4. Discussion

The data in Fig. 1, which is marked with the results of the analysis of variance and Duncan Multiple Ranges Test with different notations, shows that the combination of a dose of 40 t ha⁻¹ vermicompost and 20 g of mycorrhizal plants⁻¹ with 50% synthetic fertilizer (V2P3M2) produced a number of bulbs that were almost equivalent to the use of 100% synthetic fertilizer (V2P1M2), namely 8.9 bulbs compared to 9.4 bulbs. This finding is in line with the research of Arifah et al. (2021) which showed an increase in shallot yields with the use of vermicompost, but this study added that the combination with mycorrhizae was also effective in achieving similar results. This shows that the use

of vermicompost and mycorrhizae can reduce dependence on synthetic fertilizers by up to 50%, which has not been widely discussed in previous studies.

The results in Fig. 2 show that the treatment of 40 t ha⁻¹ vermicompost and 20 g of mycorrhizal plants⁻¹ together with 50% synthetic fertilizer (V2P3M2) resulted in a fresh bulb weight of 77.6 grams, or an increase of 49.2% compared to using only 50% synthetic fertilizer (V0P3M0). This study strengthens the findings of Guzman and Gonzales (2023) who reported an increase in shallot weight with vermicompost, but also provides new findings that the fresh bulb weight can be further increased by adding mycorrhizae. This shows the superiority of the combination of the two organic materials in achieving high bulb weight by reducing the use of synthetic fertilizers.

Fig. 3 shows that the largest bulb diameter (3.3 cm) was obtained from a combination of 40 t ha⁻¹ vermicompost and 20 g of mycorrhizal plants⁻¹ with 50% synthetic fertilizer (V2P3M2), which was not significantly different from the diameter obtained in the 100% synthetic fertilizer treatment (V0P1M0). This result is in line with the research of Kumari et al. (2020) which stated that the application of vermicompost can increase the size of shallot bulbs, but this study adds a new finding that the addition of mycorrhizae can provide results equivalent to 100% synthetic fertilizer. This finding is important because it shows that the combination of vermicompost and mycorrhizae is able to maintain the quality of bulb size with reduced synthetic fertilizer.

This study also showed that the combination of vermicompost and mycorrhiza produced tuber diameters that were not inferior to the application of full synthetic fertilizers, supporting the findings of Setyowati et al. (2023) who reported that vermicompost improved tuber quality. However, these findings provide additional evidence that mycorrhiza plays an important role in expanding nutrient absorption through the roots, producing larger and stronger tuber quality, and providing sustainable yields.

Application of vermicompost at high doses (40 t ha⁻¹) combined with mycorrhiza also plays a role in improving soil quality that supports the growth of shallots. Lv et al. (2020) stated that vermicompost can increase microbial activity and phosphatase enzymes, which enrich the availability of nutrients in the soil. This study supports this claim and shows that increasing nutrient availability through vermicompost can be optimized by adding mycorrhiza, which forms a hyphal network that helps shallot roots absorb nutrients more efficiently, especially phosphorus.

Mycorrhiza has the ability to increase the absorption of water and nutrients such as nitrogen, phosphorus, and potassium through wider hyphae in the soil. This supports the research of Fall et al. (2022) which shows the important role of mycorrhiza in increasing the availability of nutrients for plants. This study adds a new dimension by showing that the addition of vermicompost strengthens the ability of mycorrhiza to increase nutrient absorption by shallots, resulting in larger bulb weights and diameters.

Although the application of 100% synthetic fertilizer gave good results in terms of the number and weight of bulbs, this study showed that the combination of vermicompost and mycorrhiza at low doses of synthetic fertilizer was able to produce comparable values. This shows that the use of organic materials such as vermicompost and mycorrhiza is not only environmentally friendly but also efficient in supporting shallot yields. These findings support Showler's (2022) statement that the use of organic fertilizers and mycorrhiza can partially replace the role of synthetic fertilizers, while minimizing environmental impacts.

Supporting this, Pathma and Sakthivel (2012) and (Lim et al., 2015) stated that vermicompost contains essential nutrients in a form that can be taken up directly by plants. The application of vermicompost enriches the soil with micro and macronutrients, vitamins, enzymes, and hormones and contributes to plant development by regulating the physico-chemical properties of the soil (Hazra et al., 2018). This is also in line with the opinion of Mahmoud and Gad (2020) which states that the application of vermicompost can improve soil quality by increasing microbial activity. Increasing the number and activity of microbes can indirectly increase the amount and availability of nutrients in the soil (Lee et al., 2018; Mukhtar et al., 2018; Erana et al., 2019)

The results of this study provide a significant contribution to sustainable agriculture efforts. By reducing dependence on synthetic fertilizers by up to 50%, a cultivation system that uses vermicompost and mycorrhiza can help reduce soil and water pollution from chemical fertilizer residues. In addition, improving soil quality and productivity through these practices supports long-term soil health, which is essential in maintaining agricultural sustainability. This research offers innovative and applicable solutions in developing a more environmentally friendly and sustainable agricultural system.

5. Conclusions

Shallot plants were given 50% synthetic fertilizer (69 kg N ha⁻¹, 36 kg P₂O₅ ha⁻¹ and 90 kg K₂O ha⁻¹) and added 40 t ha⁻¹ of vermicompost and 20 t plant⁻¹ of mycorrhiza to produce a total of tubers, tuber weight and tuber diameter were 8.9 tubers, 77.6 g and 3.1 cm respectively. There was an increase in the number of bulbs, bulb weight, and bulb diameter of shallots by 17%, 30%, and 24% respectively compared to shallots grown using only synthetic fertilizer as much as 100%. Furthermore, it is necessary to conduct research on the long-term effects of providing vermicompost and mycorrhiza (without adding synthetic fertilizer) on shallots and other plants to see the efficiency and effectiveness of providing vermicompost and mycorrhiza.

Author Contributions: The author's contribution to this research is as follows “Conceptualization, A.M.P. and Y.R.A.; methodology, A.M.P.; software, A.M.; validation, A.M.P., A.M. and Y.R.A.; formal analysis, A.M.P.; investigation, A.M.; resources, Y.R.A.; data curation, Y.R.A.; writing—original draft preparation, A.M.P.; writing—review and editing, A.M. and Y.R.A.; visualization, A.M.P.; supervision, Y.R.A.; project administration, A.M.; funding acquisition, A.M.P.. All authors have read and agreed to the published version of the manuscript”.

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Data availability statement: Data presented in this study will be available on a fair request to the corresponding author

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