Research article

Impact of Metarhizium sp. and Trichoderma sp. on Soil Fertility and Growth of Tomatoes (Solanum Lycopersicum L.) in Post-Mining Land

Sopialena Sopialena*, Alexander Mirza, and Maria Fatima Nggudu

Laboratory of Insect and Plant Pathology, Faculty of Agriculture, Mulawarman University, Indonesia

ORCID
Sopialena https://orcid.org/0000-0002-8078-6204

Abstract.
Soil conditions in coal mining areas are generally poor in terms of nutrient availability, necessitating the addition of nutrients as well as microbial investment to improve aeration and increase nutrient availability for plants. This study examined the ability of the fungi *Metarhizium* sp. and *Trichoderma* sp. to increase tomato plant growth and yield, as well as the ability of these fungi to increase soil fertility in post-coal mining soil. The data were compiled using a completely randomized design with four replications, and the study used post-coal mining soil. *Metarhizium* sp. and *Trichoderma* sp. were used, with doses of 0 g, 3 g, and 5 g in each treatment. Plant height, number of branches, number of flowers, and fruit production were all evaluated as growth parameters. The data were analyzed using variance with a level of 5% using the least significant difference test. Increases were found in soil pH, C-organic, nitrogen, phosphorus, and potassium, resulting in an increase in soil fertility. Adding *Metharizium* sp. and *Trichoderma* sp. increased soil fertility, tomato plant growth, and production.

Keywords: *Metarhizium* sp., *Trichoderma* sp., post-coal mining soil

Corresponding Author: Sopialena Sopialena; email: sopialena88@gmail.com

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1. Introduction

Coal mining activities have been the backbone for East Kalimantan's economy for several decades. East Kalimantan Province has issued Mining Business Permits (IUP) as many as 442 production IUPs with an area of 925,619.33 ha, and 517 exploration IUPs with an area of 2,007,146.17 ha, in the 2014 – 2019 IUP period. Meanwhile, the amount of coal production based on the 2014 IUP was 72,027,369.44 tons [1] The most important environmental problems from uncontrolled mining activities in East Kalimantan are land reclamation and rehabilitation, and the decline in soil quality from ex-mining land. Of the approximately 1,200 mining companies operating in Indonesia, only large mining companies fulfill their obligations to carry out reclamation, while for small companies, there are still many that have not done so. Although legally, the government has made regulations to preserve ecosystems through PP No. 78 of 2010 concerning reclamation and post-mining, but this does not guarantee that permit owners do not abuse their rights and great responsibilities. In terms of soil quality degradation, soil quality degradation is one of the problems in the coal mining process using the open pit mining method, due to changes in topography, vegetation cover, hydrological patterns, and damage to the soil body. The use of heavy equipment in this activity also plays a role in giving negative effects to the physical, chemical and biological properties of the soil.

In this regard, it is deemed necessary to develop research on ex-mining land reclamation and link it to efforts to accelerate the return of ex-mining soil quality at a low cost, easy to implement, effective and environmentally friendly. As an alternative that can be used in this case is the use of bioremediation techniques [2], by exploiting the wealth of microbes by investing in the fungus *Metarhizium* sp. and *Trichoderma* sp. through the addition of organic matter is believed to help increase the aggregation of particles that make up the soil in the long term. Therefore, this research is focused on conducting a comprehensive study of post-mining reclamation efforts through in-situ bioremediation techniques using the fungus *Metarhizium* sp. and *Trichoderma* sp. through the addition of organic matter, namely manure and husks. The plant that will be used as an indicator in this research is tomato plant (*Lycopersicum esculentum* Mill.).

2. Methodology

This research was conducted for 4 (four) months, starting from sampling, isolation to analysis of the plants grown. Research sites. Soil sampling was carried out in one of the post-coal mining sites in the Makroman Village, Sambutan Regency, Samarinda City. Microbial propagation was carried out in the Insect and Plant Diseases Laboratory. Tomato plants were grown in The greenhouse of The Faculty of Agriculture, University of Mulawarman, Samarinda.

2.1. Breeding of Metarhizium sp and Trichoderma sp

The fungus *Metarhizium* sp. and *Trichoderma* sp was developed from isolates that already exist in the Laboratory of Pests and Plant Diseases, Faculty of Agriculture, University of Mulawarman. Isolates planted in each petri dish that had been filled with PDA media, then incubated for 3-4 days. Then, transplanted the isolates to the rice media with the method as follow: cook the rice until it is half cooked, then wrap it in plastic, then the plastic is tightly and tightly closed, let stand for about 30 minutes, after that inject the fungus isolate *Metarhizium* sp. and *Trichoderma* sp. which has been diluted with distilled water, then loosen the plastic wrapping the rice and re-incubate for 5 – 11 days. After the fungus grows, we grind it and then we can apply it.

2.2. Planting Preparation.

Soil extraction is carried out at the pre-determined location of post-coal mining land. Soil sampling for planting was carried out using a hoe with a depth of approximately 20 cm at 5 sampling points. From these 5 points the soil is taken and mixed together. Furthermore, the soil is given chicken manure, husks and mixed evenly. The mixture ratio is 3.5 kg of ex-coal mined soil, 1 kg of chicken manure, and 0.5 kg of husks. Furthermore, each polybag was given treatment.

2.3. Soil Chemical Analysis

Soil chemical analysis was carried out twice, namely pre-treatment analysis and post-treatment analysis. Analysis of chemical properties observed were: N, P, K, C-organic and soil pH

2.4. Tomato Plant Analysis

For plant analysis, the indicators observed were from the physical side of the plant which included plant height, number of branches, number of flower stalks and fruit weight.

2.5. Experimental design

This study used a completely randomized design, with

P1: control (not given fungi)

P2 : Giving *Metharizium* sp. 3 gr/polybag

P3 : Giving *Metharizium* sp. 5 gr/polybag

P4 : Giving *Trichoderma* sp. 3 gr/polybag

P5 : Giving *Trichoderma* sp. 5 gr/polybag

Each treatment was repeated 4 times. Observations of plant growth were carried out from the vegetative phase to harvest with the treatment parameters of plant height, number of branches, number of flowers and fruit weight.

2.6. Data analysis

The data collected was carried out with a variance fingerprint. If it is significantly different, then to compare the average treatment, the Least Significant Difference Test (BNT) is carried out at the 5% level.

3. Results and Discussion

3.1. Metarhizium sp.

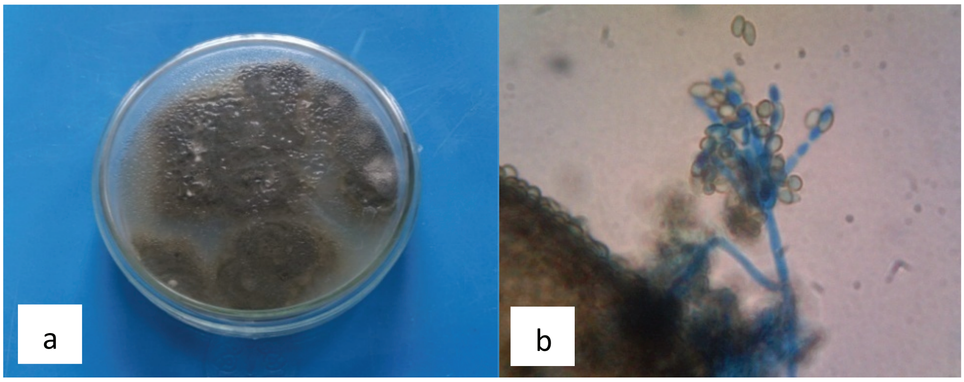

Figure 1: (a) Colonies of *Metharizium* sp., (b) Microscopically of *Metharizium* sp.

From the observation of the isolation of the fungus *Metarhizium* sp., it was seen that the color of the fungal colonies was initially white and then gradually became dark green when ripe (Figure 1a), having an uneven colony shape on the edges or surface. Microscopically the fungus *Metarhizium* sp. has the characteristics of septate hyphae, with hyaline conidiophores, the conidia are single-celled, hyaline in color and cylindrical in shape. According to [3] the fungus Metarhizium sp. have single, paired or circular phyla. Conidia are produced in basipetal chains, compacted into long oval cylindrical colonies (Fig. 1b).

Colonies of *Metarhizium* fungus at the beginning of growth are white, then dark green with increasing age. This fungus is commonly found in the soil, is saprophytic, and is generally found in various stages of infected insects, growing at a temperature of 18.30 – 29.50C and humidity of 30 – 90%. The pH level for the growth of *Metarhizium* sp. ranged from 3.3 to 8.5. Optimal growth occurs at pH 7. Conidia formation consists of buds and shoots that extend on both sides of the conidiophores. Generally a chain of conidia unite to form a crust in the medium [4]. *Metarhizium* sp. is a fungus is a soil microbe and lives as a saprophytic fungus. There are two hundred and four types of isolates of the fungus *Metarhizium* sp. successfully isolated from the soil and grown on agar media at an optimum temperature of 25°C and a pH ranging from 3.3-8.5 [5].

3.2. Trichoderma sp.

Based on macroscopic observations, it was seen that the color of the fungal colonies on the third day was green (Figure 2a). According to Watanabe (2002) mentioned that the fungus *Trichoderma* sp. has a dark green color with a yellowish tint on PDA media. The colony shape of the isolates spread irregularly and had uneven colony edges. Microscopically isolates of *Trichoderma* sp. have septate hyphae, many and branched conidiophores, hyaline, semi-spherical conidia and clustered between hyphae. Based on [3]on the fungus *Trichoderma* sp. has septate hyphae, hyaline, many conidiophores and branching and growth is easy and fast (Figure 2b).

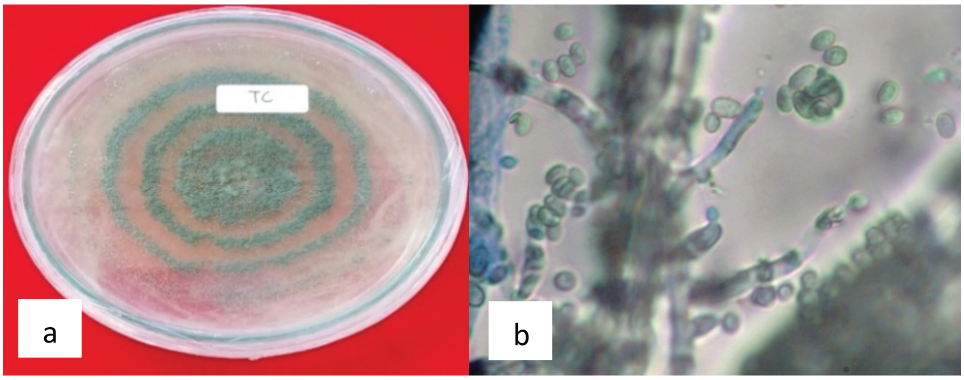

Figure 2: (a) Colonies of *Trichoderma* sp., (b) Microscopic *Trichoderma* sp.

Colonies on the medium were originally hyaline in color, then turned greenish white and then dim green, especially on the part that showed a lot of conia. Conidiophores can be branched like a pyramid, namely at the bottom of the lateral branch which is repeated, while towards the end of the branching it becomes shorter. The phialid looks slender and long, especially the apex of the branch and has smooth walls. Chlamydospores are generally found in the mycelia of old colonies, located intercalally sometimes terminally, generally round, hyaline in color and smooth-walled [6]. According to [7], *Trichoderma* sp. in the initial medium it looks white then the mycelium will turn green-green then it looks mostly green in the middle of the colony surrounded by mycelium which is still white and in the end the whole medium will be green. According to [8], Trichoderma sp. is one of the most widespread (cosmopolitan) soil fungi, which is commonly found in agricultural lands. This fungus is also found on the root surface of various plants, on rotten bark, especially on wood that is attacked by fungus. *Trichoderma* sp. known as saprophytic fungi that live in the soil, especially on organic matter, in litter and dead wood.

3.3. Soil Fertility Analysis

Based on the results of soil analysis before treatment, the pH of the post-coal mining soil was very acidic with a value of 4.69. C-Organic indicates that the soil in the research area has a low C-organic status with a value of 1.24%, the Nitrogen (N) content in post-mining soil has a very low status with a value of 0.24%, the phosphorus (P) nutrient content of the soil high with a value of 27.24 ppm, and the content of potassium (K) is very high with a value of 93.25 ppm.

Based on the results of soil analysis after treatment, the results obtained soil pH that has been mixed with the microbial *Metarhizium* sp. is Neutral with a value of 6.75, while the pH of the soil that has been mixed with *Trichoderma* sp. also neutral. C-Organic in soil that has been mixed with *Metarhizium* sp. has a very high status with a score of 8.59, while in *Trichoderma* sp. has a higher status with a value of 14.31. Nitrogen content in the soil that has been mixed with *Metarhizium* sp. has a high status with a value of 0.59, while in post-coal mining soil that has been mixed with *Trichoderma* sp. has a high status with a value of 0.72. The content of phosphorus (P) in the soil that has been mixed with *Metarhizium* sp. has a very high status with a value of 681, 82, while the P content in the soil that has been mixed with *Trichoderma* sp. has a very high status as well. The content of element K in the post-coal mining soil that has been mixed with *Metarhizium* sp. has a very high status with a value of 262.50, while the K content in the soil that has been mixed with *Trichoderma* sp. has a very high status as well with a value of 256.87.

This proves that the mushrooms invested in the planting medium are able to increase the nutrients in the post-coal mining soil so that the plant continues to grow, due to the relatively high content of N nutrients and enriching nutrients, especially K. The higher the availability of K in the soil, then the absorption of K nutrients will be more fulfilled so as to produce better plant growth [9]. Organic matter has the ability to bind and hold nutrient ions and regulate their release, besides that it plays a role in incorporating soil particles into a more stable aggregate form, so that water flow and air circulation can run well and the ability of the soil to hold water will increase [10].

3.4. Soil pH

Mining soils are generally soils with very strong, dense aggregates. The soil surface is less stable and mixed with mining materials besides that the condition of the land is very infertile. With the results of the soil pH has a value of 4.69 with a very acidic status. The low pH is thought to be due to alkaline leaching of the adsorption complex and is lost through water. In accordance with the opinion of [11] that when the soil has been washed out, Al and H cations remain as the dominant cations that cause the soil to become acidic, besides that there is a spill of mining material in the form of coal which contains acidic properties, in contrast to the pH of the soil which is acidic. has invested the microbial Metarhizium sp. and Trichoderma sp. the pH status of the soil is neutral. The difference between soil pH that has been given Microbia *Metarhizium* sp. with soil pH that has been given *Trichoderma* sp. not much different. The soil pH status of these two microbes is included in the neutral criteria, where the pH of the soil is able to grow plants. The increase in soil pH from acidity is caused by decomposed organic matter. Microorganisms given to acid soil have an important role, especially in terms of processing organic matter that has not been decomposed in the soil. If the organic matter has decomposed, then the decomposition process occurs more quickly. It should be noted that if the organic matter has not completely decomposed, the soil may become more acidic. This is in line with the opinion of [12] that the addition of organic matter can increase or even decrease soil pH, depending on the type of organic matter added. This is also in accordance with the research of [13] which stated that soil pH increased at harvest time compared to before planting, with the highest increase (4.41 to 4.73) in Cu3. [14] states that the rise and fall of soil pH is a function of H+ and OH- ions, if the concentration of H+ ions in the soil solution increases, the pH will decrease and if the concentration of OH- ions increases, the pH will increase.

3.5. C-Organic

C- Organic is the main constituent of organic matter. Soil organic matter is complex organic compounds that undergo a decomposition process, either in the form of humified humus or inorganic compounds resulting from the mineralization of organic matter. Organic matter has a very important role in the soil, especially its effect on soil fertility, the lack of vegetation on post-coal mining land has an impact on the weathering process of organic matter in the soil which results in low C-organic content in the soil. Soil properties both physical, chemical and biological soil are directly and indirectly influenced by organic matter produced from vegetation cover. Based on data from research analysis, the value of organic C is low with a value of 1.24% so that the N content in the soil also has a low content [15]. [16], that the N element can increase the activity of microorganisms for the decomposition of organic matter and if the N element is low, the activity of microorganisms will also be low so that it affects the C-organic being low. Basically, C-organic in the soil has a role in determining soil fertility, but in the research area the value of C-organic or organic matter has a low status so that it affects the level of plant life because it has little organic matter, in contrast to the case with post-coal mining soil. which has invested the fungus *Metarhizium* sp. and *Trichoderma* sp., The organic C- content of both soil samples after treatment was very high, much different from the low C-organic content before treatment. From the soil samples that have been observed among the soil samples added with *Metarhizium* sp. and *Trichoderma* sp. The highest organic C-content was found in soil samples that had been added with *Trichoderma* sp. with a value of 14.31%. The process of decomposition of organic matter is mostly carried out by microbes. In general, the growth of microbes increased in quantity, along with the increasing incubation period of organic matter in manure and husk in the soil media. This shows that as the incubation time increases, the organic matter in the soil undergoes a decomposition process. The increasing content of organic matter in the soil will increase the number of microbial populations [17]. Microbial *Trichoderma* sp. able to decompose organic matter in the soil well so as to increase the c-organic in the soil.

3.5.1. Nitrogen (N) Soil

The test results for the N value content have a value of 0.24% with a very low status, the low N value is caused because N is widely used by plants and microorganisms. In addition, the very low N is caused because the element N is in organic form or is not available to plants. In accordance with the opinion of [12], that N is present in small amounts in the soil and some of this element is in the form of insoluble compounds and is not available to plants due to the inhibition of the weathering process of organic matter in the soil that is not available Added by [18], that organic matter is the main source of N in the soil, so that if the organic matter is low, the N content is also low, so in this case soil organic matter can affect the N content in the soil. The low nitrogen content is influenced by the characteristics of the nitrogen element which has high mobility. Nitrogen is the element that is most easily lost in the soil. Nitrogen in the soil can be lost because it is absorbed by plants and microorganisms, evaporates and is washed away by rainwater. But the main factor that can influence is the relatively high leaching at the sampling site, but in the post-coal mine soil where *Trichoderma* sp. and *Metarhizium* sp., showed that the N content in the soil samples after treatment was equally high. In the treated soil *Trichoderma* sp. N content was higher with a value of 0.72% when compared to *Metarhizium* sp. treatment soil, the high N content in the soil after treatment was caused by the content of organic matter that had been composed. The element N is very influential for plant growth. The possibility of an increase in total soil N levels was caused by the addition of organic fertilizers where according to [19] organic matter was a source of N, P, K and S elements. Budirman Bachtiar (2020) further stated that decomposed organic matter would produce a number of proteins and minerals. amino acids that break down into ammonium (NH4+) or nitrate (NO3-) which is the largest contributor to nitrogen (N) in the soil. Juarsah (2014) also added that after the ribosomal organic matter obtained through the absorption of nutrients in the soil, the improved absorption is decomposed, the compounds it contains will be released. The increase in the concentration of nitrogen (N) in plant tissues was caused by the contribution of nitrogen (N) from chicken manure because it has a fairly high nitrogen content. The increased ability of the soil to supply N has something to do with the ability of the given organic matter to provide available N to plants. Hidayat (2017) states that when macronutrients in the soil increase, the amount that can be absorbed by plants will also increase, accompanied by the formation of organic compounds in plant tissues. In addition, the volume of photosynthate that plants can produce is not only determined by the absorption of sunlight, but also by the level of availability of raw materials in nutrients which is also influenced by the improvement in soil pH. The final stage of the transformation of N, which is present in organic compounds in soil, is the amount of ammonium and N ions [22]. The very low N content is thought to be influenced by the immobility of N due to the high C/N ratio of the material. According to [23], immobilization is a change in the form of inorganic N compounds (NH4+, NH3, NO3-) into organic N (amino acids and proteins) through biological activity. Mineralization of N and C is the main process that regulates the availability of nutrients to plants and the release of toxic compounds [24].

3.5.2. Phosphorus (P)

According to the results of soil chemical analysis, the status of the available phosphorus nutrient content in the soil sample is high with a value of 27.24 ppm. This means that the soil at the research site is classified as having a high available P content and has a high potential in providing phosphate elements for plant needs. The availability of phosphate with low status may occur because phosphate in the soil is in a form that is not immediately available or because of pH, aeration, temperature, organic matter and micro elements that can affect the availability of phosphate. The principle of providing phosphate in the P cycle must be considered to overcome this. According to [25], the principle of supplying P to plants in the P cycle shows that the water content of P-solution is the result of a balance between the supply of P from weathering of P minerals, dissolution (solubility), fixed P and P-organic mineralization and P loss in the form of immobilization by plants. The P content of rocks is generally between 500 and 1400 g P/g, depending on the type of host rock. Of the igneous rocks basalt is usually at the upper end of this range, whereas granite and most sedimentary rocks are at the lower end. Above this range are rock phosphates, some limestones, and some basic volcanic lava. Typical total P content in soil ranges from 150 to 700 g P/g [26].

Nitrogen and phosphorus are the elements that are considered to be the most limiting for plant growth and productivity because they are often present in small amounts locally or present in forms that are not usable by plants. As a result, the evolution of many plant species has included the development of mutually beneficial symbiotic relationships with soil-borne microorganisms. In this connection, both the host plant and the microorganism symbol acquire the valuable resources they need for their own productivity and survival as a result of the association [27]. The results of soil chemical analysis after treatment showed that the phosphorus content in the soil in both treatments was very high. The high content of phosphorus is caused by the availability of phosphate in the soil itself and the decomposition process of organic matter. Organic matter can increase the availability of phosphate, through its decomposition which produces organic acids and CO2. Organic matter that is being decomposed produces a number of organic acids that will accelerate the process of dissolving phosphate rock so that it will release a number of phosphate anions into the compost, as a result, the available P also increases [28]. In acidic soils, P can be predominantly absorbed by Al/Fe oxides and hydroxides, such as gibbsite, hematite, and goethite [29].

3.5.3. Potassium (K) Soil

Potassium is the third nutrient after nitrogen and phosphorus. Nutrients Potassium is absorbed by plants in amounts approaching or sometimes even exceeding the amount of Nitrogen. Analysis of the chemical properties of the potassium content has a very high value of 93.25. Availability of K is defined as the availability of potassium which can be exchanged and can be absorbed by plants. Thus, the availability of K in the soil is highly dependent on the addition of external sources, fixation by the soil itself and the addition of potassium itself [12]. The main source of K in the soil is feldspar minerals (orthoclase, sanidin), so the presence of these minerals in the soil indicates a source of K [30]. Nutrient K is high, because indeed this nutrient in the earth's crust or on the surface of the soil is quite high, and the deeper it is from the soil surface, the K nutrient content is lower [31]. From the results of soil chemical analysis after treatment, the administration of Trichoderma sp. and Metarhizium sp. Potassium content in the soil is very high. The potassium content of the two treatments did not differ much, this was because the microbes that had been invested were able to decompose the existing organic matter, so that the potassium content of the soil after treatment was very high. Husk is one of the main sources of soil potassium content. Husk is broken down by microbes so that it becomes smooth, so it is quickly available to plants. Plants need potassium is quite high and its effects are related to the growth of jagur and healthy plants. Potassium plays a role in increasing resistance to certain diseases and increasing root growth. Potassium tends to inhibit plant stagnation, counteract the adverse effects of excessive nitrogen application, and has the effect of preventing the accelerated ripening of the phosphorus nutrient. In general, potassium functions to maintain a balance in both nitrogen and phosphorus [32]. In soil fertility, the balance of K with other elements is important to note because of the physiological properties of plants that often require K in balance with other elements. In addition, K has antagonistic properties with other elements. The imbalance between element K and other elements causes symptoms of weakness in one element [31].

3.5.4. Analysis of Tomato Plants (Lycopersicum esculenium Mill)

According to the results of the isolation of *Tricohderma* sp and *Metarhizium* sp. is an antagonist fungus that both have properties as biological agents, therefore in this study for the analysis of indicator plants we can use the fungus *Trichoderma* sp. and *Metarhizium* sp. as a test material for the comparison of plant growth indicators

3.6. Plant height

The results of the analysis of tomato plant height in Table 1 show that at 15 days after planting, the treatment of *Metarhizium* sp. and *Trichoderma* sp. real different. At a dose of 0 g gave a significant effect on a dose of 3 g and a dose of 5 g, but the interaction

TABLE 1: Average Plant Height.

Treatment	Dose	Average Plant Height			
		15 DAP	30 DAP	45 DAP	50 DAP
Control	0 gr	19,60 a	31,10	64,45	89,50 b
Metharizium sp.	3 gr	20,30 b	31,90	64,57	87,20 a
	5 gr	20,60 b	31,30	64,00	89,10 b
Trichoderma sp.	3 gr	20,50 b	43,50 b	99,00 b	121,40 b
	5 gr	20,40 b	45,90 c	105,50 c	135,70 c

Note: Numbers followed by the same letter in the same column or row show results that are not significantly different at the level of p <0.05

between a dose of 3 g and 5 g did not have a significant effect. At 30 DAP and 45 DAP the treatment of *Metarhizium* sp. did not show a significant effect, but in the treatment of *Trichoderma* sp. have a very significant effect on all doses given. At 50 DAP treatment with *Metharizium* sp. showed a significant effect at a dose of 3 g on a dose of 0 g and 5 g, while in the treatment of *Trichoderma* sp. showed a very significant effect on all doses.

3.7. Number of Plant Branches

The results of the analysis of the number of branches in Table 2 show that at 30 DAP the treatment of *Metarhizium* sp. did not show a significant effect, but in the treatment of *Trichoderma* sp. have a very significant effect on all doses given. At 45 DAP treatment with *Metarhizium* sp. gave a significant effect at a dose of 0 g and 3 g to a dose of 5 g, while *Trichoderma* sp. showed a very significant effect on all doses. At 50 DAP treatment with *Metharizium* sp. showed a significant effect at a dose of 0 g to a dose of 3 g and 5 g, while in the treatment of *Trichoderma* sp. showed a very significant effect on all doses.

TABLE 2: Average Number of Branches.

Treatment	Dose	Average Number of Branches		
		30 DAP	45 DAP	50 DAP
Control	0 gr	4,25	6,50 a	8,75 a
Metharizium sp.	3 gr	4,25	6,25 a	9,25 b
	5 gr	4,75	7,00 b	9,50 b
Trichoderma sp.	3 gr	6,00 b	9,00 b	10,50 b
	5 gr	7,25 c	11,25 c	13,00 c

Note: Numbers followed by the same letter in the same column or row show results that are not significantly different at the level of p <0.05.

3.8. Fruit Weight

The results of the fruit weight analysis in Table 4 show that in the treatment of *Metarhizium* sp. and *Trichoderma* sp. had a very significant effect on all doses. Based on the results of the analysis, plant height, number of branches, number of flowers and fruit weight of *Metrahzium* sp. with a dose of 5 g, a dose of 3 g, and a dose of 0 g experienced a significant increase

Table 3: Average Fruit Weight.

Treatment	**Dose**	**Average Fruit Weight**
Control	0 gr	64,80 a
Metharizium sp.	3 gr	66,20 b
	5 gr	65,90 b
Trichoderma sp.	3 gr	66,25 b
	5 gr	68,67 c

Note: Numbers followed by the same letter in the same column or row show results that are not significantly different at the level of $p < 0.05$

From each treatment of tomato plant height with *Trichoderma* sp. Statistically gives significantly different results. This proves that *Trichoderma* sp. able to increase the height of tomato plants and work well by breaking down the N elements from chicken manure and K elements from rice husks.

The results of the variance test on fruit weight showed that the treatment of *Trichoderma* sp.ini was significantly different. It is suspected that the high fruit weight of tomato plants treated with *Trichoderma* sp. as a decomposer of organic matter so as to provide sufficient nutrients for the growth of tomato plants. While in the control there was no addition or treatment of *Trichoderma* sp. only with the addition of manure so that the availability of nutrients that can be directly absorbed by tomato plants is lower than the tomatoes given *Trichoderma* sp. This assumption is supported by several previous studies such as by [33] who reported that *Trichoderma* sp. can decompose organic matter in the soil into food that is easily absorbed by plants, it is added that organic matter applied to the soil can be a source of nutrition for antagonistic microorganisms so as to increase the activity of antagonistic agents, stimulate dormancy of pathogenic propagules and produce a fungistatic effect for soil-borne pathogens. . The same thing has been reported by [34] that some fungi are associated with litter degradation processes in mangrove environments. It was further explained that Trichoderma sp. found to be associated with the environment so that its presence plays a key role in the decomposition process, especially because of its ability to degrade compounds that are difficult to degrade such as lignocellulosic.

Trichoderma sp. is a functional microorganism which is widely known as soil biological fertilizer. Culture of *Trichoderma* sp. given to the planting area and acts as a biodecomposer, decomposing organic waste (fallen leaves and old twigs) into quality compost. *Trichoderma* sp. has the ability to decompose litter that is difficult to decompose such as acacia plants (*Acasia Mangium*) [35]. *Trichoderma* sp. is a soil fungus that plays a role in reducing soil organic matter, where this soil organic matter has current components such as N, P, S and Mg and other nutrients needed by plants for growth. *Trichoderma* sp. serves to break down organic materials such as nitrogen contained in complex compounds thus this nitrogen will be used by plants to stimulate growth above the ground, especially plant height giving green color to the leaves. Some of the advantages and disadvantages of *Trichoderma* sp. the other is that it is easy to monitor and can reproduce, so that its presence in the environment can last a long time and is safe for the environment, animals and humans in the background that does not cause harmful chemical residues in the soil [36]. [34] which stated that *Trichoderma* sp. plays a key role in the decomposition process of organic compounds, especially in its ability to degrade difficult-to-degradable compounds such as lignocellulose. Based on the description above, it can be seen that Ultisol soil improvement can be done by adding organic matter to the soil. To accelerate the decomposition of organic matter, it is necessary to give *Trichoderma* sp. so that it can provide nutrients when needed by plants, so as to increase plant growth and yield.

According to [33], *Trichoderma* sp. able to increase plant growth, because it has the ability to stimulate plants to increase growth hormone. Utilization of *Trichoderma* sp. as potential antagonist microorganisms. *Trichoderma* is a native soil fungus that is beneficial because it has high antagonistic properties against pathogenic fungi and if applied to the soil can improve soil chemical properties [6]. Species of *Trichoderma* sp. in addition to being a decomposer organism, it can also function as a biological agent. *Trichoderma* sp. in its role as a biological agent, it works based on its antagonistic mechanism [37]. [35], said that *Trichoderma* sp. is a parasitic fungus that can attack and take nutrients from other fungi. The ability of *Trichoderma* sp. which is able to parasitize plant pathogenic fungi and is antagonistic, because it has the ability to kill or inhibit the growth of other fungi.

Trichoderma sp. is an antagonist fungus that is preventive against plant diseases and has the ability to increase the speed of plant growth and development. This fungus also has the ability to trigger root production and increase the depth of roots below the soil surface. This deeper root causes plants to become more resistant to drought, such as corn and ornamental plants. The mechanism of this fungal antagonist can be understood as follows. When the microbes are in a dormant period, the antagonist attack of the fungus *Trichoderma* sp. can cause biological damage to the pathogen inoculum. The antagonist mechanism can be in the form of predation (biological activity where predators, organisms that hunt eat their prey, in this case the fungus *Trichoderma* sp. . will kill bad pathogens). Antibiosis (*Trichoderma* sp. also produces antibiotics belonging to the furanone group which can inhibit the growth of pathogenic microbial spores and hyphae). Parasitism (meaning that this fungus can inhibit growth by parasitism. The mechanism that occurs *Trichoderma* sp. can wrap around the hyphae of pathogenic microbes. This fungus also secretes enzymes that are able to remodel the cell walls of pathogenic microbes, so that pathogens die quickly).

4. Conclusion

Based on the results of the study, it can be concluded that the presence of the fungus *Metarhizium* sp. and *Trichoderma* sp. able to increase soil fertility after coal mining. Furthermore, investment in the fungus *Metarhizium* sp. and *Trichoderma* sp. able to increase the growth and yield of tomato plants. *Trichoderma* sp. starting from plant height, number of branches, number of flowers and fruit weight.

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