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SEED PRIMIG AND FOLIAR APPLICATION OF PLANT GROWTH REGULATORS AFFECT THE GROWTH AND YIELD OF OKRA UNDER CALCAREOUS SOILS

Muhammad T. Tahir, Muhammad A. Anjum, Muhammad Saqib, Muhammad F. Khalid, Sajjad Hussain✉

Department of Horticulture, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, 60800, Pakistan

ABSTRACT

A field study was conducted to evaluate the effect of different plant growth regulators (PGRs) applied through seed priming and foliar spray on growth and yield of three okra cultivars grown under calcareous soils. The cultivars of Punjab Selection and Sabzpari produced significantly higher number of branches and leaves per plant, pod length and diameter and pod yield as compared to cv. Green ferry, while, cv. Punjab selection produced significantly greater number of flowers and pods per plant as compared to other two cultivars. Seed germination (%), plant height, and fruit set (%) were not affected by the cultivars. Among the PGR treatments, seed primed with GA_3 resulted in significantly higher germination percentage and greater plant height at flowering. Seed priming and foliar spray with NAA and GA_3 were effective in increasing the final plant height, number of branches, number of leaves, number of flowers and number of pods per plant and fruit set (%), fresh weight per pod and pod yield. However, pod diameter, pod moisture content and dry weight per pod were not influenced by the PGR treatments applied. These results suggested that the PGRs have great potential to improve seed germination, enhance growth and increase yield of okra cultivars under calcareous soils.

Keywords: *Abelmoschus esculentus*, foliar spray, GA_3, kinetin, NAA, seed soaking

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) belongs to *Malvaceae* family and is also known as lady's finger. It was originated in tropical Africa [Shah et al. 2011]. However, now it is cultivated in many tropical and subtropical regions of the world. Different cultivars of okra are cultivated in different regions of the world. These cultivars vary in different characters like plant height, shape and color of leaves, shape and size of fruits and yield attributes etc.

In Pakistan, okra is grown as a summer crop in tropical and subtropical areas, where soils are mostly calcareous. These soils are characterized by the presence of calcium carbonate in the profile, have moderate to high alkalinity, high pH ranging from 7.5 to 8.5 and low organic matter content. Nutrient management in calcareous soils is different from non-calcareous soils, as soil pH affects the nutrients availability and chemical processes affecting fixation or complete loss of nutrients. Plant growth and yield is badly affected in these soils and it requires improved fertilizer management to grow crops successfully. However, application of plant growth regulators (PGRs) along with fertilizers can be an alternative to improve growth and yield of crops in calcareous soils. The role of PGRs in agriculture is well documented for improving the growth, yield and quality of crops. These play import-

✉ sajjad.hussain@bzu.edu.pk

ant roles in physiological and biological processes of plants. However, their effectiveness depends upon their concentration, method of application and crop growth stage etc. These PGRs can also act as growth retardants at different concentrations.

Among PGRs, auxins help in increasing the cell size at low concentrations, while at higher concentrations, decrease cell size or even leads to a cell death. Auxins promote root growth and help in shoot elongation, apical dominance and thinning of fruits [Nafea and Abdulfatah 2015]. These also help in breaking dormancy, flower development and fruit formation. Naphthalene acetic acid (NAA) increases fruit weight, number of fruits and yield per plant in tomato [Alam and Khan 2002], and plant height and number of pods per plant in okra [Shahid et al. 2013] and yield in chillies [Balraj et al. 2002]. Gibberellins play vital role in floral initiation, thus they are helpful in induction of flowering and are important for sex determination. These also promote seed germination and improve the fruit set. Among the gibberellins, gibberellic acid (GA_3) is very commonly used in agriculture. GA_3 promotes cell elongation and cell division [Akhtar et al. 2008], thus increasing the stem elongation and improving the flower development and total yield [Yamaguchi and Kamiya 2000]. GA_3 significantly affects the seed germination [Ogawa et al. 2003, Dhoran and Gudadhe 2012, Roychowdhury et al. 2012], breaking dormancy, plant height in dwarf plants [Azizi et al. 2012], and also affects different parameters of plant growth and development [Haba et al. 1985, Balraj et al. 2002, Shahid et al. 2013]. Cytokinins play their role in cell division and cell expansion; these also help in transport of amino acids in plants. Naeem et al. [2004] stated that kinetin reduced plant height and number of nodes, and improved stem diameter and leaf diameter. Thus, PGRs play a key role in increasing nutrition and quality of horticultural crops, hence show a progress towards attaining global food security [Olaiya 2010]. However, the efficacy of PGRs is influenced by various factors such as plant type, growth stage, and PGRs concentration, its method and frequency of application. Therefore, the aim of the current study was to evaluate effect of different plant growth regulators (PGRs) on vegetative growth and yield of three okra cultivars, when applied through seed priming and foliar spray, grown under calcareous soils.

MATERIALS AND METHODS

The present work was conducted at the Vegetable Research Area, Department of Horticulture, Bahauddin Zakariya University Multan during summer seasons of two consecutive years to evaluate the effect of application method, i.e. seed priming and foliar application of different plant growth regulators on growth and yield of okra (*Abelmoschus esculentus* L. Moench). There were three cultivars of okra viz. Sabzpari, Green ferry and Punjab selection. Naphthalene acetic acid (NAA), gibberellic acid (GA_3) and kinetin were used as seed priming and also for foliar application. Distilled water was used as control for both methods of application. Concentration of all PGRs was the same, i.e. 100 ppm. Seeds were soaked for 12 hours, separately in each solution. Then seeds were removed from solutions and dried at room temperature. Dried seeds were then sown in field on ridges. Foliar application of PGRs was done twice, 1st at 30 days after sowing (DAS) and 2nd at 45 days after sowing (DAS). The experiment was laid out under randomized complete block design (RCBD) with factorial arrangement. Each treatment was replicated thrice.

The experiment was performed in calcareous soil. Physicochemical attributes of the soil (0−15 cm depth) taken from experimental field were; texture loamy, EC 5.53 dSm^{-1}, pH 8.3, organic matter 0.79%, available P 10.5 ppm and available K 210 ppm. The land was thoroughly prepared to a fine tilth by ploughing and planking and ridges were made 60 cm apart. Net size of the plot was 12 × 18 m and it was further subdivided into 8 subplots (growth regulator treatment). Well rotten farm yard manure was mixed in the soil at the rate of 25 tons per hectare at the time of land preparation. The seeds were sown on 24th March during both the years on both sides of ridges at a distance of 22 cm. Chemical fertilizers were applied as per recommendations of the Agriculture Department, Government of the Punjab at the rate of N = 80 and P_2O_5 = 68 kg per hectare. All experimental plots were treated similarly for their cultural operations like irrigation, hoeing and plant protection practices. Plants were uprooted at the end of fruiting season. Data were collected on different growth and yield characteristics during the course of study. Moisture content of pod was determined using the following formula:

Pod moisture content (%) =
= fresh weight – dry weight × 100/fresh weight

Pod yield per hectare was estimated by multiplying pod yield per plant with total number of plants in one hectare. To estimate seed germination percentage after priming, they were grown in pots containing the soil taken from the experimental field. Ten seeds were grown in each pot and there were five pots in each treatment. The experiment was arranged in a completely randomized design (CRD) with factorial arrangement having three repeats.

The data collected for two years were pooled and subjected to analysis of variance using statistical software Statistix 8.1. Differences among the cultivars and PGR treatments means were compared by employing least significant difference (LSD) test at 0.05% probability level.

RESULTS AND DISCUSSION

Seed primed with GA_3 resulted in significantly higher seed germination percentage, while seeds primed with distilled water (control) and those primed with kinetin gave significantly lower germination percentage. However, seed germination was not affected among the cultivars (Tab. 1). In the case of interactive effect of okra cultivars and seed priming treatments, the maximum seed germination was noted in Punjab selection when seeds were primed with GA_3, followed by cv. Green ferry seeds also primed with GA_3, and cv. Sabzpari when seeds were primed with GA_3 and NAA. These results clearly show supremacy of GA_3 as seed priming agent (Fig. 1). Our results are in agreement with findings of previous workers that GA_3 improves the seed germination [Ogawa et al. 2003, Akhtar et al. 2008, Dhoran and Gudadhe 2012, Roychowdhury et

Table 1. Effect of PGR treatments on vegetative growth of okra cultivars

Treatments	Seed germination (%)	Plant height at flowering (cm)	Final plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}
Cultivars (Cv)					
Sabzpari	72.67	33.43	95.11	3.20 a	29.13 a
Punjab selection	69.67	32.41	92.95	3.18 a	29.31 a
Green ferry	71.67	30.35	92.13	2.57 b	25.15 b
LSD value	3.39	3.12	2.98	0.25	2.49
Significance	ns	ns	ns	*	*
Treatments (T)					
Control (SP with H_2O)	67.22 c	30.04 b	86.64 de	2.49 b	21.83 d
SP with GA_3	79.44 a	40.43 a	98.63 ab	3.20 a	29.61 ab
SP with NAA	72.22 b	33.24 b	100.74 a	3.18 a	31.61 a
SP with Kinetin	67.22 c	29.51 b	89.74 de	3.13 a	25.22 cd
Control (FS with H_2O)	–	31.96 b	91.49 cd	2.63 b	24.67 cd
FS with GA_3	–	30.58 b	100.62 a	3.14 a	31.67 a
FS with NAA	–	29.65 b	94.76 bc	3.25 a	32.33 a
FS with Kinetin	–	31.09 b	85.88 e	2.84 ab	25.94 bc
LSD value	3.92	5.09	4.86	0.41	4.06
Significance	*	*	*	*	*
Cv × T					
LSD value	6.79	8.81	8.42	0.71	7.03
Significance	*	ns	ns	ns	ns

SP – seed priming, FS – foliar spray, ns – non-significant, * – significant

al. 2012]. Seed priming helps in breaking dormancy of seed. It also catalyzes different biochemical reactions inside the seed, which improves germination rate and its uniformity [Khan et al. 2008, Khalil et al. 2010].

Maximum plant height at flowering was recorded when seeds were primed with GA_3, which was significantly greater than all other treatments. All other treatments behaved statistically alike (Tab. 1). However, final plant height was the maximum when seeds were primed with NAA, followed by foliar application of GA_3 and seeds primed with GA_3. These three treatments were statistically similar to each other. Foliar application and seed priming with kinetin and distilled water resulted in the minimum plant height (Tab. 1). NAA and GA_3 increase plant growth due to their promoter effect. NAA induces apical dominance causing an increase in plant height. These results are in accordance with those reported by Shantappa et al. [2009], who found that GA_3 and NAA improved plant height in paprika chillies. It was also observed that seed soaking in GA_3 increased the plant growth in spinach [Akhtar et al. 2008], while foliar application of GA_3 increased plant height in chillies [Balraj et al. 2002, Thapa et al. 2003] and okra [Ayyub et al. 2013]. Plant height also increased when NAA at the rate of 50 ppm was applied to paprika plants [Kannan et al. 2009].

The maximum number of branches per plant was produced in cv. Sabzpari, closely followed by Punjab selection and these two cultivars were statistically similar. While, significantly lesser number of branches was recorded in cv. Green ferry. Concerning the PGR treatments, the maximum number of branches per plant was produced by plants foliar sprayed with NAA followed by seed priming with GA_3 and NAA, foliar application of GA_3, seed priming with kinetin and foliar application of kinetin. All these six treatments behaved statistically alike. The minimum number of branches per plant was produced when seed was primed with distilled water, followed by foliar application of distilled water and kinetin. These three treatments also behaved statistically alike (Tab. 1). These results confirmed the findings of Shahid et al. [2013], who reported the effect of foliar application of GA_3 and NAA on okra. They recorded the maximum number of branches in those plants that were sprayed with GA_3 and NAA at the rate of 100 ppm. Similarly, Balraj et al. [2002] and Thapa et al. (2003) recorded increasing number of branches in chillies with foliar application of GA_3.

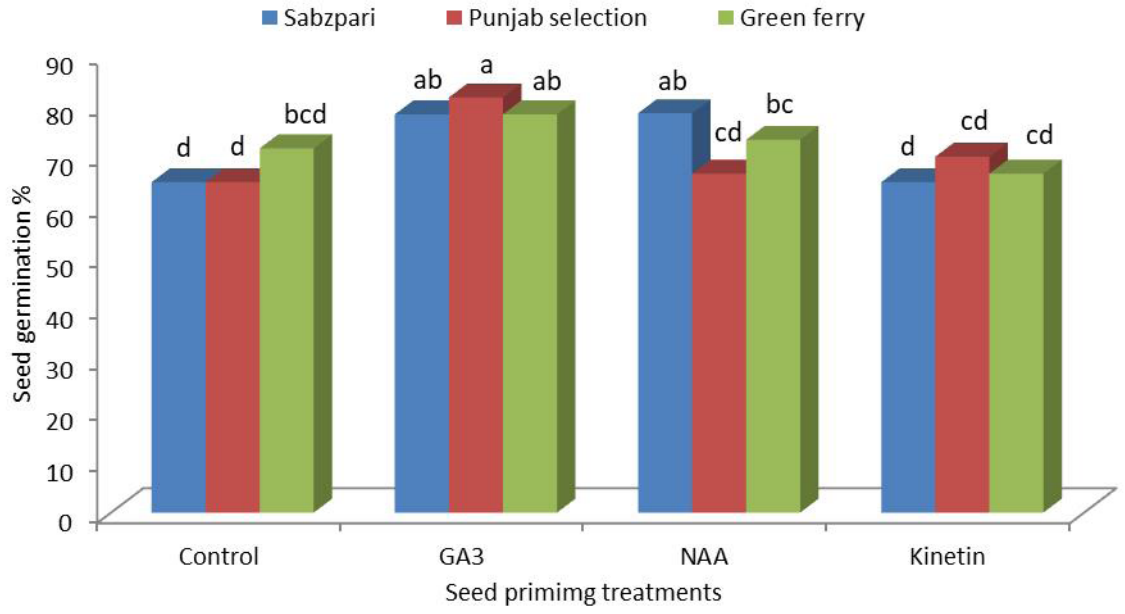

Fig. 1. Effect of seed priming treatments on germination percentage of okra cultivars

The leaf number per plant recorded was significantly greater in Punjab selection, followed by Sabzpari as compared to Green ferry. Among the PGR treatments, NAA applied as foliar spray performed better over all other treatments by giving more number of leaves per plant, followed by foliar application of GA_3 and seed priming with NAA and GA_3. The minimum number of leaves per plant was noted when seeds were treated with distilled water, being statistically similar to foliar spray of distilled water and seed priming with kinetin (Tab. 1). Leaf number in okra plants depends upon plant height, intermodal distance and number of branches per plant. Experiment conducted by Kokare et al. [2006] revealed that application of GA_3 and NAA at the rate of 200 ppm resulted in increase in the number of leaves of okra. Shahid et al. [2013] described that PGRs affect various aspects of plant physiology, mainly vegetative and reproductive traits. GA_3 and NAA alone and in different combinations were sprayed on okra plants at 2-true leaf stage. All vegetative and reproductive growth variables were significantly influenced by different combinations of PGRs. The maximum leaf number was produced when plants were sprayed with GA_3 at the rate of 200 ppm and NAA at the rate of 100 ppm. Kannan et al. [2009] recorded increased number of leaves in paprika cultivars by foliar spray of NAA at the rate of 50 ppm.

Significantly higher number of flowers per plant was produced in cv. Punjab selection. While, significantly lower number of flower was recorded in cv. Sabzpari, being statistically similar with cv. Green ferry. On the other hand, NAA primed seeds dominated over all other PGR treatments by resulting in the maximum number of flowers per plant, followed by GA_3 primed seeds, foliar application of NAA and foliar application of GA_3, all being statistically at par with each other (Tab. 2). In the current study, flower number followed almost the same pattern as observed in the case of number of branches per plant. NAA and GA_3 enhance cell division and produce some desirable effects like

Table 2. Effect of PGR treatments on reproductive growth of okra cultivars

Treatments	Number of flowers plant^{-1}	Fruit set (%)	Number of pods plant^{-1}	Pod length (cm)	Pod diameter (mm)
Cultivars (Cv)					
Sabzpari	18.80 b	80.09	14.78 b	9.40 a	11.49 a
Punjab selection	28.89 a	80.24	23.82 a	9.34 a	11.30 a
Green ferry	20.98 b	79.09	16.93 b	7.50 b	9.90 b
LSD value	2.75	3.47	2.42	0.66	0.95
Significance	*	ns	*	*	*
Treatments (T)					
Control (SP with H_2O)	17.11 b	76.01 cde	13.13 b	7.76 c	9.97
SP with GA_3	27.20 a	88.05 a	24.65 a	9.47 a	11.26
SP with NAA	27.89 a	82.70 ab	23.33 a	9.45 a	11.37
SP with Kinetin	17.61 b	74.73 def	13.49 b	7.99 c	10.52
Control (FS with H_2O)	18.83 b	69.45 f	13.64 b	8.40 bc	10.94
FS with GA_3	26.17 a	80.85 bc	21.22 a	9.46 a	11.29
FS with NAA	26.89 a	77.66 bcd	22.30 a	9.10 ab	11.00
FS with Kinetin	21.42 b	70.32 ef	16.31 b	8.29 bc	10.83
LSD value	4.49	5.67	3.95	1.08	1.55
Significance	*	*	*	*	ns
Cv × T					
LSD value	7.78	9.83	6.84	1.87	2.69
Significance	ns	ns	ns	ns	ns

SP – seed priming, FS – foliar spray, ns – non-significant, * – significant

increased plant height, uniform flowering, increased flower number and size and fruiting in chillies [Chaudhary et al. 2006]. Kannan et al. [2008] observed that foliar application of NAA strongly influences the number of flowers per plant, fruit set (%) and fruit numbers per plant in paprika. Similar effects were recorded in the present study.

Fruit set was markedly influenced by the PGR treatments. Seed priming with GA_3 proved superior by giving the maximum fruit set (%), followed by seed priming with NAA. The minimum fruit set was recorded in the treatment, where distilled water was applied as foliar spray, followed by foliar spray and seed priming with kinetin (Tab. 2). Ayyub et al. [2013] evaluated the effectiveness of foliar application of GA_3 on vegetative and reproductive growth of okra and found that increase in number of foliar applications substantially improved vegetative as well as reproductive growth. Exogenous application of GA_3 also significantly improved the pod set in broad beans [Rylott and Smith 1990].

Significantly higher number of pods per plant was obtained in cv. Punjab selection, while significantly lesser number of pods was recorded in cv. Sabzpari, followed by Green ferry. The latter two cultivars behaved statistically alike. It is clear from the data that seed primed with GA_3 resulted in the maximum number of pods per plant, followed by the seed primed with NAA, foliar application of NAA and also foliar application of GA_3. All these four treatments stood statistically at par with each other. The minimum number of pods per plant was produced when seeds were primed with distilled water, followed by seed primed with kinetin, and foliar application of distilled water and kinetin. These four treatments were statistically similar to each other (Tab. 2). Pod number per plant depends upon the flower number produced per plant, and fruit set and retention. In the present study, the pattern of pod number was almost similar to flower number in okra cultivars and also in response to the PGR treatments applied. The results of the current study are also in agreement with findings of Kokare et al. [2006], who recorded increased number of pods in okra plant sprayed with NAA at the rate of 200 ppm. NAA also increased number of fruits per plant in *Capsicum* cultivars [Singh et al. 2012] and in brinjal [Sharma 2006], while Rylott and Smith [1990], Thapa et al. [2003] and Ayyub et al. [2013] found that foliar application of GA_3 increased number of pods/fruits per plant in broad beans, chillies and okra, respectively.

The pod length and diameter were significantly greater in cv. Sabzpari and Punjab selection as compared to Green ferry, which significantly differed from the former two cultivars for the parameter under study. Regarding the PGR treatments, the maximum pod length was recorded in seed primed with GA_3, followed by foliar application of GA_3, seed primed with NAA and foliar application of NAA. While, seed priming and foliar spray with distilled water and kinetin resulted in the minimum pod length. However, pod diameter was not affected by the PGR treatments (Tab. 2). Pod size (length and diameter) is a genetic character and may vary among the okra cultivars. Amjad et al. [2001] also observed difference in pod length among the cultivars tested in their experiment. Results of the present study are also in close conformity with findings of Shahid et al. [2013], who observed that GA_3 in combination with NAA significantly improved the pod length, possibly due to the role of GA_3 in promoting the cell elongation and cell division. Treatment with GA_3 also resulted in increased fruit length in chillies [Thapa et al. 2003] and pod length in okra [Ayyub et al. 2013].

Pods of cv. Punjab selection and Sabzpari had significantly greater fresh weight as compared to those of Green ferry (Tab. 3), indicating that larger pods had greater fresh weight, as pod length and diameter were greater in cv. Punjab selection and Sabzpari, which resulted in increased pod weight. Further, seed primed with NAA surpassed all other treatments by giving the maximum pod fresh weight, followed by seed primed with GA_3, foliar application of GA_3 and foliar application of NAA. All these four treatments were statistically similar to each other. Seed primed with distilled water resulted in the minimum pod fresh weight, followed by foliar application of kinetin and foliar application of distilled water (Tab. 3). Amjad et al. [2001] also recorded significant differences for pod fresh weight among different okra cultivars. Our results can be also related with findings of Chaudhary et al. [2006], who stated that GA_3 increases plant height, pod number, pod length and pod fresh weight in okra. Shahid et al. [2013] found that PGRs play vital role in increasing photosynthetic process and as a result, storage of photosynthates increases in plant parts to ac-

count for more fresh weight. However, in the present study, pod dry weight was not affected by the cultivars used and PGR treatments applied (Tab. 3).

Pod moisture content followed the same pattern as pod fresh weight, being significantly greater in the pods of cv. Punjab selection and Sabzpari as compared to that of Green ferry (Tab. 3), indicating that higher moisture content in pods of these cultivars was also responsible for their greater fresh pod weight. However, pod moisture content was not affected by the PGR treatments applied (Tab. 3).

The maximum pod yield per plant was estimated in cv. Punjab selection, followed by cv. Sabzpari, behaving statistically alike. The minimum pod yield per plant was recorded in cv. Green ferry, which was statistically at par with Sabzpari. Concerning the PGR treatments, the maximum pod yield per plant was recorded in plants sprayed with GA_3, followed by seed primed with NAA, foliar application of NAA and seed primed with GA_3. All these four treatments behaved statistically alike, while the foliar application of distilled water gave the minimum pod yield per plant, followed by foliar application of kinetin, seed treated with distilled water, and seed treated with kinetin. These four treatments were also statistically similar to each other (Tab. 3). Pod yield per hectare also followed the same pattern, because it was calculated from pod yield per plant. Pod yield in okra depends upon many factors, including pod number per plant and fresh weight per pod. The cultivars and PGR treatments resulting in more number of pods per plant with greater pod weight resulted in higher pod yields. Kokare et al. [2006] also found that NAA and GA_3 at the rate of 200 ppm increased pod yield in okra possibly due to stimulating effects of auxins and gibberellins on various vegetative growth characters, which resulted in higher pod yield. The highest fruit yield in chillies [Balraj et al. 2002], brinjal [Sharma 2006] and in okra [Kannan et al. 2008, 2009] were recorded in response to NAA at the rate of 20, 40 and 50 ppm, respectively. NAA increases

Table 3. Effect of PGR treatments of yield and yield components of okra cultivars

Treatments	Fresh weight pod^{-1} (g)	Dry weight pod^{-1} (g)	Pod moisture content (%)	Pod yield plant^{-1} (g)	Pod yield ha^{-1} (t)
Cultivars (Cv)					
Sabzpari	6.48 a	1.01	84.53 a	105.07 ab	7.96 ab
Punjab selection	6.72 a	0.97	85.50 a	116.06 a	8.79 a
Green ferry	4.70 b	1.08	71.73 b	95.32 b	7.22 b
LSD value	0.58	0.29	6.29	12.05	0.91
Significance	*	ns	*	*	*
Treatments (T)					
Control (SP with H_2O)	4.72 d	0.82	81.16	93.12 cd	7.05 cd
SP with GA_3	6.80 ab	1.21	81.67	111.86 abc	8.47 abc
SP with NAA	6.90 a	1.23	81.73	117.85 ab	8.93 ab
SP with Kinetin	5.93 bc	0.88	82.14	101.72 bcd	7.71 bcd
Control (FS with H_2O)	5.31 cd	0.98	80.44	88.42 d	6.70 d
FS with GA_3	6.67 ab	1.19	79.71	124.93 a	9.46 a
FS with NAA	6.06 abc	0.97	79.26	114.69 ab	8.69 ab
FS with Kinetin	5.36 cd	0.91	78.61	91.28 d	6.92 d
LSD value	0.95	0.47	10.27	19.67	1.49
Significance	*	ns	ns	*	*
Cv × T					
LSD value	1.64	0.82	17.79	34.07	2.58
Significance	ns	ns	ns	ns	ns

SP – seed priming, FS – foliar spray, ns – non-significant, * – significant

fruit yield by reducing flower drop and is helpful in increasing the fruit yield in tomato [Alam and Khan 2002] and pod yield in chickpea [Karim 2005].

CONCLUSIONS

The cultivars used in the current study markedly differed for number of branches, leaves, flowers and pods per plant, pod length and diameter and pod yield. The cultivar Punjab selection exhibited the maximum number of leaves, flowers and pods per plant and pod yield, closely followed by Sabzpari. Seed priming with GA_3 improved the seed germination and plant height at early growth stage. Seed priming and foliar spray with NAA and GA_3 were quite effective in enhancing the growth and flowering, improving the fruit set and increasing the pod yield and yield components in okra cultivars grown under calcareous soil conditions.

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