Journal of Tropical Crop Science Vol. 12 No. 1, February 2025
www.j-tropical-crops.com

Received 14/10/2024; Revised 05/11/2024; Accepted 08/01/2025
https://doi.org/10.29244/jtcs.12.01.70-76

Response of Growth and Yield of "IPB 9G" Rice to The Application of NPK and Biofertilizers

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Abstract

Rice is a staple food crop that is challenging to replace with alternative crops. Strategies that balance high yields with environmental sustainability are crucial to enhance rice production. One such approach is integrating organic, biological, and chemical fertilizers. This study aimed to evaluate the effects of combining these fertilizers on the growth and yield of "IPB 9G" rice.

The experiment was conducted at the IPB experimental farm in Cikabayan, Bogor, Indonesia, from March to June 2024, using a randomized complete block design with two factors and three replications. Treatments included two doses of NPK fertilizer (100% and 50% of the recommended dose) and five combinations of organic and biofertilizers: *Azotobacter* sp., *Azotobacter* sp. + *Pseudomonas* sp., humic acid, PGPR (Plant Growth-Promoting Rhizobacteria), and a combination of *Azotobacter* sp. + *Pseudomonas* sp. + humic acid + PGPR. Parameters observed included leaf area, root volume, shoot dry weight, and yield components such as the number of panicles, 1000-grain weight, and the number of grains per panicle. The results demonstrated a significant interaction between NPK dosage and organic-biofertilizer combinations on plant growth and yield. Notably, applying 50% of the recommended NPK dose combined with *Azotobacter* sp. + *Pseudomonas* sp. produced comparable or superior yields to the full NPK dose. These findings highlight the potential of reducing chemical fertilizer usage by incorporating biofertilizers, offering an environmentally sustainable strategy for rice cultivation.

Keywords: *Azotobacter* sp., environmental sustainability, humic acid, PGPR, *Pseudomonas* sp.

Introduction

Rice is the primary staple food for Indonesia's population, with approximately 98% relying on it as their primary dietary source (Harahap et al., 2023). The demand for rice continues to grow yearly due to population increases. In 2023, the harvested rice area was approximately 10.21 million hectares, producing 53.98 million tons of dry-milled grain (DMG), equivalent to about 30.90 million tons of rice. However, this marked a decline of 645.09 thousand tons (2.05%) compared to the 31.54 million tons of rice produced in 2022 (Badan Pusat Statistik, 2024).

Several strategies to boost rice production have been explored to meet the increasing demand. One approach is developing high-yielding rice varieties through breeding programs (Hasan et al., 2022). Another effective strategy involves integrating organic, biofertilizers, and chemical fertilizers to achieve high yields while addressing environmental concerns (Zaki et al., 2020). Organic and biofertilizers are increasingly viewed as sustainable alternatives to optimize fertilizer use, minimize the environmental impact of chemical fertilizers, and maintain soil health.

Biofertilizers, composed of beneficial microorganisms, can be applied to seeds or soil to improve plant nutrient availability. These microorganisms can enhance plant growth, increase yield components, and reduce dependency on chemical fertilizers (Moelyohadi et al., 2012). When combined with chemical fertilizers like NPK, organic fertilizers have also improved soil properties, microbial activity, and crop productivity (Himmelstein et al., 2014; Dhillon et al., 2021). Unlike organic fertilizers that primarily add nutrients such as minerals, carbohydrates, and fats, biofertilizers directly interact with soil microbes to support plant growth and maintain long-term soil fertility (Punjee et al., 2020).

Humic acid is critical in improving nutrient availability and soil properties among organic fertilizers. It

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enhances cell division and elongation, increasing plant height and overall growth (Alfatlawi and Alrubaiee, 2020). Humic acid, fulvic acid, and humin are key components of soil organic carbon (Ndzelu et al., 2020). Studies show that applying humic acid at a rate of 20 $kg.ha^{-1}$ combined with silica can significantly increase tiller number, panicle number, and yield, achieving up to 4.2 tons of dry harvested grain per hectare (Dzikrullah et al., 2021).

Biofertilizers utilize microorganisms to fix atmospheric nitrogen, solubilize phosphates, and produce growth-promoting hormones. Azotobacter, for instance, not only fixes nitrogen but also produces compounds like thiamine, riboflavin, indole acetic acid (IAA), and gibberellins (GA), all of which enhance plant growth (Sahoo, 2023). Similarly, *Pseudomonas* sp., a phosphate-solubilizing bacterium, increases plant biomass, improves soil fertility, and enhances the availability of nitrogen, phosphorus, and potassium (Nosheen et al., 2018; John et al., 2017). PGPR (Plant Growth-Promoting Rhizobacteria) microorganisms are particularly beneficial in mitigating abiotic stresses such as salinity and drought, offering a cost-effective and eco-friendly alternative to conventional fertilizers (Elnahal et al., 2022).

Given the critical need to sustain soil health and improve rice productivity, research into the combined application of organic, biofertilizers, and NPK fertilizers is essential. This approach is particularly relevant for cultivating "IPB 9G" rice, ensuring sustainable growth and yield enhancement while minimizing environmental impact.

Materials and Methods

This research was conducted from March to June 2024 in a greenhouse at the IPB experimental farm in Cikabayan, Bogor, and in the Plant Molecular Biology Laboratory 1, Department of Agronomy and Horticulture, IPB.

This experiment used a randomized complete block design with two factors. The first factor was the NPK fertilizer dose, consisting of two levels: (1) 100% NPK (112.5 kg N per ha, 36 P P kg per ha, 60 kg K per ha), (2) 50% NPK (56.25 kg N per ha, 18 kg P per ha, 30 kg K per ha). The second factor was organic and biofertilizers, consisting of five levels: (1) *Azotobacter* sp. (2) *Azotobacter* sp. + *Pseudomonas* sp., (3) 30 kg humic acid per ha, (4) PGPR 10 $g.L^{-1}$, (5) *Azotobacter* sp. + *Pseudomonas* sp. + PGPR + humic acid. Each treatment was replicated three times, resulting in 30 experimental combinations, each consisting of 8 plants, totaling 240 plants.

Experimental Procedures

Rice seeds were directly planted into polybags with seven seeds per hole, then thinned to five seeds per hole two weeks after planting.

Fertilizer and Plant Growth-Promoting Rhizobacteria (PGPR) Application

Phosphorus and potassium fertilizers were applied at planting, while nitrogen was split into two applications: half at planting and the other half six weeks after planting. PGPR was applied three times, consisting of Azotobacter sp. and a combination of *Azotobacter* sp. + *Pseudomonas* sp. The first application was during seed soaking, followed by applications at 7 and 14 days after planting (DAP). The bio-agent isolates of *Azotobacter* sp. and *Pseudomonas* sp. were cultured on nutrient agar medium for 48 hours, then diluted to a concentration of approximately 10^7 $CFU.mL^{-1}$. A 10 mL suspension was applied per plant during each application. PGPR was applied once during seed soaking, while humic acid was applied at planting. The humic acid was directly added to the planting holes.

Soil Amendments

To enhance soil fertility, 1 $ton.ha^{-1}$ of cow manures and 2 $ton.ha^{-1}$ of dolomite were incorporated into the soil one week before planting.

Measured Variables

The study measured several growth and yield parameters, including leaf area, shoot dry weight, number of panicles per clump, panicle length (cm), number of grains per panicle, 1000-grain weight (g), number of empty grains, harvest index, total number of grains per panicle

Harvesting Protocol

Harvesting was performed at physiological maturity, determined by 90% of the grains turning yellow across the population.

Data Analysis

The collected data were analyzed using an F-test to identify significant effects. When significant differences were detected, a Tukey's test compared treatments at a significance level of $\alpha = 0.05$. Statistical analysis was performed using SAS software.

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Result and Discussion

Plant Growth and Development

The analysis of variance revealed a significant interaction between NPK fertilizer dosages and the application of organic and biofertilizers on the leaf area (Table 1). During the primordia phase (53 DAP), the treatment involving *Azotobacter* sp. + *Pseudomonas* sp. at the 100% NPK dose resulted in a 32.9% reduction in the leaf area (2539.2 cm²) compared to the highest leaf area achieved (3784.0 cm²) with the PGPR treatment at the 50% NPK dose. Similarly, during the 50% flowering phase (83 DAP), *Azotobacter* sp. at the 50% NPK dose produced a smaller leaf area (3195.8 cm²) compared to the highest value (5105.6 cm²), achieved with humic acid at the 100% dose, a reduction of 37.4%. These findings suggest that combining biofertilizers with organic matter is more effective in enhancing leaf area.

A significant interaction between NPK and organic fertilizers affected root volume (Table 2). PGPR at the 50% NPK dose resulted in a root volume of 75.0 mL, 16.7% lower than the 90.0 mL recorded for PGPR at the 100% NPK dose. This indicates that a reduced NPK dose with PGPR alone is less effective in increasing root volume.

Organic and biofertilizer treatments significantly affected the shoot dry weight at harvest (Table 3). The treatment involving *Azotobacter* sp. alone produced a lower shoot dry weight (38.1 g) compared to the best treatment (*Azotobacter* sp. + *Pseudomonas* sp. + Humic acid + PGPR) at 46.1 g, representing a 17.37% decrease.

Table 1. Effect of the interaction between NPK fertilizer dose and application of organic fertilizer and biofertilizer on leaf area in the primordia phase and 50% flowering

Treatment	Leaf area (cm²)			
	100% NPK fertilizer	50% NPK fertilizer	100% NPK fertilizer	50% NPK fertilizer
	Primordia (53 DAP)		50% Flowering (83 DAP)	
Azotobacter sp.	3569.6ab	3256.8abc	4933.4ab	3195.8c
Azotobacter sp. + *Pseudomonas* sp.	2539.2c	3278.9abc	3139.3c	4729.5ab
Humic acid	3373.2ab	2929.8bc	5105.6a	4722.6ab
PGPR	3454.7ab	3784.0a	4356.0ab	4374.4ab
Azotobacter sp.+ *Pseudomonas* sp. + Humic Acid + PGPR	2983.1abc	3517.6ab	4818.1ab	4091.1bc

Notes: 100% NPK fertilizers consist of 112.5 kg N per ha, 36 kg P per ha, 60 kg K per ha; 50% NPK fertilizer consists of 56.25 kg N per ha, 18 kg P per ha, 30 kg K per ha. Values followed by different letters in the same column are significantly different in the Tukey test; ns=non-significant; * = significant at α=0.05.

Table 2. Effect of the interaction between NPK fertilizer dose and application of organic fertilizer and biofertilizer on root volume at the primordia phase

Treatment	Root volume (mL)	
	100% NPK fertilizer	50% NPK fertilizer
Azotobacter sp.	71.7b	88.7ab
Azotobacter sp.+ *Pseudomonas* sp.	88.3ab	78.3ab
Humic Acid	78.3ab	78.3ab
PGPR	90.0a	75.0ab
Azotobacter sp.+ *Pseudomonas* sp. + Humic acid + PGPR	75.0ab	88.3ab

Notes: 100% refers to the full dose of the recommended NPK fertilizers, which consist of 112.5 kg N per ha, 36 P kg P per ha, and 60 kg K per ha; 50% refers to the 50% of the recommended NPK fertilizer, consisting of 56.25 kg N per ha, 18 kg P per ha, 30 kg K per ha. Values followed by different letters in the same column are significantly different in the Tukey test; ns=non-significant; * = significant at α=0.05.

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Table 3. Effect of NPK fertilizer dose and application of organic fertilizer and biofertilizer on shoot dry weight

Treatment	Shoot dry weight (g)
NPK dose	
100%	40.2
50%	44.7
Organic and biofertilizer	
Azotobacter sp.	38.1b
Azotobacter sp. + *Pseudomonas* sp.	42.6ab
Humic acid	43.2ab
PGPR	42.4ab
Azotobacter sp. + *Pseudomonas* sp. + Humic Acid + PGPR	46.1a

Notes: 100% refers to the full dose of the recommended NPK fertilizers, which consist of 112.5 kg N per ha, 36 P kg P per ha, and 60 kg K per ha; 50% refers to the 50% of the recommended NPK fertilizer, consisting of 56.25 kg N per ha, 18 kg P per ha, 30 kg K per ha. . Values followed by different letters in the same column are significantly different in the Tukey test; ns=non-significant; * = significant at α=0.05.

Rice Yield

Applying NPK fertilizers, organic fertilizers, and biofertilizers did not significantly affect the number of panicles per clump, panicle length, number of grains per panicle, 1000-grain weight, empty grains, or harvest index (Table 4). However, grain weight per clump tended to be higher in plants receiving 50% of the recommended NPK dose than those receiving 100%. Among organic and biofertilizer treatments, grain weight per clump was highest in plants treated with *Azotobacter* sp. + *Pseudomonas* sp. + humic acid + PGPR. In contrast, humic acid alone had the lowest number of panicles per clump. Significant interactions between NPK dosages and organic and biofertilizer treatments were observed for the number of grains per panicle (Table 5). Humic acid increased the number of grains by 37.7% at the 50% recommended NPK dose compared to the 100% dose. Conversely, the performance of *Azotobacter* sp. remained unchanged across NPK dosages.

Correlation Between Variables

The correlation analysis (Figure 1) highlighted a positive relationship between shoot dry weight at harvest and grain weight per clump. This suggests that increased shoot dry weight contributes to higher grain weight per clump, though the correlation was weak.

The interaction between humic acid and 100% recommended NPK dose significantly increased leaf area at the 50% flowering phase. This indicates that humic acid enhances the soil's physical, chemical, and biological properties, improving water and nutrient uptake (Gao et al., 2020). Its ability to slow nitrogen release minimizes nutrient losses due to leaching and evaporation, ensuring better nitrogen absorption by plants (Ismillayli et al., 2019).

Combining PGPR and the 100% recommended NPK dose significantly increased root volume. PGPR inoculation promotes the production of indole acetic acid (IAA), an essential hormone in cell elongation, division, and differentiation. This facilitates root hair development, improving water and nutrient absorption (Hartmann et al., 1983; Sitawati et al., 2022).

The treatment involving *Azotobacter* sp. + *Pseudomonas* sp. + Humic Acid + PGPR significantly increased shoot dry weight. This synergistic effect of biofertilizers and organic matter enhances nutrient availability, boosting photosynthesis and plant biomass. Azotobacter sp. plays a role in nitrogen fixation, while Pseudomonas sp. enhances nutrient uptake and improves overall plant productivity (John et al., 2017). Although no significant differences were observed in panicle traits, the 50% recommended NPK dose resulted in higher grain weight per panicle than the 100% dose, highlighting the potential for reduced fertilizer use when combined with biofertilizers. This aligns with findings by Aryanto et al. (2015), who reported that biofertilizers could reduce synthetic fertilizer usage by 50% while maintaining yield levels.

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Received 14/10/2024; Revised 05/11/2024; Accepted 08/01/2025
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Table 4. Effect of NPK fertilizer dose and application of organic fertilizer and biofertilizer on number of panicles per clump, panicle length, number of grains per panicle, 1000-grain weight, number of empty grains, and harvest index

Treatment	Number of panicles per clump	Panicle length (cm)	1000-grain weight (g)	Grain weight per clump (g)	Harvest index
NPK dose					
100% Recommended	16.9a	31.0a	25.6a	56.3a	0.6a
50% Recommended	16.3a	31.2a	25.8a	59.2a	0.6a
Organic and biofertilizer					
Azotobacter sp.	18.3a	31.0a	25.4a	56.3a	0.6a
Azotobacter sp. + *Pseudomonas* sp.	15.3a	31.2a	26.0a	58.1a	0.6a
Humic acid	15.0a	31.3a	26.2a	57.7a	0.6a
PGPR	16.1a	31.2a	25.7a	55.4a	0.6a
Azotobacter sp. + *Pseudomonas sp.* + Humic acid + PGPR	18.3a	30.8a	25.3a	61.5a	0.6a

Notes: values followed by different letters in the same column are significantly different in the Tukey test; ns=non-significant at α=0.05.

Table 5. Effect of the interaction between NPK fertilizer dose and application of organic fertilizer and biofertilizer on the number of grains per panicle

Treatment	Number of grains per panicle (grains)	
	100% NPK fertilizer	50% NPK fertilizer
Azotobacter sp.	229.8abc	229.9abc
Azotobacter sp. + *Pseudomonas* sp.	195.2bc	249.8 a
Humic acid	178.0c	245.2 ab
PGPR	213.3abc	235.8 ab
Azotobacter sp. + *Pseudomonas* sp. + Humic acid + PGPR	196.2bc	200.1 bc

Notes: 100% refers to the full dose of the recommended NPK fertilizers, which consist of 112.5 kg N per ha, 36 P kg P per ha, and 60 kg K per ha; 50% refers to the 50% of the recommended NPK fertilizer, consisting of 56.25 kg N per ha, 18 kg P per ha, 30 kg K per ha. Values followed by the same letter are not significantly different according to the Tukey test at the 5% level.

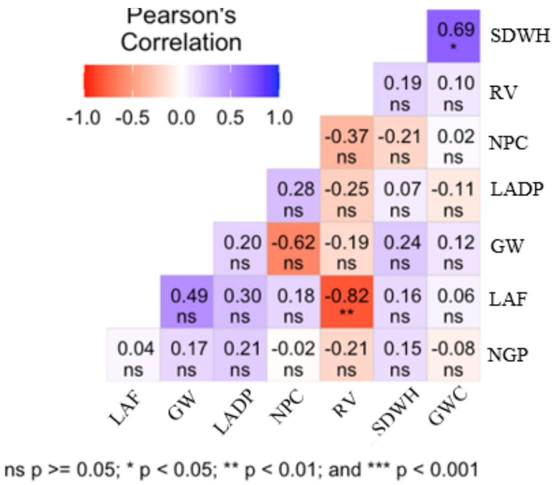

Figure 1. Correlation between growth variables, SDWH: shoot dry weight at harvest; RV: root volume; NPC: number of panicles per clump; LADP: leaf area at primordial phase; LAF: leaf area at 50% flowering; GW: 1000-grain weight; NGP: number of grains per panicle; GWC: grain weight per clump.

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Conclusion

The study demonstrates that integrating biofertilizers, particularly *Azotobacter* sp. and *Pseudomonas* sp., with a reduced NPK fertilizer dose (50% of the recommendation) supports optimal growth and yield in "IPB 9G" rice. This approach enhances shoot dry weight and grain yield per panicle, reducing dependency on synthetic fertilizers while maintaining productivity. Additionally, humic acid and PGPR significantly improve leaf area and root volume, contributing to the resilience and sustainability of rice cultivation. This integrated strategy offers economic and environmental advantages and promotes sustainable agricultural practices.

Acknowledgment

This research did not receive any specific grant from funding agencies in the public, commercial, or nonprofit sectors.

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Received 14/10/2024; Revised 05/11/2024; Accepted 08/01/2025
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