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EFFECTS OF APPLICATION OF BIOLOGICAL SOIL AMELIORANT AND REDUCTION OF INORGANIC FERTILIZERS DOSES ON GROWTH, YIELD AND QUALITY OF TOMATOES (*Lycopersicum esculentum Mill*)

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ABSTRACT
The current condition of agricultural land in Indonesia is getting less and less healthy, due to the dependence of farmers on agrochemicals. For this reason, it is necessary to use biological soil ameliorant to restore the ecological function of the soil. The purpose of this study was to explain the effect of the application of biological soil ameliorant and reduction of inorganic fertilizers doses on the growth, yield and quality of tomato. A field experiment was carried out in Merjosari Village, Lowokwaru District, Malang City. This experiment used a factorial randomized block design (RBD) where the factor I was the dose of the biological ameliorant which consisted of three levels, namely: without the biological ameliorant, 0.5, and 1 ml L-1. Factor II is the percentage reduction in the dose of inorganic fertilizer which consists of 4 levels, namely: 100%, 75%, 50% and 25% of the inorganic fertilizer dose. From these two factors there were 12 treatment combinations which were repeated three times to obtain 36 experimental plots. The variables observed included variables of plant growth, yield and fruit quality as measured by the Vitamin C content of tomato. Application of biological soil ameliorant with a concentration of 0.5 ml L-1 and 50% of recommended NPK fertilizer dose is able to provide plant growth and yields as high as the use of biological soil ameliorant with a concentration of 1 ml L-1 and a dose of 100% of recommended NPK fertilizer dose. Average of total weight fruit per plant and per hectare of the two treatments were 624.48 g plant-1 and 24.98 tons ha-1 and 431.97 g plant-1 and 17.28 tons ha-1. The vitamin C content of all treatments was not statistically significantly different except for the treatment using 1 ml L-1 water+100% of inorganic fertilizers dose which had the lowest vitamin C content.

Keywords:
Biological Soil Ameliorant; Inorganic Fertilizer; Growth; Yield; Quality Of Tomato

INTRODUCTION
Global trends nowadays towards long term sustainable crop production is hinged on either supplementing the use of chemical fertilizers with organic materials or a complete use of organic materials. This is more so since substituting chemical fertilizers with organic materials reduces the risks of exposure to ailments that arise on account of synthetic compounds and increases farmers' gains via reduced soil erosion and carbon emissions and increased bio-diversity.

To achieve food and energy security in agricultural development, an agricultural intensification program has been implemented which aims to increase production per unit area. Agricultural intensification is characterized by the use of agrochemicals in high doses to increase crop productivity. Several research results in the last few decades reported that the excessive application of fertilizers and pesticides in the long term has negative impacts on the environment, including soil degradation, greenhouse gas emissions, accumulation of pesticides, and reduction of water availability and quality (Scherr, 1999; Jie et al. ., 2002; Hafez and Thiemann, 2003; Mandal et al., 2020), as well as on human health resulting in several human health problems such as rheumatoid arthritis, kidney disease, and different cancers (Jayasumana et al., 2015 ; Parks et al., 2016). The application of synthetic fertilizers and pesticides also damages soil biodiversity. On the other hand, soil microbes are important biological components of soil and perform functions in soil fertility through nutrient cycling and organic matter degradation (Tejada et al. 2014). Soil microbes have a critical role in the functioning of terrestrial ecosystems and act as drivers of plant diversity (Van Der Heijden et al. 2008). Free-living soil microbes promote plant diversity by increasing the nutrient pool and altering the plant dominance due to symbiotic and pathogenic interactions (Prober et al. 2015). It is, therefore, necessary to consider the risks and challenges posed by agrochemical applications in agriculture for safeguarding the human health, ecosystem and environment

When organic matter is reduced, the physical structure of the soil changes. This change causes modulation in various soil physiological processes in crop production systems so that soil performance begins to decrease in productivity (Kumar et al., 2018; Tripathi et al., 2020). The decrease in the productivity of agricultural land is caused by a decrease in the performance of the soil in the agricultural production system as measured by several indicators, namely the soil structure compacts, the nutrient cycle does not go well and requires the addition of high doses of fertilizer, the water cycle is less than optimal as indicated by a decrease in soil water retention capacity, and the life cycle in the soil is disrupted as indicated by the decreased activity of soil microorganisms to support the decomposition of organic matter and various other soil processes (Lewandowski, 2000). Soil microbes are one of the most sensitive biological indicators for monitoring changes in soil quality (Pulleman et al., 2012; Schloter et al., 2003). For soil to perform well in crop production systems, it needs to be cared for and healthy. Provision of beneficial microbes to improve biological soil is beneficial to accelerate the restoration of the quality of the soil.

The use of organic soil ameliorant, such as compost, manure, biochar has been widely used to improve soils polluted by heavy metals through remediation processes (Saifullah et al., 2018; Baruah et al., 2020), and soils contaminated with toxic compounds (Palansooriya et al., 2020). These organic soil amendments can improve soil physical properties, even in sandy soils they can reduce soil erosion (Hernandez et al., 2016; Abdalla et al., 2020). Biological soil ameliorant usually use beneficial microbes to enhance processes that occur in the soil thereby improving soil quality and land productivity. It is renewable, in-situ, and relatively inexpensive, and can support the conservation of carbon in the soil. Microorganisms play a key role in soil biogeochemical processes and respond quickly to environmental disturbances (Hao et al., 2019). Various beneficial microbes play a role in various mechanisms to help plants adapt to environmental pressures (Lu et al., 2020). This study used biological soil ameliorant containing beneficial microbes in improving soil performance. The effectiveness of soil microbes was tested with a combination of inorganic fertilizers in increasing crop production. The effectiveness of these microbes can be seen from how much reduced the dose of inorganic fertilizers applied in the cultivation of tomato plants. Tomato plants were chosen as an indicator of plant productivity because tomato plants are an important commodity in supporting food availability and nutritional adequacy of the community. Tomatoes are a multipurpose commodity, namely as fruit tomatoes, beverages, appetite enhancers, cooking tomatoes, and processing products. Besides having a good taste, it also contains protein, carbohydrates, Ca, Fe, Mg, and vitamin C (± 21 mg), as well as vitamin A, phosphate, potassium and lycopene (Siagian, 2005). Vitamin A and C levels increase with increasing fruit ripeness (Opena and Van der Vossen, 1997; Wener, 2000; Sunarmani, 2008). Tomato production both in quantity and quality is still relatively low. This is due to, among other things, the effects of weather and climate, cultivation techniques applied by farmers, unbalanced fertilization, pest and disease attacks, and most importantly due to low soil quality, namely hard soil and poor in nutrients. From the description above, this study is needed on the effect of the application of biological soil ameliorant and reducing the dose of inorganic fertilizer use on the growth, yield and quality of tomatoes.

METHOD

Site, time and experimental design of this study

This research is a field experiment conducted in Merjosari Village, Lowokwaru District, Malang City. Analysis of plant yields and vitamin C content of tomatoes was carried out at the Central Laboratory of the Islamic University of Malang. The research was conducted from March 2021 to June 2021.

This field experiment used a factorial randomized block design (RBD) consisting of two factors. Factor 1 is the concentration of biological soil ameliorant which consists of 3 levels, namely: M0 = without application of biological soil ameliorant, M1 = 0.5 ml/liter biological soil ameliorant, and M2 = 1 ml/liter. Factor 2 the dosage reduction of inorganic fertilizers which consisted of 4 levels, namely: P1 = 100% of the recommended dose, P2 = 75% of the recommended dose, P3 = 50% of the recommended dose and P4: 25% of the recommended dose. From these two factors, 12 treatment combinations were obtained with 3 replications. For each treatment, 4 sample plants were taken to measure the growth, yield and quality of tomatoes. The total number of sample plants is 144.

Experimental procedures

Tomato seeds were planted in the medium mixture of rice husk biochar and soil with a ratio of 1:1. This seedling takes 3 weeks (21 days) to be ready for transplanting. Land preparation was done by tilling the soil with a hoe and then making a bed of 1m × 2m.

The biological soil ameliorant used is the NOVELGRO TERRA brand, which contains beneficial bacteria, namely phosphate solubilizing bacteria, Cellulolitic bacteria, N fixing bacteria and other bacteria. The biological soil ameliorant solution was prepared by dissolving 8 ml of Novelgro Terra in 16 liters of water for the M1 treatment, while for the M2 treatment, dissolving 16 ml of the biological soil ameliorant in 16 liters of water.

Then, the solution of biological soil ameliorant was sprayed on the well-prepared beds evenly using a sprayer two days before planting. Tomato seedlings were planted at a spacing of 60 cm × 50 cm, 21 days after seeding. Total tomato plants in each bed as many as 8 plants. Inorganic fertilizers are applied 1 week after planting by immersing them around the plants at a distance of 3-5 cm from the stems of the tomato plants and then covering them with soil. The dose of NPK fertilizer applied was 2 grams/plant (P1), 1.5 grams/plant (P2), 1 gram/plant (P3), and 0.5 grams/plant (P4). The second fertilization is done when the plants are 3 weeks old after planting with doses of 5 grams/plant (P1), 3.75 grams/plant (P2), 2.50 grams/plant (P3), and 1.25 grams/plant (P4).

Watering and manual weeding was done. The tomatoes were harvested 75 days after transplanting and were harvested three times. The observed variables were plant growth of tomato (plant height, number of leaves and leaf area, plant yield (Number of fruits, Weight of fruits per plant (g), Weight of fruit per ha (tonnes). The vitamin C content in tomatoes) fruits was measured using iodometric titration method.

The data collected was analyzed using Analysis of Variance in accordance with a Factorial Randomized Block Design (RBD) with 2 factors, if there is a significant effect then it is continued with a 5% Tukey test (HSD) to differentiate between treatments.

RESULT AND DISCUSSION

The results of the analysis of variance showed that the interaction between the application of biological soil amendments and reducing the dose of inorganic fertilizers had a significant effect on the growth of tomato plants. The addition of a biological soil ameliorant solution of 0.5 ml L^{-1} combined with the use of inorganic fertilizer 50% of the recommended dose gave the best plant growth as measured by the variable plant height, number of leaves and leaf area (Table 1).

Table 1. Effect of application of biological soil ameliorant and reduction of inorganic fertilizer dose on plant growth of tomato

Treatments		Plant Height (cm)	Number of Leaves	Leaves area (cm2)
M0	P_1	59.56 ab	109.92 b	3254.51 ab
	P_2	55.36 ab	88.92 ab	3011.61 ab
	P_3	53.46 ab	67.58 a	1947.81 a
	P_4	51.48 a	87.25 ab	2631.29 ab
M1	P_1	57.08 ab	84,00 ab	2814.03 ab
	P_2	58.46 ab	76.92 ab	2439.42 ab
	P_3	65.20 b	104.42 ab	3890.20 b
	P_4	52.75 ab	77.17 ab	1965.82 a
M2	P_1	65.28 b	70.92 ab	2016.02 a
	P_2	58.33 ab	87.00 ab	2725.54 ab
	P_3	64.92 b	91.25 ab	2698.92 ab
	P_4	66.77 b	87.50 ab	2459.39 ab
HSD 5%		13.13	39.44	1752.36

Remark : Means followed by different letters in the same column are statistically significant different by Tukey test at P=0.05; HSD =Honest Significant Difference

This means that the application of a biological soil ameliorant solution can reduce the recommended dosage of inorganic fertilizers by 50% for tomato plants. Plant growth and productivity are related to the level of soil health and fertility (soil chemistry). Soil fertility and quality can be maintained with proper soil management by adding soil organic matter or by adding biological soil enhancers (Nurhidayati, 2022). The addition of soil amendments can improve soil quality due to an increase in the activity of microorganisms in the soil in supporting biological processes in the soil. Soil microbes overcome the toxic effects of these chemicals by performing different functions in soils and making them less toxic to the environment (Malik et al., 2017). Growth is a process that occurs in plant life which causes a change in the size of the plant and the growth of the plant is getting bigger. Plant growth is influenced by 2 factors, namely genotypic factors and growing environmental factors. These plants can grow well if sufficient nutrients, water and air are available. Soil microorganisms are closely associated with plant roots, contribute to nutrient cycling, and show resistance and tolerance to pests, diseases, drought, and heavy metals and improve the soil structure. In this regard, soil microbial diversity and community composition are important indicators of soil health (Liu et al. 2016). Provision of biological soil enhancers can help release the nutrients absorbed by soil colloids so that they are available and can be absorbed by plants (Firdausi and Muslihatin, 2016). In addition, the provision of soil enhancers contains microorganisms which function as decomposers which can decompose complex compounds in the soil thereby releasing nutrients into the soil (Bending et al., 2004).

Table 2. Effect of application of biological soil ameliorant and reduction of inorganic fertilizer dose on yield of tomato

Treatments		Number of fruits	Weight of fruits per plant (g)	Weight of fruit per ha (ton)
M0	P_1	19.83 b	378.63 a	15.15 a
	P_2	17.50 ab	373.03 a	14.92 a
	P_3	12.25 a	257.37 a	10.29 a
	P_4	14.42 ab	236.47 a	9.46 a
M1	P_1	20.17 b	394.57 a	15.78 a
	P_2	16.50 ab	330.89 a	13.24 a
	P_3	19.58 b	431.97 ab	17.28 ab
	P_4	15.58 ab	285.05 a	11.40 a
M2	P_1	19.75 b	624.48 b	24.98 b
	P_2	18.92 b	380.17 a	15.21 a
	P_3	17,00 ab	406.17 a	16.25 a
	P_4	12.75 a	350.30 a	14.01 a
HSD 5%		5.97	209.07	8.36

Remark : Means followed by different letters in the same column are statistically significant different by Tukey test at P=0.05; HSD =Honest Significant Difference

The results of the analysis of variance showed that the interaction between the application of biological soil amendments and reducing the dose of inorganic fertilizers had a significant effect on tomato fruit yield. The application of a biological soil enhancer solution of 1 ml L^{-1} combined with the use of inorganic fertilizer 100% of the recommended dosage gave the highest tomato fruit yield as measured by the parameters of fruit number, fruit weight per plant and per ha (Table 2). However, this treatment was not statistically significantly different from the application of a biological soil enhancer solution of 0.5 ml L^{-1} combined with the use of inorganic fertilizers 50% of the recommended dose. Plant yield is determined by the availability of nutrients in the soil from the vegetative phase to the generative phase. The addition of biological soil amendment solutions helps increase the activity of microorganisms in the nutrient cycle which has a positive impact on plant growth and yield (Mishra et al. 2012; Bulgarelli et al. 2013). Soil bacteria and fungi are responsible for a wide range of crucial ecosystem functions and services, including primary production and nutrient mineralization (Chu et al., 2018; Mahawar and Prasanna, 2018). Meanwhile, soil microbiome (especially rhizosphere microbes) play crucial roles in soil chemical and biological processes and have important values in maintaining ecological balance and ecosystem stability (Xu et al., 2021). These processes mainly contain nutrient decomposition and uptake by plant roots (Wu et al., 2019; Zhang et al., 2020).

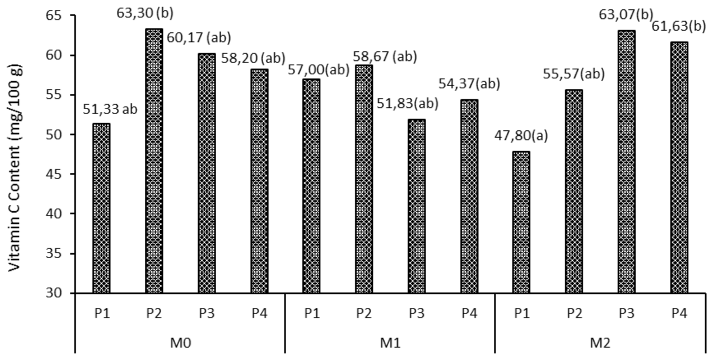

Figure 1. Effect of application of biological soil ameliorant and reduction of inorganic fertilizer dose on Vitamin C content of tomato fruits.

The results of the analysis of variance showed that the interaction between the application of biological soil amendments and reducing the dose of inorganic fertilizers had a significant effect on the vitamin C content of tomatoes. The application of 1 ml L-1 biological soil enhancer solution combined with the use of inorganic fertilizer 100% of the recommended dosage gave the highest quality of tomato fruit as measured by the parameter of vitamin C content (Figure 1). However, this treatment was not statistically significantly different from the application of a biological soil enhancer solution of 0.5 ml L-1 combined with the use of inorganic fertilizers 50% of the recommended dose. Zhen et al. (2012) reported that beneficial soil microbes not only increase plant growth and yield, but also improve cucumber quality. Nada et al. (2022) microbes in the soil are capable of producing growth regulators which can stimulate metabolic processes in plants so that the quality of crop yields increases.

CONCLUSION

Application of biological soil ameliorant with a concentration of 0.5 ml L^{-1} and 50% of recommended NPK fertilizer dose is able to provide plant growth and yields as high as the use of biological soil ameliorant with a concentration of 1 ml L^{-1} and a dose of 100% of recommended NPK fertilizer dose. Average of total weight fruit per plant and per hectare of the two treatments were 624.48 g $plant^{-1}$ and 24.98 tons ha-1 and 431.97 g $plant^{-1}$ and 17.28 tons ha^{-1}. The vitamin C content of all treatments was not statistically significantly different except for the treatment using 1 ml L^{-1} water+100% of inorganic fertilizers dose which had the lowest vitamin C content.

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