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The inoculation of mycorrhiza and *Talaromyces pinophilus* toward the improvement in growth and phosphorus uptake of oil palm seedlings (*Elaeis guineensis* Jacq) on saline soil media

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Abstract

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The saline soil is one of the most untapped land for crop cultivation, as it contains dissolved salt which can inhibit nutrient absorption and one of them is phosphorus. Mycorrhiza and *Talaromyces pinophilus* are microorganisms that can increase P uptake and plant growth. The purpose of this research is to determine the effect of mycorrhiza and *T. pinophilus* on the growth and P uptake of oil palm trees on saline soil media. The materials used are 3 months old palm seedlings of D X P Simalungun variety, saline soil, compost of oil palm bunches, mycorrhiza, and *T. pinophilus*. The parameters investigated were: plant height (cm), stem circumference (cm), plant dry weight, plant roots dry weight (g), colonization in roots (%), P uptake of roots and P uptake of plant. The research results showed that interaction between mycorrhiza and *T. pinophilus* can improve plant growth by 13.01-55.54% and P uptake by 15.38-69.28%. In general the best treatment is mycorrhizae application 40 g/plant and *T. pinophilus* 20 ml/plant (M2P2).

Keywords: oil palm seedlings; phosphorus uptake, mycorrhiza; *Talaromyces pinophilus*; saline soil

Introduction

Oil palm nurseries are the first step that determines the success of planting in the field, the success in breeding is determined by the availability of nutrients and soil fertility in addition to other factors. The saline soil can put pressure on the growth of the plant so that the growth and production of the plant becomes decreased. The saline soil occupies 7% of the world's land area (Sheng et al., 2011). The soil salinity significantly reduces nutrient uptake, especially phosphorus (P), since phosphate ions are absorbed with Ca^{2+}, Mg^{2+} and Zn^{2+} ions in saline soils and become unavailable for plants. Mycorrhizae is widespread in salt affected environments, and form roots symbiotic associations, in most plant species. This association allows plants to explore larger volumes of soil to absorb more water and nutrients uptake and transport, and increases absorption of immobile mineral elements such as phosphorus, and improves water-use efficiency (Al-Karaki, 2000). Therefore, arbuscular mycorrhiza (AM) symbiosis increases salinity resistance in several host plants, such as maize and tomato (Feng et al., 2000; Kaya, 2009; Çekiç et al., 2012). Several studies have suggested that improvement of plant P status is the most important mechanism through which arbuscular mycorrhizal fungus (AMF) confers salinity tolerance to plants (Al-Karaki, 2006). Phosphorus is a very important macro element for plant growth but its availability in plants is lower than N, K and Ca. One attempt to address the low phosphate availability in the soil is to utilize a group of phosphate solubilizing microorganisms and organic material. Microorganisms and organic material can produce organic acids that chelating metals in the soil so that phosphate becomes available to the plant. The utilization of phosphate solubilizing microorganisms and organic material is expected to overcome the P problem on acid soils which can also suppress the use of inorganic fertilizer and is needed to maintain soil fertility by maintaining and improving soil microorganism function so as to increase nutrient availability and also increase fertilizer effectiveness (Ritonga et al., 2015).

Arbuscular mycorrhizal fungus have a specific ability to increase the absorption of P from the poorly soluble P form, either the P which naturally occurred or derived from fertilizers, on marginal soils with low P availability. Plants in general (80%) are able to be in symbiosis with mycorrhiza and mycorrhiza can increase root absorption area and nutrient uptake with drought tolerance and resistance to high salt content (Daei et al., 2009). The existence of mycorrhizae in plant roots can increase plant growth (Redman et al., 2002; Lewis, 2004).

Talaromyces pinophilus is a type of phosphate solubilizing fungi, capable of dissolving phosphate compounds that are difficult to dissolve into available forms for plants by producing organic acids so that the P availability is increased (Sembiring and Fauzi, 2017; Sembiring et al., 2017). Based on the description above, to increase the low availability of P nutrients in the soil, in this research we used mycorrhiza and *T. pinophilus*.

Materials and Methods

The materials used are 3 month old oil palm seedlings taken from PPKS variety D X P Simalungun, saline soil, oil palm empty fruit bunch compost, mycorrhizal fungi and *T. pinophilus* (8×10^9) from the Laboratory of Soil Biology, Agriculture faculty, USU. Phosphate Rock fertilizer (PR), dolomite, kieserite and NPK fertilizer (12:12:17:2) were applied.

This research used Factorial Randomized Block Design with 4 replications. Factor I is mycorrhiza with application consisting of M0 = 0 g mycorrhiza/plant, M1 = 20 g mycorrhiza/plant, M2 = 40 g mycorrhiza/plant. Factor II is *T. pinophilus* with applications consisting of P0 = 0 ml *T. pinophilus*/plant, P1 = 20 ml *T. pinophilus*/plant, P2 = 40 ml *T. pinophilus*/plant.

The planting media used is a medium of saline soil as much as 7 kg/polybag in addition with 3 kg of oil palm empty fruit bunch compost. Mycorrhiza and *T. pinophilus* applications were conducted three days after oil palm seedlings were planted. 5 kg of Phosphate Rock fertilizer (PR) was applied a day before oil palm was planted. NPK fertilization (12:12:17:2) 5 g, kieserite 4 g and dolomite 5 g (50% of recommendation dose) were applied at planting time around the root of the plant.

The parameters investigated were: plant height (cm), stem circumference (cm), plant dry weight, plant roots dry weight (g), colonization in roots (%), P uptake of roots and P uptake of plants. Preparation of root colonization was following the procedures of Giovanneti and Mosse (1980). Colonization of root was calculated using the method of the length of colonized roots described by Kormanik and McGraw (1982).

The data were analyzed by the method of one way ANOVA and comparison of means were tested for significance using Least Significant Difference (LSD) p = 0.05 (Gomez and Gomez, 1984).

Results and Discussion

The statistical analysis showed that mycorrhiza application has significant effect on plant height in observation V and VI. Applications of *T. pinophilus* had no significant effect on plant height (Table 1). Mycorrhiza application (M2) can increase plant height by 3.37% compared to control. Mycorrhiza can prevent dehydration of plants on saline soil so that plant growth can increase (Ruiz-Lozano and Azcón, 2000; Aliasgharzadeh et al., 2001). Mycorrhiza had a significant effect on the growth of stem circumference in observations V and VI (Table 2). Mycorrhiza application (M2) increased stem circumference by 8.8% compared to variant with no application (M0). This is in accordance with the results of Beltrano et al. (2013). On saline soils, salt solubility is high so that it can inhibit the absorption of water and nutrients especially phosphorus by plants. The existence of mutualistic symbiosis between mycorrhiza and plant roots can help to a better plant growth, especially on marginal soil. This is because mycorrhiza is effective in increasing the absorption of nutrients especially P. According to Shah et al. (2008a, 2008b) plant growth increased positively with AM inoculation and improved plant biomass.

The AM application can increase P uptake and plant root growth (Smith and Read, 2010; Sheng et al., 2011; Lee et al., 2014). Al-Karaki et al. (2006) found that AM inoculation can increase P uptake of plant on saline soil. The mycorrhizal application gives a significant effect on plant root dry weight, plant root infections and plant P uptake (Table 3). Mycorrhiza application (M2) increased root dry weight by 32.85%, plant dry weight by 59.45%, plant root P uptake by 39.8% and P uptake by 67.83% when compared to con-

Table 1
Average height (cm) of oil palm plant in observations I to VI (one month interval)

Treatment	Observation					
	I	II	III	IV	V	VI
Mycorrhiza (g)						
0 (M0)	41.81	46.62	54.61	60.42	65.41a	79.32 a
20 (M1)	41.82	47.01	55.41	61.01	67.42a	80.24 a
40 (M2)	42.32	47.91	56.12	62.42	67.92 b	82.01 b
T. pinophilus (ml)						
0 (P0)	41.32	47.68	55.45	61.23	67.11	80.23
20 (P1)	41.22	46.79	54.79	61.34	67.12	80.56
40 (P2)	41.68	47.34	56.23	61.68	67.12	81.12
M	NS	NS	NS	NS	*	*
P	NS	NS	NS	NS	NS	NS
MxP	NS	NS	NS	NS	*	NS

Note: Means in columns followed by a common letter are not significantly different at 0.05 level by LSD; NS: not significant

Table 2
Stem circumference (cm) average of oil palm plant on observations I to VI (one month interval)

Treatment	Observation					
	I	II	III	IV	V	VI
Mycorrhiza (g)						
0 (M0)	5.56	5,72	8,10	10,32	11,23 a	13,24 a
20 (M1)	5.56	5,90	8,11	11,11	12,08 a	14,09 a
40 (M2)	5.44	5,79	8,26	11,12	12,21 b	14,43 ab
T. pinophilus (ml)						
0 (P0)	5.82	6.12	8.36	10.95	12.01	13.58
20 (P1)	5.23	5.68	8.21	10.95	11.91	13.76
40 (P2)	5.45	5.68	7.98	10.56	11.51	14.35
M	NS	NS	NS	NS	*	*
P	NS	NS	NS	NS	NS	NS
MxP	NS	NS	NS	NS	NS	NS

Note: Means in columns followed by a common letter are not significantly different at 0.05 level by LSD; NS: not significant

trol (M0). According to Giri and Mukerji (2004), AMF applications can increase nutrient uptake of N, P and Mg for plants so the plant growth becomes increasing. According to Miransari et al. (2007) AMF inoculation can increase the surface area of plant roots so that nutrient uptake and plant growth can increase.

T. pinophilus treatment did not have a significant effect on plant growth. Increased plant height with application of *T. pinophilus* is 1.26%, compared to control. The interaction of mycorrhiza and *T. pinophilus* had a significant effect on plant height growth in V observed period. Mycorrhiza and *T. pinophilus* interactions can increase plant height by 5.08% (Figure 1). Application of *T. pinophilus* (P2) is able to increase stem circumference growth by 5.67%, compared to control. Interaction between mycorrhiza and *T. pinophilus* (M2P2) can increase stern circumference by 14.74%, compared to control (Figure 2). The application of *T. pinophilus* has a significant effect on plant root dry weight and plant root infections. *T. pinophilus* application (P2) can increase root dry weight by 29.47%, plant dry weight increased by 2.37%, P nutrient uptake by plant roots increased 42.44% and P uptake of plant increased by 11.41%. The results of Ritonga et al. (2015); Sembiring et al. (2016); Marbun et al. (2015) showed that *T. pinophilus* applications can increase P nutrient uptake and plant dry weight. Phosphate solubilizing microorganisms application can increase P availability and plant growth (Sharma et al., 2013; Musarrat and Khan, 2014). *T. pinophilus* application alone can reduce colonization in roots (%), by 78.08% when compared to control, this is because *T. pinophilus* is a microbe that lives free in the soil

Table 3
The average of roots dry weight, plant dry weight, plant root infections, P content in plants, P uptake of roots and P uptake of plant

Treatment	Roots dry weight (g)	Plant dry weight (g)	Colonization in roots (%)	P content in plants (%)	P uptake of roots (mg/plant)	P uptake of plant (mg/plant)
Mycorrhiza (g)						
0 (M0)	111.05 a	125.01	1.12 A	0.19	21.10	23.75a
20 (M1)	132.33a	173.73	39.01 C	0.21	27.78	36.48b
40 (M2)	147.53b	199.33	38.38 B	0.20	29.50	39.86c
T. pinophilus (ml)						
0 (P0)	117.45a	164.81	31.72 C	0.20	23.49	32.96
20 (P1)	121.48 a	168.72	18.05 A	0.21	25.51	35.43
40 (P2)	152.08 b	166.91	29.01 B	0.22	33.46	36.72
M	*	NS	**	NS	NS	*
P	*	NS	**	NS	NS	NS
MxP	NS	NS	**	NS	*	NS

Note: Means in columns followed by a common letter are not significantly different at 0.05 level by LSD; NS: not significant

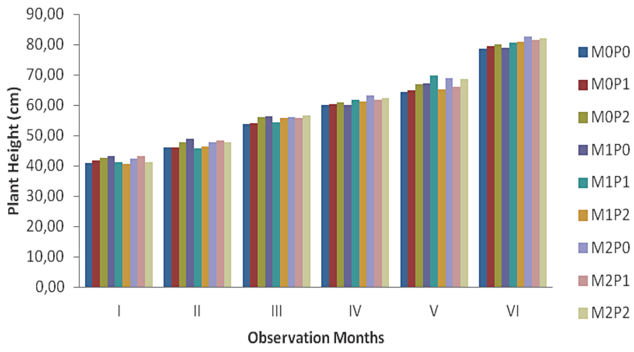

Fig. 1. Plant height after treatment with mycorrhiza and *T. pinophilus* interactions in observation months I-VI

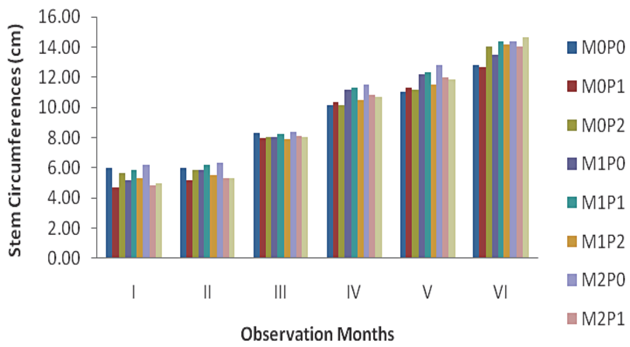

Fig. 2. Stem circumference (cm) after treatment with mycorrhiza and *T. pinophilus* interactions in observation months I-VI

and does not infect plant roots so that although applied to the plant but does not affect colonization in roots (%).

The interaction of mycorrhiza and *T. pinophilus* had no significant effect on root dry weight observation, plant dry weight, P nutrient uptake of plant but had significant effect on plant root infection and P uptake of plant roots. Mycorrhiza and *T. pinophilus* (M2P2) interactions can increase dry weight of plant roots by 68.8% higher than control. There was an increase of plant root dry weight by 38.14% when compared to M0P2 treatment and 46.7% when compared to M2P0 treatment. The interaction of mycorrhiza and *T. pinophilus* can increase plant dry weight by 55.54%, plant roots P uptake by 68.78% and P uptake of plant by 69.28% when compared to the control (Figure 3).

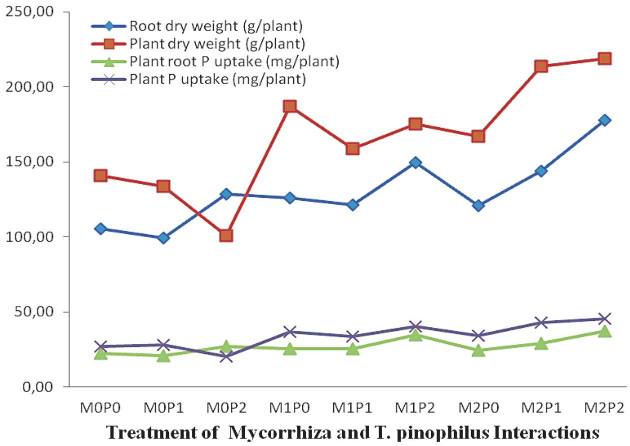

Fig. 3. The average of root dry weight, plant dry weight, P uptake of roots and P uptake of plant after treatment with mycorrhiza and *T. pinophilus* interactions

There are positive mycorrhiza and *T. pinophilus* interactions that can increase plant growth, this is because the phosphate solubilizing microorganisms (*T. pinophilus*) can increase the P availability of the soil by producing an organic acid that can penetrate the metal in the soil so that P becomes available (Johnson and Loeppert, 2006). Meanwhile the mycorrhiza infects plant roots and the presence of internal and external hypes play a role in increasing the absorption of P nutrients by plants (Grace et al., 2009; Lett et al., 2011; Majewska et al., 2017). Saito and Ezawa (2017) found that mycorrhiza inoculation may increase P uptake of plant so that plant growth increases. According to Postma et al. (2007), Zubek et al. (2009), Ouzounidou et al. (2015) mycorrhiza inoculation may increase colonization of plant roots so that root growth and nutrient uptake of plants increase (Beltrano et al., 2013). Increasing of P uptake by AMF in plants grown under salt stress conditions can reduce the negative effects of Na and Cl ions by maintaining the vacuolar membrane integrity and selectivity of ion intake to prevent ion entering the metabolic pathway for plant growth (Cantrell and Linderman, 2001).

Conclusions

Mycorrhiza inoculation can increase the growth of plant height by 1.15-3.37%, stem girth by 6.41-8.8%, roots dry weight by 19.16-32.85%, plant dry weight by 38.97-59.45%, P uptake of plant roots by 31.65-39.8%, plant P nutrient uptake by 53.6-67.83%, in general the best treatment is mycorrhiza application of 40 g (M2). *T. pinophilus* inoculation can increase plant height by 1.26%, stem girth by 5.67%, root dry weight by 3.43-29.47%, plant dry weight by 1.27-2.37%, P uptake of plant roots by 8.6-42.44%, plant P nutrient uptake by 7.41-14.41%, in general the best treatment is *T. pinophilus* application of 20 ml (P2). Mycorrhizal interaction with *T. pinophilus* can increase the growth of plant height by 1.67-4.2%, stem girth by 11.67-14.74%, root dry weight by 15.26-68.8%, plant dry weight by 13.01-55.54%, P uptake of plant roots by 15.38-68.78%, plant P nutrient uptake by 25.09-69.28%, generally the best treatment is application of mycorrhiza 40 g and *T. pinophilus* 20 ml (M2P2).

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