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EFFECT OF THE COMBINED APPLICATION OF MANURE COMPOST AND *Trichoderma* sp. ON PRODUCTION PARAMETERS AND STEM ROT DISEASE INCIDENCE OF SHALLOT

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ABSTRACT

Manure compost is a type of organic fertilizer derived from animal feces. Even though compost has a slow-release nature, it can be a good alternative to chemical fertilizers. The addition of *Trichoderma* sp. as a decomposer microorganism can accelerate nutrient availability. The objective of this study was to determine the effect of the combined application of different types of manure compost and doses of *Trichoderma* sp. on the growth performance, yield as well as stem rot disease incidence of shallot (*Allium cepa* L. var. *aggregatum*). The study was carried out using a split-plot design ($P<0.05$) with the types of manure compost as the main plot with five levels (no compost, cattle manure, chicken manure, goat manure, and petrogenic compost), and different doses of *Trichoderma* as subplots with three levels (no *Trichoderma*, 200 kg ha^{-1}, and 400 kg ha^{-1}). In general, the combined application of manure compost and *Trichoderma* significantly increased growth performance and yield of shallot compared to no compost (B0) and *Trichoderma* (T0). However, no differences were observed between manure compost and the addition of *Trichoderma*. Growth performance of shallots grown in soil amended with cattle manure compost was better compared to the other treatments. The use of 5 t ha^{-1} cattle manure compost combined with 400 kg ha^{-1} *Trichoderma* increased yield by 10.02 t ha^{-1} and reduced stem rot diseases incidence by 0.67%.

Key words: Cattle manure, *Fusarium* rot disease, organic fertilizer, soil microbial.

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INTRODUCTION

Intensive cultivation of agricultural land causes a reduction in soil organic matter, affecting soil physical, chemical, and biological properties. The addition of soil organic matter can increase soil organic carbon, which is a key factor in maintaining soil fertility (Li et al., 2017) and agricultural sustainability (Blanchet et al., 2016).

Soil organic matter is composed of humus and non-humus ingredients (Tobiašová et al., 2018). Decomposed organic matter is essential in improving soil structure and cation exchange capacity in the soil, sustaining soil pH, and strengthening soil moisture retention, while un-decomposed soil materials are energy sources for soil microorganisms and sources of nutrients for plants (Zandonadi et al., 2013). As a soil component, organic matter has a direct effect on the growth and development of plants and soil microbes, acting as a source of many plant growth stimulators such as hormones and vitamins. Furthermore, it influences soil structure and porosity, water infiltration rate, soil moisture resistance, diversity and biological activity of soil organisms, and availability of plant nutrients (Iwasaki et al., 2017).

Organic fertilizers can reduce the use of synthetic NPK fertilizers in agriculture (Sani et al., 2020; Idham et al., 2021). The composition and amount of nutrients found in compost manure depend on the type and age of the animal as well as feed given to it (Watson et al., 2006). Manure compost contains macro-nutrients, essential micro-nutrients, vitamins, growth-promoting indole acetic acid (IAA), gibberellic acid (GA), and beneficial microorganisms (Katoh et al., 2016). The carbon to nitrogen (C/N) ratio affects composting because microorganisms need a good balance of carbon and nitrogen. High C/N ratios can hamper the composting process, and thus several cycles of microorganisms are needed to degrade the compost, while low C/N ratios enhance nitrogen loss because excess nitrogen that is not used by microorganisms cannot be assimilated and is lost through volatilization as ammonia or denitrification (Guo et al., 2012).

Trichoderma sp. is a soil-dwelling microorganism that can accelerate the decomposition of soil organic matter. In fact, it produces enzymes that are essential in the process (Pandey et al., 2015). As a bio-activator, *Trichoderma* sp. can increase soil microbial activity (García-Gil et al., 2000), producing growth-regulating enzymes and phosphate-solubilization, which can stimulate seed germination rate and plant growth (Rawat and Tewari, 2011), while it has also been reported as a biological control for plant pathogens through mycoparasitism, antibiosis and competition (Harman et al., 2004). Recent studies have reported that the application of *Trichoderma* sp. reduces disease incidence in different crop species (Commatteo et al., 2019; López-López et al., 2016).

At the country level, shallot production in 2018 was 5.2 t ha^{-1}, which is still low compared to the average global yield of 10-12 t ha^{-1} (Central Bureau of Statistics of Indonesia, 2020). A popular variety among farmers in Central Sulawesi-Indonesia is known as 'Lembah Palu' (*Allium cepa* L. var. *aggregatum*), being a "local brand" of Palu City, mainly used as raw material for the fried onion industry. The uniqueness of the Lembah Palu variety of shallot relies on its distinctive aroma, dense texture, savory taste, and storage resistance after frying.

The objective of this study was to evaluate the effect of the combined application of different types of manure compost and doses of *Trichoderma* sp. on the growth performance and yield of shallot (*A. cepa* L. var. *aggregatum*) as well as on stem rot disease incidence caused by *Fusarium oxysporum* in sub-optimal land.

MATERIALS AND METHODS

Study site and treatments

A field experiment was conducted from April to November 2018 in Sidera, District of Sigi-Biromaru, Sigi Regency, Central Sulawesi, Indonesia (1°0.37" South, 119°56" East), 239 m above sea level. The soil is inceptisol, and the climate is E4 (Oldeman).

The study was designed as a split-plot ($P<0.05$) experiment with three replications. The main plot was the type of compost, with the following treatments: B0 = no compost; B1 = cattle manure compost; B2 = chicken manure compost; B3 = goat manure compost; and B4 = petroganic (industrial) compost. The subplots were different doses of *Trichoderma* sp., T0 = no *Trichoderma* added; T1 = *Trichoderma* added at a rate of 200 kg ha^{-1}; and T2 = *Trichoderma* added at a rate of 400 kg ha^{-1}.

The size of a unit plot was 2 m × 4 m, with spacing of 30 cm and 50 cm between plots and groups, respectively. Manure compost was applied one week before planting at a dose of 5 t ha^{-1} by immersing and then leveling. Shallot seedlings, which corresponded to the local variety from Palu, Central Sulawesi - Indonesia (*A. cepa* var. *aggregatum*), were planted at a distance of 15 cm × 20 cm. Cultural practices, including irrigation and weeding, were similarly applied to all plots. Irrigation was done in the morning and depending on soil conditions. Weeding was performed as needed, while pest and disease control was conducted using an integrated pest control method for lowland vegetables, i.e., chemical control was performed when the densely populated pest reached the level of economic injury.

Data collection and statistical analysis

The growth performance indicators evaluated were plant height, number of leaves, total leaf area, root length, root dry weight, number of tillers, fresh weight per clump, and yield of shallot per hectare. The number of plants observed was ten clumps in each variable.

Plant height was measured from ground level to the highest point of the plant; the number of leaves was determined by counting the number of leaves in each plant clump; total leaf area was measured on green and fully opened leaves, using a leaf area meter. Root length was measured from the base to the longest root apex by digging around the plant, watering, and then lifting the entire clump out of the ground. Root dry weight was determined by drying the samples at 70 °C in a hot air oven for 48 hours and then weight was measured using an analytical balance. The number of tillers was measured by counting all the tillers in a clump. Fresh weight per clump was measured by weighing the bulbs then converted to t ha^{-1} to get yield per hectare.

The incidence of stem rot disease caused by *Fusarium oxysporum* was calculated as $P = a/b \times 100\%$. (P = incidence of disease, a = number of plants affected by the disease, b = number of plants observed).

The Shapiro-Wilk test was used to test for normality. The data obtained were subjected to split plot analysis of variance (ANOVA) and mean separation was calculated by Fisher's Least Significant Difference at a 5% significance level.

RESULTS

Growth performance

There was no interaction effect between the types of manure compost and *Trichoderma* doses on several of the parameters evaluated. However, the single factor of compost manure and *Trichoderma* addition showed a significant effect. We found that the use of manure compost showed better results on all the growth performance parameters of the crop (Table 1).

Plants cultivated in B4 (petroganic compost amended soil) were taller and had a significantly ($P<0.05$) higher number of leaves than the control (B0), but no significant differences were found with respect to B1, B2 or B3. In terms of leaf area, the highest value observed in cattle compost (B1) significantly differed from the control (B0) and the other compost treatments, except for petroganic compost (B4). The highest root length and root dry weight were observed in cattle compost amended soil (B1), being significantly ($P<0.05$) higher than the other compost treatments (Table 1).

Growth parameters were also influenced by *Trichoderma* addition. The highest growth parameters values were obtained at a dose of 400 kg ha^{-1} (T2), showing significant differences in the

Table 1. Effect of the combined application of manure compost and *Trichoderma* sp. on growth performance of shallot.

Treatment	Plant height (cm)	Number of leaves (per strands)	Leaf area (cm^2)	Root length (cm)	Root dry weight (g)
Manure compost					
No compost	22.64 a	19.32 a	173.92 a	4.94 a	0.53 a
Cattle manure	25.90 b	20.52 ab	306.36 d	9.14 c	1.58 c
Chicken manure	25.44 b	21.12 b	227.06 ab	6.87 b	1.24 b
Goat manure	25.34 ab	21.43 b	234.08 bc	7.86 b	1.32 b
Petroganic	27.61 b	22.15 b	282.64 cd	7.38 b	1.39 b
LSD 0.05	2.74	1.66	55.32	1.02	0.17
Trichoderma doses					
0	23.59 a	20.06 a	192.43 a	5.22 a	0.62 a
200 kg ha^{-1}	25.98 b	21.10 ab	251.63 b	7.40 b	1.41 b
400 kg ha^{-1}	26.55 b	21.56 b	290.38 c	9.10 c	1.60 c
LSD 0.05	2.05	1.06	22.08	0.91	0.171

Note: LSD = Least Significant Difference. Data presented are means. Mean value within each column followed by different letters differ significantly at $p<0.05$ according to Fisher's Least Significant Difference.

other doses in the parameters evaluated, except for the number of leaves (Table 1).

Crop yield

Cattle compost (B1) resulted in significantly (P<0.05) higher values of tiller numbers, fresh weight, and yield with respect to the control (B0). However, no significant differences were observed between this treatment and the rest of manure compost treatments (B1, B2, and B3), except for goat manure (B2) in terms of fresh weight and yield of shallot bulbs. Yield was also influenced by the addition of *Trichoderma*. The dose of 400 kg ha^{-1} (T2) showed higher tiller number and fresh weight, while the highest yield per hectare was significantly (P<0.05) different from the other doses except at 200 kg ha^{-1} (T1) but only in terms of tiller number (Table 2).

Stem rot disease incidence of shallot

Rot disease symptoms were observed four weeks after planting (WAP). Since the study site previously presented *Fusarium* stem rot disease, it is important to note that there was a lower than 10% disease incidence (Table 3).

The type of manure compost had no significant effect on disease incidence, but *Trichoderma* addition did. *Trichoderma* at a dose of 400 kg ha^{-1} (T2) tended to reduce disease incidence, showing significant differences with respect to the other doses at 4 and 5 WAP. However, no significant differences were observed at the rate of 200 kg ha^{-1} (T1) at 6 and 7 WAP (Table 3).

DISCUSSION

Growth performance

The obtained results showed that the application of manure compost and *Trichoderma* sp. increased the growth performance of shallots compared to no compost and *Trichoderma* sp. (Table 1), which agrees with the results reported by Gougoulias et al. (2018).

The use of manure compost as a source of organic material has many advantages. It increases organic carbon sources (Are et al., 2018), acts as a potential bio-stimulator (Zaborowska et al., 2018), prevents and controls diseases and weeds (Skuodiene et al., 2021), and improves the biological, chemical, and physical properties of the soil, which can ultimately increase soil fertility (Bonanomi et al., 2014). In fact, there is evidence that manure compost increases growth performance (Christophe et al., 2019; Lasmini et al., 2021; 2022). In the present study, cattle manure compost increased growth performance of shallot plants (B1) compared to other manure treatments, which can be explained by its higher nitrogen content. Hartati and Widowati (2006) reported that nitrogen content reached 1.53, 1,41 and 1.50% in cattle, goat and chicken manure compost, respectively.

The addition of *Trichoderma* sp. to cattle manure compost accelerated the decomposition process of organic matter, resulting in increased growth performance (Table 1) and crop yield (Table 2). *Trichoderma* sp. produces several active compounds, including enzymes and

Table 2. Effect of the combined application of manure compost and *Trichoderma* sp. on crop yield of shallot.

Treatment	Number of tillers (per plant)	Fresh weight of total plant (g)	Bulb yield (t ha^{-1})
Manure compost			
No compost	4.7 a	27.84 a	5.87 a
Cattle manure	5.51 b	39.66 c	10.02 c
Chicken manure	5.02 ab	34.07 b	8.74 b
Goat manure	5.24 ab	37.57 bc	9.97 c
Petroganic	5.3 ab	36.66 bc	9.56 bc
LSD 0.05	0.76	5.56	0.86
Trichoderma doses			
0	4.74 a	31.13 a	7.3 a
200 kg ha^{-1}	5.22 ab	35.34 b	8.82 b
400 kg ha^{-1}	5.5 b	39.00 c	10.07 c
LSD 0.05	0.63	3.03	0.61

Note: LSD = Least Significant Difference. Data presented are means. Mean value within each column followed by different letters differ significantly at p <0.05 according to Fisher's Least Significant Difference.

Table 3. Effect of the combined application of manure compost and *Trichoderma* sp. on the incidence of stem rot disease in shallot.

Treatment	Incidence of stem rot disease (%)				Note
	4 WAP	5 WAP	6 WAP	7 WAP	
	ns	*ns*	*ns*	*ns*	< 10% infection
Manure compost					
No compost	5.00 a	3.33 a	2.22 a	1.67 a	
Cattle manure	1.67 a	1.67 a	0.56 a	0.00 a	
Chicken manure	2.78 a	1.67 a	1.67 a	1.67 a	
Goat manure	2.22 a	1.67 a	0.56 a	0.56 a	
Petroganic	1.67 a	1.67 a	1.11 a	1.11 a	
LSD 0.05	3.53	2.11	1.90	1.46	
Trichoderma doses					
0	5.00 c	4.00 c	3.00 b	2.67 b	
200 kg ha^{-1}	2.33 b	2.00 b	0.67 a	0.33 a	
400 kg ha^{-1}	0.67 a	0.00 a	0.00 a	0.00 a	
LSD 0.05	2.00	1.97	1.33	1.06	

Note: LSD = Least Significant Difference. WAP= week after planting. ns = non-significant. Data presented are means. Mean values within each column followed by different letters differ significantly at p <0.05 according to Fisher's Least Significant Difference.

several secondary compounds that are able to enzymatically degrade organic matter and release nutrients that are easily absorbed by plants (Condron et al., 2010; Khatoon et al., 2017). During the early phase of vegetative growth, the plant needs nutrients, especially N elements, for the process of cell division and extension. The addition of organic matter containing N affects total N level and helps activate plant cells and photosynthesis, which ultimately increases plant height and number of leaves. It has been reported that vegetative growth occurs due to cell division and enlargement, which occurs in the meristematic region of the plant (Hakim et al., 2012).

The combined use of cattle compost and *Trichoderma* sp. enhanced plant growth (Fig. 1a; b) and yield components of shallots (Fig. 1c, d, e) compared to no compost and *Trichoderma* sp. This agrees with Hadiawati et al. (2020), who described that the addition of *Trichoderma* sp. to cattle manure compost accelerates the decomposition process to improve soil physical properties rapidly, increasing nutrient absorption for plant growth.

Plant growth rate depends on the type of organic material to be decomposed. Organic materials that decompose rapidly will provide nutrients needed by plants more quickly. Apart from speeding up the decomposition process, *Trichoderma* also improves the root system. The most typical manifestation of growth promotion reported by *Trichoderma* is an increase in root and/or shoot biomass, but alterations in plant shape and development have also been observed. Growth promotion can vary greatly depending on parameters such as crop type, growing conditions, inoculum rate, and formulation type (Stewart and Hil, 2014). There is certain evidence indicating that auxin modulates root system architecture. Contreras-Cornejo et al. (2009) discovered that auxin signaling is critical for *T. virens* plant growth enhancement. *T. virens* generated auxin-related chemicals indole-3-acetic acid, indole-3-acetaldehyde, and indole-3-ethanol when cultivated in axenic conditions. Subsequently, this would increase the ability of roots to absorb more water and nutrients (Haque et al., 2012).

Crop yield

The results show that the use of manure compost and *Trichoderma* sp. increases yield components of shallot (Table 2). This agrees with previous studies that have reported that compost influences agricultural production by contributing nutrients to the soil, improving soil physical and biological properties (Hermosa et al., 2012). In the present study, Galindez et al. (2016) recommend the application of 8-ton ha^{-1} organic fertilizer combined with 526 kg ha^{-1}*Trichoderma* spp. to harvest 15.33ton ha^{-1} red onion.

The combined application of cattle compost and *Trichoderma* sp. increased fresh weight per clump and yield per hectare (Fig. 2). This occurs because cattle manure compost can

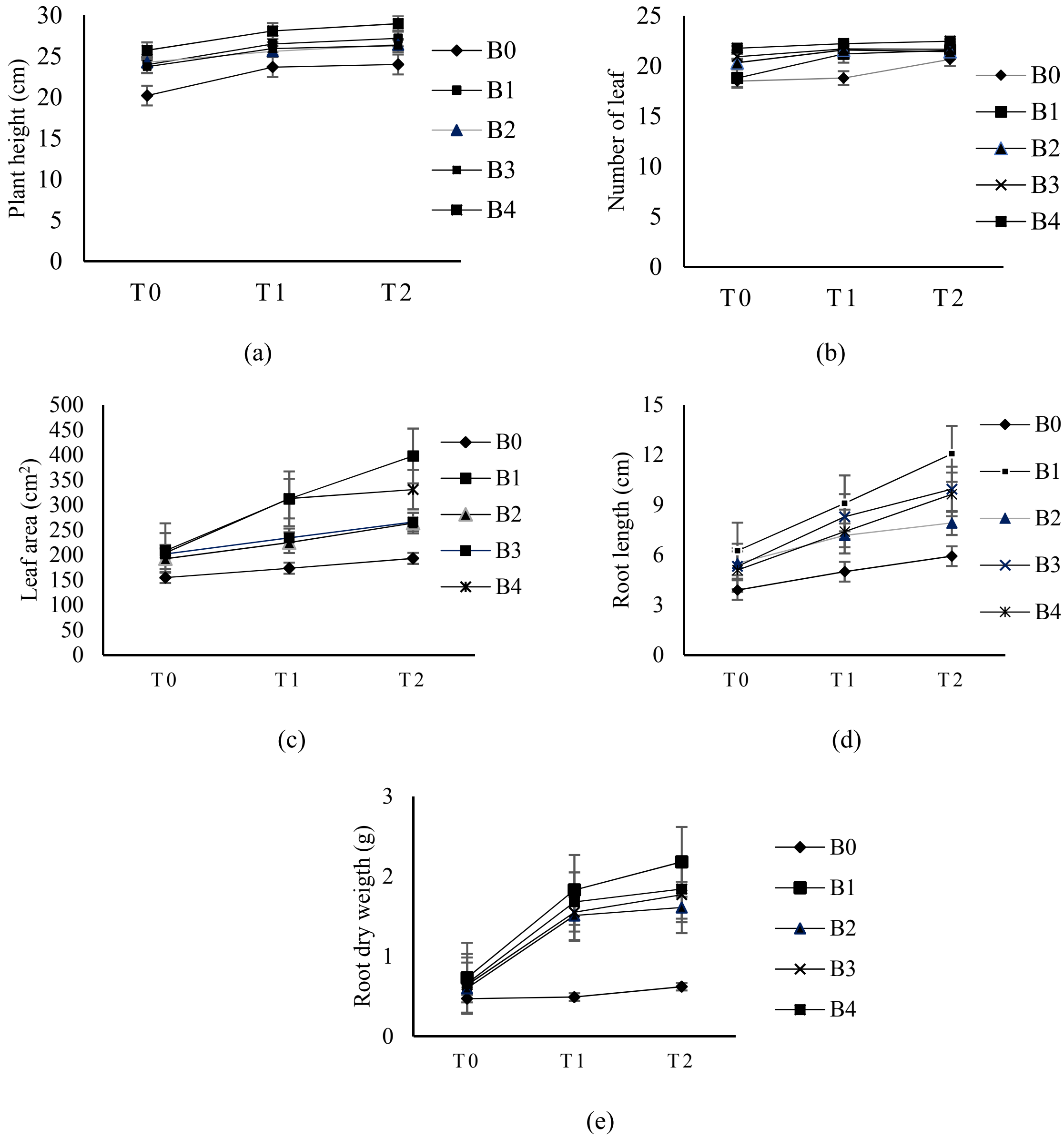

Fig. 1. Effect of the combined application of manure compost and different doses of *Trichoderma* sp. on shallot growth (a = plant height; b = number of leaves; c = number of tillers; d = root length; e = root dry weight).

provide macro and micronutrients to the plants, improve soil texture and structure, loosen soil, increase soil microbial composition, thereby facilitating plant root growth, and longer water absorption in the soil (Bonanomi et al., 2014). The availability of nutrients increases the size and number of cells, thus triggering the enlargement of shallot bulbs (Yoldas et al., 2011). In the present study, the highest leaf area resulted in the highest shallot bulb yield per hectare (Fig. 2), indicating that optimal leaf area is expected to increase crop yields.

No addition of manure compost and *Trichoderma* sp. resulted in a decrease in bulb yield per hectare. Hypothetically, the lack of nutrients, especially P and K may explain this situation. The reduction in P and K nutrients inhibits root growth, nutrients, and water uptake, cell division, cell development, respiration, and photosynthesis. It has been reported that the addition of *Trichoderma* sp. increases bulb yield (Galindez et al., 2016), by optimizing soil nutrient uptake (Singh and Reddy,

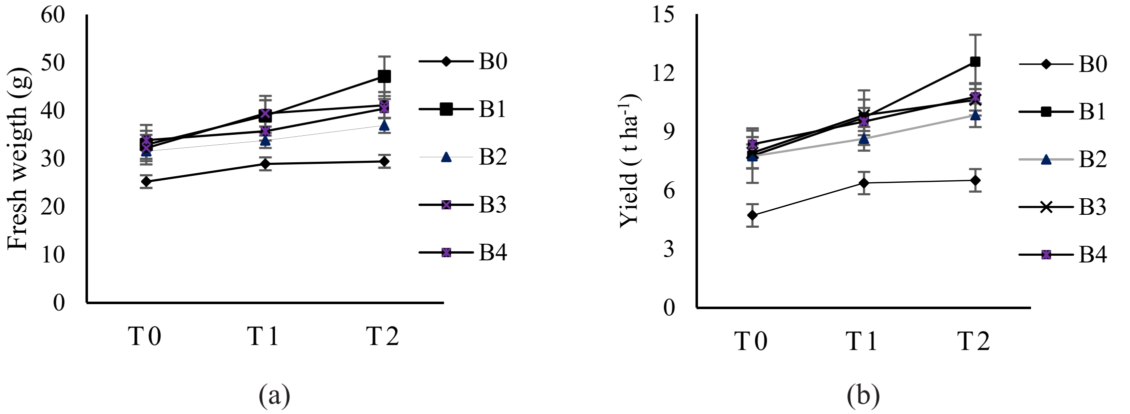

Fig. 2. Effect of the combined application of manure compost and different doses of *Trichoderma* sp. on bulb fresh weight (a) and yield per hectare (b) in shallot.

2014), increasing microbial activity and inhibiting soil-borne pathogens (Luo et al., 2010). Manure compost combined with *Trichoderma* sp. reduces the C/N ratio of the soil and increases pH, N, and C content in the soil (Oh et al., 2018; Thomas et al., 2019). However, the C/N ratio may potentially vary depending on the organic manure used.

Stem rot disease incidence

Trichoderma sp. addition decreased disease incidence of <10% (Table 3). This can be explained by the action of the antibiotics produced by *Trichoderma* sp., such as trichodermin, suzukalin, and alamethicin, which have antifungal and bacterial efficacy (Nusaibah and Musa, 2019). Besides, compost or manure can also increase soil organic matter, promote soil biological activity, and suppress plant diseases (Raviv, 2016). *Trichoderma* sp. is an antagonistic saprophytic fungus, and thus its application into the soil reduces the development of pathogens and prevents them from entering the roots. Lower plant disease indicates that in the combined use of *Trichoderma* sp. and manure compost suppresses plant disease (Harman et al., 2004).

Variation among the different isolates of *Trichoderma* sp. in a compost formulation depend on their genetic variability related to antagonistic activity against other organisms. Virulence factors such as metabolite trichodermin (Barúa et al., 2019) and a variety of extracellular lytic enzymes, such as high chitinase and β-(1,3)-glucanase, have been reported to be produced by *T. harzianum* (Gao et al., 2020), while there may be relationship between the production of these enzymes and the ability to inhibit pathogens.

The application of *Trichoderma* sp. accelerates the process of decomposition of organic matter because *Trichoderma* sp. can produce three enzymes, namely, cellobiohydrolase enzymes, endoglycanase enzymes that break down dissolved cellulose, and β-glucosidase enzymes that hydrolyze cellobiose into a glucose molecule. These enzymes work synergistically so that the decomposition process takes place more quickly and intensively (Compant et al., 2005).

CONCLUSIONS

The best growth performance of shallot was observed in the cattle manure treatment. In fact, the combined application of cattle manure and *Trichoderma* sp. at a rate 400 kg ha^{-1} increased plant growth and yield of shallot by 10.02 t ha^{-1}, and reduced stem rot disease incidence. The study was conducted in one growing season, which may limit the generalizability of the results However, the obtained results certainly contribute to a better understanding of the positive impact of the combined application of manure compost and *Trichoderma* sp. on the production of shallots and the sustainable control of stem rot disease, providing valuable information for the management of shallot crop in Central Sulawesi, Indonesia.

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