

POTENTIAL OF PGPR AND NUTRIENT SOLUTION APPLICATION IN INCREASING PSB POPULATION DENSITY, P UPTAKE AND YIELD OF TOMATO (*Solanum lycopersicum* L.) PLANT IN A HYDROPONIC SYSTEM

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ABSTRACT

The hydroponic system is an alternative technology to plant cultivation as a solution to overcome the limitation of agricultural land. Tomato (*Solanum lycopersicum* L.) production with this system has its own market segment. To increase the production of tomatoes in a hydroponic system requires the precise composition and dosage of nutrients, and the use of nutrients effectiveness needs to be increased through the application of an effective “Plant Growth Promoting Rhizobacteria” (PGPR) consortium. This experiment aims to determine the potential effectiveness of the PGPR consortium and to find the properly dose of hydroponic nutrients to increase the viability of Phosphate Solubilizing Bacteria (PSB), plant P uptake, and tomato yield in a hydroponic system. The research design used was a factorial randomized block design (RBD) consisting of two factors, namely the dose of the PGPR consortium consisting of three levels (0 ml/polybag, 5 ml/polybag, and 10 ml/polybag and the second factor was the nutritional dose: three levels (0 ml, 250 ml, and 500 ml). The experimental results showed that there was no interaction between the application of the PGPR consortium and hydroponic nutrition on the population of phosphate solubilizing bacteria, P uptake of tomato plants and tomato yield. The application of the PGPR consortium did not show a significant effect in increasing the PSB population, P uptake and yield, but the PGPR consortium tended to have the potential to increase the PSB population density, P uptake and tomato fruit weight, although were not increasing significantly. While the application of nutrient significantly increased Phosphate uptake, population of phosphate solubilizing bacteria and tomato yield. The dose of 250 ml/pot produced the highest tomato yield which reached 839.33 g/plant.

Keywords: Consortium, Hydroponic, Phosphate Solubilizing Bacteria (Psb), P Uptake, Tomato (*Solanum Lycopersicum* L).

1. INTRODUCTION

Indonesia tomato production in 2014 according to [2], was 895,163 tons, this figure decreased compared to tomato production in 2013 which was 992,780 tons. The need for agricultural products is increasing along with the increase in population. Decreasing in tomato production can be caused by several factors, namely environmental factors and leached land due to the use of chemical fertilizers, displacement of agricultural land. So that, the alternative technology to overcome these obstacles is tomato production using a hydroponic system. Hydroponics is a technology for cultivating plants without using soil as a planting medium [12], needs macro and micro nutrient which are applied in the form of a nutrient solution. Meanwhile, the material for the planting media used in hydroponic system must selecting the porous materials and has capability strongly to hold water [28; 30]. Husk charcoal and cocopeat are media that can be used as hydroponic growing media. Husk charcoal is able to bind water and crumbly, and its structure is easy to store oxygen and has high porosity [27]. Meanwhile, cocopeat has a great water-holding ability. The water content and water retention in cocopeat are 119% and 695.4%, respectively [8].

The advantages of the hydroponic system compared to conventional planting are better in its hygiene, easier for land and weed management, very efficient use of fertilizers and water, high-quality production plants, higher crop productivity, plants that are easy to select and controlling properly and can be cultivated in a narrow area [26]. Composition and doses of nutrition in hydroponic systems are important factors [15]. Using nutrition too low doses lead showing no significant effect to the plant yield, while Nutrition uses at too high doses can cause plants to undergo plasmolysis [14; 32]. One of the hydroponic methods according to [29] report that is developed in Indonesia for the first time until now is substrate hydroponics. Several things that need to be considered in the development of substrate hydroponic technology are the selection of planting media and the arrangement of the nutrient composition used [4].

Phosphorus is the second essential nutrient after nitrogen needed by plants. Elemental P in nature bound with oxygen is called a phosphate compound. Plants absorb phosphate in the form of inorganic phosphate ions, especially H_2PO_4^- and HPO_4^{2-} . Phosphorus is divided into two forms, namely P-organic and P-inorganic. P-organic comes from plant, animal, and microbial residues. The availability of organic P for plants is highly dependent on microbial activity to mineralize it. In the process of mineralization of organic matter, organic phosphate compounds are decomposed into inorganic phosphate forms available for plants by the enzyme catalytic of phosphatase enzymes [7; 19]. Phosphatase is an enzyme system that will be produced when the availability of phosphate is low. Phosphatase is excreted by plant roots and microorganisms [9]. The phosphatase enzyme can break the phosphate bound by organic compounds into available forms. In addition to phosphatase enzymes produced by phosphate solubilizing bacteria, there are also other enzymes such as phytase, phyrophosphatase, and metaphosphatase enzymes.

The PGPR consortium contains various types of functional microorganisms. The consortium used in this study consisted of *Azotobacter chroococum*, *Azotobacter vinelandii*, *Azospirillum* sp., endophytic bacteria *Acinetobacter* sp., as N fixing bacteria group, and groups of phosphate solubilizing microbes such as *Pseudomonas cepacia* and *Penicillium* sp. The provision of the

PGPR consortium is expected to be able substituting the need for phosphate nutrients for plants. The results of Priyadi's research (1998)[21] showed that caisim plants treated with phosphate solubilizing bacteria, *Azospirillum* sp. and sp. produced yield of caisim of 39 - 47 t ha⁻¹ net weight. Endophytic bacteria *Acinetobacter* sp., phosphate solubilizing bacteria (*Pseudomonas cepacia*) and phosphate solubilizing fungi (*Penicillium* sp.) are useful in facilitating the supply of nutrients, as a biological fertilizer, are also able to streamline the use of NPK and increase crop yields[23]. The application of the PGPR consortium providing N and P nutrients and providing phytohormones belonging to Plant growth promoting Rhizobacteria (PGPR) group which can promote the plant growth [25].

Phosphate solubilizing microbes are included the PGPR group that can release phosphate nutrients bounded to Fe, Ca, Mg or Zn, and can produce phosphatase enzymes and phytohormones [6; 17]. The phytohormones produced can be in the form of auxins and cytokinins. Auxin phytohormones function stimulate root growth, regulate cell enlargement and trigger plant cell elongation, and increase apical dominance and xylem differentiation. Auxins are found in actively growing meristematic tissues such as plant shoots, root tips, twig shoots and leaves. Auxin phytohormones that are abundant in nature and the most active are Indole Acetic Acid [31; 18]. Indole acetic acid is the main auxin that needed for inducing plants growth [11]. Cytokinin phytohormones function to influence root growth and differentiation, promote root cell division and germination. Thus, the use of the PGPR consortium is expected to improve root growth that led to increase P uptake, population of phosphate solubilizing bacteria, tomato productivity and be able to reduce the need of inorganic nutrients in hydroponic cropping systems. However, the potential of PGPR in this research has not been tested for its effectiveness as a functional inoculant in a hydroponic system to increase tomato yields.

The purpose of this study is focused on assessing the effectiveness of the PGPR consortium inoculant on the viability of phosphate solubilizing bacteria, plant P uptake and tomato yield.

2. MATERIALS AND METHODS

The research was carried out on a greenhouse scale in the experimental garden of the Faculty of Agriculture, Padjadjaran University, Jatinangor, Sumedang Regency. The research location is at an altitude of ±725 meters above sea level (asl) with an average temperature of 29°C and an average humidity of 41.3%. The materials used in this study were (1) a mixture of husk charcoal and cocopeat with a ratio of 2: 1 and a weight of 1.7 kg/polybag; (2) Valoasis variety tomato seeds; (3) consortium of PGPR inoculants obtained from the collection of the Soil Biology Laboratory, consisting of *Azotobacter chroococum*, *Azotobacter vinelandii*, *Azospirillum* sp., endophytic bacteria *Acinetobacter* sp., phosphate solubilizing bacteria (*Pseudomonas cepacia*) and phosphate solubilizing fungi (*Penicillium* sp.), (4) hydroponic nutrition.

2.1. Experimental Design

The experiment was carried out using a factorial randomized block design (RBD) consisting of two factors.

The first factor was the dose of the PGPR consortium (P) consisting of three levels:

p0 : Control (without PGPR consortium);

p1 : PGPR Consortium 5 ml/pot;

p2 : PGPR Consortium 10 ml/pot.

The second factor was the dose of hydroponic nutrients (H) which consists of three levels:

h0 : Control (without application of hydroponic nutrients);

h1 : Hydroponic nutrition 250 ml/ pot;

h2 : Hydroponic nutrition 500 ml/ pot.

The parameters observed consisted of the population density of phosphate solubilizing bacteria (PSB) using Total Plate Count (TPC) method which using Pikovskaya's media. P uptake was carried out by wet ashing method with HClO₄ and tomato yields were the yield of the number of tomatoes per plant and the fruit weight per plant.

2.2. Tomato Seeding and Planting.

Tomato seeds of Valoasis variety were sown in pot trays measuring 25 cm x 40 cm x 5 cm with seedling media in the form of husk charcoal. Seeds were sown in planting holes with a depth of 1 cm. Maintenance was done by watering single day until the age of 25 days. The medium for plant growth consisted of a mixture of husk charcoal and cocopeat with a ratio of 2:1 and a weight of 1.7 kg/pot. Planting media was prepared in pot measuring 20cm x 25cm. The hydroponic nutrients used consisted of solution A (6.6 kg CaNO₃), solution B (2.4 kg KH₂PO₄; 1.8 kg KNO₃), solution C (5.4 kg MgSO₄), and solution D (0.42 kg FeSO₄; 3 g CuSO₄; 12 g MnSO₄; 12 g H₃BO₃; 1 g Ammonium-Hepta Molybdate; 6 g ZnSO₄). Water was added to each solution until it reached a volume of 30 L, then stirred until homogeneous. The treatments consisted of control (without nutrition), recommended dose (250 ml), and one recommended dose (500 ml). Tomato seeds that were 25 DAS (days after sowing) were transferred to planting media in pot.

2.3.PGPR Consortium Application and Observations.

The PGPR consortium inoculant was applied twice during observation were at the time of planting (0 WAP) and two weeks after planting (2 WAP). The method of application of the PGPR consortium was through injection in the area nearby the root.

Harvesting was done when the fruit is almost ripe, marked by the rupture of the color of the tomato fruit, which is reddish yellow and the fruit is not too hard. Harvest age of tomatoes fruit plants was 10 WAP to 12 WAP. Harvesting was done 5 times, gradually with an interval of 3-5 days of harvesting[22].

3. RESULTS AND DISCUSSION

3.1 Phosphate Solubilizing Bacteria (PSB) population.

The investigation results based on statistical analysis showed that there was no significant interaction effect between the application treatment of the PGPR consortium and hydroponic nutrition on the population density of PSB, but there was a significant difference in the treatment using hydroponic nutrition. The results of the analysis are shown in Table 1.

Table 1. Effect of PGPR consortium and Hydroponic Nutrients on PSB Population.

Treatment	Density of PSB (10^5 CFU g^{-1})
PGPR Consortium Dosage (P)	
$p_0 = 0$ ml pot $^{-1}$ (control)	53,98 a
$p_1 = 5$ ml pot $^{-1}$	43,73 a
$p_2 = 10$ ml pot $^{-1}$	64,06 a
Hydroponic Nutrition Dosage (H)	
$h_0 = 0$ ml (control)	30,21 a
$h_1 = 250$ ml pot $^{-1}$	75,52 b
$h_2 = 500$ ml pot $^{-1}$	56,03 ab

Note: The numbers with the same letter means the significantly different according to Duncan's Double

Distance Test at the 5% level.

The results of Duncan's multiple-distance test showed that the application of the PGPR consortium between different doses treatment did not show a significant difference to the population density of PSB per pot. However, the application of a dose of 10 ml/pot showed the PSB population tended increasing compared to the 5 ml/pot treatment, although statistically is not significantly increase.

The variation dose of Nutrition treatment showed a significant increase in PSB population density compared to the control treatment, but there was no significant difference between the 5 ml/pot treatment and the 10 ml/pot treatment. In fact, it appears that the PGPR consortium application of 10 ml/pot tended increasing population of PSB. The highest PSB population density occurred at a dose of 250 ml/pot (h_1) nutrition application with a population density of phosphate solubilizing bacteria of 75.52×10^5 CFU g^{-1}

The effect of the PGPR consortium application on the population of phosphate solubilizing bacteria did not show an increasing in the PSB population. This phenomenon was occurred due to the negative compatibility between indigenous species and augmented inoculants. Besides that, carbon sources derived from organic materials in the growing media have not been able to

provide the nutrient requirements for phosphate solubilizing bacteria for their growth. This is a result of the organic matter contained in the medium not yet fully decomposed, this hypothesis is proven by evident from the C/N levels of media was high. A high C/N content means that the N element in the medium is in low level, while the C element has a higher value and difficult to degraded. According to [5] reported that organic matter with low N content, high C, and high lignin will affect the rate of decomposition of the organic matter, namely the material will decompose longer when compared to a low C/N ratio, making it was unavailable carbon source for PSB community. Poerwowidodo [20] stated that rice husks and coconut husks are organic materials that are difficult to decompose, and cocopeat containing high lignin can reduce the rate of decomposition [3]. As a result of the slow decomposition rate, the sources of C, N and P for PSB are low and there will even be competition between microbial groups in the system for obtaining sources of C and the also other nutrients. Simanungkalit [24] stated that due to nutritional competition, the need for C,N, P and other nutrients was not met, microbial activity would be inhibited or work less than optimally.

Result of this study reveal that the nutritional needed by PSB are met by hydroponic nutrition. There was an increase in PSB population density at a dose of 250 ml/pot. However, it also showed that in high nutrient concentrations resulted in decreased PSBF population and inhibited growth. This phenomenon can be explained that the activity of microorganisms will not be maximized if the conditions of the growing media have an abundant nutrient content. Pal [16] reported that nutrition concentration in high level will even suppress the growth of PSB due to the phenomenon of inhibition of high substrate.

3.2 Tomato plant Phosphate uptake.

Phosphate uptake of tomato plant is the process of transporting P ions in the planting medium to plant roots through mass flow or diffusion. Elemental P is absorbed by plants in the form of primary orthophosphate ($H_2PO_4^-$) and secondary orthophosphate (HPO_4^{2-}) [33]. The results of statistical analysis showed that due to the application of the PGPR consortium there was no interaction between the PGPR consortium application and the application of hydroponic nutrients on plant P uptake, but the use of hydroponic nutrients independency application appeared to have a significant effect between treatments. The data are shown in Table 2.

Table 2. Effect of PGPR consortium and Hydroponic Nutrients on Phosphate Uptake.

Treatment	P- uptake (mg plant ⁻¹)
PGPR Consortium Dosage (P)	
b ₀ = 0 ml pot ⁻¹ (control)	123,92 a
b ₁ = 5 ml pot ⁻¹	118,09 a
b ₂ = 10 ml pot ⁻¹	126,12 a

Hydroponic Nutrition Dosage (H)	
h ₀ = 0 ml (control)	1,97 a
h ₁ = 250 ml	165,66 b
h ₂ = 500 ml	200,49 c
Note : The numbers with the same letter means the significantly different according to Duncan's Double Distance Test at the 5% level.	

The application of PGPR consortium treatments showed that were not significantly different effect, but the 10 ml/pot dose treatment tended higher than 5 ml/ pot nutrient application and control treatments, resulting in P uptake of up to 126.12 mg/plant (Table 3). This study revealed that the application of PGPR consortium at a dose of 10 ml/pot has the potential to provide P nutrients through its catalytic activity of providing available P to plants, so that P uptake at a dose of 10 ml/pot has a tendency to increase. As according to [1], microbes will produce phosphatase and phytase enzymes as well as existing organic acids, which will increase available P. Duncan's multiple distance difference test showed that the best treatment using hydroponic nutrients is shown at the addition of 500 ml/pot of nutrients with a P uptake of 200.49 mg/plant. Phosphate uptake increased with increasing nutrient dose application. Provision of nutrients is able to provide a supply of nutrients that are easily absorbed by plants through the roots. According to [10], nutrients can be absorbed by plants through roots and leaves in the form of ions available to plants. The absorption of ions by plants takes place continuously because plant roots are always in contact with nutrients. The results of this study showed that tomato plants were still able to absorb Phosphate from the nutrient solution at a dose of 500 ml/pot.

3.3 Tomato Plant Yield

The yield of tomatoes in this study was represented by the number of tomato fruits and the weight of the tomatoes produced. The results of the analysis are shown in Table 3.

The experimental results showed that the application of the PGPR consortium did not show a significant increase to the number of Tomato fruit nor tomato fruit weight, however, it appears that the application of the PGPR consortium at a dose of 5 ml/pot tends to have the potential to produce higher fruit weight than other treatments, namely 471.56 g/plant. This shows that phytohormones and growth regulators produced from the PGPR consortium can play a role in increasing the growth performance of tomato plants which results in an increase in tomato fruit weight.

Table 3. Effect of Biological Fertilizer and Hydroponic Nutrients on Tomato Yield.

Treatment	Number of Tomato fruits	Weight of the tomatoes (g plant ⁻¹)
PGPR Consortium Dosage (B)		
b ₀ = 0 ml pot ⁻¹ (control)	3 a	401,89 a
b ₁ = 5 ml pot ⁻¹	3 a	471,56 a
b ₂ = 10 ml pot ⁻¹	3 a	362,89 a
Hydroponic Nutrition Dosage (H)		
h ₀ = 0 ml (control)	0 a	0,00 a
h ₁ = 250 ml	6 b	839,33 c
h ₂ = 500 ml	3 b	397,00 b
Noted : The numbers with the same letter means the significantly different according to Duncan's Double Distance Test at the 5% level.		

The experimental results showed that based on statistical analysis the application of hydroponic nutrients showed a significant effect on increasing the number of fruits and fruit weight. Duncan's multiple spacing test showed that the treatment dose of 250 ml/pot of hydroponic nutrients was the best treatment, with a total of 6 fruits and a fruit weight of 839.33 g/plant. The use of hydroponic nutrients with the recommended dose (500 ml/ pot) turned out to produce lower tomato crop yields. This phenomenon shows that the concentration of nutrients at a dose of 500 ml/pot indicated a dose that exceeds the requirement, so that it tends leading to nutrient poisoning which can inhibits the growth rate of the plant. Thus the treatment of dose of nutrients (250 ml/pot) was quite effective in increasing the yield of tomato plants.

4.CONCLUSION

The application of the PGPR consortium and hydroponic nutrients to tomato plants (*Solanum lycopersicum* L.) in the hydroponic system did not show any interaction with PSB population density, P uptake in tomato plants and tomato yields. From the independent treatment effect, it, was shown that the application of the PGPR consortium could not significantly increase BPF

population density, P uptake, and the number and weight of tomatoes in a hydroponic system. While the application of hydroponic nutrition at a dose of 250 ml/pot increased the highest PSB population density of 75.52×10^5 CFU/g, producing the highest number of fruits and weight of tomatoes were 6 pieces/plant and 839.33 g/plant, respectively. And the dose of hydroponic nutrients that can increase the highest Phosphate uptake by plant is at a dose of 500 ml/pot.

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