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Application of *Trichoderma*-Enriched Liquid Organic Fertilizer in the Cultivation of Shallot (*Allium cepa* L.)

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Abstract

Low shallot productivity in Indonesia remains a major constraint for farmers, primarily due to pest and disease incidence. This study aimed to evaluate the effectiveness of *Trichoderma*-based liquid organic fertilizer (LOF) on crop productivity and pest and disease suppression, as well as to determine the optimal application dose for shallot cultivation. The experiment was conducted using a randomized complete block design (RCBD) consisting of six treatments and four replications. The treatments were as follows: P1 (control), P2 (10% LOF + 10 mL *Trichoderma*), P3 (25% LOF + 25 mL *Trichoderma*), P4 (50% LOF + 50 mL *Trichoderma*), P5 (75% LOF + 75 mL *Trichoderma*), and P6 (100% LOF + 100 mL *Trichoderma* + 50% inorganic fertilizer). The results demonstrated that treatment P5 produced the highest plant height, leaf number, fresh bulb weight, and dry bulb weight. Furthermore, P5 effectively reduced the incidence of moler disease caused by Fusarium oxysporum. Regression analysis indicated that the optimal dose of *Trichoderma*-based LOF for maximizing shallot productivity was approximately 77.23%, equivalent to 77.23 mL *Trichoderma* per liter of LOF solution.

Keywords: Liquid organic fertilizer; *Trichoderma*; shallot; productivity; plant disease; organic agriculture.

INTRODUCTION

Allium cepa L., commonly known as shallot, is a high-value horticultural commodity in Indonesia and plays a crucial role in national food security. Beyond its function as a staple culinary ingredient, shallot is considered a strategic commodity due to its strong influence on food price stability and inflation rates (Badan Pusat Statistik, 2023). Increasing demand, driven by population growth and shifting consumption patterns, continues to intensify production pressure (BMKG Lampung, 2023). However, domestic shallot productivity remains suboptimal and exhibits considerable yield fluctuations. These limitations are primarily associated with pest and disease incidence, particularly soil-borne pathogens, as well as climate variability that affects crop performance and yield stability (Sari & Kurniawan, 2020).

Conventional shallot cultivation in Indonesia heavily relies on synthetic fertilizers and chemical pesticides to maintain productivity. While these inputs can provide short-term yield gains, their prolonged and excessive use has contributed to soil degradation, declining soil fertility, and increased environmental risks (Nugroho et al., 2021). Consequently, there is a growing need to develop sustainable nutrient management strategies that enhance productivity while minimizing ecological impact. In this context, liquid organic fertilizer (LOF) has emerged as a promising alternative, as it can improve soil structure, stimulate microbial activity, and enhance nutrient availability. Rahmawati et al. (2022) reported that LOF application significantly improved both yield and quality of shallots compared to conventional fertilization practices.

The incorporation of beneficial microorganisms into organic fertilizers represents a further advancement toward sustainable agriculture. Among these microorganisms, *Trichoderma* spp. are widely recognized for their multifunctional roles as biological control agents and plant growth promoters. Species of *Trichoderma* exhibit antagonistic activity against a broad spectrum of plant pathogens through mechanisms such as competition, antibiosis, and mycoparasitism (Harman et al., 2004). In addition, they enhance plant growth by producing phytohormones, increasing nutrient solubilization, and inducing systemic resistance in host plants (Wicaksono et al., 2021). These combined attributes suggest that integrating *Trichoderma* into LOF formulations may provide synergistic effects, simultaneously improving plant growth and suppressing disease incidence.

Despite the documented benefits of both LOF and *Trichoderma*, studies evaluating their combined application in shallot cultivation remain limited, particularly with respect to determining optimal dosage for maximizing productivity while maintaining disease suppression. The interaction between nutrient concentration and microbial inoculum level may influence both plant physiological responses and microbial dynamics in the rhizosphere. Therefore, identifying the appropriate formulation and application rate is essential to ensure consistent agronomic performance.

Accordingly, this study aimed to (i) analyze the effects of *Trichoderma*-based LOF on the growth and yield of shallot plants, (ii) evaluate its effectiveness in suppressing pest and disease incidence, particularly moler disease caused by *Fusarium oxysporum*, and (iii) determine the optimal dose of *Trichoderma*-enriched LOF to achieve maximum shallot productivity under field conditions. The findings are expected to contribute to the development of environmentally sustainable shallot cultivation practices with reduced dependence on synthetic agrochemicals.

MATERIALS AND METHODS

Time and Location

The experiment was conducted from November 2024 to February 2025 at the Integrated Field Laboratory of Politeknik Negeri Lampung, Bandar Lampung, Indonesia. The study employed an experimental approach using a randomized complete block design (RCBD) consisting of six treatments with four replications.

Materials and Equipment

The appropriate selection of materials and equipment was essential to ensure the proper execution of the experiment. The equipment used in this study included a hand tractor for land preparation, hoes, watering cans, sprayers, a digital balance with 0.1 g precision, a ruler, a measuring tape, a soil pH meter, a drying oven for determining dry bulb weight, writing instruments, and a smartphone for documentation and data recording.

The materials used in this study consisted of shallot seedlings of the Bima Brebes variety, liquid organic fertilizer (LOF) formulated from coconut coir and banana pseudostem enriched with *Trichoderma* sp., NPK fertilizer (used as a control comparison), basal fertilizer in the form of manure, and botanical pesticides.

Experimental Design and Treatments

The experiment was arranged in a randomized complete block design (RCBD) consisting of six treatments with four replications. The treatments comprised different concentrations of liquid organic fertilizer (LOF) enriched with *Trichoderma*. The control treatment (P1) received no fertilizer application. Treatment P2 consisted of 10% LOF combined with 10 mL of *Trichoderma*, P3 involved 25% LOF with 25 mL of *Trichoderma*, P4 included 50% LOF with 50 mL of *Trichoderma*, and P5 consisted of 75% LOF with 75 mL of *Trichoderma*. The highest concentration treatment (P6) comprised 100% LOF supplemented with 100 mL of *Trichoderma* in combination with 50% of the recommended inorganic fertilizer dose. Each treatment was replicated four times, resulting in a total of 24 experimental units.

Preparation of Liquid Organic Fertilizer (LOF)

The liquid organic fertilizer (LOF) was produced through a 14-day anaerobic fermentation process. The formulation was based on a combination of plant-derived lignocellulosic substrates, natural carbohydrate sources, and a microbial starter culture. All components were homogenized in a sealed fermentation container and incubated at room temperature (28–32°C). The mixture was stirred every two days to maintain uniformity and support stable microbial activity during decomposition (Nugroho et al., 2023).

After fermentation, the liquid fraction was separated from solid residues by filtration. The filtrate was evaluated for pH (maintained within 6.5–7.0) and general nutrient characteristics prior to field application. *Trichoderma* sp. was incorporated during treatment preparation immediately before application to preserve fungal viability and ensure optimal biological performance (Syaifudin et al., 2023). The formulated LOF was designed to provide essential nutrients while enhancing rhizosphere microbial activity and supporting the plant growth–promoting and antagonistic functions of *Trichoderma* against soil-borne pathogens.

Observed Parameters

The observed parameters included plant height (cm), number of leaves (per plant), fresh bulb weight (g), dry bulb weight (g), and percentage of pest and disease incidence. Observations were conducted weekly from 2 weeks after planting (WAP) until harvest.

Data Analysis

The collected data were subjected to analysis of variance (ANOVA) at a 5% significance level. When significant differences among treatments were detected, means were separated using Duncan's Multiple Range Test (DMRT) at the 5% significance level. Regression analysis was performed to determine the optimal dose of *Trichoderma*-based LOF for maximizing shallot productivity.

RESULTS AND DISCUSSION

Observation Results

The observations conducted throughout the experimental period demonstrated that the application of *Trichoderma*-based liquid organic fertilizer (LOF) significantly affected the growth and yield of shallot (*Allium cepa* L.).

Analysis of variance (ANOVA) indicated that the treatments had a statistically significant effect on all observed parameters ($p<0.05$).

Plant Growth and Yield Performance

The mean values of plant height, number of leaves, fresh bulb weight, and dry bulb weight are presented in Table 1. Treatment P5 (75% LOF + 75 mL *Trichoderma*) consistently produced the highest values across all growth and yield parameters. At 40 days after planting (DAP), P5 resulted in an average plant height of 27.3 cm and a mean leaf number of 18 leaves per plant. In addition, the fresh bulb weight reached 47.5 g, while the dry bulb weight was 45.2 g. These results indicate that the 75% LOF concentration combined with 75 mL of *Trichoderma* provided the most favorable conditions for vegetative growth and bulb development.

Table 1. Mean growth and yield parameters of shallot under different treatments.

Treatment	Plant height (cm)	Number of leaves (no.)	Fresh bulb weight (g)	Dry bulb weight (g)
P1 (control)	24,9 [c]	14,0 [d]	13,8 [e]	11,6 [e]
P2 (LOF 10%)	26,2 [b]	13,3 [d]	28,3 [d]	23,3 [d]
P3 (LOF 25%)	24,2 [c]	12,0 [e]	30,0 [d]	26,3 [d]
P4 (LOF 50%)	25,2 [bc]	15,0 [c]	39,8 [c]	36,6 [c]
P5 (LOF 75%)	27,3 [a]	18,0 [a]	47,5 [a]	45,2 [a]
P6 (LOF 100%)	26,0 [b]	15,0 [c]	43,5 [b]	40,7 [b]

Note: Means followed by the same letter within the same column are not significantly different according to Duncan's Multiple Range Test (DMRT) at the 5% significance level.

Statistical Analysis and Interpretation

Duncan's Multiple Range Test revealed that treatment P5 differed significantly from the other treatments, particularly in plant height and bulb weight parameters. This finding confirms that the combined application of 75% LOF and 75 mL *Trichoderma* represents the most effective dose for enhancing shallot growth and productivity under the experimental conditions. The positive effect of *Trichoderma*-based LOF on shallot growth is consistent with previous findings. Rahmawati et al. (2022) reported that LOF application increased shallot productivity by up to 20% compared to inorganic fertilization. The present study further supports these findings, demonstrating significant improvements in both vegetative growth and bulb yield. The enhanced performance can be attributed to the multifaceted role of *Trichoderma*. This fungus improves nutrient availability in the rhizosphere, thereby increasing nutrient uptake efficiency (Harman et al., 2004). Moreover, its antagonistic activity against soil-borne pathogens contributes to healthier root systems, ultimately supporting better plant growth and yield formation.

Suppression of Moler Disease

In addition to enhancing vegetative growth and yield, treatment P5 markedly suppressed moler disease caused by *Fusarium oxysporum*, achieving complete disease suppression (100%) under the experimental conditions. This finding underscores the multifunctional role of *Trichoderma*-enriched LOF, which acts not only as a nutrient source but also as a biological control agent capable of protecting plants from soil-borne pathogens.

The suppression of *F. oxysporum* can be explained by several well-documented mechanisms of *Trichoderma*. First, competitive exclusion plays a crucial role, as *Trichoderma* rapidly colonizes the rhizosphere and occupies ecological niches that would otherwise be exploited by pathogenic fungi. This competition for space and nutrients limits pathogen establishment and proliferation. Second, antibiosis contributes to pathogen inhibition through the production of secondary metabolites such as gliotoxins, peptaibols, and hydrolytic enzymes (e.g., chitinases and β-1,3-glucanases), which degrade fungal cell walls. Third, mycoparasitism enables *Trichoderma* to directly attack and penetrate pathogenic hyphae, leading to structural disruption and pathogen death.

Moreover, *Trichoderma* is known to induce systemic resistance (ISR) in host plants by activating defense-related signaling pathways, including those mediated by jasmonic acid and ethylene. This activation enhances the plant's innate immune response, enabling faster and stronger defense reactions upon pathogen challenge (Syaifudin et al., 2023). The integration of LOF with *Trichoderma* may further strengthen this effect by improving plant nutritional status, thereby increasing the plant's physiological capacity to mount defense responses. Collectively, these mechanisms likely contributed to the substantial reduction in disease incidence observed in the present study.

Regression Analysis and Determination of Optimal Dose

Regression analysis revealed that the optimal concentration of *Trichoderma*-based LOF for maximizing shallot productivity was approximately 77.23%, corresponding to 77.23 mL of *Trichoderma* per liter of LOF solution. The polynomial response pattern suggests the existence of a threshold beyond which additional increases in concentration do not proportionally enhance plant performance.

The superior performance observed at intermediate concentrations (particularly P5) indicates that balanced nutrient availability combined with optimal microbial density is essential for achieving maximum growth and yield. This finding is consistent with Wicaksono et al. (2021), who reported that a concentration of 75 mL L^{-1} *Trichoderma* significantly improved shallot growth and yield parameters. At lower concentrations (P2 and P3), the microbial population and nutrient availability may have been insufficient to exert a measurable physiological effect. Conversely, the reduced effectiveness observed at the highest concentration (P6) may be attributed to microbial competition within the rhizosphere, excessive metabolite accumulation, or nutrient imbalance that could disrupt optimal plant–microbe interactions.

These results highlight the importance of dose optimization in biofertilizer application. Unlike synthetic fertilizers, where higher inputs often correlate with increased nutrient supply, microbial-based formulations require precise concentration management to maintain ecological balance in the rhizosphere. Therefore, the identified optimal concentration provides a practical recommendation for sustainable shallot cultivation, ensuring maximum agronomic benefit while maintaining microbial stability

CONCLUSIONS

Based on the findings of this study, the application of *Trichoderma*-based liquid organic fertilizer (LOF) at a concentration of 75% (treatment P5) produced the most favorable results in enhancing the growth and yield of shallot (*Allium cepa* L.). This treatment resulted in a plant height of 27.3 cm, an average of 18 leaves per plant, and the highest fresh and dry bulb weights, reaching 47.5 g and 45.2 g, respectively.

Treatment P5 also effectively suppressed moler disease caused by Fusarium oxysporum by up to 100%, indicating that *Trichoderma*-enriched LOF not only functions as a biofertilizer but also enhances plant resistance against pathogens. Regression analysis further revealed that the optimal dose for maximizing shallot productivity was approximately 77.23%, equivalent to 77.23 mL of *Trichoderma* per liter of LOF solution.

Overall, this study demonstrates that *Trichoderma*-based LOF represents an effective and environmentally sustainable alternative for shallot cultivation, with the potential to increase productivity while reducing reliance on synthetic fertilizers.

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Competing Interests: The authors declare that there are no competing interests.

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