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Effect of Plant Growth Promoting Rhizobacteria (PGPR) on Growth and Yield of Soybean

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Abstract
This study aimed to (1) examine the effect of giving PGPR (Plant Growth Promoting Rhizobacteria) to increase soybean growth and production and (2) obtain the best dose of PGPR to increase soybean growth and production. The research was carried out in Tontalete Village, Kema District, North Minahasa Regency, North Sulawesi from June 2021 to October 2021. The field experiment was arranged in a Randomized Block Design (RBD). The treatment tested was the concentration of PGPR, which consisted of P0 = 0 ml/l (control), P1 = 5 ml/l, P2 = 10 ml/l, P3 = 15 ml/l, and P4 = 20 ml/l. The treatment was repeated three times, so there were 15 experimental units. Parameters observed were: plant height, number of branches, number of pods per plant, percentage of damaged pods per plant, the weight of 100 dry seeds, and seed yield/plot. The data were analyzed using the Analysis of Variance (ANOVA) and continued with the mean difference test using the Least Significant Difference Test (LSD) at the 5% level. The results showed that the application of PGPR affected the growth and yield of soybeans by increasing plant height, the number of pods per plant, and dry seed yield. The highest dry seed yield was achieved at PGPR concentrations of 10 ml/l and 15 ml/l, which were 1.34 g and 127.87 g, equivalent to 1.34 tons ha^{-1} and 1.28 tons ha^{-1}, respectively.

Keywords: Soybean, Plant Growth Promoting Rhizobacteria (PGPR), Productivity

INTRODUCTION

Soybeans are a type of legume that has high nutritional value. As a source of protein, soybeans are very beneficial for health because they contain the nutrients the body needs. Soybeans can be processed into various types of food, for example, tofu, tempe, flour, milk, soybean oil, etc. In Indonesia, the need for soybeans will continue to increase from year to year, along with the increase in population, while there is a gap in the amount of soybean demand and soybean production. To meet this need, the government imports soybeans and throughout 2021 it will reach 2.6 million tons. Ministry of Agriculture (2021), envisions that Indonesia's soybean production will continue to decline from 2021 to 2024. In 2021, the projection for domestically produced soybeans will reach 613.3 thousand tons, down 3.01% from last year which reached 632.3 thousand tons. tons. In 2022, Indonesia's soybean production will again fall by 3.05% to 594.6

thousand tons. A year later, soybean production will decrease by 3.09% to 576.3 thousand tons. Meanwhile, soybeans originating from Indonesia fell 3.12% to 558.3 thousand tons in 2024.

It was further explained that this decline was caused by intense competition in terms of land use with other strategic commodities, such as corn and chillies. This also resulted in a decrease in harvested area of around 5% per year, higher than the projected soybean productivity increase of 2% per year.

Soybeans are a type of legume that is highly nutritious. They are an excellent source of protein and contain several essential nutrients that are beneficial for the body. In every 100g of soybeans, there are approximately 172 calories and a variety of the following nutrients: 18,2 g protein; 8,4 g carbohydrates; 9 g fat; 6 g fibre, 100 mg calcium, 8 mg iron, 850– 900 mg potassium, and 500 IU vitamin A (Makarim, 2023).

In Indonesia, the demand for soybeans continues to increase every year due to the increase in population, while there is a gap in terms of the supply of soybeans. To meet this demand, the government imports soybeans, and in 2021, it will import 2.6 million tons. The Ministry of Agriculture (2021) estimates that soybean production in Indonesia will continue to decline from 2021 to 2024. In 2021, the projection for domestically produced soybeans will reach 613.3 thousand tons, which is 3.01% lower than the previous year's production, which was 632.3 thousand tons. In 2022, Indonesia's soybean production is expected to decline by 3.05%, to 594.6 thousand tons. A year later, soybean production is projected to decrease by 3.09% to 576.3 thousand tons. Meanwhile, soybeans originating from Indonesia fell 3.12% to 558.3 thousand tons in 2024.

This decline in soybean production is due to tight competition for land use with other strategic commodities such as corn and chilies. This competition has resulted in a decrease in harvested areas, which is around 5% per year, higher than the projected soybean productivity increase of 2% per year. Efforts to increase soybean production can be achieved through intensification or extensification programs, or by expanding planting areas. Intensification efforts, such as the release of superior soybean varieties, have been carried out. These varieties have a production potential of up to 3.5 tons per hectare and an average yield of 2.5 tons per hectare when optimal cultivation technology is applied. In North Sulawesi, there is still a possibility for area expansion due to favorable climate and agricultural land conditions. However, farmers or farmer groups are not yet familiar with soybean plants, as previous planting trials have resulted in low production levels below 1 ton per hectare. As academics, we are challenged to find solutions to soybean problems, and we need to test every aspect of environmentally friendly soybean cultivation technology by utilizing plant growth-promoting bacteria.

Literature Review

Root bacteria that promote plant growth known as Plant Growth Promoting Rhizobacteria (PGPR) are a group of beneficial microbes that live in the root zone of plants. These bacteria live around the roots of plants/plants, by utilizing the exudate released by the plant in question. This group of bacteria does not damage or interfere with plant life but can provide several benefits to increase plant growth (mutualistic symbiotic relationship). Some examples of ePGPR (non-symbiotic) such as Agrobacterium, Arthrobacter, Azotobacter, Azospirillum, Bacillus, Burkholderia, Caulobacter, Chromobacterium, Erwinia, Flavobacterium, Micrococcus, Pseudomonas and Serratia etc. Similarly, some examples of iPGPR (symbiotic) are Allorhizobium, Azorhizobium, Bradyrhizobium, Mesorhizobium and Rhizobium from the Rhizobiaceae family. Most of the rhizobacteria included in this group are gram-negative bacteria. In

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addition, many actinomycetes are also one of the main components of rhizosphere microbial communities that exhibit extraordinary plant growth (Ahemad and Kibret, 2014; Bhattacharyya and Jha, 2012;).

Plant Growth Promoting Rhizobacteria (PGPR) are soil bacteria that live around or on the surface of roots. They are involved in promoting plant growth and development directly or indirectly through the production and secretion of various growth-regulating compounds around the rhizosphere (root area). These rhizobacteria facilitate growth by helping plants acquire nutrients such as nitrogen, phosphorus, and other essential minerals. They also modulate plant hormone levels. Additionally, they act as biocontrol agents by reducing or inhibiting the development of soil pathogens. The mechanism of action of PGPR is presented in the figure. (Ahemad and Kibret, 2014; Chandran, et.al., 2020; Backer, et.al., 2018; Shah, et.al., 2021).

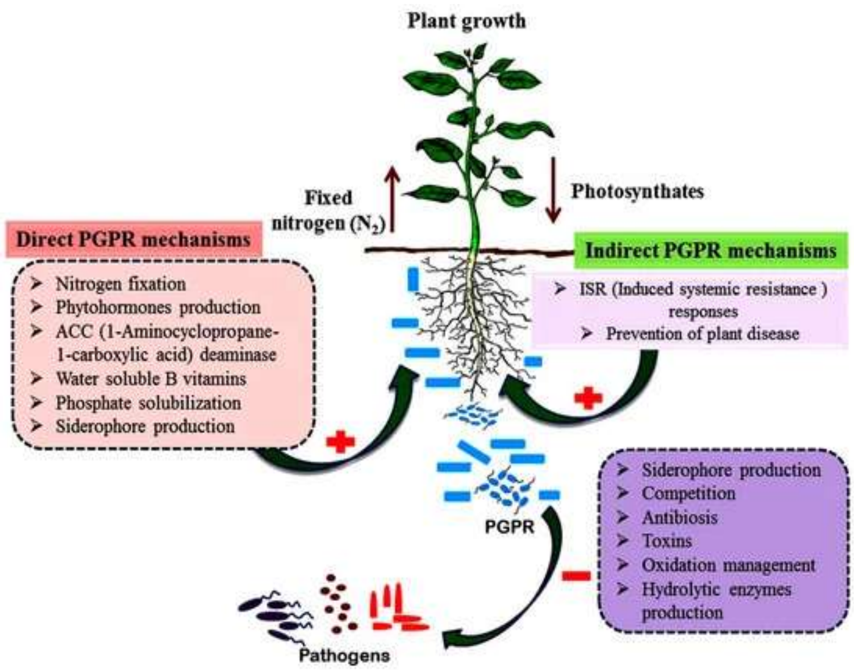

Figure 1. Mechanism of PGPR (Chandran, et.al., (2020)

Research on PGPR has been widely carried out by researchers both on food crops and horticultural crops, and from the research results it was found that PGPR affects plants in terms of increasing plant growth and production. Arfandi (2019) in the results of his research on soybean plants showed that giving PGPR affected the growth and production of soybean plants and the use of PGPR bamboo roots gave the best results in the parameters of number of leaves, number of bases, number of pods, weight of pods per plant, weight of 100 seeds per plot. , and seed weight per plot. Marom, et. at the pod formation stage (30 DAP to 45 DAP), average flowering age, wet weight of pods per cluster, dry weight of pods per cluster, weight of 100 seeds, and dry pod production per hectare.

Testing of several PGPR isolates to increase shallot productivity in coastal sand areas, reported by Tuhuteru, et al., (2019) in research results showed that several PGPR isolates tested could produce IAA, with the highest concentration shown by isolate BrSG.5 (Burkholderia seminalis) combined with three types of cultivars (22.46 mg kg^{-1}, 28.61 mg kg^{-1}, 41.41 mg kg^{-1}). Isolate BP25.2 (Bacillus methylotrophicus)

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was effective in producing N (0.05%), while isolate BP25.7 (Bacillus subtilis) was effective in producing residual P (0.22 ppm). Testing of PGPR isolates was also carried out by Sutariati, et al., in the results of their research it was concluded that the majority of PGPR isolates isolated from the rhizosphere of healthy rice from 4 districts in Southeast Sulawesi could dissolve phosphate and fix nitrogen. Isolates PKNW 6, t PKMN 7, PKNS 3, PKNS 9 and PKNW 4 were able to dissolve phosphate and nitrogen better than the other isolates.

Research on the use of PGPR to control tungro disease, reported by Salamiah and Wahdah (2015), in the results of research on the use of PGPR in controlling tungro disease in local rice in South Kalimantan, concluded that of the 15 PGPR isolates tested, 5 isolates were obtained that had potential as biological agents to induce the plant's defence system against tungro attacks, because they are capable of producing sufficient amounts of HCN and can dissolve phosphate. Three isolates were taken for testing in the field. The research results showed that the application of PGPR was not able to suppress tungro attacks on local rice, but there was one PGPR (Pseudomonas flourescens isolate 2) that was able to suppress tungro attacks on Inpara-4 and 5 rice.

METHODS

Research was carried out in Tontalete Village, Kema District, North Minahasa Regency, North Sulawesi. Research starts from June 2021 to October 2021. The materials and tools used are soybean seeds var. Biosoy 2, manure, rhizobium bacteria, PGPR (Plant Growth Promoting Rhizobacteria), NPK Phonska fertilizer, liquid organic fertilizer (POC), vegetable and chemical pesticides. The equipment used includes a sprayer, measuring cup, infusion tool, funnel, meter, digital scale, and stationery.

The field experiment was arranged in a Randomized Block Design (RAK). The treatment tested was the PGPR dose, which consisted of P0 = 0 ml/l (control), P1 = 5 ml/l, P2 = 10 ml/l, P3 = 15 ml/l, and P4 = 20 ml/l. The treatment was repeated 3 times, so there were 15 experimental units.

Implementation of the experiment, including: (1) Making 15 beds measuring 4m x 1 m (according to the treatment to be tested); (2) Application of manure at a dose of 8 kg/bed is carried out simultaneously with soil processing 2 weeks before planting; (3) Applying Phonska NPK fertilizer (15 : 15 : 15) by reducing the recommended dose by 1/3, carried out at 10 days after planting (DAP); (4) Application of Liquid Organic Fertilizer (POC) is carried out every week, starting at 14, 21, 28, 35, 42, 49, and 56 DAP; (5) PGPR application is carried out entirely on the seeds to be planted by soaking the seeds for 5 hours with PGPR and rhizobium for inoculation; (6) Application of PGPR to each bed with concentrations acording to treatment: 5, 10, 15, and 20 ml PGPR/litre of water; applied every 10 days, starting at age 10, 20, 30, 40, and 50 DAP; (7) Weeding is carried out twice at 10 DAP and 20 DAP and is adjusted to the condition of the weeds in the beds and surrounding areas; (8) Due to the presence of green ladybird pest attacks on plant leaves at the age of 25 and 30 DAP, botanical pesticides were sprayed from tobacco raw materials; (9) The application of chemical pesticides was carried out because the attack by green ladybugs (Nezara viridula) and pod-sucking caterpillars on the plantations had reached an attack level of 50%, so pesticide spraying was carried out 3x at the ages of 56, 66 DAP and 76 DAP; (10) Harvesting is carried out at the age of 85 days with the harvest criteria being 90% of the leaves are yellow and the pods are brownish yellow.

The parameters observed were: (1) Plant height, measured from the base of the stem to the tip of the longest leaf, at 41 DAP (flowering phase); (2) Number of branches, measured at harvest and counting all branches including main branches; (3) Number of pods per plant, measured after harvest by counting all

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the pods; (4) Percentage of damaged pods per plant, measured after harvest; (5) Weight of 100 dry seeds, measured after the seeds are dried; (6) Yield of seeds/tile plots, measured after the seeds are dried.

Data were analyzed using Analysis of Variance (ANOVA) at a test level of 5%. If the test results using the F test are significant, continue with the mean difference test using the BNT Test (Least Significant Difference) at the 5% level.

RESULTS AND DISCUSSION

Plant height and number of branches

The results of statistical analysis showed that PGPR had an effect on plant height, but had no effect on the number of branches (Table 1).

Table 1. Effect of PGPR on plant height and number of branches (41 DAP)

Treatment	Plant height (cm)	Number of branches
0 ml/l (P_0)	58,17 b	5,16
5 ml/l (P_1)	59,13 b	5,25
10 ml/l (P_2)	62,27 a	5,30
15 ml/l (P_3)	60,57 ab	5,29
20 ml/l (P_4)	59,20 b	5,24
BNT 5%	2,448	-

Note: Numbers followed by the same letter in the same column are not significantly different at the 5% BNT test level.

The application of PGPR at doses of 10 ml/l and 15 ml/l resulted in the highest plant height at 62.27 cm and 60.57 cm respectively, followed by treatments of 20 ml/l, 5 ml/l, and control at 59.20 cm, 59.13 cm, and 58.17 cm respectively. At 41 days after planting (DAT), soybeans enter the flowering or generative phase, and no further increase in plant height occurs. In the flowering phase, the administration of PGPR at treatment doses of 10 ml/l and 15 ml/l had a positive effect on plant growth. Optimal plant growth is crucial for determining plant yields, as reported by Luvitasari and Islami (2018). Their research showed that giving PGPR increased plant height, the number of leaves and leaf area of two soybean varieties (Grobogan and Dena-1).

According to Gardner et al. (1991), plant height growth occurs due to increased cell division and enlargement, increasing the number of cells, cell size, and cell differentiation. Plant growth is influenced by various factors, both internal and external, such as solar radiation, water, and nutrients. By providing PGPR, plants can obtain three benefits simultaneously. Firstly, PGPR serves as a source of nutrients to

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increase plant growth. Secondly, it acts as a growth regulator that stimulates and encourages plant growth. Finally, it helps reduce damage caused by soil pathogens. The number of branches is not affected by the application of PGPR. It is suspected that the number of branches is determined by the genetic characteristics of the plant.

Number of pods per plant and number of damaged pods per plant

The statistical analysis results revealed that PGPR affected the number of pods per plant and the percentage of damaged pods. The differences between treatments are shown in Table 2.

Table 2: Effect of PGPR on the number of pods per plant and the percentage of damaged pods per plant

Treatment	Number of pods per plant	Percentage of damaged pods per plant (%)
Control (P_0)	58,75 b	58,80 a
5 ml/l (P_1)	65,76 a	45,59 b
10 ml/l (P_2)	65,13 a	45,64 b
15 ml/l (P_3)	60,58 b	47,94 b
20 ml/l (P_4)	59,46 b	48,07 b
BNT 5%	3,894	3,564

Note: The numbers followed by the same letter in the same column are not significantly different at the 5% BNT test level.

The study found that the highest number of pods per plant was achieved when PGPR was given at 5 ml/l and 10 ml/l, with values of 65.76 pods and 65.13 pods respectively. This was followed by treatments at 15 ml/l, 20 ml/l, and the control treatment, with 60.58 pods, 59.46 pods, and 58.75 pods respectively. The control treatment and the 5, 10, 15, and 20 ml/l treatments showed the highest percentage of damaged pods, at 45.59%, 45.64%, 47.94%, and 48.07% respectively.

The study also found that pod damage was severe, with an average value of 52% for all treatments. This high level of pod damage was caused by the presence of weeds in the research plot, which acted as host plants for insect pests. Despite the use of vegetable pesticides and chemical pesticides, the soybean plot became the main target for insect pests. The main culprits were green ladybugs (Nezara viridula), armyworms (Spodoptera litura), and grasshoppers. The damage to the pods was mostly to young pods that had just formed seeds, or mature pods that had already produced seeds. This resulted in a decrease in the quality of the seeds. In addition to attacking the pods, these pests also ate plant leaves, causing damage and holes in many leaves.

It has been proven that PGPR can have a positive influence on the development of pests and diseases in soybean plants. According to a report by Agustini et al. (2013), the application of

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PGPR on soybean plants can inhibit the development of Aphis glycine. Soybean plants treated with PGPR showed lower development of a glycines compared to those that were not treated. PGPR can also suppress the occurrence of diseases in plants by inducing systemic resistance mechanisms or producing growth hormones. The results of Mulyadi's (2018) research showed that the PGPR isolates from the Pseudomonas fluorescents group and Bacillus sp. can suppress disease attacks by inducing plant resistance through increased secondary concentration of silicic acid metabolites and peroxidase. This increase can lead to the growth of plants attacked by CMV, especially in terms of plant height parameters.

Weight of 100 dry beans and the yield of seeds per plot.

The statistical analysis revealed that while the weight of 100 dry seeds remained unaffected by the PGPR treatment, it did have an impact on the dry seed yield per plot of tiles. The differences between the treatments are detailed in Table 3, which shows the effect of PGPR on the Weight of 100 dry beans and the yield of seeds per plot.

Treatment	Weight of 100 dry beans (g)	Yield of seeds per plot (g)
0 ml/l (P_0)	21,27	115,07 c
5 ml/l (P_1)	21,43	125,53 b
10 ml/l (P_2)	21,43	134,00 a
15 ml/l (P_3)	21,13	127,87 ab
20 ml/l (P_4)	21,43	125,73 b
BNT 5%	-	7,515

Note: The numbers followed by the same letter in the same column are not significantly different at the 5% BNT test level.

The application of PGPR at concentrations of 10 ml/l and 15 ml/l resulted in the highest dry bean yield of 134.00 g and 127.87 g, respectively. This was followed by the 20 ml/l and 5 ml/l treatments, which produced yields of 125.73 g and 125.53 g, respectively. The control treatment yielded the lowest at 115.07 g. The weight of 100 dry seeds was not affected by PGPR treatment, suggesting that plant genetic factors played a more dominant role. In this study, the variables of plant height, number of pods, and dry seed yield showed that PGPR application can increase soybean plant growth and yield. This is supported by similar research conducted by Luvitasari and Islami (2018), which found that PGPR application increased the growth of soybean plants in terms of plant height, number of leaves, leaf area, fertile nodes, number of flowers, number of pods, and yield. Ramlah and Guritno (2019) also reported that PGPR treatment of the Detam-1 variety at a concentration of 10 ml/l resulted in improved plant height, number of leaves, leaf area, and dry weight, number of flowers, total plant pods, dry weight, filled pods, empty pods, and harvest yield.

Additionally, the weight of 100 seeds yielded positive results with the Anjasmoro variety at a concentration of 10 ml/l.

The highest dry seed yield was obtained at concentrations of 10 ml/l and 15 ml/l, which resulted in yields of 1.34 tons ha^{-1} and 1.28 tons ha^{-1}, respectively. Soybean yields are generally low due to significant pod damage. In this study, the control treatment (without PGPR) resulted in the highest percentage of pod damage at 58.80%, while all PGPR treatments showed lower percentages of pod damage at 46.81%.

CONCLUSIONS

Based on the results of the research that has been carried out, it can be concluded:

1. Providing Plant Growth Promoting Rhizobacteria (PGPR) affects the growth and yield of Biosoy 2 soybean variety, by increasing plant height, number of pods per plant, and dry seed yield.
2. The highest dry bean yield was achieved by administering PGPR 10 ml/l and 15 ml/l, namely 1.34 g and 127.87 g, equivalent to 1.34 tons ha^{-1} and 1.28 tons ha^{-1}.

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