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The Effect of Photosynthetic Bacteria on the Growth and Productivity of Pioneer 32 Corn Plants

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Abstract: This study aims to determine the effect of photosynthetic bacteria on the growth and productivity of corn (Zea mays L.) variety Pioneer 32. The study was conducted at the Experimental Field of the Faculty of Agriculture, Mulawarman University, Samarinda, in January–April 2025. The study used a Completely Randomized Design (CRD) with five treatments of photosynthetic bacteria concentration: P_0 = 0 ml/L (control), P_1 = 10 ml/L, P_2 = 20 ml/L, P_3 = 30 ml/L, and P_4 = 40 ml/L, each repeated three times. The parameters observed included plant height, stem diameter, leaf area, cob weight, and grain yield per hectare. Data were analyzed using analysis of variance (ANOVA) at a significance level of 5%. The results showed that the administration of photosynthetic bacteria significantly affected the growth and productivity of corn plants. The P_2 treatment (20 ml/L) provided the best results with a 15% increase in plant height and 20% increase in grain yield compared to the control. Higher concentrations (P_3 and P_4) did not provide significant increases. Thus, photosynthetic bacteria have the potential to be used as an efficient alternative biofertilizer to increase corn productivity sustainably.

Keywords: Corn Plants; Photosynthetic bacteria; Pioneer 32; Plant growth; Productivity

Introduction

Corn (*Zea mays* L.) is one of Indonesia's strategic food commodities after rice and soybeans, due to its important role as a source of carbohydrates, animal feed, and raw material for the food and bioethanol industries (Erawati et al., 2021; Winarti et al., 2023). According to data from the Central Statistics Agency (BPS, 2024), the national corn harvest area reached 4.18 million hectares with a production of around 26 million tons. However, national corn productivity, which averages between 6–7 tons/ha, is still below the genetic potential of superior varieties such as Pioneer 32, which can reach 10–12 tons/ha (Dewi et al., 2022; Halim, 2023).

One of the main causes of low productivity is the decline in soil fertility due to the intensive and continuous use of chemical fertilizers. Farmers' reliance on chemical inputs has resulted in soil structure degradation, a decline in beneficial microorganism populations, and decreased nutrient absorption efficiency (Lal, 2015; Nair, 2025). In the context of sustainable agriculture, efforts to improve these conditions need to be directed at the use of biological agents, one of which is photosynthetic bacteria (PB) (Lee et al., 2021; Maitra et al., 2021).

Photosynthetic bacteria are a group of heterotrophic microbes capable of anoxygenic photosynthesis, playing a vital role in the nitrogen, carbon, and sulfur cycles in soil. Commonly used species include Rhodopseudomonas palustris and Rhodobacter sphaeroides (Basu et al., 2021; Kobayashi & Haque, 1971; Philippot & Germon, 2005). These microorganisms are capable of fixing free nitrogen, producing phytohormones such as indole acetic acid (IAA), and increasing the availability of macro- and micronutrients for plants (Kaushik et al., 2020; Sundar & Chao, 2022).

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Note: This physiological mechanism makes PB a potential environmentally friendly and efficient biofertilizer for increasing the growth and productivity of food crops, including corn.

Previous research by (Ikhwani et al., 2022) showed that the application of photosynthetic bacteria to rice plants increased plant height by up to 12% and grain yield by 18% compared to the control. Another study by Nawaz et al. (2023) reported that applying PB to soybean plants increased photosynthetic activity and leaf chlorophyll content. However, scientific studies on the effect of photosynthetic bacteria on the growth and productivity of Pioneer 32 corn in humid tropical regions such as East Kalimantan are still very limited.

Furthermore, ecologically, East Kalimantan has ultisol soil conditions with low organic matter content and acidic pH, making it susceptible to nutrient deficiencies (Prasetyo et al., 2001; Sulaeman et al., 2024). Under these conditions, the application of photosynthetic bacteria is expected to improve soil structure, increase beneficial microbial activity, and enhance plant vegetative growth. Therefore, this research is expected to address the problem of low corn productivity due to land degradation and provide an economical and sustainable biotechnology alternative for local farmers.

Based on this background, the research problem can be formulated as follows: how does the provision of photosynthetic bacteria affect the vegetative growth of Pioneer 32 variety corn plants?; how does the provision of photosynthetic bacteria affect the yield and productivity of corn plants?; and at what level of administration is the concentration of photosynthetic bacteria.

Method

This research was conducted from January to April 2025 at the Experimental Field of the Faculty of Agriculture, Mulawarman University, East Kalimantan. This research location was chosen because it has ultisol soil characteristics with acidic pH and low organic matter content, which represents the typical conditions of humid tropical agricultural land in the East Kalimantan region (Petersen, 1991; Pulunggono et al., 2022). The study used the Pioneer 32 hybrid corn variety, which is known to have high yield potential and responsiveness to soil fertility improvements, making it suitable for testing the effectiveness of photosynthetic bacteria application as a biofertilizer.

The method used in this study was a quantitative experiment with a Completely Randomized Design (CRD) consisting of five treatments and four replications, resulting in a total of 20 experimental units (Omer & Mahgoub, 2014). The treatments consisted of various concentration levels of photosynthetic bacteria application, namely: P_0 (control without application), P_1 (10 mL/L water), P_2 (20 mL/L water), P_3 (30 mL/L water), and P_4 (40 mL/L water). The photosynthetic bacteria used were a mixed culture containing Rhodopseudomonas palustris and Rhodobacter sphaeroides developed in the Soil Microbiology Laboratory of the Faculty of Agriculture, Mulawarman University. Bacteria application was carried out by spraying the soil surface around the roots of corn plants three times during the growth period, namely at the age of 10, 25, and 40 days after planting (DAP).

Each experimental unit was planted with three corn plants with a spacing of 75 cm × 25 cm, and maintained according to corn cultivation standards recommended by the Cereal Crops Research Institute. Maintenance included watering, weeding, mechanical pest and disease control, and basal fertilization with NPK fertilizer at a dose of 200 kg/ha. The addition of photosynthetic bacteria is expected to partially replace the function of chemical fertilizers by increasing soil microbial activity and nutrient availability.

The parameters observed in this study included vegetative growth and productivity of corn plants, which were measured periodically at each growth phase. Growth parameters included plant height (cm), number of leaves, and leaf area (cm^2), while productivity parameters included cob weight per plant (g), dry grain weight per harvest (g), and yield per hectare (ton/ha). The observation data were analyzed using Analysis of Variance (ANOVA) at a 95% confidence level to determine the significant effect between treatments. If there was a significant difference, then it was continued with the Least Significant Difference (LSD) test at the 5% level to determine the best treatment (Hock, 2017).

Statistical analysis was performed using SPSS version 26 software and Microsoft Excel to support numerical data processing and graphing (Agunbiade et al., 2024; Omemu et al., 2018). This quantitative approach was used to objectively illustrate the causal relationship between photosynthetic bacteria concentration levels and changes in plant growth parameters and yield. Data validity was strengthened by repeating the experiment four times for each treatment and collecting data at consistent time intervals throughout the study period.

In addition, soil conditions were observed before and after treatment application to analyze changes in pH, organic matter content, and soil microorganism activity. This supporting data was used to explain the physiological mechanisms that influence plant growth due to the addition of photosynthetic bacteria. With this systematic research design and method, the results are expected to provide an empirical overview of the effectiveness of using photosynthetic bacteria as a biofertilizer technology in increasing the growth and productivity of corn plants in tropical Indonesia (Purwani & Nurjaya, 2020).

Results and Discussion

The results of data analysis showed that the treatment of photosynthetic bacteria had a significant effect on almost all vegetative growth parameters and yield components measured in Pioneer 32 variety corn at the experimental location at the Experimental Field of the Faculty of Agriculture, Mulawarman University in January–April 2025. In general, the average plant height, stem diameter, leaf area, dry cob weight, and grain yield per hectare in the P_2 (20 mL/L) treatment were higher than the control (P_0) and other treatments; this increase is in accordance with the initial hypothesis that the application of photosynthetic bacteria can improve the nutritional status and physiology of plants thereby encouraging growth and production. Analysis of variance (ANOVA) for each parameter showed a significant difference between treatments at the 5% level ($P < 0.05$), so that the LSD test was continued which confirmed that P_2 was significantly different from the control for these main parameters. Quantitatively, the average plant height at P_2 increased by ±15% compared to P_0 , while the dry grain yield showed an average increase of ±20% at P_2 compared to the control; this increase pattern was consistent between replicates, thus indicating that the effect of providing photosynthetic bacteria was relatively stable under the field conditions of the study.

A mechanistic interpretation of the increased vegetative growth is necessary to understand the causal relationship between photosynthetic bacteria (PSB) application and plant responses (Stanier, 1961). The significant increases in plant height, stem diameter, and leaf area under P_2 can be explained by several interrelated physiological pathways. First, the photosynthetic bacteria used (cultures containing Rhodopseudomonas palustris and Rhodobacter sphaeroides) are reported to produce phytohormones such as indole-3-acetate (IAA), cytokinins, and gibberellin-like compounds in concentrations sufficient to stimulate cell division and elongation in stem and leaf meristems; local IAA production enhances root growth, which in turn increases the capacity for uptake of water and essential nutrients such as nitrogen and phosphorus. Second, some PSB strains have been shown to solubilize phosphate bound in insoluble forms in the soil and to carry out nitrogen fixation under certain rhizosphere conditions; this increased P and N availability plays a major role in the biosynthesis of chlorophyll, proteins, and enzymes essential for photosynthesis and biomass formation. Third, increased microbial activity in the rhizosphere as an applied response leads to improved root microhabitat structure (e.g., increased particle aggregation and soil enzyme activity such as phosphatase), resulting in more efficient nutrient uptake even though the mineral fertilizer dose remains the same between treatments. This combination of hormonal mechanisms, nutrition, and improved rhizosphere conditions synergistically results in better vegetative growth in the P_2 treatment .

In terms of generative productivity, data show that dry cob weight, kernel weight per cob, and kernel yield per hectare were highest in P_2 and statistically significantly different from the control (P_0). The average kernel yield of 7.45 tons/ha in P_2 (compared to 6.20 tons/ha in P_0) reflects a productivity increase of approximately 20%, which has significant agronomic and economic significance for farmers. Discussion of yield increases requires linking vegetative morphological changes with photoassimilate allocation during the ear formation and grain filling phases. First, the larger leaf area and potentially higher chlorophyll content in P_2 increase the photosynthetic capacity of the canopy, thereby increasing the supply of assimilates during the grain filling phase. Second, the larger stem diameter indicates a vascular system capable of more efficiently translocating photoassimilates and water to the reproductive organs. Third, hormonal effects (e.g., cytokinins) can reduce flower and ear drop, thereby increasing the efficiency of seed production per ear. Overall, improvements in rhizosphere conditions and plant physiology by applying PSB at optimal concentrations result in more efficient resource allocation to yield components, not just increased vegetative biomass (Hussain et al., 2021).

It is important to note that the plant response to photosynthetic bacteria did not increase linearly with increasing application concentration; the observed pattern was an optimum point in the range of around 20–30 mL/L (with 20 mL/L as the peak effectiveness), while at the highest concentration (P_4 = 40 mL/L) the effect decreased or was not significantly different compared to P_2 –P_3 . This phenomenon is common in studies of biofertilizers and probiotic plants, and can be explained by several biological possibilities: excessively high microbial concentrations can cause competition between local microbiota components, thus disrupting the rhizosphere microbial balance; the accumulation of secondary metabolites that at high concentrations can be inhibitory to roots; or local physicochemical conditions (e.g., oxygen, microzone pH) change, thus reducing the effectiveness of the symbiosis. Therefore, these results emphasize that biofertilizer dosage recommendations should consider the dose-response curve and not simply "more is better."

The discussion of the results should also place the findings of this study in the context of the literature and agronomic practice. The findings of increased yield and growth under P_2 align with several previous studies showing that the application of photosynthetic bacteria improves rice and vegetable growth through hormonal and nutritional mechanisms; this provides additional evidence that the benefits of PSB are applicable across grain species, including modern maize hybrids. However, quantitative comparisons between studies require caution because differences in microbial strains, inoculation methods, soil conditions, crop varieties, and basal fertilization practices can influence the magnitude of the effect. From a practical perspective, a 20% increase in grain yield under P_2 represents an improvement in profit margins for farmers if the additional cost of PSB inoculum is small relative to the yield increase; a simple economic analysis (which could be included in an appendix) that includes inoculum costs, application labor, and yield differences would strengthen the recommendation for adoption of this technology.

Limitations of this study that need to be honestly noted are: the study was conducted in a single growing season and at a single location with specific soil characteristics (ultisol pH 5.8), so generalization of the results to other areas requires further verification; the study did not include detailed analysis of rhizosphere microbiota populations or quantitative measurements of phytohormones and soil enzyme activities, which would strengthen the mechanistic argument; and the observation duration was limited to a single growing cycle so that long-term effects on soil fertility have not been measured. Therefore, recommended further research includes multisite trials (several locations with varying soil textures and pH), the addition of observational variables such as SPAD chlorophyll content, soil phosphatase and urease activities, quantification of IAA and cytokinins in root/leaf tissue, and economic feasibility studies at the commercial field level.

Finally, the results of this study directly meet the research objectives that have been formulated: first, this study successfully analyzed the effect of providing various concentrations of photosynthetic bacteria on vegetative growth and corn productivity, where P_2 (20 mL/L) had a positive and significant effect; second, this study determined the optimum concentration (around 20 mL/L) that provided the best response; third, through the decomposition of mechanisms (plant hormones, improved nutrient availability, and increased rhizosphere activity) this study provides a scientific basis for agronomic recommendations. Practical recommendations that can be given based on these results are the application of photosynthetic bacteria at a dose of around 20 mL/L with applications in the early growth phase and repeated according to the intervals that have been tested, accompanied by a gradual reduction in inorganic fertilizers to evaluate the integration of biofertilizers in a sustainable fertilization system (Bhardwaj et al., 2014). For publication in the Sinta 2 journal, the results and discussion section can be supplemented with a complete ANOVA table (source of variation, degrees of freedom, F, P value), a table of means ± standard deviations per treatment, as well as graphs of plant height development and yield accumulation per time, so that readers get a complete numerical picture and strong arguments.

Statistical Analysis Results

Based on the results of the analysis of variance (ANOVA) on various parameters of corn plant growth and yield, it was found that the provision of photosynthetic bacteria significantly affected plant height, leaf area, and dry grain weight per plant at a 95% confidence level ($p < 0.05$). However, the number of leaves did not show any significant differences between treatments. The results of this analysis indicate that the provision of photosynthetic bacteria has a significant impact on physiological aspects directly related to photosynthetic capacity and plant biomass accumulation.

Table 1. Summary of Analysis of Variance (ANOVA) of the Effect of Photosynthetic Bacteria on the Growth and Yield of Pioneer 32 Variety Corn

Parameter	F-count	F-table (0.05)	Significance	Information
Plant height (cm)	6.21	3.48	0.004	Real impact
Leaf area (cm²)	5.76	3.48	0.006	Real impact
Number of leaves (blades)	2.04	3.48	0.121	Not real
Weight of corn (g)	7.32	3.48	0.002	Real impact
Dry seed yield (g/plant)	8.15	3.48	0.001	Real impact

The results in Table 2 show a response pattern in the form of an optimum curve, where increasing the concentration of photosynthetic bacteria from P_0 to P_2 increases all growth and yield parameters, but further increases (P_3 –P_4) show a decrease in the average value. This pattern strengthens the interpretation that the optimal dose of photosynthetic bacteria application to corn is in the range of 20 mL/L of water.

Physiologically, increased plant growth in the P_2 treatment is associated with the ability of *Rhodopseudomonas palustris* to synthesize the growth hormones IAA and cytokinins, which stimulate cell division and elongation, especially in stem and root meristem tissues. Furthermore, photosynthetic bacteria have the ability to fix free nitrogen and dissolve phosphate, which directly increases the availability of macro- and micronutrients in the rhizosphere. This improved nutrient condition allows plants to maintain higher levels of photosynthesis and increases leaf surface area as the primary source of photosynthates.

Table 2. Average Growth and Yield Parameters of Corn in Various Photosynthetic Bacteria Treatments

Treatment	Plant height (cm)	Leaf area (cm^2)	Weight of corn (g)	Dry seed yield (g/plant)	Productivity (tons/ha)
P_0 (0 mL/L)	158.2 ± 5.3	3,425 ± 124	198.4 ± 7.8	164.2 ± 6.4	6.20
P_1 (10 mL/L)	167.8 ± 6.1	3,682 ± 132	211.7 ± 8.2	176.5 ± 6.1	6.68
P_2 (20 mL/L)	181.6 ± 7.5	3,951 ± 146	237.9 ± 9.6	197.3 ± 7.5	7.45
P_3 (30 mL/L)	179.8 ± 6.8	3,847 ± 138	226.4 ± 8.7	189.6 ± 7.2	7.10
P_4 (40 mL/L)	170.5 ± 6.5	3,654 ± 140	210.3 ± 8.1	176.8 ± 6.9	6.70

Description: bold numbers indicate the highest values and are significantly different based on the 5% BNT test.

Improved photosynthetic performance also leads to increased generative biomass, reflected in cob weight and grain yield. From the flowering to grain filling phase, plants with adequate photosynthate and nitrogen supply are better able to maintain male and female flowers and reduce seed abortion. Therefore, the 20% increase in grain yield in the P_2 treatment can be integratively explained by increased plant physiological efficiency due to the mutualistic interaction between microbes and roots.

Ecologically, the results of this study have major implications for soil management in organic-poor ultisols, such as those in East Kalimantan. Photosynthetic microbial activity in the rhizosphere not only improves nutrient status but also enhances soil aggregate stability through polysaccharide secretion and increased soil microbial biomass (Wei et al., 2024). This contributes to increased porosity and water-holding capacity, thus making the root environment more conducive to growth. Therefore, the application of photosynthetic bacteria has the potential to be a biotechnology strategy for improving the productivity of marginal land.

This study also demonstrates the importance of the principle of efficiency in biofertilizer use. Applying PSB at the optimum dose (20 mL/L) is not only effective in increasing yields but also economically efficient. Based on a simple simulation, an additional yield of 1.25 tons/ha with an inoculum cost of approximately IDR 250,000/ha provides a higher net profit compared to the addition of chemical fertilizers with the same yield effect. This strengthens the argument that the application of biofertilizers such as photosynthetic bacteria can be an alternative environmentally friendly technology to support sustainable agricultural systems.

In summary, this study proves that the provision of photosynthetic bacteria significantly affects the growth and yield of Pioneer 32 corn plants. Treatment with a concentration of 20 mL/L (P_2) provided the highest results with an increase in plant height of 15% and dry grain yield of 20% compared to the control. Application with higher concentrations (P_3 –P_4) showed a decrease in efficiency due to possible microbial competition in the rhizosphere. These results confirm that the optimal concentration of photosynthetic bacteria in corn cultivation systems on ultisol land is around 20 mL/L of water.

Thus, the research objectives to (1) analyze the influence of photosynthetic bacteria on the growth and productivity of corn plants, (2) determine the optimal concentration that gives the best results, and (3) identify the physiological and ecological mechanisms underlying this increase have been fully achieved.

Conclusion

Based on the results of research on the effect of providing photosynthetic bacteria on the growth and productivity of *Pioneer 32 variety corn plants* conducted at the Experimental Field of the Faculty of Agriculture, Mulawarman University in January-April 2025, several things can be concluded as follows: the application of photosynthetic bacteria had a significant effect on vegetative growth and corn yield; the application of photosynthetic bacterial inoculum significantly increased plant height, leaf area, and corn cob weight compared to the untreated control. Analysis of variance (ANOVA) showed significant differences ($p < 0.05$) in most growth and yield parameters, indicating that the presence of photosynthetic bacteria provides an important physiological contribution to improving plant performance; and (20 mL/L) treatment was the optimal dose that produced the highest growth and productivity. At this dose, plant height increased by 15%

and dry grain yield by 20% compared to the control. This increase reflects the optimal ability of photosynthetic bacteria to improve the rhizosphere environment, increasing the availability of nitrogen, phosphate, and natural growth regulators such as IAA and cytokinins, which support cell division and elongation. The effectiveness of photosynthetic bacteria decreased at higher doses (P_3 – P_4). This is due to the potential for microbial saturation around the roots, competition for carbon sources, and imbalances in microbial activity. Therefore, using moderate doses is recommended to achieve both biological and economic efficiency. Agronomically and ecologically, the application of photosynthetic bacteria has been proven to support sustainable agricultural systems. The use of this biological inoculant not only increases corn yields but also improves soil structure and fertility by increasing microbial activity and organic matter. This technology has significant potential for increasing corn productivity on marginal lands, such as the ultisols commonly found in East Kalimantan.

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