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Influence of Plant Growth Regulators on Growth, Yield and Quality of Okra (*Abelmoschus esculentus* L. Moench)

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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

A field experiment was conducted at the Horticultural Research Farm of Prof. Rajendra Singh (Rajju Bhaiya) University, Naini, Prayagraj, during the Rabi season of 2025–26 to evaluate the effect of plant growth regulators of okra cv., *Arka Anamika*. The research experiment was laid out in a Randomized Block Design (RBD) with nine treatment and three replications. The results revealed that the combined application of GA_3 and NAA significantly influenced the growth, yield and quality attributes of okra. Among all treatments, T_9

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(GA_3 @ 200 ppm + NAA @ 200 ppm) recorded the maximum plant height (39.44, 128.29 and 176.44 cm at 30, 60 and 90 DAS, respectively), number of leaves per plant (8.74 and 21.65 at 30 and 60 DAS, respectively), leaf length (21.78 and23.30cm at 30 and 60 DAS), leaf width (29.82 and 34.18 cm at 30 and 60 DAS), number of branches per plant (3.90 at 60 DAS). Additionally, T_9 minimized the crop duration, requiring only 47 days to first flowering and 56 days to first harvest. While, maximizing reproductive and yield components such as the number of flower buds per plant (3.34 and 11.02 at 30 and 60 DAS), pod length(15.11cm), pod diameter (1.94 cm), number of seed per pods (53.33), number of pods per plant (14.37), fresh weight of pod (17.38g), pod yield per plot (3.51kg), total yield t/ha (8.78). Conversely qualitative parameters were also improved T_7 (GA_3 @ 100 ppm + NAA @ 200 ppm) producing superior ascorbic acid content(16.70mg/100g), total soluble solids (5.33^0brix) and moisture percentage in pods (90.07%). Overall, the combined application of GA_3 and NAA exhibited enhanced vegetative development, overall plant vigor, and yield traits compared to the control treatment.

Keywords: Okra; GA₃; NAA; growth; yield; quality.

1. Introduction

Okra (*Abelmoschus esculentus*) is an important warm-season vegetable crop belonging to the family Malvaceous. It is believed to have originated in Ethiopia (Northeast Africa) and possesses a chromosome number of 2n = 130. Okra is predominantly self-pollinated, but a considerable amount of cross-pollination (about 4–19% or sometimes higher depending on insect activity) may occur, mainly through insects such as bees. Therefore, it is often described as an often-cross-pollinated crop. The flowers are large, bisexual, and generally open in the morning, facilitating pollination. It was initially classified under the genus *Hibiscus*, but later reassigned to the genus *Abelmoschus* (Aladele *et al*., 2008). In India, okra is grown throughout the year, and its pods are generally harvested within 5–10 days after flowering, depending on the cultivar. Okra pod contains many nutritional contents which important for human health. The edible fruit of okra one hundred gram of fresh pod has around; 1.9 g of protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fibre (Adetuyi et al., 2011; Gemede et al., 2016). Okra pods are rich in dietary fibre, vitamins A and C, minerals, antioxidants and mucilage, making them an important component of a balanced diet (Durazzo et al., 2019; Gemede et al., 2016). Okra roots and stems are also traditionally used to purify sugarcane juice for producing jaggery (Chavan et al., 2007)**.** Okra is one of the major vegetable crops cultivated throughout tropical and subtropical regions. India is the world's largest producer of okra, contributing nearly 70–75% of global production. According to recent FAOSTAT and NHB reports, India cultivates approximately 0.54 million hectares with an annual production exceeding 6.5 million tonnes. Major producing states include Gujarat, West Bengal, Odisha, Bihar and Maharashtra. Owing to its high productivity and market demand, okra is considered an important commercial vegetable crop in India. In the Konkan region, Thane district has the largest area under okra cultivation. GA_3 application enhanced vegetative growth, flowering, fruit set, fruit development, yield, and seed quality, demonstrating its crucial role in regulating growth processes and improving overall crop productivity (Kokare et al., 2006; Shree et al., 2022). Plant growth regulators (PGRs) are naturally occurring or synthetic organic compounds that, when applied in small quantities, regulate various physiological processes involved in plant growth and development. GA3 and NAA is type of plant growth regulators which is enhance the plant height, cell elongation, breaking dormancy, prevent the premature falling of flower and fruit drop, nutrient uptake and promote the root initiation (Hedden & Sponsel, 2015; Rademacher, 2015).

2. Materials and Methods

The present investigation entitled "Effect of Plant Growth Regulators on Growth, Yield and Quality of Okra (*Abelmoschus esculentus* L. Moench)" was conducted during the Rabi season of 2025–26 at the Horticultural Research Farm, Prof. Rajendra Singh (Rajju Bhaiya) University, Naini, Prayagraj, Uttar Pradesh, India. The experimental field was characterized by alluvial soil with a loamy to sandy loam texture and good drainage conditions suitable for vegetable cultivation. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments and three replications using okra cv. Arka Anamika. The treatments comprised T_1 (Control), T_2 (GA_3 @ 100 ppm), T_3 (GA_3 @ 200 ppm), T_4 (NAA @ 100 ppm), T_5 (NAA @ 200 ppm), T_6 (GA_3 @ 100 ppm + NAA @ 100 ppm), T_7 (GA_3 @ 100 ppm + NAA @ 200 ppm), T_8 (GA_3 @ 200 ppm + NAA @ 100 ppm) and T_9 (GA_3 @ 200 ppm + NAA @ 200 ppm). Each experimental plot measured 2.0 m × 2.0 m and the crop was established through direct seed sowing at a spacing of 60 cm × 45 cm. Gibberellic acid (GA_3) and

Naphthalene Acetic Acid (NAA) were applied as foliar sprays according to the treatment schedule. Two sprays were given during the crop growth period, first at 20 days after sowing (DAS) and second at 40 DAS. Fresh solutions were prepared before application and sprayed uniformly on the foliage until runoff. Observations were recorded on growth parameters, viz., plant height(cm), number of leaves per plant, leaf length(cm), leaf width(cm), number of branches per plant, days to first flowering and days to first harvest. Yield attributes such as pod length(cm), pod diameter(cm), number of pods per plant, number of seeds per pod, fresh pod weight(g), pod yield per plot(kg) and pod yield(q/ha) were also recorded. Quality parameters including total soluble solids (TSS), ascorbic acid content(mg/100g) and moisture percentage (%) were determined using standard procedures. Economic analysis was carried out by calculating cost of cultivation, gross return, net return and benefit-cost ratio.

2.1 Statistical Analysis

The recorded data were subjected to analysis of variance (ANOVA) appropriate for Randomized Block Design, and treatment means were compared at the 5% level of significance.

3. Results and Discussions

3.1 Plants Height (cm)

Plant height was significantly influenced by the application of different plant growth regulators at all stages of crop growth. Among the treatments, T_9 (GA_3 @ 200 ppm + NAA @ 200 ppm) recorded the maximum plant height of 39.44, 128.29 and 176.44 cm at 30, 60 and 90 DAS, respectively, whereas the minimum plant height was observed under the control treatment (35.82, 103.86 and 156.02 cm). The increased plant height under T_9 may be attributed to the synergistic effect of GA_3 and NAA, which enhanced cell elongation, cell division and internodal growth, resulting in vigorous vegetative development. Similar findings were reported by Abdullah et al. (2024) and Meena et al. (2017), who observed significant improvement in plant height of okra following the application of GA_3 and NAA (Table 1).

Table 1. Effect of GA_3 and NAA on growth characters of okra

Treatments	Plant height (cm)			Number of leaves plants^{-1}	
	30DAS	60DAS	90DAS	30DAS	60DAS
T_1-CONTROL	35.82	103.86	156.02	3.95	10.26
T_2-GA_3@100ppm	36.89	119.32	160.17	5.15	12.89
T_3-GA_3@200ppm	37.33	121.22	162.52	5.85	15.26
T_4-NAA@100ppm	35.68	116.73	158.79	4.26	10.74
T_5-NAA@200ppm	36.34	117.17	160.36	4.65	12.35
T_6-GA_3@100ppm+NAA@100ppm	36.77	118.59	168.73	6.74	17.11
T_7-GA_3@100ppm+NAA@200ppm	36.66	114.83	171.18	7.35	19.11
T_8-GA_3@200ppm+NAA@100ppm	38.15	123.58	172.36	8.26	20.26
T_9-GA_3@200ppm+NAA@200ppm	39.44	128.29	176.44	8.74	21.65
CD.at5%	0.498	4.312	0.375	0.365	0.334
SE(m)$\pm$	0.165	1.426	0.124	0.121	0.111

3.2 Number of Leaves per Plant

The number of leaves per plant increased significantly due to foliar application of plant growth regulators. The highest number of leaves per plant was recorded in T_9 (8.74 and 21.65 at 30 and 60 DAS, respectively), while the control treatment recorded the lowest values (3.95 and 10.26). The increase in leaf number might be due to enhanced meristematic activity, increased photosynthetic efficiency and better nutrient translocation induced by the combined application of GA_3 and NAA. These results are in close agreement with the findings of Abdullah et al. (2024) and Shree et al. (2022), who reported increased leaf production in okra under growth regulator treatments (Table 1).

3.3 Leaf Length (cm) and Leaf width (cm)

Leaf length and leaf width were significantly enhanced by the application of growth regulators. The maximum leaf length (21.78 and 23.30 cm at 30 and 60 DAS, respectively) and leaf width (29.82 and 34.18 cm at 30 and

60 DAS, respectively) were recorded in T_9 (GA_3@ 200ppm + NAA@ 200ppm), whereas the minimum values were observed in the control. Larger leaf area under T_9 may have improved light interception and photosynthetic activity, thereby promoting plant growth (Table 2). These findings are in agreement with those reported by Abdullah et al. (2024) and Kokare et al. (2006).

3.4 Number of Flower Buds per Plant

The number of flower buds per plant was significantly affected by plant growth regulator treatments. The highest number of flower buds was recorded in T_9 (GA_3 @ 200 ppm + NAA @ 200 ppm) with 3.34 and 11.02 flower buds per plant at 30 and 60 DAS, respectively, while the lowest values were observed in the control treatment. The increased flower bud formation may be attributed to enhanced physiological activity, improved nutrient translocation and better hormonal balance under the combined application of GA_3 and NAA (Table 2). Similar findings were reported by Abdullah et al. (2024) and Meena et al. (2017).

Table 2. Effect of GA_3 and NAA on growth characters of okra.

Treatments	Leaf length (cm)		Leaf width (cm)		No. of flower buds plant^{-1}	
	30DAS	60DAS	30DAS	60DAS	30DAS	60DAS
T_1-CONTROL	14.83	15.15	20.80	21.94	1.84	5.28
T_2-GA_3@100ppm	18.41	19.64	24.54	25.54	2.92	7.43
T_3-GA_3@200ppm	19.85	21.24	26.90	31.41	2.95	9.17
T_4-NAA@100ppm	16.10	18.71	22.00	24.52	2.37	7.72
T_5-NAA@200ppm	17.01	19.22	22.18	23.99	2.87	6.81
T_6-GA_3@100ppm+NAA@100ppm	19.54	20.70	26.51	28.00	2.91	6.98
T_7-GA_3@100ppm+NAA@200ppm	18.87	20.21	25.60	26.90	2.72	7.56
T_8-GA_3@200ppm+NAA@100ppm	20.71	22.59	29.19	32.65	3.06	9.40
T_9-GA_3@200ppm+NAA@200ppm	21.78	23.30	29.82	34.18	3.34	11.02
C.D.at5%	0.88	1.196	1.38	2.452	0.656	0.793
SE(m)$\pm$	0.291	0.396	0.456	0.811	0.217	0.262

3.5 Number of Branches per Plant

The number of branches per plant was significantly influenced by the application of plant growth regulators. Treatment T_9 (GA_3 @ 200 ppm + NAA @ 200 ppm) recorded the maximum number of branches per plant (3.90), whereas the minimum number of branches (1.67) was observed in the control treatment. The increase in branching may be due to enhanced cell division, cell elongation and stimulation of lateral bud growth by GA_3 and NAA (Table 3). Similar results were reported by Abdullah et al. (2024) and Verma et al. (2016).

3.6 Number of Days Taken to First Flowering

The number of days taken to first flowering was significantly influenced by the application of plant growth regulators. The minimum number of days to first flowering (47.00 days) was recorded in T_9 (GA_3 @ 200 ppm + NAA @ 200 ppm), followed by T_8 (47.33 days), whereas the maximum number of days (52.67 days) was observed in the control treatment. The reduction in days to flowering under GA_3 and NAA treatments may be attributed to enhanced physiological activities, rapid vegetative growth and accelerated floral initiation. Similar findings were reported by Meena et al. (2017) and Verma et al. (2016), who observed earlier flowering in okra with the application of plant growth regulators (Table 3).

3.7 Number of Days Taken to First Harvest

The number of days taken to first harvest was significantly reduced by different plant growth regulator treatments. Treatment T_9 (GA_3 @ 200 ppm + NAA @ 200 ppm) recorded the earliest first harvest (56.00 days), followed by T_8 (56.52 days), while the control treatment required the maximum number of days (60.33 days) for first harvest. Early harvesting under the combined application of GA_3 and NAA may be due to earlier flowering, improved fruit set and faster pod development. These findings are in agreement with the results of Meena et al. (2017) and Verma et al. (2016), who reported that plant growth regulators promoted earliness in okra cultivation (Table-3).

3.8 Yield Parameters

3.8.1 Pod Length and Pod Diameter(cm)

Pod length differed significantly among the treatments. The maximum pod length (15.11 cm) was recorded under T_9, while the minimum pod length (7.45 cm) was observed in the control treatment. Increased pod length under T_9 may be due to enhanced cell elongation and better translocation of photosynthates to developing pods. The highest pod diameter (1.94 cm) was recorded in T_9, whereas the lowest pod diameter (1.34 cm) was observed in the control treatment (Table 3). The increase in pod diameter may be attributed to improved cell enlargement and enhanced metabolic activity under the combined application of GA_3 and NAA. Similar results were reported by Abdullah et al. (2024) and Meena et al. (2017).

Table 3. Effect of GA_3 and NAA on growth and yield characters of okra

Treatments	Number of branchesplants^{-1}	No. of days taken to first flower and first harvest		Pod length (cm)	Pod diameter (cm)	Number of seed Pod^{-1}
		First flower	First harvest			
T_1-CONTROL	1.67	52.67	60.33	7.45	1.34	37.67
T_2-GA_3@100ppm	2.17	49.33	58.45	10.34	1.61	40.67
T_3-GA_3@200ppm	3.07	49.00	58.00	10.97	1.70	50.00
T_4-NAA@100ppm	1.77	51.00	59.00	8.36	1.50	41.00
T_5-NAA@200ppm	1.80	50.00	59.33	9.18	1.57	43.00
T_6-GA_3@100ppm+NAA@100ppm	2.73	48.33	57.45	12.07	1.77	45.33
T_7-GA_3@100ppm+NAA@200ppm	2.87	48.00	57.00	12.86	1.76	48.67
T_8-GA_3@200ppm+NAA@100ppm	3.50	47.33	56.52	13.55	1.85	51.67
T_9-GA_3@200ppm+NAA@200ppm	3.90	47.00	56.00	15.11	1.94	53.33
C.D.at5%	1.441	1.211	1.408	0.878	0.118	3.82
SE(m)$\pm$	0.476	0.401	0.466	0.29	0.039	1.263

3.8.2 Number of Seeds per Pod

The number of seeds per pod was significantly influenced by the treatments. Treatment T_9 recorded the highest number of seeds per pod (53.33), while the control treatment recorded the lowest number (37.67). Improved seed development under T_9 may be due to better fertilization, nutrient translocation and assimilate accumulation in developing fruits (Table 3). The higher number of seeds per pod may be due to better pollination, fertilization and seed development under the influence of growth regulators. Similar observations were reported by Meena et al. (2017) and Shree et al. (2022).

3.8.3 Number of Pods per Plant

The highest number of pods per plant (14.37) was recorded in T_9, whereas the lowest number (9.47) was observed in the control treatment. Increased pod production may be attributed to higher flower bud formation, improved fruit set and reduced flower drop. The increased number of pods per plant under T_9 may be associated with higher flower bud production and improved fruit set. Similar findings were reported by Abdullah et al. (2024) and Meena et al. (2017) (Table 4).

Table 4. Effect of GA3 and NAA on Yield characters of okra

Treatments	Number of pod plant^{-1}	Fresh weight of pod (g)	Pod yield plot^{-1}(kg)	total yield t/ha
T_1-CONTROL	9.47	11.15	2.18	5.44
T_2-GA_3@100ppm	11.94	13.40	2.62	6.54
T_3-GA_3@200ppm	12.19	14.49	3.11	7.78
T_4-NAA@100ppm	11.38	12.15	2.47	6.18
T_5-NAA@200ppm	11.13	15.34	2.33	5.83
T_6-GA_3@100ppm+NAA@100ppm	12.29	12.98	2.79	6.97
T_7-GA_3@100ppm+NAA@200ppm	13.42	15.83	3.12	7.80
T_8-GA_3@200ppm+NAA@100ppm	14.32	16.20	3.08	7.69
T_9-GA_3@200ppm+NAA@200ppm	14.37	17.38	3.51	8.78
C.D.at5%	0.19	1.24	0.217	0.548
SE(m)$\pm$	0.063	0.41	0.072	0.181

3.8.4 Fresh Weight of Pod

Fresh pod weight was significantly affected by plant growth regulator treatments. The maximum fresh pod weight (17.38 g) was observed under T_9, while the minimum fresh pod weight (11.15 g) was recorded in the control treatment. Increased pod weight may be due to enhanced accumulation of photosynthates and better pod development. The increase in fresh pod weight may be attributed to greater accumulation of photosynthates and improved cell enlargement (Table 4). Similar observations were reported by Abdullah et al. (2024) and Shree et al. (2022).

3.8.5 Pod Yield per Plot and per Hectare

Treatment T_9 recorded the highest pod yield per plot (3.51 kg), whereas the lowest yield (2.18 kg) was observed in the control treatment. Increased yield per plot may be attributed to superior growth, higher pod number and greater pod weight. The highest pod yield per hectare (8.78 t ha^{-1}) was recorded under T_9, while the lowest yield (5.44 t ha^{-1}) was obtained in the control treatment. The increase in yield may be due to enhanced vegetative growth, early flowering, improved fruit set and higher pod production resulting from the combined application of GA_3 and NAA (Table 4). The highest pod yield under T_9 may be due to superior growth, increased pod number and higher pod weight. Similar findings were reported by Abdullah et al. (2024), Meena et al. (2017) and Shree et al. (2022).

3.9 Quality Parameters

3.9.1 Ascorbic Acid(mg/100g), TSS (ºbrix), Moisture % inPod

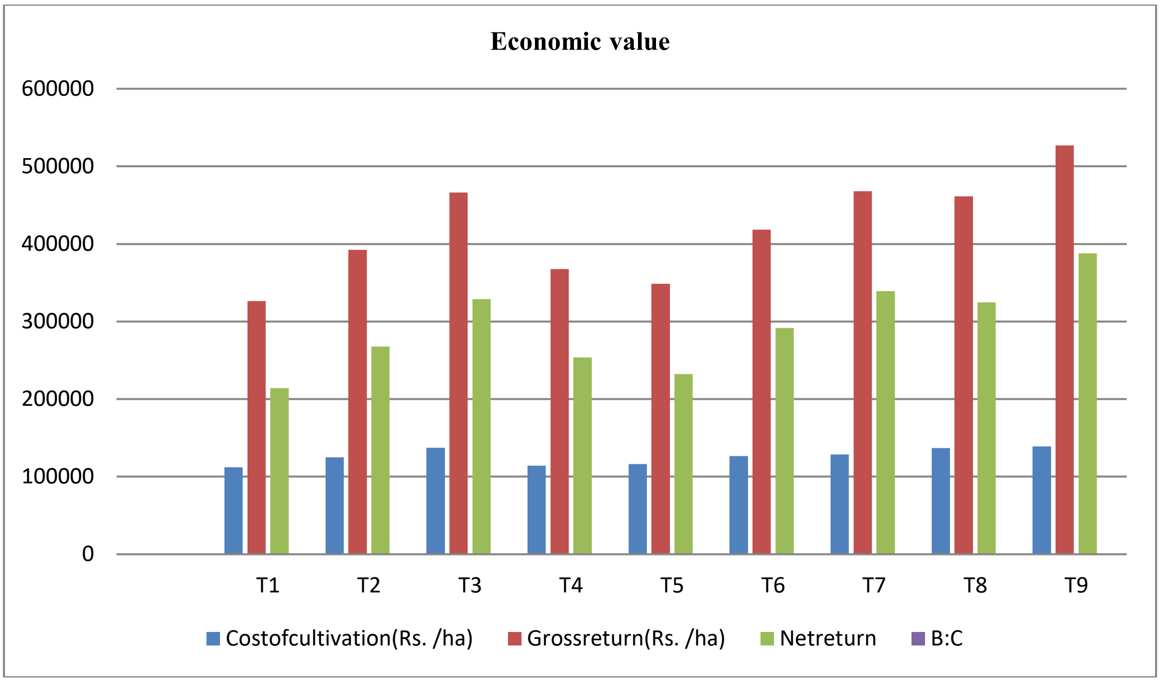
The quality parameters of okra pods were significantly influenced by the application of plant growth regulators. Among the various treatments, T_7 (GA_3@ 100 ppm + NAA@ 200 ppm) recorded the highest ascorbic acid content (16.70 mg 100 g^{-1}), total soluble solids (5.33 °Brix) and moisture content (90.07%), whereas the lowest values were observed in the control treatment, recording 13.34 mg 100 g^{-1} ascorbic acid, 3.10 °Brix TSS and 88.13% moisture content. The improvement in quality attributes under T_7 may be attributed to enhanced metabolic activity, increased synthesis and accumulation of carbohydrates, vitamins and other biochemical constituents in the pods. The combined application of GA_3 and NAA improved nutrient uptake and translocation, resulting in superior pod quality. Therefore, T_7 proved to be the most effective treatment for improving the quality characteristics of okra pods (Table 5). The improvement in quality parameters under T_7 may be due to enhanced metabolic activity and carbohydrate accumulation. Similar results were reported by Abdullah et al. (2024), Kokare et al. (2006) and Shree et al. (2022).

Table 5. Effect of GA3 and NAA on Quality characters of okra

Treatment	Ascorbic acid (mg/100g)	TSS (^{0}brix)	Moisture % in Pod
T_1-CONTROL	13.34	3.10	88.13
T_2-GA_3@100ppm	13.86	3.43	89.24
T_3-GA_3@200ppm	14.60	4.12	88.42
T_4-NAA@100ppm	15.38	5.30	89.36
T_5-NAA@200ppm	15.67	5.24	89.01
T_6-GA_3@100ppm+NAA@100ppm	15.68	3.60	89.35
T_7-GA_3@100ppm+NAA@200ppm	16.70	5.33	90.07
T_8-GA_3@200ppm+NAA@100ppm	16.08	4.16	89.30
T_9-GA_3@200ppm+NAA@200ppm	15.91	4.97	88.63
C.D.at5%	1.564	0.335	0.952
SE(m)$\pm$	0.517	0.111	0.315

3.10 Economics

The economic analysis revealed that different plant growth regulator treatments significantly influenced the profitability of okra cultivation. Among all the treatments, T_9 (GA_3 @ 200 ppm + NAA@ 200 ppm) recorded the highest yield (87.8 q/ha), gross return (526,800 Rs. / ha), net return (387,985 Rs. /ha) and benefit-cost ratio (2.79), followed by T_7 (GA_3@ 100 ppm + NAA@ 200 ppm), which recorded a net return of 339,285 Rs. /ha with a B ratio of 2.64. The lowest economic returns were obtained from the control treatment, which recorded a net return of 214,185 Rs. /ha and B ratio of 1.91. The higher profitability observed under T_9 may be attributed to its superior growth and yield performance, resulting in increased marketable pod yield and greater economic returns despite a comparatively higher cost of cultivation. Therefore, the combined application of GA@ 200 ppm and NAA @ 200 ppm proved to be the most economical treatment for okra cultivation (Graph 1, Table 6).



Graph 1. Effect of GA_3 and NAA combination to economic studies on okra

Table 6. Effect plant growth regulators on the Economics of ok

Treatments	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C
T1- Control	112215	326400	214185	1.91
T_2- GA_3 @ 100 ppm	124715	392400	267685	2.15
T_3- GA_3 @ 200 ppm	137215	466200	328985	2.40
T_4- NAA @ 100 ppm	114215	367800	253585	2.22
T_5- NAA @ 200 ppm	116215	348600	232385	2.00
T_6- GA_3 @ 100 ppm + NAA @ 100 ppm	126715	418200	291485	2.30
T_7- GA_3 @ 100 ppm + NAA @ 200 ppm	128715	468000	339285	2.64
T_8- GA_3 @ 200 ppm + NAA @ 100 ppm	136815	461400	324585	2.37
T_9- GA_3 @ 200 ppm + NAA @ 200 ppm	138815	526800	387985	2.79

4. Conclusion

Based on results, the present investigation showed that foliar application of GA_3 and NAA significantly influenced the vegetative growth, yield attributes, quality parameters and economics of the crop. Among the different treatments evaluated, the combined application of GA_3 @ 200 ppm and NAA @ 200 ppm (T_9) proved to be the most effective treatment for enhancing growth and yield performance. This treatment recorded maximum plant height, number of leaves, leaf dimensions, flower buds, branches, pod length, pod diameter, number of seeds per pod, fresh pod weight, pod yield per plant and pod yield per hectare, along with early flowering and harvesting. Quality parameters were also improved by plant growth regulator application, with GA_3 @ 100 ppm + NAA @ 200 ppm (T_7) producing superior ascorbic acid content, total soluble solids and moisture percentage in pods. Economic analysis further demonstrated that T_9 recorded the highest gross return, net return and benefit-cost ratio, indicating its economic viability and profitability.

As a result, it can be concluded that foliar application of GA_3 @ 200 ppm + NAA @ 200 ppm at 20 and 40 days after sowing is highly beneficial for achieving higher growth, yield and economic returns in okra. The treatment may be recommended for commercial cultivation of okra.

5. Limitation

This experiment was conducted during one Rabi season at a single location using one okra cultivar. Consequently, treatment responses may differ across cultivars, seasons, soils, weather conditions, and crop-management systems. The study did not include detailed soil nutrient measurements, physiological assessments, or multi-location validation. Quality and economic estimates were limited to the analytical procedures, input costs, and market assumptions applied in this trial. Further multi-season and multi-location studies are needed to confirm the consistency and practical applicability of the findings.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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