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The Ability of a Consortium of Cellulose-Degrading Bacteria in Fixing Nitrogen, Dissolving Phosphorus and Potassium, and Its Application as a Bifertilizer in Tomato Plants

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Abstract

This study aims to determine the ability of cellulose-degrading bacteria to fix nitrogen, dissolve phosphorus and potassium, and assess their effectiveness as biofertilizers for tomato plants. The research method used is quantitative descriptive, involving in-vitro testing and field application with two treatments: P0 (without bacteria) and P1 (with bacteria). The results of this study indicate that cellulose-degrading bacteria possess additional capabilities in nitrogen fixation, as evidenced by a color change in the NFB medium to blue, and demonstrate the ability to solubilize phosphorus and potassium, as indicated by the formation of clear zones in the Pikovskaya and Alexandrov media. Field testing showed that cellulose-degrading bacteria were effective in tomato plants, influencing plant height parameters but not affecting leaf area or number of leaves. Based on the results of the Two-Way ANOVA analysis on the treatments conducted, there was no significant effect, as the P-value was >0.005. Cellulose-degrading bacteria in vitro have the ability to provide nutrients. However, they are not yet effective in enhancing the vegetative growth of tomato plants.

Keywords: Tomato; Cellulose-Degrading Bacteria; In-Vitro; Tomato.

INTRODUCTION

Tomatoes (Lycopersicum esculentum Mill.) are a highly popular horticultural crop. Tomatoes contain complex vitamins and nutrients (Faldi et al., 2022). Tomato production in Indonesia increased from 1,114,399 tons to 1,168,744 tons in 2021 and decreased to 24,956 tons in 2023 (National Statistics Agency, 2024).

Tomato production continues to increase, including through fertilization to provide nutrients to plants. A common problem is that most tomato plants are cultivated conventionally, relying on inorganic fertilizers as a source of nutrients. However, conventional farming can negatively impact the surrounding environment and agricultural land in the long term (Nurtika & Gunadi, 2009).

The decline in tomato production in Indonesia is caused by a decline in agricultural land quality, which leads to decreased soil fertility, which in turn impacts the condition of the land itself, leading to a decline in the physical and chemical properties of the soil, including a decrease in organic content, damage to micro and macro elements, and decreased microorganism activity in the soil. This is feared to damage the chemical, physical, and biological properties of the soil in the long term (Puspitorini et al., 2025).

The decline in soil quality, or agricultural land degradation, is caused by the excessive use of chemical fertilizers, which can reduce soil fertility. According to Calvin Wuisang, reporting from Radio Republik Indonesia (RRI), excessive use of chemical fertilizers can increase soil acidity (pH) due to the accumulation of residues such as nitrate and ammonium. These compounds can reduce soil nutrients and cause nutritional imbalances. Field data indicate that chemical fertilizer use remains relatively high, as confirmed by a 2023 field survey, which found that chemical fertilizer use on crops reached 38.66 kg/ha (Central Statistics Agency, 2024).

According to Marwantika (2020), the use of chemical fertilizers in high quantities and over a long period of time causes agricultural land degradation, which reduces organic carbon in the soil, resulting in decreased crop production.

Soil loses its porosity due to increased acidity, which dissolves mineral-rich soil particles and makes it difficult for water to penetrate. This reduces soil air circulation, making it infertile. Of the 13 nutrients available to plants, only a small fraction are available for plant growth because they are in an unavailable (non-absorbable) form (Handayanto & Muddarisna, 2017).

The use of cellulose-degrading bacteria (CBA) as a biofertilizer is relatively new. These bacteria are generally used as catalysts to break down organic matter during the composting process. CBA produces the enzyme cellulase, which breaks down cellulose into simpler compounds and aids in nutrient supply. According to Simanungkalit et al. (2006), the breakdown of organic material, particularly cellulose, can restore essential macro and micro nutrients to the soil. This process also enriches the soil and helps increase tomato plant productivity.

According to Subhan et al., 2009 (in Afifi et al., 2018), tomatoes require relatively large amounts of the nutrients N, P, and K. Nitrogen plays a crucial role in protein production, leaf growth, and photosynthesis. Phosphorus plays a key role in stimulating root growth and the formation of a strong root system in young plants, as well as in the composition of the cell nucleus (nucleic acid). Potassium plays a role in protein and carbohydrate formation, as well as increasing resistance to disease and pests, and improving plant quality.

This study aimed to determine the ability of a consortium of cellulose-degrading bacteria to fix nitrogen and dissolve phosphorus and potassium in the soil. This study references the research of Febriani (2023), whose results indicate that phosphorus-solubilizing bacteria (PSOs) also have the ability to fix nitrogen and dissolve potassium. The application of PSO-based biofertilizers to tomato plants serves as a benchmark for the ability of cellulose-degrading bacteria to best increase nutrient availability for tomato plant growth.

METHOD

This research was conducted over nine months at the Integrated Laboratory of the Lebak Environmental Service (DLH). The study used a completely randomized design with two treatments (P0 = without bacteria, P1 = with bacteria) and five replications.

Research Tools and Materials

The tools used in this study include: aluminum foil, autoclave, Bunsen burner, petri dish, Drigalsky, Erlenmeyer flask (1000 ml, 500 ml, 100 ml), hot plate & stirrer, loop needle, filter paper, Laminar Air Flow (LAF), Micropipette, incubator, pipette, heat-resistant plastic, pH meter, plastic wrap, ruler, spatula, marker, gloves, UV-Vis Spectrophotometry, analytical balance, test tubes, tissue.

The materials used in this study were Selective Media (CMC, Pikovskaya, NFB, Alexandrov), tomato seeds, planting media (rice husk, soil, humus, animal manure), polybags, Aquadest, Consortium of Cellulose-Degrading Bacteria from BSIP Plantation, soil and fertilizer (Genus includes: Pseudomonas, Bacillus, Paracoccus, Cellulomonas).

Procedure

Selective Media Creation and BPS Consortium Screening.

- *Media CMC*

Composition: Carboxy Methyl Cellulose (CMC) media is made in 200 ml with a composition of 2 g CMC; 0.04 g MgSO4.7H2O; 0.15 g KNO3; 0.1 g K2 HPO2; 0.004 g FeSO4.7H2O; 0.008 g CaCl2.2H2O; 0.4 g cypress extract; 3 g bacto agar, and 0.1 g glucose. The mixed materials are then sterilized in an autoclave at 121°C for 15 minutes. The results of selective Carboxymethyl Cellulose (CMC) media.

- *Media Pikovskaya*

Prepare the tools and materials, mix 3 g of Pikovskaya specific media with 200 ml of distilled water, stir until boiling, sterilize in an autoclave at 121°C for 15 minutes, the result is Pikovskaya selective media (P).

- *Media Nitrogen Free Bromothymol Blue (NFB) semi solid*

The composition of the media is malic acid 1 g, KOH 0.8 g, K2HPO4 0.1 g, FeSO4 0.01 g, MnSO4 0.002 g, MgSO4 0.004 g, NaCl 0.004 g, CaCl2 0.004 g, Na2MoO4 0.002 g, BTB (Bromothymol Blue) 2 ml, bacto agar 0.36 g for semi-solid media, 200 mL of distilled water, put the ingredients in an Erlenmeyer flask containing distilled water, heated on a hotplate while stirring, adjust the pH to around 6.7-7.1 if it is too acidic, add 2.5% NaOH, otherwise if it is alkaline, add 2.5% HCl, add agar and stir until homogeneous, sterilize by autoclaving at a temperature of 121° at a pressure of 1 atmosphere (ATM), transfer the media to a test tube in LAF, the results of the selective NFB media.

- *Media Alexandrov*

Composition: 2.5 g glucose, 10 g agar, 0.5 g MgSO4•7H2O, 0.05 g CaCO3, 0.006 g FeCl3, 2.0 g Ca3PO4, and 1.5 g K2HPO4 Prajapati & Modi, (2012) in Jaya et al., (2021), put all the ingredients in an Erlenmeyer flask containing distilled water, heat on a hotplate while stirring, check the pH using a pH meter, set the pH to 6.7-7.1, if it is too acidic, add 2.5% NaOH, if it is too alkaline, add 2.5% HCl, add agar, stir until homogeneous, sterilize by autoclaving at 121° with a pressure of 1 atmosphere (ATM), pour the media into a petri dish in the LAF, the results of Alexandrov's selective media.

- *Media Nutrien Broth*

Weigh 8 g of instant media dissolved in 1L of distilled water while heating, stirring as often as possible, adjust the pH to around 6.7-7.1 if it is too acidic add 2.5% NaOH, otherwise if it is alkaline add 2.5% HCl, Sterilize by autoclaving at a temperature of 121° with a pressure of 1 atmosphere (ATM), transfer the media to a petri dish in LAF, Nutrient Borth liquid media.

- *Screening of Cellulose Degrading Bacteria*

A bacterial consortium was grown on selective CMC media using the spread plate method and then incubated for 4-7 days. The grown BPS were transferred to new CMC media, isolated using point inoculation (to determine the clear zone produced by the bacteria), incubated for 5-7 days in an incubator at 37°C, resulting in the isolation of Cellulose Degrading Bacteria.

Test the ability of bacteria to attach N, dissolve P and K in vitro.

- *Nitrogen Fixation Test*

Prepare the tools and materials, make Nitrogen free Bromothymol Blue (NFB) media in a test tube, observe the color change caused by the biochemical reaction with a positive result in the form of a color change from yellow to bluish.

- *Phosphorus and Potassium Dissolution Test*

Prepare the tools and materials, then make Pikovskaya (Phosphorus) and Alexandrov (Potassium) media, then inoculate the isolate on Pikovskaya media using the dot method, observe the clear zone that is formed, calculate the phosphate solubility index using a ruler.

Production of BPS-Based Biofertilizer and Its Application to Tomato Plants

- *Making Biofertilizer*

BPS-based Biofertilizer: Prepare Nutrient Broth (NB) liquid media as the main ingredient of biofertilizer and bacterial isolates with the best ability, inoculate the bacteria on the NB media using an ose needle by taking all the isolates that grow on the media. After the main ingredient of the biofertilizer is ready, mix the NB media containing the BPS isolate with the planting media (Contains: Rice husks, animal manure, soil, humus). After mixing evenly, put the planting media in a polybag (30x30 cm size) then marked according to the treatment.

- *Application in Plants*

Prepare the planting media that has been labeled according to the treatment, plant the tomato seeds that have been sown previously, observe the growth parameters using a ruler on the height of the plant, and the area of compound leaves with the formula (length x width x constant (Susilo, 2015)), and calculate the number of compound leaves.

Statistical Test (SPSS) Using Two Way Anova Test

Parameter data including plant height, leaf area, and number of leaves were entered into SPSS and analyzed using the Two-Way ANOVA test to determine the comparison between the two groups.

RESULTS AND DISCUSSION

Cellulose-degrading bacteria are bacteria that produce cellulase enzymes to decompose polysaccharides (cellulose) into simpler compounds, namely glucose. Cellulose-degrading bacteria are often found in the natural environment, such as leaf litter, soil rhizosphere, compost, and piles of organic matter.

Based on screening results and macromorphological observations of cultures incubated for 3x24 hours at 37°C, two colonies of cellulose-degrading bacteria were obtained and assigned codes A and B. Based on macromorphological observations of the cellulose-degrading bacterial colonies, they were found to be irregular in shape (not perfectly round), with a cloudy white colony color for (code A) with a smooth colony edge shape, while in (code B) the color of the bacterial colony was found to be yellowish white with a slight brownish color and an irregular colony shape (not perfectly round). These bacteria are cellulose-degrading bacteria (CB) because they can grow on specific CMC media, this is in line with the statement of Kurniawan et al. (2019) stated that bacteria that can grow in specific CMC media are cellulose-degrading bacteria because they can utilize the carboxymethyl cellulose (CMC) contained in the media as a nutrient.

According to Lynd et al., 2002, cited in Murtiyaningsih & Hazmi (2017), CMC media contains a CMC substrate that can be degraded or broken down by BPS. If bacteria can grow in this medium, it indicates that they are cellulose-degrading bacteria. These bacteria are propagated using the streak plating method and then used to test the bacteria's ability to fix nitrogen, dissolve phosphate, and potassium in vitro on specific media.

Testing the Ability of Cellulose Degrading Bacteria to Fix Nitrogen, Dissolve Phosphorus and Potassium.

Nitrogen Fixation Test

Nitrogen-fixing bacteria are bacteria that can convert free nitrogen into ammonium and nitrate, making them usable by plants. Nitrogen-Free Bromhytol Blue (NFB) semi-solid medium is a specific medium for identifying bacteria with nitrogen-fixing ability through the biochemical reactions they cause, indicated by a positive result in the form of a color change resulting from the Bromothymol Blue indicator reacting with the nitrogenase enzyme activity.

A positive result in medium coded A is indicated by a blue color change in the NFB semi-solid medium. A negative result in medium coded B is due to the absence of a color change in the NFB semi-solid medium. A positive result in the cellulose-degrading bacterial isolate indicates that the bacteria can fix nitrogen. This is in line with the research results of Ekowati et al. (2021). Based on their research, three isolates showed positive results: TBP B3, TB1 B2, and TMA B2. All three isolates showed a blue color change in the NFB semi-solid

medium due to nitrogenase activity, which produces basic ammonia compounds.

The presence of nitrogenase activity indicates a color change in the positive control coded A, which initially turned yellowish to bluish. This is because the NFB medium contains the indicator compound Bromothymol Blue, which can change color to bluish when in an alkaline environment (Hasan and Ansori, 1992 in (Ekowati et al., 2021).

According to Ekowati et al. (2021), the nitrogen fixation process carried out by bacteria is caused by the activity of the nitrogenase enzyme, which begins when free nitrogen in the air (atmosphere) binds to a complex with the nitrogenase enzyme. First, the Fe protein in the nitrogenase complex will be reduced by electrons from ferredoxin or flavodoxin. Next, the reduced Fe-Mo protein will donate a pair of electrons to the N2 substrate, so that the triple bond becomes broken HN=NH due to the addition of H+ ions. Then the double bond HN=NH is broken and becomes H2N-NH2. Ultimately, the nitrogenase process becomes 2NH3 (Simanungkalit et al., 2006).

The color change in the semi-solid NFB media, to a blue color produced by the cellulose-degrading bacteria, is not very intense or faint. This is suspected to be due to the nitrogenase enzyme produced by the cellulose-degrading bacteria not being very high, so the medium affected by the nitrogenase enzyme does not reach its optimal point.

Phosphate Dissolution Test

Phosphate-solubilizing bacteria are bacteria that can dissolve insoluble phosphates from the soil or fertilizers applied to plants (Larasati et al., 2018).

Based on the results of phosphate solubilization tests by cellulose-degrading bacteria coded A, a clear zone (halo zone) was found around the colony, while colonies of bacteria coded B did not. Qualitatively, bacteria that can be identified as phosphate-solubilizing are characterized by the presence of a clear zone on selective Pikovskaya media. Pikovskaya media containing cellulose-degrading bacterial isolates showed the formation of a clear zone surrounding the bacterial colony. The clear zone produced by the bacteria originates from the phosphatase enzyme, which works by enzymatically catalyzing the hydrolytic mineralization reaction by releasing insoluble phosphate into soluble form. Pikovskaya media contains insoluble phosphate, namely Ca3(PO4)2, which is then utilized by the bacteria (Larasati et al., 2018).

The phosphate dissolution mechanism generally occurs due to the acidification process by phosphate-dissolving microbes by producing organic and inorganic acids that can release the chelate bond between phosphate and chelators, such as calcium (Ca), thereby causing a decrease in the pH value (Mardyansah & Trimulyono, 2021).

Potassium Dissolution Test

Potassium-solubilizing bacteria are bacteria capable of dissolving difficult-to-dissolve potassium or decomposing potassium from its source, allowing plants to utilize it as a source of potassium for plant growth and development (Rivki et al., 2023).

Cellulose-degrading bacteria in Alexandrov selective media were used to determine their potassium-solubilizing ability. The bacterial colonies in Figure 4.4 produce clear zones, qualitatively indicating that these colonies are capable of dissolving potassium. The clear zones are created by bacteria producing organic acids such as oxalic acid, citric acid, tartaric acid, formic acid, and malic acid (Ketut et al., 2022). These organic acids help accelerate the mineral dissolution process in the potassium source, resulting in the release of free potassium into a readily available form (Archana, 2007 in Ketut et al., 2022).

According to Rivki et al. (2023), bacteria with the ability to dissolve potassium are characterized by the presence of a clear zone, this occurs because of the presence of organic acids produced by the bacteria which then bind with K ions from the K2HPO4 bond in Alexandrov media and release the HPO4 bond to form a clear zone in the Alexandrov selective media.

Application of Cellulose Degrading Bacterial Culture in Tomato Plants

The study was conducted in the researcher's yard from May to June 2025 with the aim of determining the effect of the application of cellulose-degrading bacteria with the ability to fix nitrogen, dissolve phosphate, and potassium on the vegetative growth of tomato plants. The parameters observed included plant height, leaf area, and number of leaves during the initial 3-week vegetative period with treatments consisting of P0 (without bacteria) and P1 (with bacteria), each treatment repeated 5 times.

Plant Height Parameters

Plant height is an indicator of growth or a parameter used to measure and determine the effect of cellulose-degrading bacteria on tomato plants, which researchers applied in this study. Increased plant height is a form of increased cell division (Harjanti et al., 2014). According to (Wicaksono et al., 2020), plant height is one parameter that can be used to determine vegetative plant growth, which is influenced by several factors such as stem physiology and others. The results of the average plant height growth values in Table 1 are presented as follows:

Table 1. Average plant height growth.

Week	Treatment	Test					Average (cm)
		I	II	III	IV	V	
Week 1	P0	6	5,3	8,1	5,7	3,2	5,66
	P1	5,8	7,1	6	5,5	4,9	5,86
Week 2	P0	7	5,7	9,4	6,7	3,4	6,44
	P1	6,3	8,1	6,7	5,9	5	6,4
Week 3	P0	7,6	6,5	13,5	6,9	4	7,7
	P1	8	12	9,8	7,6	7	8,88

The results of this study obtained an average value for plant height as shown in Table 1. The average value in the first week, the treatment without isolate (P0) showed a value of 5.76 cm, while the treatment with isolate (P1) obtained a value of 5.86 cm. The visible difference indicates that the administration of cellulose-degrading bacterial isolates with the ability, tends to be able to increase plant height parameters, with a not too large difference. In the second week of observation, the treatment without isolate (P0) was slightly higher than the treatment with bacteria (P1) this is because the bacteria can still provide available nutrients effectively in the second week. This makes tomato plants unable to grow optimally.

Tomatoes experienced an increase again when entering the 3rd week, as in Table 1, the increase shows that the average value of plant height is very visible in the P1 treatment (with bacteria) getting an average value of 8.88 cm

Compared to P0, which was 7.7 cm, the difference reached 1.18 cm. This is likely due to the tomato plant's strong response to absorbing nutrients provided by cellulose-degrading bacteria in the soil, particularly nitrogen, which aids vegetative growth.

Based on SPSS analysis using Two-Way ANOVA, it was found that the observation time factor (per week) had a significant impact or influence on plant height ($p = 0.033$ (<0.05). However, the treatment between P0 and P1 did not have a significant value ($p = 0.564$ (>0.05), meaning it had no significant effect on plant height. Similarly, the interaction between observation (per week) and treatment did not have a significant effect on plant height. Figure 1 shows a graph of plant height growth:

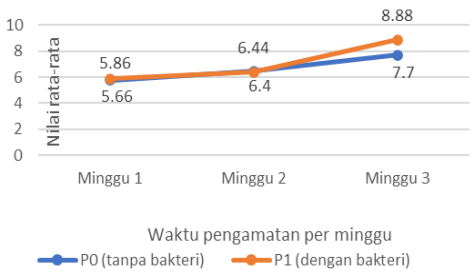

Figure 1. Graph of plant height growth.

Based on the average value graph in Figure 1, the average increase in plant height parameters in the first week to the 3rd week increased significantly in each of the P0 and P1 treatments. The increase in the P0 treatment reached 2.04 cm, while in the P1 treatment it increased by 3.02 cm in the last 3 weeks. This increase occurs due to the metabolic activities of cellulose-degrading bacteria in fixing non-symbiotic nitrogen with tomato plants during the vegetative period, bacteria provide nitrogen in available form and help the growth of tomato plants, especially helping tomato stems extend upwards. According to Sapalina et al., (2022) stated that the mechanism of nitrogen fixation by non-symbiotic bacteria is by separating O2 molecules produced during nitrogen fixation using the nitrogenase enzyme so that it produces nitrogen that can be absorbed by plants (Afifi et al., 2018).

Available nitrogen is absorbed by tomato plants which is then used in physiological processes such as the formation of chlorophyll cells for photosynthesis that produces energy, which is needed for cell division, elongation, and enlargement to increase the height of tomato plant stems, nitrogen is also used for the synthesis of amino acids, and other metabolite compounds. Nitrogen is a major component in the formation of cell walls, the formation of cells, tissues and organs in plants. Elements other than nitrogen, namely phosphorus, which helps plant growth, this is because phosphorus plays a role in the dark phase, photosynthesis, respiration, and is also part of nucleotides (Wales et al., 2023). Phosphorus is also responsible for the formation of ATP in tomato plants which affects the processes of respiration, translocation, and photosynthate in tomato plants (Adji et al., 2024), thus affecting plant growth.

Number of Leaves Parameter

According to Edu Farmers International, leaf count is the total number of leaves on a plant and is used as an indicator of plant growth. The purpose of counting leaves is to explain the growth process occurring in plants. The following are average results for tomato plants, presented in Table 2:

Table 2. The average number of leaves for tomato plants.

Week	Treatment	Test					Average
		I	II	III	IV	V	
Week **1**	P0	4	4	5	4	5	4,4
	P1	4	5	4	4	5	4,4
Week **2**	P0	4	5	5	5	4	4,6
	P1	5	5	5	4	4	4,6
Week **3**	P0	6	6	7	6	5	6
	P1	6	6	6	6	5	5,8

Based on the results of the average value of the number of leaves parameter in Table 2, in the first week, the P0 and P1 treatments obtained an average value of 4.4. However, in contrast, in the second week of observations, the P1 treatment experienced a decrease of 4.2 compared to the P0 treatment with 4.6. This occurred because in the P1 treatment, the tomato leaves were damaged, resulting in leaf loss, but the cause of the loss could not be ascertained. The results of observations in the third week showed an increase in the average number of leaves. However, the P1 treatment had a lower value than the P0 treatment due to the previous damage factor caused by leaf loss in the P1 treatment that occurred in the second week.

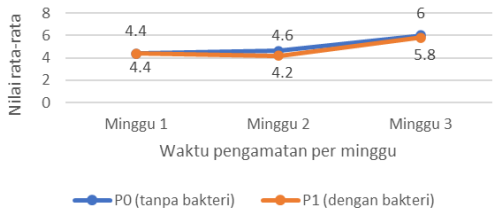

Figure 2. Graph of the average of the number of tomato leaves.

The graph in Figure 2 shows a decrease in the average value of the compound leaf number parameter for tomatoes in the second and third weeks in the P1 treatment. This loss is likely due to several external factors, such as poor weather over the past few weeks, such as high rainfall, which has caused leaf blight on tomato leaves, causing yellowing and subsequent leaf loss, which has resulted in a decrease in the average leaf number parameter. Other factors include nutrient deficiencies, such as Ca and Zn, which play a role in preventing tomato plants from experiencing chlorosis and necrosis. Chlorosis and necrosis are symptoms of yellowing tomato leaves and the death of plant tissue or leaf tissue. Approximately 50% of leaf loss occurs due to this, with initial symptoms being yellowing and then becoming paler, ultimately leading to leaf loss (Rumah Petani, 2020).

Lack of nutrients available to tomato plants can cause damage and an inability to grow, as in the leaf number parameter. In addition to external factors such as high rainfall, which causes leaf blight, nutrient deficiencies also impact plant growth. Potassium deficiency in plants affects the performance of enzymes that normally increase activity in plastids, protein synthesis, photosynthetic activity, and stomatal movement which increases chlorophyll levels in leaves (Adji et al., 2024).

According to Cahyono (2014) in Wales et al., (2023), adequate nutrients can support plant metabolism, which can run smoothly, thus increasing growth, including leaf number.

Leaf Area Parameter

Leaves are one of the plant organs with important functions, such as photosynthesis and transpiration. Therefore, leaf area is a crucial parameter in analyzing tomato plant growth (Irwan & Wicaksono, 2017). The following data on average leaf area is presented in Table 3:

Table 3. Average leaf area.

Week	Treatment	Test					Average (cm^2)
		I	II	III	IV	V	
Week **1**	P0	1,413	0,694	1,901	0,911	0,278	1,039
	P1	0,667	1,433	0,694	0,597	0,706	0,821
Week **2**	P0	1,230	0,800	2,448	1,909	0,326	1,342
	P1	1,141	2,048	1,086	0,963	0,329	1,113
Week **3**	P0	2,629	2,778	6,212	4,548	1,520	3,537
	P1	2,448	4,234	3,016	3,586	2,084	3,073

Based on the results in Table 3, the average value of each treatment increased each week. Measurements of leaf area parameters for the treatment without bacteria (P0) resulted in a larger leaf area than for the treatment with bacteria (P1). This may be due to morphological compensation in the tomato plants.

Based on the results of the SPSS Two-Way ANOVA analysis of tomato leaf area, it was found that the time factor (week of observation) significantly affected leaf area with a p-value of 0.00 (<0.05), indicating a significant increase in leaf area per week. However, the treatment administered to the plants did not significantly affect leaf area, and the interaction between treatment and time (week of observation) did not significantly affect leaf area.

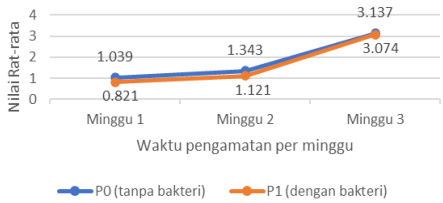

Figure 3. Graph of average of tomato leaf area.

The graph shows the average leaf surface area values, as shown in Figure 3. The treatments P0 and P1 showed an increase in leaf area from the first week to the third week. However, the P0 treatment yielded higher yields than the P1 treatment, due to leaf morphological compensation resulting from stress experienced by the tomato plants. Many factors can influence tomato plant stress, one of which is a lack of nutrient availability. This stress causes leaf expansion to optimize and maintain physiological functions (photosynthesis). This is consistent with research conducted by Trumble et al., 1993, which explains that damage caused by plant pests (OPT) causes plants to respond by compensating for morphological changes in leaf morphology, increasing leaf size to maintain photosynthetic function.

Morphological compensation in leaf area increases leaf expansion by increasing cell size through mesophyll elongation or an increase in cell number. This expansion is influenced by the enlargement of chloroplasts resulting from the accumulation of starch through increased turgor pressure, turgor pressure provides a force for expansion in cells (Trumble et al., 1993).

This study shows that biofertilizer based on cellulose degrading bacteria has no effect on the vegetative growth of tomato plants both statistically and descriptively, only the plant height parameter has a high average value. The working mechanism of BPS-based biofertilizer, the biofertilizer degrades cellulose in the planting medium or cellulose in nature, then BPS has the ability to fix nitrogen, dissolve phosphorus and potassium, making organic materials, especially cellulose, into nutrients available to tomato plants.

CONCLUSION

Based on the research conducted, the following conclusions can be drawn:

- The cellulose-degrading bacterial consortium has the ability to fix nitrogen, indicated by a bluish color change in NFB media, while the solubilization of phosphorus and potassium is indicated by the presence of a clear zone produced by the bacteria.
- The application of biofertilizer to tomato plants resulted in an average plant height effect after treatment with bacteria (P1). However, the treatment did not affect leaf number and leaf area, and the treatment did not statistically affect the parameters or did not achieve significant results in the ANOVA analysis.
- Further research is needed to determine the effectiveness of cellulose-degrading bacteria on other plants, such as those in the leguminosae family.

Conflict Of Interest Statement: The authors declare that there no conflict of interest.

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