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The Effect of Soil Orders and Mycorrhizal Biofertilizer on Growth and Yield of Aceh's Organic Patchouli

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ABSTRACT

The main obstacle in the production of patchouli is the lack of fertilizer and plants are often attacked by diseases. Besides the condition of the soil as a planting medium will determine the success of patchouli production and quality. Particularly in the highlands, other obstacles in patchouli production are poor soil fertility, physical and biological properties of Ultisols. While in the lowlands, patchouli tends to be cultivated on Entisols soil with low to medium soil nutrient and does not support patchouli production if it is not well-managed. The using of mycorrhizal as bio-fertilizer expected the production of organic Aceh's patchouli will increase. This study aims to determine the effect of soil orders and mycorrhizal bio-fertilizers on growth and yield of Aceh patchouli and the interaction between the two factors studied. This research used a Factorial Randomized Block Design with 3 replications. The first factor observed was type of soil; namely Ultisols and Entisols. While the second factor *includes* mycorrhizal genus *Glomus mosseae*, *Gigaspora* sp. and mix *Glomus mosseae* with *Gigaspora* sp. The variables observed in this study include of the plant height, stem diameter, number of leaves, number of primary branches, fresh weight, dry weight, root mycorrhizae colonization, P uptake, and oil content that produced by patchouli. The results showed that Ultisol soil order and mycorrhizal bio-fertilizer genus of *Glomus mosseae* gave the best results for the average parameters studied.

Keywords: mycorrhizae, mycorrhizal bio-fertilizers, patchouli production, Ultisol

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INTRODUCTION

Patchouli ((*Pogestemon cablin* BENTH.) is one of the plants that has the best prospects and is widely cultivated by farmers in Aceh. In patchouli cultivation the influencing factors consist of internal (genetic) and external (environmental) factors. Become one of the manufacturers of essential oils, patchouli is needed for biopharmaceutical sector, cosmetic and the perfume industry. Presently, Indonesia in particular Aceh has produced around 90% of the world's essential oils. Besides is being used as a perfume ingredient, Aceh patchouli is good for aromatherapy, treats the diabetes wounds, smoothes the skin, functions as anti-aging, prevents of hair loss, anti-bacterial and disinfectant.

As one of the plantation crops that rides the community's economy, patchouli has a intense prospect and one of Aceh's mainstay commodities which is extensively refined in Aceh Jaya, North Aceh, South Aceh, West Aceh and all other regions of Aceh. Patchouli productivity and quality is determined by genetic and many environmental factors. Organic patchouli is necessary for the cosmetic, aroma industries, and biopharmaceutical industries, because it is safer and healthier. Furthermore, organic patchouli is produced the high quality of patchouli oil (Bappeda Aceh, 2018).

Specifically, in Aceh, people cultivate the patchouli in general on Inceptisol, Ultisol and Entisol soil. On moderate to highland such as West Aceh, South Aceh and North Aceh. Patchouli production is implemented on Ultisol soil. The characteristics of Ultisol soil are having a low pH, low cation exchange capacity, low base saturation, nutrient content such as nitrogen, phosphorous, potassium, calcium, and low magnesium and high Al-dd level, resulting in the unavailability of sufficient nutrients for plant growth. The main conception of Ultisol (the last Ultimus) is red and yellow soils, which have undergone a process of further climate destruction *(ultimate*), so it is a soil that has a deep cross section (> 2 m), shows an increase in clay content and accumulates called the Argillic horizon (Subagyo *et al.,* 2014; Hardjowigeno, 2018). In addition, the other characteristic of Ultisol is the organic matter content in topsoil less than 9 percent and generally about 5 percent. Nutrient content such as nitrogen, phosphorous, potassium and calcium, generally low and soil reactions (pH) too low between 4 - 5,5. The level of permeability, infiltration and percolation is moderate to slow, the surface layer is generally moderate and slower downward. This soil has poor chemical properties, while its physical properties are not stable with less aggregate stability. As a result, this soil is susceptible to erosion due to water movement. Besides that, another characteristic of Ultisol soil is that the structure is quite good but not stable. The kaolinite clay mineral content is high, so the amount of water available to plants is somewhat reduced. Thus, soil productivity is low to moderate (Nurmasyitah *et al*., 2013).

Low pH of soil and oxygen content in Ultisol soils cause limited use of the soil even though the potential is very broad. These conditions make Ultisol ineffective in supporting crop production, including patchouli if no input is given to the soil. One of the inputs given is the provision of nutrients to the soil to streamline the absorption of N and P (Syafruddin et al, 2016; Nurmasyitah et al, 2013). Mycorrhizae can be found in almost all of host plants, includes cash crops, horticulture and plantations. Mycorrhizae plays a role as bio-fertilizer, bio-protector and bio regulator which makes it an environmentally friendly biological agent (Cameron, 2010; Douds *et al*., 2010).

On the other hand, Entisol is a soil that has a low nutrient content, especially nitrogen with sand texture and crumb structure. Main characteristics of the soils belonging to the Entisol order are very young soils, which are only at the beginning of development stage, porosity and large aeration, rapid permeability, low water holding capacity. Nutrient content phosphorous and potassium are widely available on this soil but are not available for plants. Other than that CEC and low base saturation due to the low availability of organic matter. There are no other horizons except epipedonochric, albic or histic (Syafruddin *et al*., 2016). The main limiting nutrients in the soil are insufficient nitrogen and phosphorus. Fertilization with the application of mycorrhizal as bio-fertilizers can rise the potential physical, chemical and biological characteristics of Entisol soil. Mycorrhizae can work completely on poor nutrient soils (marginal) and can support effectively absorb nitrogen and phosphorous that available to plants (Fikrinda *et al*., 2019; Sanchez, 1992).

The prominent characteristics of Entisol are low organic carbon (C-organic) content, low bulk density value, low retention of P and CEC (Hardjowigeno, 2018). Because it contains low organic matter Entisol is very suitable for development AMF (Arbuscular Mycorrhizal Fungi) and potentially as a natural AMF provider (Prasetya, 2011; Pal *et al*., 2013). One effort to increase the absorption of phosphorus and nitrogen in Entisol soils can be done through symbiosis between plants with mycorrhizal fungi. Mycorrhizal fungi have hyphae that can enhance a role in increasing of the N and P uptake by expanding the absorption area of the plant root system, so that it can be utilized to mine P residues that accumulate in the soil (Agustin *et al*., 2010; Syafruddin *et al*., 2020a).

AMF is a potential contributor to plant nutrition and suppression of pathogens in low input farming systems, even though individual species are from AMF varies greatly in functional attributes. Recent studies have suggested that in some farming systems the inoculum of AMF highly recommended for organic farming management. Until now, information about patchouli tolerance to the use of organic fertilizers and mycorrhizal bio-fertilizers on Ultisol and Entisol soils is very limited. For this reason, a study of how organic patchouli cultivation using mycorrhizal bio-fertilizers on Ultisol and Entisol soils is needed. In some of the literature shows that giving mycorrhizal is positively correlated with patchouli alcohol content and patchouli oil content, because mycorrhizal biofertilizers can meet the water needs, N and P uptake needed by patchouli through the range made by hyphae on patchouli roots (Alpana et al, 2014 ; Syafruddin et al, 2020b).

One effort to increase the absorption of phosphorus and other nutrients in Ultisol and Entisol soil can be done through symbiosis between plants with mycorrhizal fungi. Mycorrhizal fungal hyphae present a role in increasing P uptake by expanding the absorption area of the plant root system, so that it can be utilized to mine P residues that accumulate in the soil (Syafruddin *et al*., 2020c; Agustin *et al*., 2010; Nurmasyitah *et al*., 2013). Another problem for some patchouli plant varieties is the perceptivity of these plants to disease attacks, so that mycorrhizae can become bio protectants to development growth and yield of patchouli. Fertilization measures, exclusively with the utilization of mycorrhizal fertilizers can raise the potential physical, chemical and biological effects of Ultisol and Entisol soil. Mycorrhizae work effectively in the poor nutrient soils (marginal) and can cooperate take in phosphorus, nitrogen and potassium effectively, so they are able to absorb by plants. The presence of mycorrhizae for the availability of phosphorus, nitrogen and potassium nutrients in the soil, including Ultisol and Entisol is very necessary (Abdollahi *et al*., 2014; Medina and Azcon, 2014; Barret *et al*., 2011). Based on the description above, it is necessary to examine the effect of soil orders and mycorrhizal bio-fertilizers on growth and yield and quality of Aceh's organic patchouli.

MATERIALS AND METHODS

Scope of Research

This research was conducted from June to December 2019. The first year of research included the mycorrhizal propagation technique as the bio-fertilizers on Ultisol and Entisol soils and the test of the fertilizer on a greenhouse pot scale for patchouli seedlings growth. Then in the second year a large-scale trial will be carried out on farmers' land in the village of Meudheun Aceh Jaya (second year, 2020). Besides doing a thorough review of the quality of Ultisol and Entisol soils both from the physical, chemical and biological properties of the soil.

Materials and tools

Materials and tools used in this study were patchouli varieties Tapak Tuan, topsoil of Ultisol and Entisol, inoculum AMF genus *Glomus mosseae* and *Gigaspora* and mix of both with zeolite rock carrier. Nitrogen (urea), SP-36 (phosphorous) and KCl (potassium) ½ of supported dosage as the base fertilizer, corn seeds, zeolite, pot, analytical scales, fat, sifter, bucket, spray, oven, paint, board, A4 envelope, stereo microscope, gas chromatography (GC), meter, and plastic sack.

Experimental Design

The experimental design used was a factorial randomized block design (RBD) with 3 replications. The first factor to be observed was soil order with Ultisol and Entisol levels. While the genus of mycorrhizal bio-fertilizer results from propagation in the first year of the experiment consisted of 3 levels, i.e. *Glomus mosseae*, *Gigaspora* sp. and mix

Glomus mosseae + Gigaspora sp. The study consisted of 6 treatment combinations with 3 replications so that there were 18 experimental units.

Parameters observed

The parameters in this study were plant height, stem diameter, total of leaves, total of primary branches, plant fresh weight, plant dry weight, mycorrhizal colonization, P uptake, and the resulting patchouli oil content. Colonization of mycorrhizal or degree of colonization AMF in the roots of patchouli plants seen through the Kormanik and Graw coloring method (1982); Syafruddin *et al.* (2010).

STATISTICAL ANALYSIS

Data analyzed by using SPSS statistical software version 25.00 to test plant height, stem diameter, total of leaves, total of primary branches, plant fresh weight, plant dry weight, mycorrhizal colonization, P uptake, and the resulting patchouli oil content. The data obtained were analyzed by analysis of variance and continued with Turkey HSD range test at the level 5 %.

RESULTS AND DISCUSSION

Effect of soil order on patchouli growth and yield

The average values of the parameters of patchouli plants due to the treatment of soil order after being tested with Turkey HSD 0.05 are shown in Table 1.

Table 1. Average of growth, yield, root colonization, P_2O_5 absorption and oil content of patchouli due to soil orders treatment

Parameters	Soil Order		Turkey's HSD test ($p < 0.05$)
	Ultisol	Entisol	
Plant height 90 DAP (cm)	89.33^b	83.68^a	1.19
Stem diameter 90 DAP (cm)	1.33^b	1.20^a	0.11
Number of leaves (leaves)	245.89^b	225.44^a	6.39
Number of branch (branches)	31.11	29.67	-
Fresh weight 90 DAP (g)	417.27	415.09	-
Dry weight 90 DAP (g)	82.25^b	75.89^a	1.88
Mycorrhizal colonization (%)	73.25^b	59.48^a	1.43
P_2O_5 absorption (ppm)	45.78^b	43.78^a	1.40
Oil content (%)	3.46^b	2.66^a	0.07

The numbers followed by the same letters in the same rows differ not significantly at the level 0.05 (Turkey's HSD); DAP = Day after planting

Table 1 showed that plant height and stem diameter of patchouli at the age of 90 DAP were highest in Ultisol soil orders that were significantly different from Entisol soil treatments. Furthermore, for the parameters of the number of leaves, fresh weight 90 DAP, mycorrhizal colonization, P_2O_5 uptake and the highest patchouli oil content were found in the Ultisol soil order which was significantly different from the soil treatment of Entisol. The results of this study indicate that soil order has a very significant effect on production of patchouli. The best growth parameters were found in Ultisol soil orders which can be seen in the parameters of plant height, stem diameter, total of leaves, total of branches, fresh weight and dry fresh weight. It is suspected that Ultisol soil has better physical and chemical properties than Entisol soil, in this case it can be seen from the water retention capacity, texture and soil structure where it is dominated by high clay content. The results of the aligned research have been found by Syafruddin *et al.* (2000) where Ultisol soil orders give better results than Entisol for growth, yield and patchouli oil quality. On average Ultisol provides the best results in Aceh for growth and volatile yield, not only for patchouli, but also for citronella and nutmeg oil. The high clay content in Ultisol gives high yield for patchouli growth, because of its high-water resistance compared to Entisol with sand texture.

According to Syafruddin *et al.* (2000) many factors that cause differences in patchouli oil production are physical and chemical properties, climate or land character such as slope, altitude, rock conditions above the land surface and others. Specially to produce organic patchouli, the emphasis on the chemical properties of the soil, especially soil biology, must receive major attention. Production of patchouli is generally good in the lowlands 200 - 1500 m above sea level. Judging from the height needed by patchouli plants, it is possible to develop them in highland areas dominated by Ultisol soil. In addition, the ultisol is an old and weathered soil that has a higher fertility rate compared to Entisol. Patchouli plants generally increase yields are cultivated more in the highlands with Ultisol dominant soil, because it requires high humidity, compared with coastal lowlands with dominant land Entisol ((Nurmasyitah *et al.*, 2013).

Effect of mycorrhizal bio-fertilizer on patchouli growth and yield

The average values of the parameters of patchouli plants due to the treatment of mycorrhizal bio-fertilizer after being tested with Turkey HSD 0.05 are shown in Table 2.

Table 2. Average of growth, yield, root colonization, P_2O_5 absorption and oil content of patchouli due to mycorrhizal bio-fertilizer

Parameters	Mycorrhizal bio-fertilizer			Turkey's HSD test (p < 0.05)
	Glomus mosseae	*Gigaspora* sp.	*Glomus mosseae + Gigaspora* sp.	
Plant height 90 DAP (cm)	91.45^c	85.28^b	82.78^a	1.19
Stem diameter 90 DAP (cm)	1.43^c	1.13^b	1.23^a	0.11
Number of leaves (leaves)	257.67^c	238.17^b	211.17^a	6.43
Number of branch (branches)	36.00^c	31.33^b	23.83^a	3.64
Fresh weight 90 DAP (g)	469.30^c	401.71^b	377.54^a	6.86
Dry weight 90 DAP (g)	88.94^c	75.86^b	72.41^a	1.89
Mycorrhizal colonization (%)	68.44^c	64.20^b	66.46^a	1.44
P2O5 absorption (ppm)	54.67^c	41.83^b	37.83^a	1.44
Oil content (%)	3.50^c	2.89^b	2.80^a	0.073

The numbers followed by the same letters in the same rows differ not significantly at the level 0.05 (Turkey HSD Test); DAP = Day after planting

Table 2 showed the highest average growth and yields parameters found in mycorrhizal treatment *Glomus mosseae* significantly different from the order of mycorrhizae *Gigaspora* sp. and mix (*Glomus mosseae + Gigaspora* sp.). Mycorrhizal order *Glomus mosseae* has shape spore *sporocarps* with light yellow-brown to brown and spore diameter 195 μM which showed the effectiveness of the absorption of nutrients and water for plants so that the growth and yield of plants is maximum (Syafruddin, 2017; Syafruddin *et al.*, 2016). On the growth parameter, the best order of mycorrhizal bio-fertilizer was *Glomus mosseae,* play a significant role in the absorption of nutrients and water that was not reachable by hair roots. This was also stated by Smith and (Read 1997; Safrianto *et al.* 2015) which states that mycorrhizae are a component of microorganisms that play an active role in helping plants absorb nutrients and water from locations that cannot be reached by root hairs.Then for the best root mycorrhizae colonization found in mycorrhizal bio-fertilizer orders *Glomus mosseae*. It is suspected that this order of *Glomus* mycorrhiza is easy to develop and form many spores compared to other orders of mycorrhizal bio-fertilizer. This is in accordance with research (Safrianto et al 2015) stated the highest growth and yield of chili is found *Glomus mosseae*. The best yield of patchouli is also found in mycorrhizal bio-fertilizer of *Glomus mosseae*. The same thing was obtained by (Syafruddin *et al.* 2016; Langer *et al.* 2010).

Many studies have concluded that mycorrhizal inoculates on patchouli are crucial in increasing patchouli production. This proves that mycorrhizal strains determine nutrient uptake, prevention and drought conditions that are ideal for patchouli growth and yield (Arpana *et al.*, 2008; Syafruddin *et al.*, 2020c), contribute to the absorption of P and N nutrients (Pal et al, 2013), and can act as a bioremediator for polluted land.

Selection of several AMF for symbiotic responses, like *Glomus etunicatum* that was identified as the best mycorrhizal symbiont to increase growth and Phosphorus uptake for patchouli (Arpana *et al.*, 2008; Syafruddin *et al.*, 2020c). The order of mycorrhiza used also largely determines the production of patchouli. This is cause to the mycorrhizal roots ability to absorb nutrients and protect plants from pathogens, drought and other extreme situations (Syafruddin *et al.*, 2020b; Syafruddin *et al.*, 2016; Liu et al., 2014; Chauhan et al., 2011), contributes the absorption of phosphate and nitrogen (Pal *et al.*, 2013; Prasetya, 2011; Musfal, 2010) and produce the hormone such as auxin and giberralin (Zhu *et al.*, 2012) and able to remediate contaminated soil (Langer et al., 2010; Syafruddin *et al*, 2020a; Fikrinda *et al.*, 2019; Barret *et al.*, 2011; Chauhan *et al.*, 2011).

The interaction effect on plant growth, P uptake and quality of patchouli oil

The average value of interaction effect of soil orders and mycorrhizae on plant height at 90 DAP, stem diameter at 90 DAP, number of leaves, number of branches, fresh biomass weight, dry biomass weight, P uptake and oil quality after being tested with Turkey HSD 0.05 are presented in Table 3, 4, 5, 6, 7, 8, 9, and 10 consecutively.
Table 3 shows that the height of patchouli plants at 90 DAPS in Ultisol significantly different from the order of mycorrhiza tested, moreover on the order of Entisol soil with *Glomus mosseae* mycorrhizae significantly different from other orders of mycorrhiza.

Table 3. Average of patchouli plant height age of 90 DAP due to the treatment of soil orders with mycorrhizal bio-fertilizer

Soil Orders	Mycorrhizal bio-fertilizer			Turkey's HSD test (p < 0.05)
	Glomus mosseae	*Gigaspora* sp.	*Glomus mosseae + Gigaspora sp.*	
Ultisol	95.33Cb	90.03Bb	82.63Aa	1.68
Entisol	87.57Ca	80.53Aa	82.93Ba	

Numbers followed by the same letter are not significantly different at the level 0.05 (Turkey's HSD Test). Capital letters are notations in rows, lowercase letters are notations in columns

Table 4 shows that the stem diameter of the 90 DAP in soil order Ultisol was significantly different from that of *Glomus mosseae* mycorrhiza significantly different from other orders of mycorrhiza, additionally in the soil order Entisol with various orders of mycorrhizae showed no significant difference.

Table 4. Average of stem diameter of patchouli plants aged 90 DAT due to the treatment of soil orders with mycorrhizal bio-fertilizer

Soil Orders	Mycorrhizal bio-fertilizer			Turkey's HSD test (p < 0.05)
	Glomus mosseae	*Gigaspora* sp.	*Glomus mosseae + Gigaspora sp.*	
Ultisol	1.67Bb	1.10Aa	1.23Aa	0.16
Entisol	1.20Aa	1.17Ab	1.23Aa	

Numbers followed by the same letter are not significantly different at the level 0.05 (Turkey's HSD test). Capital letters are notations in rows, lowercase letters are notations in columns

Table 5 shows that the number of leaves in soil orders Ultisol and Entisol was significantly different in *Glomus mosseae* mycorrhizae significantly different from other orders of mycorrhiza.

Table 5. Average of number of leaves of patchouli plants due to treatment of soil orders with mycorrhizal bio-fertilizer

Soil orders	Mycorrhizal bio-fertilizer			Turkey's HSD test (p < 0.05)
	Glomus mosseae	*Gigaspora* sp.	*Glomus mosseae + Gigaspora sp.*	
Ultisol	277.33Cb	252.33Bb	208.00Aa	9.04
Entisol	238.00Ca	224.00Ba	214.33Ab	

Numbers followed by the same letter are not significantly different at the level 0.05 (Turkey's HSD test). Capital letters are notations in rows, lowercase letters are notations in columns

Table 6 shows that the number of branches in soil order Ultisol was significantly different in *Glomus mosseae* mycorrhizae from other orders of mycorrhiza. However, the soil order Entisol with mycorrhizae *Glomus mosseae* and *Gigaspora* sp was significantly different with mycorrhiza mixed *Glomus mosseae* + *Gigaspora* sp.

Table 6. Average of number of branches of patchouli plants due to treatment of soil orders with mycorrhizal bio-fertilizer

Soil Orders	Mycorrhizal bio-fertilizer			Turkey HSD test (p <0.05)
	Glomus mosseae	*Gigaspora* sp.	*Glomus mosseae + Gigaspora sp.*	
Ultisol	40.33Cb	31.00Ba	22.00Aa	5.11
Entisol	31.67Ba	31.67Ba	25.67Aa	

The number followed by the same letter is not significantly different at the 0.05 level (Turkey's HSD Test). Capital letters are notations in rows, lowercase letters are notations in columns

Table 7 shows that the fresh weight of the soil order Ultisol and Entisol on *Glomus mosseae* mycorrhizae is significantly different from other orders of mycorrhiza.

Table 7. Average of fresh weight of plant due to treatment of soil orders with mycorrhizal bio-fertilizer

Soil Orders	Mycorrhizal bio-fertilizer			Turkey HSD test (p <0.05)
	Glomus mosseae	*Gigaspora* sp.	*Glomus mosseae + Gigaspora sp.*	
Ultisol	495.30^{Cb}	393.25^{Ba}	363.25^{Aa}	9.64
Entisol	443.29^{Ca}	410.17^{Bb}	391.82^{Ab}	

The number followed by the same letter is not significantly different at the 0.05 level (Turkey's HSD Test). Capital letters are notations in rows, lowercase letters are notations in columns

Table 8 shows that the dry weight in Ultisol and Ultisol soil order in *Glomus mosseae* mycorrhizae is significantly different from other orders of mycorrhiza.

Table 8. Average weight dries of plant due to soil orders treatment with mycorrhizal bio-fertilizer

Soil orders	Mycorrhizal bio-fertilizer			Turkey HSD test (p <0.05)
	Glomus mosseae	*Gigaspora* sp.	*Glomus mosseae + Gigaspora sp.*	
Ultisol	96.47^{Cb}	76.49^{Ba}	73.78^{Aa}	2.65
Entisol	81.41^{Ca}	75.23^{Ba}	71.03^{Aa}	

Numbers followed by the same letter are not significantly different at the 0.05 level (Turkey's HSD Test). Capital letters are notations in rows, lowercase letters are notations in columns

Table 9 shows that P_2O_5 uptake in Ultisol and Entisol soil order in *Glomus mosseae* mycorrhizae is significantly different from other orders of mycorrhiza.

Table 9. Average of P_2O_5 absorption due to treatment of soil orders with mycorrhizal bio-fertilizer

Soil orders	Mycorrhizal bio-fertilizer			Turkey HSD test (p <0.05)
	Glomus mosseae	*Gigaspora sp*	*Glomus mosseae + Gigaspora sp.*	
Ultisol	59.00^{Cb}	40.67^{Ba}	37.67^{Aa}	1.98
Entisol	50.33^{Ca}	43.00^{Bb}	38.00^{Aa}	

The number followed by the same letter is not significantly different at the 0.05 level (Turkey's HSD Test). Capital letters are notations in rows, lowercase letters are notations in columns

Table 10 shows that oil content in soil orders Ultisol and Entisol in *Glomus mosseae* mycorrhizae is significantly different from other orders of mycorrhiza.

Table 10. Average of oil content due to treatment of soil orders with mycorrhizal bio-fertilizer

Soil orders	Mycorrhizal bio-fertilizer			Turkey HSD test (p <0.05)
	Glomus mosseae	*Gigaspora sp*	*Glomus mosseae + Gigaspora sp.*	
Ultisol	3.78^{Cb}	3.49^{Bb}	3.12^{Ab}	0.10
Entisol	3.22^{Ca}	2.29^{Aa}	2.49^{Ba}	

The number followed by the same letter is not significantly different at the 0.05 level (Turkey HSD Test). Capital letters are notations in rows, lowercase letters are notations in columns

Based on the result on some parameters of the interaction effect between soil orders and mycorrhizae the use of Ultisol and *Glomus mosseae* mycorrhizae orders tend to give the best results. This was consistent with the previous research by (Syafruddin *et al.* 2000) that Ultisol provides the best growth, yields and oil content quality for patchouli. Furthermore, (Syafruddin *et al.* 2019b) also reported that the use of *Glomus mosseae* mycorrhizal orders tended to increase the prodsuction of patchouli plants. The use of mycorrhiza in marginal soils such as Ultisol can increase the absorption of P and other nutrients and it was in line with the research conducted by (Nurmasyitah *et al* 2013; Syafruddin 2017). Additionally, (Arfana *et al.* 2014) showed that the best mycorrhiza order for accumulating production, content oil of patchouli was genus of *Glomus etunicatum*.

The presence of mycorrhizae can also increase the activity of soil microorganisms which can directly increase the absorption of nutrients needed by patchouli, especially N and P and several other micro elements. Besides that, the presence of rhizobacteria with mycorrhizae can increase plant growth through the production of substances needed by plants in the rhizosphere area such as amino acids, root exudates, and other elements released and can prevent pathogen attack (Suresh & Bagyaraj, 2002; Dey *et al.*,

2005). Therefore, this research was conducted to know more about the interaction between mycorrhizal and its effect on the growth and yield of organic patchouli.
(Syafruddin 2017) noted mycorrhizal biological fertilizer can improve the chemical properties of Ultisol and Entisol soils because it can help the process of absorption of P and N and other nutrients. The use of biological fertilizers in Ultisol and Entisol soils affects the chemical properties of the soil. In addition, many treatments that were tried on both types of soil with different textures affect the growth and yield of patchouli. Ultisol soil with the texture of dusty clay loam increases growth and patchouli yield better than Entisol soil which has sandy texture on various types of mycorrhizal biofertilizers that are tested.

CONCLUSION

Soil treatment significantly affected plant height at 90 DAP, stem diameter at 90 DAP, number of leaves, dry weights, P_2O_5 absorption and oil content, but have not significant effect on the number of branches and fresh weights. The best growth and yields on the treatment of soil orders were found in Ultisol. Mycorrhizal treatment significantly affected plant height at 90 DAP, stem diameter at 90 DAP, number of leaves, number of branches, fresh weight, dry weight, P_2O_5 absorption, root colonization and oil content. The best growth and yield were found in *Glomus mosseae* of mycorrhizal bio-fertilizer. There was a very significant interaction between soil orders and mycorrhizal bio-fertilizer on plant height at 90 DAP, stem diameter at 90 DAP, number of leaves, number of branches, fresh weight, dry weight, P_2O_5 absorption and oil content, but have not significant effect on mycorrhizal colonization. The best growth and yield were found in a combination of Ultisol and *Glomus mosseae*.

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