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Enhancing the Growth and Yield of Soybean Plants with Plant Growth Promoting Rhizobacteria and Liquid Organic Fertilizer

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Abstract

Background: Many organic wastes are currently used as organic fertilizers. Giving organic fertilizer to plants has an excellent impact on soil and plants. The combination of LOF and PGPR can undoubtedly increase the growth and production of soybean plants. **Method:** This research was conducted in Tanjung Sari Village, Rembang, Central Java, from November 2021 to January 2022. Analytical activities were conducted at the Land Resources Laboratory, Faculty of Agriculture, National Development University "Veteran" East Java. This research method uses a factorial Completely Randomized Design (CRD) consisting of 9 treatments and three replicates so that 27 experimental units are obtained. The first factor is PGPR (A), namely A0: Without PGPR A1: Banana Bark, A2: Bamboo Root, and the second factor is LOF (B), namely B0: Without LOF B1: Banana stem B2: Bamboo shoots. **Result:** The results of this study showed that the combination of PGPR + LOF treatments made from local raw materials was influential in helping the growth of soybean plants obtained by the combination A2B2 (PGPR bamboo root + LOF bamboo shoot) with the number of pods 36 pods, and plant height 56.60cm, in terms of c-organic analysis (3.05%), N (0.63%), P (15.37%), K (1.23%). This combination is best because it contains lignocellulose enzymes and growth regulators. **Conclusion:** The combination of PGPR + local raw material-based LOF effectively enhances soybean plant growth.

Keywords: PGPR; Liquid Organic Fertilizer; Soybean

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Introduction

During the increasing global food demand, soybeans have become one of the essential commodities that must be considered. Soybean serves as a source of plant-based protein and plays a strategic role in sustainable agriculture. Therefore, research on enhancing soybean plants' growth and yield is fundamental.

Plant Growth Promoting Rhizobacteria (PGPR) are a group of soil microorganisms that benefit plant growth. They are bacteria that can thrive and increase in soils with high organic content. Bamboo root PGPR contains bacteria that produce lignocellulose enzymes, which are biocatalysts in nutrient mineralization and decomposition of organic matter (Mulyawan et al., 2019). In addition to bamboo roots, banana rhizomes also contain PGPR, which plays a role in providing growth-regulating substances such as gibberellins and cytokinins, as well as microbes that significantly enhance phosphate availability for plants as phosphate solubilizers (Cahyono, 2016).

Liquid organic fertilizer (LOF) is a fertilizer solution made from fermented organic materials. Liquid fertilizer has been proven more effective and efficient when applied directly to leaves, flowers, and stems than growing media. LOF acts as a growth stimulant, especially when plants begin to bud or transition from the vegetative phase to the fruit and seed formation phase. Leaves and stems can absorb LOF directly through stomata or pores on their surfaces (Sitanggang, 2022). The generative stem LOF of bananas has a chemical

composition with a calcium content of 16%, potassium content of 23%, and phosphorus content of 32% (Laginda, 2017), as well as a high cellulose level, which can provide additional nutrients for plant growth and yield. LOF from bamboo shoots contains gibberellin hormone as a growth regulator that stimulates growth between plant nodes. The high protein content in bamboo shoot organic material can increase the nitrogen content in the resulting liquid organic fertilizer because nitrogen comes from the breakdown of protein metabolism. LOF with high nitrogen content effectively stimulates plant growth (Angraeni et al., 2018).

In the context of research on the combination of PGPR (Plant Growth-Promoting Rhizobacteria) and LOF (Liquid Organic Fertilizer) on soybean plants, there is a significant lack of data regarding the specific effectiveness of this combination. Although many studies have shown the individual benefits of PGPR and LOF in enhancing plant growth, few have explored the interactions between the two in depth.

This lack of data may be due to several factors. First, research on PGPR often focuses on specific types of microorganisms without considering how they interact with various organic fertilizers, including LOF. Second, variations in application methods, concentrations, and kinds of PGPR and LOF used in different studies can yield varying results, making it difficult to draw clear conclusions about the most effective combinations.

In this study, the researchers plan to explore the effects of the combination of PGPR and LOF on the growth and yield of soybean plants. The methods include field and laboratory testing, where the soybean plants will be divided into several treatment groups. Each group will receive different treatments, namely no treatment, only PGPR, only LOF, and a combination of both.

Metode

This research was conducted in Tanjung Sari Village, Rembang, Central Java, from November 2021 to January 2022. The analysis activities were conducted at the Soil Resources Laboratory of the Faculty of Agriculture, Universitas Pembangunan Nasional "Veteran" East Java. The research method employed a Completely Randomized Design (CRD) factorial consisting of 9 treatments with three replications, resulting in 27 experimental units. The first factor was PGPR (A), namely A0: Without PGPR, A1: Banana rhizome, A2: Bamboo root, and the second factor was LOF (B), namely B0: Without LOF, B1: Banana stem, B2: Bamboo shoot. The treatment combination is A0B0: Control, A1B0: PGPR banana rhizome 100 ml, A0B1: LOF banana stem 100 ml, A1B1: PGPR banana rhizome 50 ml, and LOF banana stem 50 ml, A2B0: PGPR bamboo roots 100 ml, A0B2: LOF bamboo shoots 100 ml, A2B2: PGPR bamboo roots 50 ml and LOF bamboo shoots 50 ml, A1B2: PGPR banana rhizome 50 ml and LOF bamboo shoots 50 ml, A2B1: PGPR bamboo roots 50 ml and LOF banana stems 50 ml.

Tools And Materials Research

The tools used in this research are a 19-liter water jug, measuring tape, measuring glass, basin, sieve, machete, scale, funnel, 40cm x 40cm polybags, and spoon. The materials used in this research are 100 grams of banana rhizome and 100 grams of bamboo root for PGPR preparation, 1 kg of banana stem and 1 kg of bamboo shoot for LOF preparation, granulated sugar, shrimp paste, boiled water, soil, and soybean seeds.

Research procedures

1. The preparation of PGPR and LOF

Preparing PGPR involves chopping 100 grams each of banana rhizome and bamboo root into small pieces, which are then weighed and placed into separate 19-liter jugs. Each jug is filled with 10 liters of boiled water, 400 grams of granulated sugar, and 200 grams of shrimp paste. The mixture is then fermented for 14 days. For the preparation of LOF, 1 kg each of bamboo shoots and chopped banana stem are weighed and placed into separate jugs. Each

jug is filled with 10 liters of boiled water, 200 grams of granulated sugar, and 200 grams of shrimp paste. The LOF is homogenized and tightly sealed for two weeks.

2. Preparation of planting media

The land used for research is first cleaned of weeds and rocks using a hoe to make it easy to place polybags. Planting media is prepared by mixing 10kg of air-dried soil into polybags and 100 grams of manure.

3. Application to plant

Soybean seedlings have been previously seeded and will be transplanted after three weeks of age. Seedlings are transferred into polybags that have been filled with planting media. The first fertilizer application was done one week after transferring the seedlings to the polybags. POC and PGPR that will be applied are taken from the stock solution of POC and PGPR that has been made by leaking at the root point, which is 5 cm from the plant stem, as much as 100 ml per polybag, and then the application of POC and PGPR is carried out periodically every week according to the treatment given, until 12 weeks after planting.

4. Treatment plant

Treatment of soil moisture is carried out by watering routine water in the morning and evening. Depending on weather conditions, if it rains, no watering is done. Pest and weed control is done manually. Pests and diseases that attack soybean plants can be prevented by collecting pests and eggs by hand. Weeding is done by pulling weeds by hand to avoid competition in the absorption of nutrients in soybean plants.

Observations include field observations such as plant height (cm). Plant height was observed when the plants were four weeks old, with an observation time interval of 1 week. Plant height was measured from the base of the lower stem to the growing point of the plant, measuring the height of the plant on each sample plant using a ruler. The number of pods per plant was counted at harvest time by counting the number of pods on each sample plant. Laboratory observations include total nitrogen (N), phosphorus (P), potassium (K), and organic carbon (C).

Data analysis

The effect of treatments is tested using an F-test. Treatments are considered significantly different if the calculated F-value is greater than the tabulated F-value at the 5% level but less than the tabulated F-value at the 1% level. Treatments are considered highly significantly different if the calculated F-value exceeds the tabulated F-value at the 1% level. Treatments are not significantly different if the calculated F-value is less than the tabulated F-value at the 5% level. If the analysis results indicate significant differences, further testing will be conducted using the Honestly Significant Difference (HSD) test at the 5% level.

Results and Discussion

Characteristics of Total Nitrogen (N total)

The total nitrogen content will experience fluctuations, either increasing or decreasing, due to the balance between the nitrogen requirements of microorganisms. The decomposition process of organic matter accelerates because microorganisms involved in compost decomposition require nitrogen for their growth (Bachtiar & Ahmad, 2019).

Table 1. Effect of PGPR and LOF Treatments on Total Nitrogen (N-Total)

Combination Test	Mean N-Total	Description	Notation
A0B0	0.410	Moderate	a
A1B0	0.540	High	b
A2B0	0.627	High	c
A0B1	0.760	Very High	d
A1B1	0.740	High	d
A2B1	0.777	Very High	d

A0B2	0.540	High	b
A1B2	0.760	Very High	d
A2B2	0.630	High	c

Note: Numbers followed by the same letter in the same column indicate no significant difference in the LSD test at 5%.

Analysis of variance of N-total test, the combination of PGPR and POC significantly affected N-total. Table 1 shows the combination of PGPR and POC treatment types with varied mean values. In the average N-total test, the combination without PGPR with the composition of raw materials is significantly different from the POC combination treatment with the composition of raw materials in the treatment without treatment (A0) has a significantly different N-total value in each combination with the composition of raw materials, which is 0.41-0.76%. Combining PGPR and POC will substantially affect the average N-total test. The highest average was found in the combination of PGPR bamboo root + POC banana stem (A2B1), which amounted to 0.77%. This is because PGPR can produce plant regulatory substances (ZPT), essential compounds from root growth to fruit formation (Cahyani et al., 2018). PGPR can increase nitrogen fixation from the air for nitrogen availability in the soil, dissolve phosphate, produce osmoprotectants in drought-stress conditions, and produce certain osmolytes that can kill plant pathogens (Fitri et al., 2020).

Characteristics of Phosphorus

Phosphorus is the second essential nutrient crucial for plant growth after nitrogen. This element is a vital component of nucleoproteins in the cell nucleus, regulating cell division and growth and DNA containing genetic information of living organisms. Phosphorus compounds also play a critical role in cell division processes, triggering early root growth, fruit maturation, energy transport within the cell, fruit formation, and seed production (Cesaria et al., 2012).

Table 2. Effect of PGPR and LOF Treatments on Phosphorus (P)

Combination Test	Mean P	Description	Notation
A0B0	8.560	Low	a
A1B0	13.073	Moderate	c
A2B0	10.983	Moderate	b
A0B1	10.347	Moderate	ab
A1B1	14.410	Moderate	cd
A2B1	16.080	High	e
A0B2	12.767	Moderate	c
A1B2	13.587	Moderate	c
A2B2	15.370	Moderate	de

Note: Numbers followed by the same letter in the same column indicate no significant difference in the LSD test at 5%.

Analysis of variance test of P, the combination treatment of PGPR and POC significantly affects P. The control group is the A0B0 treatment combination, while the highest average value of P is in the A2B1 combination group, namely the PGPR treatment combination of bamboo roots + banana stem POC. PGPR can provide P elements that support the generative phase, flowering in plants. Pseudomonas sp. in POC can increase plant growth by producing hormones such as IAA and gibberellin, fixating and dissolving P (Choliq et al., 2020). Giving POC can accelerate flowering because Rhizobium bacteria help plants absorb and fulfill their nutrient needs (Marom et al., 2017).

Characteristics of Potassium (K)

Potassium (K) plays a crucial role in protein and carbohydrate synthesis, strengthening plant woody tissues and improving the quality of seeds and fruits (Cesaria et al., 2012). Although soil contains abundant potassium, only a small portion is available for plant absorption, especially the water-soluble fraction.

Table 3. Effect of PGPR and LOF Treatments on Potassium (K)

Combination Test	Mean K	Description	Notation
A0B0	0.933	High	a
A1B0	1.190	Very High	abc
A2B0	1.113	Very High	ab
A0B1	1.073	Very High	ab
A1B1	1.433	Very High	c
A2B1	1.177	Very High	abc
A0B2	1.027	Very High	ab
A1B2	1.090	Very High	ab
A2B2	1.230	Very High	bc

Note: Numbers followed by the same letter in the same column indicate no significant difference in the LSD test at 5%.

Analysis of variance of the K test, the combination of PGPR and POC treatment significantly affected K. The control group is the A0B0 treatment combination, while the highest average value of K is found in the A1B1 combination group, namely the PGPR bamboo shoot + banana stem POC treatment combination. Significantly, the treatment combination can increase calcium levels to the highest level compared to others.

Characteristics of Organic Carbon (C-Organic)

In this study, the average organic carbon (C-organic) in each combination group can be described in Table 4.

Table 4. Effect of PGPR and LOF Treatments on Organic Carbon (C-Organic)

Combination Test	Mean C-Organik	Description	Notation
A0B0	1.9033	Low	a
A1B0	2.7000	Moderate	bc
A2B0	2.7833	Moderate	bc
A0B1	2.8833	Moderate	bc
A1B1	2.9600	Moderate	bc
A2B1	2.7700	Moderate	bc
A0B2	2.6033	Moderate	b
A1B2	3.4833	High	d
A2B2	3.0533	High	cd

Note: Numbers followed by the same letter in the same column indicate no significant difference in the LSD test at 5%.

Analysis of variance of Organic C test, the combination treatment of PGPR and POC significantly affected Organic C. The control group is the A0B0 treatment combination. At the same time, the highest average value of C-organic is found in the A1B2 combination group, namely the PGPR bamboo shoot + POC bamboo shoot treatment combination. Significantly, the treatment combination can increase the highest C-organic levels compared to others.

The Influence of PGPR and LOF Treatments on Pod Quantity

The analysis results regarding the influence of PGPR and LOF treatments on the number of pods in soybean plants can be presented in Table 5.

Table 5. The Effect of PGPR and LOF Treatments on Pod Quantity

PGPR	LOF			Mean
	B0	B1	B2	
A0	17.33 a	25.67 bc	25.00 b	22.67
A1	26.33 bc	34.00 e	31.00 cde	30.44
A2	27.00 bcd	32.33 de	36.00 e	31.78
Mean	23.56	30.67	30.67	(-)

Note: Numbers in the same column and row followed by the same letter do not show significant differences, based on the DMRT test at a 5% significance level. (-) indicates no interaction between treatments.

Analysis of variance of the combination treatment of PGPR and POC did not significantly affect the number of pods. Based on Table 5, it can be seen that the treatment of PGPR and POC has a significant effect on increasing the number of pods of soybean plants. The same thing also occurs in the provision of POC, which significantly increases the number of pods. Soybean plants that are not given PGPR or POC have the least number of pods and are substantially different from soybean plants given PGPR and POC.

The treatment combinations that significantly gave the highest number of pods were soybean plants treated with PGPR banana stem + banana stem POC (A1B1) and soybean plants treated with PGPR bamboo root + bamboo shoot POC (A2B2). Although both have several pods that are not significantly different, the number of pods in the PGPR bamboo root + bamboo shoot POC treatment combination (A2B2) has the highest number, namely 36 pods. Bamboo roots are widely colonized, one of which is by Pseudomonas fluorescens, which increases the solubility of phosphorus (P) in the soil and controls several types of pathogens. Bamboo shoots can be made into liquid organic fertilizer. In addition to its role in producing nutrients for soil and plants, this POC also improves the soil quality. Maintain the amount of air contained in the soil so that it causes the soil to not easily compact or harden.

The Influence of PGPR and LOF Treatments on Plant Height

The analysis results regarding the influence of PGPR and LOF treatments on soybean plant height can be presented in Table 6 as follows:

Table 6: The Effect of PGPR and LOF Treatments on Plant Height

Combination	4WAP	5WAP	6WAP	7WAP	8WAP	9WAP	10WAP	11WAP
A0B0	27.37	31.87	35.67	39.43	43.03	46.07	49.90	52.67
A1B0	27.57	32.53	36.43	40.70	44.77	47.73	51.43	54.73
A2B0	27.30	32.23	36.97	40.33	45.03	48.53	51.43	54.87
A0B1	27.27	32.60	37.50	42.20	48.1*	52.1*	54.80	57.13
A1B1	27.53	32.97	37.80	42.83	47.30	50.27	53.77	57.00
A2B1	27.13	34.0*	38.2*	43.6*	47.57	51.53	54.60	58.00
A0B2	27.53	31.90	36.60	40.07	43.63	46.97	51.13	54.07
A1B2	27.40	33.73	37.73	42.77	46.63	51.03	55.03*	58.27*
A2B2	27.7*	32.80	37.40	40.63	45.63	49.70	53.83	56.60

Note: *) Treatment combinations with the tallest plant height at each observation time.

Analysis of variance of the combination treatment of PGPR and POC did not significantly affect plant height at 11 weeks after planting. At the observation time of 4 weeks after planting, the combination group with the highest average plant height was PGPR bamboo root + POC bamboo shoot (A2B2), which was 27.72 cm. At the observation time of 5 weeks, six weeks, and seven weeks, the combination group of PGPR bamboo roots + banana stem POC (A2B1) had the highest average. At the observation time of 8MST and 9MST, the banana stem POC combination group (A0B1). At the observation time of 10 weeks and 11 weeks, the combination group of PGPR banana stump + bamboo shoot POC (A1B2) had the highest average. Overall, the combination group of PGPR banana stem + POC bamboo shoot (A1B2) had the highest plant height compared to the others.

Significantly, the A1B2 treatment combination best affects soybean plant height. The treatment combination that is effective on plant height is also effective on the number of root nodules. This shows that the provision of PGPR banana pith and POC bamboo shoots (A1B2) effectively increases the height of soybean plants. Banana pith is known to contain microbes that decompose organic matter.

The decomposing microbes are located on the outer and inner banana pits. The types of microbes that have been identified in banana pseudostem MOL include Bacillus sp., Aeromonas sp., and Aspergillus nigger. These microbes usually decompose organic matter.

Microbes in banana pomace will decompose organic materials to be composted (Wulandari et al., 2009).

Conclusion

The study found that the combination of PGPR + POC treatments made from local raw materials was influential in helping the growth and production of soybean plants obtained by the combination of PGPR bamboo root + POC bamboo shoot (A2B2) in terms of analysis of C-organic (3.05%), N (0.63%), P (15.37%), K (1.23%). The combination of PGPR + POC made from local raw materials of bamboo roots and bamboo shoots (A2B2) is the best combination that affects the production of soybean plants because it contains lignocellulose enzymes, and growth regulators with the number of pods 36 pods, plant height 56.60cm. It is recommended that further research be carried out on the combination of PGPR and POC so that the potential of PGPR and POC can be optimally utilized in large-scale agriculture.

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