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Research Article

Influence of plant growth regulators on growth, seed yield and quality of okra (*Abelmoschus esculentus* (L) Moench.)

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Background: The use of plant growth regulators through foliar spraying proves beneficial where roots fail to supply the required nutrients. The plant growth hormones supplementation through foliar sprays enables the direct and efficient utilization of nutrients by plants, manifesting observable effects within a short period which ultimately increases seed quality and seed yield in okra.

Methods: The present study on “Effect of foliar application of plant growth regulators on growth, seed yield and quality of okra” was conducted at Department of Agril. Botany Farm, Agriculture College, Pune and laboratory studies was conducted in STRU, MPKV, Rahuri. The field trial was conducted in randomized block design (RBD) having nine treatments including control with three replications and lab experiment was conducted in completely randomised block design (CRD). The treatments comprise of different plant growth regulators such as GA_3 at 100 ppm, 200 ppm, 250 ppm, NAA at 100 ppm, 200 ppm, IBA at 100 ppm, 150 ppm, Kinetin at 200 ppm including control (No spray control). Two foliar sprays of each plant growth regulator treatment were applied at 30 and 45 days after sowing.

Results: The plant growth regulator GA_3 at 250 ppm foliar spraying was found to be the best treatment for plant growth, seed yield and quality characters of okra variety Phule Vimukha *viz*., days to 50% flowering (40 days), plant height (89.83 cm), number of leaves (25.50), number of branches (3.92), moisture content (16.50 %), germination (93.33 %), seedling length (24.20 cm), root length (9.23 cm), shoot length (15.27 cm), shoot root ratio (1.80), seedling dry weight (29.26 g), seed vigour index (2258), hard seeds (2.50), dead seed (3.50), electrical conductivity (1.07 dS/m), number of fruits per plant (15.00), fruit length (19.53 cm), fruit diameter (2.00 cm), number of seeds per fruit (52.00), 100 seed weight (7.87 g), seed yield per plant (58.05 g).

Conclusion: Application of plant growth regulator GA_3 at 250 ppm treatment as two foliar sprayings at 30 and 45 DAS was found more promising in increasing growth, yield and quality characters of okra variety Phule Vimukha as compared to the untreated control treatment.

Keywords: *GA_3, NAA, okra, Phule Vimukha, quality, yield*

Introduction

Okra is a warm-season crop that can be found commercially in West Africa, India, Southeast Asia, the Southern United States, Brazil, Turkey, and Northern Australia. It is well recognized by a different regional name throughout the world, including lady's finger in England, Gumbo in America, and Bhindi in India. In tropical and subtropical regions of the world, okra is a commercially significant vegetable crop. Green okra pods are tasty and valued. Nutritionally okra contains high levels of calcium, phosphorus, magnesium, vitamin A, B and C as well as iodine. The seeds of okra are a source of protein, oil, and can be ground up to replace aluminium salts in the process of purifying water. Okra has 1.9 g of protein, 6.4 g of carbohydrates, 0.7 g of minerals, 0.2 g of fat and 1.2 g of fibre per 100 g of edible portion (Tiwari *et al.*, 1998). Plant growth regulators are chemicals that, when used sparingly, alter plant growth by enhancing or impairing a component of the natural growth regulatory system. The canopy structure and yield have both been proven to be altered by the growth regulators, which comprise growth promoters and retardants both (Aurovinda & Rajendra, 2003). Okra is a significant vegetable among fruits and vegetables, and its soft fruits are in high demand all year long. As the third most significant component in enhancing growth, productivity and seed quality through the use of plant growth regulators in various ways, scientists have recently given the concept of controlling plant growth and development with the attention it deserves. One of the most common techniques and a tool that many researchers have cited as being beneficial for increasing the pace and quantity of germination is the treatment of seed along with foliar sprays of plant growth regulator. Considering importance of the crop, the current study was undertaken with the objective to study the effect of growth regulators on growth, seed yield and quality of okra.

Materials and Methods

A field trial was carried out at Botany Farm, Department of Agril. Botany, Agriculture College, Pune and Laboratory studies were conducted in Seed Technology Research Unit, Mahatma Phule Krishi Vidyapeeth, Rahuri. The sowing of okra variety Phule Vimukha was done at the distance of 60 X 45 cm. The field research trial was conducted in randomized block design (RBD) having nine treatments including control with three replications while lab experiment was conducted in completely randomised block design (CRD). The treatments comprise of different plant growth regulators such as GA_3 at 100 ppm, 200 ppm, 250 ppm, NAA at 100 ppm, 200 ppm, IBA at 100 ppm, 150 ppm, Kinetin at 200 ppm including control (No spray). The Breeder Seeds of Okra *cv.* Phule Vimukha was obtained from National Agricultural Research Project, Ganeshkhind, Mahatma Phule Krishi Vidyapeeth, Pune. Phule Vimukha variety of okra is released for Western Maharashtra having high yield, excellent fruit nutritional quality, taste and resistant to yellow vein mosaic disease. The experimental plots were kept free from weeds, insect pests and diseases using proper plant protection measures. The experimental plot was given irrigation as and when required. Two foliar sprays of each plant growth regulator treatment were applied on 30 days and 45 days after sowing. The yield attributing characters data collected and analysed statistically as described by Panse & Sukhatme (1985).

Results

Morphological Characters

The data recorded on the days taken to 50% flowering, plant height, number of leaves per plant, number of branches per plant and number of nodes per plant as influenced by plant growth regulators is reported in Table 1. From the data, significant results were recorded.

Table 1. Influence of foliar application of plant growth regulators on morphological attributes of okra

Sr. No.	Treatments	Days to 50% flowering	Plant height (cm)	No. of leaves/pl	No. of branches/pl	No. of nodes per plant
1	GA_3 at 100 ppm	42.00	79.00	20.67	3.25	16.87
2	GA_3 at 200 ppm	41.17	85.00	23.25	3.83	17.17
3	GA_3 at 250 ppm	40.00	89.83	25.50	3.92	18.33
4	NAA at 100 ppm	43.25	70.17	17.33	2.67	15.17
5	NAA at 200 ppm	42.08	77.50	18.42	2.92	15.83
6	Kinetin at 200 ppm	44.17	65.00	16.75	2.17	14.17
7	IBA at 100 ppm	45.33	66.33	14.50	2.33	14.00
8	IBA at 150 ppm	45.00	69.50	16.17	2.58	14.67
9	Control (No Spray)	48.00	61.67	13.25	1.92	13.17
	SE ±	2.10	2.95	0.76	0.19	0.89
	C. D. at 5%	**6.50**	**8.85**	**2.29**	**0.59**	**2.67**
	C.V. %	**8.50**	**6.95**	**7.21**	**12**	**9.96**

The GA_3 at 250 ppm recorded minimum days to 50% flowering (40.00) whereas, the control (48.00) treatment took the highest days for 50% flowering in okra. The GA_3 at 250 ppm treatment (T3) recorded the maximum height (89.83 cm), number of leaves per plant (25.50), number of branches per plant (3.92) and number of nodes per plant (18.33) while minimum values for all these characters recorded in the Control.

Yield characters

The results for yield characters were reported in Table 2. The significant differences were found for yield and yield attributing factors in okra. The highest number of fruits per plant (15.00), maximum fruit length (19.53 cm), fruit diameter (2.00 cm), number of seeds per fruit (52.00), 100 seeds weight (7.87 g) and seed yield per plant (58.05 g) were found in the treatment sprayed with GA_3 at 250 ppm. Whereas, the least number of fruits per plant (9.33), minimum fruit length (15.70 cm), fruit diameter (1.06 cm), number of seeds per fruit (34.33), 100 seeds weight (6.07 g) and seed yield per plant (26.33 g) were noticed in untreated control.

Table 2. Influence of foliar application of plant growth regulators on yield attributing characters of okra

Sr. No.	Treatments	No. of fruits / pl	Fruit length (cm)	Fruit diameter (cm)	No. of seeds / fruit	100 Seed weight (g)	Seed Yield / plant (g)
1	GA_3 at 100 ppm	12.33	18.83	1.57	49.53	7.30	44.87
2	GA_3 at 200 ppm	14.00	19.13	1.68	50.00	7.52	52.00
3	GA_3 at 250 ppm	15.00	19.53	2.00	52.00	7.87	58.05
4	NAA at 100 ppm	11.77	18.13	1.77	48.13	7.00	39.23
5	NAA at 200 ppm	12.00	18.50	1.87	49.00	7.20	42.33
6	Kinetin at 200 ppm	11.17	18.10	1.18	47.03	6.80	35.67
7	IBA at 100 ppm	11.00	17.80	1.37	46.00	6.70	33.90
8	IBA at 150 ppm	11.33	18.00	1.48	47.67	6.90	37.42
9	Control (No Spray)	9.33	15.70	1.06	34.33	6.07	26.33
	SE ±	0.63	0.64	0.13	2.2	0.31	2.29
	C. D. at 5%	**1.9**	**1.94**	**0.39**	**6.6**	**0.95**	**6.88**
	C.V. %	**9.12**	**6.16**	**11**	**8.11**	**7.84**	**9.7**

Seed quality parameters

The data on moisture content, germination percent, seedling dry weight, number of hard seeds and number of dead seeds of okra are given in Table 3. Non-significant differences between the treatments for moisture content were recorded. The treatment GA_3 at 250 ppm (T3) reported maximum moisture content (16.50%) while minimum moisture content (14.00%) was recorded in control. Among the treatments, GA_3 at 250 ppm (T3) showed significantly the highest seed germination percentage (93.33%) and seedling dry weight (29.26 g). In contrast, the lowest seed germination percentage (82.00%) and seedling dry weight (23.03 g) showed by the control. The lowest number of hard seeds (2.50) and dead seeds (3.50) were observed in the treatment with foliar application of GA_3 at 250 ppm, while the control treatment exhibited the maximum number of hard seeds (6.00) and dead seeds (7.00).

Table 3. Influence of foliar application of plant growth regulators on seed quality of okra

Sr. No.	Treatments	Moisture content (%)	Germination (%)	Seedling dry wt. (mg)	No. of hard seeds	No. of dead seeds
1	GA_3 at 100 ppm	15.50 (23.19)	86.00 (68.06)	25.63	4.20	5.20
2	GA_3 at 200 ppm	16.00 (23.59)	89.67 (71.29)	26.56	3.40	4.40
3	GA_3 at 250 ppm	16.50 (23.97)	93.33 (75.07)	29.26	2.50	3.50
4	NAA at 100 ppm	15.13 (22.90)	85.67 (67.79)	23.77	4.67	5.33
5	NAA at 200 ppm	15.80 (23.43)	89.33 (70.97)	24.59	3.50	4.50
6	Kinetin at 200 ppm	14.50 (21.98)	83.57 (66.12)	23.23	5.17	6.17
7	IBA at 100 ppm	14.93 (22.74)	83.00 (65.68)	23.34	4.90	5.90
8	IBA at 150 ppm	15.00 (22.79)	84.00 (66.45)	25.24	4.33	5.67
9	Control (No Spray)	14.00 (21.98)	82.00 (64.92)	23.03	6.00	7.00
	SE ±	1.23	1.07	1.01	1.01	1.26
	C. D. at 5%	**N.S.**	**3.19**	**3.01**	**3.01**	**3.76**

** The bracket values denotes arcsin transfer values*

The data on root length, shoot length, shoot root ratio, vigour index, seedling length and electrical conductivity of okra seeds are given in Table 4. The maximum root length (9.23 cm), shoot length (15.27 cm), shoot root ratio (1.80), seed vigour index (2258) and seedling length (24.20) were recorded in the treatment with foliar spraying of GA_3 at 250 ppm, while in control treatment the minimum root length of 6.53 cm, shoot length (10.00 cm), shoot root ratio (0.77), seed vigour index (1403) and seedling length (17.533) were found.

Table 4. Influence of foliar application of plant growth regulators on seed quality of okra

Sr. No.	Treatments	Root length (cm)	Shoot length (cm)	Shoot & root ratio	Vigour index	Seedling length (cm)	Electrical conductivity (dS/m)
1	GA_3 at 100 ppm	8.60	14.03	1.30	1874	22.333	1.14
2	GA_3 at 200 ppm	8.87	14.47	1.67	2063	23.000	1.11
3	GA_3 at 250 ppm	9.23	15.27	1.80	2258	24.200	1.07
4	NAA at 100 ppm	7.90	12.53	1.04	1694	20.667	1.19
5	NAA at 200 ppm	8.10	12.67	1.56	1879	21.033	1.17
6	Kinetin at 200 ppm	7.07	11.40	1.17	1573	18.800	1.28
7	IBA at 100 ppm	8.38	11.53	0.90	1674	20.500	1.25
8	IBA at 150 ppm	8.40	12.37	1.04	1760	21.200	1.21
9	Control (No Spray)	6.53	10.00	0.77	1403	17.533	1.31
	SE $\pm$	1.01	1.04	0.3	1.66	1.160	0.02
	C. D. at 5%	**3.01**	**3.09**	**0.9**	**4.94**	**3.400**	**0.06**

The minimum electrical conductivity value measuring 1.07 dS/m was reported in seeds treated with foliar application of GA_3 at 250 ppm and the control treatment exhibited the maximum electrical conductivity value of 1.31 dS/m.

Discussion

Morphological Characters

The application of growth hormones significantly decreased the 50% flowering days. It is because of accumulation of accelerated photosynthates in the plant helps in growth and development in enhancing advance flowering. Sayed & Khan (2000) confirm these results. The data denotes that significantly increased plant height corelates with increasing concentrations of GA_3 and other hormones. Dhage et al. (2011); Ravat & Makani (2015) in okra also supported these results. The enhanced growth and development resulted as Gibberellins promote stem elongation and helped in cell enlargement, internodal extension, uplift the RNA and thereby protein synthesis. The number of branches and leaves improved by increasing level of plant growth regulators. The higher leaf number per plant with GA_3 might be because of speedy growth. These results were also found by Singh & Mahesh (2005); Patil & Patel (2010); Mehraj et al. (2015) in okra and Sharma & Lashkari (2009) in cluster bean. As reported by Wareing & Phillips (1976) the per plant number of nodes increased because of more vegetative growth. The findings also reported that foliar spraying of GA_3 increased length of hypocotyls and two nodes. Such findings were also noted by Mislevy et al. (1989) and Maitey et al. (2016).

Yield characters

Hormones had a major role in plant mechanism, growth and development. The increase in fruit number per plant with GA_3 might be because of rapid and better nutrient translocation from roots to various apical plant parts. These results are parallel with Munda et al. (2000); Singh et al. (2001); Bhosle et al. (2002). The GA_3 as well as NAA application increased fruit length because of speedy cell division and cell elongation. Such findings also found by Hussain et al. (2004); Mahesh & Sen (2005); Shahid et al. (2013) in okra. The expansion in fruit diameter by adding concentrations of GA_3 and NAA enhances vegetative and reproductive growth in okra. Fruit diameter is genetic character and vary among genotypes but spraying with hormones modify their growth and have great influence on seed quality. The similar results found by Mehraj et al. (2015); Ravat & Makani (2015) in okra and Khramshow et al. (2022). The higher assimilation and translocation of photosynthates from source to the seeds (sink) helps to increase in number of seeds per fruit. These findings were also found by Balaraj (1999) in chilli, Kumari et al. (2022); Ambreen et al. (2010); Meena et al. (2017) in okra. The increased seed weight might be due to more build-up of sufficient food reserves distributed by spraying of growth regulators towards the developing pods and seeds. This may be resulted by higher supply of photosynthates and translocation of food reserves in the seeds. The findings are in accordance with Bhatt & Singh (1997) in okra, and Patil (2005) in brinjal. The effective transfer and storage of these translocates in the seeds, resulted in the seed size expansion. Khramashow et al. (2022) found the same results. The GA_3 application increased the yield because by entering the plant system, the plant growth regulators enhance the net photosynthetic rate with more leaf number, branches number that resulted in more fruits, length of fruit and fruit girth. This ultimately resulted in the per plant more fruit yield. These results were also supported by Hussain et al. (2004); Ravat & Makani (2015); Mehraj et al. (2015); Meena et al. (2017) in okra. The application of NAA plays important role in delaying process of senescence, root and shoot growth hastening, increased fertility rate of reproductive organs by favourable balancing of hormones and thereby setting more fruits which automatically resulted in higher yields. The findings are in conformity with the reports of Kokare et al. (2006) in okra.

Seed quality parameters

The higher moisture content might be result of cell elongation and more moisture holding capacity. These results are conformity with Kumar & Sen (2005); Priyanka et al. (2008) in okra. The proportionate use of growth regulators helped in better vigorous and viable seeds because of well development of embryo and endosperm. Similar findings were supported by Chand et al. (2013); Kanhaiyalal et al. (2017) in okra. The application of GA_3 and NAA increased shoot root ratio which resulted by speedy cell division and more elongation of individual cell. These results were supported by Prem et al. (2013) in okra. The spraying of GA_3 at 250 ppm improved seed quality with more bold seeds percentage in addition to increased seeds test weight by more transport and accumulation of photosynthates from source to the sink (seeds). Such results were also noticed by Kanhaiyalal et al. (2017); Patil et al. (2008); Singh & Lal (1995) in chilli, Balaraj (1999) in chilli and Patil (2005) in brinjal. The percentage of dead seeds increases due to improper development of seeds during ripening and maturation stage. Heavy rains during seed maturation are also responsible for increase in seed borne infection resulting in death of seed. Further, nutrition deficiency also contributes in seed development. Deficiency in nutrients will cause underdeveloped and shrivelled seeds which fail to germinate. The results supported by Prem et al. (2013); Patil et al. (2008) in okra. In okra multiple dormancies is observed depending upon the cultivar and season. Freshly harvested seeds usually show multiple dormancies resulting in hard seeds which fail to absorb water and remain hard failing to germinate during the test period. The results also matched with the findings of Prem et al. (2013) in okra. Hormones has an important role in seed vigour. Seeds with high germination percentage and vigour will usually show low leachates resulting in low electrical conductivity. Fully well matured and healthy seeds remain viable for more duration. Conversely, seeds with higher conductivity measurements showed electrolyte leakage and lower quality. Lower quality seeds possess poor membrane structures that allow electrolytes and ions to leak through. The findings were supported by Parmar et al. (2023) in groundnut and Kachare (2022) in green gram Harvesting and handling methods of seeds will also determine the electrical conductivity. Chand et al. (2013) reported the similar results.

Conclusion

The treatments comprised of different plant growth regulators such as GA_3 at 100 ppm, 200 ppm, 250 ppm, NAA at 100 ppm, 200 ppm, IBA at 100 ppm, 150 ppm, Kinetin at 200 ppm including control (No spray) were given. Two foliar sprays of each plant growth regulator treatment were applied at 30 days and 45 days after sowing. From the data it was concluded that the two foliar sprayings of different plant growth regulators showed positive results for morphological, yield attributing and seed quality characters than control unsprayed treatment in okra. But the foliar spraying of GA_3 at 250 ppm treatment at 30 and 45 days after sowing was found effective and more beneficial in increasing growth, yield contributing parameters and seed quality attributes of okra variety Phule Vimukha in comparison to the untreated control.

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Author contributions

Viraj V. Deshmukh conducted Research trial, collection, analysis of data, Thesis writing. Hitendrasinh J. Rajput has contribution as Research guide, guided to conduct trial, observations, analysis & thesis writing. Ramesh S. Bhadane wrote the entire manuscript of research article in addition to help in collection of data, analysis and interpretation. Vitthal R. Patil involved in collection of data, analysis, field and laboratory trial formulation.

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Conflict of interest

The author declares no conflict of interest. The manuscript has not been submitted for publication in any other journal.

Ethics approval

Not applicable

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