JPPIPA 12(6) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Impact of Plant Growth Promoting Rhizobacteria (PGPR) on Nitrogen Uptake and Yield of Palu Local Shallots

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Received: March 12, 2026
Revised: May 10, 2026
Accepted: June 25, 2026
Published: June 30, 2026

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DOI: 10.29303/jppipa.v12i6.14802

Abstract: Plant Growth-Promoting Rhizobacteria (PGPR) play an important role in improving soil microbial populations and enhancing plant growth and nutrient uptake. This study aimed to evaluate the effect of different PGPR concentrations on bacterial colony populations, growth performance, biomass production, and nitrogen uptake of Palu Valley shallot plants. The experiment consisted of four treatments: control (F0), PGPR 10 mL (F1), PGPR 15 mL (F2), and PGPR 20 mL (F3). The observed variables included bacterial colony population, number of shallot bulbs, fresh biomass, dry biomass, and nitrogen uptake. The results showed that PGPR application increased the bacterial colony population in soil, with the highest population recorded in treatment F3 (3.90×10^6 CFU g^{-1} soil). The average number of shallot bulbs increased from 9 bulbs $plant^{-1}$ in the control to 12 bulbs $plant^{-1}$ in treatments F2 and F3. Fresh biomass and dry biomass also increased with higher PGPR concentrations, reaching 11.95 g and 2.42 g respectively in F3. Nitrogen uptake showed a gradual increase from 1.61% in the control to 1.69% in F3. These findings indicate that PGPR application improves soil microbial populations, plant growth, biomass accumulation, and nitrogen uptake in Palu Valley shallot plants, with the 20 mL PGPR (F3) treatment providing the most effective results.

Keywords: Nitrogen uptake; PGPR; Rhizobacteria; Palu Valley Shallot; Soil Microbial Population.

Introduction

In the soil, microbial communities linked to plant roots play a significant role in the health and growth of plants. Plants influence soil microorganisms through the release of root exudates, which in turn affect plant-soil interactions (Sun et al., 2024; Chen & Liu, 2024; Eichmann et al., 2021; Hiremath et al., 2024; Wahab et al., 2023). Given the critical role of root exudates in forming symbiotic relationships within the rhizosphere, understanding the interactions between plant roots and soil microorganisms is essential and could provide valuable insights (Chauhan et al., 2023)

Rhizosphere microorganisms enhance nutrient exchange and cycling, facilitating the release of nutrients such as nitrogen, phosphorus, and organic carbon from organic compounds and other micronutrients (Iqbal et al., 2023; Saeed et al., 2021; Mahmud et al., 2021; Pantigoso et al., 2022; Thepbandit & Athinuwat, 2024).

The roles performed by these microorganisms in agricultural systems encompass enhancing nutrient nitrogen uptake and helping the host plant resist various biotic and abiotic stresses. These microorganisms surround the roots and influence plant growth and development in both direct and indirect ways. Additionally, they help plants cope with harmful factors such as salinity, drought, heavy metals, flooding, and other stresses by stimulating the production of antioxidant enzymes like catalase, peroxidase, and superoxide dismutase (Tharanath et al., 2024; Koza et al., 2022; Lopes et al., 2021; Chiaranunt et al.,2023).

How to Cite:
Example: Bangkele, I.L., Sudewi, S., Idris., Ratnawati., Arfan., (2026). Impact of Plant Growth Promoting Rhizobacteria (PGPR) on Nitrogen Acquisition and Yield of Palu Local Shallots. *Jurnal Penelitian Pendidikan IPA, 1*(1), 1-4. https://doi.org/10.29303/jppipa.v1i1.264

Many of rhizosfer microorganism supporting nutrients acquisition by plant roots. A liquid organic fertilizer containing PGPR was utilized, encompassing *Bacillus sp*, *Bacillus amyloliquifaciens*, *Azotobacter sp*, *Pseudomonas sp* (Sudewi et al., 2021). Rhizobacteria exhibit the capacity to produce phytohormones that serve as potential plant growth stimulants (Tahir et al., 2017). The primary group of phytohormones generated by rhizobacteria in plants includes *auxins, gibberellins, cytokinins, abscisic acid, ethylene*, and *brassinosteroids*. Collectively, these phytohormones stimulate root cell growth, leading to the proliferation of lateral roots and root hairs, thereby enhancing root nutrient and water acquisition capabilities (Sureshbabu et al., 2016; Warman et al., 2022). Previous research has indicated that nitrogen uptake in shallots can be improved through the application of organic or biological fertilizers. The incorporation of organic matter into the soil amplifies the activity of soil organisms, closely tied to the natural organic matter content in the soil itself (Elias et al., 2024; Zhao et al., 2024; Tahat et al., 2020); Angst et al., 2024).

Organic matter boosts microorganism populations, thereby enhancing the mineralization of organic matter (Bangkele et al., 2019). Biofertilizers like PGPR are frequently employed to enhance soil fertility, elevate agricultural yields, and fortify plants against diseases or environmental stresses. A notable advantage of PGPR is its reduction of reliance on chemical pesticides, which can have adverse effects on the environment and human health. Plant Growth Promoting Rhizobacteria (PGPR) fosters plant growth by acting as a biostimulant and biofertilizer (Yang et al., 2024; Hasan et al., 2024; Ikiz et al., 2024; El-Saadony et al., 2024).

The presence of beneficial PGPR microbial colonies in plant roots is advantageous for enhancing plant health and stimulating plant growth. Microorganisms surrounding plant roots (Aini et al., 2019). By harnessing beneficial microorganisms, farmers can curtail the use of potentially harmful synthetic pesticides. The application of nitrogen fertilizers can be tailored to the recommended dosage and plant growth stage to meet plant requirements without overfertilization (Ishaq et al., 2023). Biofertilizers also diminish the necessity for inorganic fertilizers, hence, the adoption of biological fertilizers is believed to enhance the development and growth of shallots (Ulfa et al., 2024; Rahmawati & Ladewa, 2023; Kalasari et al., 2023).

Considering the above elucidation, an experiment is warranted to explore the impact of PGPR biofertilizer on nitrogen uptake to bolster the productivity of local hammer shallot plants (Mokoginta et al., 2022). Although PGPR has been widely reported to enhance plant growth and nutrient uptake, limited information is available regarding its role in improving nitrogen uptake in Palu local shallot, a locally adapted shallot variety with specific agroecological characteristics. Most previous studies have focused on general growth promotion, while the specific interaction between PGPR application, nitrogen uptake, and yield performance in Palu local shallot remains insufficiently explored. Therefore, this study is important to provide scientific evidence for the use of PGPR-based biofertilizer as a sustainable strategy to improve nutrient efficiency and productivity in local shallot cultivation. This study aimed to evaluate the effect of PGPR biofertilizer on nitrogen uptake and yield performance of Palu local shallot.

The application of PGPR offers promising potential for alleviating food insecurity, preserving environmental health, and reducing public health risks (AbuQamar et al., 2024; Hakim et al., 2021). It is essential to embrace biological agents on a global scale. This review aims to promote the use of PGPR as a bio-inoculant in agricultural research and to explore the design of PGPR formulations within the context of sustainable farming practices (Santos et al., 2021).

Method

Site Location

The research was carried out at the Greenhouse of the Faculty of Agriculture, Alkhairaat University, Palu City, Central Sulawesi, from October 2024 to January 2025.

Experimental Design and Materials

The materials employed in the study comprised water, soil, compost as a base fertilizer equivalent to 20 tons ha^{-1} and PGPR biofertilizer. A Randomized Group Design (RAK) was implemented, encompassing four treatment levels: F0 = 0 ml PGPR per polybag (control), F1 = 10 ml PGPR per polybag, F2 = 15 ml PGPR per polybag, and F3 = 20 ml PGPR per polybag. Each treatment was replicated thrice, resulting in 12 experimental units. The observation variables included :

Bacterial Colony Count

The number of bacterial colonies was analyzed using a serial dilution method followed by a plate count. The soil sample was diluted in stages, then 0.1 mL of the suspension was inoculated onto nutrient agar media using the spread plate method and incubated at approximately 28–30°C for 24–48 hours. The number of colony-forming units per gram (CFU g^{-1} of soil) in the bacterial sample can be determined using the following formula (Vieira and Nahas, 2005):

$$(\text{CFU g}^{-1} \text{ of soil}) = \frac{\text{Number of Colonies Counted}}{\text{Volume Plated (mL) x Dilution Factor}} \quad (1)$$

Where:

CFU g^{-1} of soil	=	Colony Forming Units per gram soil, representing the quantity of viable microorganisms in 1 mL of the original sample
Number of colony counted	=	The total colonies observed and counted on the agar plate
Volume Plated (mL)	=	The amount of the diluted sample spread on the agar plate (0.1 mL)
Dilution Factor		The extent to which the sample was diluted (for example, 1:1000 would be written as 1000)

Number of shallot bulbs

The number of bulbs was observed at harvest by counting the number of fresh bulbs produced by each plant in the experimental unit. The obtained values were then averaged to obtain the number of bulbs per plant (Aragie et al., 2023).

Fresh and Dried plant biomass

Fresh plant biomass was measured by carefully uprooting the plants, removing any soil adhering to the roots, and then weighing the entire plant using an analytical balance to obtain fresh plant weight data. Dry biomass is obtained by drying plant samples in an oven at 65–70°C for 48–72 hours until they reach a constant weight (Munser et al., 2025).

Plant nitrogen uptake

Plant nitrogen uptake is determined by analyzing the nitrogen content of plant tissue using the Kjeldahl method. Dried plant samples are digested using sulfuric acid, then distillation and titration are performed to determine nitrogen concentration. Nitrogen uptake is calculated by multiplying the nitrogen concentration by the dry biomass of the plant. Nitrogen uptake was determined according to the method of Dal Lago et al.(2024).

$$\text{N Uptake} = \frac{\text{N (\%)}}{100}\ x\ Dry\ biomass \qquad (2)$$

Where:

N uptake	=	nitrogen uptake by the plant
N concentration (%)	=	nitrogen concentration in plant tissues determined using the Kjeldahl analysis
Dry biomass (g)	=	plant dry biomass obtained after oven-drying the plant samples

Analysis Data

The data collected were subjected to analysis of variance (BNJ test) at 5% significance level, followed by the 5% BNT test if significant effects were detected.

Results and Discussion

Bacterial colony count

The results of this analysis show the average number of bacterial colonies per gram of soil on shallot plants in Palu Valley. The data obtained provides an overview of the variation in the number of bacterial colonies in various soil conditions that support the growth of shallot plants. The average number of bacterial colonies can be an indicator of soil quality and the level of activity of microorganisms that play an important role in the plant ecosystem. The following table presents the results of measuring the average number of bacterial colonies:

Table 1. Average Number of Bacterial Colonies (CFU g^{-1} of soil) on Palu Valley Shallot Plants

Treatment	Bacterial Colony Count (CFU/gram of soil sample)
F0 (Control)	3.30×10^6
F1 (PGPR 10 mL)	3.60×10^6
F2 (PGPR 15 mL)	3.80×10^6
F3 (PGPR 20 mL)	3.90×10^6

Description: CFU = colony forming unit

As shown in Table 1, the number of bacterial colonies in soil samples treated with PGPR microbes (F1, F2, and F3) was higher than those in the control group (F0). The experimental results demonstrated a linear increase in bacterial colonies with increasing levels of PGPR treatment. These findings suggest that the administered PGPR bacteria were viable and able to thrive in the medium and the shallot plants. Additionally, the PGPR treatment contributed to increased fresh and oven-dried biomass production (Purwanto et al., 2019), as well as enhanced nitrogen uptake in Palu local shallot plants.

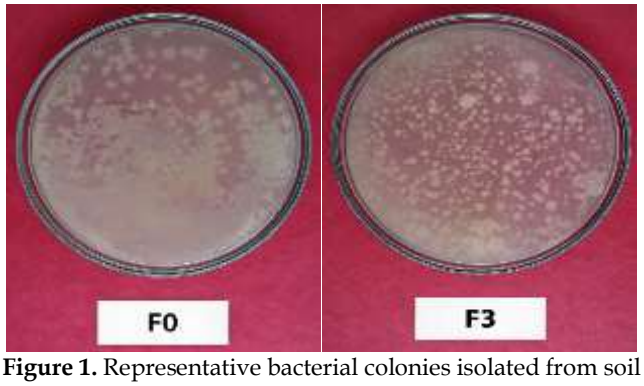

Figure 1. Representative bacterial colonies isolated from soil samples under PGPR treatment (F3) and control (F0).

The results of the variance analysis indicated that PGPR treatment did not significantly affect the number of bulbs in Palu Local Shallot. The data, however, indicate that PGPR supplementation may have the potential to improve plant height and leaf number in Palu Local Shallot plants, supporting previous research that highlighted the positive impact of PGPR on growth factors like plant height and leaf development. These findings support the idea that PGPR bacteria may contribute to overall plant vigor and growth, possibly through mechanisms like nutrient mobilization, improved soil health, or enhanced photosynthetic efficiency, even though the number of bulbs was unaffected (Aditya et al., 2025).

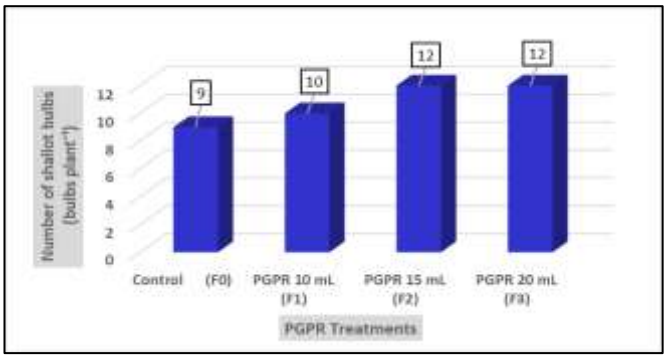

Figure 2. Effect of PGPR treatments on the number of Palu local shallot bulbs (bulbs plant^{-1}).

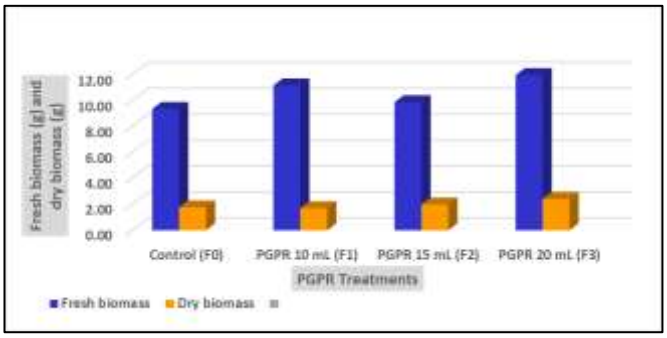

Figure 3. Effect of PGPR treatments on fresh biomass (g) and dry biomass (g) of Palu local shallot plants.

The variance analysis results showed that PGPR treatment had no significant effect on the number of bulbs, wet weight, or dry weight of Palu Local Shallot plants. However, the use of POC was found to be effective in increasing both the dry and wet weight of these plants, a finding that is consistent with several earlier studies, such as Harahap et al., (2023) and Sulandjari et al., (2025) which demonstrated that biological fertilizers containing PGPR bacteria can increase the yield of fresh bulbs, dry bulbs, and chlorophyll content in shallot plants. Furthermore, the utilization of biological liquid fertilizer containing PGPR could enhance the growth of rubber plant seedlings (Lestari et al., 2025; Zhang et al., 2024; Agustiyani, 2016).

While nitrogen uptake did not exert a significant effect based on the variance analysis results, the data exhibited a linear correlation between the number of bacterial colonies (PGPR) and nitrogen uptake. Moreover, a linear relationship was observed between nitrogen uptake and the production of fresh biomass and dry biomass of Palu local shallot plants. This signifies that PGPR can adapt and contribute to nitrogen uptake, consequently boosting the biomass production of Palu local shallot plants.

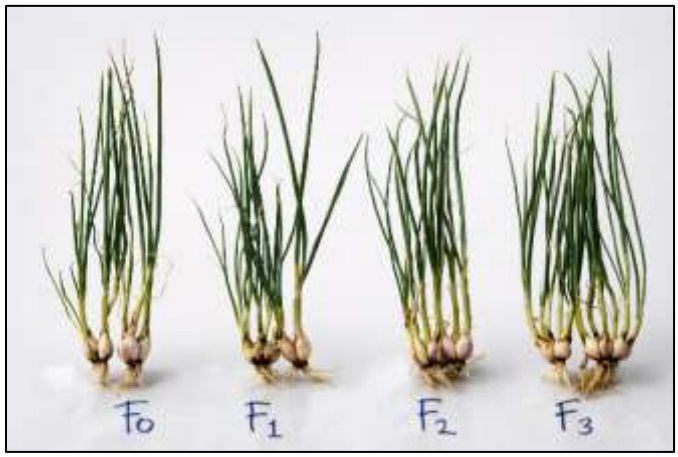

Figure 4. Morphological appearance of Palu local shallot plants under PGPR treatments: control (F0), PGPR 10 mL (F1), PGPR 15 mL (F2), and PGPR 20 mL (F3).

The results of this study align with the research previously conducted by Priyashantha et al., (2023) which posits that PGPR bacteria enhance plant nutrient acquisition, thereby elevating the production of wet biomass and dry biomass in plants. However, this contradicts the findings of Bangkele et al., (2020) who reported that the number of microorganism colonies did not influence N acquisition and biomass production of annual plant seedlings, particularly plants from the palmae family, such as rattan plant seedlings whose growth is notably sluggish.

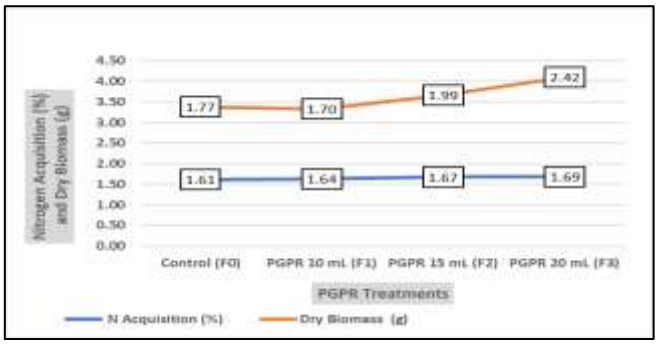

Figure 5. Nitrogen uptake (%) and dry biomass (g) of Palu local shallot plants under different PGPR treatments.

In addition, the use of PGPR did not significantly affect the number of bulbs, wet weight, or dry weight of Palu Local Shallot plants. However, it was observed that the use of PGPR organic fertilizer was effective in increasing the mass production (dry weight and wet weight) of palu local shallot plants. This finding is consistent with previous studies that demonstrated how biological fertilizers containing PGPR bacteria could enhance the yield of fresh bulbs, dry bulbs, and chlorophyll content in shallot plants. Additionally, the application of biological liquid fertilizer containing PGPR was found to improve the growth of rubber plant seedlings.

The variance analysis did not show a significant impact on nitrogen uptake, a clear linear relationship was observed between the number of bacterial colonies (PGPR) and the uptake of nitrogen. This relationship extended to the production of fresh biomass and dry biomass of Palu local shallot plants, indicating that PGPR can play a role in enhancing nitrogen uptake and subsequently increasing biomass production in these plants. These findings align with previous research that suggests PGPR bacteria can enhance plant nutrient acquisition, leading to an increase in wet biomass and dry biomass production in plants.

Conclusion

The application of PGPR increased bacterial colony populations, growth performance, biomass production, and nitrogen uptake of Palu Valley shallot plants. The highest bacterial population (3.90×10^6 CFU g^{-1} soil), biomass production, and nitrogen uptake were obtained in the PGPR 20 mL treatment (F3). Meanwhile, the highest number of shallot bulbs was observed in treatments F2 and F3. Overall, the application of PGPR at 20 mL showed the most optimal effect in improving soil microbial activity and the growth performance of Palu Valley shallot plants.

The application of PGPR increased bacterial colony populations, plant growth, biomass production, and nitrogen uptake in Palu local shallot. The PGPR treatment at 20 mL showed the most favorable effect on soil bacterial activity and overall plant performance. These findings indicate that PGPR biofertilizer has scientific and practical potential as a sustainable input to improve soil biological activity, enhance nitrogen uptake efficiency, and support the productivity of Palu local shallot cultivation.

Acknowledgments
All authors would like to thank all parties who have contributed to the completion of this research from the beginning to the end.

Author Contributions
L.I.B. proposed the idea for this article and defined the research topic; S.S. and I. performed data analysis and drafted the initial draft; R. and A. provided significant improvements to the preparation of various technical and conceptual revisions of the manuscript. All authors have read and approved the published version of the manuscript.Conceptualization, L.I.B. and S.S.; methodology, L.I.B., S.S., and I.; investigation, S.S. and I.; data curation, S.S. and I.; formal analysis, S.S. and I.; writing—original draft preparation, L.I.B., S.S., and I.; writing—review and editing, L.I.B., R., and A.; visualization, S.S. and I.; supervision, L.I.B. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding

Conflicts of Interest
The authors declare no conflict of interest.

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