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Influence of Soil Organic Amendment Mixtures and Rhizobacterial (PGPR) Inoculation on the Productivity of Cucumber Plants

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ABSTRACT

Cucumber (*Cucumis sativus* L.) is an important horticultural crop in Indonesia, but production declines in South Sulawesi have been linked to suboptimal cultivation and limited nutrients, indicating a need for better planting media and biological inputs. This study evaluated soil–organic amendment mixtures and plant growth-promoting rhizobacteria (PGPR) inoculation on cucumber growth and yield. Conducted from April to June 2025 in Libureng Hamlet, Selli Village, Bengo District, Bone Regency, the experiment used a randomized block design with five planting media compositions and three natural PGPR sources, giving 15 combinations with three replications (45 units; 135 plants). Planting media composition significantly affected plant height, leaf number at 28 days after planting, and key yield components, whereas PGPR type and the interaction were generally not significant. M4 gave the highest plant height (147.92 cm), leaf number (31.59), fruit number (10.22 fruits/plant), and fruit weight (425.78 g/plant), while M3 gave the lowest values. Fruit length was highest in M1 (23.09 cm), and fruit diameter in M2 (50.08 mm). Flowering time and production per hectare were not significantly affected. Overall, chicken manure-based media, especially with cocopeat and rice husk charcoal, improved productivity, while PGPR showed mainly non-significant positive trends, often favoring elephant grass-root PGPR, rather than a primary driver of yield under conditions.

INTRODUCTION

The effect of combining organic soil amendments and rhizobacterial inoculation on cucumber crop productivity is based on the need to sustainably increase crop yields through environmentally friendly methods (Memeli et al., 2026; Seymen et al., 2019). Healthy and fertile soil is a key factor in supporting plant growth and yield (Handayani & Hale, 2022; Pandao et al., 2024). However, agricultural intensification often leads to a decline in soil quality, such as reduced organic matter content and soil microbial activity (Barrios et al., 2023). Organic amendments, such as compost, manure, or organic waste, can improve the physical, chemical, and biological properties of soil, thereby enhancing soil fertility and crop productivity (Singh et al., 2024).

Plant growth-promoting rhizobacteria (PGPR) are microorganisms that live around plant roots and are able to enhance plant growth through various mechanisms, such as nitrogen fixation, production of growth hormones, pathogen inhibition, and increasing nutrient availability (Sinha et al., 2021). PGPR inoculation has been proven to boost the productivity of various crops, including cucumber, by improving nutrient use efficiency and tolerance to environmental stress (De Andrade et al., 2023).

However, there remains a gap in understanding the synergistic interactions between organic soil amendments and PGPR inoculation in cucumber plants (Bhandari et al., 2025). Previous studies have largely focused on the individual effects of organic amendments or PGPR, but research examining the combination of both in the context of cucumber crop productivity is still limited. In addition, the effectiveness of different organic amendment mixtures and the types of rhizobacteria used has also not been explored in depth, so there are no optimal recommendations yet for practical application in cucumber cultivation (Zapata-Sifuentes et al., 2022).

Therefore, this study aims to examine the effect of a combination of soil organic amendments and

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rhizobacterial (PGPR) inoculation on the growth and productivity of cucumber plants, as well as to identify the most effective combination for sustainably increasing crop yield.

MATERIALS AND METHODS

The research was conducted in Libureng Hamlet, Selli Village, Bengo District, Bone Regency, from April to June 2025. The climate during this period ranged from 26°C to 34°C, with humidity levels between 95% and 99%, and an average rainfall of less than 1,750 mm. The equipment utilized in this study comprised hoes, machetes, scales, rulers, labels, jars, jerry cans, stationery, a hand sprayer, a pan, a stove, a sieve, a wooden stirrer, a camera, bamboo, and rope for the trellis. The materials employed included Hercules cucumber seeds, soil, sand, chicken manure, cow manure, rice husk charcoal, bamboo roots, elephant grass roots, mimosa roots, water, granulated sugar, shrimp paste, bran, lime, molasses, and polybags measuring 35 cm by 35 cm.

This study employed a randomized block design (RBD) incorporating two factors. The first factor pertained to the composition of the planting medium, which included five treatment levels: M0 = Soil, M1 = Soil + Cow Manure + Sawdust (2:1:1), M2 = Soil + Chicken Manure + Rice Husk Charcoal (2:1:1), M3 = Soil + Cow Manure + Sand (2:1:1), and M4 = Soil + Chicken Manure + Coconut Fiber (2:1:1). The second factor involved the type of PGPR plant, with three treatment levels: P1 = Bamboo Roots, P2 = Elephant Grass Roots, and P3 = Mimosa Roots. These two factors resulted in 15 treatment combinations, each replicated three times, culminating in 45 experimental units. Each unit comprised three plants, leading to a total of 135 plants.

RESULTS AND DISCUSSION

1. Plant Height

Table 1 displays the findings concerning the height of cucumber plants 28 days post-planting. The results of the analysis demonstrate that the composition of the planting media significantly influences cucumber plant height. In contrast, neither the type of PGPR nor its interaction with the planting media exhibited a significant effect.

Table 1. Average Height of Cucumber Plants (cm) at 28 DAP in Different Planting Media Types and PGPR

Media Type	PGPR			Average	HSD 0.05
	P1	P2	P3		
M0	113.99	102.94	131.88	116.27^{ac}	41.72
M1	121.66	97.78	83.33	100.92^{ab}	
M2	138.88	132.44	148.88	140.07^{bc}	
M3	72.05	89.49	71.83	77.79^{a}	
M4	131.33	134.11	178.33	147.92^{c}	
Average	115.58	111.35	122.85		

Note: The numbers followed by different letters in columns (a, b) exhibit significant differences according to the HSD alpha 0.05 test.

The results of the 0.05 HSD test indicate that the planting medium composition significantly influences plant height, with M4 yielding the highest average height of 147.92 cm. This suggests that the components of M4 provide a more favorable environment for plant growth compared to M1 and M3. The significant difference from these two media highlights the potential limitations or suboptimal nutrient or physical properties in M1 and M3 that may restrict plant development (Sweet et al., 2024). However, the lack of significant difference between M4 and M0 or M2 suggests that these media share certain beneficial characteristics or nutrient availability that support comparable growth performance (Gamit et al., 2023).

Conversely, the lowest average plant height was observed in the M3 medium (soil + cow manure + sand) at 77.79 cm. This result points to possible inadequacies in this composition, such as nutrient imbalance, poor water retention, or less favorable soil texture, which may have constrained plant height (Alwitwat, 2022). The fact that M3 is not significantly different from M1 and M0 implies some overlap in their growth-limiting factors, though M3's composition specifically involving cow manure and sand might affect soil aeration or microbial activity differently, influencing plant vigor (Lei et al., 2025).

The apparent contradiction in the non-significant difference between M3 and M4 in the text likely requires clarification, but assuming a typographical error, the overall trend suggests that M4 is superior to M3 in promoting plant height. This underscores the importance of carefully selecting medium components to optimize physical and chemical properties that enhance root development, nutrient uptake, and ultimately shoot growth (Conner & Jacobs, 2025).

Regarding the Plant Growth-Promoting Rhizobacteria (PGPR) treatments, the use of mimosa pudica root-associated PGPR (P3) showed a clear superiority over other root types tested. This finding suggests that the specific microbial communities or strains associated with mimosa pudica roots may have unique plant growth-promoting traits, such as enhanced nitrogen fixation, phytohormone production, or pathogen suppression. These beneficial effects likely contribute to improved nutrient availability and stress tolerance, thereby supporting greater plant height (Laskar, 2024).

The tendency of P3 to outperform other PGPR treatments emphasizes the role of microbial inoculants in sustainable agriculture and soil fertility management. By selecting effective PGPR strains, it is possible to reduce dependency on chemical fertilizers and improve crop productivity through natural biological processes. This also highlights the need for further characterization of these microbial strains to understand their mechanisms and optimize their application (Shetty et al., 2025).

The combined influence of planting medium composition and PGPR treatment is critical for maximizing plant growth. The superior performance of M4 and P3 indicates that an integrated approach, combining optimized soil substrates with targeted microbial inoculation, can enhance plant height more effectively than either factor alone. Future research should focus on elucidating the interactions between soil components and microbial communities to develop tailored agronomic practices that support robust plant development (Pathak et al., 2026).

2. Number of leaves

The results of observations on the number of cucumber leaves at 28 days after planting in Table 2 show that the planting media composition treatment had a highly significant effect, whereas the type of PGPR and the interaction between the two had no significant effect on the number of cucumber leaves.

Table 2. Average Number of Leaves (blades) of Cucumber Plants 28 Days After Planting in Various Growing Media Compositions and Types of PGPR

Media Type	PGPR			Average	HSD 0.05
	P1	P2	P3		
M0	22.89	26.22	26.22	25.11^{a}	
M1	17.66	16.11	12.44	15.40^{b}	6.33
M2	30.33	28.33	31.6633	30.11^{a}	
M3	14.00	16.2167	14.2167	14.81^{b}	
M4	31.44	32.55	30.77	31.59^{a}	
Average	23.26	23.89	23.06		

Note: The numbers followed by different letters in columns (a, b) exhibit significant differences according to the HSD alpha 0.05 test.

Table 2 shows that the M4 planting medium composition yielded the highest average number of leaves, namely 31.59. This finding indicates that the specific component combination in M4 provides an optimal environment for leaf development, likely due to better nutrient availability, aeration, or water retention compared to the other media. The significant difference observed between M4 and M1 and M3 suggests that the factors in those media are less supportive of leaf growth, possibly due to nutrient deficiency or suboptimal physical properties. Conversely, the absence of significant differences from M0d and M2 indicates that these media have certain advantageous characteristics similar to M4, thereby supporting a comparable rate of leaf production (Knösche, 2025).

In contrast, the M3 medium, consisting of soil, cow manure, and sand, resulted in the lowest average leaf count of 14.81. This outcome may be attributed to an imbalanced nutrient profile or inadequate structural qualities that limit root development and nutrient uptake (Veliyeva, 2020). While the inclusion of sand may enhance drainage, it could also excessively reduce water retention, and the manure content might exhibit variable nutrient release rates, leading to suboptimal conditions for sustained leaf growth.

These combined factors likely impede the plant's ability to produce a higher number of leaves, highlighting the critical role of medium composition in plant development (Fraccica et al., 2024).

The results of the PGPR treatment underscore the superior performance of the elephant grass root PGPR (P2) compared to other root types tested. This suggests that the microbial communities associated with elephant grass roots are particularly effective in promoting plant growth, potentially through mechanisms such as nitrogen fixation, phytohormone production, or enhanced nutrient solubilization (Yandri et al., 2024). The clear trend favoring P2 highlights the potential of selecting specific PGPR strains tailored to the plant species and growth conditions to maximize growth benefits (Choudhury et al., 2022).

Integrating the findings on planting media and PGPR treatments suggests a synergistic approach to optimizing plant growth. The most effective planting media, such as M4, combined with the application of elephant grass root PGPR, could significantly enhance leaf development and overall plant vigor. Future research should investigate the interactions between medium composition and PGPR strains to identify combinations that maximize nutrient availability and microbial activity, ultimately improving crop productivity and sustainability (Prajapati et al., 2022).

3. Time of Flower Emergence

The results of observations on the time of cucumber flower emergence, as shown in Figure 1, indicate that the treatment of planting media composition and PGPR type, as well as the interaction between the two, had no significant effect on the time of cucumber flower emergence.

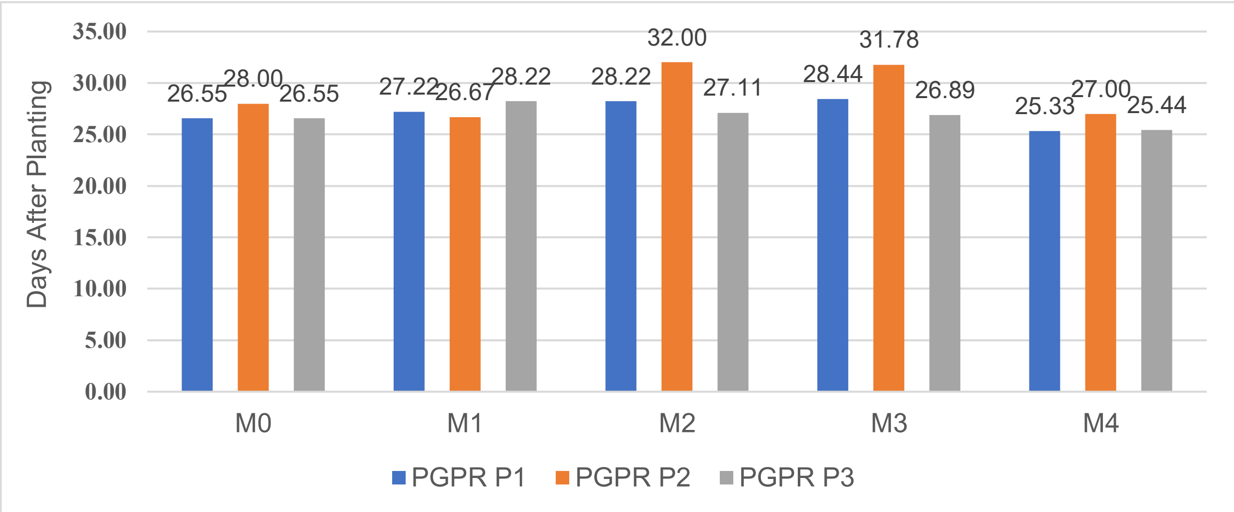

Figure 1. Average Flower Appearance Time on Cucumber Plants

Figure 1 demonstrates that the M3P2 treatment, which integrates soil with cow manure and sand (M3) in conjunction with elephant grass roots (P2), achieves the most rapid average time for flower appearance, ranging from 25.33 to 30.78 hours after sowing (DAP). This outcome implies that the nutrient composition and physical characteristics of the M3 substrate, augmented by the organic matter from cow manure and the aeration provided by sand, establish an optimal environment for early flowering. Furthermore, the root system of elephant grass likely facilitates advantageous interactions, such as enhanced nutrient uptake or microbial symbiosis, which expedite developmental processes culminating in flower emergence.(Muhammad & Kurniawan, 2025; Pezenti et al., 2022).

Conversely, the M4P1 treatment, which integrates soil with chicken manure and coconut powder (M4) in conjunction with bamboo roots (P1), demonstrates the longest average time for flower appearance, recorded at 31.78 DAP. The delayed flowering observed in this treatment could be attributed to variations in nutrient release rates or substrate texture (Proietti et al., 2022). It is possible that chicken manure and coconut powder decompose at a slower rate or modify soil moisture retention differently than cow manure and sand, thereby potentially postponing nutrient availability. Additionally, bamboo roots may possess a unique root exudate profile or microbial community association that does not promote rapid flowering, possibly due to competition or less efficient nutrient mobilization (Jiang et al., 2025).

The findings underscore the significant influence of substrate composition and root type on plant developmental timing. The interaction between soil amendments and root systems can either advance or postpone flowering by altering nutrient dynamics, microbial interactions, and the physical properties of the soil. Comprehending these interactions offers valuable insights for optimizing growth media in horticultural or agricultural practices, with the aim of controlling flowering schedules to achieve specific production objectives (Schneider & Lynch, 2024).

4. Number of fruits per plant

The results of observations on the number of cucumbers presented in Table 3 show that the composition of the growing media had a highly significant effect. Meanwhile, the type of PGPR and the interaction between the two did not have a significant effect on the number of fruits (per plant).

Table 3. Mean Fruit Count (per Plant) of Cucumber Plants Across Different Planting Media Compositions and PGPR Types

Media Type	PGPR			Average	HSD 0,05
	P1	P2	P3		
M0	8.00	9.67	8.00	8.56[a]	2.57
M1	7.67	9.00	10.00	8.89[a]	
M2	10.00	9.00	9.00	9.33[a]	
M3	4.00	5.67	5.00	4.89[b]	
M4	9.33	9.67	11.67	10.22[a]	
Average	7.80	8.60	8.73		

Note: The numbers followed by different letters in columns (a, b) exhibit significant differences according to the HSD test at an alpha level of 0.05.

The results from the 0.05 HSD test in Table 3 clearly demonstrate the significant influence of planting medium composition on fruit yield. The highest average fruit number (10.22) was recorded with the M4 medium, which suggests that this composition provides optimal conditions for fruit development compared to M0, M1, M2, and M3. This significant difference indicates that the nutrient availability, texture, or microbial interactions in M4 are more conducive to enhancing fruit production (Omokaro et al., 2024; Singh et al., 2024). Conversely, the lowest fruit yield (4.89) observed in the Soil + Cow Manure + Sand (M3) treatment highlights potential limitations within this medium, such as suboptimal nutrient balance, poor aeration, or unfavorable microbial communities that may inhibit fruit set or growth. The significant differences between M3 and the other media further emphasize the critical role of substrate composition in modulating plant productivity (Jayachitra & Kennedy, 2024).

Regarding the PGPR treatments, the clear superiority of Mimosa pudica root-associated PGPR (P3) indicates a strong plant-microbe interaction that favors growth promotion and fruit yield enhancement. This finding suggests that the specific strains or consortia of PGPR associated with Mimosa pudica roots possess traits such as efficient nitrogen fixation, phytohormone production, or pathogen suppression that directly benefit the host plant. The tendency of P3 to outperform other root types underscores the importance of selecting effective PGPR inoculants tailored to the crop and environmental conditions to maximize agricultural outputs (Aarti et al., 2024).

These results highlight the synergistic potential of optimizing growing media and selecting PGPR to improve fruit yield. The significant interaction observed supports the strategy of integrated soil and microbial management in sustainable agriculture, where the selection of substrates and beneficial microbes can be specifically tailored to enhance plant performance. Future studies should focus on characterizing the physicochemical properties of M4 media and the functional characteristics of Mimosa pudica PGPR to elucidate the mechanisms driving these observed benefits and to validate their application across various crops and cultivation conditions (Zia, 2024).

5. Fruit length

The results of cucumber fruit length observations presented in Table 4 indicate that the composition of the growing media treatment had a highly significant effect. The type of PGPR and the interaction between the two did not have a significant effect on cucumber fruit length.

Table 4. Average Length of Cucumber Fruit in Various Planting Media Compositions and PGPR Types

Media Type	PGPR			Average	HSD 0.05
	P1	P2	P3		
M0	21.27	17.67	23.00	20.64[a]	
M1	21.20	23.71	24.35	23.09[a]	
M2	23.70	24.6	20.53	22.94[a]	3.82
M3	11.93	17.23	14.6	14.59[b]	
M4	20.73	23.90	23.81	22.81[a]	
Average	19.77	21.42	21.26		

Note: The numbers followed by different letters in columns (a, b) exhibit significant differences according to the HSD test at an alpha level of 0.05.

The results of the HSD 0.05 test in Table 4 show that the planting medium composition M1 produced the highest average fruit length (23.09 cm), which was statistically significantly different from the planting medium M3 (soil + cow manure + sand) that had the lowest average fruit length (14.59 cm). This significant difference indicates that the M1 planting medium composition provides more optimal conditions for fruit growth, most likely due to a balance of nutrients and a medium structure that supports better water and air absorption compared to M3. However, there was no significant difference between M1 and M0, M2, and M4, indicating that these media have relatively comparable effectiveness in supporting fruit length, although M1 tended to be superior (Carella et al., 2023).

The M3 growing medium, which contains sand, had the lowest average fruit length. This can be explained by the characteristics of sand, which generally has low water and nutrient retention capacity, thereby limiting the availability of essential resources for the plants. In addition, the content of cattle manure that may not be fully decomposed can negatively affect the quality of the medium and soil microorganisms, which has implications for suboptimal fruit growth (Chaurasia et al., 2025).

PGPR treatment shows a clear and superior trend, particularly with the use of PGPR from elephant grass roots (P2), compared to other root types tested. This indicates that the specific interaction between PGPR P2 and the plant can significantly increase fruit length. The possible underlying mechanisms are PGPR P2's ability to enhance nutrient availability, stimulate plant growth hormones, and improve plant resistance to environmental stress. The synergistic effect between optimal growing media (such as M1) and proper PGPR application (P2) can strengthen fruit growth, resulting in superior yields (M Al-Khayri & Khan, 2024)

The findings highlight the crucial role of choosing the right growing media and incorporating particular microorganisms to enhance crop yield quality and quantity. By fine-tuning the interactions between growing media and microorganisms that promote plant growth, this research significantly advances sustainable cultivation technology.

6. Production Ton/ha

The following figure shows the results of the analysis regarding the effect of growing media composition treatments, PGPR types, and their interaction on cucumber plant yield. Based on the data, it can be seen that these treatments did not have a significant effect on plant yield.

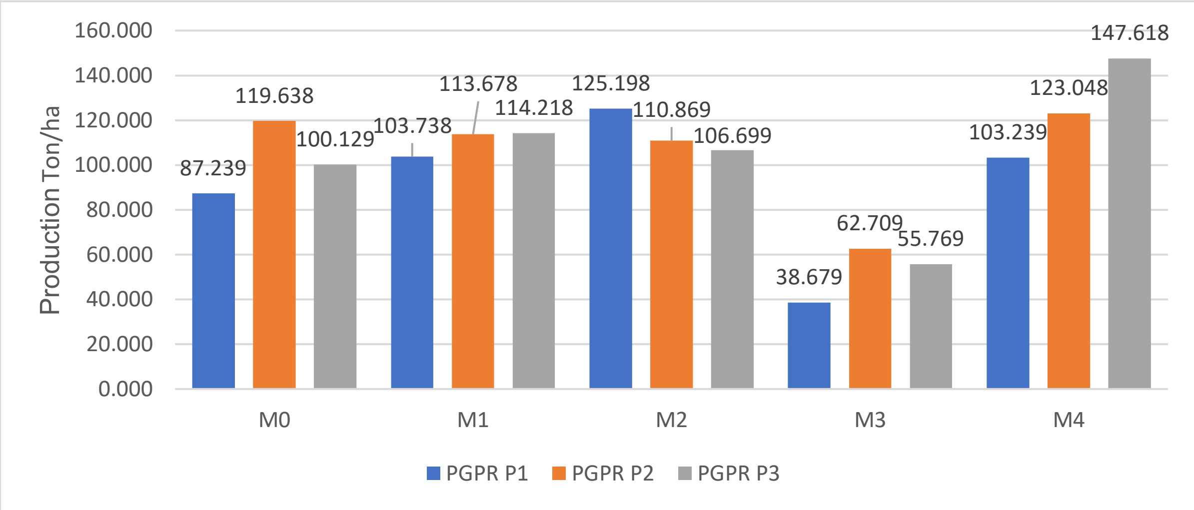

Figure 2. Average production Ton/ha of cucumber plants

The results presented in Figure 2 indicate a significant variation in average production per hectare across different treatment combinations, highlighting the influence of both organic amendments and root types on yield outcomes. The highest average production, recorded at 147,618 tons/ha, corresponds to the M4P3 treatment, which combines soil enriched with chicken manure and coconut powder (M2) with mimosa pudica roots (P3). This suggests a synergistic effect between the nutrient-rich organic amendments and the biological properties of mimosa pudica roots that likely enhance soil fertility, nutrient uptake, and plant growth (Ramzan et al., 2020)

Manure is known for its high nitrogen content and balanced nutrient profile, which can improve soil structure and microbial activity. Coconut powder or cocopeat contributes to improved soil aeration and moisture retention, creating an optimal environment for root development. Mimosa pudica roots may further contribute through nitrogen fixation or by promoting beneficial rhizosphere interactions, enhancing nutrient availability and uptake efficiency. Together, these factors create a conducive environment for maximizing biomass production, explaining the superior yield observed in M4P3 (Pawar et al., 2024).

In contrast, the M3P1 treatment, which integrates soil, cow manure, sand, and bamboo roots, yielded the lowest average of 38,679 tons per hectare, suggesting suboptimal conditions. Although cow manure provides benefits, its nutrient release may be slower compared to chicken manure, potentially limiting the immediate availability of nutrients. The addition of sand could reduce the soil's ability to retain water and nutrients, possibly impeding root development and nutrient uptake. Despite the robustness of bamboo roots, they may not effectively interact with the soil amendments to enhance nutrient cycling or microbial activity, resulting in decreased productivity (Hoang et al., 2023).

Emphasizing the significance of selecting appropriate organic amendments and root varieties for specific soil conditions is crucial for optimizing production. The findings suggest that integrating nutrient-rich organic fertilizers with root systems that enhance nutrient dynamics can significantly improve crop yields. Future research should explore the mechanistic interactions between these amendments and root types, concentrating on alterations in microbial communities and nutrient cycling processes, to develop more sustainable and efficient agricultural practices (Butay, 2026).

CONCLUSIONS

The composition of growing media has a significant effect on cucumber growth and productivity. M4 medium, consisting of soil, chicken manure, and coconut fiber, yielded the best results. Conversely, M3 medium, composed of soil, cow manure, and sand, produced the lowest results due to nutrient imbalances and the physical properties of the medium. PGPR inoculation did not show a significant effect, although PGPR from mimosa roots (P3) and elephant grass (P2) demonstrated a positive trend. The interaction between media and PGPR was generally not significant, but the M4 and P3 combination produced the highest yield. This study underscores the importance of selecting appropriate growing media and using PGPR to sustainably enhance cucumber yields.

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