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THE EFFECT OF MYCORRHIZAL BIOFERTILIZER AND RICE HUSK BIOCHAR ON THE GROWTH AND YIELD OF RED CHILI (*Capsicum Annum* L.) ON ULTISOL SOILS

Sri Nanda Sofiana[1], Syafruddin[2], Hartati Oktarina[3]
[1]*Department of Graduate Agroecotechnology, Syiah Kuala University, Banda Aceh, Indonesia*
[2]*Department of Agrotechnology, Syiah Kuala University, Banda Aceh, Indonesia*
3Department of Plant Protection, Universitas Syiah Kuala, Banda Aceh Indonesia

Abstract:
Chili is a high-value plant in Indonesia, but its productivity is still low due to soil fertility issues, especially on ultisol soil. Mycorrhiza and biochar are beneficial for plant growth and nutrient absorption. Mycorrhiza improves nutrient availability and soil structure, while biochar enhances mycorrhizal root colonization and soil characteristics. This study aims to examine the effects of mycorrhizal biographical fertilizer and rice husk biochar on the growth and yield of chili plants in ultisol soil. This research was carried out at the Eastern Sector Experimental Garden, Faculty of Agriculture, Syiah Kuala University, which took place from January to June 2022. This study used a 4x4 factorial pattern Group Randomized Design (RAK) with 3 repeats. The factors in this study are the first factor, namely the type of mycorrhiza (M0: without mycorrhiza (control), M1: G. Mosseae, M2: Gigaspora sp, M3: Gigaspora sp. + G. mosseae) and the second factor is biochar (B0: Without biochar (control), B1: biochar 5 tons ha^{-1}, B2: biochar 10 tons ha^{-1}, B3: biochar 15 tons ha^{-1}). The results showed that the addition of mycorrhizal species was able to increase growth and available P in chili plants. Rice husk biochar was able to increase the growth of plant Stem diameter at the age of 15 DAT. There was an interaction between the types of mycorrhizal biofertilizers and rice husk biochar doses capable of increasing growth and available P in chili plants. In conclusion, the addition of mycorrhizal species (Glomus mosseae, Gigaspora sp, Mixed Glomus mosseae + Gigaspora sp.) was able to increase growth and available P in chili plants. Rice husk biochar at doses (5, 10 and 15 tons ha^{-1}) was able to increase the growth of plant stem circumference at the age of 15 HSPT. There was an interaction between the types of mycorrhizal biofertilizers (Glomus mosseae, Gigaspora sp, Mixed Glomus mosseae+ Gigaspora sp.) and rice husk biochar doses (5, 10 and 15 tonnes ha^{-1}) which were able to increase growth and available P in chili plants.
Keywords*: Ultisol, Mycorrhiza, Biochar*

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I. Introduction

Chili (*Capsicum annuum* L) is a type of plant belonging to the eggplant tribe (*Solanaceae*) originating from South America. Chili is a plant that has been around for a long time and is widely cultivated in Indonesia because it has high economic value. The demand for chili in the market is increasing every year because of its uses and benefits. Indonesia still lacks 30% of chili needs, especially when there is no main harvest. Chili productivity in Indonesia is still low because it has not been able to meet the national demand for chili [1]. Chili production in 2019 in Indonesia was 2.58 million tons, in 2020 it was 2.77 million tons while in 2021 it was 2.72 million [2]. Even though red chili has increased in production every year, it has not been able to meet the demand for chili in the market, thereby increasing the price of red chili in the market [3]. The low productivity of chili is caused by many things, one of which is the lack of soil fertility, especially on ultisol soil.

Ultisols have a wide distribution of up to 113.24 million acres or about 24% of Indonesia's total land area in Sumatra, which reaches 23.48 million acres. Ultisols are spread in the Jantho area, a sub-district located in Great Aceh District, Aceh Province, Indonesia. Jantho is located on the west coast of Sumatra Island[4]. According to Jaya et al [5] the main horticultural commodity developed in Jantho is red chili. Red chili is a commodity cultivated in Jantho because it has compatibility between farming patterns, good biophysical conditions, availability of infrastructure, market and mastery of technology. Jantho's ultisol soil has high clay with an acid to neutral pH and has negatively charged soil and is dominated by mixed charges [6].

Mycorrhiza is a group of microorganisms that play a role in helping the absorption of nutrients by plants [7]. Mycorrhiza in increasing the availability of nutrients, soil structure, and activity of soil microorganisms. Evaluation of mycorrhizal applications on various types of plants and soil conditions showed significant results. The use of mycorrhizae can increase plant growth, productivity, and crop quality by reducing dependence on chemical fertilizers. In addition, the use of mycorrhiza also provides positive benefits for the environment [8].

Biochar is useful as a soil conditioner and also beneficial for plants because it can increase the abundance of mycorrhizal fungi in the soil [9] [10]. Application of biochar increases soil nutrient availability and increases mycorrhizal root colonization by improving soil characteristics [11]. [12] reported that applying 10 tons ha^{-1} of rice husk biochar increased soybean yields. [13] reported that giving 10 tons ha^{-1} rice husk biochar gave higher yields and N, P, K absorption compared to 5 tons ha^{-1} and 15 tons ha^{-1} rice husk biochar. This study aims to determine the effect of types of mycorrhizal biographical fertilizer and rice husk biochar on the growth and results of red chili plants in ultisol soil

II. Materials and methods

Preparation of Planting Media and Nurseries

This study used a planting medium in the form of ultisol soil obtained at Jalin, Jantho District, Great Aceh, Aceh. The soil is mixed with mycorrhizal biofertilizers *Glomus mosseae* and *Gigaspora* sp, as well as biochar from rice husk according to the specified treatment. The soil that had been put in a polybag was then mixed with biochar and stirred until it was completely mixed with the soil then on the 21st day it was given mycorrhizal biofertilizer. In this study, biochar was incubated for 21 days. Incubation in biochar for 21 days can increase soil CEC [14]. In the control treatment was not given biochar and mycorrhiza. Labels are attached to the polybags so that each treatment is not confused.

Seed Preparation

Seed preparation is carried out by taking into account the status of the chili seeds (seed criteria) used, namely having a germination rate of 85-90% which is stated in the description of the pioneer varieties. The soaking process was carried out using warm water for 1x24 hours to increase the germination of the seeds. The seeds used in this study were Perintis chili seeds. Seeds were sown in ultisol soil using small polybags and then given manure with a ratio of 2:1 on polybag soil, previously provided with mycorrhizal biofertilizer as much as 10 g plant-1 then divided into two parts, namely ½ dose of 5 g plant-1 given to polybag small and ½ the dose again as much as 5 g of plant-1 is given when transplanting at the age of 21 HST. Plant the seeds in the seedling media as deep as 1.5 cm, then cover again with the planting medium. The seedling medium is placed in a dark place protected from weather and sunlight for a week. After germinating, the chili seeds are exposed to sunlight. After 21 HST, the chili seeds were transferred to large polybags containing biochar which had been incubated for 21 days.

Planting and Application of Mycorrhiza and Biochar

Seedlings aged 21 HST were transferred to large polybags containing biochar. Biochar was given 21 days before planting. Seedlings are planted as much as one seed per polybag by carefully inserting into the planting hole as deep as 10 cm, which has been given ½ dose of mycorrhizal 5 g plant-1 below it, then covered with soil.

Maintenance

Stitching replaces dead plants after planting, which is done 5-7 days after transplanting. Watering is done regularly every day, in the morning and evening or adjusted to weather conditions. When it rains, watering is not done. Weeding in polybags is done manually. The pesticide used is Nasa's Natural BVR pesticide made from *Beauveria bassiana* 4.5 x 1000000 g-1 spores at a dose of 1-2 g liter-1. Pengajiran is carried out on the 15th day of DAT by using a 120 cm long bamboo split to support the plants. Removal of water shoots is done two times a week, which is done mechanically using scissors. Harvesting was carried out on days 90, 95, 100, 105, 110, 115 and 120 DAT.

Data analysis

This study used a 4x4 factorial randomized block design (RBD) with 3 replications. The observed factors were mycorrhizal species consisting of control (without mycorrhiza), *Glomus mosseae*, *Gigaspora* sp., and a combination of *Glomus mosseae* + *Gigaspora* sp. And biochar consists of no biochar (control), 5 tons ha^{-1}, 10 tons ha^{-1}, 15 tons ha^{-1}. Overall there were 16 treatment combinations with 3 replications and consisted of 2 experimental series. The first series was used to observe root colonization by mycorrhiza consisting of 1 treatment-1 plant and the second series was used to observe growth and yield variables of chili plants consisting of 2 treatment-1 plants. The first series consisted of 48 experimental units and the second series consisted of 96 experimental units so in total there were 144 experimental units.

Hypothesis testing is carried out parametrically by processing the data that has been obtained. In order to determine the effect of the treatment factors on the growth and yield of chilies, it is necessary to do a treatment test with an analysis of variance with a probability level of 0.05. If the result of analysis of variance is significant at 5%, the data would then further tested using the mean of treatment to perceive the difference between treatment using Tukey's honestly significant difference (HSD).

III. Results

Soil Analysis

Soil analysis is often carried out at the Soil and Plant Laboratory of the Faculty of Agriculture, Syah Kuala University.

Ultisol Soil Fertility Status

Parameter	Value	Description	Reference*)
pH H2O	4,97	Rather Acidic	4,5-5,5
N-total	0,24	Moderate	0,21-0,50
P-available	4,30	Very low	<4,4
C-organic	1,84	Low	1,00-2,00
Cation Exchange Capacity	16,80	Low	5-16
Electrical conductivity	0,02	Low	<1,0
Texture class	A	Clay	-

Source: Soil and Plant Laboratory Analysis, Faculty of Agriculture, Syiah Kuala University, 2022
*) Soil Research Institute (Balittanah), 2009

In general, ultisols have a low pH, high Al saturation, high active Fe and Mn, increase in clay fraction with soil depth, strong phosphate fixation, low CEC shows low organic matter content and presence of clays with low CEC such as kaolinite, saturation low base, low organic matter content except in the very thin A horizon, limited water holding capacity, low degree of aggregation and weak aggregate stability which makes the soil susceptible to erosion which is a constraint on sloping land [15].

Effect of mycorrhizal species on the growth and yield of chili plants on ultisols

The average growth and yield of chili plants with mycorrhizal types of treatment can be seen in the table below.

Average growth and yield on mycorrhizal types

Parameter	Mycorrhizal				HSD
	M0	M1	M2	M3	
Plant height 15 DAT	8,17 a	9,17 b	9,00 b	8,11 a	0,82
Plant height 30 DAT	16,64 a	18,61 ab	19,08 b	18,57 ab	2,41
Plant height 45 DAT	16,64 a	18,61 ab	19,08 b	18,57 ab	2,41
Stem diameter 15 DAT	1,84 ab	2,11 b	1,91 ab	1,76 a	0,31
Stem diameter 30 DAT	3,28 a	3,65 b	3,72 b	3,66 b	0,34
Stem diameter 45 DAT	4,97 a	5,45 b	6,34 c	5,53 b	0,38
Number of productive branches60 DAT	23,08	25,26	27,57	26,28	-
Wet weight of plant	43,01 a	48,44 b	51,42 b	49,16 b	4,08
Dry weight of plantt	10,86	11,44	12,65	12,00	-
Wet weight of plant roots	2,90	3,25	3,37	3,31	-
Dry weight of plant root	1,15	1,26	1,37	1,29	-
Planting fruit weight	96,97	108,99	114,6	109,29	-
Total fruit crop	32,92 a	37,17 ab	39,67 b	37,83 ab	5,86
Length of fruit plantations	11,13	11,09	11,02	11,14	-
Percentage of colonized roots	4,05 a	52,97 b	57,59 b	55,18 b	12,56
Yield potential ha^{-1}	7,88	8,85	9,31	8,88	-
Former P-availability	37,54 a	39,19 ab	41,70 b	41,24 b	2,63
Final P-availability	37,37 a	42,69 b	46,30 c	45,28 b	3,03

Note:Number followed by the same letter in the same column is not significantly different on the level of 0,05 (HSD).

Effect of biochar on the growth and yield of chili plants on ultisol soil
The average growth and yield of chili plants in the biochar treatment can be seen in in the table .

Average growth and yield with biochar treatment

Parameter	Biochar				HSD
	B0	B1	B2	B3	
Plant height 15 DAT	8,58	8,44	8,67	8,75	-
Plant height 30 DAT	17,6	17,66	19,82	17,82	-
Plant height 45 DAT	26,11	27,98	30,17	28,29	-
Stem diameter 15 DAT	1,89 ab	1,70 a	2,00 ab	2,03 b	0,31
Stem diameter 30 DAT	3,56	3,49	3,69	3,57	-
Stem diameter 45 DAT	5,4	5,51	5,7	5,68	-
Number of productive branches60 DAT	25,11	24,84	27,72	24,52	-
Wet weight of plant	47,73	47,64	48,93	47,73	-
Dry weight of plantt	11,55	11,49	12,42	11,49	-
Wet weight of plant roots	3,08	3,09	3,5	3,16	-
Dry weight of plant root	1,23	1,24	1,54	1,26	-
Planting fruit weight	101,99	105,71	111,2	110,96	-
Total fruit crop	36,08	36,67	38	36,83	-
Length of fruit plantations	11,14	11,12	11,1	11,03	-
Percentage of colonized roots	40,53	41,3	44,56	43,41	-
Yield potential ha^{-1}	8,28	8,58	9,03	9,01	-
Former P-availability	38,46	40,12	40,37	40,73	-
Final P-availability	41,42	43,21	43,58	43,43	-

Note:Number followed by the same letter in the same column is not significantly different on the level of 0,05 (HSD).

Interaction between mycorrhizal types and the effect of biochar on growth

Mean interaction of mycorrhizal species with biochar on chili plant height on day 15 DAT, girth of chili on day 15 DAT, former P-availability and final P-availability.

Average interaction of mycorrhizal species with biochar on chili plants

Parameter	Mycorrhizal	Biochar				HSD
		B0	B1	B2	B3	
Plant height 15 DAT	M0	7,61 Aa	8,39 Aa	8,83 ABa	7,83 Aa	1,98
	M1	9,06 Aa	9,28 Aa	7,94 Aa	10,39 Ba	
	M2	9,50 Aab	8,06 Aa	10,17 Bb	8,28 ABa	
	M3	8,17 Aa	8,06 Aa	7,72 Aa	8,49 ABa	
Stem circle 15 DAT	M0	1,66 AB a	1,75 Aa	2,18 Aa	1,77 Aa	0,75
	M1	2,24 Bab	1,94 Aab	1,69 Aa	2,55 Bb	
	M2	2,19 ABa	1,61 Aa	2,20 Aa	1,64 Aa	
	M3	1,46 Aa	1,51 Aa	1,91 Aa	2,15 ABa	
Former P-availability	M0	37,07 Aa	38,38 Aa	37,74 Aa	36,96 Aa	7,27
	M1	36,97 Aa	40,85 Aa	38,75 Aa	40,18 Aa	
	M2	40,44 Aab	38,09 Aa	45,14 Bb	43,13 Aab	
	M3	39,36 Aa	43,15 Aa	39,83 ABa	42,63 Aa	
Final P-availability	M0	37,19 Aa	38,96 Aa	37,20 Aa	36,12 Aa	7,13
	M1	40,40 ABa	44,58 ABa	41,73 ABa	44,05 Ba	
	M2	44,97Bab	41,84 ABa	50,81 Cb	47,59 Bab	
	M3	43,11 AB	47,46 Ba	44,57 Ba	45,96 Ba	

Note : Number followed by same letter is not significantly different at the level of 0,05 (Tukey’s HSD test). Uppercase is notation in the row, lowercase is notation in column.

IV. Discussion

Effect of mycorrhizal species on the growth and yield of chili plants on ultisols

Mycorrhiza has an influence on plant growth due to the symbiotic interaction that exists between plant roots and mycorrhizal fungi. Mycorrhizae can facilitate the absorption of nutrients in the soil so that it can increase plant growth which is useful for the development of plant height and stem diameter. One of the most abundant nutrients taken up by mycorrhizae in the soil is the element P which is useful for the growth of plant cells such as stems, flowers, leaves and roots, as well as transferring energy through plants. In addition, mycorrhiza is also useful for increasing the availability of water for plants and increasing plant growth promoting hormones[16].

Mycorrhizae play a role in helping plants take up macronutrients such as N, P, K and synergistically increase the ability to take these nutrients so that they will increase plant height[17]. The results of this study are also in accordance with the research of [18] which states that giving mycorrhizae is proven to increase the ability of plants to carry out photosynthesis because the presence of mycorrhizae can help host plants take mineral nutrients from the soil so that plants will grow well. The same thing was also stated by [19] that the administration of mycorrhiza will increase the rate of plant photosynthesis so that it affects the increase in plant growth and P uptake in root tissue and even transport tissue. This biological fertilizer can also act as a growth hormone enhancer which can trigger plant growth and development [20]. Mycorrhizal hyphae in the soil can create good physical conditions for plant roots and soil organisms, thus providing biological fertility from the activities of these organisms [21].

Although mycorrhiza has many positive impacts, there are also some drawbacks that need to be considered related to the soil used in this study. The soil used has several drawbacks that can affect plant growth, even with mycorrhiza. The soil used was ultisol soil which has low nutrients. Mycorrhiza can increase the uptake of nutrient P in the soil but other nutrients cannot be absorbed as much as nutrient P. Plants need various kinds of nutrients to increase plant growth. As the nutrient Fe is needed for the synthesis of chlorophyll and maintenance of the structure and function of chloroplasts. Then Zn is needed for plant growth which is also useful for branch development [22]. Then also other nutrients which if not sufficiently available in the soil cause certain physiological disturbances which impact on plant growth, development and productivity.

Effect of biochar on the growth and yield of chili plants on ultisol soil

Biochar is a very useful ingredient in enhancing soil and plant development. This is due to the ability of biochar to maintain and increase the concentration of important elements such as carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulfur (S) during the pyrolysis process. In addition, biochar is also able to store minerals such as phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and silicon (Si) in high concentrations in its structure [23]. Therefore biochar produced from mineral-rich raw materials has a high ash content. The ash content is primarily responsible for the alkalinity of the biochar, which is an important characteristic. Other properties such as C content, degree of carbonization, amount of elements vaporized, and remaining volatile matter are determined by several production conditions including temperature, heating rate, and O2 supply [24]. Biochar is known for its high carbon content, so it can increase soil organic matter content. The carbon content in the soil can be used as an indicator of soil quality, such as the stability of soil aggregates, retention and availability of nutrients [25]. Biochar incorporated into the soil is characterized by high stability and resistance to biological decomposition, therefore it is known as a very effective medium for absorption of carbon dioxide in the soil [26]. In addition, the application of biochar to the soil causes an increase in the content of not only carbon but also other biogenic compounds, such as phosphorus, potassium, magnesium and nitrogen [27]. Biochar has a fairly high water holding capacity, so its application to the soil will affect the soil's ability to hold water thereby increasing the ability of the soil to provide nutrients for plants [28].

From the results table above, it can be seen that the use of biochar does not have a significant effect on yield and plant growth. this is because biochar does not have enough nutrients for the growth of chili plants. Biochar is not a contributor to plant nutrients but rather acts as a soil conditioner, which changes the physical and biochemical conditions of the soil to become more contributive to increasing the availability and absorption of plant nutrients [29]. According to [30] rice husk biochar has lower nutrients compared to wood biochar and young coconut shell biochar, which is why rice husk biochar has lower nutrients. The application of biochar and mycorrhizal fungi can increase plant productivity, but the specific mechanism of biochar on mycorrhizal fungi is largely unknown [26].

The results of [31] showed that the application of biochar to acid soils did not show a significant effect on several physical properties such as available pore water, and fast pore drainage. This is in line with the research results of [32] administration of 10 tons ha^{-1} of biochar did not have a different effect on the application of fertilization with the same dose as well as the stability of soil aggregates. Furthermore, [33] also stated that the application of biochar to clay had not affected soil permeability and porosity. Biochar is not a contributor to plant nutrients but rather acts as a soil conditioner, which changes the physical and biochemical conditions of the soil to be more contributive to increasing the availability and absorption of plant nutrients [29]. According to [30] rice husk biochar has lower nutrients compared to wood biochar and young coconut shell biochar, which is why rice husk biochar has lower nutrients.

Interaction between mycorrhizal species and the effect of biochar on the growth and yield of chili plants

The application of biochar as a soil conditioner has benefits for host plants by increasing the decrease in the function of mycorrhizal fungi in the soil [9] and increasing the symbiosis between plants and these fungi. Biochar application can also increase soil nutrient availability and root colonization by mycorrhizae through soil features [11]. Biochar can directly increase crop productivity [34] by increasing soil nutrient content and nutrient availability in dissolved form, including its potential as a source of phosphorus with high agronomic efficiency [35]. Increased nutrient retention may also explain the indirect effect of adding biochar to soil [26].

From the results table it can be seen that the best combination was found in the *Glomus mosseae* treatment, this is because *Glomus mosseae* is more suitable in clay soil conditions. In this study, Ultisol used clay-type soils so that it is compatible with *Glomus mosseae* mycorrhiza. This is in accordance with [36] which state that soil dominated by the clay fraction is a suitable condition for the growth and development of spores of the genus Glomus.

Mycorrhizal activity in these soils can be accelerated in the presence of biochar due to better oxygen supply required for aerobic microorganisms [37]. In addition, [38] described that application of biochar to soil increases growth and biomass through improvement of soil physical properties such as soil porosity. Therefore, the main potential benefits of mycorrhizal colonization in plant roots are increased absorption of nutrients and water as well as increased resistance to drought and pathogens [39]. The plant supports the fungus by obtaining the nutrient compounds needed for the fungus to grow, provided the fungus increases the surface area of the plant's roots for better absorption of water and essential elements.

Overall, the combined use of mycorrhiza and biochar in plant growth and yield showed a positive response. This combination provides beneficial effects in terms of nutrient absorption by expanding the area of nutrient uptake in the roots through mycorrhizal hyphae and spore development.

V. Conclusion

The addition of mycorrhizal species (*Glomus mosseae, Gigaspora* sp, Mixed *Glomus mosseae* + *Gigaspora* sp.) was able to increase growth and available P in chili plants. Rice husk biochar at doses (5, 10 and 15 tons ha^{-1}) was able to increase the growth of plant stem circumference at the age of 15 HSPT. There was an interaction between the types of mycorrhizal biofertilizers (*Glomus mosseae, Gigaspora* sp, Mixed *Glomus mosseae*+ *Gigaspora* sp.) and rice husk biochar doses (5, 10 and 15 tonnes ha^{-1}) which were able to increase growth and available P in chili plants.

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