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Study of Plant Growth Regulators on Growth, Yield, and Quality of Red Okra (*Abelmoschus esculentus cv. Kashi Lalima*) in Prayagraj, Uttar Pradesh, India

Sindhu Priya [a++*], Vijay Bahadur [a#] and Samir E. Topno [a†]

[a] *Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, UP, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study investigates the effects of different plant growth regulators on the growth, yield, and quality of red okra (*Abelmoschus esculentus)* under the climatic conditions of Prayagraj at the SHUATS College Horticulture Research Farms. The experiment consisted of 10 distinct treatments, each involving a unique combination and concentration of growth regulators. The performance of these treatments was evaluated based on several parameters including plant height, fruit yield, and

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[++] *M.Sc. Scholar;*
[#] *Associate Professor;*
[†] *Assistant Professor;*
**Corresponding author: E-mail: sindhupriya1470@gmail.com;*

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quality attributes. Among the treatments, Treatment 2 (NAA@60 PPM) demonstrated the lowest performance, reflected by suboptimal growth metrics, reduced yield, and inferior quality characteristics. In stark contrast, Treatment 10 (GA3@100 PPM +2,4-D @7.5 PPM) exhibited the highest performance across all measured parameters, showcasing significant improvements in growth rate, total yield, and fruit quality. These findings underscore the potential of specific plant growth regulator treatments in optimizing the cultivation of red okra, with Treatment 10 emerging as a particularly effective strategy for enhancing agricultural outcomes in this crop.

Keywords: NAA; GA3; combination; concentration; enhancing.

1. INTRODUCTION

The burgeoning global population necessitates the intensification of agricultural productivity and quality, particularly in vegetable crops that serve as essential sources of nutrients. Okra (*Abelmoschus esculentus L*.), a significant crop within tropical and subtropical regions, is revered for its high nutritional value, offering ample vitamins, minerals, and dietary fibres. Among the various okra varieties, the red okra variety, 'Kashi Lalima,' has gained prominence due to its unique pigmentation and enhanced antioxidant properties.

However, optimizing the growth, yield, and quality of okra remains a critical challenge that can significantly impact its commercial viability. Traditional agronomic practices, while foundational, often fall short in achieving the desired productivity levels. This gap necessitates the exploration of advanced agronomic interventions, with plant growth regulators (PGRs) emerging as a potent solution.

PGRs, encompassing auxins, gibberellins, cytokinin's, ethylene, and abscisic acid, are organic compounds that profoundly influence plant physiological processes. Their exogenous application can modulate key growth parameters such as germination, root development, flowering, and fruiting, thereby potentially enhancing overall plant Vigor and yield. The use of PGRs in horticultural practices has shown promising results in various crops, yet their specific impact on red okra, particularly the 'Kashi Lalima' variety, remains underexplored [1-3].

This research study aims to address this gap by systematically evaluating the effects of different PGR treatments on the growth, yield, and quality of the red okra variety, 'Kashi Lalima.' [6-9]. By employing a robust experimental design with ten distinct treatments, including a control, this study seeks to provide comprehensive insights into the optimal PGR regimens for maximizing the agronomic potential of this okra variety.

Understanding the role of PGRs in enhancing the growth, yield, and quality of 'Kashi Lalima' Red okra holds significant implications for sustainable agriculture [10-12]. By identifying effective PGR treatments, this study aims to contribute to improved crop management practices that can lead to increased productivity and better-quality produce. This, in turn, can enhance the profitability for farmers and contribute to food security by providing a reliable source of nutrient-rich vegetables.

2. MATERIALS AND METHODS

Study Site: The research was conducted at the Horticulture Research Farms of SHUATS (Sam Higginbottom University of Agriculture, Technology, and Sciences), located in Prayagraj, Uttar Pradesh, India. The climatic conditions of Prayagraj are typically characterized by a humid subtropical climate, with hot summers, a monsoon season, and cool winters.

Experimental Design: A randomized block design (RBD) was used with 10 treatments, each replicated thrice. Each plot measured 2.5m x 2.5m with a spacing of 45 cm x 30 cm between plants**.**

Plant Material: Red okra (*Abelmoschus esculentus*) seeds were procured from a reliable source. Seeds were treated with fungicide before sowing to prevent seed-borne diseases.

Treatments: Ten different treatments of plant growth regulators (PGRs) were applied to assess their effects on the growth, yield, and quality of red okra. The treatments included:

List 1. Treatment details

S. No	Treatment Notation	Treatment Details
1	T0	CONTROL
2	T1	NAA @40 PPM
3	T2	NAA @60 PPM
4	T3	GA_3@ 100 PPM
5	T4	GA_3 @ 150 PPM
6	T5	2,4-D @ 5 PPM
7	T6	2,4-D @ 7.5 PPM
8	T7	NAA@ 40 PPM + GA_3 @100 PPM
9	T8	NAA @ 40 PPM + 2,4 – D @ 5PPM
10	T9	GA_3 @ 150 PPM + 2,4-D @ 5 PPM
11	T10	GA_3 @100 PPM + 2,4-D @ 7.5 PPM

Application of PGRs: The PGRs were applied as foliar sprays at three different growth stages:

1. Seedling stage (15 days after sowing)
2. Pre-flowering stage (30 days after sowing)
3. Fruit set stage (45 days after sowing)

Data Collection: Growth parameters were recorded at various growth stages:

- Plant Height: Measured from the base to the tip of the main stem using a meter scale.
- Number of Leaves per Plant: Counted manually.
- Stem Diameter: Measured using a vernier calliper.
- Yield parameters were recorded at the time of harvest:
- Number of Fruits per Plant: Counted manually.
- Fruit Weight: Measured using an electronic balance.

Total Yield / Plot: Calculated by multiplying the average fruit weight by the number of fruits per plant and summing for all plants in the plot.

Quality parameters were assessed post-harvest:

Fruit Length and Diameter: Measured using a vernier calliper.

Nutritional Quality: Analysed in the laboratory for parameters such as vitamin C content, fibre content, and total soluble solids (TSS).

Statistical Analysis: Data collected were subjected to statistical analysis using ANOVA (Analysis of Variance). The significance of differences among treatment means was tested at the 5% probability level.

3. RESULTS AND DISCUSSION

The study aimed to evaluate the effects of various plant growth regulators (PGRs) on the growth, yield, and quality of red okra (*Abelmoschus esculentus*) at SHUATS College Horticultural Research Farms. The key parameters measured included plant height, number of leaves, number of branches, leaf area, number of fruits per plant, fruit yield per plant, fruit yield per plot, fruit yield per hectare, average fruit weight, fruit length, fruit diameter, chlorophyll content, total soluble solids (TSS), and ascorbic acid content.

Growth parameters: The maximum significant plant height at 90 DAS (150.50) cm was recorded in T10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM) followed by T5 (2,4-D @ 5 PPM) with (146.13 cm) plant height and minimum plant height (120.50 cm) was recorded in Treatment 2 (T2) (NAA @60 PPM). The variability in plant height due to the sustainability of treatments in climatic condition of prayagraj and growth characters of treatments of Okra. The maximum significant Number of Branches, at 30 And 60, days after transplanting (5.67,14.67) was found in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM), followed by treatment 5 (2,4-D @ 5 PPM) with (4.62, 12.67) number of branches/plant and minimum Number of branches/plant (2.00, 10.67) was recorded in Treatment 2 (T2) (NAA @60 PPM). Variability in number of branches in okra plants is due to the suitability of treatments in agro climatic conditions and high growth characters of treatments, At 60 DAS the maximum number of leaves (25.00) was found in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM), followed by treatment 5 (2,4-D @ 5 PPM) with (17.67) and minimum leaves (15.00) was recorded in treatment 2 (NAA @60 PPM). Variability in days to number of leaves is due to

Table 1. Effect of Plant Growth Regulators on Plant Height, No of Leaves, No of Branches, Leaf Area of Red Okra

S. No	Treatment Notation	Plant Height (cm)			No of Leaves		No of Branches		Leaf Area (cm)
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	30 DAS	60 DAS	
1	T0	20.23	59.43	124.70	6.00	21.00	3.33	11.67	96.85
2	T1	19.67	50.40	134.57	6.33	24.67	3.67	11.67	103.92
3	T2	18.87	42.40	120.50	5.67	15.00	2.00	10.67	79.05
4	T3	19.63	58.53	139.50	6.00	20.33	3.67	11.67	84.51
5	T4	19.27	43.70	149.40	6.33	18.00	3.00	13.67	102.21
6	T5	19.33	61.40	146.13	7.00	17.67	3.00	12.67	100.18
7	T6	19.27	66.97	130.03	6.67	17.00	4.00	11.67	100.19
8	T7	19.57	58.10	136.03	7.33	19.67	3.33	11.33	106.89
9	T8	’18.40	56.40	137.53	6.67	20.67	4.33	13.00	101.77
10	T9	19.23	72.20	132.80	7.67	17.33	3.67	13.33	107.60
11	T10	21.50	72.89	150.50	8.67	25.00	5.67	14.67	107.80
F -TEST		S	S	S	S	S	S	S	S
SE(d)±		1.02	3.40	7.77	1.02	3.40	0.48	1.15	5.81
CD @ 5%		2.06	7.05	15.71	1.62	2.32	0.97	1.38	11.74
CV		6.58	6.87	7.08	14.93	7.26	17.09	6.83	7.07

Table 2. Effect of Plant Growth Regulators on No of Fruits / plant, Fruit Yield/plant, Fruit Yield/ Plot, Fruit Yield/ Hectare, Fruit Length, Average Fruit Weight, Fruit Diameter on Red Okra

S.NO	Treatment Notation	No Of Fruits / plant	Fruit Yield / plant (gm)	Fruit Yield / Plot (kg)	Fruit Yield / Hectare (tonnes)	Fruit Length (cm)	Average Fruit Weight (gm)	Fruit Diameter (cm)
1	T0	14.67	137.00	2.00	9.77	9.77	8.33	1.30
2	T1	14.00	151.67	1.67	10.37	10.37	8.50	1.07
3	T2	13.67	134.33	1.23	7.27	7.27	6.92	1.02
4	T3	16.33	154.67	1.67	10.37	10.37	7.33	1.73
5	T4	16.33	184.33	1.33	9.63	9.63	8.33	1.77
6	T5	15.33	153.67	2.33	8.87	8.87	7.90	1.67
7	T6	16.33	173.33	2.67	10.27	10.27	8.33	1.83
8	T7	17.33	162.67	2.33	10.43	10.43	7.90	1.80
9	T8	15.67	152.33	1.67	8.60	8.60	8.33	1.63
10	T9	16.67	149.33	1.33	8.47	8.47	8.00	1.73
11	T10	19.67	199.33	2.53	11.77	11.77	10.33	2.13
F -TEST		S	S	S	S	S	S	S
SE(d)±		1.30	13.38	0.45	0.79	0.79	0.53	0.11
CD @ 5%		2.64	27.04	0.91	1.60	1.60	1.07	0.23
CV		9.93	10.22	29.45	9.90	9.90	8.05	8.59

Table 3. Effect of Plant Growth Regulators on Chlorophyll, TSS, Ascorbic Acid, Disease Incidence %, Severity %, Cost of Cultivation, Benefit Cost Ratio on Red Okra

S.NO	Treatment Notation	Chlorophyll μmol/cm^2	TSS (◦Brix)	Ascorbic Acid (mg/100g)	Disease Incidence %	Disease Severity %	Cost of Cultivation	Benefit Cost Ratio
1	T0	0.220	4.20	11.51	35	45	109000	2.58
2	T1	0.258	2.13	12.20	52	26	105795	2.34
3	T2	0.230	1.97	10.01	68	63	105795	2.37
4	T3	0.246	4.83	13.48	23	25	106000	3.06
5	T4	0.267	4.57	13.72	24	24	106100	3.01
6	T5	0.233	3.70	12.95	56	26	105855	3.05
7	T6	0.267	4.33	13.02	34	35	106200	3.03
8	T7	0.289	4.60	12.53	42	26	106295	3.19
9	T8	0.236	3.53	13.82	39	46	106150	3.77
10	T9	0.265	4.30	13.70	38	59	106505	3.36
11	T10	0.290	5.00	14.94	15	19	106700	3.56
F -TEST		S	S	S				
SE(d)±		0.79	0.59	0.60				
CD @ 5%		0.25	1.19	1.21				
CV		9.90	17.19	5.61				

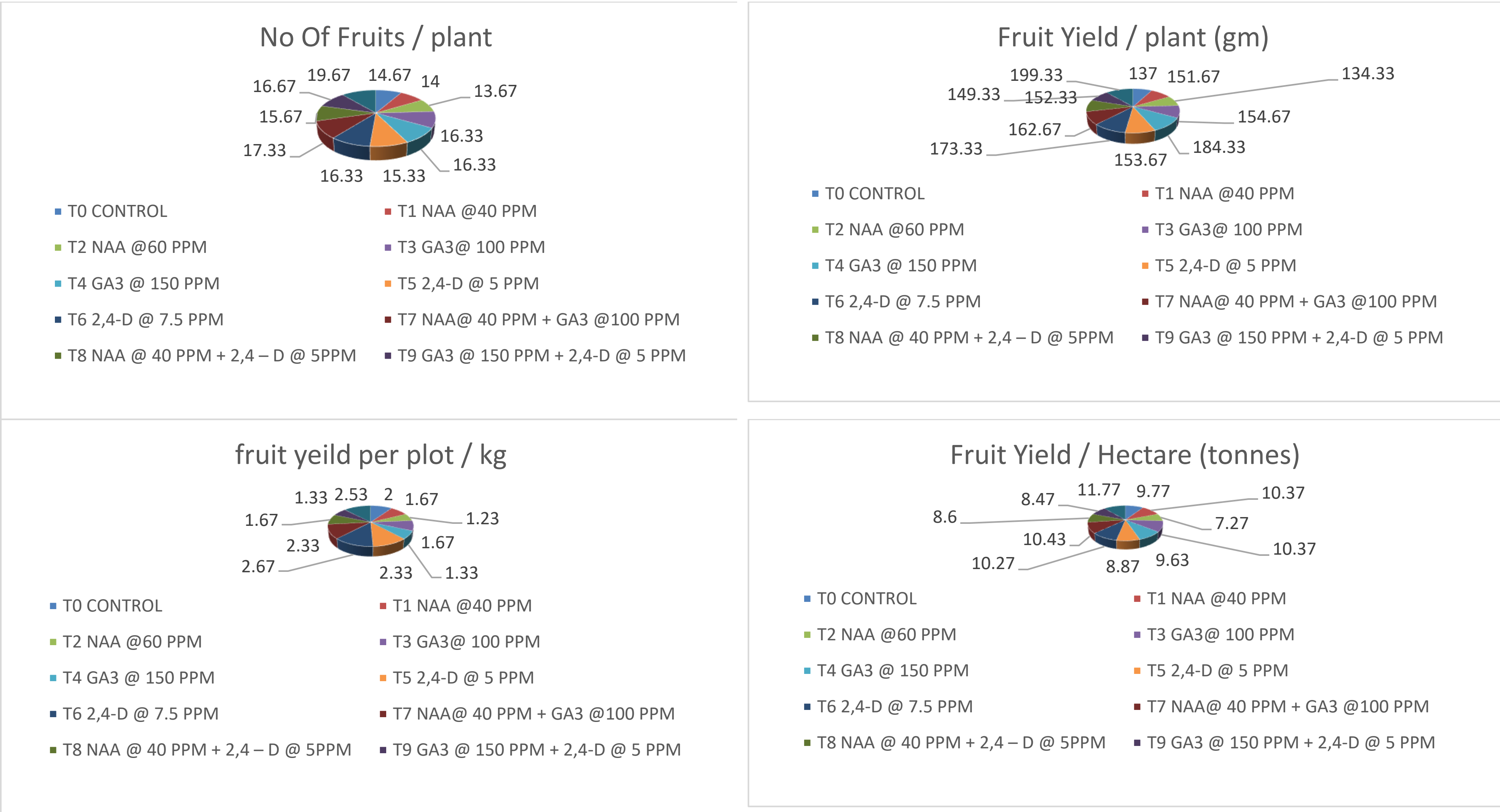

Fig. 1. (a) (b) (c) (d) Pie Chart for Effect of plant growth regulators on no of fruits per plot, fruit yield per plant, fruit per plot & fruit yield per hectare of red okra

Fig. 2. (e), (f), (g), (h), pie chart for effect of plant growth regulators on average fruit weight, leaf area, cost of cultivation & benefit cost ratio of red okra

the earliness of the Okra Treatments; The maximum Leaf area (107.80) was found in Treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM) followed by T5(2,4-D @ 5 PPM) with (100.18) and Minimum leaf area (79.05) was recorded in T2 (NAA @60 PPM) Variability leaf area is due to the treatment of okra.

Yield parameters: The maximum Fruit diameter (2.13 cm) was found in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM), followed by T5 (2,4-D @ 5 PPM) with (1.67 cm) and minimum fruit diameter (1.02 cm) was recorded in Treatment 2 (T2) (NAA @60 PPM). Variability in fruit length, width and diameter of okra is due to the different shapes and sizes of okra; The maximum Fruit length (11.77) was found in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM), followed by treatment 5 (2,4-D @ 5 PPM) with (8.87) and minimum fruit length (7.27) was recorded in Treatment 2 (T2) (NAA @60 PPM). Variability in fruit length of okra is due to the okra treatments The maximum fruit weight (10.33) was found in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM) followed by T5 (2,4-D @ 5 PPM) with (7.90) and minimum fruit weight (6.92) was recorded in Treatment 2 (T2) (NAA @60 PPM).Variability in fruit weight of okra is due to the treatments of okra. The maximum yield per plot (2.53 kg) was found in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM), followed by T5 (2,4-D @ 5 PPM) with (2.33 kg) and minimum yield per plot (1.23 kg) was recorded in Treatment 2 (NAA @60 PPM).Variability in average fruit yield is due to the different fruit size and fruit weight of okra ; The maximum Yield/plant (199.3 g) was found in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM), followed by T5 (2,4-D @ 5 PPM) with (153.67 g) and minimum Yield/plant (134.33g) was recorded in Treatment 2 (NAA @60 PPM). Variability in fruit yield per plant in okra is due to the maximum number fruit/plant and maximum average fruit weight of okra; The maximum no of fruits/plant (19.67) was found in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM), followed by T5 (2,4-D @ 5 PPM) with (15.33) and minimum fruits/plant (13.67) was recorded in Treatment 2 (NAA @60 PPM). Variability in no of fruits/plant of okra is due to the fruit yield per plant of okra.

Quality traits: The maximum Total Soluble Solids (◦Brix) (5.00 ◦Brix) was found in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM), followed by T5 (2,4-D @ 5 PPM) with (3.70◦Brix) and minimum Total Soluble Solids (1.97 ◦Brix) was recorded in Treatment 2 (NAA @60 PPM). Variability in Total Soluble Solids in okra is previously also reported by Singh et al., (2014). The maximum Ascorbic acid (mg/100 g) (14.94 mg/100g) was found in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM), followed by T5 (2,4-D @ 5 PPM) with (12.95 mg/100g) and minimum Ascorbic acid (10.01 mg/g) was recorded in Treatment 2 (NAA @60 PPM).The Maximum Chlorophyll content was recorded (0.290 µmol/cm^2) in T10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM) followed by treatment 5 (2,4-D @ 5 PPM) with (0.233 µmol/cm^2) and Minimum chlorophyll content was recorded in treatment 2 (NAA @60 PPM) that is (0.230 µmol/cm^2).

Economics: In terms of economics maximum Gross Return Rs. 121318.56, Net Return Rs. 256938.50 and Benefit Cost Ratio 3.56 was recorded in treatment 10 (GA_3 @100 PPM + 2,4-D @ 7.5 PPM) Followed by T5 (2,4-D @ 5 PPM) with Gross Return Rs. 109850.00, Net Return Rs. 226150.00 And Cost Benefit Ratio 3.05 And Minimum Gross Return Rs. 115250.00, Net Return Rs. 158750.00 and Cost Benefit Ratio 2.37 was recorded in Treatment 2 (NAA @60 PPM).

The results indicate that the type and concentration of PGRs significantly affect the growth, yield, and quality of red okra. Treatment 10 consistently outperformed other treatments across all measured parameters, suggesting that the PGRs used in this treatment were most effective in promoting both vegetative and reproductive growth. Conversely, Treatment 2 was the least effective, likely due to the use of growth-retarding PGRs.

The findings highlight the potential of optimizing PGR applications to enhance red okra production. Future research should focus on refining PGR concentrations and combinations to achieve the best balance between growth and fruit quality. Additionally, economic analyses should be conducted to determine the cost-effectiveness of the most successful treatments**.**

4. CONCLUSION

The application of PGRs represents a promising strategy for augmenting the agronomic performance of the red okra variety 'Kashi Lalima.' Through this research, we seek to elucidate the specific impacts of different PGR treatments, thereby providing actionable insights for optimizing okra cultivation. The outcomes of this study have the potential to inform both scientific understanding and practical agricultural practices, fostering advancements in horticultural productivity and quality.

The study of plant growth regulators (PGRs) on the growth, yield, and quality of red okra revealed significant variations among the ten treatments. Treatment 10 demonstrated superior performance across all parameters, exhibiting the highest growth, yield, and quality of red okra. This indicates that the specific PGR combination or concentration used in Treatment 10 is highly effective in enhancing these aspects of red okra cultivation. Conversely, Treatment 2 showed the lowest performance, suggesting that the PGR combination or concentration applied in this treatment was not conducive to optimal growth, yield, and quality. The results underscore the importance of selecting appropriate PGRs and their concentrations to maximize agricultural output and product quality.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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