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The Effectiveness Test of Biofertilizer Phosphate-Solubilizing Bacteria (PSB) and Phosphate Fertilizer on The P availability in the Soil and Tomato Plant Tissue

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ABSTRACT

Phosphorus is one of the essential nutrients whose availability is very small in the soil. Research on the effectiveness test of biofertilizer phosphate solubilizing bacteria (PSB) and phosphate fertilizer (SP-36 and rock phosphate) on the availability of soil p and p content in tomato plant tissue to determine the effectiveness of SP-36, Rock Phosphate and PSB in increasing P availability soil. The study used factorial randomized block design with two factors and three replications. The first factor is a phosphate solvent bacterial isolate consisting of two levels, without isolate Pseudomonas sp. and with Pseudomonas sp. The second factor is phosphate fertilizer with five levels of control; SP-36 fertilizer 0.32 g/plant; SP-36 fertilizer 0.63 g/plant; rock phosphate fertilizer 0.41 g/plant; and rock phosphate fertilizer 0.81 g/plant. The data obtained were analyzed using Analysis of Variety and continued with Duncan Multiple Range Test (DMRT) test with 95% confidence level. The results showed that the administration of PSB isolate gave increased P-available, P tissue, plant height, wet weight and dry weight of plant and tomato plant production. The application of SP-36 and rock phosphate fertilizer gave an increase to P-available and P-tissue variables, whereas for the production of SP-36 fertilizer plants with dose of 65 g/plant gave higher yield compared to rock phosphate fertilizer.

INTRODUCTION

Phosphate (P) is one of the essential nutrients that plays an important role in the plant metabolism process and in general to improve the quality and quantity of products produced, so the availability of phosphate (P) for plants must be sufficient and balanced. Phosphorus in the soil is in organic and inorganic forms, but 70% of phosphorus in the soil is organic phosphorus that is not available to plants (Sharma et al. 2013). The solubility of phosphorus in the soil is very low compared to other nutrients and is greatly influenced by soil pH. P fertilization is a method that is widely used to meet plant needs, but only 10-30% of P can be absorbed by plants, the rest accumulates in the soil (Havlin et al. 2013). However, about 60–70% of phosphate fertilizers applied are either adsorbed to iron, aluminum oxides, or calcium, and are no longer directly available to the plant (Jiang et al. 2018).

The use of phosphate-solubilizing bacteria is an effective alternative in increasing the solubility of phosphorus in the soil and increasing the efficiency of P fertilization through chemical and biological dissolution (Iftikhar et al. 2023). The use of PSB will directly increase the P available in the soil, and indirectly will increase the quality and levels of P in plant tissue. Tomato plants are one of the plants that require phosphorus in the process of growth and development. Tomato plants are used as an indicator to determine whether the use of PSB can effectively dissolve P into inorganic forms available to plants, by looking at the levels of P in tomato plant tissue. The study was conducted to determine the effectiveness of administering phosphate-solubilizing bacteria (PSB) and phosphate fertilizer in increasing the availability of soil P and tissue P levels in tomato plants.

METHODS

Location and Time

The research was conducted in March 2017 to June 2017 which took place in the Greenhouse of the Faculty of Agriculture and the Soil Fertility Laboratory of the Department of Soil Science, Faculty of Agriculture, University of Jember. Soil sampling as a planting media was carried out in Kesilir Village, Wuluhan District, Jember Regency, which was taken compositely. The soil to be used as a planting media was sterilized first for 2 x 4 hours.

Method of Colloecting Data

The study was conducted using a factorial Randomized Block Design (RBD) with two factors and three replications. The first factor was the inoculation of phosphate-solubilizing bacteria with two levels: without inoculation of Pseudomonas sp. (I0) and with inoculation of Pseudomonas sp. (I1). The second factor was the application of phosphate fertilizer with five levels, namely control (P0); SP-36 fertilizer 0.32 g/plant (P1); SP-36 fertilizer 0.63 g/plant (P2); rock phosphate fertilizer 0.41 g/plant (P3); and rock phosphate fertilizer 0.81 g/plant (P4).

Data Analysis

The research was carried out by implementing several stages of activities including: 1) Rejuvenation and multiplication of Pseudomonas sp. isolates. Rejuvenation and multiplication of Pseudomonas sp. bacteria were carried out for 15 days using NA (Nutrient Agar), NB (Nutrient Borth), and pikovskaya media, 2) Preparation of planting media and tomato seeds. The sterilized soil was weighed as much as 5 kg/polybag and then labeled, while the tomato plant seeds used were Permata variety tomatoes. The seeds were ready to plant after 25 HST, 3) Application of treatment. The effectiveness test intended in this study was to determine the performance of PSB isolates and phosphate fertilizers applied to increase available P and P levels in tomato plant tissues. Application of bacterial isolates and phosphate fertilizers (SP-36 and rock phosphate) was carried out before planting. Application of PSB isolates as much as 10 ml/polybag with a PSB population of 12 x 108 CFU/ml, while phosphate fertilizers according to recommendations with SP-36 0.63 g/plant and rock phosphate 0.81 g/plant. Treatment was carried out 7 days before planting so that BSP isolates and phosphate fertilizers were incubated first in the planting medium, 4) Planting and maintenance of tomatoes. Planting of tomato seedlings is done in the afternoon by planting 3 seedlings/polybag, after the plants grow well, one of best plant is selected in each polybag. The maintenance stages include watering every afternoon, weeding and installing stakes, 5) Harvesting. Harvesting is done when the plants are 78 DAP old by taking all the fruits on each plant. Harvesting is done when most of the fruits are ready to be harvested, 6) Sampling. Soil samples are taken before planting and during harvesting, while tissue samples are taken when the plants enter the generative phase, namely when the plants flower, 7) Soil and tissue analysis. Soil analysis is divided into 2 parts, namely preliminary analysis and final analysis. The preliminary and final analysis carried out include pH and soil-available P (Olsen method). While tissue P analysis uses the wet destruction method.

RESULTS AND DISCUSSIONS

Preliminary analysis was conducted to see the initial chemical properties of the planting media, the following are the results of the preliminary analysis of the soil used which can be seen in table 1.

Table 1. Chemical properties of the soil of the planting media

Types of analysis	**Unit**	**Value**	**Category*)**
pH H_2O (1:2,5)	-	6,35	Slightly acidic
P-Available	Ppm	14,39	Medium

*) (Horneck et al. 2011)

Based on the results of the analysis conducted, it shows that the available P content in the initial soil is medium, so that treatment is given to increase the available P and also the P of tomato plant tissue. The following are the results of the analysis of the diversity of observation variables shown in table 2.

Table 2. Results of the analysis of observed variables

Observed variables	**Isolate**	**P Fertilizer**	**Isolate X P Fertilizer**
P-Available	37,55**	6,93**	1,41ns
P-Tissue	1,94**	4,51*	1,81 ns
Plant height	784,46**	448,67**	3986,66**
Wet weight of plants	37,77**	2,70 ns	1,68 ns
Dry weight of plants	31,09**	3,35*	4,96**
Soil pH	14,16**	0,90ns	0,66ns
Crop production	34,98**	19,28**	2,72ns

Description: **very significantly different; *significantly different; ns not significantly different

Based on the table above, it can be seen that the interaction between phosphate fertilizer and inoculation of phosphate-solubilizing bacteria is very significantly different in the variables of plant height and plant dry weight and is not significantly different in available P, tissue P, wet weight and plant production. The combination of giving phosphate-solubilizing bacteria and P fertilizer significantly increases the height and dry weight of tomato plants. This is because the phosphate needs of tomato plants are met so that it directly supports plant growth and development.

Soil available P content

The availability of phosphorus is determined by the soil pH, the amount and level of decomposition of organic matter and microorganisms in the soil (Iftikhar et al. 2023). Based on the graph in Figure 1, it shows a difference between the provision of phosphate-solubilizing bacteria (PSB) isolates and without PSB isolates on the P-available in the soil.

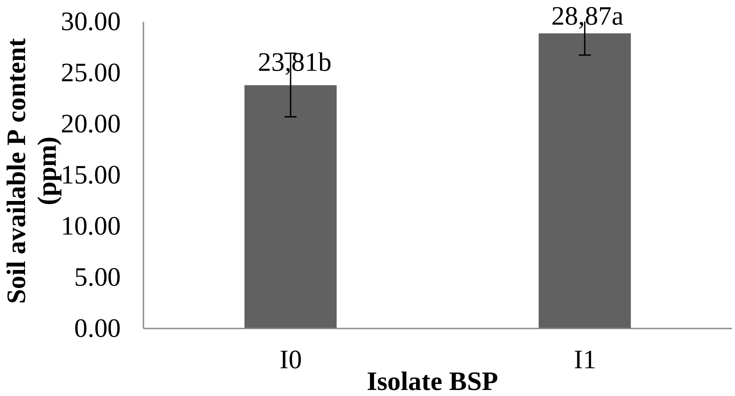

Figure 1. The effect of BSP Isolate on Available P Content in Soil

Changes in soil available P after being given BSP isolate treatment were able to increase available P by 5.06 ppm. The increase in available P compared to the control occurred because BSP isolates could dissolve unavailable P into available P for plants through biological mechanisms by producing phytase, phosphatase and phosphonatase enzymes (Khan et al., 2014) and chemically by producing organic acids such as citric acid, lactic acid and other organic acids.

Figure 2. shows the differences in response to increasing available P due to the administration of different phosphate fertilizer treatments at certain doses.

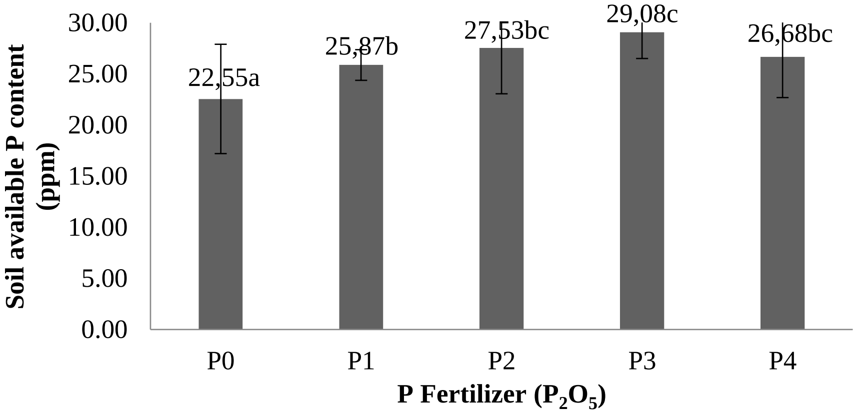

Figure 2. Effect of phosphate fertilizer on available P content in soil

The response given showed that the provision of rock phosphate fertilizer provided a higher increase in available P compared to others, namely the P3 treatment, but was not significantly different from the P2 treatment of 29.08 ppm. This is because rock phosphate fertilizer has a slow release property whose solubility is gradual compared to inorganic fertilizers such as SP-36, also because the rock phosphate used is Ciamis rock phosphate which has a fairly high reactivity (Oteino et al. 2015).

P-Tissue Content of Tomato Plants

Figure 3 shows the difference in the P response of tomato plant tissue between the administration of BSP isolate and without BSP isolate.

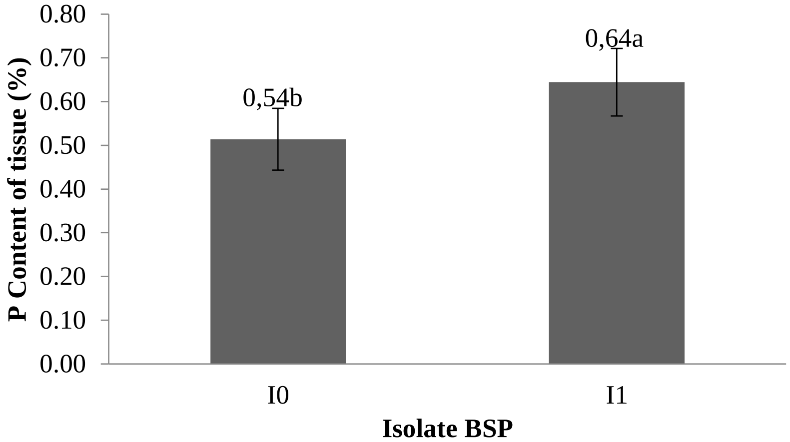

Figure 3. Effect of BSP isolate on P content of tomato plant tissue

The administration of BSP isolate can increase the P content of tomato plant tissue by 0.10%, where the BSP isolate treatment shows a tissue P value of 0.64%. Plants will easily absorb nutrients and meet their needs if the availability of nutrients in the soil is high. Application of phosphate solubilizing bacteria can enhance tomato plant growth by fulfilling phosphate requirements (Tchakounte et al. 2020). Based on Figure 4 shows the high available P results when given BSP isolate treatment. This proves that there is indeed a correlation between nutrient content in the soil and nutrients in plant tissue.

Based on Figure 4, the administration of SP-36 and rock phosphate fertilizers gives different responses to the P content of tomato plant tissues.

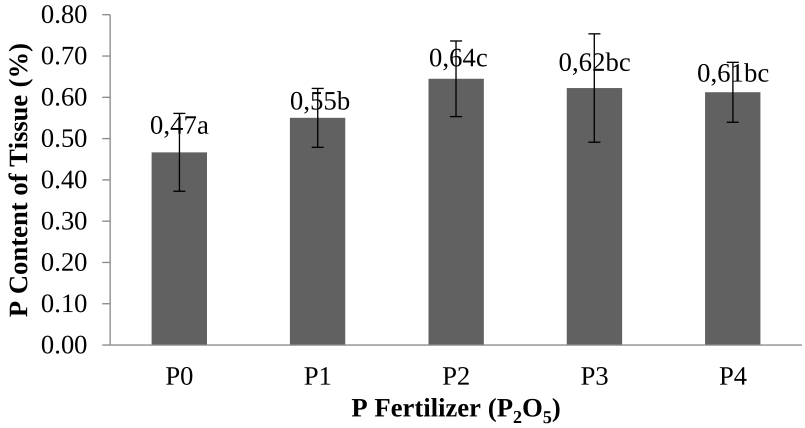

Figure 4. Effect of phosphate fertilizer on P content of tomato plant tissue

The highest tissue P value was obtained from the P2 treatment, which was 0.64%, but it was not significantly different from the P3 and P4 treatments. The P2 treatment was the administration of SP-36 fertilizer with a dose of 0.63 g/plant. SP-36 fertilizer has a higher solubility compared to rock phosphate so that P absorption by plants is higher, but after further testing, it turned out to show no significant difference.

Plant Height

The combination of BSP isolate and phosphate fertilizer treatments had a significant effect on the plant height variable as shown in Figure 5.

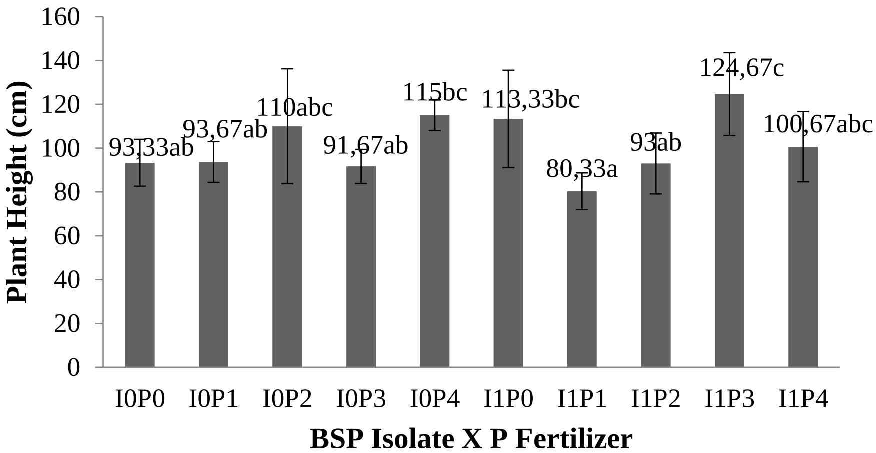

Figure 5. Tomato plant height in the 9th week

The best treatment with the highest plant height value was I1P3 which was not significantly different from the treatments I0P2, I0P4, I1P0 and I1P4. However, the combination treatment of bacteria with rock phosphate fertilizer at a dose of 0.41 g/plant (I1P3) still contributed to a higher increase in plant height compared to the bacterial control, so that the inoculation treatment of phosphate-solvent bacteria had a significant effect on increasing the height of tomato plants. The I1P3 treatment gave the highest plant height value of 124.67 cm.

Wet Weight of Plants

Figure 6. shows the effect of BSP isolate on the wet weight of tomato plants.

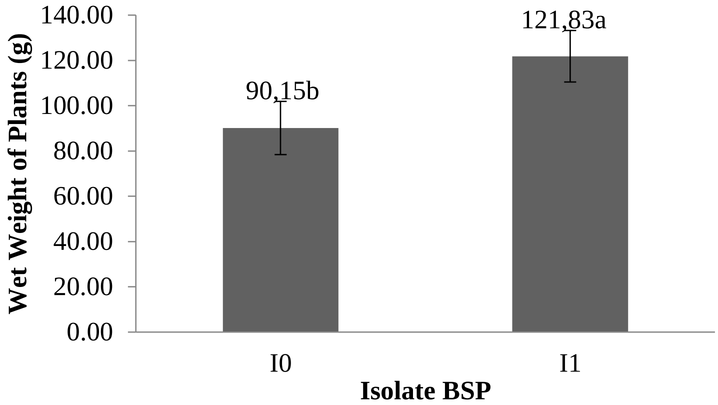

Figure 6. Wet weight of tomato plants in the 9th week

On average, the administration of BSP isolate was able to increase 31.68 grams of the wet weight of tomato plants compared to without BSP isolate. The administration of BSP isolate was significantly able to increase the available P in the soil. If the available P content is high, the absorption of P nutrients by plants is also high. The need for P is met, encouraging increased plant metabolic activity so that the process of adding plant biomass or the process of plant growth increases, thus directly increasing the wet weight of plants.

Dry Weight of Plants

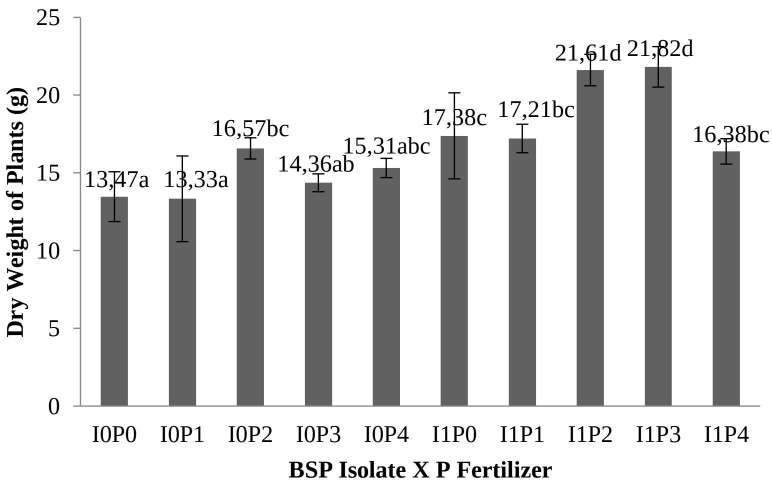

Figure 7. Dry weight of tomato plants in the 9th week

Based on Figure 7, it shows that the combination of BSP isolate and phosphate fertilizer provides a significant interaction on increasing plant dry weight. The highest plant dry weight value in the I1P3 treatment combination, namely the combination of BSP isolate and rock phosphate fertilizer with a dose of 0.41 g/plant of 21.82 grams.

Tomato Plant Production

The response of tomato plant production to the administration of BSP isolate in Figure 8

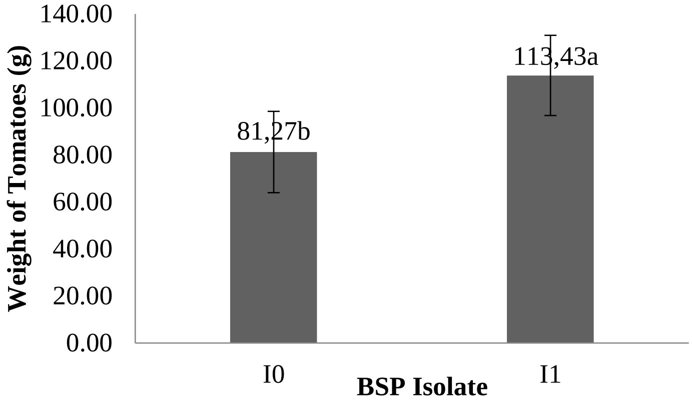

Figure 8 Effect of BSP isolate on production per tomato plant at 78 DAP

The administration of BSP isolates resulted in higher production compared to without BSP isolates. Tomato plant production at 78 DAP with BSP isolate treatment was 113.43 grams. The administration of BSP isolates affected the increase in tomato plant production by 32.16%. This is because BSP is able to increase P-available in the soil and indirectly has a positive effect on fruit production.

The difference in tomato plant production response to the phosphate fertilizer treatment given is shown in Figure 9.

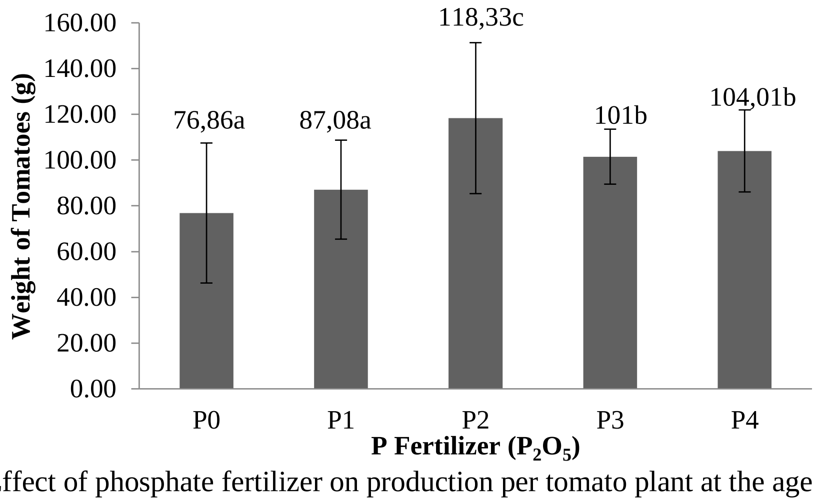

Figure 9. Effect of phosphate fertilizer on production per tomato plant at the age of 78 DAP

Treatment P2 gave the highest results compared to other treatments. The increase in fruit weight produced per plant was 118.33 grams. The provision of SP-36 fertilizer affected fruit production. The P element plays an important role in the fruit formation process, so if the P content of the tissue is high, it will indirectly have a positive effect on fruit formation.

Discussion

Phosphorus (P) is one of the macronutrients that is absolutely needed by plants and plays an important role in the metabolic process, so that its availability greatly affects the growth and development of plants. The provision of phosphate-solubilizing bacterial isolates is expected to be able to increase the P-available soil so that it will directly have a positive effect on plant growth and development which can be seen from the observation variables carried out.

The administration of BSP isolates had a very significant effect on increasing available P, tissue P, plant fresh weight, and fruit production. Phosphate fertilizer treatment had a significant effect on the variables of available P, tissue P, and fruit production per plant. The interaction of the two treatments only affected the variables of plant height and dry weight and had no significant effect on other variables.

The increase in available P is influenced by the administration of BSP isolates and also by phosphate fertilizers. The ability of BSP isolates to dissolve P provides an increase in available P in the soil. The mechanism of dissolving phosphate compounds by phosphate-solubilizing bacteria is carried out biologically and also chemically. Biological dissolution by producing phosphatase, phytase and phosphonatase enzymes (Ginting, 2007) which play a role in the mineralization process where organic phosphate compounds are broken down into inorganic ones by breaking phosphate bound by organic compounds into available forms (Suliasih et al., 2010) and chemically by producing organic acids which play a role in releasing bonds by organic ligands. The increase in available P by BSP isolates directly increases the P of tomato plant tissue, fresh weight and tomato plant production. This is because the P element plays an important role in the plant growth process which directly affects plant biomass and plant development which plays a role in the process of fruit formation and maturity.

The combination of I1P3 treatment is a treatment that provides an increase in plant height and also higher dry weight compared to other treatments. This is not only because of the high phosphorus content but also because the phosphate-solubilizing bacteria used (Pseudomonas sp.) is a type of bacteria that also has the ability to stimulate plant growth. Phosphate-solubilizing bacteria act as PGPR which produce growth regulators such as IAA hormones and gibberellins and resist root pathogens. This ability further supports the growth process of tomato plants, so that the use of phosphate-solubilizing bacteria has many uses besides being able to dissolve phosphorus into available forms and also act as PGPR (Sabrina et al. 2020). In addition, the combination of isolate and rock phosphate fertilizers contributes effectively to increasing phosphorus in the soil. The increase in dry weight of plants is because the P element contributes 0.2-0.8% of the total dry weight of the plant.

CONCLUSIONS

Based on the research that has been done, it can be concluded that application biofertilizer of bacterial solubilizing Phosphate (BSP) and phosphate fertilizer (SP-36 and rock phosphate) increases the height and dry weight of tomato plants, while administration of bacterial solubilizing Phosphate (BSP) isolates can increase P-available, P-tissue, wet weight and tomato plant production compared to phosphate dissolving bacteria controls, and administration of SP-36 and rock phosphate fertilizers can increase P-available and P-tissue of tomato plants.

Further research on the effectiveness test of phosphate solubilizing bacterial biofertilizer and phosphate fertilizers (SP-36 and rock phosphate) on the availability of soil P and the P content of tomato plant tissue can be conducted on a wider area and up to the final production of tomato plants so as to fully understand the effect of treatment on plant production.

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