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MODULATING OKRA SEED YIELD AND QUALITY THROUGH APPLICATION OF PLANT GROWTH INHIBITORS

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ABSTRACT

The investigation entitled “Modulating Okra Seed Yield and quality through Application of Plant Growth Inhibitors"was conducted during kharif season (June 2021–March 2022) at the Chilli and Vegetable Research Unit, Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola. The study aimed to determine the effect of different growth inhibitors on the growth, seed yield, and quality of okra, and to identify suitable inhibitors and concentrations for optimal results. The experiment was arranged in a Randomized Block Design with three replications, consisting of PBZ (100, 200, 300 ppm), CCC (300, 400, 500 ppm), Ethrel (100, 200, 300 ppm), and a control treatment. Foliar sprays of growth inhibitors at 30 and 50 days after sowing significantly influenced various growth parameters. Minimum plant height, internodal length, and duration for flower initiation, 50% flowering, first fruiting, first harvesting, and last harvesting were recorded with CCC at 500 ppm. Qualitative traits such as the highest number of branches per plant and fruit length were observed with Ethrel at 300 ppm, while maximum leaf area was noted with PBZ at 300 ppm. For yield-contributing traits, CCC at 500 ppm resulted in the greatest number of fruits per plant, fruit diameter, seeds per fruit, seed weight per fruit, seed yield per plant, per plot, and per hectare. Additionally, CCC at 500 ppm produced seeds with superior test weight, graded seed yield, and germination percentage, making it the most effective treatment in improving yield and seed quality parameters in okra.
***Keywords* :** Plant growth inhibitors, PBZ, CCC, Ethrel, seed yield.

Introduction

Okra (*Abelmoschus esculentus* L. Moench), a member of the family Malvaceae, is considered to have its origin in Tropical America (Elkhalifa *et al*., 2021). It is widely cultivated as an annual herbaceous vegetable crop. It is often a cross-pollinated crop. It has a diploid chromosome number 2n=130 (Sheferie *et al*., 2023). It is also known as ‘Lady’s finger’ or ‘Bhendi’. Its tender green fruits are used as a vegetable and mostly sold in the fresh state, but sometimes they can be sold in canned or dehydrated form. The okra roots and stems are used for clearing the cane juice for gur or brown sugar preparation (Thai *et al*., 2012). In Turkey, its ripe seeds are crushed and ground, and it is used as a substitute for coffee (Viernes *et al*., 2024). Okra is also a potential source of natural fibers suitable for textile, paper and other engineering applications. (Gupta, 2021). The crop is easy to grow and suited to regions with moderate rainfall. Okra is a tropical crop. The seeds of okra are rich in vitamins, minerals, and medically important compounds. They contain substantial amounts of vitamins such as A, C, K, and B6, along with minerals like magnesium, calcium, potassium, iron, and zinc. The mucilage and tannins contribute to various biological activities, including antioxidant and anti-inflammatory effects (Elkhalifa *et al*., 2021) Fruit is useful against genitor-urinary disorders, spermetorrhoea and chronic dysentery. Fruits are also dried or frozen for use during off-season (Benchasri, 2012). Scientific seed production highlights the need for quality seed to achieve higher yields and better-quality vegetables. Limited availability of good seed is a major cause of low vegetable production. Although the seed production in vegetables is highly profitable, the growers are reluctant to enter this market because of a lack of technical expertise in production. (Fathima *et al*., 2024). Recently, reliable practices using growth inhibitors have been developed to improve vegetable seed quality, gaining popularity in seed production technology, especially for vegetable crops. Plant growth inhibitors are useful for the augmentation of physico-biochemical processes (Deshmukh *et al*., 2024). The yield potential of okra can be increased with the adoption of scientific cultivation technology, including the use of growth inhibitors (Sheferie *et al*., 2023). Growth inhibitors help in efficient utilisation of metabolites, which play a vital role in the regulation of plant system, formation of pods, quality seed production, etc., in crops like okra (Wang *et al*., 2022). Plant growth inhibitors are substances other than chemicals which are used in trace amounts to enhance or retard the growth of plants, such as Paclobutrazol (PBZ), Cycocel (CCC), and Ethrel. The plant growth inhibitor Paclobutrazol (PBZ) has been reported to be effective for suppression of apical dominance, thus increasing lateral shoots and increasing fruit as well as seed yield (Kumar *et al*., 2023). Cycocel (CCC) plays a major role in inhibiting the height of the plant by lowering internodal length and simultaneously increasing the formation of lateral shoots, thereby, plant bears a higher number of fruit-bearing shoots (Elateeq *et al*., 2022). Ethrel lessens the problem of shattering by limiting the flower and pod as well as seed abortions. It also enhances the crop by manipulating the source relationship at the pod development stage, when applied in a foliar spray during its vegetative growth stage. (Dhal *et al*., 2010). Thus, the experiment was conducted to ascertain the effect of different growth inhibitors on growth and seed yield of okra and its quality, to find out the suitable growth inhibitors and its concentration on better growth, seed yield and quality of okra.

Materials and Methods

The investigation was carried out during kharif (June, 2021–March, 2022) at the Instructional Farm, Department of Vegetable Science, Faculty of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in randomized block design with three replications and ten treatments on medium black soil with uniform in texture, colour and having good drainage.

Two foliar sprays of plant growth inhibitors were applied at 30 and 50 days after sowing (DAS) using a calibrated hand knapsack sprayer. Applications were made on clear, calm days (first on 2 Aug 2021, second on 22 Aug 2021) and each plant was uniformly wetted. Stock and working solutions were prepared in ppm using distilled water from commercial formulations: paclobutrazol (Cultar 23% EC), chlormequat chloride (Lihocin 50% EC) and ethephon (Ethrel 39% EC). PBZ stocks: 1000 ppm (4.3 mL Cultar per L) and 500 ppm (2.15 mL per 0.5 L); working solutions of 100, 200 and 300 ppm were obtained by dilution. CCC stocks: 1000 ppm (2.0 mL Lihocin per L) and 500 ppm (1.0 mL per 0.5 L); working solutions of 400, 500 and 600 ppm were obtained by dilution. Ethrel stock: 1000 ppm (2.5 mL Ethrel per L); working solutions of 100, 200 and 300 ppm were obtained by dilution. Sprays were applied immediately after preparation; volumes per plot were adjusted to ensure full canopy coverage.

Results and Discussion

The results and discussion of an experiment “Influence of plant growth inhibitors on growth and seed yield of okra” which was carried out during kharif (June, 2021-March 2022) at Chilli and Vegetable Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.).

The observations were recorded on various parameters viz., pre-harvest observations, post-harvest observations and seed quality of okra. The observations recorded during the course of investigation were statistically analyzed, presented under appropriate headings and subheadings and discussed in the light of available literature. Similarly, the data has been interpreted with the help of histograms. Attempts have also been made to provide appropriate reasoning for the result obtained during the course of investigation.

Plant height (cm)

The data in respect of plant height were recorded at 60 and 90 DAS and were presented in Table 1. and illustrated in Figure. 1.

At 60 DAS, significant differences were found in respect of plant height. The data from Table 1, clearly expressed that, significantly the minimum (115.45 cm) plant height was recorded with application of inhibitor CCC at the concentration of 500 ppm (T6). It was found statistically at par with (117.40 cm) the treatment T3 and (117.82 cm) the treatment T6, in which the inhibitor PBZ was applied at the concentration of 300 ppm as well as ethrel at the concentration of 300 ppm (T9), respectively. However, significantly maximum plant height (142.86 cm) was recorded, when there was no application of plant inhibitors (T10) in okra.

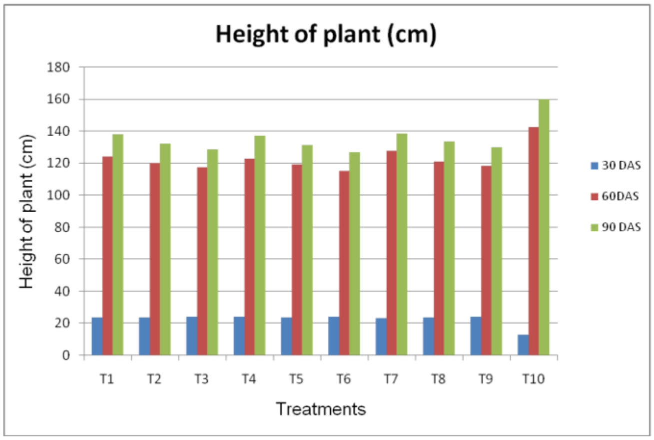

Fig. 1 : Effect of plant growth inhibitors on height of plant (cm)

At 90 DAS, significant differences were found in respect of plant height. The data from Table 1 clearly showed that, significantly, the minimum (126.89 cm) plant height was recorded with application of inhibitor CCC at the concentration of 500 ppm (T6). It was found statistically at par with treatments T2 (PBZ 200ppm), T3 (PBZ 300ppm), T5 (CCC 500 ppm), and T9 (Ethrel 300ppm). However, significantly maximum plant height (160.18 cm) was recorded when there was no application of plant inhibitors (T10) in okra.

Table 1: Effect of plant growth inhibitors on plant height (cm),Internodal length (cm), Number of branches plant^{1}, Days required for flower initiation, Days required for first fruiting, Days required for first 50% flowering, Leaf area (cm$^{2)}$

Treatments	Treatment details	Plant height (cm)		Internodal length (cm)		Number of branches plant^{1}		Days required for flower initiation	Days required for first fruiting	Days required for first 50% flowering	Leaf area (cm$^{2)}$
		60DAS	90DAS	60DAS	90DAS	60DAS	90DAS				
T_1	PBZ 100ppm	124.42	138.13	4.41	3.73	4.63	6.67	40.00	45.00	52.33	301.36
T_2	PBZ 200ppm	120.32	132.46	4.24	3.47	5.33	8.40	39.33	43.66	50.33	312.48
T_3	PBZ 300ppm	117.40	129.01	3.74	3.24	6.36	9.30	37.33	42.00	47.67	324.50
T_4	CCC 300ppm	122.97	137.31	4.38	3.69	4.96	7.33	39.66	44.66	51.00	300.92
T_5	CCC 400ppm	119.23	131.68	4.18	3.42	5.40	8.26	37.66	42.33	48.00	311.05
T_6	CCC 500ppm	115.45	126.89	3.44	2.97	6.87	10.83	36.66	41.33	47.00	320.16
T_7	Ethel 100ppm	128.11	138.90	4.83	3.95	5.06	7.93	41.67	46.00	48.66	300.05
T_8	Ethel 200ppm	121.13	133.98	4.26	3.50	5.70	8.73	42.00	47.00	53.00	308.74
T_9	Ethel 300ppm	117.82	130.32	3.81	3.33	7.60	11.26	42.33	47.33	54.66	316.28
T_{10}	Absolute control	142.86	160.18	5.86	5.55	3.26	5.40	43.00	48.00	55.00	296.49
	F Test	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
	SE (m) ±	0.80	2.28	0.21	0.17	0.46	0.67	0.29	0.28	0.23	4.10
	CD *p*=0.05	2.39	6.82	0.63	0.51	1.38	2.02	0.87	0.86	0.71	12.30

The effect of different plant growth inhibitors on plant height in Table 1 revealed that foliar application of different growth inhibitors significantly retards the plant height of okra. The reason for the reduction in the height of the plant might be that growth inhibitors produce shorter stems and internodes its length through inhibition of cell division. Growth inhibitors interact with gibberellins or lower the levels of diffusible auxin and thereby suppressed vegetative growth as described by Pateliya *et al*. (2008) and Malshe *et al*. (2020) in okra.

Internodal Length (cm)

The data in respect of internodal length were recorded at 60, and 90 DAS and were presented in Table 1. and illustrated in Figure. 2. At 60 DAS, significant differences were found in respect of internodal length. The data from Table 1 clearly showed that, significantly, the minimum (3.44 cm) internodal length was recorded with application of inhibitor CCC at the concentration of 500 ppm (T6), which was significantly superior over all other treatments. However, significantly, the maximum (5.86cm) internodal length was recorded when there was no application of plant inhibitors (T10) in okra.

At 90 DAS, significant differences were found in respect of internodal length of the okra plant. The data from Table 1 clearly observed that, significantly, the minimum (2.97 cm) internodal length was recorded with application of inhibitor CCC at the concentration of 500 ppm (T6). It was found statistically at par with treatments T2 (PBZ 200ppm), T3 (PBZ 300ppm), T5 (CCC 500ppm) and T9 (Ethrel 300ppm). However, a significantly maximum (5.55 cm) internodal length was recorded when there was no application of plant inhibitors (T10) in okra.

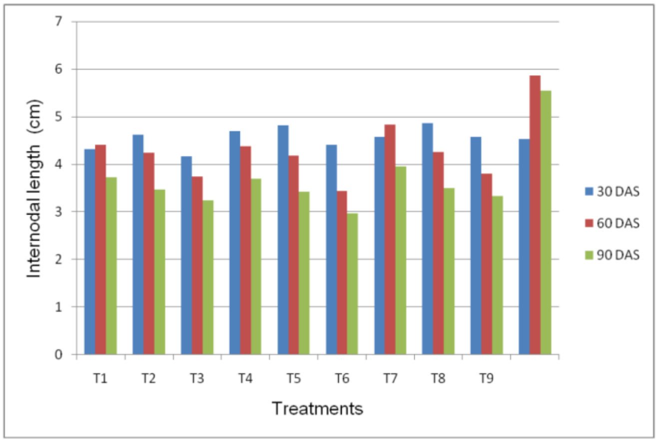

Fig. 2 : Effect of plant growth inhibitors on internodal length (cm)

The growth inhibitors were effective in decreasing the internodal length significantly, than the control treatment. Minimum internodal length was recorded in treatment T6, with application of growth inhibitor CCC at the concentration of 500 ppm at 60 and 90 DAS, respectively. The length of internodes was decreased with an increase in the concentration of growth inhibitors. The growth of internodes was short in the okra plant mainly due to growth inhibitors application, which restricted cell division and cell elongation in the apical meristem; hence length of internodes might be decreased. These results were in agreement with Pateliya (2008) and Malshe *et al*. (2020) in okra.

Number of branches plant^{1}

The data with respect to the number of branches plant^{1} were recorded at 60, and 90 DAS and were presented in Table 1. At 60 DAS, significant differences were found in respect of the number of branches plant^{1}. The data from Table 1 clearly exhibited that, significant differences among all the treatments were found. Significantly, the superior and maximum (7.60) number of branches plant^{1} was recorded in the treatment Ethrel applied at the concentration of 300 ppm (T9) as compared to other treatments. It was found statistically at par with treatments T3 (PBZ 300ppm). However, a significantly minimum (3.26) number of branches plant^{1} was recorded when there was no application of plant inhibitors (T10) in okra.

At 90 DAS, significant differences were found in respect of the number of branches plant^{1}. The data from Table 3 showed that, significantly the maximum (11.26) number of branches plant^{1} was recorded with application of inhibitor Ethrel at the concentration of 300 ppm (T9). It was found statistically at par with treatments T3, in which PBZ was applied at the concentration of 300ppm, and T6 in which CCC was applied at the concentration of 500ppm. However, a significantly minimum (5.40) number of branches plant^{1} was recorded, without the application of a plant growth inhibitor (T10) in okra.

The maximum number of branches plant^{1} was recorded with the application of growth inhibitors, with an increase in concentration at 60 and 90 DAS in okra. The increase in the number of branches might be due to suppression of apical dominance, with the result that several meristems start functioning at a time, leading to more number of branches, which was in agreement with the findings of Rafeekher *et al*. (2001).

Days Required for Flower Initiation.

The data with respect to days required for flower initiation were noted and were presented in Table 1 in okra. The data from Table 1 exhibited significant differences among the various treatments in okra, and noticed that significantly the minimum number of days (36.66) was required to flower initiation with application of inhibitor CCC at the concentration of 500ppm (T6). It was found statistically at par with (37.33 days) in the treatment T3 in which the PBZ was applied at the concentration of 300ppm. Treatment T7 (ethrel 100ppm) and T8 (ethrel 200ppm), T8 (ethrel 100ppm) and T9 (ethrel 300ppm) were found to be at par with each other. However, a significantly maximum number of days (43.00 days) were required for flower initiation, when there was no application of plant inhibitor (T10), it was followed by (42.00 days) treatment T9, in okra.

The initiation of first flowering in okra was found to be significantly affected due to application of plant growth inhibitors. Higher concentration of cycocel and paclobutrazol induced early flowering, which might be due to suppression of vegetative growth, which led to less demand for food materials synthesized by the treated plant. Thus, the excessive carbohydrate reserves in axillary buds and which might have induced early flowering and accelerated the reproductive phase of the plant. The increased concentration of ethrel delayed first flowering. It might be due to a decrease in the endogenous gibberellin levels in the plants by ethrel. Furthermore, increased evolution of ethrel artificially in turn reduces the activity of gibberellins and increases the synthesis of abscissic acid in the okra plant. These results were in corroborative with Malshe *et al*. (2021) in okra.

Days required for first fruiting.

The data in respect of days required for first fruiting were recorded and were presented in Table 1.

The data from Table 1 clearly revealed that, significantly, the minimum number of days (41.33) was required for first fruiting due to the application of inhibitor CCC at the concentration of 500ppm (T6). It was found statistically at par with treatments T3, in which PBZ was applied at the concentration of 300ppm. However, significantly maximum number of days (48.00) required for first fruiting was recorded when there was no application of growth inhibitor (T10) in okra.

Days required for first fruiting in okra were significantly affected due to the application of plant growth inhibitors. Significantly, the minimum number of days was required for first fruiting with the application of growth inhibitors as compared to control treatments. This might be due to the suppression of vegetative growth and induction of the early reproductive phase. These results were also in conformity with earlier findings of Khel *et al*. (2025) in okra.

Days Required for 50% Flowering.

The data with respect to the days required for 50 % flowering were recorded and were presented in Table 1. The data on days required for 50% flowering is depicted in Table 1, showing significant differences among the different treatments. The data from Table 1, clearly showed that, significantly the minimum number of days (47.00 days), was required for 50% flowering in the experimental plot treated with inhibitor CCC at the concentration of 500 ppm treatment (T6). It was found statistically at par with (47.67 days) treatment T3, in which inhibitor PBZ was applied at the concentration of 300ppm. However, significantly maximum number of days (55.00) required for 50% flowering was recorded, without any application of growth inhibitor (T10) in okra. Which was followed by (54.66 days) treatment T9 in okra.

The 50% flowering in okra was found to be significantly affected due to the application of plant growth inhibitors in okra. Higher concentration of cycocel and paclobutrazol, as well as lower concentration (100 ppm) of ethrel, induced early flowering, which might be due to suppression of vegetative growth and induction of the early reproductive phase. Similar findings were also reported by Rajput *et al*. (2011), in okra.

Leaf Area (cm^2)

The data with respect to leaf area are recorded and presented in Table 7 and illustrated in Figure. 1.

The data on leaf area was presented in Table 1, and it reflected significant differences among the different treatments. The data from Table 1 expressed that, the maximum (324.48 cm^2) leaf area was recorded with application of inhibitor PBZ at the concentration of 300ppm (T3). It was found statistically at par with the treatments T2 (PBZ 200ppm), T6 (CCC 500ppm), and T9 (Ethrel 300ppm). However, the minimum (296.49 cm^2). Leaf area was recorded when there were no applications of the growth inhibitor (T10) in okra.

The leaf area increased significantly with an increase in growth inhibitors concentration. The reduction in plant height also minimized the number of leaves also minimized leaves were the sites of photosynthesis; ultimately, it maximized the leaf area and leaf area influenced the photosynthetic capacity of the plant. This was in accordance with the findings of Weraduwage *et al*. (2025) in okra.

Days Required for First Harvesting

The data with respect to the days required for first harvesting were recorded and presented in Table 8 and illustrated in Figure 2.

The data on days required for first harvesting was given in Table 2, indicating significant differences among the different treatments. The data from Table 2 revealed that, significantly, the minimum (80.00) days required for first harvesting were recorded with the application of growth inhibitor CCC at the concentration of 500ppm (T6) in okra. This was followed by (82.33 days) found in treatment (T3), also with growth inhibitor PBZ at the concentration of 300 ppm. Whereas, significantly maximum (91.66) days required for first harvesting were noted, when there was no application of growth inhibitor (T10) in okra.

Table 2: Effect of plant growth inhibitors on the days required for first harvesting, Days required for the last harvesting, Number of fruits plant^{1}, Length of fruits (cm), Diameter of fruits (cm), Number of seeds fruit^{1}, Weight of seed fruit^{1} (g), Seed yield plant^{1} (g), Seed yield ha^{1} (kg).

Treatments	Treatment details	Days required for first harvesting	Days required for the last harvesting	Number of fruits plant^{1}	Length of fruits (cm)	Diameter of fruits (cm)	Number of seeds fruit^{1}	Weight of seed fruit^{1} (g)	Seed yield plant^{1} (g)	Seed yield ha^{1} (kg)
T_1	PBZ 100ppm	87.33	108.66	11.80	11.53	1.37	55.13	2.84	33.56	1016
T_2	PBZ 200ppm	85.00	107.00	12.63	12.37	1.42	61.46	3.09	38.97	1177
T_3	PBZ 300ppm	82.33	98.67	14.50	13.07	1.63	63.67	3.40	49.01	1418

T_4	CCC 300ppm	86.66	108.00	11.50	11.76	1.39	57.93	3.10	35.99	1090
T_5	CCC 400ppm	84.00	105.33	12.93	12.46	1.44	62.13	3.19	41.26	1248
T_6	CCC 500ppm	80.00	97.66	14.86	13.29	1.78	64.93	3.43	51.14	1485
T_7	Ethrel 100ppm	88.00	108.00	11.73	12.29	1.29	54.80	2.78	32.75	993
T_8	Ethrel 200ppm	90.66	110.66	12.26	12.97	1.40	61.13	2.98	36.53	1107
T_9	Ethrel 300ppm	91.00	111.00	13.26	13.44	1.60	62.53	3.20	44.21	1346
T_{10}	Absolute control	91.66	112.00	11.31	10.84	1.09	52.43	2.04	27.12	817
	F Test	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
	SE (m)±	0.24	0.36	0.64	0.20	0.06	1.16	0.12	2.38	0.70
	CD p=0.05	0.73	1.08	1.93	0.60	0.17	3.49	0.37	7.08	2.09

Days Required For Last Harvesting

The data with respect to the days required for the last harvesting were recorded and are were presented in Table 9 and illustrated in Figure 2. The data on days required for the last harvesting were presented in Table 2, and they represented significant differences among the treatments. The data from Table 2 clearly expressed that, significantly, the minimum (97.66) days required for last harvesting were recorded with the application of inhibitor CCC at the concentration of 500ppm (T6). It was found statistically at par with (98.67 days) treatment T3, in which the inhibitor PBZ was applied at the concentration of 300ppm. Whereas, significantly maximum (112.00) days required for last harvesting were recorded, when there was no application of plant inhibitor (T10) in okra.

Number of Fruits Plant[1]

The data with respect to the number of fruits plant[1] in okra were recorded and were presented in Table 2. The data on the number of fruits plant[1] was deplicated in Table 2, showing the significant differences among the treatments. Significantly, the maximum (14.86) number of fruits plant[1] was recorded with the application of growth inhibitor CCC at the concentration of 500ppm (T6). It was found statistically at par with treatment T3 (PBZ 300ppm), T5 (CCC 400ppm), and T9 (ethrel 300ppm). However, a significantly (11.31) minimum number of fruits plant[1] was recorded when there was no application of growth inhibitor (T10) in okra.

The number of fruits plant[1] in okra was found to be significantly affected due to the application of plant growth inhibitors. The increasing number of fruits plant[1] might be due to the application of higher concentrations of growth inhibitors to treated plants, which had a higher number of internodes, i.e., short internodal length, ultimately resulting in the production of a larger number of fruits. Significant improvement in yield might be due to growth inhibitors, reduced height of the plant and increased branching, resulting in diversion of food material for the improvement of flowering and fruiting. It might also be due to the result of a decrease in the level of auxin, this was resulted in an increase in the level of cytokinins, which might have resulted in more flowering and fruiting as described by Pateliya *et al*. (2014), Khel *et al*. (2025), Harpeet *et al*. (2025) in okra.

Length of Fruit (cm)

The data with respect to the length of fruit in okra were recorded and were presented in Table 2.

The data on the length of fruit in okra was depicted in Table 2, clearly showing significant differences among the treatments. Significantly, the maximum (13.44 cm) length of fruits was recorded with the application of inhibitor ethrel at the concentration of 300ppm (T9). It was found statistically at par with treatment T3 (PBZ 300ppm), T6 (CCC 500ppm), and T8 (ethrel 200ppm). However, the significantly lowest (10.84 cm) length of fruit was recorded when there was no application of a growth inhibitor in okra.

The response of different growth inhibitors to the fruit length of okra differed significantly. The maximum fruit length was observed in the plant treated with growth inhibitors and the minimum was in the control. This might be due to growth inhibitors that trigger off the mobilization of metabolites, produced in other parts of the plants, into the fruit. Thus, fruit length could be promoted and stem growth inhibited. These findings were in accordance with the results narrated by Goetz *et al*. (2021) in okra.

Diameter of Fruit (cm)

The data with respect to the diameter of fruit in okra were recorded and were presented in Table 2.

The data on the diameter of fruit was given in Table 2, which clearly showed significant differences among the treatments. Significantly, the maximum (1.78 cm) diameter of fruit was recorded with the application of inhibitor CCC at the concentration of 500ppm (T6). It was found statistically at par with treatments T3 (PBZ 300ppm), T9 (Ethrel 300ppm). However, a significantly minimum diameter of fruit (1.09) was recorded, without any application of growth inhibitor (T10) in okra.

The response of different growth inhibitors to the diameter of fruit in okra differed significantly. The maximum diameter of fruit was recorded in the treatment with the application of growth inhibitors in okra. The reason for the increase in fruit diameter might be due to the increased rate of respiration and photosynthesis of growth inhibitor-treated plants than the plants in the control treatment. These results were in accordance with the results explained by Pateliya *et al*. (2014), and Sanganagoud (2014) in okra.

Number of Seeds Fruit[1]

The data with respect to the number of seeds fruit[1] of okra were recorded and were presented in Table 2.

The data on the number of seeds fruit[1] was depicted in Table 2, which exhibited significant differences among the treatments. Significantly, the maximum (64.93) number of seeds fruit[1] was recorded with the application of growth inhibitor CCC at the concentration of 500 ppm (T6). It was found statistically at par with treatments T3 (PBZ 300ppm), T5 (400ppm), and T9 (Ethrel 300ppm). However, a significantly minimum number of seeds fruit[1] (52.43) was recorded when there was no application of growth inhibitor (T10) in okra.

The number of seeds fruit[1] in okra was found to be significantly affected due to application of plant growth inhibitors. The increasing number of seeds fruit[1] might be due to the stimulating effect of GA_3 in plants like okra on the complete growth of the plant, which resulted in the formation of larger quantities of synthesized products, so the assimilates were distributed to pods, ultimately to the seeds naturally. It was a proven fact that, as the concentration of inhibitors increases, the production of GA_3 decreases. Comparing to the concentration of inhibitors, the maximum GA_3 would be produced in plants treated with a lower concentration. These results were in close conformity with the results of Sanganagoud (2014) in okra.

Weight of Seed Frui[1] (g)

The data in respect to the weight of seed fruit[1] in okra were recorded and were presented in Table 2.

The data on the weight of seed fruit[1] in okra was presented in Table 2, clearly noticed significant differences among the treatments. Significantly, the maximum (3.43 g) weight of seed fruit[1] was recorded with the application of growth inhibitor CCC at the concentration of 500ppm (T6). It was found statistically at par with treatments T3 (PBZ 300ppm), T5 (400ppm), and T9 (Ethrel 300ppm). However, a significantly minimum weight of seed fruit[1] (2.04g) was recorded when there was no application of growth inhibitor (T10) in okra.

The weight of seeds fruit[1] in okra was found to be significantly affected due to application of plant growth inhibitors. The increasing weight of seeds fruit[1] might be due to the accumulation of carbohydrates, leaf area, and chlorophyll content of leaves that produced more photosynthates towards the economic parts of the plant like okra seed producing one. These findings were in agreement with the findings of Sanganagoud (2014) and Kumar *et al*. (2018) in okra.

Seed Yield Plant[1] (g)

The data with respect to seed yield plant[1] in okra were recorded and were presented in Table 2. and illustrated in Fig.3.

The data on seed yield plant[1] in okra is given in Table 2, which showed significant differences among the treatments. Significantly, the maximum (51.14 g) seed yield plant[1] was recorded with the application of growth inhibitor CCC at the concentration of 500ppm (T6). It was found statistically at par with treatment T3 (49.01 g) with application of growth inhibitor PBZ at the concentration of 300ppm and T9 (44.21 g) with application of growth inhibitor ethrel at the concentration of 300ppm. However, significantly minimum (27.12 g) seed yield plant[1] was recorded when there was no application of growth inhibitors (T10) in okra.

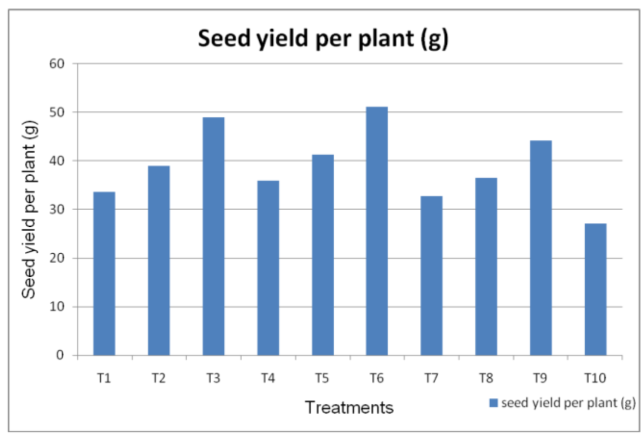

Fig. 3 : Effect of plant growth inhibitors on seed yield per plant (g)

The response of different growth inhibitors on seed yield plant[1] in okra differed significantly. The maximum seed yield plant[1] was noticed under the treatment of foliar application of growth inhibitors as compared to control treatments. The increasing seed yield in the plant of okra treated with growth inhibitors might be due to a decrease in the plant height and an increase in the number of branches. As a result, there would be in diversion of the flow of food materials for increasing in flowering and fruiting in such okra plants. Similar trends of results were also observed by Singh *et al*. (1995) in okra.

Seed Yield ha^{1}(kg)

The data with respect to seed yield ha^{1} in okra were recorded and were presented in Table 2. and illustrated in Fig.4.

The data on seed yield ha^{1} in okra was given in Table 2, which exhibited significant differences among the various treatments. Significantly, the maximum (1485 kg) seed yield ha^{1} was recorded with the application of growth inhibitor CCC at the concentration of 500ppm (T6). It was found statistically at par with treatment T3 (1418 kg) with application of growth inhibitor PBZ at the concentration of 300ppm and T9 (1346 kg), with application of growth inhibitor ethrel at the concentration of 300ppm. However, significantly minimum (817 kg) seed yield ha^{1} was recorded, when there was no application of growth inhibitors (T10) in okra.

The response of different growth inhibitors on seed yield ha^{1} differed significantly. The maximum seed yield ha^{1} in okra was recorded under the plants treated with growth inhibitors as compared to the control treatment. The maximum seed yield of okra might be due to triggering effects of physiological processes that ultimately increased in individual fruit weight, seed weight, fruit size, and the number of fruits of okra.

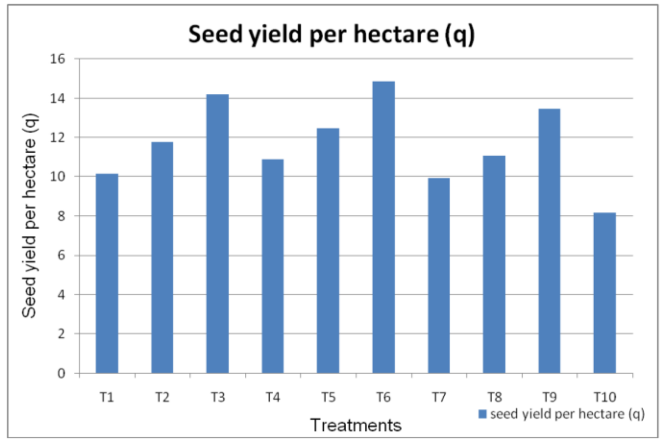

Fig. 4 : Effect of plant growth inhibitors on seed yield per hectare (q)

Application of inhibitors also reduced the okra plant height and increased the number of branches, which might result in diversion of flow of food materials for improvement of flowering, fruit set, fruit yield, and finally the Seed yield. These results were in accordance with the results obtained by Prasad and Shrihari (2008), Pateliya *et al*. (2008), and Rajput *et al*. (2011) in okra.

Table 3: Effect of plant growth inhibitors on test weight of seed (g), Graded seed yield (%), Germination percentage (%).

Treatments	Treatment details	Test weight of seed (g)	Graded seed yield (%)	Germination percentage (%)
T$_{1}$	PBZ 100ppm	53.33	64.62	72.00
T$_{2}$	PBZ 200ppm	58.06	66.17	74.66
T$_{3}$	PBZ 300ppm	64.43	69.55	78.33
T$_{4}$	CCC 300ppm	55.43	65.48	72.66
T$_{5}$	CCC 400ppm	60.20	66.51	76.66
T$_{6}$	CCC 500ppm	66.77	70.36	80.00
T$_{7}$	Ethrel 100ppm	50.30	64.32	71.33
T$_{8}$	Ethrel 200ppm	56.06	65.64	73.33
T$_{9}$	Ethrel 300ppm	62.06	69.37	78.00
T$_{10}$	Absolute control	49.19	63.94	70.33
	F Test	Sig	Sig	Sig
	SE (m)±	2.11	0.89	1.25
	CD p= 0.05	6.32	2.68	3.75

The data related to the test weight of seed in okra was represented in Table 3, clearly showing the significant differences among the various treatments. The maximum (66.77g) test weight was recorded with application of growth inhibitor CCC at the concentration of 500ppm (T6). It was found statistically at par with treatments T3 (PBZ 300ppm) and T9 (Ethrel 300ppm). However, a significantly minimum (49.19 g) test weight was recorded when there was no application of growth inhibitors (T10) in okra.

The response of different growth inhibitors to the test weight of seed in okra has differed significantly.

The maximum test weight of seed was recorded due to foliar application of growth inhibitors, as compared to control treatments. The maximum test weight of okra seed in the previous study might be due to the fact that assimilates transferred to seeds during filling and maturation time at very faster rate with a higher concentration of every inhibitor might have resulted in a higher test weight of seed. This result was similar to the findings of Gonge *et al*. (2005) in okra.

Graded Seed Yield (%)

The data in respect of graded seed yield was deplicated in Table 19, clearly showed significant differences among the various treatments. Significantly, the maximum (70.36%) graded seed yield of okra was recorded with the application of growth inhibitor CCC at the concentration of 500 ppm (T6). It was found statistically at par with treatments T3 (PBZ 300 ppm) and T9 (Ethrel 300 ppm). However, the significantly lowest (63.94%) graded seed yield percentage was recorded when there was no application of growth inhibitors (T10) in okra.

The response of different growth inhibitors to the graded seed yield of okra differed significantly. The maximum graded seed yield was recorded under foliar application of growth inhibitors over the control treatment. Increased leaf area for production of more photosynthesis and thereafter, assimilates were transferred to the seed during maturation time, thereby increasing the size of the seed, resulting in higher graded seed yield in okra plants treated with inhibitors. These results were similar to the findings of Gonge *et al*. (2005) in okra.

Germination Percentage (%)

The data in respect of germination percentage given in Table 3, reflected significant differences among the different treatments. Significantly, the maximum (80.00%) germination percentage was recorded with the application of growth inhibitor CCC at the concentration of 500 ppm (T6). It was found statistically at par with treatments T3 (PBZ 300 ppm) and T9 (Ethrel 300 ppm). However, a significantly minimum (70.33%) germination percentage was recorded when there was no application of growth inhibitor (T10) in okra.

The growth inhibitors improved the seed quality parameters over the control. The foliar application of growth inhibitors applied at 30 and 50 DAS on the okra plant were recorded the maximum germination percentage. Maximum germination of seed might be due to the fact that, seeds become more viable and vigorous due to proper development of embryo and endosperm by proportionate use of growth inhibitors. These results were in conformity with the earlier findings of Gonge *et al*. (2005) in okra.

Economics of treatment

The data on economics of different treatments in okra was presented in Table no. 4. The data indicated that, maximum gross and net return (742500 Rs /ha^{1} and 556356 Rs /ha^{1} respectively) and maximum benefit cost ratio (3.98) were recorded with application of growth inhibitor CCC at the concentration of 500 ppm (T6). It was found statistically at par with treatments T3 (PBZ 300ppm) and T9 (Ethrel 300 ppm). However, minimum gross and net return (408500 Rs /ha^{1} and 223098 Rs /ha^{1}, respectively) and minimum benefit cost ratio (2.2) were recorded when there was no application of growth inhibitor (T10) in okra.

Table 4: Effect of plant growth inhibitors on the economics of okra seeds

Treatment No.	Treatments	Yield (q ha^{1})	GMR (Rs ha^{1}) at 500 Rs kg^{1}	NMR (Rs. ha^{1})	B :C ratio
T_1	PBZ 100ppm	10.16	508000	320866	2.71
T_2	PBZ 200ppm	11.77	588500	400118	3.12
T_3	PBZ 300ppm	14.18	719000	532614.7	3.78
T_4	CCC 300 ppm	10.90	545000	359153	2.93
T_5	CCC 400 ppm	12.48	624000	438004	3.35
T_6	CCC 500 ppm	14.85	742500	556356	3.98
T_7	Ethrel 100ppm	9.93	496500	310727	2.67
T_8	Ethrel 200 ppm	11.07	553500	367356	2.97
T_9	Ethrel 300 ppm	13.46	711333	525183	3.81
T_{10}	Control	8.17	408500	223098	2.2
	F Test	Sig	Sig	Sig	
	SE(m)±	0.70	8601.2	1041.8	
	CD p=0.05	2.09	25552.6	3095.2	

Conclusion

The application of growth inhibitors significantly enhanced okra seed yield and associated growth attributes. Specifically, foliar application of Cycocel at 500 ppm markedly improved growth parameters, seed yield, yield-contributing characters, and seed quality. Comparable positive effects were also observed with paclobutrazol (300 ppm) and ethrel (300 ppm) treatments, indicating their efficacy in promoting agronomic performance and seed quality in okra.

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