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Effectiveness of *Trichoderma* sp. and Compost on the Intensity of *Fusarium* sp. Disease Attack and Growth of Shallots (*Allium cepa*)

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ABSTACT

Shallots (*Allium cepa*) are a key agricultural commodity in Indonesia, serving as a significant economic contributor and export product. However, production is often hampered by *Fusarium wilt* caused by *Fusarium oxysporum*, leading to decreased yield and quality. This study aimed to evaluate the effectiveness of *Trichoderma sp.*, compost, and their combination in controlling *Fusarium wilt* and improving shallot growth. The research was conducted from July to September 2022 using a completely randomized design with four treatments control (T0), *Trichoderma sp.* (T1), compost (T2), and *Trichoderma sp.* + compost (T3). Results showed T3 significantly reduced disease intensity (20.31%) compared to T0 (53.12%) and enhanced plant height, leaf number, and bulb production. The combined application of *Trichoderma sp.* and compost is recommended as an eco-friendly alternative to synthetic fungicides for sustainable shallot cultivation.

INTRODUCTION

Shallots (*Allium cepa*) are one of the important agricultural commodities in Indonesia, contributing significantly to economic development and food security. Shallots are widely cultivated across the country, particularly in regions such as Central Java, East Java, and West Nusa Tenggara, where production continues to increase. However, challenges such as *Fusarium wilt* disease caused by the soil-borne pathogen *Fusarium oxysporum* pose a serious threat to shallot yields. This disease causes symptoms such as leaf yellowing and ultimately plant death, necessitating effective disease management strategies to maintain production levels (Kalasari et al., 2023).

To address *Fusarium wilt*, farmers have traditionally relied on synthetic fungicides, which can lead to environmental pollution and health risks due to toxic residues. In contrast, biological control methods, such as the use of antagonistic fungi like *Trichoderma* sp. and bacteria like Pseudomonas fluorescens, have emerged as promising alternatives. These biological agents not only suppress the growth of pathogenic fungi but also enhance plant growth and resilience (Asrijal, 2021; Karsidi et al., 2020). Research has shown that combining biological agents with organic fertilizers, such as compost, can further improve soil health and increase shallot productivity by enhancing nutrient availability and microbial activity in the soil (Muarif et al., 2022; Supyani et al., 2023).

Application of organic fertilizers, particularly compost made from agricultural waste, has been proven to improve soil structure, increase nutrient retention, and encourage the growth of beneficial microbial populations. Studies have demonstrated that compost can effectively reduce the incidence of soil-borne pathogens, including *Fusarium oxysporum*, thereby improving the overall health of shallot crops (Juwanda et al., 2020; Satria et al., 2022). Furthermore, the integration of organic fertilizers with biological control agents like *Trichoderma* sp. can produce synergistic effects, enhancing disease resistance and crop yield (Arfiana et al., 2024; Tefa et al., 2023).

Despite the potential benefits of these integrated approaches, there remains a research gap regarding the specific interactions between biological agents and organic fertilizers in the context of shallot production. Further studies are needed to evaluate the effectiveness of these combinations in

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different soil types and environmental conditions, as well as their impact on disease severity and overall yield (Resiani et al., 2021; Ridho et al., 2021). This study aims to address this gap by investigating the combined effects of *Trichoderma* sp. and compost on *Fusarium wilt* suppression, soil quality improvement, and enhanced shallot yields.

MATERIALS AND METHODS

This research was conducted in Racak, Mampu Village, Anggeraja Distric, Enrekang Regency. The research was carried out from July 2022 to September 2022. The tools used in this research were measuring tools, hoes, watering cans, writing equipment, scales, and stakes. The materials used were Tajuk variety shallot seeds, solid *Trichoderma* sp, and leaf compost. This research was conducted using a non-factorial Randomized Complete Block Design (RCBD) with 4 treatment levels, namely T0 = Without *Trichoderma* sp and compost (control), T1 = 15 g *Trichoderma* sp/plant, T2 = 15 g Compost/plant, T3 = 15 g *Trichoderma* sp + 15 g compost/plant.

Intensity of attack, plant height, number of leaves, number of tillers per plant, and number of bulbs per plant were all considered in the study. Analysis of variance at the 5% level was used to evaluate the research data. If the effect was significant, then a Honestly Significant Difference (HSD) test was conducted.

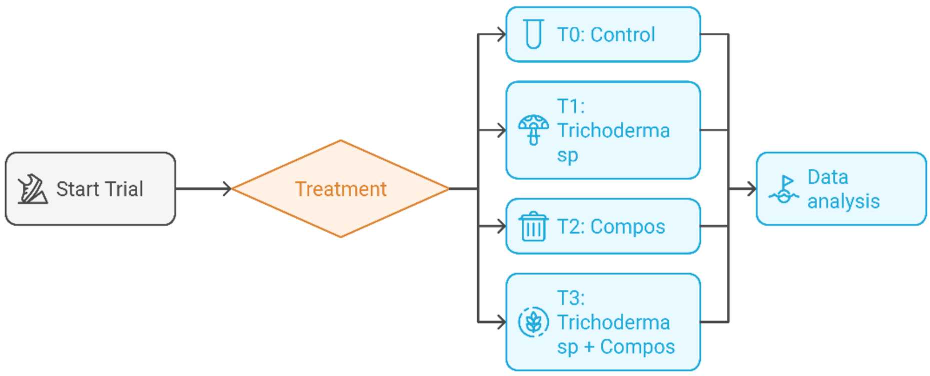

Figure 1. Research Flowchart

RESULTS AND DISCUSSION

1. Intensity of Attack

The mean disease severity of *Fusarium wilt* in shallots varied across treatments (T0, T1, T2, and T3) and observation periods 1-6 Weeks after planting (WAP), indicating differences in the efficacy of treatments in managing *Fusarium wilt* symptoms.

Table 1. Average Intensity of *Fusarium wilt* Disease on Shallot Plants

Treatment	Intensity of Attack (%)					
	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP
T0	29.69^{a}	37.50	45.31	51.56	51.56	53.12
T1	12.5^{ab}	14.06	18.75	20.31	25.06	25.06
T2	10.94^{ab}	12.50	18.75	18.75	23.44	23.44
T3	7.81^{b}	12.50	17.19	18.75	20.31	20.31
HSD 0.05	19.33					

Note: Numbers followed by the same letter (a, b) indicate no significant difference according to the HSD test at the 0.05 level.

The results of the HSD test at the 0.05 level in Table 1 showed that the treatment with *Trichoderma* sp + compost (T3) at week 1, with an average disease severity of 7.81, was significantly different from the treatment without *Trichoderma* sp and compost (T0) at week 1, with an average disease severity of 29.69. However, it was not significantly different from the treatment with *Trichoderma* sp (T1) at week 1, with an average disease severity of 12.50, and also not significantly different from the treatment with compost (T2) at week 1, with an average disease severity of 10.94. At weeks 2, 3, 4, 5 and 6, the lowest *Fusarium wilt* disease severity was observed in the treatment with *Trichoderma* sp + compost (T3), while the highest disease severity tended to occur in the treatment without *Trichoderma* sp and compost (T0).

Application of *Trichoderma* sp. combined with compost in the management of *Fusarium wilt* in shallots (*Allium cepa*) has shown promising results. Recent research indicates that the integration of this biological agent significantly reduces disease intensity compared to untreated controls. In a controlled experiment, the treatment with *Trichoderma* sp. and compost showed a significant reduction in disease severity in the first week, with an average disease intensity of 7.81, which was statistically different from the control treatment that recorded an intensity of 29.69 (Sataral, 2021). This indicates that the synergistic effect of *Trichoderma* sp. and compost can effectively suppress the impact of pathogens on shallots.

Effectiveness of *Trichoderma* sp. in disease management has been well-established. *Trichoderma* sp. operates through various mechanisms, including competition for nutrients, production of antifungal metabolites, and enhancement of plant growth. *Trichoderma* spp. are known to produce enzymes such as chitinase and glucanase, which degrade the cell walls of pathogenic fungi, thereby inhibiting their growth (Abdul-Halim et al., 2022; Oviya et al., 2022). Results from the second to sixth weeks further reinforced the effectiveness of *Trichoderma* sp. and compost, as the lowest disease intensity was consistently observed in the treatment with *Trichoderma* sp. and compost, while the highest was observed in the control group (Sataral et al., 2020).

The use of compost not only enhances the biological control capabilities of *Trichoderma* sp. but also improves soil health, which is essential for sustainable agriculture. Compost enriches the soil with organic matter, thus supporting a diverse microbial community that can outcompete pathogens such as *Fusarium* oxysporum (Altaf et al., 2024). combination of practices aligns with sustainable agriculture practices that aim to reduce the use of chemicals and promote ecological balance in agricultural systems

Table 2. *Fusarium wilt* disease intensity in shallots at 6 weeks after planting

Treatment	Intensity of Attack (%)	
	Rate	Category
T0	53.12	Light attack
T1	25.00	Heavy attack
T2	23.44	Heavy attack
T3	20.31	Heavy attack

Results of the *Fusarium wilt* disease intensity observation in Table 2 indicate that the treatments of *Trichoderma* sp. (T1), compost (T2), and the combination of *Trichoderma* sp. and compost (T3) had a relatively low disease intensity, with values of 25.00%, 23.44%, and 20.31%, respectively. In contrast, the treatment without *Trichoderma* sp. and compost (T0) showed the highest disease intensity at 53.12%, which falls into the severe category. These findings suggest that the simultaneous use of *Trichoderma* sp. and compost can significantly reduce the intensity of *Fusarium wilt* disease in plants

Trichoderma sp. is known as an effective biocontrol agent in controlling various plant diseases, including *Fusarium wilt* caused by *Fusarium oxysporum*. The control mechanisms include mycoparasitism, antibiotic production, and enhanced plant resistance through the induction of defense responses (Nusaibah & Musa, 2019). Research has shown that *Trichoderma* can reduce pathogen populations in the soil and improve plant health by increasing nutrient availability and improving soil structure (Gorliczay et al., 2021).

Compost application also contributes to reduced disease severity. Compost serves as a rich nutrient source, which can enhance the activity of beneficial soil microbes, including *Trichoderma*. The combination of *Trichoderma* and compost can produce a greater synergistic effect in disease control, as demonstrated by research examining the impact of *Trichoderma* on *Fusarium wilt* in various crops (Gilardi et al., 2018).

Treatment T0, which did not receive *Trichoderma* sp. and compost, exhibited the highest disease intensity. This indicates that without the intervention of biocontrol agents and additional nutrients, plants become more susceptible to disease attacks. Previous studies have also shown that plants without biostimulation treatments tend to have increased susceptibility to pathogens (Kutama et al., 2022; Shirin et al., 2021).

Application of *Trichoderma* sp. and compost in controlling *Fusarium wilt* not only reduces disease severity but also enhances plant health and productivity, which is crucial for sustainable agriculture (Zhou et al., 2018).

2. Plant Height

Average plant height of onion plants under various treatments of *Trichoderma* sp. and compost, measured at 1, 2, 3, 4, 5 and 6 weeks after planting (WAT), showed variations in growth rate among treatments

Table 3. Average plant height of onion plants treated with *Trichoderma* sp. and compost

Treatment	Plant Height (cm)					
	1 WAT	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT
T0	4.96^{b}	14.09^{b}	17.88^{b}	19.78	20.78	21.21^{b}
T1	5.65^{b}	15.19^{ab}	18.68^{b}	20.04	21.50	23.66^{a}
T2	5.37^{b}	15.28^{ab}	19.98^{ab}	22.04	23.20	23.95^{a}
T3	7.89^{a}	17.08^{a}	21.11^{a}	23.66	24.99	25.89^{a}
HSD 0.05	1.69	2.25	2.29	tn	tn	3.54

Note: Numbers followed by the same letter (a, b) indicate no significant difference according to the HSD test at the 0.05 level.

Based on the HSD test at the 0.05 significance level, Table 3 revealed that the combined treatment of *Trichoderma* sp. and compost (T3) resulted in significantly higher plant heights compared to the control treatment (T0) at all measured time points (weeks 1-6). However, no significant differences were found between treatment T3 and the treatment with *Trichoderma* sp. alone (T1) at weeks 1 and 6, or between treatment T3 and the treatment with compost alone (T2) at weeks 2, 3, and 6.

Based on the results of the HSD test at a significance level of 0.05, the combined treatment of *Trichoderma* sp. and compost (T3) showed a significant increase in plant height compared to the control treatment (T0) at all measured time points (weeks 1-6). This is in line with previous research indicating that the use of compost can enhance plant growth by providing essential nutrients and improving soil structure (Jiang et al., 2019; Murga-Orrillo et al., 2023). Compost can release nitrogen slowly, supporting plant vegetative growth (Budiastuti et al., 2023). This significant increase in plant height suggests that the combination of *Trichoderma* sp. and compost can provide synergistic benefits in supporting plant growth.

However, no significant difference was found between treatment T3 and the *Trichoderma* sp. treatment alone (T1) at the 1 and 6 weeks, and between treatment T3 and the compost-only treatment (T2) at the 2, 3 and 6 weeks. This indicates that both *Trichoderma* sp. and compost, individually, are already quite effective in supporting plant growth at certain times. Compost can increase nutrient availability in the soil, contributing to plant growth (Waheed & Muhammad, 2021). Additionally, treatment with compost can yield good results in plant growth, although it does not always show a significant difference compared to other treatments (Ameen et al., 2020).

The timing of plant growth observations is also crucial. Compost application can influence plant growth outcomes, where the effects of compost may not be immediately visible and can vary depending on the plant growth stage (Nurcholis et al., 2020). This shows that the interaction between treatment and measurement time is essential to consider in plant growth research.

3. Number of leaves

Mean leaf number of shallot plants as influenced by the application of *Trichoderma* sp. and compost at different weeks after planting. Data were subjected to a HSD test at a 0.05 significance level to compare treatment means.

Table 4. Average number of leaves of shallot plants treated with *Trichoderma* sp. and compost.

Treatment	Number of Leaves (Leaf)				
	2 WAT	**3 WAT**	**4 WAT**	**5 WAT**	**6 WAT**
T0	10.07[b]	13.67	14.16	16.06	17.78
T1	11.45[b]	13.82	14.31	15.37	16.67
T2	10.89[ab]	14.58	15.79	18.47	22.76
T3	13.07[a]	17.31	18.34	21.89	23.63
HSD 0,05	1.85	tn	tn	tn	tn

Note: Numbers followed by the same letter (a. b) indicate no significant difference according to the HSD test at the 0.05 level.

The HSD test at the 0.05 level showed that *Trichoderma* sp. treatment (T1) at the second week resulted in an average of 11.45 leaves. which was significantly different from the *Trichoderma* sp. + compost treatment (T3) with an average of 13.07 leaves. However. treatment T1 was not significantly different from the control treatment without *Trichoderma* sp. and compost (T0) with an average of 10.07 leaves. and the compost treatment (T2) with an average of 10.89 leaves. These findings indicate that the addition of compost significantly increased leaf growth compared to the use of *Trichoderma* sp. alone.

Trichoderma sp. is known as an effective biocontrol agent that can enhance plant growth by increasing nutrient availability and stimulating root growth (Hassan et al., 2022; Mulyana et al., 2021). Research has shown that *Trichoderma* can produce phytohormones such as auxin and gibberellin. which contribute to increased leaf number and overall plant growth (Muhae-Ud-Din et al., 2018). However. in some cases. the application of *Trichoderma* can yield variable results depending on environmental conditions and interactions with other factors such as soil pH and mineral availability. (Hirst et al., 2024).

The *Trichoderma* sp. + compost treatment (T3) showed better results compared to the *Trichoderma* sp. treatment (T1) alone. This is in line with findings indicating that the combination of *Trichoderma* with organic matter such as compost can enhance microbial activity in the soil. which in turn increases nutrient availability for plants (Abdelhameed & Metwally, 2022). Other studies have also shown that the application of *Trichoderma* in combination with organic matter can enhance plant growth and disease resistance (Solis-Palacios et al., 2021).

Control treatment without *Trichoderma* sp. and compost (T0) and the compost treatment (T2) showed no significant difference. indicating that while compost may provide some benefits. without *Trichoderma* sp. these benefits may not be optimal. This suggests the importance of *Trichoderma* in enhancing the effectiveness of compost in supporting plant growth (Kumar et al., 2020). Research underscores the importance of using *Trichoderma* sp. in combination with compost to achieve optimal plant growth. and demonstrates that the interaction between various treatments can significantly influence final plant growth outcomes.

4. Number of Plant Tillers

Mean number of onion plant tillers recorded at 3, 5 and 7 weeks with different treatments of *Trichoderma* sp. and compost.

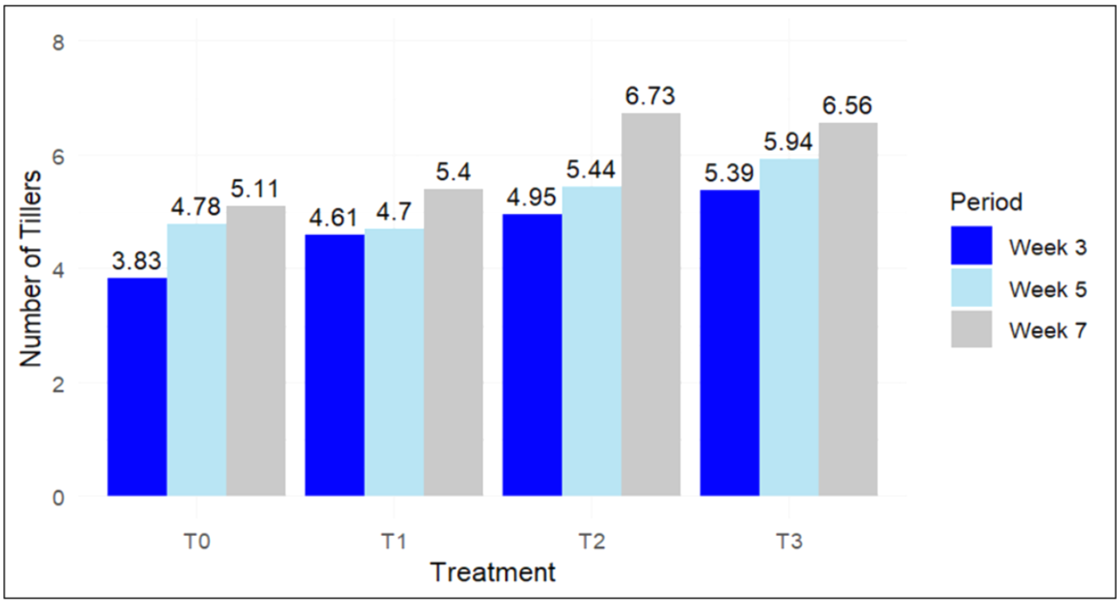

Figure 2. Average number of shallot tillers at the 3, 5 and 7 weeks with the application of *Trichoderma* sp. and compost.

Histogram in Figure 2 demonstrates a progressive increase in the number of onion plant tillers each week. The treatment involving *Trichoderma* sp. and compost (T3) exhibited the highest average number of tillers. whereas the control treatment without *Trichoderma* sp. and compost (T0) displayed the lowest. These findings corroborate the hypothesis that the combination of *Trichoderma* sp. and compost can significantly enhance the growth of onion plants.

Trichoderma sp. is recognized as an effective biostimulant in enhancing plant growth. Research has shown that *Trichoderma* can increase nutrient availability and stimulate root growth. thereby contributing to a higher number of tillers (Patkowska et al., 2020). In addition. *Trichoderma* also functions as a biological control agent that can protect plants from soilborne pathogens such as *Fusarium*. a common pathogen in onions (Abeyratne & Deshappriya, 2018). The combination of *Trichoderma* and compost can increase microbial activity in the soil. which in turn increases nutrient availability for plants (Morales-Corts et al., 2018).

Treatment T3. which is compost. serves as an additional source of nutrients that enriches the planting medium. allowing plants to utilize nutrients more effectively. Research has shown that the use of compost can increase root growth and the number of tillers in plants. as compost contains organic matter that can improve soil structure and water retention capacity (Vukelić et al., 2021). In addition. humus produced from compost decomposition plays a crucial role in enhancing the activity of beneficial microbes in the plant rhizosphere (Saadaoui et al., 2023).

Treatment T0. which did not involve the use of *Trichoderma* and compost. exhibited lower growth rates. This indicates that without the intervention of *Trichoderma* and additional nutrients from compost. red onion plants were unable to reach their optimal growth potential. Previous studies have also shown that plants that did not receive biostimulation treatments tended to experience stunted growth and were more susceptible to diseases (Vojnović et al., 2023).

Trichoderma is known as an effective biological control agent that functions to inhibit soil pathogens and enhance plant health through various mechanisms. including the production of bioactive compounds that stimulate plant growth and increase resistance to diseases (Amin et al., 2024)

5. Number of Bulbs per Plant

Average number of onion bulbs under different treatments of *Trichoderma* sp. and compost application.

Table 5. Average number of onion bulbs under different treatments of *Trichoderma* sp. and compost.

Treatment	Average number of bulbs	HSD 0,05
T0	4.47[b]	2,43
T1	5.25[ab]	
T2	6.09[ab]	
T3	7.31[a]	

Note: Values followed by the same letter (a. b) are not significantly different according to the HSD test at the 0.05 level.

The HSD test at the 0.05 level in Table 5 revealed that the treatment with *Trichoderma* sp. and compost (T3) with an average of 7.31 bulbs differed significantly from the control treatment without *Trichoderma* sp. and compost (T0) which had an average of 4.47 bulbs. However. treatment T3 did not differ significantly from the treatment with *Trichoderma* sp. alone (T1) with an average of 5.25 bulbs or the treatment with compost alone (T2) with an average of 6.09 bulbs. These findings suggest that the combination of *Trichoderma* sp. and compost had a significant positive impact on onion bulb growth compared to the control treatment.

Trichoderma sp. is a widely used biostimulant that promotes plant growth by improving nutrient uptake and controlling plant diseases (Joshi et al., 2019; Serri et al., 2021). Studies have demonstrated that *Trichoderma* stimulates root and bulb development through the production of phytohormones like auxin and gibberellin. thereby promoting plant vegetative growth (Altaf et al. 2024). Furthermore. *Trichoderma* improves the efficiency of nutrient uptake from the growing medium. playing a vital role in bulb formation (Heyman et al., 2019).

Compost treatment (T2) was also effective. resulting in an average of 6.09 bulbs. Compost. a rich source of organic matter and essential nutrients. improved soil conditions. water holding capacity. and provided a steady supply of nutrients. thereby promoting plant growth (Irawan et al., 2019; Syed et al., 2023). Studies have demonstrated that compost stimulates plant growth by improving soil physical properties and promoting the proliferation of beneficial microorganisms in the root zone (Bononi et al., 2020).

While treatment T1 (*Trichoderma* sp.) increased bulb number compared to the control. there was no significant difference between T1. T2. and T3. This indicates that although *Trichoderma* can promote growth. the synergistic effect of combining *Trichoderma* and compost led to a greater increase in bulb number. Previous research has supported this finding. showing that the combination of *Trichoderma* and organic matter can significantly boost crop yields (Khan et al., 2021). Synergistic effect of *Trichoderma* sp. and compost has significantly increased onion bulb yield. This combination enhances nutrient uptake and disease resistance. contributing to improved and sustainable agricultural production (Zhang et al., 2020).

CONCLUSIONS

Based on field experiment and analysis. it can be concluded that the lowest intensity of *Fusarium wilt* was found in the treatment with 15 g/plant *Trichoderma* sp. and 15 g/plant compost. with an intensity of 20.31%. categorized as a mild attack. The highest intensity of *Fusarium wilt* was observed in the treatment without *Trichoderma* sp. and compost. with an intensity of 53.12%. categorized as a severe attack. The application of 15 g/plant *Trichoderma* sp. and 15 g/plant compost tended to have the best effect on plant height. number of leaves. and number of bulbs.

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