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Effect of plant growth regulators on growth, yield and quality of Okra [*Abelmoschus esculentus* (L.) Moench]

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Abstract

The present investigation was carried out in the Agricultural Research Farm, at Department of Horticulture, School of Agriculture, S.G.V.U., Jaipur (Rajasthan) during 2024-25 *Kharif* Season. The experiment was laid down in Randomized Block Design which consisted nine treatment combinations viz; T₁-Control (Water Spray), T₂- GA3 (50 PPM), T₃- GA3 (100 PPM), T₄- GA3 (150 PPM), T₅-NAA (20PPM), T₆-NAA (40PPM), T₇-NAA (60PPM), T₈-CCC (200PPM), T₉-CCC (400PPM), T₁₀-CCC (600PPM) and treatments were replicated three times. The results revealed that plant growth regulators significantly influenced growth, yield, and quality parameters of okra. The maximum plant height at 30, 60, and 90 DAS (30.45, 61.12 and 84.47 cm, respectively) were recorded under GA3 at 150 ppm (T₄) and maximum number of branches per plant (3.23, 4.12 and 4.56 at 30, 60 and 90 DAS) were recorded under Cycocel at (400 PPM) (T₉). The minimum Days to 50% flowering (39.74 days) and maximum number of fruits per plant (23.10), fruit length (12.67 cm), fruit diameter (2.04 cm), fruit weight (15.27 g), and yield per hectare (262.87 q/ha) were observed with NAA at 60 ppm (T₇). Quality parameters such as ascorbic acid content (23.76 mg/100 g) and Acidity (%) (0.25%) were also highest in T₇. Economically, NAA at 60 ppm recorded the highest net return (₹2,58,582.3/ha) and benefit–cost ratio (3.11), followed by NAA at 40 ppm. Therefore, it can be concluded that foliar application of NAA at 60 ppm proved to be the most effective treatment for achieving maximum growth, yield, quality, and profitability in okra cultivation under Jaipur agro-climatic conditions.

Keywords: GA₃, Okra, plant growth regulators, NAA, yield

Introduction

Okra, also known as *Abelmoschus esculentus* (L.) Moench, is an important vegetable crop that grows well in tropical and subtropical regions. It belongs to the Malvaceae family and is believed to have originated in tropical Africa (Islam, 2019) ^[6]. It is a very important vegetable for people of all age groups. It is rich in iodine and other nutrients, and it also has good taste, medicinal value and industrial uses. Okra is mainly grown for its fiber and edible pods (fruits), but all parts of the plant—like leaves, flowers, stem, seeds and pods—can be used in different ways. This makes okra a useful and valuable crop with many benefits (Wankhade *et al.*, 2013) ^[26]. The juice of sugarcane, used to make jaggery, is often cleaned or clarified using the root and stem of the okra plant. Okra is widely grown throughout the year in India for its soft, non-fibrous and tasty edible fruits. Farmers like to grow okra because it is easy to cultivate and can grow well in different climates. It is rich in nutrients and also useful in medicine and industry (Das *et al.*, 2024) ^[4]. As a valuable source of carbohydrates, proteins, vitamins, minerals, basic salts and crude fibers, vegetables play a significant part in a balanced diet. In India total area under okra crop is 0.56 million hectares with the production of 7.6 million tonnes and productivity of 13.57 tonnes per hectare. In Rajasthan, okra is cultivated on about 2.81 thousand hectares, producing around 13.58 thousand metric tonnes of green pods. The average productivity in the state is approximately 4.83 tonnes per hectare (NHB, 2024-25). Major okra growing districts in Rajasthan include Jaipur, Sirohi, Bundi, Alwar, Chittorgarh and Hanumangarh. Among these, Jaipur district ranks highest in both area and productivity. Plant Growth Regulators (PGRs) are organic substances, either natural or synthetic, which influence

various physiological processes in plants at very low concentrations. They are not nutrients but signal molecules that regulate plant growth and development such as seed germination, cell division, elongation, flowering, fruit development and senescence (Taiz *et al.*, 2015) [25]. Application of PGRs has emerged as a valuable tool in modern horticulture to improve vegetative and reproductive performance of vegetable crops including okra.

Gibberellic acid (GA₃) is a natural plant hormone belonging to the class of gibberellins, which promote cell elongation, stem elongation, leaf expansion and flowering. GA₃ is known to break seed dormancy and enhance seed germination, increase internodal length and accelerate vegetative growth and reproductive efficiency in several crops (Chettri *et al.*, 2025) [3]. NAA is a synthetic auxin widely used in horticultural crops. It plays a crucial role in cell elongation, apical dominance, root initiation and fruit set. In okra, foliar application of NAA at concentrations ranging from 10 to 40 ppm has been found to improve fruit setting percentage, reduce fruit drop and increase yield and fruit quality (Mishra *et al.*, 2019) [11]. CCC is a growth retardant that inhibits gibberellin biosynthesis, thereby restricting internodal elongation and resulting in more compact plants. It promotes reproductive growth by diverting assimilates from vegetative to reproductive organs, thus improving flowering, fruiting and yield (Bhatt *et al.*, 2016) [2]. Keeping in view the above facts in mind an investigation was conducted to study effect of plant growth regulators on growth, yield and quality of okra [*Abelmoschus esculentus* (L.) Moench].

Materials and Methods

The experiment was conducted at Agricultural Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur and laid out in Randomized Block Design (RBD) with 10 treatments viz. Control (Water Spray) (T₁), GA₃ (50PPM) (T₂), GA₃ (100PPM) (T₃), GA₃ (150PPM) (T₄), NAA (20PPM) (T₅), NAA (40PPM) (T₆), NAA (60PPM) (T₇), Cycocel (200PPM) (T₈), Cycocel (400PPM) (T₉) and Cycocel (600PPM) (T₁₀) replicated thrice. Varsh Uphar variety of okra was selected for the experiment. Seeds were sown at 45cm (row to row) x 30cm (plant to plant) spacing by dibbling method in plots having dimension of 1.5m x 2.25m = 3.35 m². Farm Yard Manure @ 20 tonnes per hectare were applied during the final ploughing and well mixed in the soil. Fertilizers were applied @ 100:50:50 NPK kg/ha, in the form of the urea, DAP and MOP, respectively. At the time of sowing of seed, half of the dose of nitrogen in the form of urea and full dose of phosphorous in the form of DAP and potassium in the form of MOP were applied as basal dose. Remaining half dose of the nitrogen was applied as top dressing after 30 DAS during earthing up. Observed data were analyzed in OPSTAT.

Results and Discussion

Results have shown significant differences among the treatments. The data on plant height at different growth stages revealed that GA₃ treatments significantly enhanced vegetative growth in okra. At 30, 60, and 90 DAS, the maximum plant height (30.45 cm, 61.12 cm, and 84.47 cm, respectively) (Table 1) was consistently recorded under treatment T₄ (GA₃ 150 PPM), followed by T₃ (GA₃ 100 PPM) with slightly lower but comparable values. In contrast, the minimum plant height at all stages (24.62 cm, 54.62 cm, and 78.63 cm, respectively) (Table 1) was observed in the control treatment (T₁). These results clearly indicate the positive and consistent role of GA₃, particularly at 150 PPM, in promoting plant height throughout the crop growth period. Among different plant growth

regulators, GA₃ recorded maximum plant height followed by NAA, where as minimum plant height was observed with control. These results are in conformity with the finding of Dhage *et al.*, (2011) [5], Ravat and Makani (2015) [21], Surendra *et al.*, (2006) [24], Pal and Hussain (2001) [17] and Patil *et al.*, (2024) [18] in okra. The number of branches per plant was significantly influenced by the application of Cycocel. At all stages of observation 30, 60 and 90 DAS the highest number of branches was consistently recorded under T₉ (Cycocel 400 PPM) with 3.23, 4.12 and 4.56 branches (Table 1) respectively, followed by T₁₀ (Cycocel 600 PPM) which showed 3.08, 3.82 and 4.33 branches per plant. In contrast, the lowest number of branches at each stage (1.34, 1.95 and 2.25) was observed in the control treatment (T₁). This clearly indicates that Cycocel, particularly at 400 PPM, effectively promotes branching in okra. Among the different plant growth regulators cycocel recorded maximum number of branches per plant followed by GA₃ and NAA whereas minimum number of branch was observed by control. The increase in number of branches with the application of Cycocel might be due to its effectiveness in suppressing the apical dominance, thereby promoting growth and axillary buds into new shoots (Narse Gowda and Mundappa Gowda, 1980) [14]. These results are also in accordance with the finding of Prasad and Srihari (2008) [20], Sajjan (2003) [22] and Mahorkar (2007) [9], Patil *et al.*, (2024) [18] in okra. The earliest flowering (39.74 days) was recorded under treatment T₇ (NAA at 60 ppm), followed by treatment T₆ (NAA at 40 ppm) (40.37 days). In contrast, the maximum number of days to reach 50% flowering (48.97 days) was observed in the control treatment (T₁). The early flowering observed under NAA treatments may be attributed to the role of Auxins in enhancing cell division, cell elongation, and the mobilization of nutrients and photosynthates towards the actively growing regions, thereby accelerating the transition from vegetative to reproductive phase. Moreover, NAA improves physiological efficiency and hormonal balance within the plant, which promotes early floral initiation. On the other hand, delayed flowering in the control treatment might be due to the absence of exogenous growth regulators, resulting in slower metabolic and developmental processes. Similar findings have also been reported by Ravat and Makani (2015) [21], Mehraj *et al.*, (2015) [10] and Patil *et al.*, (2024) [18] in okra. The highest number of fruits per plant (23.10) was obtained with treatment T₇-NAA at 60 PPM, followed by treatment T₆ -NAA at 40 PPM (22.47) (Table 1). In contrast, the lowest number of fruits per plant (17.96) was recorded under the control treatment (T₁) (Table 1). The data presented in above table clearly indicated that the maximum fruits length (12.67 cm) was recorded with the application of T₇- NAA 60 PPM followed by T₆- NAA 40 PPM (12.11 cm). The minimum (8.56 cm) fruit length was found under the treatment T₁ (control). The increase in the of fruit length may be a result of cell enlargement and cell elongation, which is caused by the supply of growth regulators within the plants. These results were supported by Pawar *et al.*, (1977) [19] and Kinjalba *et al.*, (2024) [7] in okra. The data presented in above table clearly indicated that the maximum fruits diameter (2.04 cm) was recorded with the application of T₇- NAA 60 PPM followed by T₆- NAA 40 PPM (1.98 cm). The minimum (1.70 cm) fruits diameter was found under the treatment T₁ (control). These results are similar to findings of Pawar *et al.*, (1977) [19] and Kinjalba *et al.*, (2024) [7] in okra. The data presented in above table clearly indicated that the maximum fruits weight (15.27 g) was recorded with the application of T₇- NAA 60 PPM followed by T₆- NAA 40 PPM

(14.33 g). The minimum (11.25 g) fruit weight was found under the treatment T₁ (control). Similar result was observed in Prasad *et al.*, (2013) ^[20] and Kinjalba *et al.*, (2024) ^[7]. The maximum fruit yield per plant (0.355 kg) was recorded with the application of application of T₇- NAA 60 PPM followed by T₆- NAA 40 PPM (0.328 cm). The minimum (0.203 kg) fruit yield per plant was found under the treatment T₁ (control). The maximum fruit yield per plot (8.89 kg) (Table 2) was recorded with the application of application of T₇- NAA 60 PPM followed by T₆- NAA 40 PPM (8.20 cm). The minimum (5.07 kg) fruit yield per plot was found under the treatment T₁ (control). The data presented in above table clearly indicated that the maximum fruit yield per hectare (262.87 q/ha) was recorded with the application of application of T₇- NAA 60 PPM followed by T₆- NAA 40 PPM (242.60 q/ha). The minimum (149.94 q/ha) fruit yield per hectare was found under the treatment T₁ (control) (Table 2). NAA might be responsible for increase in photosynthetic activities within the plant which might be resulted in more production of carbohydrates and related products responsible for increase in number of fruit, fruit length, fruit diameter and fruit weight of okra, ultimately responsible for increased yield of okra. These results were in tune with the results reported by Kokare *et al.*, (2006) ^[8], Naruka and Paliwal (2000) ^[15], Ambreen *et al.*, (2009) ^[1] and Mujeera and Arunachalam (2006) ^[13] in okra. Sanodiya *et al.*, (2017) ^[23], Kinjalba *et al.*, (2024) ^[7] in okra, Prasad *et al.*, (2013) ^[20] in tomato. The data reveals that the application of different treatments resulted in a substantial increase in ascorbic acid content. The highest ascorbic acid content (23.76 mg/100g) was recorded under treatment T₇-NAA at 60 PPM, followed by T₈ - NAA at 40 PPM (23.21 mg/100g) (Table 2). In contrast, the lowest ascorbic acid content (19.24 mg/100g) was observed under the control treatment (T₁). Similar result was observed in Kokare *et al.*, (2006) ^[8] in okra. The highest acidity (0.25%) was recorded under treatment T₇ (NAA 60 ppm), followed by T₆ (NAA 40 ppm) with 0.24%, while the lowest acidity (0.12%) was observed in the control (T₁). The increased acidity may be

due to the effect of Auxins (NAA), which enhance metabolic activities and promote the synthesis of organic acids in plant tissues. These results are in agreement with the findings of Moniruzzaman *et al.* (2014) ^[12] in brinjal and Kokare *et al.* (2006) ^[8] in okra. Gross return quantifies the total revenue generated from okra sales, providing an overall measure of financial income. Net return, on the other hand, deducts production costs from the gross return, reflecting the actual profit obtained from okra production. It helps growers assess the profitability and economic viability of their cultivation practices. B:C ratio compares the benefits (gross returns) to the costs incurred in okra production, indicating the profitability and efficiency of the investment. These measurements assist growers in evaluating the financial performance of their okra crops, making informed decisions regarding resource allocation, cost management, and assessing the economic feasibility of okra cultivation. The data in Table 4.8 clearly shows that the application of different Growth regulators treatments significantly affects the net return of okra fruit production in Jaipur, Rajasthan. The maximum net return (₹.258582.3 /ha) from okra production was recorded in T₇-NAA (60 PPM) treatment followed by (₹.236227.9 /ha) in T₆- NAA 40 PPM. Whereas, the minimum net return (₹. 236227.9 /ha) was recorded in Control (T₀) (Table 3). Hence, the application NAA (60 PPM) treatment was found the best treatment for maximum net return per hectare. The the highest B: C ratio (3.11) was recorded under application of T₇-NAA (60 PPM) treatment followed by (2.98) in T₆- NAA 40 PPM. Whereas, the lowest B: C ratio (1.50) was recorded under Control treatment. Hence, the application NAA (60 PPM) was found the best treatment to get highest benefit: cost in okra production. Foliar application of NAA enhances physiological efficiency, particularly photosynthetic activity, resulting in better plant growth and higher yield in various agronomic crops without a substantial increase in production costs. Similar findings were reported by Sanodiya *et al.*, (2017) ^[23] in okra, Prasad *et al.*, (2013) ^[20] in tomato, Moniruzzaman *et al.*, (2014) ^[12] in brinjal.

Table 1: Effect of plant growth regulator's on plant height (cm) at 30, 60, and 90 DAS, Number of branches per plant at 30, 60 and 90 Das, days to 50% flowering, number of fruits per plant and fruit length (cm) of okra

S. No.	Treatment Detail	Plant Height (cm)			Number of branches per plant			Days to 50% flowering	Number of fruits per plant	Fruit length (cm)
		30 DAS	60 DAS	90 DAS	30DAS	60DAS	90DAS			
1.	T ₁ -Control (Water Spray)	24.62	54.62	78.63	1.34	1.95	2.25	48.97	17.96	8.56
2.	T ₂ -GA3 (50PPM)	29.35	59.45	82.53	2.33	2.97	3.35	44.65	20.05	10.37
3.	T ₃ -GA3(100PPM)	29.75	60.36	83.33	2.43	3.2	3.47	42.45	21.23	11.26
4.	T ₄ -GA3 (150PPM)	30.45	61.12	84.47	2.61	3.41	3.76	43.54	20.76	10.75
5.	T ₅ -NAA (20PPM)	28.33	58.1	81.43	1.86	2.38	2.53	41.92	21.81	11.78
6.	T ₆ -NAA (40PPM)	26.87	57.43	81.23	2.18	2.87	3.12	40.37	22.47	12.11
7.	T ₇ -NAA (60PPM)	28.70	58.65	82.15	2.05	2.63	2.86	39.74	23.10	12.67
8.	T ₈ -Cycocel (200PPM)	26.37	56.87	80.67	2.87	3.72	4.18	45.57	19.18	10.25
9.	T ₉ -Cycocel (400PPM)	25.32	55.37	79.25	3.23	4.12	4.56	46.87	18.85	9.48
10.	T ₁₀ -Cycocel (600PPM)	25.68	56.54	80.00	3.08	3.82	4.33	47.75	18.46	9.18
	SE (m)	1.47	1.73	1.82	0.104	0.146	0.172	1.98	1.034	0.506
	C.D. at (5%)	4.33	4.51	3.25	0.311	0.437	0.516	5.92	3.09	1.51
	C.V.	9.24	8.39	8.10	11.16	8.12	8.67	8.18	8.78	8.22

Table 2: Effect of plant growth regulator's on number of fruits per plant and fruit length (cm) of okra

S. No.	Treatment Detail	Fruit diameter (cm)	Fruit weight (g)	Fruit yield per plant (kg)	Fruit yield per plot (kg)	Fruit yield per hectare (q)	Ascorbic acid (mg/100 g)	Titrateable Acidity (%)
1.	T ₁ -Control (Water Spray)	1.70	11.25	0.203	5.07	149.94	19.24	0.12
2.	T ₂ -GA ₃ (50PPM)	1.86	12.68	0.257	6.42	190.02	21.13	0.20
3.	T ₃ -GA ₃ (100PPM)	1.92	13.18	0.287	7.18	212.51	22.08	0.23
4.	T ₄ -GA ₃ (150PPM)	1.90	12.83	0.272	6.80	201.15	21.68	0.21
5.	T ₅ -NAA (20PPM)	1.96	13.68	0.299	7.48	221.17	22.65	0.23
6.	T ₆ -NAA (40PPM)	1.98	14.33	0.328	8.20	242.60	23.21	0.24
7.	T ₇ -NAA (60PPM)	2.04	15.27	0.355	8.89	262.87	23.76	0.25
8.	T ₈ -Cycocel (200PPM)	1.83	12.45	0.241	6.04	178.59	20.65	0.15
9.	T ₉ -Cycocel (400PPM)	1.79	12.32	0.235	5.87	173.74	20.37	0.14
10.	T ₁₀ -Cycocel (600PPM)	1.75	11.85	0.224	5.61	165.87	20.16	0.13
	SE (m)	0.365	0.452	0.02	0.52	15.45	0.62	0.004
	C.D. at (5%)	0.21	1.24	0.063	1.56	46.27	1.87	0.011
	C.V.	8.40	8.76	10.96	10.99	10.99	2.51	3.34

Table 3: Effect of plant growth regulators on economics of treatments

Treatment	Fixed Cost (Rs/ha)	Operational Cost (Rs/ha)	Total Cost	Gross Return (Rs/ha)	Net Return (Rs/ha)	B:C Ratio
T ₁	70500	7550	78050	194919.9	116869.9	1.50
T ₂	70500	7360	77860	247019.9	169159.9	2.17
T ₃	70500	11500	82000	276261.0	194261.0	2.37
T ₄	70500	18562	89062	261491.2	172429.2	1.94
T ₅	70500	7560	78060	287526.4	209466.4	2.68
T ₆	70500	8652	79152	315379.9	236227.9	2.98
T ₇	70500	12652	83152	341734.3	258582.3	3.11
T ₈	70500	4852	75352	232170.8	156818.8	2.08
T ₉	70500	7655	78155	225864.1	147709.1	1.89
T ₁₀	70500	10500	81000	215626.0	134626.0	1.66

Conclusion

In the present investigation, the application of plant growth regulators significantly enhanced the growth, yield and quality of okra [*Abelmoschus esculentus* (L.) Moench]. The study clearly showed that plant growth regulators significantly improved the growth, yield and quality of okra. GA₃ at 150 PPM produced the tallest plants. The best overall performance was recorded with NAA at 60 PPM, which resulted in early flowering, maximum fruit yield, better quality (higher ascorbic acid and acidity), and the highest net returns and B:C ratio. Therefore, NAA at 60 PPM is recommended as the most effective and economical treatment for okra production under the present conditions.

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