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Application of Organic Fertilizers and Biofertilizers on Growth, Yield, and *Spodoptera exigua* Infestation in Shallot (*Alium ascalonicum* L.)

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ABSTRACT

Shallot (*Allium ascalonicum* L.) is an important horticultural commodity in Indonesia, and demand is increasing as the population grows. However, its productivity remains low, owing to land degradation caused by the extensive and continual use of inorganic fertilizers and pesticides. Organic fertilizers and biofertilizers have been offered as a long-term solution for increasing soil fertility and agricultural yield. The purpose of this study was to assess the effects of organic and biofertilizers on plant growth, yield, and *Spodoptera exigua* infestation in shallots. The experiment used a randomized block design with five treatments. These included 100% inorganic fertilizer and mixes of organic fertilizer (15−30 t ha^{-1}) and biofertilizer (6 mL plant^{-1}). The results showed that using organic fertilizers in conjunction with biofertilizers had no significant changes in plant growth and yield when compared to using only inorganic fertilizers. The highest bulb weight was attained by applying 30 t ha^{-1} organic fertilizer coupled with biofertilizer. In contrast, the incidence of *S. exigua* infestation was considerably reduced in organic and biofertilizer treatments compared to inorganic fertilizer treatments. These findings suggest that combining organic and biofertilizers can reduce reliance on inorganic fertilizers while preserving yields and controlling pest infestation.

Keywords: biofertilizer, organic fertilizer, shallot production, *Spodoptera exigua*

INTRODUCTION

Shallot (*Allium ascalonicum* L.) is one of the leading horticultural commodities in Indonesia and has been grown by farmers for a long time. As the population grows, so does the demand for shallots. However, current agricultural techniques, which include the excessive and continual use of inorganic fertilizers and pesticides, have resulted in land degradation (Navitasari & Latarus 2021).

This deterioration has contributed to a drop in soil fertility and reducing crop yield. One of the primary signs of deteriorating soil fertility is a lack of necessary nutrients, particularly in marginal lands.

In Indonesia, shallot productivity remains poor, averaging only approximately 9.48 t ha^{-1}, which is significantly below its potential yield of more than 20 t ha^{-1} as mentioned in the national strategy plan (Suratno 2022). Thus, enhancing soil fertility is critical to increasing shallot productivity.

One solution is to use organic fertilizers, which have been shown to prevent land degradation and improve soil fertility (Kamsurya & Botanri 2022). Low nutrient availability in soil can also be caused by the presence of minerals such as Al, Mg, and Ca, which bind important nutrients and render them unavailable for plant absorption.

This condition emphasizes the importance of developing techniques for converting scarce nutrients into forms that plants can use. One promising solution is to use biofertilizers.

Biofertilizers based on bacterial consortia serve crucial functions such as nitrogen fixers, phosphate solubilizers, and potassium mobilizers, boosting soil nutrient availability. Furthermore, biofertilizers can produce phytohormones, which promote plant growth and development.

However, research on the combined impact of organic fertilizers and biofertilizers on shallot growth, yield, and insect infestation remains limited. The purpose of this study was to assess the effects of organic fertilizers and biofertilizers on plant growth, yield, and *Spodoptera exigua* infestation in shallots.

METHODS

Study Site and Duration

The investigation was carried out from March to November 2023 at the Plant Protection Laboratory and experimental field of the Politeknik Pembangunan Pertanian (Polbangtan), Malang, Indonesia. A nationally accredited laboratory carried out soil and fertilizer testing.

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Experimental Design

The trial followed a randomized complete block design (RCBD), with five treatments and five replications. The treatments included: (1) P1: 100% inorganic fertilizer (control); (2) P2: organic fertilizer at 15 t ha^{-1} + biofertilizer at 6 mL $plant^{-1}$; (3) P3: organic fertilizer at 20 t ha^{-1} + biofertilizer at 6 mL $plant^{-1}$; (4) P4: organic fertilizer at 25 t ha^{-1} + biofertilizer at 6 mL $plant^{-1}$; and (5) P5: organic fertilizer at 30 t ha^{-1} + biofertilizer at 6 mL.

Shallots were planted 20 cm apart. The organic fertilizer utilized was compost made from animal manure and *Tithonia diversifolia*. The biofertilizer was a bacterial consortium composed of *Pseudomonas fluorescens*, *Azotobacter*, and *Azospirillum*. This consortium serves plant growth-promoting rhizobacteria (PGPR), increasing nutrient availability through nitrogen fixation, phosphate solubilization, and phytohormone synthesis while also strengthening plant resistance to pathogens.

Soil Analysis

Soil analysis was performed at the Agricultural Instrument Standardization Agency (BSIP) in Central Java Province. The parameters studied included available nitrogen (N), phosphorus (P), and potassium (K), organic matter content, cation exchange capacity (CEC), organic carbon (C-organic), and soil pH.

Fertilizer Analysis

Fertilizer analysis was also conducted at the BSIP. The parameters tested were organic carbon (%), C/N ratio, pH, macronutrients (N, P_2O_5, and K_2O), and micronutrients (Fe, Mn, and Zn).

Plant Growth, Biomass, and Yield Measurements

Plant growth, biomass, and yield characteristics were monitored. Plant height and leaf number were two criteria used to assess plant growth. The fresh and dried weights of plant shoots were used to calculate biomass. Fresh biomass was measured immediately after harvesting by uprooting the plants, removing any adhering soil from the roots, and weighing the fresh shoots. Dry biomass was evaluated by drying plant samples to a fixed weight. The yield criteria were the number of bulbs per clump, bulb diameter, and bulb weight per clump. The total yield was calculated by weighing the harvested bulbs from each experimental unit.

Assessment of *S. exigua*

Pest observations were made on sample plants to determine pest species and infestation levels. Pest species that could not be identified in the field were later identified in the laboratory. The intensity of the *S. exigua* infestation was determined using the following formula (Rivai 2006):

$$IS = \frac{\sum(n_i \times v_i)}{N \times V} \times 100\%$$

Where:
IS = Infestation intensity (%)
n_i = Number of plants in each damage category
v_i = Damage score
N = Total number of observed plants
V = Highest damage score

The damage scoring system ranged from 0 to 5, where 0 = no damage; 1 = 1–20% damage; 2 = 21–40% damage; 3 = 41–60% damage; 4 = 61–80% damage; and 5 = 81–100% damage.

Statistical Analysis

Data were evaluated for plant growth, biomass (fresh and dry weight), shallot yield, and *S. exigua* infestation %. ANOVA was performed on all data using a randomized complete block design (RCBD). When significant differences between treatments were found, mean comparisons were performed using Duncan's Multiple Range Test (DMRT) at a 5% significance level (α = 0.05).

RESULTS AND DISCUSSION

Soil Characteristics

The soil analysis results showed that the pH was close to neutral, with comparatively low nitrogen (0.19%), phosphorus (79.07 ppm), and potassium (216.83 ppm) levels. In addition, the soil organic carbon level was low at 2.20% (Table 1). The soil analysis also revealed that the soil had low nutrient availability, with total nitrogen (0.19%), accessible phosphorus, and potassium at relatively low levels. This situation suggests that the soil is marginal, with low nutrient content and a need for increased fertilizer

Table 1 Soil analysis results

Parameter	Value*
pH (H_2O)	6.97
pH (KCl)	5.87
Total N (%)	0.19
Organic C (%)	2.20
Available P_2O_5 (ppm)	79.07
Available K (ppm)	216.83

Remarks: *Soil analysis at the BSIP Bogor.

inputs and intense management (Rengganis 2017). The low organic carbon content (2.20%) reinforces this classification, as marginal soils often contain only 1−5% organic matter (Sari & Zahrosa 2022). Low nutrient availability can have a direct impact on plant growth and development. According to Jones and Jacobsen (2005), the ideal nutrient concentrations for plant growth are 1−5% nitrogen, 0.1−0.5% phosphorus, and 0.5−0.8% potassium. The soil's low nutritional status emphasizes the requirement for exogenous nutrient additions. The use of organic fertilizers obtained from livestock manure, *Tithonia diversifolia*, and tea waste is regarded as an effective technique for increasing soil fertility and supporting plant growth.

Fertilizer Characteristics

The organic fertilizer employed in this study included goat manure, calf manure, *T. diversifolia* leaves, and tea waste. The research revealed that the fertilizer contained a high organic carbon content (41.30%), total nitrogen of 2.46%, and a C/N ratio of 16.81. The organic fertilizer contains macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as micronutrients such as sodium (Na) and calcium (Ca) (Table 2). The fertilizer analysis revealed that an organic fertilizer made from a blend of bovine dung, goat manure, *T. diversifolia*, and tea waste met the basic technical parameters for organic fertilizers. This is demonstrated by its high organic carbon content (41.30%), total nitrogen (2.46%), C/N ratio (16.81), pH (5.90), and sodium level (800 ppm).The Indonesian Ministry of Agriculture sets minimum quality standards for organic fertilizers, which include organic carbon ≥15%, C/N ratio ≤25, total macronutrients (N, P, and K) ≥2%, pH between 4 and 9, and sodium concentration ≤2000 ppm (Indonesia 2019). As a result, the organic fertilizer employed in this study is high-quality and appropriate for increasing soil fertility.Despite satisfying these quality standards, the use of organic fertilizers at varying doses in conjunction with biofertilizers did not result in significant differences in shallot plant growth, biomass, and yield.

This finding is consistent with previous studies indicating that the use of organic fertilizers and biofertilizers does not always have a significant effect on plant growth and yield when soil nutrient availability is adequate or plant response to treatment is limited (Sutanto 2002; Suriadikarta & Simanungkalit 2006).

Effect of Organic Fertilizer and Biofertilizer on Plant Growth

Plant growth was assessed using plant height and leaf number. The results showed that applying organic fertilizers in various doses, along with biofertilizers, had no significant effect on plant height compared to 100% inorganic fertilizer at 7 to 28 days after planting (DAP) (Table 3). A similar pattern was seen in the quantity of leaves, with no significant differences between treatments over the observation period (Table 4). These findings show that the combined use of organic and biofertilizers maintained plant development comparable to that attained with full inorganic fertilization.

The outcomes show that the use of organic fertilizers in conjunction with biofertilizers can efficiently replace inorganic fertilizers without significantly compromising plant growth, biomass, or output. This is demonstrated by the lack of substantial changes between treatments in plant height and leaf number. Similarly, biomass characteristics, such as fresh and dry weights, showed no significant difference among treatments (Table 5). The same

Table 2 Fertilizer analysis results

Parameter	Value*
pH (H_2O)	5.90
Organic C (%)	41.30
Total N (%)	2.46
C/N ratio	16.81
P_2O_5 (%)	1.04
K_2O (%)	1.30
Na (%)	0.08
Ca (%)	1.76

Remarks: *Analysis of fertilizer at the BSIP Central Java.

Table 3 Plant height (cm) of shallot under various fertilizer treatments

Treatment	Plant height (cm)			
	7 DAP	14 DAP	21 DAP	28 DAP
Inorganic fertilizer (100%);	24.5^{a}	31.7^{b}	37.7^{b}	42.7^{c}
Organic fertilizer 15 t ha^{-1} + biofertilizer 6 mL $plant^{-1}$;	26.2^{a}	32.1^{b}	37.5^{b}	40.8^{bc}
Organic fertilizer 20 t ha^{-1} + biofertilizer 6 mL $plant^{-1}$;	24.3^{a}	30.9^{ab}	36.7^{ab}	40.7^{bc}
Organic fertilizer 25 t ha^{-1} + biofertilizer 6 mL $plant^{-1}$	23.5^{a}	30.9^{ab}	36.9^{ab}	41.6^{bc}
Organic fertilizer 30 t ha^{-1} + biofertilizer 6 mL $plant^{-1}$	23.6^{a}	31.7^{b}	38.5^{b}	42.9^{bc}

Remarks: Values followed by the same letters within the same column are not significantly different according to Duncan's Multiple Range Test (DMRT) at α = 0.05. DAP = days after planting.

Table 4 Number of leaves of shallot under various fertilizer treatments

Treatment	Leaves plant^{-1}			
	7 DAP	14 DAP	21 DAP	28 DAP
Inorganic fertilizer (100%);	22.5^{ab}	30.3^{ab}	39.8^{ab}	41.8^{bc}
Organic fertilizer 15 t ha^{-1} + biofertilizer 6 mL plant^{-1};	24.7^{b}	32.9^{b}	42.8^{b}	43.5^{bc}
Organic fertilizer 20 t ha^{-1} + biofertilizer 6 mL plant^{-1};	23.9^{b}	32.5^{b}	42.8^{b}	42.4^{bc}
Organic fertilizer 25 t ha^{-1} + biofertilizer 6 mL plant^{-1}	23.8^{b}	30.8^{ab}	40.0^{b}	41.9^{bc}
Organic fertilizer 30 t ha^{-1} + biofertilizer 6 mL plant^{-1}	24.7^{b}	32.9^{b}	42.6^{b}	42.9^{bc}

Remarks: Values followed by the same letters within the same column are not significantly different according to Duncan's Multiple Range Test (DMRT) at α = 0.05. DAP = days after planting.

Table 5 Biomass of shallot under various fertilizer treatment

Treatment	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})
Inorganic fertilizer 100%;	144.0^{b}	87.0^{a}
Organic fertilizer 15 t ha^{-1} + biofertilizer 6 mL plant^{-1};	104.0^{ab}	69.2^{a}
Organic fertilizer 20 t ha^{-1} + biofertilizer 6 mL plant^{-1};	140.2^{ab}	79.8^{a}
Organic fertilizer 25 t ha^{-1} + biofertilizer 6 mL plant^{-1}	113.4^{ab}	70.6^{a}
Organic fertilizer 30 t ha^{-1} + biofertilizer 6 mL plant^{-1}	128.4^{ab}	73.4^{a}

Remarks: Values followed by the same letters within the same column are not significantly different according to Duncan's Multiple Range Test (DMRT) at α = 0.05.

pattern was observed for yield components, with no significant changes found in bulb weight, number of bulbs per clump, or bulb diameter when compared to the 100% inorganic fertilizer treatment (Table 6).

The combination of organic and biofertilizers can be a long-term solution for reducing dependency on inorganic fertilizers. Biofertilizers with beneficial microorganisms have been shown to minimize reliance on synthetic fertilizers (Farid *et al.* 2021). In this study, the use of organic fertilizers in combination with biofertilizers kept biomass and yield levels comparable to those reached with 100% inorganic fertilization. Reducing inorganic fertilizer use may help to promote more environmentally sustainable farming practices. Continuous use of large doses of inorganic fertilizers has been shown to reduce soil fertility and contribute to environmental pollution (Mariana *et al*. 2012). Organic fertilizers, on the other hand, improve soil physical, chemical, and biological qualities, increase soil fertility and promote plant development (Aryani *et al*. 2019).

Despite these benefits, there were no significant changes in plant growth, biomass, or yield across the various doses of organic fertilizer mixed with biofertilizers. This implies that increasing the amount of organic fertilizer above a particular threshold does not always result in further benefits. Similar findings were observed by Kawilarang *et al*. (2023) and Ruhimat *et al.* (2023), that while organic amendments can increase productivity, the addition of biofertilizers does not necessarily have a meaningful effect on shallot growth.

Organic fertilizers and biofertilizers play synergistic roles in the combined application, which may explain their effectiveness. Organic fertilizers supply necessary macro- and micronutrients, whereas biofertilizers containing beneficial microbes like *Azotobacter*, *Azospirillum*, and *Pseudomonas fluorescens* increase nutrient availability through nitrogen fixation, phytohormone synthesis, and nutrient solubilization. These systems help plants receive enough nutrients for development and output. Adequate nitrogen supply stimulates vegetative development by increasing leaf area and chlorophyll content, hence enhancing photosynthetic potential (Dasgupta *et al.* 2021).

Furthermore, biofertilizers boost nutrient uptake efficiency, particularly nitrogen, resulting in increased plant biomass (Nugrahini 2013). Biofertilizers also improve phosphorus availability by increasing phosphate-solubilizing bacteria. Species like *Pseudomonas* are known to transform bound phosphorus into accessible forms that plants can absorb (Surdiarti 2017).

Phosphorus is essential for bulb formation and growth, making it a critical predictor of yield (Siagian *et al*. 2019). In this study, increased phosphorus availability most likely contributed to the comparatively high bulb weight found in treatments using organic fertilizers and biofertilizers, which averaged around 65 g per clump. This number is significantly higher than that reported by Siagian *et al*. (2019), who produced a bulb weight of 19.6 g using both NPK and biofertilizer.

Effect of Organic Fertilizer and Biofertilizer on *S. exigua* Infestation

This study evaluated insect infestation as well as plant growth, biomass, and yield. The findings revealed that *S. exigua* was the only major pest found in shallot plants. The level of infestation was significantly higher in the 100% inorganic fertilizer treatment (23.4%) than in treatments that included organic fertilizers and biofertilizers. In contrast, all treatments with organic fertilizers and biofertilizers resulted in much decreased infestation levels, with no significant differences among them (Table 7). These data suggest that using organic fertilizers in conjunction with biofertilizers can effectively control *S. exigua* infestations compared to standard inorganic fertilization.

The results revealed a considerable difference in the severity of *S. exigua* infestations across treatments. When organic fertilizers were mixed with biofertilizers, infestation levels were much lower than when only inorganic fertilizers were used. All treatments that received organic fertilizers and biofertilizers showed consistently lower infestation rates. This reduction in pest infestation could be related to the use of biofertilizers containing a group of beneficial bacteria such as *Azotobacter*, *Azospirillum*, and *P. fluorescens*. These bacteria are known to improve plant resistance through a variety of processes, including the development of systemic resistance and the generation of bioactive molecules. Dasgupta *et al*. (2021) found that *Azospirillum* spp. can generate pest and disease resistance, whereas Kousar *et al.* (2020) discovered that *P. fluorescens* increases plant tolerance to *Spodoptera* spp. by producing salicylic acid and abscisic acid.

The presence of this microbial consortium shows that biofertilizers could serve as both plant growth promoters and biocontrol agents. Furthermore, the application of organic fertilizers may improve soil conditions, making plants more resistant to pest attack. As a result, using organic fertilizers in conjunction with biofertilizers appears to be a good technique for integrated pest management in shallot agriculture. The reduced infestation of *S. exigua* found in this study may also assist in maintaining or improving output with less inorganic fertilizer input.

The use of organic fertilizers in various doses in conjunction with biofertilizers resulted in plant growth, biomass, and shallot yield comparable to 100% inorganic treatment. Using 30 t ha^{-1} organic fertilizer in combination with biofertilizer resulted in the maximum bulb weight. In contrast, when organic fertilizers and biofertilizers were used together, the infestation of *S. exigua* was dramatically reduced compared to inorganic fertilization. These findings demonstrate that organic and biofertilizer-based fertilization can preserve yield while increasing insect resistance, making it a feasible technique for sustainable shallot agriculture.

Table 6 Yield components of shallot under various fertilizer treatments

Treatment	Bulb weight (g clump^{-1})	Number of bulbs (clump $^{-1}$)	Bulb diameter (cm)
Inorganic fertilizer 100%;	69.2^{b}	8^{a}	2.6^{b}
Organic fertilizer 15 t ha^{-1} + biofertilizer 6 mL plant^{-1};	62.1^{ab}	9^{a}	2.4^{ab}
Organic fertilizer 20 t ha^{-1} + biofertilizer 6 mL plant $^{-1}$	62.1^{ab}	9^{a}	2.3^{ab}
Organic fertilizer 25 t ha^{-1} + biofertilizer 6 mL plant^{-1}	64.9^{ab}	9^{a}	2.4^{ab}
Organic fertilizer 30 t ha^{-1} + biofertilizer 6 mL plant^{-1}	73.1^{b}	9^{a}	2.6^{ab}

Remarks: Values followed by the same letters within the same column are not significantly different according to Duncan's Multiple Range Test (DMRT) at α = 0.05.

Table 7 *Spodoptera exigua* infestation (%) on shallot under various fertilizer treatments

Treatment	Infestation (%)
Inorganic fertilizer 100%;	23.4^{b}
Organic fertilizer 15 t ha^{-1} + biofertilizer 6 mL plant^{-1};	2.8^{a}
Organic fertilizer 20 t ha^{-1} + biofertilizer 6 mL plant^{-1};	6.4^{a}
Organic fertilizer 25 t ha^{-1} + biofertilizer 6 mL plant^{-1}	4.8^{a}
Organic fertilizer 30 t ha^{-1} + biofertilizer 6 mL plant^{-1}	3.0^{a}

Remarks: Values followed by the same letters within the same column are not significantly different according to Duncan's Multiple Range Test (DMRT) at α = 0.05.

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