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Increasing the Growth and Yield of Soybean Genotype in Dryland by Applying Vesicular Arbuscular Mycorrhiza (VAM) and Tricho-compost

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ABSTRACT

This research aimed to examine the increase in growth and yield of soybean (*Glycine max* (L.) Merr) genotypes in the application of Vesicular Arbuscular Mycorrhizae (VAM) and tricho-compost in dryland. This research was conducted in the form of an experiment using a Split plot design. The application of SPD in this research was conducted as follows: all treatments were given NPK fertilizer at 50% of the recommended dosage and 5–10 g mycorrhizae (*Glomus* sp. + *Gigaspora* sp. + *Acaulospora* sp.). The Main Plot (MP) consisted of six genotypes of the 5^{th} generation (G), namely, g_1 (gM50Gy), g_2 (gO50Gy), g_3 (gT50Gy), g_4 (gM), g_5 (gO), and g_6 (gT). The main plot (MP) had six genotypes (G). The sub-plot (SP) was *mycorrhizae* +tricho-compost (T): *mycorrhizae* +without tricho-compost (t_0), *mycorrhizae* +tricho-compost 50 g plant^{-1} (t_1), and *mycorrhizae* +2tricho-compost 100 g plant^{-1} (t_2). The results showed that soybean genotypes *gM50Gy*, *gO50Gy,* and *gT50Gy* have the stability of agronomic characteristics on the shoot dry weight, root dry weight, and soybean dry weight in the adaptation test in dryland. The treatment of tricho-compost 100 g Mg^{-1} had the highest increased shoot dry weight, root dry weight, percentage of mycorrhizal infection, and Nitrogen (N), Phosphorus (P), and Potassium (K) uptake. The interaction of *gT50Gy*t_2 *;* *gO50Gy*t_2 and *gT*t_2 resulted in higher root dry weight and N, P, and K uptake than *gM50Gy*t_2*;* *gM*t_2*;* *gO*t_2.

Keywords: Genotype, mycorrhizae, soybean, tricho-compost

INTRODUCTION

Soybean (*Glycine max* (L.) Merr) is a legume that contains several valuable nutrients, including oil (19%), protein (36%), carbohydrates (35%), vitamins, and minerals (Hassan, 2013). It makes soybean a vegetable protein important for improving people's nutrition. Indonesia's soybean production currently needs to catch up to the national needs of 2020 (approximately 2.95 million tons of dry beans per year) (Setyawan and Huda, 2022). The national soybean production was 963 183 dry tons, and the import of soybeans was 2.49 million tons in 2021 (BPS-Statistics Indonesia, 2022). Opportunities to increase domestic soybean production remain open by increasing productivity and expanding the planting area.

One of the obstacles to developing soybeans is the limited fertile lands, so the areal extension is more directed at the marginal lands, such as dryland. Dry land is potential "available" land for developing food crop agriculture and horticulture. The challenges of future agricultural development will be even more severe with various obstacles. Strategic efforts to meet food needs through three strategies, namely (1) intensification of existing agricultural land, (2) extensification or new expansion, and (3) controlling the conversion of paddy fields (Mulyani et al., 2017)

Structural characteristics can identify vesicular-arbuscular mycorrhizae (VAM) infection, including hyphae, mycelia, vesicles, and arbuscles, as well as spores on roots and hyphae in the rhizosphere. The formation of hyphal networks by AMF on plant roots significantly increases root access to a large soil surface area, increasing plant growth and translocation of various nutrients. Mycorrhizae application will expand the field of nutrient absorption so that it will increase nutrient absorption, including the P and Ca elements (Begum et al., 2019). VAM can extend and expand the roots' reach to absorb nutrients, especially the immobile nutrients in the soil, such as phosphate. The VAM external hyphae expand the root absorption area to absorb nutrients and water from the soil to its host plant. Furthermore, hyphae have a higher affinity for P than root hair (Johri et al., 2015). In addition, the application of *Trichoderma* compost (referred to as tricho-compost) can be used as an effort to manage soil fertility.

Tricho-compost is a compost organic fertilizer containing the antagonist fungus *Trichoderma* sp. used in the composting process as a decomposer to speed up the decomposition process and as a biological agent (Rahman et al., 2015). Tricho-compost and tricho-leachate applications efficiently produce healthy cabbage seeds (Nahar et al., 2012). Further, *Trichoderma harzianum* WKY5 significantly increases growth and potentially increases the yields of potatoes (Al-Askar et al., 2016); on the other hand, *Trichoderma* spp. potentially increases soil fertility and mangrove growth (*Avicennia marina*) (Saravanakumar et al., 2013). Furthermore, the *T. harzianum* application in soil or corn seeds increases growth, chlorophyll content, nucleic acids, total protein, and plant phytohormone content (Akladious et al., 2014).

Combination treatment of tricho-compost and mycorrhizae significantly affected the percentage of VAM infection and the percentage of active root nodules, plant height, root length, and plant biomass of soybean on calcareous soil growing media (Charisma et al., 2012). Using *Glomus* sp. + *Gigaspora* sp. + *Acaulospora* sp. increases the absorption of N, P, and K and the production of the soybean genotype (Widiati et al., 2017). Based on the above, this research aimed to examine the dry weight increase of the shoot and root, the nutrient uptake of N, P, K, and the yield of several soybean genotypes after mycorrhizae and tricho-compost application with a reduction of 50% of the fertilizer recommended dose on dryland.

MATERIALS AND METHODS

Time and place

This research was conducted from April to September 2020 in Damai Village, Tanralili District, Maros Regency, South Sulawesi Province.

Materials

The materials used in this research were soybean genotype seeds. The mycorrhizae fungus used was from the collection of the Faculty of Agriculture, Animal Husbandry, and Forestry of Muslim Maros University. The chemicals used to measure the root infections by mycorrhizae were 90% alcohol, distilled water, glycerin, lactic acid, and acid fuchsin.

Experimental design

The experimental study was conducted using the split-plot design (SPD). The characteristics of SPD are in the arrangement of the experimental plot layout and the technical analysis of its variety. For the problems with irregular rows and the difficulty in making experimental plots and the data observation technique, using SPD simplifies the making of the plots, and the rows of plants become more regular (Wardiana, 2016). The application of SPD in this research was conducted as follows: all treatments were given NPK fertilizer at 50% of the recommended dosage and 5–10 g mycorrhizae (*Glomus* sp. + *Gigaspora* sp. + *Acaulospora* sp.). The Main Plot (MP) consisted of six genotypes of the 5th generation (G), namely, g_1 (gM50Gy), g_2 (gO50Gy), g_3 (gT50Gy), g_4 (gM), g_5 (gO), and g_6 (gT). The sub-plot (SP) was composed of mycorrhizae + tricho-compost (T), namely, mycorrhizae + without tricho-compost (t_0), and mycorrhizae + tricho-compost 50 g plant^{-1} (t_1), and mycorrhizae + tricho-compost 100g plant^{-1} (t_2). Each treatment on the MP and SP was combined for 18 treatment combinations. Each treatment combination was repeated three times for 54 unit plots. The data was tested statistically based on analysis of variance at the 5% level, then tested for mean differences using the least significant difference test (LSD).

The making of tricho-compost

This research used tricho-compost fertilizer (100 kg) (Rahman et al., 2015) composed of 61% cow manure, 33% dry rice straw, 0.5% ash (as the potassium provider), 0.5% rice bran (as the feed inoculum), 0.5 kg of sugar, 10–15 L of water, *Trichoderma* sp. 250 g L^{-1} of water, and *Trichoderma* sp. 250 g. The procedure for making tricho-compost began with cutting rice straws of approximately 5 cm. Then, cow manure, rice straw, ash, and fiber were mixed until evenly distributed (mixture A). Mixture A was feast over a 20 cm thick soil. Mixture B, namely, *Trichoderma* sp., was mixed with a sugar solution (a solution consisting of 1/2 kg of sugar and 10 L of water). Next, combine mixture B and mixture A until evenly distributed. The last step is to cover the tightly using plastic for about 7 days. After 7 days, the plastic cover is opened; add *Trichoderma* sp. as much as 250 g, then stir again. The mixture of ingredients is closed again for approximately 21 days. The appearance of fine white threads indicated that the compost was ready to use.

Vesicular arbuscular mycorrhizae (VAM) inoculation and planting

The mycorrhizae culture inoculant of three genera mixtures, namely, *Glomus* sp. + *Gigaspora* sp. + *Acaulospora* sp., used in the field had an amount of 150–200 spores in 30 g of sand or culture media. 5–10 g of VAM was inoculated 5–7 cm deep into the planting hole prepared according to treatment and then covered with soil. The nature of fungus is to require carbon/energy from the host plant for growth. The most straightforward mycorrhizae application is the propagation of fungi through pot culture with a starter inoculum in the form of spores and pieces of infected roots immersed into the substrate in the seeding (Brundrett, 2004).

At the same time, the application and planting of soybeans for four perforated plants were made, with a spacing of 40 cm × 30 cm; after seven days, the plants were spared by selecting the plants with the best growth, leaving two plants per hole.

Soil chemical analysis

The soil samples were obtained from several locations using the field survey method and tested in a composite way for the soil chemical analysis in the laboratory. The sampling was only focused on mycorrhizae + without tricho-compost experimental land (t_0) and mycorrhizae + tricho-compost of 100 g plant^{-1} (t_2). The composite soil samples collected in the field were then analyzed in the laboratory for chemical properties, which included CEC, base saturation (BS), C-organic, total P, and total K soil. The data obtained were compared with the chemical properties assessment criteria (Balittanah, 2009). The comparison was intended to determine the status of soil chemical properties with mycorrhizae + without tricho-compost application and mycorrhizal + tricho-compost of 100 g plant^{-1}.

Plant Analysis

The plant analysis consisted of observations on the root and calculation of VAM infection. The observation parameters included the root dry weight (g plant^{-1}) and shoot dry weight (g plant^{-1}), observed after the roots and shoot of the plants were dried in an oven at 60 °C for 2× for 24 h (Tidar University, 2014), as well as the plant tissue nutrient contents of N, P, and K (%). The plant tissue analysis was carried out when the plant was 73 DAP and included N, P, and K nutrient analyses. The N nutrient analysis was performed using the Kjeldahl method. The wet ashing method extracted the P and K nutrients using HNO_3 and $HClO_4$. Then, the levels of nutrients were measured by UV–VIS spectrophotometer, flame photometer, and Atomic Absorption Spectrophotometer (Horwitz et al., 2000; Indonesian Soil Research Institute (Balittanah, 2009).

Calculation of root infection needs to be done by root staining. The root staining was carried out by a modified method (Kormanik et al., 1980; Leah Wathira, 2016); the root was soaked in 10% KOH solution for ±24 h until the roots showed white or clear yellow, the root was rinsed with water and then soaked with 10% H_2O_2 for a few minutes, the root soaked with 2% HCl solution for ±24 h, then the root soaked with the staining solution until turn bluish red for ±24 h, and the root soaked into a destaining solution for ±24 h. A 250 mL destaining solution consists of 100 mL of glycerin + 100 mL of lactic acid + 50 mL of distilled water.

The root observation was done by cutting the roots that had been stained for approximately 1 cm long, and then the roots were arranged on the preparations and covered with a glass cover; the number of roots in each preparation was 10 pieces. The root infections can be seen through vesicles, arbuscules, hyphae, or spores that infected the roots, observed with a Nikon Eclipse 80i camera microscope (magnification of 40–1000×). The root infection was calculated using the following formula (Giovannetti et al., 1980).

$$\text{Infected root (\%)} = \frac{\sum Infected\ root\ sample}{\sum all\ samples}\ x\ 100\%$$

Data analysis

The experimental study was conducted using the Split Plot Design (SPD). The characteristics of SPD are in the arrangement of the experimental plot layout and the technical analysis of its variety. For the problems with irregular rows and the difficulty in making experimental plots and the data observation technique, the use of SPD simplifies the making of the plots and the rows of plants. Suppose the results of the analysis of variance show a significant effect of genotype (G), mycorrhizal+trichocompost (T), and Genotype x mycorrhizal+trichocompost (G×T) interactions. In that case, further analysis is needed to determine the mycorrhizal+trichocompost needs of each genotype tested.

The least significant difference test (LSD) was used for pairwise comparisons. This test provides a single LSD value at a specified significant level, determining the boundary between significant and non-significant differences between each pair of treatment means. Two treatments are declared significantly different if the difference exceeds the calculated LSD value; if the difference is smaller than the LSD value, then they are not significantly different.

RESULTS AND DISCUSSION

Soil Analysis

The content of organic matter, Nitrogen (N) and Phosphorus (P), cation exchange capacity (CEC) and base saturation (BS) in the soil increased with the application of mycorrhizae + tricho-compost of 100 g, compared to the mycorrhizae + without tricho-compost (Table 1). The nutrient contents in the mycorrhizae + tricho-compost (t_2) experimental land was P Olsen of 18.2 mg kg^{-1} (10–20 cmol kg^{-1} classified as low), the N of 0.21% (0.21%–0.50% classified as moderate), and BS of 63% (51%–70% classified as high) according to Indonesian Soil Research Institute (Balittanah, 2009).

The soil pH is one of the most critical determinants of soil fertility through the supply of cation and anion nutrients and its effect on the microorganism's activity in the soil (Husson, 2013; Neina, 2022; Oliver et al., 2013). The pH in the experimental land of mycorrhizae + without tricho-compost (t_0) treatment and the mycorrhizae + tricho-compost (t_2) was relatively similar to pH 6.8–6.9. BS and CEC values of mycorrhiza + tricho-compost treatment (t_2) were higher than those of mycorrhiza + without tricho-compost (t_0) treatment (Table 1).

Utilization of tricho-compost can improve soil quality, soil pH, water holding capacity, and soil structure (Rahman et al., 2015). Compost application increases organic C, soil biological activity, and soil CEC, which allows for maintaining the availability of nutrients (cations and anions), thereby increasing crop production (Scotti et al., 2015). Soil with a high percentage of BS is directly proportional to the pH and CEC, thus increasing soil fertility, containing more essential plant nutrients such as K^+, Ca^{2+}, and Mg^{2+} cations needed for plants (Sonon et al., 2014). The composition and concentration of soil organic matter will help form soil aggregates associated with cations and soil particles (Hoffland et al., 2020). Cooked compost application can improve soil aggregate stability. Organic substances as adhesives increase the bonding between particles in soil aggregates (Lata Verma et al., 2013; Lucas et al., 2014).

Table 1. Soil properties.

No.	Nature of the soil			Soil analysis	
				t_0	t_2
1	Extract 1:2.5	pH	H_2O	6.9	6.8
			KCl	–	–
2	Against dry *samples* 105°C	Organic ingredients	Carbon (%) (Walkley and Black)	1.63	2.14
			Nitrogen (%) (Kjeldahl)	0.14	0.21
			C/N	12	10
		P_2O_5 (Olsen)	(mg kg^{-1})	12.6	18.2
		Cation exchange rates	Ca (cmol(+) kg^{-1})	5.63	10.24
		(NH_4-acetate 1 ***N***, pH 7	Mg (cmol(+) kg^{-1})	0.65	0.77
			K (cmol(+) kg^{-1})	0.24	0.19
			Na (cmol(+) kg^{-1})	0.41	0.51
		Total		6.93	11.71
			CEC (cmol(+) kg^{-1})	16.87	18.63
			BS (%)	41	63
3	Texture soil classification	Sand	(%)	33	30
		Dust	(%)	44	46
		Clay	(%)	23	24
		Texture class		clay	clay

Note: t_0: mycorrhizae + without tricho-compost; t_2: mycorrhizae + tricho-compost 100 g.plant^{-1}.

Table 2. F-value of the treatment on several observation parameters.

Observation parameters	F-value			F-table	
	Main Plot soybean genotype (g)	Sub-Plot mycorrhizae + tricho-compost (t)	Interaction of soybean genotype and mycorrhizae + tricho-compost (g×t)	0.05	0.01
Shoot dry weight	3.81*	4.06*	2.08^{ns}	(g) 3.33	5.64
Root dry weight	6.73**	3.61*	7.59**	(t) 3.4	5.61
% Mycorrhizae infection	3.70*	2.48^{ns}	2.51*	(g×t) 2.25	3.17
Nitrogen absorption	10.90**	206.49**	2.93*		
Phosphorus absorption	1.78^{ns}	225.6 **	6.39**		
Potassium absorption	15.99**	77.33**	4.51**		
Seed weight per plant	3.53*	7.23**	0.43^{ns}		

Note: * = significant/ ** = highly significant/ ns = not significant

The mycorrhizae + tricho-compost (t_2) treatment had higher N, P, K, and Ca (cmol(+) kg^{-1}) contents than the t_0 treatment in sequence: the mycorrhizae + tricho-compost (t_2) treatment: 0.21 (moderate), 18.2 (low), 0.51 (very low), and 0.77 (very low), whereas the mycorrhizae + without tricho-compost (t_0): 0.14 (low), 12.6 (low), 0.24 (very low), and 0.65 (very low) (Indonesian Soil Research Institute (Balittanah, 2009). Mycorrhizae improve nutrition in low soil fertility and degraded land and help expand the root system with external hyphae to increase plant growth (Aliyu et al., 2019; Salim et al., 2020). The vesicular-arbuscular mycorrhizae and *Trichoderma* spp., in addition to increasing plant growth, also increase resistance to crops' biotic and abiotic stresses (Buysens et al., 2016).

Plant Analysis

The F-value on the analysis of variance of several observational parameters showed that the treatment of soybean genotype, mycorrhizae + tricho-compost, and the interaction of soybean genotype and mycorrhizae + tricho-compost (gxt) had a significant effect on the root dry weight parameters, mycorrhizae infection percentage, N, P, and K absorption (Table 2).

Root and shoot dry-weight

The F-value of the shoot dry weight parameters indicated that the treatment of soybean genotype and mycorrhizae + tricho-compost had a significant effect; however, the combination of soybean genotype and mycorrhizae + tricho-compost had no significant effect (Table 2). The average shoot dry

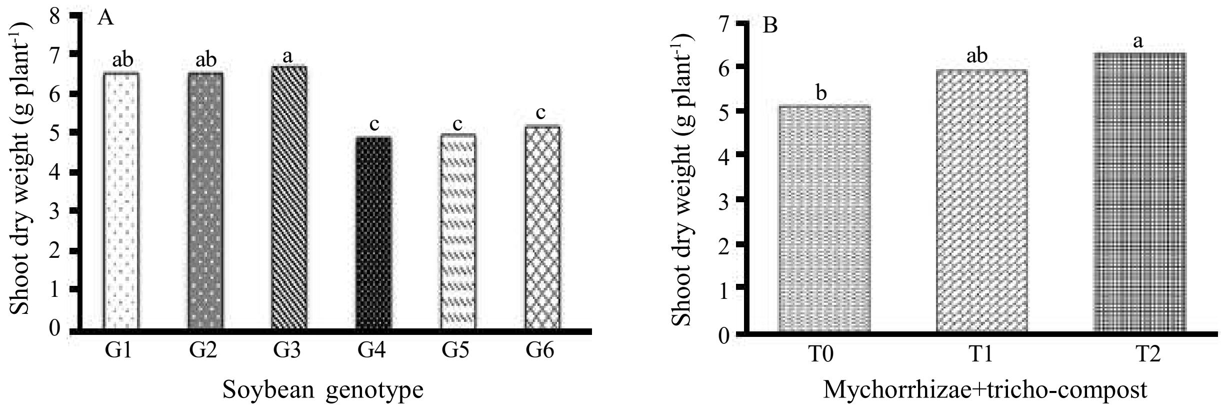

Figure 1. A). Shoot dry weight of six different soybean genotypes. B). Shoot dry weight after mychorrhizae + tricho-compost addition (t_0: mycorrhizae + without tricho-compost; t_1: mycorrhizae + tricho-compost 50 $g.plant^{-1}$; t_2: mycorrhizae + tricho-compost 100 $g.plant^{-1}$).

weight of soybean genotypes g_1, g_2, and g_3 significantly differs from g_4, g_5, and g_6 (Figure 1a). There was an effect of genotype and environmental interactions that causes adaptability in diverse environments, which was necessary for the development of potential genotypes that have the stability of plants (Ligarreto–Moreno et al., 2022; Mudada, 2017; Mustamu et al., 2018). Stable strains or varieties generally have less diversity if planted in different environmental conditions or have a fixed variety in various environments (Rasyad et al., 2010). The soybean genotypes g_1, g_2, and g_3 have stable agronomic characteristics as indicated by the shoot dry weight in the adaptation test in dryland. The adaptability test still needs to be done at a different location; therefore, a stable genotype is expected to be obtained so it can be further developed.

The treatment of mycorrhizae + tricho-compost on shoot dry weight showed that the treatment of mycorrhizae + tricho-compost of 100 g.plant^{-1} (t_2) was not significantly different from mycorrhizae + tricho-compost of 50 g.plant^{-1} (t_1), but was significantly different with mycorrhiza + without tricho-compost (t_0) (Figure 1b). It is in line with previous research (Kaushish et al., 2012) that stated that inoculation of endomycorrhizal fungi either alone or in combination with *Trichoderma viride* affects the morphological and physiological of *Rauwolfia serpentina* and in chili (Bhuvaneswari et al., 2014). Tricho-compost acts as a biocontrol and promoter of plant growth (Zin et al., 2020). Mycorrhizae and tricho-compost increase the shoot dry weight of plants. The development of *Trichoderma* conidia on the soil and then colonization occurs in the plant rhizosphere. *Trichoderma* can play a role in protecting plants; thus, they are not susceptible to disease. Inoculation of *Mycorrhiza* in plants leads to infection hyphae in plant roots and can help absorb air and nutrients, increasing the dry weight of the plant shoot.

The F-value of root dry weight showed that the treatment of soybean genotype and mycorrhizae + tricho-compost and the interaction of soybean genotype and mycorrhizae + tricho-compost significantly influenced the root average dry weight of soybean genotype (Table 2). The treatment of soybean genotype interaction of gM50Gy and mycorrhiza + tricho-compost of 50 g.plant^{-1} (g_1t_1) was significantly different from other treatment interactions to the average root dry weight of soybean genotype (Table 3). It aligns with the statement (Cardoso et al., 2006) that VAM generally plays a role in the extensive physical exploration of VAM colonized plant roots, not only in lengthening the plant root systems.

The role of VAM on metabolism in plants causes an increase in their growth (Begum et al., 2019). *Trichoderma* acts as a bio-pesticide and promotes growth. It can significantly increase the growth of

Table 3. Root dry weight of soybean genotype due to applying soybean genotype and Mycorrhizae + Tricho-compost.

Treatment	Average Root Dry Weight of Soybean Genotype		
Soybean Genotype	Mycorrhizae + Tricho-compost		
	t_0	t_1	t_2
	….........g.plant^{-1}..............		
g_1	2.10 bd C	4.80 a A	3.23 a B
g_2	2.27 bc A	1.93 b A	2.50 abc A
g_3	1.87 cd B	2.50 b AB	2.87 ab A
g_4	2.67 ab AB	2.17 b B	3.10 a A
g_5	3.10 a A	1.73 b B	2.23 bc B
g_6	1.47 d A	1.77 b A	2.00 ac A
LSD *gxt* (0.05)	0.777		

Note: numbers followed by the same letter between the column (lowercase letter) and between the row (capital letter) are not significantly different at the level of 5%

root hairs, the number of tillers, and the seed weight of wheat plants (Sharma et al., 2012). Mycorrhizae with the external hipa tissue will expand the water and nutrient uptake fields. Tricho-compost can improve soil structure, hold water, and increase nutrient availability. Mycorrhizae and tricho-compost increase the root dry weight of soybean genotypes. The *Trichoderma*-based biofertilizer also showed significant potential in rice crop growth, its physiological traits, and productivity. *Trichoderma*-inoculated rice showed significantly higher plant height, photosynthetic rate, chlorophyll a and b content, stomatal conductance, and tiller and panicle numbers (Doni et al., 2018).

Percentage of Mycorrhizae infection

The analysis of soybean genotype treatment showed that the combination of soybean genotype and mycorrhizae + tricho-compost had a significant influence. In contrast, the mycorrhizae + tricho-compost had no significant influence on the percentage of mycorrhizal infections (Table 2). The treatment of soybean genotype interaction of gO and mycorrhiza + tricho-compost of 50 g.plant^{-1} (g_5t_1) had a high mean percentage of mycorrhizal infection and was significantly different from other treatments (Table 4). The highest infection rate of mycorrhizae without tricho-compost (t_0) treatment was found in the g_2, g_3, g_4, g_5, and g_6 soybean genotypes, whereas the g_1 soybean genotype had the lowest infection rate. Furthermore, combining mycorrhizae and tricho-compost 50 g plant^{-1} (t_1 treatment) resulted in a similar infection rate in all soybean genotypes. When the concentration of tricho-compost was increased (t_2 treatment), the infection rate varied, with g_1, g_3, g_5, and g_6 soybean genotypes having a high infection rate. This result is in line with the opinion of (Brundrett, 2004), who stated that each type of mycorrhizae could be associated with the characteristics of the root system type. The mutualistic association between a mycorrhizal fungus and its host plants is beneficial for both, where the plants with mycorrhizae obtain the nutrients needed for growth and survival, and the mycorrhizae fungus obtains carbohydrates in the form of simple sugars and carbon from the plants (Begum et al., 2019; van der Heijden et al., 2015). The application of tricho-compost is also very influential on plants. The colonization by more than one fungal species can benefit the host plants, not only the P absorption but also the N absorption (Begum et al., 2019). *Trichoderma* sp. protects plants by infecting disruptive pathogens, producing several secondary metabolites that increase plant and root growth, and stimulating plant defense mechanisms (Zin et al., 2020). The synergy of mycorrhizae and *Trichoderma* sp. stimulates plant

Table 4. Mycorrhizae Infection Percentage of Soybean Genotype due to applying Soybean Genotype and Mycorrhizae + Tricho-compost.

Treatment	Average Mycorrhizae Infection Percentage of Soybean Genotype		
Soybean Genotype	Mycorrhizae + Tricho-compost		
	t_0	t_1	t_2
	…...........%.................		
g_1	70.00 b A	82.22 a A	81.67 ab A
g_2	89.44 a A	86.11 a A	62.22 c B
g_3	92.78 a A	82.22 a A	92.78 a A
g_4	80.00 ab AB	89.44 a A	74.45 bc B
g_5	88.33 a A	93.89 a A	87.78 ab A
g_6	90.00 a A	87.78 a A	85.00 ab A
LSD gxt (0.05)	14.678		

Note: numbers followed by the same letter in the column (abc) and the row (ABC) are not significantly different at the level of 5%

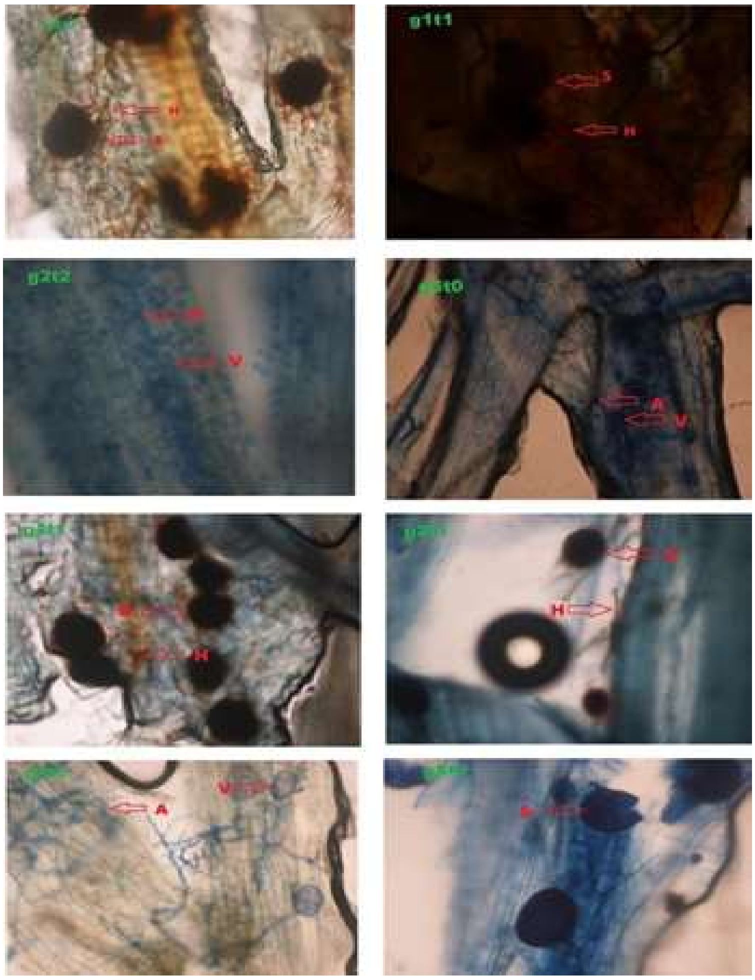

Figure 2. Spores (S), hyphae (H), vesicular (V), and arbuscular (A) in the soybean genotype root tissue in mycorrhizae + tricho-compost treatment.

roots that grow better due to improved conditions in the rhizosphere, thereby increasing the percentage of mycorrhizal infections in plant roots.

In this study, endomycorrhiza has several characteristics such as the infectious root does not enlarge, a thin layer of hyphae on the root surface, and hyphae enter individual cortical tissue cells, the presence of oval-shaped particular form (vesiculae), and dichotomous hyphal branching system (arbuscules) (Brundrett, 2004). Figure 2 shows the presence of spores (S), hyphae (H), vesicular (V), and arbusculae (A) in the soybean genotype root tissue in mycorrhizae + tricho-compost treatment.

Nitrogen (N) absorption

The treatment of genotype, mycorrhizae + tricho-compost and the combination of genotype and mycorrhizae + tricho-compost produced a significant effect on the average nitrogen absorption in soybean (Table 2). The increasing N absorption aligned with the increasing tricho-compost dose in soybean genotype plant tissue. The interaction of g_5 (gO), g_2 (gO50Gy), g_3 (gT50Gy), g_4 (gM), and g_6 (gT) with the application of mycorrhizal + tricho-compost 100g.plant^{-1} produces N absorption which was higher and significantly different from g_1 (gM50Gy) at the same dose of mycorrhizae + tricho-compost (Table 5). In the t_0 treatment, g_5 and g_6 soybean genotypes had the best N fixation capacity than other soybean genotypes. In contrast, after the addition of mycorrhizae and tricho-compost 50 g.plant^{-1} (t_1 treatment), g_2 and g_3 soybean genotypes and g_5 and g_6 soybean genotypes were able to fix N more efficiently than g_1 and g_4 soybean genotypes. Moreover, combining mycorrhizae and tricho-compost 100 g.plant^{-1} (t_2 treatment), g_2, g_3, and g_5 soybean genotypes possessed similar high N fixation capacity. The effect of compost showed increased plant growth, higher N content, organic matter, available P, and microbial activity (Ojo et al., 2016; Yang et al., 2020). *Trichoderma virens* GV_{41}

Table 5. Nitrogen Absorption of Soybean Genotype due to applying Soybean Genotype and Mycorrhizae + Tricho-compost.

Treatment	Average Nitrogen Absorption		
Soybean Genotype	Mycorrhizae + Tricho-compost		
	t_0	t_1	t_2
		…..........%..................	
g_1	2.14 ab B	3.71 cd A	3.27 b A
g_2	2.02 b B	4.35 ab A	4.29 a A
g_3	2.16 ab B	4.51 a A	4.50 a A
g_4	2.08 b C	3.50 d B	4.22 a A
g_5	2.62 a B	4.15 abc A	4.55 a A
g_6	2.50 ab A	3.98 bcd A	4.03 a A
LSD gxt (0.05)	0.528		

Note: numbers followed by the same letter in the column (abcd) and the row (ABC) are not significantly different at the level of 5%

increased fertilizer N use efficiency (NUE) of lettuce, favored the uptake of native soil N by both lettuce and rocket, and also improved N uptake by roots under low N availability conditions (Fiorentino et al., 2018).

Phosphorus (P) Absorption

The F-value results (Table 2) showed that the P absorption of soybean genotype in treating genotype, mycorrhizae + tricho-compost, and the combination of genotype and mycorrhizae + tricho-compost produced significant influence. The increasing P absorption aligned with the increasing tricho-compost dose in soybean genotype plant tissue. The interaction of soybean genotype g_5 produced more P absorption and was not significantly different from g_3 but different from g_1, g_2, g_4, and g_6 with mycorrhizal application + tricho-compost of 100 g.plant^{-1} (Table 6). The g_1 soybean genotype displayed the highest capacity to absorb P in the t_0 treatment. However, mycorrhizae + tricho-compost 50 g.plant^{-1} addition (t_1 treatment) could significantly increase the P absorption in g_4 and g_6 soybean genotypes, resulting in both genotypes having similar absorption capacity with the g_1 soybean genotype. In mycorrhizae + tricho-compost 100 g.plant^{-1} (t_2) treatment, g_4 soybean genotype had higher P absorption compared to g_3 and g_1 soybean genotypes, whereas g_4 soybean genotype had similar P absorption capacity with g_2, g_5, and g_6 soybean genotypes. Mycorrhizae fungus can increase the absorption of nutrients, especially P and several other nutrients such as Cu and Zn (Begum et al., 2019). *Trichoderma* sp. inoculation increases phosphate dissolution and mangrove seed biomass (*A. marina*) compared to the control (Saravanakumar et al., 2013). In addition, the increase of P-uptake was also shown after inoculation of *Trichoderma asperellum* T34 in cucumber (Garcia-Lopez et al., 2015).

Potassium (K) absorption

Potassium absorption can be affected by the treatment of genotype, mycorrhiza + tricho-compost, and the combination of genotype and mycorrhizae + tricho-compost (Table 2). The increasing K absorption aligned with the increasing tricho-compost dose in soybean genotype plant tissue. The interaction of the genotype g_3 was not significantly different from the tricho-compost of 100 g.plant^{-1} application, producing higher K absorption, and was significantly different from g_4 but significantly different from g_1, g_2, g_5, and g_6 at the same dose of mycorrhizae + tricho-compost (Table 7). In the t_0 treatment, the g_6 soybean genotype absorbed the highest K compared to other genotypes. Furthermore, in the t_1 treatment, the soybean g_6 genotype showed a similar K absorption capacity

Table 6. Phosphorus Absorption of Soybean Genotype due to applying Soybean Genotype and Mycorrhizae + Tricho-compost.

Treatment	Average Phosphorus Absorption		
Soybean Genotype	Mycorrhizae + Tricho-compost		
	t_0	t_1	t_2
	...........%.............		
g_1	2.14 cd C	3.71 e A	3.27 f B
g_2	2.02 e B	4.35 b A	4.29 b A
g_3	2.16 c B	4.51 a A	4.5 a A
g_4	2.08 de C	3.5 f B	4.22 c A
g_5	2.62 a C	4.15 c B	4.55 a A
g_6	2.5 b B	3.98 d A	4.03 d A
LSD gxt (0.05)	0.065		

Note: numbers followed by the same letter in the column (abcdef) and the row (ABC) are not significantly different at the level of 5% .

Table 7. Potassium Absorption of Soybean Genotype due to applying Soybean Genotype and Mycorrhizae + Tricho-compost.

Treatment	Average Potassium Absorption		
Soybean Genotype	Mycorrhizae + Tricho-compost		
	t_0	t_1	t_2
	...........%.............		
g_1	2.19 b B	2.69 c AB	3.25 c A
g_2	2.35 b B	3.22 bc A	3.65 bc A
g_3	2.41 b C	3.51 b B	4.52 bc A
g_4	2.33 b C	3.67 ab B	4.79 a A
g_5	2.36 b B	3.65 ab A	3.52 a A
g_6	3.54 a B	4.21 a A	3.84 b AB
LSD gxt (0.05)	0.582		

Note: numbers followed by the same letter in the column (abc) and the row (ABC) are not significantly different at the level of 5%

with the g_4 soybean genotype, but it was significantly different with the g_5, g_3, g_2, and g_1 soybean genotypes. In higher doses of tricho-compost 100 g.plant^{-1}, g_3, and g_4, soybean genotypes demonstrated high K absorption with similar capacity but significantly lower than g_1, g_2, g_5, and g_6 soybean genotypes. Mycorrhizae and *Trichoderma* sp. affect external hyphae, thereby expanding the absorption capacity of soybean roots. Mycorrhizae and *Trichoderma* sp. can stimulate root

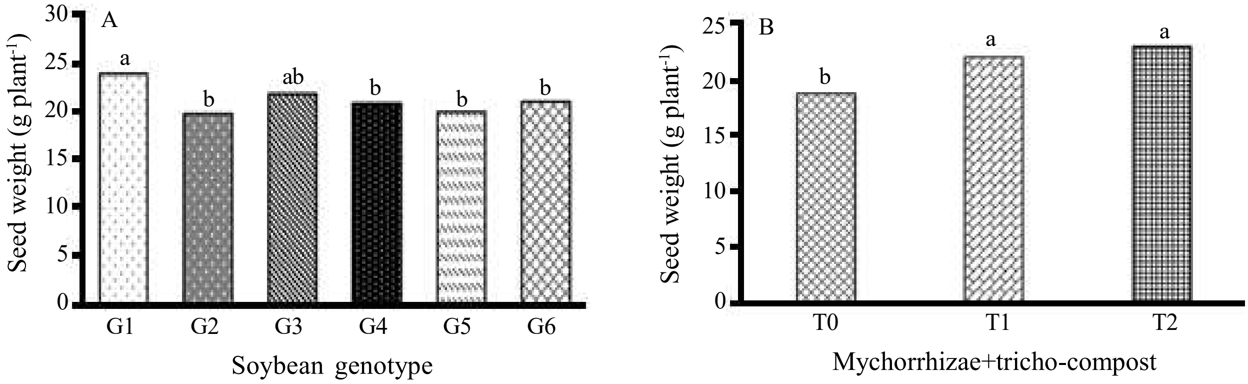

Figure 3. A). Seed weight of six different soybean genotypes. B). Seed weight after mychorrhizae + tricho-compost addition (t_0: mycorrhizae + without tricho-compost; t_1: mycorrhizae + tricho-compost 50 g.plant^{-1}; t_2: mycorrhizae + tricho-compost 100 g.plant^{-1}).

formation, thus increasing the uptake of N, P, and K from the soil by expanding the surface in contact with the soil. In addition, *Trichoderma* sp. increases the protection of soybean plants. (Gao et al., 2012) showed that inoculation with rhizobia and arbuscular mycorrhizal fungi could directly inhibit pathogen growth and reproduction in soybeans and activate the plant's overall defense system through increasing PR gene expressions. Moreover, the inoculation with mycorrhizal fungi in Sesame (*Sesamum indicum*) also increased the amount of chlorophyll index, N, P, K, zinc, iron, and copper uptake compared with the absence of mycorrhizal fungi (Askari et al., 2018).

Soybean Yield

The average weight of the soybean genotype showed that the treatment of the soybean genotype and mycorrhizae + tricho-compost had a significant influence; however, the combination of soybean genotype and mycorrhizae + tricho-compost had no significant influence (Table 2). The average weight of the soybean seeds g1 was not significantly different from g_2 but significantly different from g_3, g4, g_5, and g_6 (Figure 3a). The dose of tricho-compost did not have a significant effect on seed weight per plant (100 g.plant^{-1} (t_2) or 50 g.plant^{-1} (t_1)), but it did affect the yield only given by mycorrhizae (t_0) (Figure 3b).

Vesicular arbuscular mycorrhizae can increase the absorption of P, K, and Ca to influence the quality of crop yields (Nicolás et al., 2015). VAM can increase nutrient absorption, both macro and micronutrients, to reduce and streamline the use of inorganic fertilizers (Begum et al., 2019). Vesicular arbuscular mycorrhizae help plants to absorb nutrients (incredibly immobile nutrients) and water from the soil, reduce inorganic fertilizers, increase plant tolerance to biotic and abiotic stresses, provide once-in-a-lifetime plants, and provide benefits to the next plant's rotation (Treseder, 2013). Plants symbiotic with the VAM can take P in two pathways: directly by root epidermal cells and root hair and through the VAM (Filho et al., 2017). Mycorrhizae and tricho-compost produce organic acid and phosphatase enzymes that can release P from specific bonds, making them available to plants. The nutrient P plays a role in increasing the seed weight of soybean genotypes.

Table 8. Correlation test results.

Variable	Shoot dry weight per plant	Seed weight per plant
Root dry weight	0.081ns	0.352 ns
Percentage of mycorrhizae infection	0.399 ns	0.414 ns
Nitrogen absorption	0.384 ns	0.635**
Phosphorus absorption	0.552*	0.743**
Potassium absorption	0.242 ns	0.455 ns

Note: * = significant/ ** = highly significant/ ns = not significant

Relationship between observation variables

The correlation test results showed a real correlation between the average P absorption and the soybean genotype shoot dry weight with a correlation coefficient of (r) = 0.552. The average N and P nutrient absorption correlated significantly with the average seed weight per soybean genotype plant, with the correlation coefficient values of r = 0.635 and r = 0.743 (Table 8). A significant relationship exists between P uptake and shoot dry weight per plant. In addition, there was a positive relationship between N and P uptake and seed weight per plant. Increased absorption of N and P will increase plant dry weight and seed weight per soybean plant (Grümberg et al., 2015). The regression coefficient value also shows the strain response to adaptability, environment, and production stability (Tukamuhabwa et al., 2012).

CONCLUSIONS

The soybean genotypes gM50Gy, gO50Gy, and gT50Gy have the stability of agronomic characteristics on the shoot dry weight, root dry weight, and soybean dry weight in the adaptation test in dryland. The treatment of mycorrhiza + tricho-compost 100 g.Mg^{-1} increased shoot dry weight, root dry weight, percentage of mycorrhizal infection, N, P, and K uptake higher than that of mycorrhiza + tricho-compost 50 g.Mg^{-1} and mycorrhizal + without tricho-compost of soybean genotypes on dryland. The interaction of $gT50Gyt_2$, $gO50Gyt_2$ and gTt_2 resulted in higher root dry weight and N, P, and K uptake than $gM50Gyt_2gMt_2$; gOt_2. The soybean genotype adaptability test still needs to be conducted at a different location; therefore, a stable genotype characteristic is expected to be obtained, developing it further.

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