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Increasing the Growth and Yield of Okra (*Abelmoschus esculentus*) Plants with the Use of PGPR (*Plant Growth Promoting Rhizobacteria*) and Gibberellin

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Abstract

Okra (*Abelmoschus esculentus*) is a horticultural crop rich in minerals, antioxidants, polyphenols, and flavonoids. One of the limiting factors for okra production is inadequate nutrition. The use of Plant Growth-Promoting Rhizobacteria (PGPR) and gibberellins is a promising approach to enhance okra production. This study aimed to determine the optimal concentrations of PGPR and gibberellin combinations for improving the growth and yield of okra. The experiment was conducted from March to June 2025 at the Experimental Field of the Faculty of Agriculture, Veteran National Development University, East Java. A factorial experiment was designed using a Randomized Block Design (RBD) with two factors: PGPR concentration at four levels (0 ml/l, 10 ml/l, 15 ml/l, and 20 ml/l) and gibberellin concentration at four levels (0 ppm, 100 ppm, 150 ppm, and 200 ppm), resulting in 16 treatment combinations, each replicated three times. The interaction between PGPR and gibberellin treatments significantly affected plant height and the number of flowers. The 20 ml/l PGPR treatment had the most significant positive effect on the number of leaves between 28 and 49 days after planting and on fruit weight during the 1st, 3rd, and 5th harvests. The 200 ppm gibberellin treatment significantly accelerated flower emergence, with an average of 35.39 days to flower emergence. The combination of 20 ml/l PGPR and 200 ppm gibberellin was the most effective treatment for enhancing okra plant growth and yield.

Keywords: Concentration, Gibberellin, Okra, PGPR, Plant Cultivation

1. Introduction

The okra plant, with the Latin name *Abelmoschus esculentus*, is a horticultural crop that can be grown in tropical and subtropical regions. This plant is distributed and cultivated across Africa, the Americas, Europe, and Asia. Okra fruit contains various nutrients, including protein, fat, carbohydrates, calories, minerals, antioxidants, polyphenols, and flavonoids. Okra fruit has benefits for relieving fatigue and preventing oxidative stress, and has the potential to reduce the risk of diabetes and Alzheimer's (Ikharwati & Rokmah, 2018). Okra plants have great potential in the agricultural sector, both in the domestic and international markets. Current okra production is still fluctuating and has not met national demand. In 2017, 30% of okra production was marketed locally as ready-to-eat frozen okra, while 70% of total production was exported to Japan, Taiwan, Australia, and several other countries. One

of the regions with large okra production is Jember. The area of okra production land in the Jember region is around 300 hectares, with a yield of 550–600 tons in 2019 (Millah et al., 2022).

Okra can be cultivated in various soil types, but various factors often limit okra production. One factor limiting okra production is the availability of optimal nutrients. Excessive use of chemical fertilizers can lead to soil degradation and potentially leave residues in crops. One effort to increase okra growth and yield is to use PGPR (Plant Growth-Promoting Rhizobacteria) and gibberellins. PGPR is composed of microorganisms that live in the rhizosphere. The microorganisms in PGPR have three main roles: as a biofertilizer to accelerate nutrient uptake, as a biostimulant to stimulate plant growth through phytohormone production, and as a bioprotectant to protect plants from pathogens. Administering PGPR can reduce the

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need for chemical fertilizers. PGPR directly stimulates growth, vitamin production, and various organic acids, and increases nutrient intake for plants (Karmila *et al.* 2023). Meanwhile, gibberellins will support generative growth in plants. Gibberellin is a plant growth hormone that stimulates cell elongation, cell division, and flower and fruit formation in plants. Gibberellin plays a role in promoting seed development and stimulating flowering and fruit development (Muhyidin *et al.* 2018).

PGPR and gibberellin treatments can positively affect the growth and yield of okra plants. Previous research by Alpandari *et al.* (2024) reported that applying PGPR at 20 ml/L twice increased flowering age, fruit weight per plant, and fruit diameter. Similarly, Farida and Rohaeni (2019) found that applying gibberellin at 200 ppm produced the best growth and yield in okra, with a fruit weight per plot of 971.333 grams. Both studies examined the effects of PGPR and gibberellin on okra plants separately. This study distinguishes itself by examining the combined effects of PGPR and gibberellin on okra growth and yield. The results are expected to provide new insights for enhancing okra plant performance. The objective of this study is to determine the optimal concentration of the PGPR-

gibberellin combination for improving the growth and yield of okra plants.

2. Material and Methods

This research was conducted in March – June 2025 at the Experimental Field of the Faculty of Agriculture, National Development University “Veteran” East Java at the coordinate point -7.3065° South Latitude and 112.7777° East Longitude with an altitude of 3.5 meters above sea level. The tools used in this study include 40 x 40 cm polybags, shovels, meters, plant scissors, labels, measuring cups, watering cans, stationery, digital scales, and cameras. The materials used include Lucky Five variety okra seeds, soil planting media, compost, rice husk charcoal (1:1:1), Plant Growth Promoting Rhizobacteria (PGPR), and gibberellin.

This study was a factorial experiment arranged in a Randomised Block Design (RBD) with 2 factors. The first factor was PGPR concentration, with 4 treatment levels: 0 ml/l, 10 ml/l, 15 ml/l, and 20 ml/l. The second factor was gibberellin, with 4 treatment levels (0 ppm, 100 ppm, 150 ppm, and 200 ppm), resulting in 16 treatment combinations, each repeated 3 times.

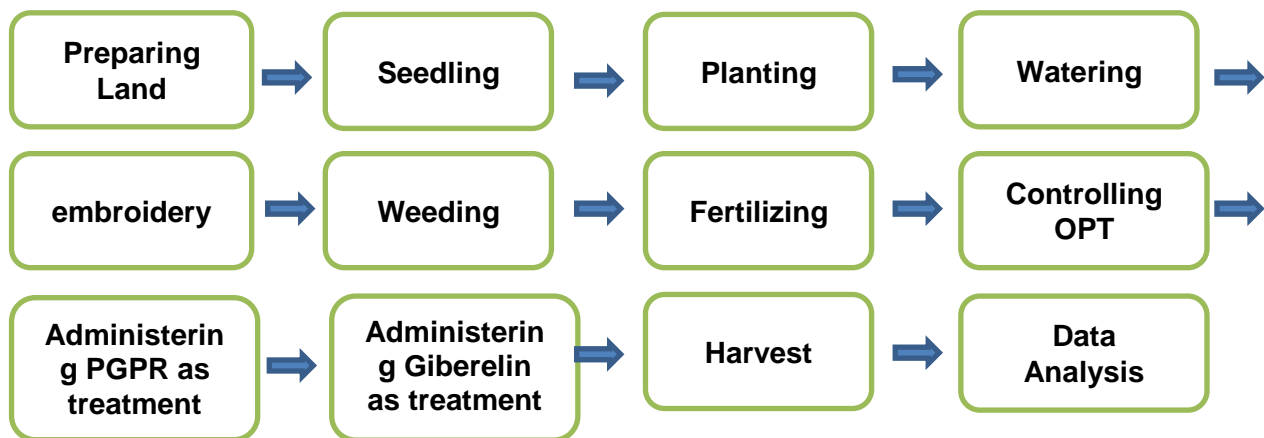


Figure 1. Research Flowchart

Observation parameters included plant height, number of leaves, flower emergence age, number of flowers, and fruit weight. Plant height was measured using a meter. Measurements began at the base of the stem and extended to the highest point of the plant. Plant height was measured at weekly intervals. The number of leaves was calculated by counting all fully opened leaves on each sample plant. Leaf counts were carried out at weekly intervals. Observations of flower emergence age were carried out by calculating the number of days required for the okra plant to flower, starting from the day after planting until the first flower appears on each sample plant. Observations of the number of flowers per plant were observed by counting the flowers that appeared on each sample plant. Fruit weight was measured by weighing the fruit from the beginning of the harvest until the study was completed. This process involved picking all the fruit from the sample plants and

weighing each fruit with a digital scale.

Data analysis from the experimental results was carried out using analysis of variance in accordance with the design used, namely a two-factorial Randomized Block Design (RAK). If the treatment has a significant effect, then the calculated *F* is greater than the 5% *F* table value; if the treatment does not have a significant effect, then the calculated *F* is smaller or equal to the 5% *F* table value. If a significant effect is found, to test the interaction of treatments, a 5% BNJ test is used. Data analysis was performed using Microsoft Excel 2013.

3. Results and Discussion

The analysis of variance shows that there is a significant interaction between the PGPR and gibberellin concentration treatments on the height of okra plants at 49 DAP (Table 1) and the number of flowers (Table 4). The

single PGPR concentration treatment has a significant effect on the observation parameters of leaf number and fruit weight (Table 2 and Table 5). The single gibberellin

treatment has a significant effect on the age parameter of flower emergence (Table 3).

Table 1. Average Height of Okra Plants 14 – 49 DAP (cm) in the Interaction of PGPR and Gibberellin Concentration Treatments

Treatment PGPR and Gibberellin	Average Height of Okra Plant (cm)					
	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP
PGO0	10.94±0.15a	17.00±0.38a	37.00±0.38a	52.89±1.13a	72.33±0.96a	82.11±0.99a
PG1	10.89±0.11a	18.89±0.68a	38.89±0.68a	59.78±2.70a	78.11±0.22a	88.22±0.11bc
PG2	10.44±0.11a	18.00±0.51a	38.00±0.51a	55.11±3.12a	72.33±2.08a	85.11±0.40ab
PG3	11.06±0.20a	17.44±0.87a	37.44±0.87a	59.22±2.06a	76.00±0.84a	85.89±0.56abc
PIG0	11.39±0.31a	17.00±1.20a	37.00±1.20a	55.56±1.57a	74.78±1.13a	84.67±0.69ab
PIG1	11.11±0.29a	17.39±1.20a	37.39±1.20a	56.44±2.51a	75.89±1.42a	86.22±0.40abc
PIG2	10.89±0.11a	16.28±0.20a	36.28±0.20a	61.33±2.83a	78.89±1.31a	87.89±0.96bc
PIG3	11.00±0.19a	15.89±0.40a	35.89±0.40a	61.78±0.44a	79.44±2.08a	88.56±1.44bc
P2G0	11.33±0.19a	17.33±1.45a	37.33±1.45a	53.78±1.09a	74.22±0.80a	84.56±0.95ab
P2G1	10.67±0.19a	18.44±1.57a	38.44±1.57a	58.56±1.74a	78.44±0.97a	87.78±0.89bc
P2G2	11.00±0.19a	19.67±1.35a	39.67±1.35a	60.33±4.93a	80.78±3.25a	88.44±1.39bc
P2G3	10.67±0.38a	17.11±0.11a	37.11±0.11a	60.56±3.56a	79.78±2.47a	90.22±1.56c
P3G0	11.00±0.19a	18.78±1.37a	38.89±1.47a	60.89±3.01a	80.44±1.93a	90.56±1.35c
P3G1	11.28±0.15a	16.89±0.73a	36.89±0.73a	60.67±0.58a	80.78±0.40a	90.00±0.19c
P3G2	11.33±0.19a	20.50±0.76a	40.50±0.76a	63.78±3.09a	82.44±2.02a	90.56±0.99c
P3G3	11.22±0.22a	20.56±0.68a	40.56±0.68a	68.67±1.53a	86.33±0.67a	90.67±0.51c
BNJ 5%	tn.	tn.	tn.	tn.	tn.	4.87

Description: The numbers that follow the same letters at the same age show no difference in the BNJ 5% test

The combination of PGPR P₃ (20 ml/l) and gibberellin G₃ (200 ppm) treatments was different. real with rice combination PGPR treatment P₀ (0 ml/l) and gibberellin G₀ (0 ppm), PGPR P₀ (0 ml/l) and gibberellin G₂ (150 ppm), PGPR P₁ (10 ml/l) and gibberellin G₀ (0 ppm), and PGPR P₂ (15 ml/l) and gibberellin G₀ (0 ppm) against tall okra plants aged 49 days after planting. Combination treatment PGPR P₃ (20 ml/l) and gibberellin G₃ (200 ppm) produced the highest average, with the best okra plants at age 49 DAP, with a value of 90.67 cm (Table 1).

The significant interaction between PGPR and gibberellin concentration treatments on okra plant height is influenced by both factors, which support each other during the plant's vegetative phase. PGPR administration can support the absorption of nitrogen (N), phosphorus (P), and potassium (K) nutrients required for plant growth. The results of research conducted by Handayani *et al.* (2022) showed that PGPR concentration treatment of 30 ml/l had a very significant effect on the height of okra plants aged 14 and 28 days after planting, with values of 23.38 and 32.10, respectively. The optimal concentration of the gibberellin hormone promotes optimal plant growth. The presence of the gibberellin hormone supports cell elongation, cambium activity, and the formation of new RNA and proteins (Triadiawarman *et al.* 2020).

Single treatment of PGPR P₃ concentration (20 ml/l) gave the best results for the amount of leaf at 35 DAP, with an average of 17.69 strands, which are not different from treatment P₂ (15 ml/l), with a value of 17.31 strands.

Treatment concentration of PGPR P₃ (20 ml/l) provides the best influence on the number of leaves of 28 -year-old okra plants - 49 DAP with an average value of 15.56 strands, 17.69 strands, 19.72 strands, and 22.42 leaves (Table 2). Meanwhile, the single gibberellin treatment did not significantly affect leaf number.

PGPR (Plant Growth-Promoting Rhizobacteria) used in this study contains macronutrients, such as nitrogen (N), which are essential for plants during the vegetative phase. The results of research conducted by Simanjuntak (2024) showed that the PGPR concentration treatment of 12.5 ml/l produced the best results for the number of leaves of okra plants aged 6 weeks after planting, with a value of 8.27. The single gibberellin treatment did not have a significant effect on the number of leaves parameter. This result could be due to several factors. Environmental factors, such as water availability and nutrient content in the planting medium, can affect leaf growth and cause other factors, such as gibberellin hormone administration, to go unnoticed (Fauza, 2019).

The single factor gibberellin significantly influences the flowering time parameter. The fastest average flowering time was observed with the gibberellin G₃ (200 ppm) treatment, with a value of 35.39, which was significantly different from other gibberellin treatments (Table 3). Gibberellin can meet the needs of several species to induce flowering, including okra. Research by Farida & Rohaeni (2019) showed that gibberellin treatments at 200 and 250 ppm concentrations resulted in the fastest flowering time,

with values of 32.66 and 32.16, respectively.

The combination of PGPR and gibberellin concentration treatments provided a significant interaction on the number of flowers parameter. The highest average number of flowers was produced by the combination of PGPR P₃ (20 ml/l) and gibberellin G₃ (200 ppm)

concentration treatments of 19.33, which was significantly different from the lowest value of the combination of PGPR P₀ (0 ml/l) and gibberellin G₀ (0 ppm) concentration treatments of 15.67 (Table 4).

Table 2. Average Number of Leaves of Okra Plants 7 – 49 DAP in Single PGPR and Gibberellin Treatments

Treatment	Average Number of Okra Leaves					
	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP
concentration (ml/l)						
P0 (0)	6.97 ±0.05a	11.72 ±0.20a	15.00 ±0.16 a	17.03 ±0.09 ab	19.14 ±0.08 a	21.56 ±0.14 a
P1 (10)	6.92 ±0.09a	11.75 ±0.16a	14.78 ±0.16 a	16.72 ±0.09 a	19.03 ±0.10 a	21.47 ±0.14 a
P2 (15)	7.1 ± 0.09a	12.08 ±0.19a	15.08 ±0.26 a	17.31 ±0.15 bc	19.31 ±0.10 a	22.25 ±0.16 b
P3 (20)	7.00 ±0.12a	12.19 ±0.11a	15.56 ± 0.23 b	17.69 ± 0.18 c	19.72 ±0.13 b	22.42 ±0.15 b
BNJ 5%	tn.	tn.	0.19	0.12	0.33	0.49
Gibberellin (ppm)						
G0 (0)	6.89 ±0.07a	11.61 ±0.19a	14.83 ±0.21a	16.97 ±0.17a	19.25 ±0.14a	21.83 ±0.17a
G1 (100)	7.03 ± 0.10a	12.08 ±0.18a	15.17 ±0.21a	17.14 ±0.11a	19.33 ±0.06a	22.03 ±0.18a
G2 (150)	6.97 ±0.08a	11.94 ±0.15a	15.22 ±0.24a	17.28 ±0.19a	19.25 ±0.13a	22.00 ±0.21a
G3 (200)	7.11 ± 0.10a	12.11 ±0.16a	15.19 ±0.22a	17.36 ±0.18a	19.36 ±0.16a	21.83 ±0.21a
BNJ 5%	tn.	tn.	tn.	tn.	tn.	tn.

Description: The numbers that follow the same letters at the same age show no difference in the BNJ 5% test.

Table 3. Average Age of Flower Emergence of Okra Plants in Single PGPR and Gibberellin Treatments

Average Age of Okra Plant Flowers: Appearance	
Treatment	
concentration (ml/l)	
P0 (0)	36.14 ± 0.14 a
P1 (10)	36.17 ± 0.19 a
P2 (15)	36.11 ± 0.21 a
P3 (20)	35.81 ± 0.22 a
BNJ 5%	tn.
Gibberellin (ppm)	
G0 (0)	36.67 ± 0.06 c
G1 (100)	36.39 ± 0.11 bc
G2 (150)	35.78 ± 0.18 b
G3 (200)	35.39 ± 0.11 a
BNJ 5%	0.37

Description: The numbers that follow the same letters at the same age show no difference in the BNJ 5% test

Table 4. Average Number of Flowers of Okra Plants in the Interaction of PGPR and Gibberellin Concentration Treatments

Average Number of Flowers on Okra Plants				
PGPR concentration (ml/l)	Gibberellin (ppm)			
	G0 (0 ppm)	G1 (100 ppm)	G2 (150 ppm)	G3 (200 ppm)
P0 (0 ml/l)	15.67 ± 0.19 a	16.22 ± 0.45 abc	16.56 ± 0.29 abc	16.78 ± 0.55 abc
P1 (10 ml/l)	16.44 ± 0.11 abc	16.89 ± 0.11 abc	16.22 ± 0.29 abc	17.55 ± 0.22 bcd
P2 (15 ml/l)	16.00 ± 0.33 ab	16.55 ± 0.40 abc	17.33 ± 0.69 abc	17.89 ± 0.49 cd
P3 (20 ml/l)	16.11 ± 0.29 abc	17.56 ± 0.44 cd	16.89 ± 0.40 abc	19.33 ± 0.38 d
BNJ 5%			1.77	

Description: The numbers that follow the same letters at the same age show no difference in the BNJ 5% test

Plants require phosphorus (P) for physiological and structural processes. Phosphorus is an essential component

in energy transfer and storage. Furthermore, phosphorus plays a role in flower formation. PGPR microorganisms

can provide P, which supports the generative phase of plants (Alpandari *et al.*, 2024). Gibberellin promotes flower formation by stimulating flowering. Previous research conducted by Arifiana & Krismiratsih (2022) showed that a gibberellin concentration of 50 mg/l gave the best results in

terms of flower number, with a value of 27.33. According to Maulani *et al.* (2024), one of the hormones that can stimulate okra plant production is the gibberellin hormone, which stimulates flowering.

Table 5. Average Okra Fruit Weight in Single PGPR and Gibberellin Treatments

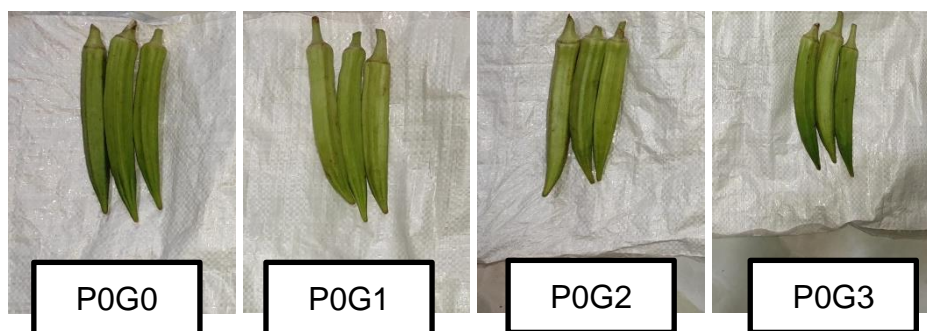
Average Weight Okra Fruit (g)					
Harvest Week -					
	1	2	3	4	5
Treatment concentration (ml/l)					
P0 (0)	26.42 ±0.07 a	26.52 ±0.04a	26.58 ±0.05 a	26.59 ±0.04a	26.50 ±0.04 a
P1 (10)	26.58 ±0.05 ab	26.65 ±0.04a	26.62 ±0.04 a	26.50 ±0.04a	26.60 ±0.03 ab
P2 (15)	26.55 ±0.04 ab	26.57 ±0.04a	26.66 ±0.01 ab	26.59 ±0.04a	26.66 ±0.03 b
P3 (20)	26.62 ±0.04 b	26.65 ±0.05a	26.76 ±0.04 b	26.61 ±0.04a	26.72 ±0.03 b
BNJ 5%	0.17	tn.	0.13	tn.	0.13
	1	2	3	4	5
Treatment Gibberellin (ppm)					
G0 (0)	26.54 ±0.05a	26.54 ±0.04a	26.72 ±0.03a	26.53 ±0.04a	26.64 ±0.05a
G1 (100)	26.56 ±0.04a	26.55 ±0.04a	26.63 ±0.05a	26.57 ±0.04a	26.60 ±0.03a
G2 (150)	26.59 ±0.05a	26.67 ±0.05a	26.66 ±0.04a	26.64 ±0.04a	26.61 ±0.04a
G3 (200)	26.48 ±0.07a	26.62 ±0.05a	26.60 ±0.04a	26.56 ±0.04a	26.63 ±0.05a
BNJ 5%	tn.	tn.	tn.	tn.	tn.

Description: The numbers that follow the same letters at the same age show no difference in the BNJ 5% test

The 3 concentration (20 ml/l) was significantly different from the PGPR P 0 concentration (0 ml/l) at the 1st harvest. The highest average value of okra fruit weight was produced by the PGPR P₃ concentration treatment (20 ml/l) at the 1st, 3rd, and 5th harvests with values of 26.62 g, 2.76 g, and 26.72 g (Table 5). Meanwhile, a single gibberellin treatment had no significant effect on okra fruit weight.

PGPR treatment can support the absorption of nitrogen (N), phosphorus (P), and potassium (K) nutrients needed for plant fruit development. Research conducted by Ichsan *et al.* (2018) showed that the administration of gibberellin at a concentration of 375 ppm resulted in the highest okra fruit yield, specifically 5 grams. The microorganisms in

PGPR can bind N₂ in the air and dissolve P and K into available forms, thereby meeting plant nutrient needs (Harum *et al.*, 2024). In addition, microorganisms play a role in soil decomposition, helping plants absorb nutrients, increasing plant resistance, and promoting plant growth. Administration of gibberellin hormones can be effective if the concentration given is appropriate. Administration of gibberellin with a concentration that suits plant needs can affect biochemical processes in plants so that the photosynthesis process increases and affects fruit weight. According to Deviyanti *et al.* (2023), The absence of an effect of gibberellin concentration application on fruit weight may be due to an incorrect dose.



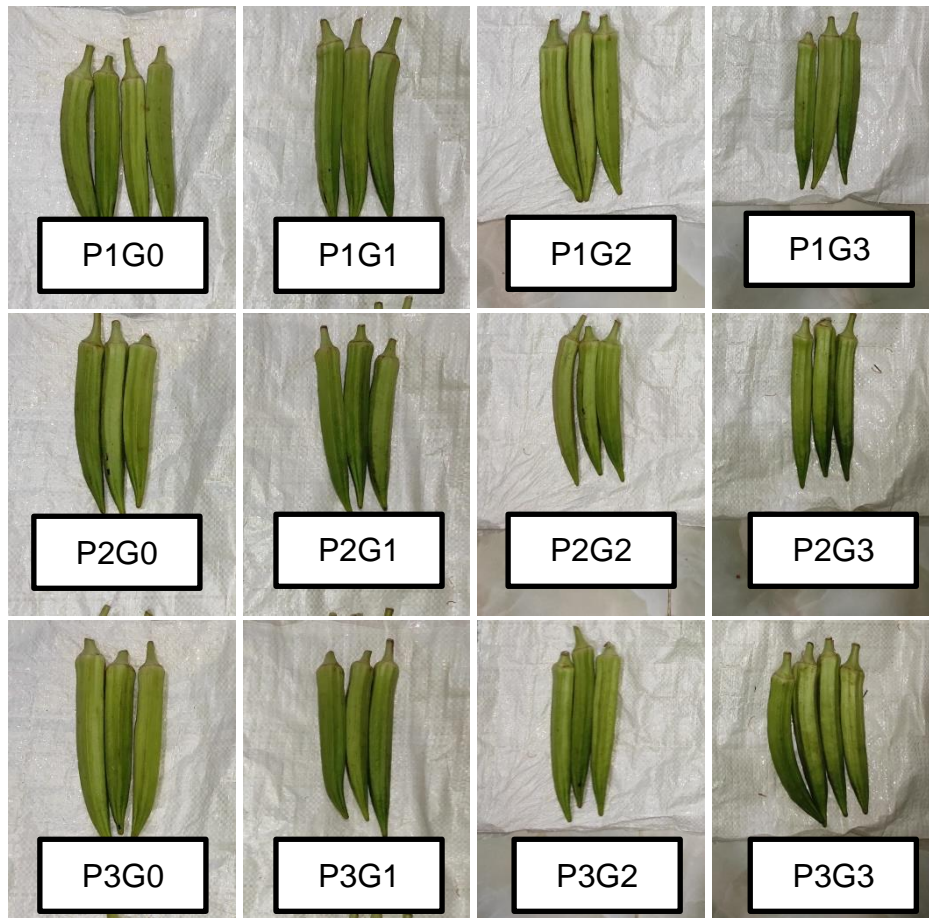


Figure 2. Comparison of Okra Plant Yields Between PGPR and Gibberellin Treatments

4. Conclusion

This study concludes that there is a significant interaction between the treatment of PGPR P3 (20 ml/l) and gibberellin G3 (200 ppm) concentrations, yielding the best results in okra plant height at 49 days after sowing (DAS) and the number of flowers, with values of 90.67 cm and 19.33 flowers, respectively. The single treatment with PGPR at 20 ml/l produced the most significant effects on leaf number and fruit weight. Meanwhile, the single treatment with 200 ppm gibberellin significantly influenced

the timing of flower emergence, resulting in the earliest flowering at 35.39 days. It is recommended that future research focus on the combined application of PGPR at 20 ml/l and gibberellin at 200 ppm, as this combination outperformed other treatments. Additionally, further studies are needed to explore a broader range of effects of PGPR and gibberellin.

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