BIODIVERSITAS
Volume 24, Number 4, April 2023
Pages: 2426-2433

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240458

Application of organic fertilizer enriched with *Trichoderma harzianum* on shallot (*Allium cepa*) cultivation in ultisols

NUNI GOFAR[1], TRI P. NUR[1,♥], SHINTA D. I. PERMATASARI[1], SITI MUSLIMAH[1], HAMDHANIE FIKRI[1], ANUNG HARYONO[2], PUJIATI[2], HANA ALFIANITA UTAMI[2]

[1]Faculty of Agriculture, Universitas Sriwijaya. Jl. Raya Palembang-Prabumulih Km 32, Ogan Ilir 30662, South Sumatra, Indonesia. Tel./Fax.: +62-711-580276, ♥email: triputrinur3@gmail.com

[2]Research Department of PT Pupuk Sriwidjaja. Sei Selayur, Palembang 30119, South Sumatra, Indonesia

Manuscript received: 8 December 2022. Revision accepted: 29 April 2023.

Abstract. *Gofar N, Nur TP, Permatasari SDI, Muslimah S, Fikri H, Haryono A, Pujiati, Utami HA. 2023. Application of organic fertilizer enriched with* Trichoderma harzianum *on shallot (*Allium cepa*) cultivation in ultisols. Biodiversitas 24: 2426-2433.* Shallot is a critical commodity with substantial economic value. However, several factors, such as pests and diseases, negatively impact its low productivity. Therefore, to address these challenges, the agricultural sector is developing an organic fertilizer enriched with the biological agent *Trichoderma harzianum.* This biological agent improves soil fertility, controls *Fusarium* wilt, and enhances shallot production. This study aimed to evaluate the effectiveness of organic fertilizer enriched with *Trichoderma harzianum* in suppressing the growth of *Fusarium oxysporum* and increasing shallot production. Therefore, it included five treatments of organic fertilizer enriched with *Trichoderma harzianum* at varying concentrations of 0, 200, 300, 400, and 500 kg ha^{-1}. The results showed that applying 400 kg ha^{-1} organic fertilizer enriched with *Trichoderma harzianum* suppressed the *Fusarium* wilt. The dose of 500 kg ha^{-1} had the highest pH value of 5.50-5.78 among other treatments and increased 55.7% shallot production on Ultisols compared to the application of NPK $16^{-1}6^{-1}6$. Based on these results, organic fertilizer enriched with *Trichoderma harzianum* could improve soil fertility, increase production and control the *Fusarium* wilt on shallot.

Keywords: *Fusarium* wilt, production, shallot, *Trichoderma*, ultisols

INTRODUCTION

Shallot (*Allium cepa* L.) is a vegetable commodity with a significant economic value but relatively low productivity (Fitriana and Susandarini 2019). Therefore, Shallot cultivation is highly promising, considering the high demand for community consumption in domestic and global markets (Purnawanto and Nugroho 2015). The Indonesian market, in particular, has seen an increase in demand for shallot over the past years. In 2017, the demand was at 1,470,155 tons, which increased to 1,503,436 tons and 1,580,247 tons in 2008 and 2019. However, shallot production in South Sumatra decreased by approximately 3.69% in 2019 (Kementerian Pertanian 2019). Therefore, it is necessary to increase shallot production in South Sumatra, Indonesia by utilizing Ultisols.

Ultisols have low fertility levels, with a pH value < 5. The organic matter content, total N, available N, and available P in this soil type are generally low (Fitriatin et al. 2014). Syahputra et al. (2015) also explained the low P and stated that the availability ranged from 0.53-2.00 ppm. This is due to the low phosphate content of the Ultisols parent material and the presence of fixate phosphate, i.e., Al3+ and Fe3+. Despite having a low fertility level, Ultisols can be used for the cultivation of shallot through the application of liming technology, adding organic matter, and fertilizing (Aryani et al. 2019). Shallot (*Allium cepa* L.) thrives in soil with a crumb structure, good drainage, and high soil fertility levels, with an optimal acidity level of soil pH ranging from 5.6 to 6.5 (Balai Penelitian Sayuran 2013).

The low shallot production can be attributed to multiple factors, including low soil fertility levels (Sumarni et al. 2013) and a high rate of pest and disease attacks (Basuki 2016). Based on farmer reports, about 87-90% of damage occurs due to pests, diseases, fog, and rain. The main disease that could be controlled is *Fusarium* wilt, caused by *Fusarium oxysporum* (Supriati et al. 2019). This disease leads to up to 50% of crop failure that attacks shallot at 0-35 DAP (Fernandes and Abadi 2018). Shallot can easily develop at 29°C with a 67% humidity level and soil pH of about 5.6 (Latifah et al. 2011).

An organic fertilizer product enriched with biological agents, such as *Trichoderma harzianum*, is currently under development to address this issue. This solid organic fertilizer comprises compost made from dry leaves, fresh grass, and *Trichoderma harzianum*, which was directly isolated from oil palm roots. The product contains 1.5×10^6 CFU g^{-1} *Trichoderma harzianum*, a type of Deutromycetes commonly found in agricultural lands or forests. Furthermore, it is antagonistic fungi known for controlling various plant diseases caused by *Macrophomina phaseolina* (Javaid et al. 2017, 2018), *Sclerotium rolfsii* (Ali et al. 2020; Javaid et al. 2021), and *Fusarium oxysporum* (Akhtar and Javaid 2018). Based on research by Suhaida et al. (2013), *Trichoderma* spp. secrete antifungal and toxic metabolites against *Fusarium* proliferation. Several studies showed that *Trichoderma pseudokoningii* and *Trichoderma viride* could control the growth of the fungal pathogen by degrading their DNA and releasing an antifungal substance (Khan and Javaid 2020; Khan et al. 2021). According to Cheng et al. (2015), *Trichoderma hamatum* can inhibit the growth of bacterial wilt by producing proteins. Meanwhile, the combination of *Trichoderma* spp. and compost can delay the incubation period of the *Fusarium* wilt pathogen on shallot (Supriati et al. 2019). *Trichoderma* spp. in compost also plays an active bio activator in composting. Organic fertilizer enriched with *Trichoderma* spp. increase the efficiency of plant disease suppression by direct application to the soil. Therefore, *Trichoderma* spp. (Sharma et al. 2019). Moreover, *Trichoderma* species can also increase the production of shallot and onion (Akhtar and Javaid 2018). The study by Tiara et al. (2021) stated that the production of shallot by applying *Trichoderma spp.* was higher than without it.

Enrichment of organic fertilizer with *Trichoderma harzianum* is believed to improve Ultisols' fertility. The productivity of shallot cultivation on Ultisols is expected to increase through improving soil fertility and preventing *Fusarium* wilt disease by *Trichoderma* spp. Therefore, applying organic fertilizer enriched with *Trichoderma harzianum* can optimize the growth and production of shallot in Ultisols. This study aims to evaluate the effectiveness of organic fertilizer in suppressing the growth of *Fusarium oxysporum* and increasing the production of shallot in the experimental field of Sriwijaya University.

MATERIALS AND METHODS

Study area

The study was conducted at the Experimental Field of Sriwijaya University, Indralaya Sub-district, Ogan Ilir District, South Sumatra, Indonesia, from June to August 2021.

Procedures

Treatment

The experiment was designed in a Randomized Block Design with five treatments of 0, 200, 300, 400, and 500 kg ha^{-1} organic fertilizer enriched with *Trichoderma* spp. Furthermore, the treatment was replicated five times to obtain 25 experimental units.

Land preparation

Land management was conducted by eradicating weeds using herbicides, cleaning them up, then plowing using a tractor. Soil sampling was collected in a composite manner before tillage to analyze physical, chemical, and biological properties. The initial pH was less than 5.6; hence, Dolomite limed the soil at a dose of 1 × Al-ex (exchangeable Al) and incubated for two weeks. Subsequently, experimental plots were made with the size of 1.2 m × 4 m, and the height was 0.3 m. The distance between the plots and lanes was 0.5 m and 1 m. Organic fertilizer enriched with *Trichoderma harzianum* was applied with soil loosening in the experimental plots. The treatment application was carried out one week before planting, and then the plots were covered with a plastic mulch of 5 m × 1.2 m.

Shallot cultivation

The shallot bulbs used were the Tajuk variety, with the bulbs medium size of 5-10 g, taken two months after harvest with the shoot characteristics reaching the pointy end. The plant spacing used was 0.2 m × 0.15 m. Before planting, the soil was watered until moist, then the seeds/bulbs were inserted into the hole and covered with soil. Subsequently, the shallot seedlings planted were given fertilizer using NPK (16:16:16) at a dose of 500 kg ha^{-1}. The supplemental fertilizer given was urea at 46% N, with a dose of 180 kg ha^{-1}. It was periodically applied at 10-15 days after planting (DAP) and 30-35 DAP.

Shallot maintenance was conducted by watering, weeding, and observing the cultivation area twice daily, in the early morning and late afternoon. Meanwhile, watering was started from the planting until the harvest time of shallots. While wedding activity was performed by pulling the weeds around the shallot cultivation when needed. The visual observations of plants were carried out daily to observe pest and disease attacks.

The criteria of shallot that can be harvested are if more than 80% of the leaves fall, start to wither, and change color to pale yellow. Furthermore, dark red/purplish-red bulbs are visible on the soil surface, and the shallots emit a distinctive odor. Harvest was achieved by pulling the plant from the ground, and the shallot bulbs were dried under the sunlight for three days. Bulbs that had been dried should be turned every day to enable even dryness.

Observed variables

The soil's initial physical, chemical, and biological properties were observed before conducting the study. The observation consisted of soil porosity, aggregate stability, soil moisture content, texture, structure, soil pH, C-organic, total N, total P, available P, total K, exchangeable K, exchangeable Na, exchangeable Ca, exchangeable Mg, exchangeable Al, CEC, base saturation, and Al saturation. Furthermore, the observation of the *Trichoderma* population in the soil was carried out three times, before tillage, during the study, and after harvest in each experimental plot. The observed variables consisted of soil pH values measured at 2, 4, and 6 weeks after planting (WAP), plant height, number of leaves, and tillers measured at the age of 20, 30, and 35 DAP, and observing symptoms of plants infected by *Fusarium oxysporum* at 15 and 43 DAP. Plant mortality was observed at 62 DAP, and the perished number due to F. oxysporum was computed during harvest. Additionally, an analysis of the N, P, and K levels of the plant tissue in the late vegetative phase at 36 DAP was conducted. The wet and dry weight of shallot bulbs, production per plot, production per hectare, and population of Trichoderma spp. were also estimated at three stages, namely, before treatment, at 36 DAP, and after harvest, using the initial soil.

Data analysis

Data were analyzed statistically using Analysis of Variance to determine the treatment's effect on the observed variables. The best dose that produced the optimal production was determined based on Duncan's Multiple Range Test (DMRT) at a significant level of 0.05. Moreover, the instrument used to analyze data was Microsoft excel.

RESULTS AND DISCUSSION

Based on the analysis before treatment, the soil location had a loam texture with 57% sand, 9% silt, and 34% clay content. The soil had a lumpy structure, good porosity, and stable aggregate with a 38% moisture content field capacity. Furthermore, the soil condition was slightly acidic, with moderate Al saturation, moderate Ca, Mg, and Na cations, and low K. The condition had very high contents of total P and available P due to frequent fertilizer application. Although the saturation of exchangeable Al, Ca, and Mg was moderate, liming was still carried out based on 1 × Al-ex (exchangeable Al), considering the slightly acidic pH and the optimal condition for soil microbial activity to reduce high C and N ratios. The soil in the area exhibited a low Cation Exchange Capacity (CEC) and high base saturation, consequently leading to a limited holding capacity. Despite being limed, the pH increase was negligible due to this condition. After the lime incubation, the pH increased slightly from 5.7 to 5.8.

Soil reaction

The soil reaction was indicated by the pH, measured at 2, 4, and 6 weeks after planting shallots, as shown in Table 1. Analysis of variance showed that the treatment of organic fertilizer enriched with *Trichoderma harzianum* had no significant effect on soil pH.

The soil pH fluctuated during these observations at 2, 4, and 6 weeks after planting. This fluctuation was caused by the dynamics of nutrient uptake and release of H^+ or OH^- from shallot roots, affecting the soil pH value at the measurement time. Meanwhile, the alkaline nature of the organic material could cause pH value enhancement. For example, organic matter mineralization releases base cations, causing an increase in pH value. Ammonium-based N fertilizers reduce the pH over time, specifically for soils with low buffer capacity (Schumann et al. 2010).

Table 1. The average soil pH value due to organic fertilizer enriched with *Trichoderma harzianum*

Organic fertilizer with	**Soil pH after planting**		
Trichoderma harzianum	**2 weeks**	**4 weeks**	**6 weeks**
0 kg ha^{-1} (P0)	5.47±0.27	5.28±0.44	5.60±0.27
200 kg ha^{-1} (P1)	5.55±0.23	5.05±0.15	5.35±0.05
300 kg ha^{-1} (P2)	5.60±0.21	5.29±0.38	5.41±0.31
400 kg ha^{-1} (P3)	5.47±0.26	5.34±0.29	5.45±0.23
500 kg ha^{-1} (P4)	5.78±0.32	5.35±0.31	5.50±0.37

Plant height

Organic fertilizer enriched with *Trichoderma harzianum* did not significantly affect the shallots' plant height at 20, 30, and 35 DAP. However, plant height increased by the fertilizer dose organic enriched with *Trichoderma harzianum,* as shown in Figure 1. Shallots that grew during this study were relatively short, compared to the description of the Tajuk variety, with a plant height range from 26.4 to 40.0 cm. The plant height increased due to the dose of organic fertilizer, which presumably released macro and micronutrients for shallots.

Number of tillers

The number of tillers was not significantly affected by the treatment of organic fertilizer enriched with *Trichoderma harzianum*. According to the description of the Tajuk variety, the number of shallot tillers should be 6-12 for each plant. During the observation periods at 20, 30, and 35 days after planting, the number met the criteria for the Tajuk variety, as shown in Figure 2. However, after 35 days, there was no further increase in the number of tillers in the shallot plants, as this period marked the onset of the bulb-filling stage.

Number of leaves

The number of leaves per clump was observed at 20, 30, and 35 DAP. The analysis of variance showed that the treatment of organic fertilizer enriched with *Trichoderma harzianum* had no significant effect on the average number of leaves per clump. Based on the description of the Tajuk variety, the number of leaves per clump ranged from 15-45. The number observed 35 days after planting ranged from 24.84 to 31.64 leaves, as shown in Figure 3. Therefore, the average number of leaves per clump obtained the highest result in treating 400 kg ha^{-1} organic fertilizer enriched with *Trichoderma harzianum.* The highest number of tillers (8.92) were obtained in the treatment of 500 kg ha$^{-1,}$ as shown in Figure 2. Based on the results, the tillers do not affect the number of leaves produced by shallots.

Percentage of *Fusarium* wilt attack on shallot

The disease symptoms were observed 15 and 43 days after planting (DAP). The disease symptoms were minimal at 15 DAP due to the plants' relatively young and small size, compared to the further observation at 43 DAP. Figures 4 (a) and (b) show a healthy plant and a plant attacked by a *Fusarium* wilt. The symptoms included wilting, yellowing, curling, dropping of leaves, and rotten root.

The number and percentage of plants attacked by *Fusarium* wilt were observed at 43 DAP, while the mortality was at 62 DAP. At 43 DAP, the percentage attacked by *Fusarium* wilt in each treatment ranged from 1.08% to 1.84%, as shown in Table 2. The low permanent wilting attack indicates that the organic fertilizer treatment enriched with *Trichoderma harzianum* can control the *Fusarium* wilt attack on shallots cultivation. However, in the cultivation not treated with organic fertilizers enriched *Trichoderma harzianum,* the attack was low. This is because the plants had been fertilized with sufficient NPK and urea fertilizers, making them more disease-resistant. In the cycle, ammonium-based fertilization, such as urea, can form nitrite in the nitrification process. Nitrite is a toxic compound that can inhibit soil-borne diseases such as *Fusarium*, even without applying *Trichoderma*. Therefore, its presence can suppress the fungal activity of *Fusarium* (Schumann et al. 2010).

Based on the analysis of variance, the organic fertilizer enriched with *Trichoderma harzianum* in various doses did not significantly affect plant mortality at 62 DAP. The percentage of plant mortality ranged from 9.6 to 20.0% (Table 2). In plant mortality, the visible symptom was bulb rot, but the crown showed no signs of wilting. However, the bulb rotted when removed due to *Erwinia carotovora* or *Pectobacterium carotovorum*. Arriani et al. (2020) stated that shallots cultivated in Java and Sumatra can be infected by this bacteria, which causes bulbs' soft rot. In Java and Sumatra, it is known as bulb rot, caused by *Erwinia carotovora*. Furthermore, bacterial infection can occur when the plant is approaching maturity.

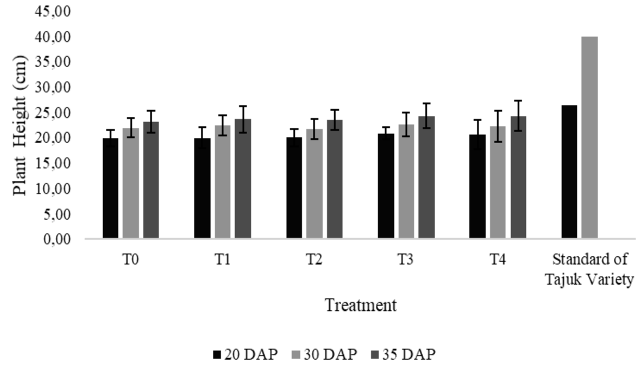

Figure 1. Each treatment's average shallot plant height at observations 20, 30, and 35 days after planting (DAP)

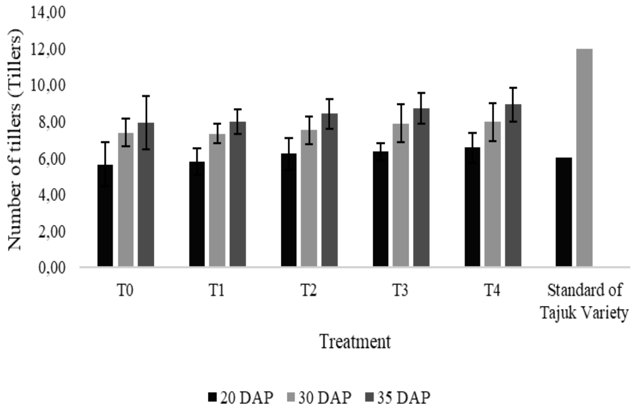

Figure 2. The tillers number of shallot on each treatment at observations 20, 30, and 35 days after planting (DAP)

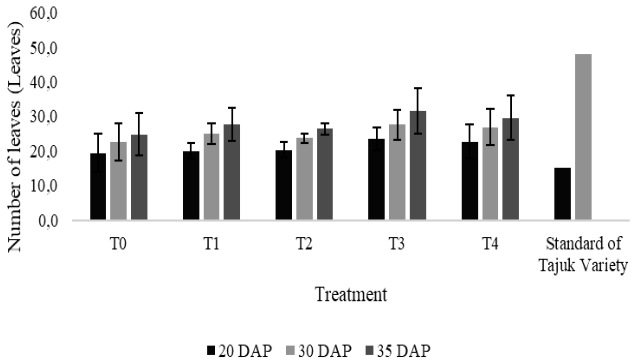

Figure 3. Number of leaves per clump on each treatment at observations 20, 30, and 35 days after planting (DAP)

A B

Figure 4. A. Healthy shallot plant; B. Shallot plant attacked by *Fusarium* wilt

Table 2. Number and percentage of plants attacked by *Fusarium* wilt and plants mortality in each treatment of organic fertilizer enriched with *Trichoderma harzianum*

Organic fertilizer with *T. harzianum*	Number and percentage of plant attacked at 43 DAP		Number and percentage of plant mortality at 62 DAP	
	Total	%	Total	%
0 kg ha^{-1} (P0)	17±0.49	1.84±0.13 c	67±5.75	13.4±5.75
200 kg ha^{-1} (P1)	10±1.26	1.35±0.43 ab	100±3.22	20.0±3.22
300 kg ha^{-1} (P2)	7±1.02	1.23±0.30 a	86±8.45	17.2±8.45
400 kg ha^{-1} (P3)	6±0.40	1.08±0.16 a	48±2.80	9.6±2.80
500 kg ha^{-1} (P4)	13±0.80	1.59±0.24 bc	90±11.45	18.0±11.45

Note: Mean ± standard deviation. Numbers followed by the same letters on the same line are not significantly different at the 5% probability level (DMRT 0.05)

Plant canopy biomass

The wet and dry biomass were measured at the end of the vegetative phase of shallot plants. Furthermore, three plants were taken in each plot to measure the biomass from the leaves and root components accumulated as plant biomass. The samples were taken 35 DAP, and the analysis of variance showed that the organic fertilizer enriched with *Trichoderma harzianum* treatment significantly affected the wet and dry biomass. The average biomass on the treatments of 400 and 500 kg ha^{-1} organic fertilizer was higher and significantly different compared to 0 and 200 kg ha$^{-1,}$ as shown in Table 3.

Nutrient levels and uptake of N, P, and K in shallot

N, P, and K nutrient levels of shallot plants were obtained 35 DAP. The nutrient levels were analyzed from leave tissue oven-dried for 48 hours at a temperature of 70°C. Therefore, to obtain nutrient uptake, the analysis content was multiplied by the dry biomass of the shallot plant. In the shallot bulb filling period, the criteria for nutrient N content were deficient <5%, sufficient 3-4 %, and excessive > 4% (Haifa Group.com 2016). Therefore, the N nutrient content ranged from 3-4%, classified as excessive in shallots, as shown in Table 4. The P nutrient content was also classified as excessive because the value exceeded 2000 ppm. Based on the criteria from Haifa Group.com (2016), P levels were classified as deficient (< 1000 ppm), sufficient (1000-2000 ppm), and excessive (> 2000 ppm). Therefore, the P nutrient content in shallot plants was classified as excessive (> 2000 ppm or 0.23-0.25%), while K nutrients were sufficient in the 3-4% range.

Analysis of variance showed that the organic fertilizer enriched with *Trichoderma harzianum* in various doses significantly affected the uptake of N, P, and K nutrients by shallot plants. Based on Duncan's test, N and K uptake in shallot plants applied with 400 and 500 kg ha^{-1} organic fertilizer significantly differed from that in shallot plants not applied with organic fertilizer. In addition, the P nutrient uptake of shallot plants with 500 kg ha^{-1} significantly differed from 0-300 kg ha^{-1}.

Production of shallots

The analysis of variance showed that the organic fertilizer enriched with *Trichoderma* spp. significantly affected the wet and dry weight of shallot bulbs. The highest weight per clump planted in the experimental field of the Agriculture Faculty, Sriwijaya University, was obtained by application of 500 kg ha^{-1} organic fertilizer enriched with *Trichoderma harzianum*, but not significantly different compared to the dose of 300 kg ha^{-1} (Table 5).

Based on the description of the shallots Tajuk variety, the wet weight of bulbs per clump ranged from 32.5-68.3 g. In this study, the wet weight ranged from 19.21-29.23 g per clump with various doses of organic fertilizer. Sumarni et al. (2012) reported that for the soil with high P status, the dose of the fertilizer was more than 60 kg ha^{-1}. Furthermore, P2O5 could reduce the yield of fresh and dry shallot weight per plant. Even though applying organic fertilizers enriched with *Trichoderma harzianum* on the vegetative variables had no significant effect, it caused an increase in the wet and dry weight of shallot bulbs compared to the control.

The analysis of variance showed that the effect of organic fertilizer had a significant effect on the shallot production per plot and hectare. Based on Duncan's results, the treatment of 400 kg ha^{-1} organic fertilizer enriched with *Trichoderma harzianum* was not significantly different from 500 kg ha^{-1}. However, it significantly differed from the control treatment at 0 kg ha^{-1}, as shown in Table 6. Therefore, applying 500 kg ha-1 organic fertilizer can increase production by 55.7% compared to applying 0 kg ha^{-1}.

Compared to the production based on the description of the Tajuk shallot variety, the yield obtained was relatively low. According to the description, the optimal shallots production is 11 to 16 tons per hectare. Furthermore, although the description mentions that the Tajuk variety exhibits good adaptability to dry and rainy seasons, it is also known to thrive in lowland areas. However, the highest yield achieved was only 76% of the minimum production threshold specified in the variety description when the Tajuk variety was cultivated in the experimental field of the Agriculture Faculty, Sriwijaya University, located in lowland areas during the dry season.

Table 3. Wet and dry biomass of shallots due to the application of organic fertilizer enriched with *Trichoderma harzianum* treatment

Organic fertilizer with *T. harzianum*	Wet biomass (g)	Dry biomass (g)
0 kg ha^{-1} (P0)	15.11±3.03 a	13.85±2.88 a
200 kg ha^{-1} (P1)	15.75±2.42 a	14.45±2.40 a
300 kg ha^{-1} (P2)	17.02±4.26 ab	15.84±3.91 ab
400 kg ha^{-1} (P3)	21.18±5.08 bc	19.14±4.64 bc
500 kg ha^{-1} (P4)	23.01±5.64 c	21.24±4.86 c

Table 4. Nutrient level and uptake of plant tissue in shallot fertilized with organic fertilizer-enriched *Trichoderma harzianum*

Organic fertilizer	Nutrient level (%)		
with *T. harzianum*	N	P_2O_5	K_2O
0 kg ha^{-1} (P0)	3.54±0.16	0.23±0.02	3.76±0.19
200 kg ha^{-1} (P1)	3.63±0.14	0.23±0.02	3.25±0.43
300 kg ha^{-1} (P2)	3.58±0.12	0.22±0.01	3.45±0.33
400 kg ha^{-1} (P3)	3.37±0.09	0.25±0.02	3.27±0.28
500 kg ha^{-1} (P4)	3.51±0.12	0.23±0.01	3.64±0.22
Organic fertilizer	**Nutrient Uptake (g/clump)**		
with *T. harzianum*	**N**	**P_2O_5**	**K_2O**
0 kg ha^{-1} (P0)	0.534±0.098 a	0.032±0.009 a	0.513±0.130 a
200 kg ha^{-1} (P1)	0.522±0.073 a	0.033±0.005 a	0.474±0.119 a
300 kg ha^{-1} (P2)	0.563±0.119ab	0.035±0.008 a	0.551±0.158 ab
400 kg ha^{-1} (P3)	0.669±0.146 b	0.054±0.016 b	0.701±0.192 b
500 kg ha^{-1} (P4)	0.713±0.164 b	0.043±0.011 ab	0.703±0.205 b

Note: Mean ± standard deviation. Numbers followed by the same letters on the same line are not significantly different at the 5% probability level (DMRT0.05)

Table 5. The effect of organic fertilizer enriched with *Trichoderma harzianum* on the wet and dry weight of shallot bulb

Organic fertilizer with *T. harzianum*	Dry weight bulb/clump (g)	Wet weight bulb/clump (g)
0 kg ha^{-1} (P0)	19.21±1.50 a	17.90±1.74 a
200 kg ha^{-1} (P1)	25.06±1.48 b	24.32±1.41 b
300 kg ha^{-1} (P2)	24.77±3.25 b	23.42±3.31 b
400 kg ha^{-1} (P3)	27.59±2.42 bc	26.20±2.67 bc
500 kg ha^{-1} (P4)	29.23±2.68 c	27.87±2.21 c

Note: Mean ± standard deviation. Numbers followed by the same letters on the same line are not significantly different at the 5% probability level (DMRT 0.05)

Table 6. The average of shallot production due to the application of organic fertilizer enriched with *Trichoderma harzianum* and the percentage of shallot production enhancement to the application of 0 kg ha^{-1}

Organic fertilizer with *T. harzianum*	Production per plot (g/plot)	Production per hectare (ton ha^{-1})	Production enhancement (%)
0 kg ha^{-1} (P0)	1222.31±106.72 a	5.37±0.52 a	0
200 kg ha^{-1} (P1)	1507.71±112.08 a	7.30±0.42 b	30.9
300 kg ha^{-1} (P2)	1548.76±453.78 ab	7.03± 0.99 b	35.9
400 kg ha^{-1} (P3)	1715.75±367.28 bc	7.86± 0.80 bc	46.4
500 kg ha^{-1} (P4)	2020.75±210.68 c	8.36± 0.66 c	55.7

Note: Mean ± standard deviation. Numbers followed by the same letters on the same line are not significantly different at the 5% probability level (DMRT0.05)

Table 7. The population of *Trichoderma* spp. in the soil

Organic fertilizer with *Trichoderma* spp.	Initial soil (x10^6 cfu g^{-1})*	36 days after planting** (×10^4 cfu g^{-1})	After harvest (×10^4 cfu g^{-1}) **
0 kg ha^{-1} (P0)	2.65	0.154	0.190
200 kg ha^{-1} (P1)	-***	5.333	5.200
300 kg ha^{-1} (P2)	-	6.233	6.133
400 kg ha^{-1} (P3)	-	6.233	5.967
500 kg ha^{-1} (P4)	-	0.740	0.827

Note: *Laboratory test results in Laboratorium of Balittanah, Bogor, ** Laboratory test result in Laboratorium of PT. Sampurna Agro Tbk, Palembang. -***not calculated

The population of *Trichoderma* in the soil

Population *Trichoderma* in the soil was calculated before liming treatment and harvesting at 36 and 63 DAP (Table 7). In the initial soil, the indigenous *Trichoderma* population reached 2.65 × 10^6 CFU g^{-1}. On the other hand, the population at 36 DAP ranged from 0.154 to 0.740 × 10^4 CFU g^{-1}, on the soil with the dose of organic fertilizer increased with *Trichoderma*. However, the population in the soil. Based on the result, the *Trichoderma* population treating 500 kg ha-1 organic fertilizer was lower than 200-400 kg ha-1 because the growth was inhibited in the soil.

Microorganisms on the soil after the crop was harvested generally declined, and the food obtained from the photosynthate released by the roots was no longer available. In vegetative, the plant exudes photosynthetic products into the soil to nourish its symbiotic microorganisms. The roots release organic compounds that can stimulate microbial growth and be utilized by microbes to survive and reproduce in the rhizosphere (Widyati 2020). All photosynthate was transported to the storage organ to prevent its release into the soil in the bulb-filling stage. Bui et al. (2019) stated photosynthate produced from photosynthesis could be translocated to a food reserve storage area on the tubers or bulbs. Therefore, the population of beneficial soil microorganisms decreases when entering the generative phase.

Discussion

The soil under consideration demonstrated favorable physical properties attributable to its clay texture, lumpy structure, good porosity, and stable aggregate stability, with a field capacity moisture content of 38%. Conversely, the soil's chemical characteristics indicated a slightly acidic reaction, moderate Al saturation, low CEC, and high base saturation. This condition led to a low holding capacity of the soil, such that even with liming, the increase in soil pH was insignificant. Even though the soil had a very high total and available P, it demonstrated a low total N and K. In the observation of soil pH, there was a fluctuation in the pH value. This was due to the dynamics of nutrient uptake and release of H+ ions or OH- ions from the roots affecting the soil pH value at the measurement time. The increase in pH can be caused by the alkaline nature of organic fertilizer, where the mineralization of organic matter can release alkaline cations, causing an increase in pH. Ammonium-based N fertilizers reduce pH over time, specifically for soils with low buffer capacity (Schumann et al. 2010). Therefore, fluctuations in pH are possible, but they may not be significant.

Applying organic fertilizers aims to enhance crop yields and quality, increase soil fertility, reduce chemical inputs, support sustainability, and be environmentally friendly (Galindez et al. 2016). *Trichoderma harzianum* enriched in organic fertilizers acts as antagonistic fungi in controlling plant diseases. Ratnawati et al. (2020) stated that *Trichoderma* spp. could protect plants from pathogens by releasing antimicrobial compounds to inhibit the growth of these pathogens and enhance shallot yields. According to Tiara et al. (2021), the production of shallots by applying *Trichoderma* spp. was higher than without *Trichoderma harzianum*. Yu and Luo (2020) showed that *T. koningiopsis* control *F. oxysporum* by reducing reactive oxygen, lipid peroxidation, and cell death. It also increases osmolyte content, stimulating antioxidant enzyme activity and increasing soil fertility. Illumina MiSeq sequencing also indicated that *T. koningiopsis* increased plant growth-promoting bacteria by 19,9% and reduced the attack of *F. oxysporum* by 92.0%. In this study, applying organic fertilizer enriched with *Trichoderma harzianum* can increase shallot production in Ultisol.

Several factors beyond the treatment variables could affect the shallot yield. The dry season required daily plant watering during the study, also high air temperatures led to increased transpiration and respiration, reducing photosynthate supply for plant tissue development.

According to Purnomo et al. (2018), high temperatures can increase the respiration process of potato plants. This causes the photosynthetic results, which should be a food reserve in the form of tubers, to be diverted as energy for plant respiration. Furthermore, it inhibits the formation of potato tubers which causes a decrease in yields. Adequate levels of mineral nutrition can enhance plant resistance to fungal and bacterial infections. Although sufficient N levels in plant tissues can boost resistance to most bacterial diseases, excessive N levels have the opposite effect. Some bacteria depend on food sources from living tissues, which increases conditions of high N levels in plants (Schumann et al. 2010). In this study, excessive N levels allowed pathogenic bacteria to multiply in the plant tissues, specifically in bulbs, resulting in death. Meanwhile, the number of plant mortality per plot did not correlate with the dose of organic fertilizer enriched with *Trichoderma harzianum*. That is caused by the resistance of individual plants to bacterial attacks that increase in plant tissues due to high levels of N.

Before applying lime and fertilizer, the P nutrients in the soil were classified as very high (111 ppm P2O5) through NPK $16^{-1}6^{-1}6$ fertilization. The high level of soil P and the supply from NPK fertilizer caused the levels and uptake of the nutrients in shallot to be classified as excessive. Adequate P availability in the soil is crucial in increasing crop yield because the nutrient improves plant carbohydrate content, root development, and nutrient uptake, leading to increased crop yield (Lindang et al. 2021). However, excessive P uptake interferes with absorbing other nutrients, specifically micronutrients like Fe, Cu, and Zn, without any visible symptoms in plants. Masthura et al. (2013) stated that excessive levels of this nutrient could interfere with the absorption of others and decrease crop yields.

The relation between disease and K content was more consistent. A review of 534 articles found that sufficient K in plant tissues can enhance plant resistance to pests and diseases (Schumann et al. 2010). The uptake was categorized as sufficient, but the balance of nutrients, specifically due to excess levels of N and P, suppressed the positive effect of K in increasing plant resistance to disease.

The study results indicate that the mortality of shallots ranged from 9.6-20%, and the visible symptom was bulb rot, which was already known at the time of harvest. According to several studies, the cause is bacteria. For example, Torimiro et al. (2020) found that all bacterial isolates could cause the rotting of shallots. Based on the diameter of rot formation within seven days, *Flavobacterium* sp. and *Micrococcus* spp. (28 mm) were the most and least pathogenic at 28 mm and 14 mm, respectively (Torimiro et al. 2020). Therefore, bacteria can cause shallot rot, and bulbs showing signs of contamination should be separated to avoid cross-contamination. In addition, adequate care should be taken before the consumption of shallots to avoid foodborne illness and disease.

Environmental factors constantly change throughout the growth of the plant. Nurcholis et al. (2015) stated the external factors that affect plant growth include water availability, nutrients, solar energy, temperature, and humidity. Moreover, pH and plant inputs such as fertilizers and pesticides also affect growth. The temperature and humidity of the air around the plant greatly affect the physiological process, specifically in the transpiration, absorption, and translocation of nutrients. High air temperature and low humidity increase evaporation, which affects the absorption of water and nutrients by plant root hairs. That increases the amount of food produced during photosynthesis (Lakitan et al. 2021). Darmawan and Baharsjah (2010) stated that nutrients are essential for photosynthesis. Therefore, the photosynthate can be translocated to all plant parts as food reserves.

The average and optimum temperature for shallots is 25 to 32°C and 22°C, while the daily air temperature measurements ranged from 28 to 35°C. Therefore, the air temperature during the study was above the optimum and the average for the growth of shallots. Furthermore, high temperature causes an increase in the kinetic energy of plant molecules, improving the rate of biochemical reactions to a certain extent, but the temperatures that are too high are no longer favorable for plants. In some cases, the assimilate translocation is hindered at high temperatures because of dehydration due to increased respiration. This also causes growth disorders in merismatic tissue due to assimilation as a base material that can not reach the tissue. In the formation of generative cells, high temperatures cause damage to the mitotic division system. It affects enzyme activity and reduces cleavage and protein synthesis (Pessarakli 2002).

In conclusion, applying organic fertilizer enriched with *Trichoderma harzianum* could suppress the *Fusarium* wilt attack on shallot plants. However, the percentage of plant mortality ranged from 9.6 to 20.0%, showing the symptoms of bulb rot caused by *Erwinia carotovora* or *Pectobacterium carotovorum*. Moreover, 500 kg ha-1 organic fertilizer enriched with *Trichoderma* sp. had increased 55.7% shallot production in Ultisol compared to NPK 16-16-16.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support of Organic Fertilizer Enriched with *Trichoderma* spp. developed by PT. Pupuk Sriwijaya, Palembang, Indonesia with the work order number 5500025996.

REFERENCES

Akhtar R, Javaid A. 2018. Biological management of basal rot of onion by *Trichoderma harzianum* and *Withania somnifera*. Planta Daninha 36: e017170507. DOI: 10.1590/S0100-83582018360100009.

Ali A, Javaid A, Shoaib A, Khan IH. 2020. Effect of soil amendment with *Chenopodium album* dry biomass and two *Trichoderma* sppecies on growth of chickpea var. Noor 2009 in *Sclerotium rolfsii* contaminated soil. Egypt J Biol Pest Control 30: 102. DOI: 10.1186/s41938-020-00305-1.

Arriani IF, Abadi AL, Aini LQ. 2020. Karakterisasi bakteri patogen penyebab layu pada tanaman bawang merah (*Allium ascalonicum* L.).

VIABEL: Jurnal Ilmiah Ilmu-Ilmu Pertanian 14 (1): 69-75. DOI: 10.35457/viabel.v14i1.1004. [Indonesian]

Aryani N, Hendarto K, Wiharso D, Niswati A. 2019. Peningkatan produksi bawang merah dan beberapa sifat kimia tanah ultisol akibat aplikasi vermikompos dan pupuk pelengkap. J Trop Upland Res 1 (1): 145-160. DOI: 10.23960/jtur.vol1no1.2019.18. [Indonesian]

Balai Penelitian Tanaman Sayuran. 2013. Budidaya Bawang Merah. Available at : https :// balitsa. litbang. pertanian. go.id /ind/ index.php/berita-terbaru/171-budidaya-bawang-merah. (Accessed : 2 August 2021). [Indonesian]

Basuki RS. 2016. Identifikasi permasalahan dan analisis usahatani bawang merah di dataran tinggi pada musim hujan di Kabupaten Majalengka. Jurnal Hortikultura 24 (3): 266. DOI: 10.21082/jhort.v24n3.2014.p266-275. [Indonesian]

Bui LT, Ella ES, Dionisio-Sese ML, Ismail AM. 2019. Morphophysiological changes in roots of rice seedling upon submergence. Rice Sci 26 (3): 167-177. DOI: 10.1016/j.rsci.2019.04.003.

Cheng Y, Dong C, Huang C, Zhu Y. 2015. Enhanced Production of Diosgenin from Dioscorea zingiberensis in Mixed Culture Solid-State Fermentation with *Trichoderma* reesei and *Aspergillus fumigatus*. Biotechnol Biotechnol Equipment 29 (4): 773-778. DOI: 10.1080/13102818.2015.1032352.

Darmawan J, Baharsjah JS. 2010. *Dasar-Dasar Fisiologi Tanaman*. SITC: Jakarta. [Indonesian]

Fernandes F, Abadi AL. 2018. Utilization of plant growth promoting rhizobacteria (PGPR) in disease control important in plants onion (Allium ascalonicum L.). Intl J Res Granthaalayah 6 (1): 126-136. DOI: 10.5281/zenodo.1162718. [Indonesian]

Fitriana N, Susandarini. 2019. Short Communication: Morphology and taxonomic relationships of shallot (*Allium cepa* L. group aggregatum) cultivars from Indonesia. Biodiversitas 20 (10). DOI: 10.13057/biodiv/d201005.

Fitriatin BN, Yuniarti A, Turmuktini T, Ruswandi FK. 2014. The effect of phosphate solubilizing microbe producing growth regulators on soil phosphate, growth and yield of maize and fertilizer efficiency on ultisol. Eurasian J Soil Sci 3 (2): 101. DOI: 10.18393/ejss.34313.

Galindez JL, Porciuncula FL, Pascua MP, Claus SM, Lopez LLMA. 2016. Performance of Red onion (bulb type) in fully converted organic area as affected by frequency of organic fertilizer application combined with *Trichoderma* sppp. J Agric Sci Technol B 6 (1): 10-17. DOI: 10.17265/2161-6264/2016.01.002.

Haifa-Group.com. 2016. *Nutritional Recommendations for Onion*. Available at: https://www.haifa-group.com/crop-guide-onion-nutrient-requirements. (Accessed : 27 July 2021).

Javaid A, Afzal L, Shoaib A. 2017. Biological control of charcoal rot of mungbean by *Trichoderma harzianum* and shoot dry biomass of *Sisymbrium irio*. Planta Daninha 35: e017165756. DOI: 10.1590/S0100-83582017350100075.

Javaid A, Khan IH, Shoaib A. 2018. Management of charcoal rot of mungbean by two *Trichoderma* sppecies and dry biomass of *Coronopus didymus*. Planta Daninha 36: e018182795. DOI: 10.1590/S0100-83582018360100124.

Javaid A, Ali A, Shoaib A, Khan IH. 2021. Alleviating stress of *Sclertium rolfsii* on growth of chickpea var. Bhakkar-2011 by *Trichoderma harzianum* and *T. viride*. J Anim Plant Sci 31 (6): 1755-1761. DOI: 10.36899/JAPS.2021.6.0378.

Kementerian Pertanian. 2019. Data Produksi Hortikultura. Available at : https:// www.pertanian.go.id/ home/?show=pageandact=viewandid=61. (Accessed : 3 June 2021). [Indonesian]

Khan IH, Javaid A. 2020. *In vitro* biocontrol potential of *Trichoderma pseudokoningii* against *Macrophomina phaseolina*. Intl J Agric Biol 24 (4): 730-736. DOI : 10.17957/IJAB/15.1494.

Khan IH, Javaid A, Ahmed D. 2021. *Trichoderma viride* controls *Macrophomina phaseolina* through its DNA disintegration and production of antifungal compounds. Intl J Agric Biol 25 (4): 888-894. DOI: 10.17957/IJAB/15.1743.

Lakitan B, Kartika, Susilawati, Wijaya A. 2021. Acclimatingleaf celeryplant (*Apium graveolens*) via bottom wet culturefor increasing its adaptability to tropical riparian wetland ecosystem. Biodiversitas 22 (1): 320-328. DOI: 10.13057/biodiv/d220139.

Latifah A, Kustantinah, Soesanto L. 2011. Pemanfaatan beberapa isolat *Trichoderma harzianum* sebagai agensia pengendali hayati penyakit layu *Fusarium* pada bawang merah in Planta. EUGENIA 17 (2): 86-95. DOI: 10.35791/eug.17.2.2011.4105. [Indonesian]

Lindang HU, Subbiah VK, Rodrigues KF, Budiman C. 2021. Isolation, identification,and characterization of phosphate solubilizing bacteria, *Paenibacillus* sp., from the soil of Danum Valley Tropical Rainforest, Sabah, Malaysia. Biodiversitas 22 (10): 4370-4378. DOI: 10.13057/biodiv/d221030.

Masthura SP, Sufardi, Syakur. 2013. Pengaruh pemupukan phosfat dan sulfur terhadap pertumbuhan dan serapan hara serta efisiensi hasil padi sawah (*Oryza sativa* L.). Jurnal Manajemen Sumberdaya Lahan 2 (3): 285-295. [Indonesian]

Nurcholis M, Sumarsih S, Brotodjoj R, Haryanto D. 2015. Environmental Factors in the Growth of Jatropha at Potorono Village, Yogyakarta. Sains Tanah - J Soil Sci Agroclimatol 12 (1): 10. DOI: 10.15608/stjssa.v12i1.215.

Pessarakli M. 2002. *Handbook of Plant and Crop Physiology*. 2nd Ed. Revised and Expanded. Marcel Dekker, New York. DOI: 10.1201/9780203908426.

Purnawanto AM, Nugroho B. 2015. Efektivitas kompos limbah media tanam jamur tiram sebagai pupuk organik pada budidaya bawang merah di tanah ultisol. AGRITECH XVII (2): 97-105. DOI: 10.30595/agritech.v17i2.1722.

Purnomo D, Damanhuri FN, Winarno W. 2018. Respon Pertumbuhan dan Hasil Tanaman Kentang (*Solanum tuberosum* L.) Terhadap Pemberian Naungan dan Pupuk Kieserite di Dataran Medium. Agriprima: J Appl Agric Sci 2 (1): 67-78. DOI: 10.25047/agriprima.v2i1.72. [Indonesian]

Ratnawati R, Sjam S, Rosmana A, Tresnapura US. 2020. Endophytic *Trichoderma* sppecies of palu valley shallot origin with potential for controlling purple blotch pathogen *Alternaria porri*. Intl J Agric Biol 23 (5): 977-982. DOI: 10.17957/IJAB/15.1376.

Schumann AW, Spann TM, Vashisth T. 2010. Mineral Nutrition Contributes to Plant Disease and Pest Resistance: HS1181/HS1181, 7/2010. EDIS 2010 (4). DOI: 10.32473/edis-hs1181-2010.

Sharma S, Kour D, Rana KL, Dhiman A, Thakur S , Thakur P , Thakur S, Thakur N, Sudheer S , Yadav N, Yadav AN , Rastegari AA , Singh K . 2019. *Trichoderma*: Biodiversity, Ecological Significances, and Industrial Applications. Recent Adv White Biotechnol Through Fungi 85-120. DOI: 10.1007/978-3-030-10480-1_3.

Suhaida S, Ain IN, Zainudin M. 2013. The Efficacy of *Trichoderma* harzianum T73s as a Biocontrol Agent of *Fusarium* Ear Rot Disease of Maize. Intl J Agric Biol 15 (6): 1175-1180.

Sumarni N, Rosliani R, Basuki RS, Hilman Y. 2012. Respons tanaman bawang merah terhadap pemupukan fosfat pada beberapa tingkat kesuburan lahan (status P-tanah). J Hortikultura 22 (2): 130. DOI: 10.21082/jhort.v22n2.2012.p130-138. [Indonesian]

Sumarni N, Rosliani R, Suwandi. 2013. Optimasi jarak tanam dan dosis pupuk NPK untuk produksi bawang merah dari benih umbi mini di dataran tinggi. J Hortikultura 22 (2): 148. DOI: 10.21082/jhort.v22n2.2012.p148-155. [Indonesian]

Supriati L, Basuki, Mulyani RB, Muliansyah, Muliana. 2019. Peranan Trichokompos dan Pupuk KCl dalam Mengendalikan Penyakit Layu *Fusarium* pada Tanaman Bawang Merah di Tanah Berpasir. Jurnal Agripeat 20 (1): 19-26. DOI: 10.36873/agp.v20i01.21. [Indonesian]

Syahputra E, Fauzi, Razali. 2015. The characteristics of the chemichal properties of ultisols sub groups in some areas of Northern Sumatra. J Agroekoteknologi 4 (1): 1796-1803. DOI: 10.32734/jaet.v4i1.12366.

Tiara D, Tantawi AR, Mardiana S. 2021. Penggunaan *Trichoderma* spp. untuk Mengendalikan Busuk Umbi pada Bawang Merah (*Allium ascolanicum* L.). Jurnal Ilmiah Pertanian (JIPERTA) 3(1): 64-75. DOI: 10.31289/jiperta.v3i1.431. [Indonesian]

Torimiro N, Makinde IO, Omole RK, Daramola OB. 2020. Deterioration Profile of Postharvest Onion (*Allium cepa* L.) Bulbs Induced by Potential Pathogenic Microorganisms. Intl J Pathog Res 5 (2): 39-45. DOI : 10.9734/ijpr/2020/v5i230130.

Widyati E. 2020. Memahami Komunikasi Tumbuhan-Tanah dalam Areal Rhizosfir untuk Optimasi Pengelolaan Lahan. Jurnal Sumberdaya Lahan 11 (1): 33. DOI: 10.21082/jsdl.v11n1.2017.33-42. [Indonesian]

Yu C, Luo X. 2020. *Trichoderma* koningiopsis Controls *Fusarium* oxysporum causing Damping-off in *Pinus massoniana* Seedlings by Regulating Active Oxygen Metabolism, Osmotic Potential, and The Rhizosphere Microbiome. Biol Control 150: 104352. DOI: 10.1016/j.biocontrol.2020.104352.