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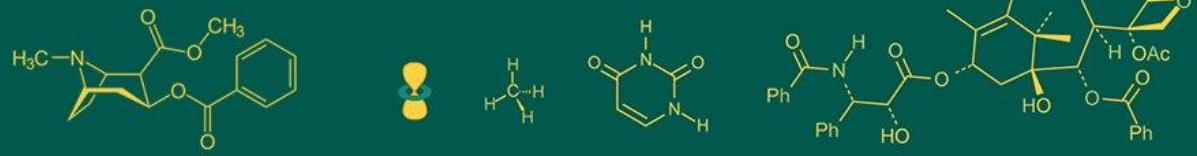

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Asmita T Patil
M.Sc. Student, Department of Agricultural, Botany, College of Agriculture Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

SG Mahadik
Vegetable Breeder, Vegetable Improvement Scheme, Central Experimental Station, Wakawali, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

AV Mane
Deputy Director of Research (Seed), Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

PB Vanave
Assistant Breeder, Khar Land Research Station, Panvel, Raigad, Maharashtra, India

VG Chavan
Assistant Professor, Department of Agronomy, College of Agriculture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

ST Burhade
M.Sc. Student, Department of Agricultural Botany, College of Agriculture Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

SS Misal
M.Sc. Student, Department of Agricultural Botany, College of Agriculture Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

Shraddha V Nevase
M.Sc. Student, Department of Soil Science and Agricultural Chemistry, College of Agriculture Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

Corresponding Author:
Asmita T Patil
M.Sc. Student, Department of Agricultural, Botany, College of Agriculture Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

Effect of plant growth regulators on yield and yield parameters of okra (*Abelmoschus esculentus* (L.) Moench) in Konkan condition

Asmita T Patil, SG Mahadik, AV Mane, PB Vanave, VG Chavan, ST Burhade, SS Misal and Shraddha V Nevase

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Abstract
A field experiment was conducted during the summer season of 2023-24 at the Central Experiment Station, Wakawali, Tal- Dapoli, Dist- Ratnagiri evaluated the effect of plant growth regulators on okra yield and yield parameters under Konkan conditions. Thirteen treatments, including T_1- NAA 50 ppm, T_2- NAA 100 ppm, T_3- NAA 150 ppm, T_4- NAA 200 ppm, T_5- GA_3 50 ppm T_6- GA_3 100 ppm, T_7- GA_3 150 ppm, T_8 GA_3 200 ppm, T_9- Seaweed extract 3 ml, T_{10}- Seaweed Extract 4 ml, T_{11}- Seaweed extract 5 ml, T_{12}- Absolute control and T_{13}- Control (Water spray), were tested in a Randomized Block Design with two replications. Among the treatments, GA_3 at 100 ppm (T_6) achieved the highest yield per plant (382 g) and per hectare (268.80 q), along with superior fruit length, diameter, and weight. Treatment T_6 demonstrated a 42.79% increase in yield per hectare compared to over the absolute control. These results highlight the effectiveness of GA_3 at 100 ppm in enhancing both yield and quality of okra.

Keywords: Okra, PGR, NAA, GA_3, seaweed extract

Introduction
Okra (*Abelmoschus esculentus*), an economically important vegetable of the Malvaceae family, is cultivated globally for its tender, edible pods. Initially classified under the genus *Hibiscus*, it was later reassigned to *Abelmoschus* (Aladele *et al*. 2008) [3]. In India, okra is grown year-round, with pods typically harvested 5–10 days after flowering, depending on the cultivar (Adetuyil *et al*. 2008) [2]. Okra pods are highly nutritive, providing essential vitamins (A, C, B-complex) and minerals like calcium, potassium, and iron (Adebooye and Opunta, 1996) [1]. A 100 g serving of fresh okra contains 89.6% moisture, 103 mg potassium, 90 mg calcium, 56 mg phosphorus, 43 mg magnesium, and 18 mg vitamin C, along with trace metals like aluminium and iron. The crop offers potential health benefits, including diabetes management and cancer prevention (Aykroyd, 1963) [6]. Okra roots and stems are also traditionally used to purify sugarcane juice for producing jaggery (Chavan *et al*. 2007) [8].
Globally, okra is cultivated on 2.53 million hectares, producing approximately 9.96 million tons, with India accounting for 73% of the total production (FAOSTAT, 2020) [11]. India's major okra-producing states include Gujarat, West Bengal, and Maharashtra, with Maharashtra alone cultivating 13.98 million hectares, yielding 139.40 million metric tons (Anonymous, 2017) [5]. In the Konkan region, Thane district has the largest area under okra cultivation (Anonymous, 2012) [4]. Plant growth regulators (PGRs) have revolutionized agriculture by enhancing plant growth, flowering, and yield. These organic compounds, applied in small quantities, influence physiological and biochemical functions such as dormancy, organ size, crop improvement, and nutrient uptake (Nickell *et al*. 1978) [21]. PGRs like gibberellins, auxins, and cytokinins promote key processes including cell elongation, leaf expansion, and fruit set (Singh *et al*. 2012). At higher concentrations, some regulators may act as inhibitors (Taiz *et al*. 2010) [24].
Gibberellic acid (GA_3), a widely used gibberellin, was discovered in 1926 from *Gibberella fujikuroi* and is known for enhancing plant height, flowering, and fruit development (Kumari *et al*. 2022) [17]. GA_3 application also improves chlorophyll synthesis, petiole length, and leaf area (Ilias *et al*. 2007) [15].

It promotes seed germination, breaks dormancy in bulbs and tubers, and enhances fruit size and yield. Naphthalene Acetic Acid (NAA), a synthetic auxin, influences cell division, root initiation, flowering, and fruit retention (El-Otmani *et al*. 2000) [10]. NAA has been shown to enhance plant height, branch number, and overall yield, while improving pod traits such as length, diameter, and weight (Hossain, 2023) [14]. Seaweed extracts, rich in natural plant hormones like auxins, cytokinins, and gibberellins, along with bioactive compounds such as polysaccharides and phenolics, have long been used in agriculture (Crouch and van Staden, 1993) [9]. These extracts improve chlorophyll content, nutrient uptake, and plant growth (Yuanyuan *et al.* 2020) [26]. However, the effectiveness of PGRs depends on the appropriate dosage, timing, and environmental conditions (Khan and Chaudhary, 2006) [16].

Considering the potential of PGRs to enhance okra growth and yield, this study investigates the optimal concentrations of GA_3, NAA, and seaweed extract for improving yield and yield traits of okra.

Materials and Methods

The study was carried out at Central Experiment Station, Wakawali, Tal- Dapoli, Dist- Ratnagiri. Geographically positioned between 1700 40' to 1700 45' North Latitude and 7500 16' to 7500 19' East Longitude, the station resides at an elevation of 250 meters above sea level. The experiment was laid out in Randomized Block Design with two replications and thirteen treatments. The size of the experimental was 4.5 m × 3 m with spacing 45cm×30cm. Growth regulators was foliar sprayed at 30 DAS, 45 DAS and 60 DAS. The treatment details as follows: T_1: 50 ppm Naphthalene Acetic Acid (NAA), T_2: 100 ppm Naphthalene Acetic Acid (NAA), T_3: 150 ppm Naphthalene Acetic Acid (NAA), T_4: 200 ppm Naphthalene Acetic Acid (NAA), T_5: 50 ppm Gibberellic Acid (GA_3), T_6: 100 ppm Gibberellic Acid (GA_3), T_7: 150 ppm Gibberellic Acid (GA_3), T_8: 200 ppm Gibberellic Acid (GA_3), T_9: 3 ml seaweed extract, T_{10}: 4 ml seaweed extract, T_{11}: 5 ml seaweed extract, T_{12}: Absolute Control, T_{13}: Control (Water spray)

Preparation and application of growth regulators

1. Gibberellic Acid (GA_3)

The solution was prepared by dissolving 50 mg, 100 mg, 150 mg and 200 mg of gibberellic acid in small quantity of ethyl alcohol for dissolving all particles of GA_3 and stirred it, when complete GA_3 granules dissolved in ethyl alcohol the volume was made to one litre by adding water to obtain 50,100,150 and 200 ppm concentration respective.

2. Naphthalene Acetic Acid

The 50,100,150 and 200 ppm solution of NAA was prepared by dissolving 50 mg, 100 mg, 150 mg, 200 mg NAA in 1000 ml of water and sprayed.

3. Seaweed Extract

3 ml, 4 ml, 5ml of seaweed extract mixed in 1000 ml of water and sprayed.

Results and Discussion

1. Total number of fruits per plant

The investigation into the effect of foliar application of growth regulators such as NAA, (GA_3) and Seaweed extract on the total number of fruits per plant in okra unveiled significant findings. Treatment T_6, receiving a foliar application of gibberellic acid at the rate of 100 ppm, demonstrated the maximum total number of fruits per plant, with 30.23. This was closely followed by treatments T_7 (29.85), T_8 (29.18), T_3 (29.13), T_2 (29.00), T_4 (28.31), T_{11} (26.39) and T_1 (25.96), which were statistically comparable to each other. In contrast, treatment T_{12} (absolute control) had the minimum number of fruits per plant, with 19.31. The increase in the number of fruits per plant might be due to the maximum leaf area which produced healthy and stockier plant that were physiologically more active to produce maximum fruits. The results in the present study are supported by findings reported by Gaikwad *et al.* (2021) [13], Pavitra *et al.* (2017) [22] and Meharaj *et al.* (2015) [19].

Table 1: Influence of foliar spraying of Naphthalene Acetic Acid (NAA), Gibberellic Acid (GA_3) and Seaweed extract on total number of fruits per plant, yield per plant, yield per plot, yield per hectare of okra and percent increase in yield per hectare over absolute control.

Treatments	Total number of fruits per plant	Yield per plant (g)	Yield per plot (kg)	Yield per hectare (q)	Percent (%) increase in yield per hectare over absolute control
T_1	25.96	311.16	29.56	218.93	27.76
T_2	29.00	361.80	34.37	254.58	39.60
T_3	29.13	375.01	35.63	263.90	41.73
T_4	28.31	344.27	32.70	242.25	36.52
T_5	24.73	303.51	28.83	213.58	28.00
T_6	30.23	382.00	36.29	268.80	42.79
T_7	29.85	372.23	35.36	261.93	41.29
T_8	29.18	368.91	35.05	259.60	40.77
T_9	23.63	283.51	26.24	194.37	20.89
T_{10}	23.69	288.25	26.93	199.49	22.92
T_{11}	26.39	338.71	31.23	231.30	33.52
T_{12}	19.31	219.21	20.76	153.77	0.00
T_{13}	21.27	245.01	23.28	172.42	10.82
S. E±	1.98	15.24	1.78	13.19	-
CD at 5 %	4.31	46.96	5.49	40.26	-

2. Yield per plant (g)

Upon examining the effect of foliar application of growth regulators such as NAA, (GA_3), and Seaweed extract on yield per plant in okra, Treatment T_6, with 100 ppm gibberellic acid (GA_3), achieved the maximum yield per plant at 382.00 grams, outperforming other treatments. This was followed by treatments T_3 (375.01 g), T_7 (372.23 g), T_8 (368.91 g), T_2 (361.80 g), T_4 (344.27 g) T_{11} and (338.71 g), all of which had yields that were statistically similar to each other. The absolute control treatment T_{12} had the minimum

yield per plant at 219.21 grams, confirming T_6 as the most effective treatment for maximizing yield. The increase in yield by the application of GA_3 over the rest of the treatments might be due to the plant growth regulator entering into the plant system and increasing the net photosynthetic rate by increasing the number of leaves, increasing the number of branches. Ultimately, the increased number of fruits, fruit length and fruit girth, resulted in the increased fruit yield of the plant. These results are conformity with findings reported by Kushawaha *et al.* (2020) [18], Navdeep Singh *et al.* (2020) [20], Gadade *et al.* (2017) [12], Pavitra *et al.* (2017) [22], Baraskar *et al.* (2018) [7]

3. Yield per plot (kg)

Treatment T_6, with 100 ppm gibberellic acid (GA_3), achieved the maximum yield per plot at 36.29 kg, making it the most effective treatment. This was notably higher than the yields from treatments T_3 (35.63 kg), T_7 (35.36kg), T_2 (34.37 kg), T_4 (32.70 kg), T_8 (35.05 kg) and T_{11} (31.23 kg) which were statistically comparable. The absolute control treatment T_{12} yielded the minimum at 20.76 kg, further emphasizing T_6's superior performance in enhancing plot yield. This is because of the role of GA_3 in promoting cell division, cell elongation, which also contribute to increase in the number of branches, number of leaves and leaf area which resulted in increased photosynthesis and produce maximum food result in increased yield per plant and per plot. Similar results were found in studies reported by Baraskar *et al.* (2018) [7].

4. Yield per hectare (q)

Treatment T_6, utilizing a foliar application of 100 ppm gibberellic acid (GA_3), achieved the maximum yield per hectare at 268.80 q, demonstrating a significant improvement over the absolute control treatment T_{12}, which had a yield of 153.77 q. This superior performance was followed by treatments T_3 (263.90 q), T_7 (261.93 q), T_8 (259.60 q), T_2 (254.58 q), T_4 (242.25 q) and T_{11} (231.30 q), all of which were statistically similar to each other. Treatment T_6 demonstrated a 42.79% increase in yield per hectare compared to over the absolute control. The substantial increase in yield with T_6 underscores its efficacy in enhancing crop productivity compared to the control and other treatments. This might be due to increased yield per plant or per plot due to the application of gibberellic acid. These findings are supported by Kumari *et al.* (2022) [17] and Tomar *et al.* (2020) [25].

5. Mean fruit length (cm)

The data presented in Table No. 2 indicated that treatment T_6, with 100 ppm gibberellic acid (GA_3), achieved the maximum fruit length at 45, 60, and 75 days after sowing, reaching 14.73 cm at 45 days. This was significantly greater than the absolute control treatment T_{12}, which had the minimum fruit length of 10.50 cm. T_6's fruit length was also comparable to T_3 (13.83 cm), T_{11} (13.63 cm), T_7 and T_2 each with 12.75 cm, demonstrating its superior performance. These results could be attributed mainly to the stimulatory effect of GA_3 on plant growth, which resulted in higher rates of biosynthesis and therefore higher amounts of assimilates available for distribution to the pods. This finding aligns with the previous result reported by Baraskar *et al.* (2018) [7]. Gaikwad *et al.* (2021) [13], Kumari *et al.* (2022) [17] and Gadade *et al.* (2021) [12].

6. Mean fruit weight (g)

Treatment T_6, with a foliar spray of 100 ppm gibberellic acid (GA_3), achieved the maximum fruit weight of 13.00 grams at 75 days after sowing. This was significantly greater than the absolute control treatment T_{12}, which had the minimum fruit weight of 11.08 grams. T_6's fruit weight was also comparable to that of treatments T_3 (12.84 grams), T_2 (12.68 grams), T_{11}, and T_7 each (12.67 grams), highlighting its superior performance in promoting fruit weight. This might be due to the role of GA_3 in promoting cell elongation and division, which directly contributes to increase fruit size. Comparable outcome was discovered by Gaikwad *et al.* (2021) [13] and Kumari *et al.* (2022) [17].

Table 2: Influence of foliar spraying of Naphthalene Acetic Acid (NAA), Gibberellic Acid (GA_3) and Seaweed extract on mean fruit length, mean fruit weight, mean fruit diameter of okra.

Treatments	Fruit length (cm)			Fruit weight (g)			Fruit diameter (cm)		
	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS
T_1	11.71	11.50	11.75	10.78	12.00	12.00	4.87	4.93	5.13
T_2	12.75	12.92	12.71	11.75	12.50	12.68	5.50	5.18	5.30
T_3	13.83	14.32	14.01	12.13	12.65	12.84	6.00	5.67	5.84
T_4	12.00	12.17	12.42	11.67	12.17	12.05	5.24	5.16	5.23
T_5	11.75	12.00	11.96	11.64	12.13	12.00	5.00	5.08	5.00
T_6	14.73	14.43	14.33	13.25	12.88	13.00	6.23	5.90	5.98
T_7	12.75	13.43	13.08	12.00	12.50	12.67	5.55	5.18	5.46
T_8	12.29	12.58	12.54	11.38	12.15	12.17	5.10	5.12	5.30
T_9	11.43	11.64	11.76	11.13	12.00	11.42	4.98	5.08	5.13
T_{10}	12.05	12.13	12.33	11.58	12.17	11.50	5.08	5.11	5.23
T_{11}	13.63	13.62	13.50	11.83	12.50	12.67	5.98	5.45	5.57
T_{12}	10.50	10.81	11.09	10.13	11.34	11.08	4.48	4.48	4.68
T_{13}	10.94	11.25	11.58	10.50	11.50	11.17	4.67	4.50	4.81
S. E±	0.65	0.55	0.53	0.44	0.23	0.26	0.23	0.18	0.19
CD at 5 %	2.00	1.71	1.66	1.36	0.70	0.80	0.72	0.55	0.61

7. Mean fruit diameter (cm)

Treatment T_6, with 100 ppm gibberellic acid (GA_3), recorded the maximum fruit diameter of 6.23 cm at 45 days after sowing, significantly larger than the absolute control treatment T_{12}, which had the minimum diameter of 4.67 cm. Treatments T_3 (6.00 cm), T_{11} (5.98 cm), and T_7 (5.55 cm) also had substantial fruit diameters and were statistically similar to each other

Conclusion

The results concluded that, the treatment T_6, comprising gibberellic acid (GA_3) at 100 ppm, achieved the highest yield per plant (382.00 g) and per hectare (268.80 q) and demonstrated a 42.79% increase in yield per hectare compared to over the absolute control. significantly outperforming the absolute control and other treatments. It also recorded the maximum fruit length, diameter, and weight, highlighting the effectiveness of GA_3 at 100 ppm in enhancing both yield and fruit quality. These results indicate that GA_3 at 100 ppm optimizes growth and development processes, leading to increased productivity and improved marketable produce.

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