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RESEARCH PAPER

Influence of plant growth regulators on growth, seed yield and seed quality in okra [*Abelmoschus esculentus* (L.) Moench] cv. GAO-5 under middle Gujarat condition

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Abstract : A field experiment was conducted, to study the effect of plant growth regulators on growth, seed yield and seed quality of okra [*Abelmoschus esculentus* (L.) Moench] cv. GAO-5 under middle Gujarat condition. Among the different treatments GA_3 @ 100 ppm was the best for growth and seed yield characters *viz*., plant height (cm), number of leaves, number of internodes per plant, days to flower initiation, days to 50 (%) flowering and GA_3 @ 50 ppm was the best for growth and seed quality characters *viz.*, average pod weight (g), 100 seed weight (g), seedling dry weight (g) and seedling vigour index-II, while the plants sprayed with thiourea @ 500 ppm yielded the best for growth and yield characters *viz*., leaf area (cm^2), LAI, total dry weight of plant (g), number of pods per plant, length of pod (cm), number of seeds per pod, seed yield per plant (g) and seed yield per hectare (q).

Key Words : Okra seed, GA_3, NAA, Thiourea, Ethrel, Growth parameters, Seed yield parameters, Seed quality parameters

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INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] popularly known as lady's finger is an important annual vegetable crop belongs to Malvaceae. It is said to be native of south Africa and Asia and is widely grown in tropical and subtropical parts of the world. Plant growth regulators are the chemical substances, when applied in small amounts modify the growth of plants by stimulating or inhibiting part of the natural growth regulatory system. About 60 plant growth regulators are now commercially available and several of them have reached considerable importance in crop production. The growth regulators include both growth promoters and retardants, which have been shown to modify the canopy structure and however, yield (Aurovinda and Rajendra, 2003). Though plant growth regulators have great potentials, its application and actual assessments etc. have to be judiciously planned in terms of optimal concentrations, stage of application, species specificity, season etc. for obtaining higher seed yield and quality (Kore *et al.*, 2003). Quality seed often determines the stability of yield in crops. So supply of quality seeds is an important aspect of vegetable seed production. It has been experience of research workers that regulating fruit number by proportionate retention of fruits on the plant has a direct bearing on the yield and quality of fruits and seeds (Venkata and Bhatt, 1997). Various aspects of methodology for seed production *viz.*, seed treatment, time and method of sowing, nutritional management, cultural practices and stage of harvest

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were widely studied in okra, but not the research on the effect of growth plant regulators. In view of this, the present investigation was envisaged with a view to know the effect of plant growth regulators on crop growth, seed yield and quality in okra.

MATERIAL AND METHODS

The present investigation was carried out at main Vegetable Research Station, Anand Agricultural University, Anand. Seeds of okra cv. GAO-5 were sown during *Kharif* of 2012 in the field condition at spacing of 60×30 cm. The experiment was laid out in Randomized Complete Block Design with three replications adopting the recommended package of practices. The treatment involving plant growth regulators *viz.*, gibberellic acid (GA_3) naphthalene acetic acid (NAA), thiourea and ethrel each at two different concentrations (GA_3- 50 ppm, 100 ppm, NAA -100 ppm, 200 ppm, thiourea 500 ppm, 1000 ppm and ethrel 500 ppm, 1000 ppm) applied as foliar sprays on 30 and 45 days after sowing. The details of all the treatments are furnished below: T_1: GA_3- 50 ppm, T_2: GA_3- 100 ppm, T_3: NAA -100 ppm, T_4: NAA-200 ppm, T_5: Thiourea -500 ppm, T_6: Thiourea -1000 ppm, T_7: Ethrel-500 ppm, T_8: Ethrel-1000 ppm and T_9: Control (Water spray). For analyzing the growth patterns of the crop *viz.*, plant height and number of leaves was recorded on five randomly selected plants in a plot of each treatment at different stages *viz.*, 30 DAS, 60 DAS and 90 DAS. Other growth parameter *viz.*, leaf area (cm^2) and LAI was recorded on five randomly selected plants in a plot of each treatment at different stages *viz.*, 45 DAS, 60 DAS and 75 DAS. Number of internodes per plant was recorded on five randomly selected plants in a plot of each treatment at different stages at 30 DAS and harvest. The observations on days to flower initiation and days to 50 per cent flowering were recorded on plot basis, while days to maturity were recorded based on the visual observations was recorded on five randomly selected plants in a plot of each treatment at harvest. The fruit maturity was decided based on the drying of fruits and development of hairline cracks on the fruits. The observations on yield parameters like total dry weight of plant (g), number of pods per plant, average pod weight, length of pod (cm), girth of pod (cm), number of pods per plant, number of seeds per pod, seed yield per plant and seed yield per hectare were recorded based on five randomly selected plants in a plot of each treatment at the time of harvest. The observations on seed quality attributes like germination percentage, test weight, seedling length and seedling dry weight as per the standard procedures (Anonymous, 1999), and seedling vigour index I and II (Abdul-Baki and Anderson, 1973).

RESULTS AND DISCUSSION

In the present investigation, effect of different plant growth regulators on plant height presented in Table 1 revealed that foliar application of different growth regulators significantly increased plant height as compared to control at 60 and 90 DAS. The highest plant height was recorded under T_2 GA_3 @ 100 ppm *i.e.* 115.93 cm and 122.46 cm at 60 and 90 days after sowing, respectively. It might be due to that GA_3 could be involved in cell enlargement, internodal elongation, stimulated RNA and protein synthesis and there by leading to enhanced growth and development. Increased plant height may probably be due to stimulating action of GA_3, which increased cell wall plasticity, the results confirmed the reports of Veerkumar (2002) and Sreedhar (2003). The results presented in the Table 1 revealed that the response of different growth regulators treatments on number of leaves per plant differed significantly. Significantly higher number of leaves per plant was recorded with T_2 (GA_3 @ 100 ppm) at 90 days after sowing, and the value being 26.27, over control (17.20). It might be due to the effect of GA_3 which increased the rate

Table 1 : Effect of plant growth regulators on plant height (cm) and number of leaves per plant in okra cv. GAO-5

Treatments	Plant height (cm)			No. of leaves / plant				
	30 Days	60 Days	90 Days	30 Days	45 Days	60 Days	75 Days	90 Days
T_1: GA_3 @ 50ppm	46.06	103.53	117.87	5.20	7.80	14.00	20.80	25.13
T_2: GA_3 @ 100ppm	46.93	115.93	122.46	5.33	8.13	11.87	18.40	26.27
T_3: NAA @ 100ppm	46.66	86.73	110.33	6.26	7.93	11.93	18.06	21.93
T_4: NAA @ 200ppm	44.86	80.73	101.26	6.33	8.53	14.60	18.46	22.13
T_5: Thiourea @ 500ppm	44.40	95.53	105.33	5.60	9.26	12.60	19.80	24.27
T_6: Thiourea @ 1000ppm	45.33	75.06	95.06	5.46	8.33	12.00	18.26	21.73
T_7: Ethrel @ 500ppm	45.53	70.36	90.13	5.40	7.73	11.40	14.73	18.80
T_8: Ethrel @ 1000ppm	45.13	67.93	84.06	5.27	8.20	12.87	15.06	19.40
T_9: Control	45.00	103.93	120.33	5.27	8.06	12.20	14.06	17.20
S.E. ±	1.39	4.15	5.73	0.27	0.28	0.51	0.73	0.71
C.D. (P=0.05)	NS	12.45	17.17	NS	0.86	1.53	2.19	2.15
C.V. %	5.29	8.09	9.42	8.41	6.08	7.01	7.23	5.69

NS=Non-significant

of cell division and cell elongation and ultimately increased the inter nodal length, number of leaves and better vegetative growth in okra plants as reported by Singh and Singh (1977). The results presented in the Table 2 revealed that the response of different treatments on leaf area and LAI of plant differed significantly due to application of PGR"s. There was significant effect of various PGRs on leaf development through enhancement in leaf area and LAI at 45, 60 and 75 DAS. Significantly higher leaf area and LAI of plant were recorded with the T_5 (thiourea @ 500 ppm) the values being 59.637 cm^2 and 3.30 at 90 DAS, respectively. Leaf area and LAI increased due to application of thiourea, which enhanced cell division and leaf development which ultimately increased net photosynthetic rates as well as the total chlorophyll content in the leaves. Thiourea also played a positive role in enhancing nitrogen metabolism as it significantly increased nitrate reductase activity and concentration of soluble protein in the treated plants. Similar results were also reported by Garg *et al.* (2011). The results presented in Table 2 revealed that there was non-significant effect of various PGRs on number of nodes per plant at 30 DAS. Number of internodes per plants recorded with T_2 (GA_3 @ 100 ppm) at last picking *i.e.* 21.60 was statistically superior over the control and rest of the treatments. The highest number of internodes per plant might be due enhanced vegetative growth as stated by Wareing and Phillips (1976). The results also revealed that foliar application of GA_3 increased hypocotyls length and length of two nodes, the similar results were also reported by Mislevy *et al.* (1989). The data presented in the Table 2 indicated that the initiation of flower in okra was found to be significantly affected due to application of PGR's. Significantly, the less number of days required to flower initiation (34.67 days) was

Table 2 : Effect of plant growth regulators on leaf area (cm^2), LAI, number of internodes per plant and days to flower initiation in okra cv. GAO-5

Treatments	Leaf area (cm^2)			LAI			No. of internodes / plant		Days to flower initiation
	45 Days	60 Days	75 Days	45 Days	60 Days	75 Days	30 Days	At last picking	
T_1: GA_3 @ 50ppm	18.531	32.763	58.597	1.02	1.81	3.24	3.53	20.93	36.67
T_2: GA_3 @ 100ppm	17.996	32.706	53.211	0.99	1.81	2.95	3.60	21.60	34.67
T_3: NAA @ 100ppm	14.367	31.665	51.703	0.79	1.75	2.86	4.46	19.00	37.33
T_4: NAA @ 200ppm	21.982	42.263	56.621	1.22	2.34	3.14	3.00	17.66	40.33
T_5: Thiourea @ 500ppm	22.235	33.299	59.637	1.23	1.84	3.30	3.13	20.00	35.67
T_6: Thiourea @ 1000ppm	20.985	35.141	52.285	1.16	1.94	2.90	2.93	18.20	37.00
T_7: Ethrel @ 500ppm	13.828	24.502	37.631	0.76	1.35	2.08	2.86	17.80	41.00
T_8: Ethrel @ 1000ppm	22.869	25.593	36.240	1.26	1.41	2.01	3.20	18.00	41.67
T_9: Control	21.557	29.356	44.376	1.19	1.62	2.46	2.93	17.60	42.67
S.E. ±	0.86	0.94	2.44	0.04	0.05	0.13	0.18	0.88	1.62
C.D. (P=0.05)	2.60	2.82	7.33	0.14	0.15	0.40	NS	2.66	4.87
C.V. %	7.76	5.12	8.47	7.87	5.14	8.52	9.83	8.11	7.30

NS=Non-significant

Table 3 : Effect of plant growth regulators on days to 50 (%) flowering, number of branches / plant at last picking, total dry weight of plant (g), number of pods per plant, average pod weight at harvest (g), length of pod (cm) and girth of pod (cm) in okra cv. GAO-5

Treatments	Days to 50 (%) flowering	No. of branches / plant at last picking	Total dry weight of plant (g)	No. of pods per plant	Average pod weight (g)	Length of pod (cm)	Girth of pod (cm)
T_1: GA_3 @ 50ppm	43.33	2.86	97.46	10.00	5.62	17.03	5.36
T_2: GA_3 @ 100ppm	41.66	2.80	91.84	10.73	4.73	16.17	5.33
T_3: NAA @ 100ppm	44.66	2.93	94.10	9.93	5.35	15.50	5.32
T_4: NAA @ 200ppm	47.66	3.13	81.11	8.53	5.21	15.97	5.27
T_5: Thiourea @ 500ppm	42.66	2.26	98.78	10.86	5.59	17.80	5.39
T_6: Thiourea @ 1000ppm	43.66	2.73	81.54	9.06	5.18	15.30	5.12
T_7: Ethrel @ 500ppm	49.33	2.86	76.95	8.60	4.36	14.03	4.92
T_8: Ethrel @ 1000ppm	47.66	3.06	77.17	9.00	4.30	13.83	4.92
T_9: Control	49.66	2.66	80.27	8.26	5.16	15.87	5.22
S.E. ±	1.71	0.16	3.74	0.53	0.23	6.67	0.20
C.D. (P=0.05)	5.14	NS	11.22	1.61	0.71	2.01	NS
C.V. %	6.52	9.93	7.48	9.89	8.13	7.41	6.64

NS=Non-significant

with the treatment T_2 (GA_3 @ 100 ppm) as compared to control and rest of the treatments. This might be due to increase in the endogenous gibberellins level in the plant as stated by Deepak *et al*. (2007). The data presented in the Table 3 suggested that the 50 per cent flowering in okra was found to be significantly affected due to application of PGR"s. Significantly, the minimum days required for 50 per cent flowering (41.66 days) was with the treatment T_2 (GA_3 @ 100 ppm) as compared to control and rest of the treatments. This might be due to increase in the endogenous gibberellins level in the plant as reviewed by Deepak *et al*. (2007). The number of branches per plant was found to be non-significant, and the results are presented in Table 3. Numerically higher number of branches per plant (3.13) was recorded under T_4 (NAA @ 200 ppm) and the minimum (2.26) was recorded with the treatment T_5 (Thiourea @ 500 ppm). Thiourea @ 500 ppm increased total dry weight of plant, and value was 98.78 g. It might be due to that thiourea could have delayed leaf ageing and senescence and enhance photosynthetic efficiency leading to increase in growth and yield of plants. Thus, thiourea application favourly affected both carbohydrate and nitrogen metabolism, which in turn enhanced plant performance. It was reported by Mathur *et al*. (2006) that application of thiourea increased dry matter production and seed yield of mung. Thiourea @ 500 ppm increased the number of pods per plant, and value was 10.86 as shown in Table 3. It might be due to exogenous application of thiourea stimulated the effect of natural occurring hormones that accelerated and modified the growth and development of plants. Similar results were also reported by Sharma and Singh (2004), Yadav *et al*. (2004) and Burman *et al*. (2006) in cluster bean. The results presented in Table 3 revealed that the response of different treatments of plant growth regulators differed significantly. The highest average pod weight (5.62 g) was recorded with T_1 *i.e.* (GA_3 @ 50 ppm) as compared to control and rest of the treatments. This might be due to better translocation of photosynthates diversified toward source to newly developed sink, which could be supported by heavier build up of sufficient food reserves in the developing pods and seeds in the physiologically active plant due to spraying of growth regulators as reported by Bhatt and Singh (1997). This might have favoured increased supply of photosynthates and mobilization efficiency in plants giving rise to more developed seeds in the pods. The results are in agreement with the findings of Bhatt and Singh (1997) in okra, Goudappalavar (2000) in tomato and Patil (2005) in brinjal. The treatment of thiourea @ 500 ppm increased pod length, and value was 17.80 cm. It might be due to the exogenous application of thiourea, which stimulated the effect of natural occurring hormones that accelerated and modified the growth and development of plants, similar results were also reported by Sharma *et al*. (2004), Yadav *et al*. (2004) and Burman *et al*. (2006) in cluster bean. The girth of okra pod was found to be non-significant, the results are presented in Table 3. Though, the numerically higher value of pod girth (5.39 cm) was recorded with T_5 (thiourea @ 500 ppm), while minimum was recorded with the treatment T_7 (4.92 cm) and T_8 (4.92 cm) *i.e.* ethrel @ 500 and 1000 ppm, respectively. The results presented in Table 4 revealed that the response of different treatments of plant growth regulators differed significantly. The highest number of seeds per pod (51.63) was recorded under T_5 (thiourea @ 500 ppm) as compared to control and rest of the treatments. It might be due to the treatment of thiourea could have cause delay leaf ageing and senescence and enhanced photosynthetic efficiency leading to increase in growth and yield of plants. Thus, thiourea application favourly affected both carbohydrate and nitrogen metabolism, which in turn enhanced plant performance. It was reported by Mathur *et al*. (2006) that application of thiourea increased dry matter production and seed yield of mung. Thiourea @

Table 4 : Effect of plant growth regulators on number of seeds per pod, seed yield per plant (g), seed yield per hectare (q), 100 seed weight (g) and germination (%) in okra cv. GAO- 5

Treatments	No. of seeds per pod	Seed yield per plant (g)	Seed yield per hectare (q)	100 seed weight (g)	Germination (%)
T_1: GA_3 @ 50ppm	51.46	33.78	14.07	6.65	93.33
T_2: GA_3 @ 100ppm	46.10	30.90	11.15	6.41	91.66
T_3: NAA @ 100ppm	50.00	32.92	13.25	6.13	90.00
T_4: NAA @ 200ppm	49.46	27.74	9.63	6.36	91.00
T_5: Thiourea @ 500ppm	51.63	35.36	14.65	6.48	89.66
T_6: Thiourea @ 1000ppm	45.40	27.22	9.07	6.44	89.33
T_7: Ethrel @ 500ppm	44.30	20.24	5.90	6.21	88.00
T_8: Ethrel @ 1000ppm	43.10	22.94	7.00	6.48	87.00
T_9: Control	48.26	24.98	6.59	5.63	89.66
S.E. ±	1.94	1.19	0.43	0.07	1.51
C.D. (P=0.05)	5.84	3.57	1.3	0.23	NS
C.V. %	7.06	7.25	7.41	2.18	2.91

NS=Non-significant

500 ppm significantly increased seed yield/plant and seed yield /ha (35.36 g) and (14.65 q/ha) as presented in Table 4. It might be due to the exogenous application of plant growth regulators (thiourea) stimulated the effect of natural occurring hormones that accelerated and modified the growth and development of plants and also enhanced the photosynthetic activity, which ultimately increased yield attributing parameters. Similar results were also reported by Sharma *et al*. (2004), Yadav *et al*. (2004) and Burman *et al*. (2006) in cluster bean. Significantly higher 100 seed weight (6.65 g) was under T_1 (GA_3 @ 50 ppm) as compared to control and rest of the treatments. This might be due to better translocation of photosynthates from source to sink. These could be because of heavier build up of sufficient food reserves diversified towards the developing pods and seeds due to spraying of growth regulators (Bhatt and Singh, 1997). This might have favoured increased supply of photosynthates and mobilization efficiency in plants giving rise to more developed seeds in the pods. The results are in agreement with the findings of Bhatt and Singh (1997) in okra, Goudappalavar (2000) in tomato and Patil (2005) in brinjal. Seed germination (%) was found to be non-significant. Numerically higher germination (93.33 %) was recorded under T_1 (GA_3 @ 50 ppm) and the minimum germination (87.00 %) was recorded with the treatment T_8 (ethrel @ 1000 ppm). Seedling length was found to be non-significant (Table 5). Numerically higher seedling length (17.06 cm) was recorded under T_4 (NAA @ 200 ppm) and the minimum seedling length (12.67 cm) was recorded with the treatment T_6 (thiourea @ 1000 ppm). Among seed quality parameters, seedling dry weight exhibited marked variations due to growth regulators spray. The seed quality parameters showed significant differences among the treatments. Higher values of most of quality parameters was noted in the treatment of GA_3 @ 50 ppm (9.66×10^{-2} g). The increase in seed quality parameters obtained due to spraying of (GA_3 50 ppm) might be due to higher percentage of bolder seeds coupled with the higher test weight of seeds due to increased translocation and assimilation of photosynthates from source to the sink (seeds). Similar findings were also reported by Balakumar and Balsubramanian (1988), Singh and Lal (1995), Revanappa (1993) and Balaraj (1999) in chilli and Patil (2005) in brinjal. The results of the present investigation revealed that foliar application of GA_3 @ 50 ppm at the time of flower initiation stage of okra plants was proved to be better in recording higher seed quality parameters compared to control. The results presented in Table 5 revealed that the response of different growth regulators on SVI-I was found to be non-significant. Numerically higher SVI-I (1551.73) was found with T_4 *i.e.* NAA @ 200 ppm. Whereas, minimum SVI-I was observed under T_6 (thiourea @ 1000 ppm) (1130.56) (Fig. 1). Among the seed quality parameters, vigour index-II exhibited marked variations due to growth regulators spray. This quality parameter was significantly higher in the treatment of GA_3 @ 50 ppm (*i.e.* 9.02). The increase in seed quality parameter obtained due to spraying of GA_3 50 ppm might be due to higher percentage of bolder seeds coupled with the heavier seed weight due to increased translocation and assimilation of photosynthates from source to the sink (seeds). Similar findings were also reported by Balakumar and Balsubramanian (1988), Singh and Lal (1995), Revanappa (1993) and Balaraj (1999) in chilli and Patil (2005) in brinjal. The results of the study revealed that foliar spraying of GA_3 @ 50 ppm at the time of flower initiation stage of okra plants was proved to be better in recording higher seed quality parameters compared to control.

Conclusion :

Among the different treatments thiourea @ 500 ppm was the best for growth and yield characters *viz*., leaf area (cm^2), LAI, total dry weight of plant (g), number of pods per plant, length of pod (cm), number of seeds per pod, seed yield per plant (g) and seed yield per hectare (q). Among the different treatments GA_3 @ 100 ppm was the best for growth and yield

Table 5 : Effect of plant growth regulators on seedling length (cm), seedling dry weight $\times 10^{-2}$ (g) seedling vigour index-I and seedling vigour index-II in okra cv. GAO-5

Treatments	Seedling length (cm)	Seedling dry weight $\times 10^{-2}$ (g)	Seedling vigour index-I	Seedling vigour index-II
T_1: GA_3 @ 50ppm	14.83	9.66	1384.83	9.02
T_2: GA_3 @ 100ppm	14.73	8.06	1351.10	7.39
T_3: NAA @ 100ppm	15.60	8.10	1404.60	7.29
T_4: NAA @ 200ppm	17.06	8.23	1551.73	7.48
T_5: Thiourea @ 500ppm	16.13	8.70	1448.00	7.80
T_6: Thiourea @ 1000ppm	12.67	8.80	1130.56	7.86
T_7: Ethrel @ 500ppm	16.33	6.50	1434.66	5.73
T_8: Ethrel @ 1000ppm	15.67	5.60	1360.50	4.87
T_9: Control	15.70	7.53	1409.83	6.75
S.E. ±	0.91	0.12	82.91	0.17
C.D. (P=0.05)	NS	0.36	NS	0.53
C.V. %	14.83	9.66	10.36	4.35

NS=Non-significant

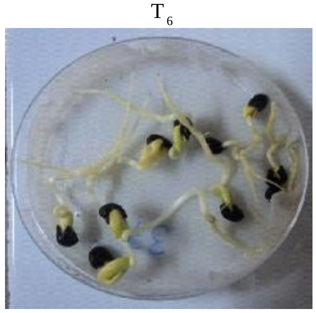
T_1

T_5

T_2

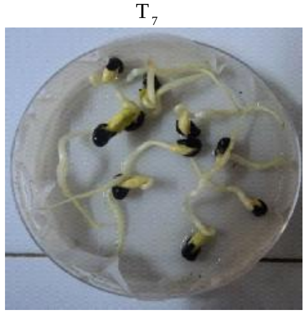
T_6

T_3



T_7

T_4



T_8

T_9

T_1: GA_3 @ 50ppm T_4: NAA @ 200ppm T_7: Ethrel @ 500ppm
T_2: GA_3 @ 100ppm T_5: Thiourea @ 500ppm T_8: Ethrel @ 1000ppm
T_3: NAA @ 100ppm T_6: Thiourea @ 1000ppm T_9: Control (Water spray)

Fig. 1 : Seedling growth influence by various plant growth regulators

characters *viz*., plant height (cm), number of leaves, number of internodes per plant, days to flower initiation, days to 50 (%) flowering and GA_3 @ 50 ppm was the best for growth and seed quality characters *viz*., average pod weight (g), 100 seed weight (g), seedling dry weight (g) and seedling vigour index-II.

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