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Effect of spacing and plant growth regulators on seed yield and seed quality parameters in okra [*Abelmoschus esculentus* (L.) moench]

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Abstract
The present investigation entitled "Effect of spacing and plant growth regulators on seed yield and seed quality parameters of okra *Abelmoschus esculentus* (L.) Moench" was conducted for two consecutive seasons (*kharif* 2015 and 2016). Seeds of okra variety GJO 3 were treated with aqueous solution of growth regulators viz., GA_3, IBA and NAA, each at 50, 100 and 150 ppm concentrations and without growth regulators (water soaking). A treated seeds were grown in field with three plant spacing (S_1: 45 cm × 30 cm, S_2: 60 cm × 30 cm and S_3: 60 cm × 45 cm) during *kharif* 2015 and 2016 at the farm of Junagadh Agricultural University, Junagadh in Split Plot Design (Factorial) replicated thrice. Seed yield and seed quality parameters (after harvest) studied were significantly influenced by different plant spacing and application of different plant growth regulators as seed treatment prior to sowing, except seed viability test during both the years of experimentation as well as pooled over years due to spacing. Among spacing, wider spacing of 60 cm x 45 cm (S_3) and among growth regulators, seeds treated with GA_3 150 ppm (T_3) recorded significantly the maximum values for seed yield per plant, 100 seed weight; and all the seed quality parameters (after harvest) studied.

Keywords: growth regulators, okra, spacing, viability

Introduction
Okra *Abelmoschus esculentus* L. (Moench), is an economically important vegetable crop grown in tropical and sub-tropical parts of the world (Tindall, 1986) [27]. Common name of okra is bhindi and lady's finger comes under family Malvaceae. It is an important fruit vegetable crop cultivated in various states of India. Several species of the genus *Abelmoschus* are grown in many parts of the world among them *Abelmoschus esculentus* L. (Moench) is most commonly cultivated in Asia and has a great commercial demand due to its nutritional values.

During 2013-14, okra is gown in the world on an area of 11.17 lakh hectares with a production of 8.71 million tonnes and productivity of 7.8 t/ha (Anon., 2015b) [4]. India ranks first in the world with 6.35 million tonnes (around 70 percent of the total world production) of okra produced from over 5.33 lakh hectares land with a productivity of 11.9 t/ha during 2013-14 (Anon., 2015a) [3]. In Gujarat, okra is grown during 2013-14 on an area of 0.66 lakh hectares with a production of 0.76 million tonnes and productivity of 11.50 t/ha (Anon., 2015a) [3].

The seed is basic element of agriculture that determines the quantitative and qualitative traits of the crop that is going to be harvested later on.

The seed is the prime factor that determines the quantitative and qualitative characteristics of the crop that is going to be harvested later on. So that there is need of enhance the yield of seed and maintain quality. The production can be increased by two means, first by bringing more area under cultivation, which is not possible at present and second by increasing the productivity, which can be possible through development of high yielding varieties and through agronomical/physiological manipulations.

The density of plant population is an important factor, which affect the growth, yield and quality of crops, by efficient utilization of field conditions. It also determines optimum seed rate and improve the value of seed economy. Plant spacing has been found to have an enhancing influence on yielding ability and quality of seed (Feleafel and Ghoneim, 2005; Moniruzzaman *et al*., 2007; Sharma *et al*., 2012; Kumar *et al.*, 2016) [9, 16 24 12].

Plant growth regulators considered as a new generation of agrochemicals when added in small amounts can bring the changes in the phenotypes of plants and affect growth either by enhancing or by stimulating the natural growth regulatory systems from seed germination to senescence (Das and Das, 1995) [7]. These can improve the physiological efficiency of plants including photosynthetic capacity and effective partitioning of assimilates, resulting into

increase in yield. Several reports also indicated that, plant growth regulators effect not only on accelerating germination or growth, but also help in the augmentation of produce (Naylor and Davis, 1950; Ferres, 1951) [17, 10]. Application of plant growth regulator is effective tool in hand of horticulturist to get more yield. Wide range of methods developed for application of growth regulators. Amid them, application of growth hormones directly to seed by seed treatment is well known technique and it has been reported as tool for enhancing germination and vigour and seed yield (Patil *et al.,* 2008) [20].

Keeping this view in mind, an experiment was planned to know the proper density of plants and the optimum dose of plant growth regulators for improving seed yield per plant and its quality parameters in okra.

Materials and Methods

The study entitled "Effect of spacing and plant growth regulators on seed yield and seed quality parameters of okra *Abelmoschus esculentus* (L.) Moench" Seeds of okra variety GJO 3 were treated with aqueous solution of growth regulators *viz*., GA_3, IBA and NAA, each at 50, 100 and 150 ppm concentrations and without growth regulators (water soaking). The growth regulators were applied as seed soaking treatment for 8 hours. A treated seeds were grown in field with three plant spacing (S_1: 45 cm × 30 cm, S_2: 60 cm × 30 cm and S_3: 60 cm × 45 cm) during *kharif* 2015 and 2016 at the Sagdividi Farm, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh in Split Plot Design (Factorial) replicated thrice. Seed yield per plant (g) was recorded in the field followed by seed quality parameters from freshly harvested seeds viz., 100 seeds weight (g). germination percentage (as per ISTA, 1993) [11], seedlings length (cm), seedlings dry weight (mg), seedling vigour index (length) (as per formula given by Abdul Baki and Anderson, 1973) [1], seedling vigour index (mass) (as per formula given by Abdul Baki and Anderson, 1973) [1] and seed viability (%) in the laboratory of the Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh. The data were subjected to statistical analysis of variance following Split Plot Design for individual year as well as polled over years as per the statistical procedure described by Steel and Torrie (1980) [26].

Results and Discussion

Effect of plant spacing on seed yield and seed quality parameters in okra

The analysis of variance for seed yield per plant was carried out for the experimental design (Split Plot Design) for individual years of experimentation (*kharif* 2015 and 2016) as well as pooled over years revealed the existence of significant difference among plant spacing for seed yield per plant during both the years of experimentation (*kharif* 2015 and 2016) as well as pooled over years. The analysis of variance revealed the existence of significant difference among plant spacing for all the seed quality parameters studied (after harvest) during both the years of experimentation (*kharif* 2015 and 2016) as well as pooled over years, except seed viability test (%) during both the years of experimentation and pooled over years (Table 1).

Plants spaced with 60 cm x 45 cm (S_3) recorded significantly the highest seed yield per plant (30.14, 29.93 and 30.04 g) during both the years of experimentation (*kharif* 2015 and 2016) and pooled over years. Significantly the lowest seed yield per plant (19.22, 20.70 and 19.96 g) was recorded by plant spaced at 45 cm x 30 cm (S_1) during both the years of experimentation (*kharif* 2015 and 2016) and pooled over years. Plants spaced at 60 cm x 30 cm (S_2) recorded the seed yield per plant of 24.47g, 25.01g and 24.74g during *kharif* 2015, *kharif* 2016 and pooled over years, respectively (Table 2). The highest seed yield per plant was recorded at wider spacing may be attributed to greater availability of nutrients, moisture and photosynthesis leading to better vegetative growth increased number of flowers, fruits and seed set with proper size and shape of seed. The high seed yield in okra at wider spacing was reported earlier by Moniruzzaman *et al*. (2007) [16], Philip *et al.* (2010) [21], Sharma *et al.* (2012) [24], Maurya *et al.* (2013) [15], El-Waraky (2014) [8] and Madisa *et al.* (2015) [14].

The plants spaced at 60 cm x 45 cm (S_3) recorded significantly the highest test weight (6.16, 622 and 6.19 g) during both the years of experimentation as well as in pooled analysis and it was at par with 60 cm x 30 cm spacing (S_2) during *kharif* 2015 and *kharif* 2016 with a test weight of 5.82 g and 5.95 g, respectively. Significantly the lowest 100 seed weight (5.49, 5.70 and 5.59 g) was noted in the plant spacing of 45 cm x 30 cm (S_1) during both the years of experimentation as well as in pooled analysis (Table 3). The highest seed weight was obtained with wider spacing may be due to proper development of seeds on account of greater availability of food material in seeds. Results of present study are in agreement with the findings of Singh (2003) [25] and Kumar *et al.* (2015) [13].

Significantly the highest germination percentage was recorded by plant spacing 60 cm × 45 cm (S_3) (89.77, 87.03 and 88.40%) during both the years of experimentation (*kharif* 2015 and 2016) as well as in pooled over years and it was at par with plant spacing of 60 cm x 30 cm (S_2) with germination percentage of 88.00 and 84.40 during *kharif* 2015 and *kharif* 2016, respectively (Table 4). This higher germination percentage may be due to higher seed weight and bolder size quality seeds at wider spacing on account of greater availability of food material in seeds due to more availability of nutrients, moisture and sunlight to plants in comparison to closer spacing. Singh (2003) [25] reported that speed of germination was significantly higher in wider spacing in okra. Sharma *et al.* (2012) [24] noted that plant density had significant effect on standard germination percentage and 60 x 30 cm spacing proved better than closer spacing in okra. El-Waraky (2014) [8] also reported that the less plant density increased seed germination percentage in okra.

Significantly the highest seedling length (12.24, 12.40 and 12.32 cm), seedling dry weight (31.29, 29.59 and 30.44 mg), seedling vigour index (length) (1110.24, 1080.90 and 1090.57) and seedling vigour index (mass) (2817.33, 2583.20 and 2700.27) were recorded in plant spacing of 60 cm x 45 cm (S_3), while significantly the lowest seedling length (10.67, 11.15 and 10.91 cm), seedling dry weight (25.83, 23.40 and 24.62 mg), seedling vigour index (length) (905.32, 909.84 and 907.58) and seedling vigour index (mass) (2193.54, 1918.14 and 2055.84) were recorded by plant spacing of 45 cm x 30 cm (S_1) during both the years of experimentation and pooled over years (Table 5, 6, 7 and 8). Seedling vigour index (length) and seedling vigour index (mass) are based on the standard germination percentage, seedling length (cm) and seedling dry weight (mg). Higher the germination percentage, higher will be the seedling length, seedling dry weight and seedling vigour index I and II. The results are in close

agreement with those reported by Singh (2003) [25], who reported that seedling length and vigour index were significantly higher in wider spacing in okra. Sharma *et al.* (2012) [24] observed the highest value of vigour index I (1348.93) at a spacing of 60 cm x 30 cm in okra and it was significantly superior to all other plant spacing (45 cm x 30 cm and 60 cm x 20 cm).

Comparatively the highest seed viability (95.97 and 95.60%) was recorded by the plant spaced at 45 cm x 30 cm (S_1) during first year of experiment and in pooled data, while during second year of experiment; it was recorded highest (96.27%) in plants spaced at 60 cm x 45 cm (S_3) (Table 9).

Effect of plant growth regulators on seed yield and seed quality parameters in okra

The analysis of variance revealed the existence of significant difference among growth regulators for seed yield per plant and all the seed quality parameters studied (after harvest) during both the years of experiment as well as in pooled analysis over years (Table 1).

Seeds treated with GA_3 150 ppm (T_3) was found significantly superior and producing the highest seed yield per plant (33.10, 33.44 and 33.27 g) during both the years of experimentation (*kharif* 2015 and 2016) and pooled over years. Seeds treated with IBA 150 ppm (T_6) was the next best treatment producing the seed yield per plant of 28.94g, 29.42g and 29.18g during *kharif* 2015, *kharif* 2016 and pooled over years, respectively. Seeds soaked in water (T_{10}) produced significantly the lowest seed yield per plant (14.71, 17.68 and 16.19 g) during both the years of experimentation and in pooled over years (Table 2). The increase in seed yield per plant due to GA_3 growth regulators may be due to influence on better growth of plant, number of branches per plant, length of fruits, number of fruits, higher number of fruits per plant and well seed set, lower flower and fruit drop, proper size and shape, lower damage and shrivelled seeds. Bhagure and Tambe (2013) [6] reported that soaking of okra seeds with GA_3 @ 100 ppm recorded significantly the highest seed yield per plant. The results obtained under the present study were similar to those reported in okra earlier by Patil *et al.* (2008) [20], Patil *et al.* (2010) [19], Ayyub *et al.* (2013) [5] and Patil *et al.* (2014) in okra.

Seeds treated with GA_3 150 ppm (T_3) was found significantly superior and exhibited the highest values for 100 seed weight (6.19, 6.41 and 6.30 g) during both the years of experimentation and pooled over years and it was at par with the seeds treated with IBA 150 ppm (T_6) (6.06 g), IBA 100 ppm (T_5) (6.04 g), NAA 150 ppm (T_9) (6.03 g), GA_3 100 ppm (T_2) (5.89 g), NAA 100 ppm (T_8) (5.82 g), GA_3 50 ppm (T_1) (5.81 g) and IBA 50 ppm (T_4) (5.73 g) during first year of experimentation; with IBA 150 ppm (T_6) (6.26 g), NAA 150 ppm (T_9) (6.22 g), IBA 100 ppm (T_5) (6.13 g), NAA 100 ppm (T_8) (6.00 g) and GA_3 100 ppm (T_2) (5.99 g) during second year of experimentation; and with IBA 150 ppm (T_6) (6.16 g), NAA 150 ppm (T_9) (6.12 g) and IBA 100 ppm (T_5) (6.08 g) in pooled results. Water soaked seeds (T_{10}) noted significantly the lowest 100 seed weight (4.94, 5.12 and 5.03 g) during both the years of experimentation and in pooled results (Table 3). Shahid *et al.* (2013) reported that the application of growth regulators might have improved the metabolism and resulted in accumulation of photosynthates ultimately yielding seeds of large size. Similar results for test weight were obtained earlier in okra by Singh (2003) [25], Patil *et al.* (2008) [20] and Ravat and Makani (2015) [22].

Seeds treated with GA_3 150 ppm (T_3) recorded significantly the highest germination percentage (91.33, 90.56 and 90.94%) during both the years as well as in pooled over years. NAA 150 ppm (T_9) (89.78%) was the at par treatment during *kharif* 2015 with GA_3 150 ppm (T_3). Significantly the lowest germination percentage (83.22, 81.22 and 82.22%) was recorded by water soaked seeds (T_{10}) during both the years of experimentation (*kharif* 2015 and 2016) and in pooled analysis (Table 4). Patil *et al.* (2010) [19] reported that the application of GA_3 at 150 ppm recorded the highest values for seed germination for two consecutive years, which depends not only on the accumulation of photosynthates during crop growth and development, but also on its partitioning in the desired storage organs. Shahid *et al.* (2013) reported that the application of growth regulators might have improved the metabolism and resulted in accumulation of photosynthates ultimately yielding seeds of large size with better germination. Similar beneficial effect of GA_3 on germination percentage in okra have also been reported by Patil *et al.* (2008) [20], Patil *et al.* (2010) [19] and Bhagure and Tambe (2013) [6].

Significantly the highest seedling length (12.87, 12.66 and 12.77 cm), seedling dry weight (34.22, 34.18 and 34.20 mg), seedling vigour index (length) (1178.89, 1146.92 and 1162.85) and seedling vigour index (mass) (3132.34, 3096.72 and 3114.53) was recorded by seeds treated with GA_3 150 ppm (T_3) during both the year of experimentation (*kharif* 2015 and 2016) as well as in pooled over years. Significantly the lowest seedling length (10.51, 10.67 and 10.59 cm), seedling dry weight (21.45, 20.76 and 21.11 mg), seedling vigour index (length) (878.01, 866.50 and 872.26) and seedling vigour index (mass) (1792.89, 1688.30 and 1740.60) was recorded by water soaked seeds (T_{10}) during both the years of experimentation (*kharif* 2015 and 2016) as well as in pooled over years (Table 5, 6, 7 and 8). The increase in seed quality parameter obtained due to application of GA_3 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) (Patil *et al.*, 2008) [20]. Similar beneficial effect of GA_3 on seedlings length was reported by Singh (2003) [25] and on seedling dry weight and seedling vigour index (length and mass) by Omran *et al.* (1980), Ahmed and Tahir (1996) and Ravat and Makani (2015) [22].

Seeds treated with GA_3 150 ppm (T_3) recorded significantly the highest seed viability (99.11, 99.00 and 99.06%) during both the years of experimentation as well as in pooled analysis and it was at par with seeds treated with NAA 150 ppm (T_9) (96.11%) and GA_3 50 ppm (T_1) (96.12%) during *kharif* 2015; and with GA_3 50 ppm (T_1) (97.78%) and GA_3 100 ppm (T_2) (97.11%) during *kharif* 2016. Significantly the lowest seed viability (91.78, 89.89 and 90.83%) was recorded by water soaked seeds (control) (T_{10}) during both the years (*kharif* 2015 and 2016) and in pooled analysis (Table 9). The application of gibberellic acid might have improved the metabolism and resulted in accumulation of photosynthates ultimately yielding seeds of large size with better prolonged viability (Shahid *et al.*, 2013) [23].

Interaction effects of plant spacing and plant growth regulators on seed yield and seed quality parameters in okra

The results of analysis of variance revealed that mean squares due to interaction effects of spacing × seed treatments were found non-significant for seed yield per plant during both the

years of experimentations as well as pooled over years. The analysis of variance for seed quality parameters (after harvest) revealed that mean squares due to interaction effects of spacing × seed treatments were found significant for seedling dry weight, seedling vigour index (mass) and seed viability during both the years and for seedling vigour index (length) and seed viability during pooled analysis (Table 1).

Plant spacing of 60 cm x 45 cm and seeds treated with GA_3 150 ppm (S_3T_3) produced relatively the highest seed yield per plant (40.67, 42.00 and 41.33 g) during both the years of experimentation and in pooled over years. Plant spaced with 60 cm x 30 cm with IBA 150 ppm (S_3T_6) and NAA 150 ppm (S_3T_9) were the next best treatment combinations producing the seed yield per plant of 35.73, 35.86 and 35.80 g and 35.15, 34.72 and 34.93 g during *kharif* 2015, *kharif* 2016 and pooled over years, respectively. Relatively the lowest seed yield per plant (11.83, 14.67 and 13.25 g) was noted in water soaked seeds space planted at 45 cm x 30 cm (S_1T_{10}) during both the years of experimentation as well as in pooled analysis (Table 2). The highest seed yield per plant was recorded by the combination of wider spacing and growth regulator GA_3 may be attributed to greater availability of nutrients, moisture and photosynthesis leading to better vegetative growth increased number of flowers, fruits and seed set with proper size and shape of seed. Singh (2003) [25] reported that the interaction combination GA_3 150 ppm with wider spacing (60 cm x 45 cm) gave maximum seed yield per plant.

Plant spacing of 60 cm x 45 cm and seeds treated with GA_3 150 ppm (S_3T_3) produced relatively the highest 100 seed weight (6.61, 6.85 and 6.73 g) during both the years of experiment (*kharif* 2015 and 2016) as well as in pooled data, while relatively the lowest 100 seed weight (4.77, 4.70 and 4.73 g) was recorded by plant spaced at 45 cm x 30 with water soaked seeds (S_1T_{10}) during both the years of experimentation and pooled over years (Table 3).

Plant spacing of 60 cm x 45 cm and seeds treated with GA_3 150 ppm (S_3T_3) recorded comparatively the highest germination percentage (95.00, 91.67 and 93.33%) and seedling length (14.30, 13.54 and 13.92 cm) during both years of experimentation as well as pooled over years. Relatively the lowest germination percentage (82.00, 79.33 and 80.66%) and seedling length (9.62, 10.21 and 9.91 cm) were recorded by plant spaced at 45 cm x 30 cm and seeds soaked in water (control) (S_1T_{10}) during both years of experimentation as well as pooled over years (Table 4 and 5). Plant spacing of 60 cm x 45 cm and seeds treated with GA_3 150 ppm (S_3T_3) recorded significantly the highest seedling dry weight (37.00 and 37.40 mg) and seedling vigour index (mass) (3514.67 and 3428.88), while significantly the lowest seedling dry weight (20.09 and 19.67 mg) and seedling vigour index (mass) (1660.44 and 1560.67) was recorded in water soaked plants spaced at 45 cm x 30 cm (S_1T_{10}) during both the years of experiment (Table 6 and 8). Comparatively the highest (37.20 mg and 3471.78) and the lowest (19.88 mg and 1610.55) seedling dry weight and seedling vigour index (mass), respectively were recorded by the treatment combinations S_3T_3 and S_1T_{10}, respectively in pooled analysis. Plant spacing of 60 cm x 45 cm and seeds treated with GA_3 150 ppm (S_3T_3) noted relatively the highest seedling vigour index (length) (1358.53 and 1241.90) during both the years, while it was noted relatively the lowest (794.97 and 809.71) in water soaked seeds space planted at 45 cm x 30 cm (S_1T_{10}) during both the years. In pooled analysis, significantly the highest (1300.22) and the lowest (802.34) seedling vigour index (length) was noted in the treatment combinations S_3T_3 and S_1T_{10}, respectively. Singh (2003) [25] also observed non-significant difference for seedling vigour index (length) over years.

The plant spaced with 60 cm x 45 cm (S_3) recorded significantly the highest seed viability (99.33, 99.67 and 99.50%) during both the years of experimentation (*kharif* 2015 and 2016) as well as in pooled over years, while significantly the lowest seed viability (90.00, 88.67 and 89.33%) were recorded by plant spaced at 45 cm x 30 cm (S_1) during both the years of experimentation (*kharif* 2015 and 2016) as well as in pooled over years (Table 9).

Table 1: Analysis of variance for experimental design (SPD) for seed yield per plant and seed quality parameters (after harvest) in okra during *kharif* 2015 and 2016

Source of variation	d. f.	Seed yield per plant (g)		100 seed weight (g)		Germination percentage		Seedling length (cm)		Seedling dry weight (mg)		Seedling vigour index (Length)		Seedling vigour index (Mass)		Seed viability test (%)	
Kharif 2015																	
Spacing (S)	2	895.04	**	3.40	*	190.14	**	18.55	**	224.84	**	284963.34	**	2938176.51	**	10.48	
Error (A)	4	6.66		0.31		7.68		0.32		1.88		2701.43		23086.57		13.24	
Treatments (T)	9	224.21	**	1.08	**	42.59	**	3.67	**	117.08	**	55109.89	**	1173098.59	**	30.17	**
S × T	18	8.86		0.05		7.34		0.33		4.11	**	4684.04		43084.35	*	23.24	*
Error (B)	54	5.93		0.24		6.37		0.28		1.75		3372.04		21971.60		10.26	
Kharif 2016																	
Spacing (S)	2	640.00	**	2.02	*	224.23	*	11.84	**	290.38	**	219534.41	**	3335073.90	**	10.85	
Error (A)	4	16.41		0.26		23.27		0.32		1.74		8379.02		12925.18		8.71	
Treatments (T)	9	186.10	**	1.16	**	60.79	**	3.25	**	143.63	**	56652.00	**	1468417.09	**	56.79	**
S × T	18	9.92		0.07		5.28		0.34		6.20	**	3711.41		58318.15	**	10.28	*
Error (B)	54	11.70		0.20		8.89		0.31		1.23		2821.89		13374.91		4.66	
Pooled																	
Year (Y)	1	16.69		0.80		457.61	**	4.89	**	177.27	**	3490.73		2939448.58	**	3.58	
Spacing (S)	2	1524.28	**	5.33	**	411.54	**	30.01	**	512.99	**	502277.08	**	6266830.44	**	4.69	
Y x S	2	10.76		0.09		2.84		0.38		2.23		2220.68		6419.97		16.64	
ERROR (a)	8	11.54		0.29		15.47		0.32		1.81		5540.22		18005.88		10.98	
Treatments (T)	9	404.50	**	2.21	**	87.80	**	6.53	**	251.87	**	107210.20	**	2565675.63	**	77.19	**
Y x T	9	5.81		0.03		15.58	*	0.39		8.84	**	4551.69		75840.05	**	9.78	
S x T	18	14.81		0.08		8.20		0.42		6.48		6078.65	*	64585.64		27.96	**
Y x S x T	18	3.96		0.05		4.43		0.26		3.83	**	2316.81		36816.86	*	5.57	
Error (b)	108	8.81		0.22		7.63		0.29		1.49		3096.96		17673.25		7.46	

*,** Significant at 5 percent and 1 percent levels of significance, respectively

Table 2: Effect of plant spacing and seed treatments with growth regulators on seed yield per plant (g) of okra during *kharif* 2015 and 2016

Treatments /Year	2015				2016				Pooled			
	S_1	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Pooled**
T_1	16.87	20.81	24.74	20.81	18.81	22.01	26.00	22.27	17.84	21.41	25.37	21.54
T_2	20.28	23.14	27.82	23.74	20.70	24.47	29.70	24.95	20.49	23.80	28.76	24.35
T_3	25.83	32.80	40.67	33.10	25.48	32.86	42.00	33.44	25.65	32.83	41.33	33.27
T_4	17.09	21.98	28.89	22.65	20.08	21.73	23.83	21.88	18.59	21.86	26.36	22.27
T_5	20.45	26.32	32.19	26.32	21.80	26.49	30.99	26.43	21.12	26.40	31.59	26.37
T_6	20.63	30.46	35.73	28.94	23.35	29.06	35.86	29.42	21.99	29.76	35.80	29.18
T_7	18.69	22.36	28.23	23.09	18.63	22.58	26.98	22.73	18.66	22.47	27.60	22.91
T_8	19.33	24.48	30.55	24.78	20.57	24.12	27.95	24.21	19.95	24.30	29.25	24.50
T_9	21.18	27.47	35.15	27.93	22.95	29.75	34.72	29.14	22.06	28.61	34.93	28.54
T_{10}	11.83	14.85	17.44	14.71	14.67	17.07	21.31	17.68	13.25	15.96	19.37	16.19
Mean	19.22	24.47	30.14	24.61	20.70	25.01	29.93	25.21	19.96	24.74	30.04	24.91
Treatment effect	S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %	
Spacing (S)	0.47	1.85	10.49		0.74	2.90	16.06		0.44	1.43	13.63	
Treatments (T)	0.81	2.30	9.89		1.14	3.23	13.56		0.70	1.96	11.92	
Interaction effect												
S x T	1.41	NS	9.89		1.97	NS	13.56		1.21	NS	11.92	
Y x S									0.62	NS	13.63	
Y x T									0.99	NS	11.92	
Y x S x T									1.71	NS		

Table 3: Effect of plant spacing and seed treatments with growth regulators on 100 seed weight (g) of okra during *kharif* 2015 and 2016

Treatments /Year	2015				2016				Pooled			
	S_1	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Pooled**
T_1	5.49	5.86	6.09	5.81	5.75	5.78	5.84	5.79	5.62	5.82	5.96	5.80
T_2	5.59	5.88	6.19	5.89	5.84	6.04	6.08	5.99	5.72	5.96	6.13	5.94
T_3	5.88	6.09	6.61	6.19	6.06	6.33	6.85	6.41	5.97	6.21	6.73	6.30
T_4	5.17	5.97	6.07	5.73	5.41	5.99	6.04	5.81	5.29	5.98	6.05	5.77
T_5	5.58	6.06	6.48	6.04	5.86	6.18	6.34	6.13	5.72	6.12	6.41	6.08
T_6	5.60	6.08	6.50	6.06	5.99	6.22	6.58	6.26	5.80	6.15	6.54	6.16
T_7	5.45	5.68	6.01	5.71	5.67	5.80	6.01	5.83	5.56	5.74	6.01	5.77
T_8	5.55	5.81	6.09	5.82	5.85	5.96	6.19	6.00	5.70	5.89	6.14	5.91
T_9	5.77	5.83	6.48	6.03	5.86	6.18	6.63	6.22	5.81	6.01	6.56	6.12
T_{10}	4.77	4.98	5.08	4.94	4.70	5.05	5.62	5.12	4.73	5.02	5.35	5.03
Mean	5.49	5.82	6.16	5.82	5.70	5.95	6.22	5.96	5.59	5.89	6.19	5.86
Treatment effect	S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %	
Spacing (S)	0.10	0.40	9.59		0.09	0.37	8.62		0.07	0.23	9.11	
Treatments (T)	0.16	0.46	8.68		0.15	0.43	7.63		0.11	0.31	8.00	
Interaction effect												
S x T	0.28	NS	8.68		0.26	NS	7.63		0.19	NS	8.00	
Y x S									0.10	NS	9.11	
Y x T									0.16	NS	8.00	
Y x S x T									0.27	NS		

Table 4: Effect of plant spacing and seed treatments with growth regulators on germination percentage (after harvest) of okra during *kharif* 2015 and 2016

Treatments /Year	2015				2016				Pooled			
	S_1	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Pooled**
T_1	83.67	89.67	93.33	88.89	80.00	84.33	87.67	84.00	81.83	87.00	90.50	86.44
T_2	82.33	86.00	90.33	86.22	81.33	87.33	88.33	85.67	81.83	86.67	89.33	85.94
T_3	88.00	91.00	95.00	91.33	89.67	90.33	91.67	90.56	88.83	90.67	93.33	90.94
T_4	84.67	89.33	86.67	86.89	80.67	83.33	83.67	82.56	82.67	86.33	85.17	84.72
T_5	84.67	86.67	87.67	86.33	81.67	85.00	87.67	84.78	83.17	85.83	87.67	85.56
T_6	84.33	89.33	90.33	88.00	82.00	84.00	89.33	85.11	83.17	86.67	89.83	86.56
T_7	86.00	87.33	89.67	87.67	79.33	80.33	87.00	82.22	82.67	83.83	88.33	84.94
T_8	85.00	86.33	88.67	86.67	80.00	83.33	85.33	82.89	82.50	84.83	87.00	84.78
T_9	86.67	90.67	92.00	89.78	81.67	84.67	86.67	84.33	84.17	87.67	89.33	87.06
T_{10}	82.00	83.67	84.00	83.22	79.33	81.33	83.00	81.22	80.66	82.50	83.50	82.22
Mean	84.73	88.00	89.77	87.50	81.57	84.40	87.03	84.33	83.15	86.20	88.40	85.92
Treatment effect	S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %	
Spacing (S)	0.51	1.99	3.17		0.88	3.46	5.72		0.51	1.66	4.58	
Treatments (T)	0.84	2.38	2.88		0.99	2.82	3.53		0.93	2.98	3.21	
Interaction effect												
S x T	1.46	NS	2.88		1.72	NS	3.53		1.13	NS	3.21	
Y x S									0.72	NS	4.58	
Y x T									0.92	2.58	3.21	
Y x S x T									1.59	NS		

Table 5: Effect of plant spacing and seed treatments with growth regulators on seedlings length (cm) (after harvest) of okra during *kharif* 2015 and 2016

Treatments /Year	2015				2016				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Pooled
T_1	10.13	11.09	11.58	10.93	10.70	11.92	12.49	11.70	10.41	11.51	12.03	11.32
T_2	10.45	11.58	12.44	11.49	10.89	12.32	12.91	12.04	10.67	11.95	12.68	11.77
T_3	11.81	12.50	14.30	12.87	11.64	12.80	13.54	12.66	11.73	12.65	13.92	12.77
T_4	10.14	11.52	12.03	11.23	11.44	11.33	11.83	11.53	10.79	11.43	11.93	11.38
T_5	10.47	11.36	12.28	11.37	11.54	11.83	12.33	11.90	11.01	11.60	12.31	11.64
T_6	11.07	11.60	12.69	11.79	11.57	12.34	13.19	12.37	11.32	11.97	12.94	12.08
T_7	10.55	10.79	11.85	11.06	10.50	11.16	11.47	11.04	10.53	10.97	11.66	11.05
T_8	10.77	11.13	11.92	11.27	11.19	11.07	12.42	11.56	10.98	11.10	12.17	11.42
T_9	11.65	11.71	12.14	11.84	11.77	12.04	12.74	12.18	11.71	11.88	12.44	12.01
T_{10}	9.62	10.78	11.13	10.51	10.21	10.70	11.10	10.67	9.91	10.74	11.12	10.59
Mean	10.67	11.41	12.24	11.44	11.15	11.75	12.40	11.77	10.91	11.58	12.32	11.60
Treatment effect	S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %	
Spacing (S)	0.10	0.40	4.92		0.10	0.41	4.83		0.07	0.24	4.87	
Treatments (T)	0.18	0.50	4.63		0.18	0.52	4.71		0.13	0.36	4.67	
Interaction effect												
S x T	0.31	NS	4.63		0.32	NS	4.71		0.22	NS	4.67	
Y x S									0.10	NS	4.87	
Y x T									0.18	NS	4.67	
Y x S x T									0.31	NS		

Table 6: Effect of plant spacing and seed treatments with growth regulators on seedling dry weight (mg) (after harvest) of okra during *kharif* 2015 and 2016

Treatments /Year	2015				2016				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Pooled
T_1	23.89	24.33	28.78	25.67	20.67	21.99	24.15	22.27	22.28	23.16	26.47	23.97
T_2	25.11	31.67	33.00	29.93	23.28	29.59	30.55	27.80	24.20	30.63	31.77	28.87
T_3	31.00	34.66	37.00	34.22	32.05	33.07	37.40	34.18	31.53	33.87	37.20	34.20
T_4	23.22	28.56	30.67	27.48	22.49	24.88	26.65	24.67	22.85	26.72	28.66	26.08
T_5	29.22	29.78	32.00	30.33	22.86	25.86	31.80	26.84	26.04	27.82	31.90	28.59
T_6	29.44	32.67	34.00	32.04	23.61	30.05	32.19	28.62	26.53	31.36	33.10	30.33
T_7	23.67	26.89	29.89	26.82	20.54	25.04	27.31	24.30	22.10	25.97	28.60	25.56
T_8	24.22	28.67	31.44	28.11	21.91	28.35	29.38	26.55	23.07	28.51	30.41	27.33
T_9	28.41	30.67	33.15	30.74	26.97	31.56	34.31	30.94	27.69	31.11	33.73	30.84
T_{10}	20.09	21.33	22.93	21.45	19.67	20.48	22.13	20.76	19.88	20.91	22.53	21.11
Mean	25.83	28.92	31.29	28.68	23.40	27.09	29.59	26.69	24.62	28.01	30.44	27.69
Treatment effect	S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %	
Spacing (S)	0.25	0.98	4.78		0.24	0.95	4.95		0.17	0.57	4.86	
Treatments (T)	0.44	1.25	4.61		0.37	1.05	4.16		0.70	2.24	4.41	
Interaction effect												
S x T	0.76	2.16	4.61		0.64	1.82	4.16		0.80	NS	4.41	
Y x S									0.25	NS	4.86	
Y x T									0.41	1.14	4.41	
Y x S x T									0.70	1.97		

Table 7: Effect of plant spacing and seed treatments with growth regulators on seedling vigour index (length) (after harvest) of okra during *kharif* 2015 and 2016

Treatments /Year	2015				2016				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Pooled
T_1	847.47	994.65	1080.64	974.25	856.80	1005.21	1094.08	985.36	852.14	999.93	1087.36	979.81
T_2	860.84	994.68	1124.06	993.19	885.55	1074.43	1140.52	1033.50	873.19	1034.55	1132.29	1013.35
T_3	1040.09	1137.73	1358.53	1178.79	1043.32	1155.53	1241.90	1146.92	1041.71	1146.63	1300.22	1162.85
T_4	858.32	1028.58	1042.47	976.46	922.81	944.60	989.07	952.16	890.56	986.59	1015.77	964.31
T_5	885.89	985.28	1076.80	982.66	943.19	1005.15	1081.14	1009.83	914.54	995.21	1078.97	996.24
T_6	933.27	1036.45	1145.74	1038.48	948.12	1037.67	1178.50	1054.76	940.69	1037.06	1162.12	1046.62
T_7	907.57	941.89	1062.38	970.61	832.53	895.62	997.70	908.62	870.05	918.76	1030.04	939.62
T_8	915.09	960.77	1057.86	977.90	895.20	922.33	1060.13	959.22	905.15	941.55	1059.00	968.56
T_9	1009.73	1062.42	1117.04	1063.07	961.14	1018.94	1105.33	1028.47	985.44	1040.68	1111.19	1045.77
T_{10}	794.97	902.18	936.87	878.01	809.71	869.17	920.63	866.50	802.34	885.68	928.75	872.26
Mean	905.32	1004.46	1100.24	1003.34	909.84	992.86	1080.90	994.53	907.58	998.66	1090.57	998.94
Treatment effect	S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %	
Spacing (S)	9.49	37.26	5.18		16.71	65.52	9.20		9.61	31.34	7.45	
Treatments (T)	19.36	54.88	5.79		17.71	50.21	5.34		13.12	36.77	5.57	
Interaction effect												
S x T	33.53	NS	5.79		30.67	NS	5.34		22.75	63.69	5.57	
Y x S									13.59	NS	7.45	
Y x T									18.55	46.81	5.57	
Y x S x T									32.13	81.07		

Table 8: Effect of plant spacing and seed treatments with growth regulators on seedling vigour index (mass) (after harvest) of okra during *kharif* 2015 and 2016

Treatments /Year	2015				2016				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Pooled
T_1	1998.70	2182.55	2685.99	2289.08	1656.00	1855.51	2117.05	1876.18	1827.35	2019.03	2401.52	2082.63
T_2	2067.63	2720.33	2980.81	2589.59	1896.74	2580.87	2698.40	2392.01	1982.19	2650.60	2839.61	2490.80
T_3	2726.00	3156.36	3514.67	3132.34	2874.47	2986.82	3428.88	3096.72	2800.23	3071.59	3471.78	3114.53
T_4	1966.70	2552.43	2658.67	2392.60	1808.79	2074.54	2229.18	2037.50	1887.74	2313.49	2443.93	2215.05
T_5	2475.26	2582.02	2804.60	2620.62	1867.92	2199.12	2788.32	2285.12	2171.59	2390.57	2796.46	2452.87
T_6	2482.68	2917.78	3071.00	2823.82	1931.81	2524.13	2875.31	2443.75	2207.25	2720.96	2973.16	2633.79
T_7	2035.67	2348.99	2682.76	2355.81	1629.46	2008.85	2378.62	2005.64	1832.56	2178.92	2530.69	2180.72
T_8	2059.03	2474.89	2792.23	2442.05	1753.07	2362.18	2507.19	2207.48	1906.05	2418.53	2649.71	2324.76
T_9	2463.30	2780.00	3048.98	2764.09	2202.47	2670.33	2970.38	2614.39	2332.88	2725.17	3009.68	2689.24
T_{10}	1660.44	1784.67	1933.56	1792.89	1560.67	1665.53	1838.70	1688.30	1610.55	1725.10	1886.13	1740.60
Mean	2193.54	2550.00	2817.33	2520.29	1918.14	2292.79	2583.20	2264.71	2055.84	2421.39	2700.27	2392.50
Treatment effect	S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %	
Spacing (S)	27.74	108.92	6.03		20.76	81.50	5.02		17.32	56.49	5.61	
Treatments (T)	49.41	140.09	5.88		38.55	109.30	5.11		64.91	207.66	5.56	
Interaction effect												
S x T	85.58	242.65	5.88		66.77	189.32	5.11		78.33	NS	5.56	
Y x S									24.50	NS	5.61	
Y x T									44.31	124.22	5.56	
Y x S x T									76.75	215.16		

Table 9: Effect of plant spacing and seed treatments with growth regulators on seed viability test (per cent) (after harvest) of okra during *kharif* 2015 and 2016

Treatments /Year	2015				2016				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Pooled
T_1	97.37	94.67	96.33	96.12	97.00	97.33	99.00	97.78	97.18	96.00	97.67	96.95
T_2	97.67	94.00	92.00	94.56	97.33	96.00	98.00	97.11	97.50	95.00	95.00	95.83
T_3	98.67	99.33	99.33	99.11	98.33	99.00	99.67	99.00	98.50	99.17	99.50	99.06
T_4	92.33	97.67	95.00	95.00	93.33	97.33	97.00	95.94	92.83	97.50	96.00	95.45
T_5	97.00	94.00	92.33	94.44	95.33	95.00	91.00	93.78	96.17	94.50	91.67	94.11
T_6	98.67	89.33	98.67	95.56	98.00	92.33	96.00	95.44	98.33	90.83	97.33	95.50
T_7	99.33	93.33	94.00	95.56	96.33	92.67	96.33	95.11	97.83	93.00	95.17	95.33
T_8	93.33	97.00	93.67	94.67	95.33	97.67	97.33	96.78	94.33	97.33	95.50	95.72
T_9	95.33	98.33	94.67	96.11	92.67	95.00	97.00	94.89	94.00	96.67	95.83	95.50
T_{10}	90.00	92.33	93.00	91.78	88.67	89.67	91.33	89.89	89.33	91.00	92.17	90.83
Mean	95.97	95.00	94.90	95.29	95.23	95.22	96.27	95.57	95.60	95.11	95.58	95.43
Treatment effect	S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %		S. Em ±	CD at 5%	C. V. %	
Spacing (S)	0.66	NS	3.82		0.54	NS	3.09		0.43	NS	3.47	
Treatments (T)	1.07	3.03	3.36		0.72	2.04	2.26		0.64	1.80	2.86	
Interaction effect												
S x T	1.85	5.24	3.36		1.25	3.53	2.26		1.11	3.13	2.86	
Y x S									0.60	NS	3.47	
Y x T									0.91	NS	2.86	
Y x S x T									1.58	NS		

Conclusion

From the overall results obtained from the present investigation, it can be concluded that wider spacing S_3 (60 × 45 cm) was found effective in improving seed yield and quality of seeds of okra. The maximum improvement was observed in seed yield and seed quality of harvested crop by the application of growth regulator GA_3 150 ppm. A combination of wider plant spacing 60 x 45 cm and seed treatment of GA_3 @ 150 ppm before sowing for 8 hours was found the best suited, as it had produced the maximum seed yield per plant and good quality seed after harvest in terms of 100 seed weight, seed germination/viability, seedling length, seedling dry weight and seedling vigour index (length and mass). Therefore, it is advantageous to grow the okra crop after giving 8 hours seed treatment of GA_3 150 ppm with a plant spacing of 60 x 45 cm for getting high and quality seed production.

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