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The Effect of Plant Growth-Promoting Rhizobacteria (PGPR) Types and Concentration on Soybean (*Glycine max* L. Merrill) Growth and Yield

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Abstract: This study evaluated the effects of Plant Growth-Promoting Rhizobacteria (PGPR) types and concentrations on the growth and yield of soybean (*Glycine max* L. Merrill). The experiment was conducted from December 2023 to February 2024 in Krapyak Village, Jepara Regency, Indonesia, at an altitude of approximately 20 m above sea level on latosol soil. The study employed a factorial Completely Randomized Block Design (CRBD) with two factors: PGPR type (without PGPR, bamboo root PGPR, and commercial PGPR) and PGPR concentration (0, 10, 20, and 30 ml L^{-1}), with three replications. Observed parameters included vegetative growth traits (plant height, number of branches, flowering time), yield components (total pods per plant, empty pods, 100-seed dry weight, seed dry weight per plot), and biomass accumulation (plant fresh and dry weight). The results showed that PGPR type significantly affected the number of branches at 4 weeks after planting (WAP), total pod number, and plant fresh and dry weight. Commercial PGPR produced the highest number of branches, total pods, and biomass accumulation. PGPR concentration of 20 ml L^{-1} resulted in the highest number of branches at 4 WAP. Significant interactions between PGPR type and concentration were observed for plant fresh and dry weight. However, PGPR application had no significant effect on plant height, flowering time, 100-seed dry weight, or seed dry weight per plot. Overall, the results indicate that PGPR effectiveness depends on microbial source and optimal concentration, with commercial PGPR showing greater potential to enhance soybean vegetative growth and pod formation under field conditions.

Keywords: PGPR type; PGPR concentration; soybean; growth; yield

1. Introduction

Soybean (*Glycine max* L. Merrill) is a strategic food commodity in Indonesia due to its role as a primary source of plant-based protein, raw material for the food industry, and animal feed. Increasing population growth and rising awareness of healthy, plant-based diets have led to a steady increase in soybean demand, positioning this crop as a key component of national food security. However, domestic soybean production remains insufficient to meet national consumption needs, resulting in a high dependence on imports.

Low soybean productivity is influenced by multiple factors, including suboptimal cultivation technology (Prakoso & Khakim, 2024), declining harvested land area, adverse climatic conditions (Nur Fajri et al., 2025), and decreasing soil fertility due to excessive reliance on inorganic fertilizers and pesticides. Long-term use of chemical inputs has been shown to reduce soil biological activity and nutrient-use efficiency, ultimately constraining plant growth and yield (Prakoso et al., 2023). These challenges highlight the need for sustainable and environmentally friendly cultivation technologies to improve soybean productivity.

One promising alternative is the use of Plant Growth-Promoting Rhizobacteria (PGPR). PGPR are beneficial microorganisms that colonize the rhizosphere and promote plant growth through various mechanisms, including biological nitrogen fixation, phosphate solubilization, phytohormone production, and enhancement of plant tolerance to biotic and abiotic stresses (Chieb & Gachomo, 2023). PGPR can be sourced from natural environments, such as bamboo root rhizospheres, which are rich in functional microbial communities, or from commercial formulations developed for agricultural use.

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Previous studies have demonstrated that PGPR application can improve vegetative growth, root development, nodulation, and yield components in soybean plants (Swarnalakshmi et al., 2020; Putri et al., 2024). However, the effectiveness of PGPR is strongly influenced by microbial source compatibility, soil conditions, and application dosage. Inappropriate concentrations may reduce microbial performance or cause competition in the rhizosphere, thereby limiting plant responses (Alpandari et al., 2025).

Therefore, understanding the interaction between PGPR type and concentration is essential to optimize its application in soybean cultivation. This study aimed to evaluate the effects of different PGPR types and concentrations on soybean growth and yield, with the objective of identifying an effective and sustainable biological input strategy to support increased soybean production.

2. Materials and Methods

2.1 Site Description and Experimental Period

The experiment was conducted in Krapyak Village, Jepara District, Jepara Regency, Indonesia, at an altitude of approximately ±20 m above sea level. The soil at the research site was classified as latosol with an average pH of 6.0. The study was carried out from December 2023 to February 2024, coinciding with the soybean growing season under field conditions.

2.2 Experimental Design and Treatments

The study employed a factorial Randomized Completely Block Design (RCBD) consisting of two factors with three replications. The first factor was PGPR type, comprising: without PGPR (P0), bamboo root PGPR (P1), and commercial PGPR (P2). The second factor was PGPR concentration, consisting of 0 ml L^{-1} (K0), 10 ml L^{-1} (K1), 20 ml L^{-1} (K2), and 30 ml L^{-1} (K3). A total of 12 treatment combinations were generated, resulting in 36 experimental units.

Each experimental plot measured 1.5 m × 1.5 m and contained 36 soybean plants. Land preparation involved soil tillage, plot formation (30 cm height), and spacing of 50 cm between plots and 100 cm between blocks. Chicken manure was applied at a rate of 10 t ha^{-1} seven days before planting, followed by basal application of SP-36 fertilizer at 75 kg ha^{-1}.

2.3 Crop Establishment and PGPR Application

Soybean seeds (Grobogan variety) were pre-soaked for 15 minutes, and non-viable floating seeds were discarded. Planting was performed at a spacing of 25 cm × 25 cm with two seeds per planting hole. PGPR solutions were prepared according to treatment concentrations and applied by watering at a volume of 250 ml per plant at 7, 14, 21, and 28 days after planting (DAP). Applications were conducted in the afternoon to maintain microbial viability.

2.4 Observed Variables

Growth parameters included plant height, number of branches, and flowering time. Yield parameters consisted of total pods per plant, number of empty pods per plant, 100-seed dry weight, seed dry weight per plot, plant fresh weight, and plant dry weight.

2.5 Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) at a 5% significance level. Significant treatment effects were further evaluated using the Least Significant Difference (LSD) test at $\alpha = 0.05$.

3. Result and discussions

3.1 Plant Height (cm)

Based on the research results presented in Table 1, it shows that the treatment of Plant Growth Promoting Rhizobacteria (PGPR) type and concentration has not been able to provide a significant effect on soybean plant height at the age of 2, 4, and 6 weeks after planting (WAP). Plant height in all treatments showed a relatively uniform growth pattern, both in the treatment without PGPR and in the treatment of bamboo root PGPR and commercial PGPR. Similarly, increasing the PGPR concentration to 30 ml L^{-1} did not result in a significant difference in plant height. The absence of interaction between PGPR type and concentration indicates that the response of plant height growth was not influenced by the combination of these two factors under the conditions of this study.

Table 1: Effect of PGPR Type and Concentration on Soybean Plant Height

Treatment	Plant Height (cm)

	2 WAP	4 WAP	6 WAP
Types of PGPR			
Without PGPR (p0)	21,58 a	44,98 a	67,38 a
Bamboo Root PGPR (p1)	21,02 a	44,21 a	65,35 a
Plant PGPR (p2)	20,85 a	45,02 a	67,38 a
PGPR concentration			
0 ml/liter (k0)	21,03 a	45,50 a	69,11 a
10 ml/liter (k1)	21,53 a	44,78 a	65,94 a
20 ml/liter (k2)	21,75 a	45,14 a	65,25 a
30 ml/liter (k3)	20,31 a	43,53 a	66,50 a
Interaksi	-	-	-

Description: Numbers followed by the same letter in the same column show no significant difference with the 5% LSD test. (-) there is no interaction between the requirements.

The lack of difference in soybean plant height between treatments is thought to be related to the relatively optimal growing environment and soil nutrient availability during the study. The application of chicken manure and basic phosphate fertilizer before planting is thought to have met the essential nutrient needs of plants in the early growth phase. This is also in line with research (Anwar et al., 2025), which states that organic matter plays a role in providing good nutrient sources for plants. Therefore, the role of PGPR as a provider of additional nutrients and growth stimulants has not been seen significantly. This condition is in line with the opinion of Vocciante et al., (2022) that plant response to PGPR is greatly influenced by initial soil fertility and the level of plant need for functional microbial intervention.

In addition to soil fertility, the effectiveness of PGPR is largely determined by the success of bacterial colonization in the root zone. In field soils with established indigenous microbial communities, applied PGPR bacteria potentially compete for space (Zhang et al., 2024) and energy sources, thus limiting their activity in producing phytohormones such as auxin or increasing nutrient availability (Pereira et al., 2020). This condition can result in an insignificant plant response to PGPR, particularly in vegetative growth parameters such as plant height, which are heavily influenced by genetic factors of the variety and environmental conditions.

Furthermore, soybean plant height is a relatively conservative growth trait and is more controlled by genetic factors than other physiological parameters. The Grobogan variety used in this study has a relatively stable plant height growth potential (Sebastian & Banjarnahor, 2019), so its response to external treatments such as PGPR is less pronounced (Swarnalakshmi et al., 2020). Several previous studies have reported that the effects of PGPR on soybean plants are more pronounced in other parameters, such as root nodule formation, nutrient uptake efficiency, and yield components during the generative phase. Therefore, the insignificant effect of PGPR on plant height in this study indicates that the benefits of PGPR are more likely to be expressed in later growth phases and yield parameters, rather than in early vegetative growth.

3.1. Number of Branches

Branch number is an important vegetative growth parameter in soybean plants because it is directly related to the potential for flower and pod formation, given that branches function as the site for the emergence of generative organs (Ramadhan et al., 2022). Therefore, observing branch number is an important indicator in evaluating the vegetative growth of soybean plants and serves as a basis for predicting potential yields in the next generative phase.

The results of the study, as shown in Table 2, show that the PGPR treatment significantly affected the number of soybean plant branches at 4 weeks after planting (WAP), but had no significant effect at 6 WAP. At 4 WAP, the factory PGPR treatment produced the highest number of branches, while the bamboo root PGPR treatment showed the lowest number of branches. Meanwhile, at 6 WAP, all PGPR treatments showed a relatively uniform number of branches and were not significantly different. This indicates that the effect of PGPR on soybean plant branch formation is temporary and more visible in the early vegetative phase.

Table 2: Effect of PGPR Type and Concentration on the Number of Branches of Soybean Plants

Treatment	Number of Branches (branches)

	4 WAP	6 WAP
Types of PGPR		
Without PGPR (p0)	1,56 ab	3,06 a
Bamboo Root PGPR (p1)	1,21 b	3,17 a
Plant PGPR (p2)	1,71 a	3,35 a
PGPR concentration		
0 ml/liter (k0)	1,50 e	3,17 a
10 ml/liter (k1)	1,36 e	3,28 a
20 ml/liter (k2)	1,92 d	2,36 a
30 ml/liter (k3)	1,19 e	2,97 a
Interaksi	-	-

Description: Numbers followed by the same letter in the same column show no significant difference with the 5% LSD test. (-) there is no interaction between the requirements

The superior effect of factory-grown PGPR at 4 weeks post-plantation (WAP) is thought to be related to its more comprehensive microbial and nutrient content and more stable formulation compared to natural PGPR from bamboo roots. In the early growth phase, soybean plants are highly responsive to the availability of growth hormones, particularly auxin and cytokinin (Amaliah et al., 2023), which play a role in branch initiation and development. Factory-grown PGPR is thought to increase the production or availability of these phytohormones, thereby stimulating earlier branch formation. However, as the plants age, this effect tends to decrease as the plants enter a more advanced growth phase and physiological mechanisms are more controlled by internal plant factors (Srg & Harahap, 2023).

Regarding the PGPR concentration factor, the results showed that differences in concentration significantly affected the number of branches at 4 WAP, but had no significant effect at 6 WAP. A concentration of 20 ml L^{-1} showed the highest number of branches at 4 WAP, while a concentration of 30 ml L^{-1} actually produced a lower number of branches. This condition indicates that there is an optimum concentration of PGPR capable of supporting branch growth, while concentrations that are too high have the potential to reduce PGPR effectiveness due to microbial imbalance or competition in the root zone (Alfa Mustafa et al., 2023).

The lack of interaction between PGPR type and concentration indicates that both factors operate independently in influencing the number of soybean plant branches. Furthermore, the insignificant effect of treatment at 6 weeks post-planting (WAP) indicates that branch formation in subsequent growth phases is more influenced by genetic factors of the variety and environmental conditions, such as light availability and soil nutrients, than by PGPR treatment. Therefore, the results of this study confirm that PGPR application is more effective in influencing the early phase of branch formation, while its role becomes less dominant in later phases.

3.2. Flower Appearance Time

Flowering time is an important phenological parameter in soybean plants because it is closely related to the transition phase from vegetative to generative growth. This parameter reflects the plant's ability to respond to environmental conditions and agronomic treatments. The speed of flowering directly influences harvest time, flowering synchronization, and the efficiency of resource utilization such as water and nutrients (Wicaksono et al., 2024). Plants that flower at the optimal time generally have a greater chance of producing maximum pods and seeds, especially under suitable environmental conditions (Fuskhah & Darmawati, 2020). Therefore, observing flower emergence time is often used as an early indicator of the success of a treatment, including the application of Plant Growth Promoting Rhizobacteria (PGPR).

Based on the research results presented in Table 3, the application of various types of PGPR did not show a significant effect on the flowering time of soybean plants. The treatments without PGPR (p0), bamboo root PGPR (p1), and plant PGPR (p2) resulted in relatively uniform flowering times, ranging from 31.08 to 31.25 days after planting. This uniformity indicates that soybean plants generally have strong genetic control over the flowering phase, so the response to PGPR inoculation during this phase is relatively limited. In addition, the homogenous environmental conditions during the study, such as light availability, temperature, and humidity, are thought to be more dominant in determining flowering time than differences in the PGPR sources used.

Table 3: Effect of PGPR Type and Concentration on Flower Emergence Time of Soybean Plants

Treatment	Flower Emergence Time (days)
Types of PGPR	
Without PGPR (p0)	31,17 a
Bamboo Root PGPR (p1)	31,25 a
Plant PGPR (p2)	31,08 a
PGPR concentration	
0 ml/liter (k0)	30,67 a
10 ml/liter (k1)	31,56 a
20 ml/liter (k2)	30,78 a
30 ml/liter (k3)	31,67 a
Interaksi	-

Description: Numbers followed by the same letter in the same column show no significant difference with the 5% LSD test. (-) there is no interaction between the requirements

In terms of PGPR concentration, the results also showed no significant difference between treatments in terms of flowering time. Concentrations of 0, 10, 20, and 30 ml/liter resulted in flowering times ranging from 30.67 to 31.67 days. This indicates that increasing PGPR concentrations was unable to significantly accelerate or delay the flowering phase. One possible reason is that PGPR plays a more dominant role in increasing vegetative growth and nutrient uptake, while flowering initiation in soybeans is more influenced by photoperiodism and plant physiological age. Thus, although PGPR has the potential to increase plant vigor (Wicaksono et al., 2024), its effect on flowering time tends to be indirect. The lack of interaction between PGPR type and concentration on flowering time indicates that these two factors operate independently and do not reinforce each other in influencing the flowering phase. Other factors that may influence these results include the sufficient initial nutrient content of the growing medium (Hafiz Sitompul & Mardiyah, 2022), making the additional role of PGPR less apparent, and the adaptability of soybean plants to the research environmental conditions (Ratna et al., 2024). Furthermore, plant response to PGPR is strongly influenced by the compatibility between microbes, host plants, and soil conditions. Therefore, even though there is no significant difference in flowering time, PGPR application still has the potential to provide benefits on growth parameters and other yields related to the advanced generative phase.

3.3. Yield Parameters

The total number of pods per plant is a key parameter in determining the potential yield of soybean plants because it directly reflects the success of the flowering, pollination, and pod formation processes during the generative phase. The higher the total number of pods, the greater the chance of the plant producing optimal numbers of seeds, as long as the seed filling process occurs normally (Adi Pratama & Zakiah, 2017). The results of the study presented in Table 4 show that the type of PGPR significantly affected the total number of pods per plant. The plant PGPR treatment (p2) produced the highest number of pods (65.23 pods) and was significantly different from the treatment without PGPR (p0) and bamboo root PGPR (p1).

This indicates that the plant PGPR has a more effective microbial composition in increasing nutrient availability, especially phosphorus and nitrogen (Mustari et al., 2023), and produces phytohormones such as auxin and cytokinin, which play a role in stimulating flower and pod formation (Putri et al., 2024). Meanwhile, the lack of difference in p0 and p1 indicates that the effectiveness of local PGPR in bamboo roots is likely influenced by the level of microbial adaptation to the soybean rhizosphere environment or suboptimal microbial population concentration.

The number of empty pods per plant is an indicator of the efficiency of the seed filling process and the balance between sources and sinks within the plant. Empty pods generally form due to limited photosynthate supply, environmental stress, or nutrient imbalance during the seed filling phase. Data show that the plant PGPR treatment (p2) produced the highest number of empty pods (18.58 pods), significantly different from the bamboo root PGPR treatment (p1). The increase in the number of empty pods in treatments with a high total pod number indicates internal competition between pods for photosynthate utilization. In other words, increased pod formation is not always accompanied by the plant's ability to fill all pods optimally (Umami & Wiharyanti, 2025). Other factors that may influence the high number of empty pods are limited potassium (Alpandari et al., 2025) and microenvironmental conditions, such as light intensity and water availability, which play a significant role in the translocation of photosynthetic products to the seeds.

Table 4: Effect of PGPR Type and Concentration on Pod Yield

Treatment	Total Number of Pods per Plant (pods)	Number of Empty Pods per Plant (pods)	Dry Weight of 100 Seeds (g)	Seed Dry Weight per Plot (kg)
Types of PGPR				
Without PGPR (p0)	53,71 b	13,60 ab	12,54 a	0,28 a
Bamboo Root PGPR (p1)	45,08 b	11,17 b	10,91 a	0,29 a
Plant PGPR (p2)	65,23 a	18,58 a	14,18 a	0,26 a
PGPR concentration				
0 ml/liter (k0)	57,14 d	12,56 d	13,70 a	0,34 d
10 ml/liter (k1)	59,00 d	15,67 d	13,06 a	0,25 e
20 ml/liter (k2)	55,08 d	13,75 d	12,66 a	0,28 e
30 ml/liter (k3)	47,47 d	15,83 d	10,76 a	0,24 e
Interaksi	-	-	-	-

Description: Numbers followed by the same letter in the same column show no significant difference with the 5% LSD test. (-) there is no interaction between the requirements

A 100 seed dry weight is a yield quality parameter that reflects the success rate of seed filling and dry matter accumulation during the final generative phase. This parameter is relatively genetically stable and is often used as an indicator of seed size. Research has shown that neither the type nor concentration of PGPR significantly affected 100-seed dry weight, with values ranging from 10.76–14.18 g. This indicates that seed size is more controlled by the genetic factors of the soybean variety used than by the PGPR treatment. Furthermore, the relatively uniform environmental conditions during the seed filling phase are thought to have caused the dry matter accumulation process to occur evenly across all treatments (Erwan et al., 2019). PGPR plays a greater role in increasing the number of reproductive organs than in increasing seed size, so its effect on 100-seed dry weight is insignificant.

Seed dry weight per plot is the most representative final yield parameter because it reflects the integration between the number of pods, seed filling rate, and seed size. This parameter is the main basis in evaluating soybean plant productivity at the cultivation scale. The results showed that PGPR concentration significantly affected seed dry weight per plot, with a concentration of 0 ml/liter (k0) producing the highest weight (0.34 kg) and significantly different from all PGPR concentration treatments. This finding indicates that PGPR application at a certain concentration does not necessarily increase the final yield, and even has the potential to reduce the efficiency of seed formation if there is a microbial imbalance in the rhizosphere. Another possibility is supported by the research of Tyas et al., (2025), that microbial competition with plants in the utilization of nutrients at high concentrations occurs. The absence of interaction between PGPR type and concentration indicates that both factors work independently in influencing pod yield, and emphasizes the importance of determining the correct dose and type of PGPR to maximize its benefits in soybean production.

3.4. Fresh and Dry Weight of Plants

Plant fresh weight is a growth parameter that reflects the accumulation of total plant biomass at harvest, including water content in plant tissue (Prakoso & Alpandari, 2024) This parameter is important because it describes plant vigor, the level of physiological activity, and the plant's ability to absorb water and nutrients from its growing environment (Paulus & Tooy, 2024). The results in Table 5 show that the type of PGPR significantly affected the fresh weight of soybean plants. The factory PGPR treatment (p2) produced the highest fresh weight (41.03 g) and was significantly different from the bamboo root PGPR treatment (p1), and tended to be higher than without PGPR (p0). The increase in fresh weight in the p2 treatment indicates that the factory PGPR has better effectiveness in increasing root activity, thereby improving water and nutrient absorption (Paulus & Tooy, 2024). PGPR microbes generally play a role in producing phytohormones such as auxins and gibberellins that stimulate root and shoot elongation, and increase the absorption surface area, ultimately contributing to increased plant fresh weight.

Plant fresh weight is also significantly influenced by tissue water content, so plant response to PGPR treatment reflects not only structural growth but also physiological status. The lower fresh weight value in the bamboo root PGPR treatment (p1) is thought to be related to the suboptimal adaptation of local microbes to the soybean rhizosphere or a less stable microbial population during the growth phase. Furthermore, there was a significant interaction between PGPR type and concentration on plant fresh weight, indicating that PGPR effectiveness is highly dependent on the compatibility between the microbial source and the application dose (Dubey et al., 2021). This interaction confirms that plant responses to PGPR are complex and cannot be explained by a single factor, but are influenced by the balance between microorganisms, the host plant, and the growing environment.

Table 5: Effect of PGPR Type and Concentration on Fresh and Dry Weight of Soybean Plants

Treatment	Fresh Weight of Plant (g)	Plant Dry Weight (g)
Types of PGPR		
Tanpa PGPR (p0)	34,33 ab	23,75 b
PGPR Akar Bambu (p1)	30,07 b	20,49 b
PGPR Pabrik (p2)	41,03 a	32,14 a
PGPR concentration		
Without PGPR (p0)	39,79 d	28,57 d
Bamboo Root PGPR (p1)	37,95 d	27,53 d
Plant PGPR (p2)	33,45 d	25,11 d
Without PGPR (p0)	29,38 d	20,62 d
Interaksi	+	-

Description: numbers followed by the same letter in the same column show no significant difference with the 5% LSD test. (-) there is no interaction between treatments and (+) there is an interaction between treatments

Plant dry weight is a parameter that reflects the accumulation of dry matter resulting from photosynthesis after the water content in the tissue is removed. This parameter is very important because it describes the actual growth and photosynthetic efficiency of plants, as well as being an indicator of the plant's ability to convert light energy and nutrients into biomass. The results showed that the type of PGPR significantly affected plant dry weight. The plant PGPR treatment (p2) produced the highest dry weight (32.14 g) and was significantly different from the treatment without PGPR (p0) and bamboo root PGPR (p1). This increase in dry weight indicates that plant PGPR not only increases water uptake but also plays a role in increasing the rate of photosynthesis and plant metabolic efficiency by increasing the availability of essential nutrients, especially nitrogen and phosphorus, which play an important role in plant tissue formation.

In terms of PGPR concentration, there was no significant effect on plant dry weight, although numerically there was a tendency for dry weight to decrease with increasing PGPR concentration. A concentration of 0 ml/liter (k0) produced the highest dry weight (28.57 g), while a concentration of 30 ml/liter (k3) produced the lowest dry weight (20.62 g). This phenomenon indicates that PGPR application at high concentrations has the potential to cause microbial imbalance in the root zone, resulting in competition between microorganisms and plants for nutrient utilization. The absence of interaction between PGPR type and concentration on plant dry weight indicates that dry biomass accumulation is more influenced by the characteristics of the PGPR itself than by the application dose (Jabborova et al., 2021). These findings emphasize the importance of selecting the right PGPR type and rational application dose to achieve optimal plant growth.

4. Conclusion

The type and concentration of PGPR had no significant effect on most soybean growth and yield parameters. However, plant PGPR and bamboo root PGPR showed a positive trend in supporting vegetative growth. PGPR type affected pod formation, with plant PGPR increasing the total pod number but accompanied by an increase in empty pods, while bamboo root PGPR produced pods with a lower number of empty pods, potentially increasing yield efficiency.

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Conflict of Interest

The authors declare no conflict of interest.

References

Adi Pratama, R., & Zakiah, K. (2017). Pengaruh Pemberian Fungi Mikoriza Arbuskula (FMA) dan PGPR terhadap Bintil Akar Tanaman Kedelai Hitam. *JAGROS*, *2*(1), 36–41.

Alfa Mustafa, P., Paulus, J. M., & Polii, M. G. (2023). Growth Response and Yield of Soybean Plants at Concentration Plant Growth Promoting Rhizobacteria (PGPR) From Bamboo Root (Bambusa sp.). *Jurnal Agri-SosioEkonomi Unsrat*, *19*(1), 579–584.

Alpandari, H., Prakoso, T., Suharijanto, & Widiatmoko, A. (2025). Pengaruh Dosis Dan Frekuensi Kcl Terhadap Pertumbuhan Dan Hasil Tanaman Melon (Cucumis melo L.) Di Jaken, Pati. *Jurnal Viabel Pertanian*, *19*(1).

Amaliah, B. N., Irfan, M., Mutakin, J., & Sativa, N. (2023). Respons Pertumbuhan Bibit Jahe Merah (Zingiber officinale var. rubrum) Terhadap Waktu Perendaman dan Konsentrasi Plant Growth Promoting Rhizobacteria (PGPR). *Agroteknika*, *6*(2), 213–225. https://doi.org/10.55043/agroteknika.v6i2.225

Anwar, K., Alpandari, H., Prakoso, T., & Herlina, N. (2025). The Impact Of Nitrogen Balance And Liquid Organic Fertilizer From Cow Urine On The Growth And Production Of Pakcoy Plants (Brassica chinensis L.) In Regosol Soil. *Jurnal Agrotek Tropika*, *13*(1), 82. https://doi.org/10.23960/jat.v13i1.7648

Chieb, M., & Gachomo, E. W. (2023). The role of plant growth promoting rhizobacteria in plant drought stress responses. *BMC Plant Biology*, *23*(1), 1–23. https://doi.org/10.1186/s12870-023-04403-8

Dubey, A., Saiyam, D., Kumar, A., Hashem, A., Abduallah, E. F., & Khan, M. L. (2021). Bacterial root endophytes: Characterization of their competence and plant growth promotion in soybean (glycine max (L.) merr.) under drought stress. *International Journal of Environmental Research and Public Health*, *18*(3), 1–20. https://doi.org/10.3390/ijerph18030931

Erwan, S., Istiqomah, N., & Mahdiannoor, M. (2019). Pemberian Berbagai Dosis Bokashi Jerami Padi yang Difermentasikan dengan PGPR Akar Bambu pada Tanaman Kedelai. *RAWA SAINS : JURNAL SAINS STIPER AMUNTAI*, *9*(1), 688–698. https://doi.org/10.36589/rs.v9i1.93

Fuskhah, E., & Darmawati, A. (2020). Plant Growth Promoting Rhizobacteria Growth and Production of Black Soybean (Glycine max L. Merill) on Various Types of Manure and Concentration of Plant Growth-Promoting Rhizobacteria. *Buletin Anatomi Dan Fisiologi*, *5*(1), 52–59.

Hafiz Sitompul, F., & Mardiyah, A. (2022). Pengaruh Waktu Aplikasi Pgpr (Plant Growth Promoting Rhizobacteria) Dan Jenis Pupuk Kandang Terhadap Pertumbuhan Dan Hasil Tanaman Kedelai Hitam (Glycine max L.). *Agrosamudra*, *9*(1), 2716–4101.

Jabborova, D., Kannepalli, A., Davranov, K., Narimanov, A., Enakiev, Y., Syed, A., Elgorban, A. M., Bahkali, A. H., Wirth, S., Sayyed, R. Z., & Gafur, A. (2021). Co-inoculation of rhizobacteria promotes growth, yield, and nutrient contents in soybean and improves soil enzymes and nutrients under drought conditions. *Scientific Reports*, *11*(1), 1–9. https://doi.org/10.1038/s41598-021-01337-9

Mustari, A., Bahri, S., & Juanda, R. B. (2023). Pengaruh Konsentrasi Pupuk Hayati Pgpr Dan Dosis Biourin Sapi Terhadap Pertumbuhan Dan Produksi Kedelai (Glycine max L.). *Agrosamudra*, *10*(1), 7–14.

Nur Fajri, W., Nur Afifah, A., Widyastuti, W., Alpandari, H., Prakoso, T., & Anwar, S. (2025). Pembangunan Pertanian: Persepsi Masyarakat Terhadap Pertanian Urban (Urban farming) Di Kota Kudus. *Journal Agribusiness Sciences*, *9*(1), 2614–6037. https://doi.org/10.30596/jasc.v9i1.24218

Paulus, J. M., & Tooy, D. (2024). Effect of Plant Growth Promoting Rhizobacteria (PGPR) on Growth and Yield of Soybean. *Journal of Agriculture*, *3*(01), 30–38. https://doi.org/10.47709/joa.v3i01.3613

Pereira, S. I. A., Abreu, D., Moreira, H., Vega, A., & Castro, P. M. L. (2020). Plant growth-promoting rhizobacteria (PGPR) improve the growth and nutrient use efficiency in maize (Zea mays L.) under water deficit conditions. *Heliyon*, *6*(10). https://doi.org/10.1016/j.heliyon.2020.e05106

Prakoso, T., & Alpandari, H. (2024). The Physiological Properties and Growth of Eggplant Plant (Solanum melongena L.) due to Applicated of Nitrogen and Iron on Hoagland solution. *Jurnal Agroekotek*, *16*(2), 119–134.

Prakoso, T., Ariyanto, S. E., Widyastuti, W., & Murrinie, E. D. (2023). Perbaikan Bahan Tanam Kopi Robusta Sebagai Perintisan Desa Agrowisata Desa Ternadi Kecamatan Dawe, Kabupaten Kudus. *Madaniya*, *4*(4), 1844–1850.

Prakoso, T., & Khakim, L. (2024). Response Of Planting Distance And Urea Dosage On The Growth And Yield Of Sweet Corn Plants (Zea mays saccharata. Sturt). *Jurnal Pertanian Agros*, *26*(2), 1214–1221.

Putri, H. R., Nufus, N. H., & Azhari, A. P. (2024). The Effect Of Plant Growth Promoting Rhizobacteria (PGPR) Putri Malu Root On The Growth And Yield Of Two Soybean Varieties. *Ganec Swara*, *18*(2), 1139–1146.

Ramadhan, A., Nurhayati, D. R., & Bahri, S. (2022). BIOFARM Jurnal Ilmiah Pertanian Pengaruh Pupuk Npk Mutiara (16-16-16) terhadap Pertumbuhan beberapa Varietas Kacang Hijau (Vigna Radiata L.) Effect of Npk Mutiara (16-16-16) Fertilizer on the Growth of Several Varieties of Green Beans (Vigna Radiata L.). *Biofarm : Jurnal Ilmiah Pertanian*, *18*(1).

Ratna, Ayu Kade Sutariati, G., & Muhidin. (2024). Efektivitas Perlakuan Rizobakteri Tanah Salin dan Pupuk Organik Terhadap Pertumbuhan Tanaman Kedelai (Glycine max (L.) Merrill) Di Lingkungan Pesisir. *Journal of Agronomi Research*, *12*(1), 21–32. https://doi.org/10.33772/bpa.v12i1.906

Sebastian, N., & Banjarnahor, D. (2019). Evaluasi pertumbuhan generatif dan hasil tanaman kedelai varietas grobogan di kecamatan Pabelan dan kecamatan Bancak, kabupaten Semarang. *AGRILAND Jurnal Ilmu Pertanian*, *7*(2), 135–143. https://jurnal.uisu.ac.id/index.php/agriland

Srg, J. R., & Harahap, S. R. (2023). Pengaruh Ekstra Lidah Buaya (Aloe vera) Sebagai ZPT Alami untuk Pertumbuhan Tanaman Kacang Tanah (Arachis hypogaea). *Jurnal Agroplasma*, *10*(2), 648–654.

Swarnalakshmi, K., Yadav, V., Tyagi, D., Dhar, D. W., Kannepalli, A., & Kumar, S. (2020). Significance of plant growth promoting rhizobacteria in grain legumes: Growth promotion and crop production. In *Plants* (Vol. 9, Issue 11, pp. 1–25). MDPI AG. https://doi.org/10.3390/plants9111596

Tyas, N. T., Fitriani, D., Podesta, F., Usman, & Suryadi. (2025). The Effect Of PGPR Biostimulant Concentration and Phosphorus Dosage on the Growth and Yield of Black Soybean (Glycine max (L.) Merril). *Nabatia*, *13*(2), 143–154. https://doi.org/10.21070/nabatia.v13i2.1667

Umami, A., & Wiharyanti, R. (2025). Efektivitas PGPR dan Nanosilika terhadap Pertumbuhan dan Hasil Kedelai Varietas Anjasmoro di Tanah Regosol. *Jurnal; Agro Wiralodra*, *8*(2), 57–66.

Vocciante, M., Grifoni, M., Fusini, D., Petruzzelli, G., & Franchi, E. (2022). The Role of Plant Growth-Promoting Rhizobacteria (PGPR) in Mitigating Plant's Environmental Stresses. *Applied Sciences (Switzerland)*, *12*(3). https://doi.org/10.3390/app12031231

Wicaksono, I., Astuti, A., & Isnawan, B. H. (2024). Transformasi Sistem Pangan menuju Kedaulatan Pertanian Uji efektivitas konsentrasi PGPR dari perakaran bambu dan urin kelinci pada pertumbuhan dan hasil tanaman kedelai (Glycine max (L.) Merril). *Prosiding Seminar Nasional Kedaulatan Pertanian UMY*, *1*(1), 235–248.

Zhang, T., Jian, Q., Yao, X., Guan, L., Li, L., Liu, F., Zhang, C., Li, D., Tang, H., & Lu, L. (2024). Plant growth-promoting rhizobacteria (PGPR) improve the growth and quality of several crops. *Heliyon*, *10*(10). https://doi.org/10.1016/j.heliyon.2024.e31553