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Utilization of Biochar and Mycorrhiza to Increase the Absorption of Elemental Nutrients of Cayenne Chili (*Capsicum frutescens* L.)

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ABSTRACT

This study aimed to study the relationship between biochar as a soil enhancer and mycorrhizal dose on the nutrient uptake of cayenne plants. The experiment was done in a split-plot design with a randomized block design. The main plot was a vesicular-arbuscular mycorrhiza or VAM (m) with three levels: 10 g plant^{-1} mycorrhiza (m_1), 15 g plant^{-1} mycorrhiza (m_2), and 20 g plant^{-1} mycorrhiza (m_3). The subplot was a biochar composition as soil enhancer (b) with three levels: 50% rice husk biochar + 25% soil + 25% sand (b_1), 25% wood biochar + 25% soil + 50% sand (b_2), and 50% wood biochar + 25% soil + 25% rice husk biochar (b_3). Each level of the VAM dose factor was combined with each level of the biochar composition; each combination was repeated three times, accounting for 27 experimental units. The phosphorus uptake, potassium uptake, and fresh root weight positively correlated to the percentage of mycorrhizal infections. The combination treatment of 20 g plant^{-1} mycorrhiza and 50% rice husk biochar + 25% soil + 25% sand; 15 g plant^{-1} mycorrhiza with 50% wood biochar + 25% soil + 25% rice husk biochar; and 20 g plant^{-1} mycorrhiza are the best planting medium.

Keywords: Mycorrhiza, nutrient, planting media, soil enhancers

INTRODUCTION

The *Capsicum frutescens* L (cayenne) plant has a high economic value due to extensive utilization in the food industry or consumption in small households. This high food demand is due to an increased population. When the agricultural sector has not been able to meet all demands, so, in the future, expansion of the area and intensification of agriculture is necessary (Mulyani and Agus 2017). To overcome this problem, utilizing narrow land requires alternative technology, one of which is planting cayenne in a pot to facilitate growth and yield observation.

The composition of the growth media determines plant growth. It should meet the requirements of proper drainage, nutrient retention, and water-resistant to washing by utilizing the availability of local materials (Kazemi and Mohorko 2017). Soil enhancers can be used as an alternative planting medium to improve the soil's physical, biological, and chemical properties. According to Dariah *et al.* (2015), soil ameliorants can be divided into three categories based on forming compounds, namely organic, biological, and mineral soil ameliorants. Biochar is widely considered organic soil ameliorant as a growth medium. Biochar application to the soil can increase soil carbon content, water retention, and nutrients in the soil, increase the availability of macronutrient cations, increase soil fertility, and improve the quality of degraded soils (Atkinson *et al.* 2010).

Biochar as a soil enhancer is aimed to increase nutrient availability, cation exchange capacity, nutrient retention, and water (Glaser *et al.* 2002). Biochar has been potentially used in agriculture, energy sector, environmental purpose, replacement of aggregates in the growing media industry (Ioannidou and Zabaniotou 2007; Nemati *et al.* 2015). Biochar types are mainly wood-based materials, stone, manure, and leaves (Chrysargyris *et al*. 2020; Dorais *et al*. 2016). The temperature

during the process of biochar pyrolysis significantly influences the increase in carbon content (773 K), cation exchange capacity, and pH of the produced biochar (van Zwieten *et al.* 2010; Surdianto *et al.* 2015). In addition, biochar has many pores, which results in increased water retention and nutrient availability and decreased nutrient leaching rate (11% reduction), and soil erosion (Oguntunde *et al.* 2008; Nemati *et al.* 2015). A previous study was investigated the potential use of biochar as effective solid media material in the hydroponic system (Karakas *et al*. 2017; Chrysargyris *et al*. 2020; Dorais *et al*. 2016).

Biochar provides a suitable habitat for various soil microbes (Rondon *et al.* 2007). The shape of the biochar structure, such as pore volume and the surface area, protect beneficial soil microorganisms such as mycorrhiza and bacteria (Atkinson *et al.* 2010). Inoculation with Vesicular-Arbuscular Mycorrhiza (VAM) can increase various nutrient uptake, nitrogen fixation ability, and growth of green beans (Xiao *et al.* 2010), as well as significantly increase the absorption of phosphorus (P), sulfur (S), magnesium (Mg), and zinc (Zn) and soybean crop yields (Karaca *et al.* 2013).

According to Adelman and Morton (1986), a mycorrhizal infection can enhance plant growth and its ability to utilize nutrients present in the soil, especially the P, Ca, N, Cu, Mn, K, and Mg elements. VAM is associated with most terrestrial plants, providing nutrition and protection from environmental stresses (Aggarwal *et al.* 2011). Mycorrhizal fungi increase nutrient uptake of P and Zn in plant tissue (Lehmann *et al.* 2014), increase nutrient uptake of N, P, K in chili plants (Carballar-Hernández *et al.* 2018). VAM inoculation can increase rhizosphere soil aggregates and host plant growth compared with controls (Zhang *et al.* 2019). The use of biofertilizers requires an appropriate dose of fertilizer application so that the results obtained can meet expectations (Simanjuntak *et al.* 2017). Mycorrhiza requires suitable biochar composition as a soil enhancer to increase the density of its spore population at the correct dose.

The purpose of the research was to study the effect of biochar composition as a growth medium and mycorrhizal dose on the nutrient uptake of cayenne plants.

MATERIALS AND METHODS

Experimental Design

The laboratory experiment was conducted in Damai Village, Maros District, South Sulawesi, in February-July 2018. This study used a split-plot design with a randomized block design. The main plot was VAM (m) with three levels: 10 g plant^{-1} mycorrhiza (m_1), 15 g plant^{-1} mycorrhiza (m_2), and 20 g plant^{-1} mycorrhiza (m_3). The subplot is biochar composition as soil enhancer (b) with three levels: 50% rice husk biochar + 25% soil + 25% sand (b_1), 25% wood biochar + 25% soil + 50% sand (b_2), and 50% wood biochar + 25% soil + 25% rice husk biochar (b_3). Each VAM dose and biochar factor level was combined, so there are nine combinations of treatment. Each level combination treatment was repeated three times, accounting for 27 experimental units (Figure 1).

Vesicular-arbuscular mycorrhiza (Super Mycorrhiza produced by CV. Abadi Sejahtera, Indonesia) is a type of *Glomus* sp. and *Gigaspora* sp (3460 spores per 100 g zeolite). All treatments were done using podzolic soil, zeolite soil as a carrier, and a manually watering system. Nitrogen, phosphorus, and potassium (NPK) fertilizer (16:16:16) in a concentration equal to 320 mg N kg soil^{-1} was added to the soil at two weeks after planting, early flowering phase, and two weeks after flowering (Horel *et al*. 2019).

Biochar Treatment

Chaff Charcoal

Fire-resistant zinc/aluminum cylinder-sized 20 liters were needed. First, the top of the cylinder was discarded. Then, in the bottom, a circular hole was made of 10 cm in diameter. Then holes were made with nails on the cylinder wall (diameter approximately 0.5 cm) with a distance between holes about 2–3 cm. After that, a 1 cm long zinc pipe with a 10 cm diameter was glued, which functions as a chimney placed perpendicular to the middle of the circle. Finally, the bottom part of the cylinder was covered with a dial plate zinc before burning. Fires were made using firewood and cylinder-sized dry leaves that had been made before.

Then cover the fire with a cylinder that has been given the chimney earlier. Next, fill a cylindrical combustion chamber in which it was already aflame with rice husk. The hoarding was carried up to a 1-meter height with the top of a pile of chimneys poking out. After 20–30 minutes, the brown husk down was raised when the top of the rice husk was blackened. After all, the husk turns black, flush with water until it was evenly distributed to stop the burning process. After watering, and the temperature decreases, the husk charcoal was dried (Surdianto *et al.* 2015).

Wood charcoal was obtained from the local market and broken into small sizes. Then it was

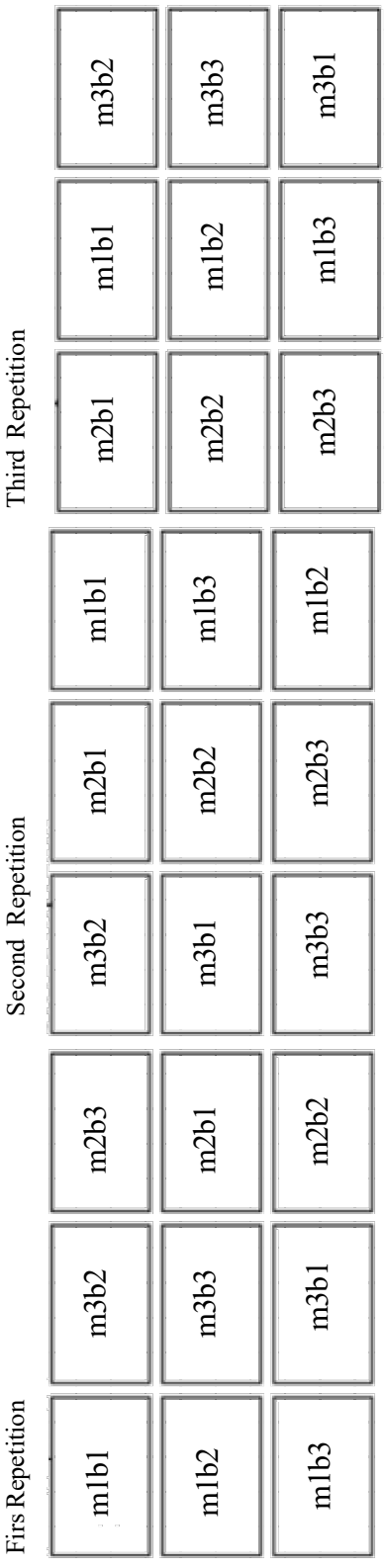

Figure 1. Illustrations of the experimental setup.

sifted to separate gravel and other impurities. The soil from Abbakae Hamlet, Damai Village, Tanralili District, Maros Regency, South Sulawesi, was air-dried for one week and then sifted to separate gravel and other impurities and weighed 1.625 kg polybag^{-1}. Planting media was prepared by mixing husk charcoal, wood charcoal, soil, and sand according to the treatment and put into a 30 × 40 cm polybag with a media weight (soil + biochar) of 6.5 kg polybag^{-1}.

VAM Inoculation

The material used in this research is VAM (Super Mycorrhiza, CV Abadi Sejahtera, Indonesia), cayenne chili seeds (var. Dewata f1). The seeds were soaked in warm water for 1 hour and spread on the growth media for 12 days before transplantation. The planting hole was of 3 to 5 cm depth on the planting medium that has been prepared. Mycorrhiza was inoculated when transplanting by giving them directly to the planting hole according to the treatment dose, then the seeds were placed and then covered again with the planting media.

Plant Parameters

The plant parameters observed included root and shoot dry weight (g plant^{-1}) and N, P, and K content of plant tissue (%). Shoots (taken from the root base to the shoot without chili) and root (taken from the base of the root to the tip of the root) wet weight (g tan^{-1}) were measured at harvest. Dried root weight (g) and dried canopy weight (g) were observed after the roots and canopy of plants were dried in an oven at 600 °C for 2 × 24 hours (Soil Research Center 2009). Plant tissue was analyzed 73 days after planting, which included N, P, and K uptake. N analysis was performed using the Kjeldahl method by the wet ashing with H_2SO_4 (Soil Research Center 2009). The P and K analyses were extracted by the wet ashing method using HNO_3 and $HClO_4$ (Soil Research Institute, 2009). Furthermore, the levels of nutrients were measured by UV–VIS spectrophotometer, flame photometer, and atomic absorption spectrophotometer (Indonesian Soil Research Center 2009).

Calculation of VAM Infection and Its Population in the Medium

The root infections were analyzed by the staining method, according to Kormanik et al. (1980). First, the roots were soaked in 10% KOH solution for 24 hours until the roots appeared white or clear yellow. Then, the roots were rinsed and soaked in 10% H_2O_2 for several minutes, followed by a 2% HCl solution for 24 hours. Next, the roots were soaked in a staining solution until the roots turned bluish red for 24 hours. Then, the roots were soaked with 250 ml staining solution for 24 hours, which contained 100 ml glycerin + 100 ml lactic acid + 50 ml distilled water.

Stained roots were observed by cutting for 1 cm. Then, the roots were arranged on top of the preparation and covered with a glass cover. Ten root pieces of each preparation were observed. The presence of vesicles detected root infections, arbuscules, hyphae, or spores that infect the roots and then documented by Nikon Eclipse 80i camera microscope (M = 40× - 1000×). The calculation of root infection uses the following formula (Equation 1).

$$\%IR = \left(\frac{IR}{T_{RS}}\right) \times 100\% \quad (1)$$

Where %IR: percentage of an infected root; IR: number of an infected root; T_{RS}: total root samples.

Soil spore density was calculated using the wet sieve method (An *et al.* 1990). Fifty grams of rhizosphere soil samples from each pot were suspended independently in 250 ml of water, and the suspension was stirred and filtered. AM mold spores were collected on a 50 mm sieve and then transferred to a 9 cm Petri dish for counting under a microscope dissecting Olympus Sz-51 (M= 0.8 - 4×).

Statistical Analysis

Data were statistically analyzed based on analysis of variance (ANOVA) at a 5% level. Then, the mean value difference was analyzed using the least significant difference test (LSD).

RESULTS AND DISCUSSION

Significance of Mycorrhizal and Biochar Application Toward Plant Growth and Development

Table 1 presents the F_{-count} for ANOVA of several observational parameters. It shows whether it is statistically different from the mycorrhizal, biochar, and combination of mycorrhizal and biochar effects toward the canopy and dried fresh root weight parameters, dried canopy and root weight, and N, P, K absorption, mycorrhizal population, and percentage of mycorrhizal infections.

Fresh Canopy and Roots Weight

Fresh Canopy Weight

Mycorrhiza, biochar, and combination of mycorrhiza and biochar treatments have a significant effect on fresh canopy weight (Table 1). However, it was not significantly different from mycorrhiza 10 g plant^{-1} and wood charcoal biochar 50%+soil 25%+biochar charcoal husk 25% (m_1b_3), mycorrhiza 15 g plant^{-1} and wood charcoal biochar 50%+soil 25%+biochar charcoal husk 25% (m_2b_3) to the fresh cayenne canopy weight (Table 2). The biochar has a function to retain moisture so that it helps plants in times of lack of water and nutrient retention in the soil so that nutrients present in the soil are avoided from the washing process and will ultimately affect the increase in plant growth (Lehmann *et al.* 2003). In addition, biochar is good for increasing C, N, P, and soil pH (Chan *et al.*

Table 1. Effect the mycorrhiza, biochar, and combination of mycorrhiza and biochar treatments on observed parameters.

Parameter	$F_{Account}$			F-Table	
	The main plot (mycorrhiza)	Subplot (biochar)	Combination PU x AP (mycorrhiza x Biochar)	0.05	0.01
Fresh canopy weight	27.554**	22.393**	18.052**	(m) 6.944	18.000
Fresh roots weight	10.235*	0.449 *sn*	0.596 *sn*	(b)3.885	6.927
Dried canopy weight	1.846 *sn*	0.155 *sn*	1.991 *sn*	(m×b)3.259	5.412
Dried roots weight	0.874 *sn*	0.038 *sn*	2.800 *sn*		
Nitrogen uptake	27.550**	1.302 *sn*	1.466 *sn*		
Phosphor uptake	1.658 *sn*	2.300 *sn*	3.399*		
Potassium uptake	2.146 *sn*	6.042*	3.117 *sn*		
Mycorrhizal population	11.049*	34.349**	16.183**		
Infection percentage of Mycorrhiza	213.345**	0.964*	40.504**		

Note: ns = non-significant; * = significant; ** = highly significant

Table 2. The mean value of fresh canopy weight (g) on the combination of mycorrhiza and biochar applied to cayenne chili.

Mycorrhiza	Biochar			NPLSD(b) 1.611
	b1	b2	b3	
m1	21.138^{b}_{y}	23.958^{a}_{x}	25.402^{a}_{x}	
m2	19.543^{b}_{y}	24.742^{a}_{x}	25.352^{a}_{x}	
m3	26.805^{a}_{x}	25.048^{a}_{y}	24.932^{a}_{y}	
NPLSD(m)	1.938			

Note: Values followed by the same letters (a and b) in the columns and (x, y, and z) in the same rows means not significant. LSD α = 0.05. 50% husk biochar + 25% soil + 25% sand (b1), 25% wood biochar + 25% soil + 50% sand (b2), and 50% wood charcoal biochar + 25% soil + 25% charcoal husk biochar (b3), 10 g plant^{-1} mycorrhiza (m1), 15 g plant^{-1} mycorrhiza (m2), and 20 g plant^{-1} mycorrhiza (m3).

2008). Inoculation with mycorrhiza has a more significant effect than biochar, whereas the combination of mycorrhiza and biochar has the most potent effect (Liu *et al*. 2018).

Fresh Roots Weight

Table 1 shows that the F_{ount} of mycorrhizal treatment has a significant effect, whereas the biochar treatment and the combination of mycorrhiza and biochar have no significant effect on the cayenne, fresh weight. The 20 g was not significantly different from the 15 g mycorrhizal dose, but it was significantly different from the 10 g mycorrhizal dose (Figure 2). According to the study by Echave *et al.* (2005), mycorrhiza-infected plant roots can increase the fresh weight of canopy and plant roots. Therefore, mycorrhiza plays a vital role in increasing the growth of crops, horticulture, and forest plants (Wubet *et al.* 2003).

Canopy dan Root Dry Weight

Mycorrhizal treatment, biochar composition, and the combination did not significantly affect cayenne's canopy and dry root weight (Table 1). Therefore, it is suspected that the role of biochar is not helpful due to the slow decomposition process.

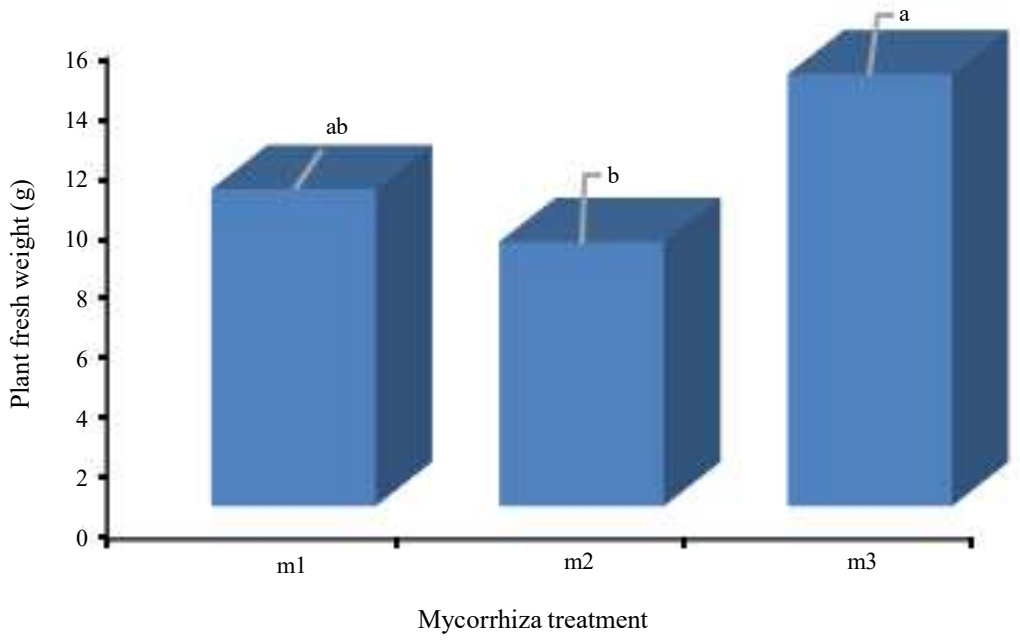

Figure 2. Effect of Mychorriza treatment on plant fresh weight of cayenne plants (m1: 10 g plant^{-1} mycorrhiza; m2: 15 g plant^{-1} mycorrhiza; and m3: 20 g plant^{-1} mycorrhiza).

According to Schnell *et al.* (2012), there is no difference in the increase of sourgum biomass with biochar treatment due to the slow recovery of nutrients from biochar. Jaya *et al.* (2018) also reported that the treatment of biochar types and N doses is not significantly affected by dry crop stover weight because biochar in the soil has not been well decomposed to affect nutrient release on plant growth vegetative phase.

Nitrogen, Phosphorus, Potassium Uptake of Cayenne Plant

Nitrogen Uptake

Based on the ANOVA results, mycorrhizal treatment was significantly affected, while the composition of biochar and its combination did not significantly affect the nitrogen uptake of cayenne plants (Table 1). Application 20 g plant^{-1} mycorrhiza (m_3) was not different from 15 g plant^{-1} mycorrhiza (m_2), but it was different from 10 g plant^{-1} mycorrhiza (m_1) to Nitrogen uptake of cayenne plants (Figure 3). Mycorrhizal inoculation increases the concentration of inorganic nutrients N, P, and K and membrane stability that affects the growth and production of chili (Selvakumar and Thamizhiniyan 2011). Mycorrhiza increases nutrient uptake, especially P, N, and Zn (Sharma *et al.* 2014). The combination of biochar and mycorrhiza positively affects AM mushroom abundance and root colonization (Hu *et al.* 2014).

Amendola *et al.* (2017) also reported that the application of biochar in soils improves soil characteristics in terms of available water, organic carbon, and nitrogen, and a significant increase in biomass of root hair. Biochar application can increase soil moisture and pH, thereby stimulating N mineralization and nitrification, which causes plant uptake increases. Biochar increases the inorganic N required for plant assimilation by increasing retention and reducing the effects of N leaching (Nguyen *et al.* 2017). Biochar reduces N leaching (NH_4^+), increasing nitrogen retention so N content in the soil will be high (Li *et al.* 2019).

Phosphorous Uptake

The combination of m_2b_3 treatment has a P absorption value of 0.123% and is not different from the treatment of m_2b_1, m_1b_2, m_3b_3, but different from m_1b_1, m_1b_3, m_2b_2, m_3b_1, m_3b_2 to phosphorus uptake in cayenne plants. The m_2b_3 treatment was the best (Table 3). According to Schnell *et al.* (2012), also reported that biochar, which is used as soil ameliorant material, provides nutrients for N, P, and K. The utilization of biochar and mycorrhiza increases the availability of soil P, expanding the area of root uptake to water associated with external hyphae (Mickan *et al.* 2016). Mycorrhizal inoculation is effective in increasing plant P uptake (Selvakumar *et al.* 2018). The application of biochar to the soil can increase soil C-content, water retention, and nutrients in the soil, increase the availability of significant cations and P, increase soil fertility, and restore degraded soil quality (Karer *et al.* 2013). Biochar increases CEC, retains N and P nutrients, and reduces nutrient leaching (Hale *et al.* 2013).

Mycorrhizal inoculation applied in the field significantly increases yields compared to plants that are not inoculated. Mycorrhizal inoculation also increases P, Z, and Cu absorption by plants (Ortaº 2019). Mycorrhiza invades plant roots to extract carbohydrates; on the other hand, mycorrhiza assists plants in the P absorption, similar to nodule-forming bacteria that provide nitrogen to legumes (Parnes 2013). Significant increase in P uptake and yield of

Table 3. The mean value of Phosphor uptake (%) of cayenne chili plants applied by biochar combination (α=0.05).

Mycorrhiza (m)	Biochar (b)			NPLSD(b)
	b1	b2	b3	0.007
m1	0.096^{b}_{z}	0.120^{a}_{x}	0.111^{b}_{y}	
m2	0.120^{a}_{x}	0.102^{b}_{y}	0.123^{a}_{x}	
m3	0.102^{b}_{y}	0.111^{ab}_{x}	0.117^{ab}_{x}	
NPLSD (m)	0.010			

Note: Values followed by the same letters (a and b) in the columns and (x, y, and z) in the same rows means not significant. LSD α = 0.05. 50% husk biochar + 25% soil + 25% sand (b1), 25% wood biochar + 25% soil + 50% sand (b2), and 50% wood charcoal biochar + 25% soil + 25% charcoal husk biochar (b3), 10 g plant^{-1} mycorrhiza (m1), 15 g plant^{-1} mycorrhiza (m2), and 20 g plant^{-1} mycorrhiza (m3).

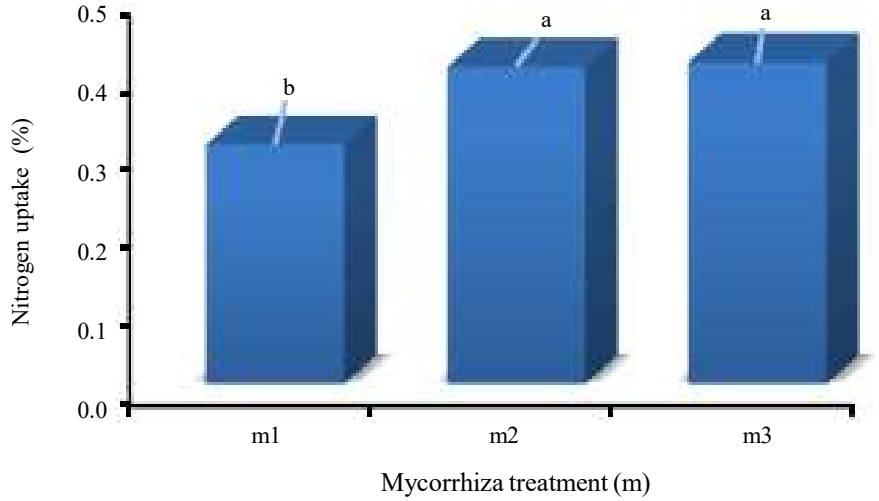

Figure 3. Effect of Mycorrhiza treatment on Nitrogen uptake (%) of the cayenne plant (m1: 10 g plant-1 mycorrhiza; m2: 15 g plant^{-1} mycorrhiza; and m3: 20 g plant^{-1} mycorrhiza).

soybean plants inoculated with *G. mosseae* (Thioub *et al.* 2019).

Potassium Uptake

Based on ANOVA, the biochar treatment was significantly affected, while mycorrhizal treatment and the combination of mycorrhiza and biochar did not significantly affect the Potassium uptake of cayenne plants (Table 1). A b_3 treatment is significantly different from b_2 concerning potassium uptake (Figure 4).

The quality of biochar depends on the manufacturing process and is influenced by temperature, whereas the nutrient content of biochar depends on the raw material of biochar (Gaskin *et al*. 2008). Biochar applications with doses higher than 50 tons ha^{-1} can improve the soil chemical properties, such as increasing pH, organic carbon, Na, K, Ca, P, cation exchange capacity, but decreasing Al exchange rate; improve physical soil conditions, such as increased water holding capacity, soil aggregation binding (Chan *et al.* 2007). Rondon *et al.* (2007) reported that using biochar for the red bean plant (*Phaseolus vulgaris* L.) significantly reduced Fe and Al concentrations and significantly increased P, K, Ca, Mg, and B. Also, the concentrations of S, Zn, Cu, and Mn did not change. Biochar application significantly increased water retention and nutrients N, P, K, Mg, Ca, Mn, Cr, Pb, B, and decreased Na, Cu, Ni, and Cd in corn (Glaser *et al.* 2015).

Mycorrhizal Population and Mycorrhizal Infection Percentage

Mycorrhizal Population

The m_3b_1 treatment was not significantly different from m_3b_3, and it was significantly different from the m_3b_2, m_2b_1, and m_1b_1 treatments (Table

Table 4. The mean value of mycorrhiza population (per 100 g growth media) on the application of mycorrhiza and biochar combination to cayenne chili plant.

Mycorrhiza (m)	Mean value of mycorrhiza population per 100 g medium			NPLSD (b) 4.378
	Biochar (b)			
	b1	b2	b3	
m1	10^{c}_{y}	7^{b}_{z}	17^{b}_{x}	
m2	17^{b}_{x}	18^{a}_{x}	7^{c}_{y}	
m3	25^{a}_{x}	18^{a}_{y}	25^{a}_{x}	
NPLSD (m)	6.645			

Note: Values followed by the same letters (a and b) in the columns and (x, y, and z) in the same rows means not significant. LSD α = 0.05. 50% husk biochar + 25% soil + 25% sand (b1), 25% wood biochar + 25% soil + 50% sand (b2), and 50% wood charcoal biochar + 25% soil + 25% charcoal husk biochar (b3), 10 g plant^{-1} mycorrhiza (m1), 15 g plant^{-1} mycorrhiza (m2), and 20 g plant^{-1} mycorrhiza (m3).

Table 5. Effect of mycorrhiza and biochar combination on the mycorrhizal infection (%) of cayenne chili plant.

Mycorrhiza (m)	The mean value of mycorrhizal infection (%)			NPLSD (b) 5.229
	Biochar (b)			
	b 1	b2	b3	
m1	1.67^{b}_{y}	25.00^{a}_{x}	5.00^{c}_{y}	
m2	5.00^{b}_{y}	3.33^{b}_{y}	13.33^{b}_{x}	
m3	30.00^{a}_{x}	8.33^{b}_{z}	23.33^{a}_{y}	
NPLSD (m)	5.907			

Note: values followed by the same letters (a and b) in the columns and (x, y, and z) in the same rows means not significant. LSD α = 0.05. 50% husk biochar + 25% soil + 25% sand (b1), 25% wood biochar + 25% soil + 50% sand (b2), and 50% wood charcoal biochar + 25% soil + 25% charcoal husk biochar (b3), 10 g plant^{-1} mycorrhiza (m1), 15 g plant^{-1} mycorrhiza (m2), and 20 g plant^{-1} mycorrhiza (m3).

4). Biochars - complex minerals can increase mycorrhizal colonization, plant growth, and wheat nutrient uptake, especially N, P, K, S, and Zn (Blackwell *et al.* 2015). Thus, the addition of biochar has implications for increasing biomass, activity, and composition of soil microorganisms to improve soil quality (Lehmann *et al.* 2011).

Mycorrhizal Infection

The treatment of m_3b_1 was not different from m_3b_2, but it was different from the treatment of m_1b_1 and m_1b_2, m_1b_3, m_2b_1, m_2b_2, m_2b_3, m_3b_2 to the average percentage of mycorrhizal infections in the roots of cayenne plants (Table 5). According to Liu *et al.* (2018), biochar with AM inoculants significantly increased fungal populations compared to controls. Thus, the application of biochar in water stress environments provides environmental conditions that support mycorrhizal development, increasing mycorrhizal colonization, P uptake, and water absorption activity concerning extraradical mycelium (Mickan *et al.* 2016).

Symbiotic associations between fungi and plants (host) form complex interwoven interactions that allow the flow of nutrients, increase the surface area of nutrient uptake of host plants, while the extraradical mycelium (hypha that connects roots to the soil) of the fungus serves as transportation of carbon and other nutrients into the spores (Finlay 2008). Mycorrhizal fungi increase N, P of their host plants while fungi obtain carbon compounds from photosynthesis (Wang *et al.* 2017). The results of staining the roots of cayenne plants which were then observed with microscope Olympus compound cx-

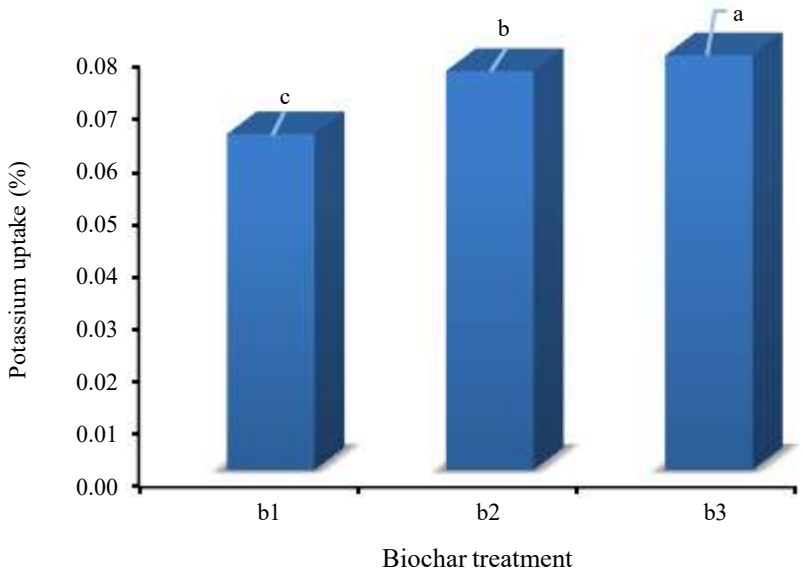

Figure 4. Effect of biochar treatment on the potassium uptake (%) of the cayenne plant.

Table 6. A correlation between nitrogen, phosphor, and potassium uptake (%), fresh canopy weight, fresh roots weight, dried canopy weight, dry roots weight (g), mycorrhiza population (mycorrhiza per 100 g growth media) (X) and the mycorrhizal infection percentage (%) (Y).

No.	Parameters	Regression formula	r
1.	Mean of Nitrogen uptake	$y1 = -0.0001x^2 + 0.0043x + 0{,}1045$	0.375 tn
2.	Mean of Phosphor uptake	$y2 = -3E\text{-}05x^2 + 0.0011x + 0.032$	0.735$*$
3.	Mean of Potassium uptake	$y3 = -5E\text{-}05x^2 + 0.0015x + 0.0181$	0.876$**$
4.	Mean of Fresh canopy weight	$y = -0.0041x^2 + 0.2388x + 22.149$	0.528 tn
5.	Mean of Fresh roots weight	$y = -0.0001x^2 + 0.0759x + 2.8083$	0.828$**$
6.	Mean of Dried canopy weight	$y = 0.3791\ln(x) + 5.0222$	0.337 tn
7.	Mean of Dried roots weight	$y = 0.0401\ln(x) + 0.7656$	0.353 tn
8.	Mycorrhizal population	$y = 0.0305x^2 - 0.7672x + 17.748$	0.404 tn

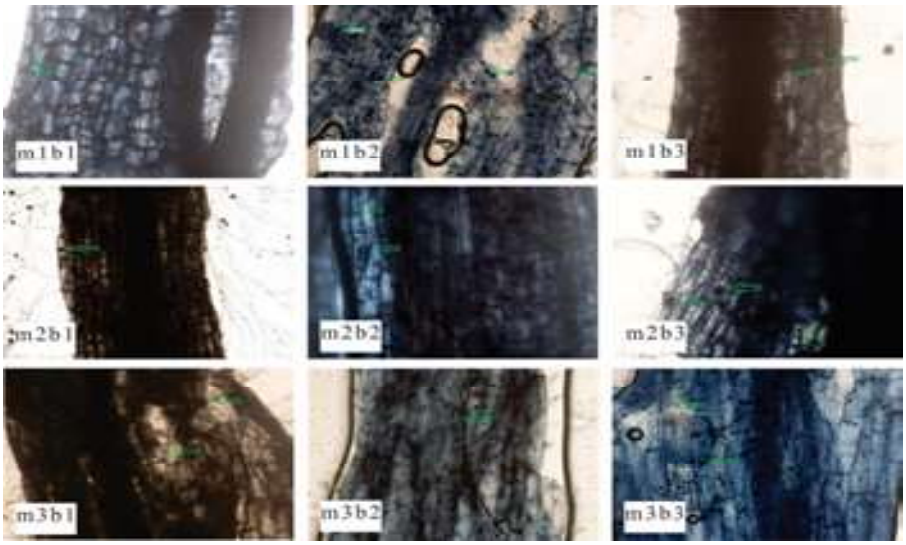

Figure 5. External hyphae (H), vesicular (V), and arbuscules (A) of the treatments (M = 20×). (m1: 10 g plant^{-1} mycorrhiza; m2: 15 g plant^{-1} mycorrhiza; and m3: 20 g plant^{-1} mycorrhiza; b1: 50% husk biochar + 25% soil + 25% sand, b2: 25% wood biochar + 25% soil + 50% sand, and b3: 50% wood charcoal biochar + 25% soil + 25% charcoal husk biochar).

31 (magnification: 40x – 1000x) showing the mycorrhizal fungal (CMA) structure in the form of hyphae (H), arbuscular (A), and vesicles (V) in mycorrhizal treatment and biochar Figure 5.

The correlation values of P uptake, K uptake, and fresh root weights were 0.735, 0.876, and 0.828, respectively, indicating a positive and significant relationship between P and K uptake with the percentage of mycorrhizal infections (Table 6). The coefficient of determination of phosphorus uptake $r^2 = 0.5404$ (Figure 6). It means that phosphorus absorption in the 54.04% cayenne plant is determined by the percentage of mycorrhizal infections, whereas other factors determine the remaining 45.96%. Likewise, potassium absorption with a coefficient of determination $r^2 = 0.7671$ means that the percentage of mycorrhizal infections determines the potassium absorption in chili plants is 76.71%, and the remaining 23.29% is determined by other factors (Figure 5). There is a close positive correlation between dry canopy weight, seed weight, and AMF colonization to N and P uptake in soybean canopy tissue (Meghvansi *et al.* 2008). Also, in line with the study (Thioub *et al.* 2019), the effect of mycorrhizal inoculation was significantly positive ($P < 0.001$, $R2 = 0.6389$) with total P uptake of soybeans.

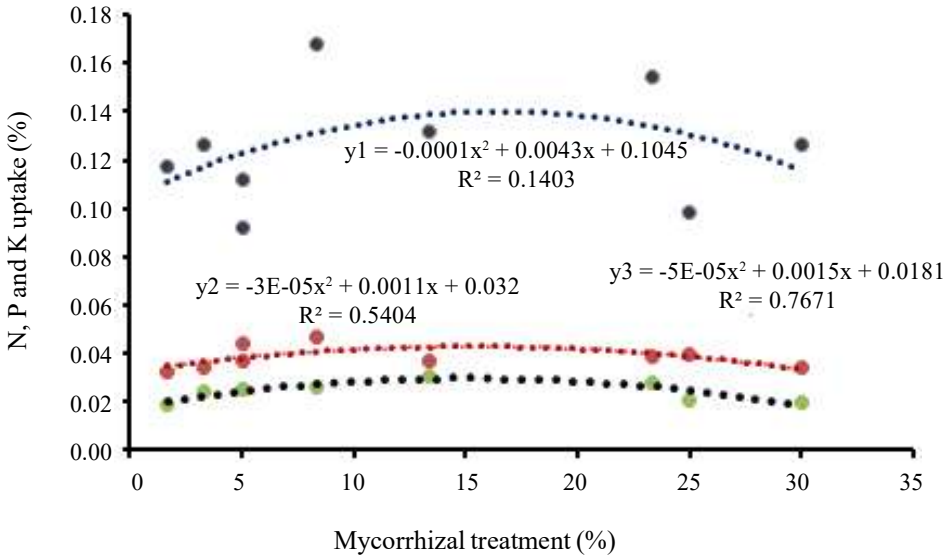

Figure 6 . Effect mychorrhizal infection on N, P, and K uptake of the cayenne plant. ● Nitrigen uptake, ● Phosphorus uptake, ● Potassium uptake.

CONCLUSIONS

Combining 20 g plant^{-1} mycorrhiza and 50% rice husk biochar + 25% soil + 25% sand (m_3b_1) is the best dose for fresh canopy weight and mycorrhiza spore density. Based on N uptake, the best mycorrhizal treatment was found in 15 g plant^{-1} with 50% wood biochar + 25% soil + 25% rice husk biochar. The correlation value, phosphorus uptake, potassium uptake, and fresh root weight have a positive and significant relationship with the percentage of mycorrhizal infections. Therefore, combined mycorrhizal treatment of 20 g plant^{-1} and composition of 50% husk biochar + 25% soil + 25% sand, 15 g mycorrhizal dose treatment with 50% wood biochar + 25% soil + 25% rice husk biochar), and 20 g plant^{-1} mycorrhiza are the best treatment as a plant growth medium. For further research, a combination of biochar and mycorrhiza requires the application to field plants to further observe the consistency of the yields results. The application of mycorrhizal inoculation, especially in chili plants, in further research is better applied at the seedling phase to make it more effective to use as inoculants.

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