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Impact of plant growth regulators on the growth and yield of summer Okra (*Abelmoschus esculentus* L.)

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Abstract
A field experiment entitled "Impact of plant growth regulators on the growth and yield of summer Okra (*Abelmoschus esculentus* L.)" was conducted at the Research Cum Instructional Farm, Mohgaon, Saja, Bemetara (C.G.) during the Zaid season of 2024-25. The experiment was laid out in a Randomized Block Design with three replications and included ten plant growth regulator treatments: T_0 – Control, T_1 – GA_3 25 ppm, T_2 – GA_3 50 ppm, T_3 – GA_3 75 ppm, T_4 – NAA 25 ppm, T_5 – NAA 50 ppm, T_6 – NAA 75 ppm, T_7 – Triacontanol 1000 ppm, T_8 – Triacontanol 1500 ppm, and T_9 – Triacontanol 2000 ppm. Observations were recorded for germination (days to first germination, germination percentage), growth (plant height, number of branches, internodal length, days to first flowering), and yield parameters (days to first fruit setting and harvest, fruit length and diameter, number of fruits per plant, fruit weight, and yield per plant, plot, and hectare).Results indicated that plant growth regulators significantly influenced germination, growth, flowering, and yield of summer okra. GA_3 at 75 ppm (T_3) was the most effective, producing earliest germination (6.00 days), highest germination percentage (92.38%), maximum plant height, branches, and internodal length, earliest flowering (35.67 days), longest and thickest fruits, highest number of fruits per plant (15.20), maximum fruit weight (15.49 g), and the highest fruit yield (158.18 q/ha), nearly double that of the control (71.05 q/ha). GA_3 at 25 ppm (T_1) and 50 ppm (T_2) also improved growth and yield compared to control but were slightly inferior to T_3.

Keywords: Okra, GA_3, Plant growth regulators, Yield, Summer season

Introduction

Okra (*Abelmoschus esculentus* L.), a member of the Malvaceae family, is a popular vegetable widely cultivated in tropical and subtropical regions for its tender pods. It serves as a valuable source of key nutrients, including vitamins A, C, and K, along with minerals such as calcium, magnesium, and potassium. In addition, it contains dietary fiber and bioactive compounds like flavonoids and polyphenols that contribute to several health benefits (Dutta *et al*., 2016) [7]. The tender green pods are commonly consumed as a vegetable, while they can also be processed through canning or dehydration. The fruit contains around 88 IU of vitamins and nearly 300 mg of minerals, particularly iodine; per 100 g of edible portion (Baraskar *et al.*, 2018) [3]. Okra is recommended for individuals suffering from kidney stones and is also reported to enhance semen production. Economically, okra holds immense potential as an export crop, contributing nearly 60% of fresh vegetable exports, excluding potato, onion, and garlic. Major importing regions include the Middle East, Western Europe, and the USA (Gupta *et al.*, 2019) [9]. In India, okra is cultivated over an area of about 519 thousand hectares with an annual production of 6,371 thousand metric tonnes (NHB, 2024). In Chhattisgarh, okra cultivation covers 32.774 thousand hectares with a production of 364.226 thousand metric tonnes (Directorate of Horticulture, 2024) [10]. Within the state, Bemetara district accounts for 21.959 thousand quintals of production from 1.548 thousand hectares of cultivated area (Anonymous, 2024) [1, 2]. PGRs play a crucial role in metabolite synthesis, nutrient translocation, and assimilation, which collectively contribute to higher productivity and better quality produce, When used appropriately. (Subramanyam and Bhatia, 1993) [14]. Plant growth regulators (PGRs) such as gibberellic acid (GA_3), naphthalene acetic acid (NAA), and triacontanol have been reported to exert notable positive effects on the growth, yield, and quality of okra. GA_3 stimulates internode elongation, increases plant height, and enhance fruit setting, whereas NAA promotes root development, minimizes flower and fruit drop, and supports effective pod formation (Kumar *et al*., 2018). Similarly, triacontanol, a naturally occurring fatty alcohol, has been shown to improve photosynthetic activity, chlorophyll concentration, and overall biomass accumulation in okra. Its use not only boosts flowering, fruit development, and yield but also enhances fruit quality (Gaikwad *et al*., 2021) [8].

Materials and Methods
A field investigation was carried out at Research Cum Instructional Farm, College of Horticulture and Research Station, Saja, Bemetara (C.G.) during Zaid season of 2024-25, to study the "Impact of plant growth regulators on the growth and yield of summer Okra (*Abelmoschus esculentus* L.)". The details of the materials used and methods adopted during the course of investigation are described in this chapter. The experiment was laid out in a Randomized Block Design (RBD) with three replications. A total of 10 treatments and 3 replication plot size 2.7 m × 1.8 m Spacing 45 cm × 30 cm Net plot 145.80 m^2 Gross Plot 188.37 m^2 Okra cv. Kashi Kranti seeds were treated with carbendazim 50 WP @ 2 g kg^{-1} seed to avoid against verticillium wilt incidence. T_0 – Control, T_1 – GA_3 25 ppm, T_2 – GA_3 50 ppm, T_3 – GA_3 75 ppm, T_4 – NAA 25 ppm, T_5 – NAA 50 ppm, T_6 – NAA 75 ppm, T_7 – Triacontanol 1000 ppm, T_8 – Triacontanol 1500 ppm, and T_9 – Triacontanol 2000 ppm.

Results and Discussion
Plant height
According to Table 1, T_3 (GA_3 75 ppm) produced the tallest plants (52.57 cm at 60 DAS), which was statistically at par with T_2 (51.56 cm) and T_1 (49.95 cm), while the minimum was recorded in T_0 (30.87 cm). GA_3 application enhanced cell elongation and internodal growth, resulting in greater plant height.

Number of branches per plant
Data in Table 2 revealed that the maximum branches were recorded in T_3 (1.93 at 60 DAS), followed by T_2 (1.90) and T_1 (1.88). The control (1.43) recorded the minimum. NAA treatments (1.69–1.75) gave moderate branching, while triacontanol (1.54–1.60) was less effective. GA_3 significantly promoted branching, which supports canopy development and photosynthesis.

Internodal length and flowering
As presented in Table 3, the longest internodes were observed in T_3 (6.38 cm), followed by T_2 (6.27 cm) and T_1 (6.10 cm), while the shortest internode length was in T_0 (4.12 cm). T_3 also promoted the earliest flowering (32.67 days to first flowering and 35.94 days to 50% flowering), while delayed flowering was observed in control (39.95 and 43.95 days). This shows that GA_3 accelerated vegetative-to-reproductive transition.

Number of fruits per plant and fruit weight
As shown in Table 4, T_3 recorded the maximum number of fruits (15.20) and fruit weight (15.49 g), followed by T_2 (14.90 fruits and 15.19 g) and T_1 (14.44 fruits and 14.72 g). The lowest values were recorded in T_0 (8.92 fruits and 9.10 g). NAA treatments showed moderate results, while triacontanol remained less effective.

Fruit yield
Data in Table 5 showed that the maximum yield was obtained in T_3 (235.37 g/plant, 7.47 kg/plot, and 158.18 q/ha), followed by T_2 (152.55 q/ha) and T_1 (147.25 q/ha). NAA treatments produced moderate yields (120.37–129.83 q/ha), while triacontanol recorded lower yields (92.30–101.25 q/ha). The minimum yield was in control (71.05 q/ha). GA_3 at 75 ppm nearly doubled the yield compared to control, due to its positive effect on growth, flowering, and fruit attributes.

Table 1: Effect of plant growth regulators on plant height of summer Okra (*Abelmoschus esculentus* L.)

Treatment details	Plant height (cm)		
	30 DAS	45 DAS	60 DAS
T_0 - Control	8.79	23.22	30.87
T_1 - GA_3 25 ppm	14.23	37.57	49.95
T_2 - GA_3 50 ppm	14.69	38.78	51.56
T_3 - GA_3 75 ppm	14.98	39.54	52.57
T_4 - NAA 25 ppm	12.45	32.87	43.70
T_5 - NAA 50 ppm	12.76	33.68	44.78
T_6 - NAA 75 ppm	12.93	34.13	45.38
T_7 - Triacontanol 1000 ppm	10.54	27.83	37.00
T_8 - Triacontanol 1500 ppm	10.94	28.87	38.39
T_9 - Triacontanol 2000 ppm	11.21	29.60	39.36
S.Em (±)	0.33	1.01	1.11
CD (5%)	0.99	3.02	3.28

Table 2: Effect of plant growth regulators on number of branches of summer Okra (*Abelmoschus esculentus* L.)

Treatment details	Number of branches ($plant^{-1}$)		
	30 DAS	45 DAS	60 DAS
T_0 - Control	1.02	1.33	1.43
T_1 - GA_3 25 ppm	1.34	1.74	1.88
T_2 - GA_3 50 ppm	1.36	1.77	1.90
T_3 - GA_3 75 ppm	1.38	1.79	1.93
T_4 - NAA 25 ppm	1.21	1.57	1.69
T_5 - NAA 50 ppm	1.23	1.60	1.72
T_6 - NAA 75 ppm	1.25	1.63	1.75
T_7 - Triacontanol 1000 ppm	1.10	1.43	1.54
T_8 - Triacontanol 1500 ppm	1.12	1.46	1.57
T_9 - Triacontanol 2000 ppm	1.14	1.48	1.60
S.Em (±)	0.02	0.03	0.04
CD (5%)	0.06	0.10	0.12

Table 3: Effect of plant growth regulators on internodal length, days to first flowering and 50% flowering of summer Okra (*Abelmoschus esculentus* L.)

Treatment details	Internodal length (cm)	Days to first flowering	Days to 50% flowering
T_0 - Control	4.68	39.95	43.95
T_1 - GA_3 25 ppm	6.06	33.56	36.92
T_2 - GA_3 50 ppm	6.25	33.15	36.47
T_3 - GA_3 75 ppm	6.38	32.67	35.94
T_4 - NAA 25 ppm	5.55	36.08	39.69
T_5 - NAA 50 ppm	5.67	35.73	39.30
T_6 - NAA 75 ppm	5.72	35.16	38.68
T_7 - Triacontanol 1000 ppm	5.08	38.27	42.10
T_8 - Triacontanol 1500 ppm	5.16	38.03	41.83
T_9 - Triacontanol 2000 ppm	5.21	37.65	41.42
S.Em (±)	0.09	0.49	0.56
CD (5%)	0.28	1.45	1.68

Table 4: Effect of plant growth regulators on number of fruit and fruit weight of summer Okra (*Abelmoschus esculentus* L.)

Treatment details	Number of fruits per plant	Fruit weight (g)
T_0 - Control	8.92	9.10
T_1 - GA_3 25 ppm	14.44	14.72
T_2 - GA_3 50 ppm	14.90	15.19
T_3 - GA_3 75 ppm	15.20	15.49
T_4 - NAA 25 ppm	12.63	12.88
T_5 - NAA 50 ppm	12.95	13.20
T_6 - NAA 75 ppm	13.12	13.37
T_7 - Triacontanol 1000 ppm	10.70	10.90
T_8 - Triacontanol 1500 ppm	11.10	11.31
T_9 - Triacontanol 2000 ppm	11.38	11.60
S.Em (±)	0.42	0.44
CD (5%)	1.27	1.30

Table 5: Effect of plant growth regulators on fruit yield of summer Okra (*Abelmoschus esculentus* L.)

Treatment details	Fruits yield per plant (g)	Fruits yield per plot (kg)	Fruits yield hectare (q/ha)
T_0 - Control	81.15	3.04	71.05
T_1 - GA_3 25 ppm	212.50	7.65	147.25
T_2 - GA_3 50 ppm	226.41	7.15	152.55
T_3 - GA_3 75 ppm	235.37	7.47	158.18
T_4 - NAA 25 ppm	162.66	5.96	120.37
T_5 - NAA 50 ppm	170.84	6.15	126.42
T_6 - NAA 75 ppm	175.44	6.32	129.83
T_7 - Triacontanol 1000 ppm	116.63	4.20	92.30
T_8 - Triacontanol 1500 ppm	125.52	4.52	96.88
T_9 - Triacontanol 2000 ppm	131.96	4.75	101.25
S.Em (±)	11.19	0.28	5.15
CD (5%)	33.26	0.82	15.31

Conclusion

The present investigation clearly demonstrated that plant growth regulators exerted a significant influence on seed germination, growth, flowering, yield attributes, and yield of summer okra. Among the different treatments, GA3 at 75 ppm (T_3) consistently proved to be the most effective, recording the earliest germination (6.00 days), highest germination percentage (92.38%), maximum plant height, number of branches and internodal length. It also promoted earliest flowering (35.67 days) and earliest fruit setting and harvest, along with producing longer and thicker fruits. Further, GA3 at 75 ppm (T_3) registered the highest number of fruits per plant (15.20), maximum fruit weight (15.49 g) and ultimately resulted in the highest fruit yield (158.18 q/ha), which was nearly double that of the control (71.05 q/ha). Treatments GA3 at 25 ppm (T_1) and GA3 at 50 ppm (T_2) also performed significantly better than the control but were slightly inferior to GA3 at 75 ppm (T_3).

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