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Effect of different seed priming treatments and priming duration on biochemical parameters and agronomic characters of okra (*Abelmoschus esculentus* L.)

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Maintaining optimum plant population is an important factor in maximizing crop production and productivity. Establishment of okra in the field could be improved by applying suitable priming treatment to seeds. The present investigation was undertaken to find out the effect of seed priming treatments and soaking durations on biochemical parameters and agronomic characters of okra seeds. Okra seeds primed with three priming treatments T_1, T_2 and T_3 (hydropriming, osmopriming with 5% PEG and 10% PEG solution) with soaking durations from 24 to 48 h at 6 h interval, that is, 24, 30, 36, 42 and 48 h were used. Dry okra seeds were considered control treatment. Priming treatments and soaking durations significantly increased biochemical components such as crude protein, total minerals, dry matter, iodine, phosphorus and mucilage content compared to control. Priming with T_2 treatment for 24 h soaking duration gave the best results, followed by T_1 and T_3. Agronomic characters such as number of days taken to 50% flowering, maximum number of nodes and fruiting nodes on main stem, fruit length, fruit width, plant height at first picking, plant height at final harvest, marketable yield per plant, total yield per plant and average fruit weight were improved with priming while control seeds proved to be the poorest. Primed seeds showed better performance of okra than control treatment in aspects of studied criteria.

Key words: Okra, priming duration, biochemical parameters, yield.

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is one of the most widely known dicotyledonous plants and utilized species of the family Malvaceae (Naveed et al., 2009). It is a popular summer crop. Okra are nutritious but might have poor seedling emergence and vigor. Okra seeds are sown in early April in plain areas and in last week of April at the higher elevations. It does not germinate below 20°C (Sadiq et al., 1998). The slow and uneven germination of okra seed is the main hurdle in the early spring planting (Pandita et al., 2010). The edible part of

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okra is the immature pod, which is harvested when tender. The young tender pods are cooked in curries, stewed and used in soups. Young okra leaves are also edible.

Okra pods are a good source of flavonoid antioxidants like beta carotene, xanthein and lutein (Dilruba et al., 2009). Okra has been known to be beneficial to people suffering from leucorrhoea and general weakness. Due to its high iodine content, its fruits are considered useful to control goiter and have medicinal value in curing ulcers and relief from haemorrhoids (Demir, 2001). This vegetable provides an important input of vitamins and mineral salts, including calcium which are often lacking in the diet of people in developing countries (Kahlon et al., 2007).

Seed priming is pre-sowing treatment used as a technique to enhance seed performance, notably with respect to rate and uniformity of germination (Taylor and Vananen, 1998), thereby improving seedling stand and enabling better crop establishment (Job et al., 2000). It is a simple, low cost and effective approach for early seedling growth and yield under stressed and non stressed conditions. Priming may increase resistance to abiotic stresses (Farooq et al., 2008). Primed seeds have been reported to give rise to crops, which matured earlier, and gave higher yields (Ndunguru and Rajabu, 2004).

Okra plants are known to have high amounts of essential nutrients, vitamins, minerals, fatty acids and fibre. Okra (*A. esculentus* L.) is widely consumed as a fresh vegetable in both temperate and tropical countries. Although the seed pods are most often used, the mature seed is known to have superior nutritional quality. Okra is a powerhouse of valuable nutrients, nearly half of which is soluble fibre in the form of gums and pectins which help to lower serum cholesterol, reducing the risk of heart diseases. The other half is insoluble fibre, which helps to keep the intestinal tract healthy (Shalau, 2002). Hassan et al. (1997) reported that okra contains high iodine content which is useful to control goiter and has medicinal value in curing ulcers and providing relief from haemorrhoids.

Okra is also a crop of significant nutritional value that contains a high percentage of water, averaging 85% (Kumar et al., 2010; Siemonsma and Kouame, 2004). It is highly perishable because of its high moisture content and respiratory activities; thus, it is necessary to preserve the commodity. It also contains fair proportion of carbohydrates which are present as cellulose, starch in small quantity, protein, and sugar (Kumar et al., 2010). It is a source of protein, vitamin C, vitamin A, iron, calcium and dietary fibre. Okra contains large quantities of glycans, which are responsible for the viscosity of the aqueous suspension (Kumar et al., 2010). Sliminess property of the okra fruit is of great importance to its acceptability and food value to consumers. According to Wayne et al. (1984) fruit length, fruit diameter, chlorophyll content, mucilage and fibre content determine okra fruit quality. The nutrient requirements of crops depend upon soil texture, types of previous vegetation cover, cropping intensity and soil moisture. Nitrogen, phosphorus and potassium are among the common major nutrients, which are essential for the growth and development of all plant species. Nitrogen is an important part of plant parts such as chlorophyll, amino acid, proteins and pigments. It also increases the protein content of food and feed. Phosphorus (P) is one of the major essential elements required for the development of plants (Hartmann and Geneve, 2000). Plants need P during the rapid growth period and P is a structural component of macromolecules, such as the nucleic acids (DNA, RNA) and ATP. It also creates disease resistance, triggers growth and gives early maturity.

Yield is the key parameter which depends upon both the environmental and genetic factors. Priming speeded up and synchronized seed germination, enhanced the seedling vigour and improved their vegetative and reproductive characters, which finally led to the higher yield. According to Diaz-Franco et al. (1997) fruit quality plays an important role in okra productivity and marketability in addition to yield. Fruit quality is mainly related to pod length, dry matter content, plant height, no of pods per plant and no of days to flowering. Flowering characteristics is highly correlated with physiological maturity of the crop (Sanjaykumar et al., 1996; Vijayaraghavan, 1999). It is considered as the termination of vegetative cycle and start of reproductive cycle.

Number of nodes per plant is a major component which determines the final yield. Number of nodes has direct relationship with number of leaves (Arif et al., 2005). The higher numbers of leaves have resulted in more number of nodes per plant. Priming effect on seed emergence, seedling growth and vigour has been translated to higher number of leaves and hence more pod production. Ullah et al. (2002 b) reported that priming increased yield parameters in raya like number of primary branches per plant and number of nodes and fruiting nodes on main stem. Priming enhanced the seedling vigour, improved the vegetative and reproductive characters, which finally led to the higher yield. The number of fruits per plant and number of seeds per fruit are the major yield components that determine the seed yield.

Okra farmers in Punjab and other Northern states have a major problem with germination of the seeds after planting. In order to understand the effect of different seed priming treatments on quality of okra, as well as to evaluate the best soaking sources and priming period for okra, the present study was carried out to study the effect of selected seed priming treatments on biochemical composition and yield of okra (*A. esculentus* L.) fruits.

The objective of this study was to increase quality of biochemical constituents and yield of okra with seed priming treatments and soaking durations at very wide range of favoured and unfavoured environmental

conditions.

MATERIALS AND METHODS

Experimental details and seed priming

Experiment was conducted in the field at the Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University, Ludhiana to evaluate the effect of seed priming treatments and soaking durations on biochemical parameters and agronomic characters of okra (*A. esculentus* L) viz. Punjab 8. Seed priming treatments included T_1 (hydropriming), T_2 (osmopriming with 5% (w/v) Polyethylene glycol) and T_3 (osmopriming with 10% (w/v) Polyethylene glycol).

Seeds were fully immersed in priming solutions for soaking durations of 24, 30, 36, 42 and 48 h. Dry seeds were considered as control treatment. To avoid fungal growth during the priming process, a fungicide Captan (2 g/L) was added to the priming solutions. At the end of each priming period, the seeds were air dried at room temperature for at least 3 h close to original moisture level (85%).

Extraction and estimation of biochemical parameters

Crude protein

One gram of powdered sample, 5 g of the digestion mixture (1 part of $CuSO_4$: 9 parts of K_2SO_4) and 15 ml concentrated sulphuric acid were mixed in the Kjeldhal digestion flask and heated till a clear light green or colorless solution was obtained. Digested contents were cooled to room temperature and the volume was made to 100 ml with distilled water in volumetric flask.100 ml of the sample solution after dilution was distilled with 50 ml of 40% sodium hydroxide solution using Kjeldahl distillation unit. About 100-150 ml of the distillate was collected in 25 ml of 4% boric acid solution. The boric acid solution was titrated against 0.01 N sulphuric acid till a grey colour was obtained as end point; the volume of acid used was recorded. Nitrogen content of the sample was calculated using the following formula (Micro Kjeldahl method, A.O.A.C. 2000):

% N = [{(X – blank) x 0.00014 x dilution factor (25)} / Y] X 100

X, Titre value; Y, weight of sample (g).

Dilution factor – Volume made / Volume taken for distillation.
The crude protein content was calculated by multiplying %N with a factor 6.25.

Mucilage content

One hundred (100 ml) millilitre of distilled water were added to 25 g of sample and kept for 24 h. The suspension was filtered through muslin cloth and 50 ml of ethanol added to the filtrate. It was stirred on the magnetic stirrer for 15 min and filtered through pre-weighed filter paper, and kept in the oven for drying. After drying the material, it was again weighed along with filter paper. Mucilage content was calculated using the following formula (Rao and Sulladurath, 1977):

$$\text{Mucilage content (\%)} = \frac{W_2 - W_1}{W}$$

W_2, Weight of filter paper along with material after drying; W_1, weight of pre-weighed filter paper; W, weight of sample.

Total minerals

An empty crucible was weighed and 1.0 g dry powder of the material added. This was ignited on the heater to remove fumes and kept in the muffle furnace at 500°C overnight. The furnace was switched off, cooled and the crucible weighed. Total minerals were calculated using the following formula (A.O.A.C., 1965):

$$\text{Total minerals (\%)} = \frac{W_2 - W_1}{W} \text{ X } 100$$

W, Weight of sample in g; W_1, weight of empty crucible in g; W_2, weight of empty crucible + ignited sample in g.

Dry matter

Fifty (50 g) gram sliced okra fruits from each treatment were oven dried in pre-weighed petri-plates at 65 ± 2°C till constant weight was obtained. The dried samples were cooled in a desiccator for 10 min. These were weighed and dry matter content calculated using the following formula:

$$\text{Dry matter content (\%)} = \frac{\text{Final dry weight of the sample}}{\text{Initial fresh weight of the sample}} \text{ X } 100$$

Iodine content

The glassware were thoroughly cleaned with teepol, washed with water, soaked overnight in 10% hydrochloride acid, followed by washing with tap water. These were then rinsed thoroughly with distilled water followed by drying in the oven before use. Samples were dried at 60°C in hot air oven. The dried samples were ground to a fine powder in an electric mixer-cum-grinder and stored in sealed polyethylene bags, making them airtight. One gram of dried and finely ground sample was weighed and transferred into clean test tube.

One (1 ml) millilitre of 10 times diluted 6 M potassium hydroxide solution was added to the sample and kept overnight along with blank at 95±1°C in an oven for drying. The tubes were thereafter transferred to the muffle furnace at 100°C. The temperature of the furnace was brought to 600°C at which the samples were incinerated for 1 h, renewing the air for 15 s after every 15 min. Then the tubes were transferred to the desiccators and allowed to cool to room temperature. If ashing was incomplete, then 1 ml of 10 times diluted zinc sulphate solution was added to all the tubes, continuing drying and ashing as above. After completion of ashing, 0.2 ml of water was added to test tube, stirred thoroughly, vortexed and the volume was made to 5 ml with water. The tubes were centrifuged at 3500 rpm for 30 min. The supernatant was kept for final assay.

Into the test tube 0.5 ml of double distilled water, 0.5 ml of H_2SO_4: HCl solution, 0.5 ml of cerrate reagent (Dissolved 0.316 g) of ammonium ceric (IV) sulphate in 15 ml of water was transferred add 40 ml of concentrated nitric acid added drop by drop. 5 ml of concentrated H_2SO_4 was then added and made up to final volume of 100 ml with distilled water and 0.5 ml of arsenic reagent (Dissolved 0.593 g of Arsenic trioxide and 0.6 g of potassium hydroxide in 30 ml of water, then added 0.1 ml concentrated HCl made the final volume to 100 ml with distilled water) in the same order. This was well mixed and incubated for 1 min at room temperature. Then 0.5 ml of blank or standard or sample was added, mixed well and immediately the reaction occurred for 1 min by measuring O.D. at 400 nm. The slope was calculated from standard curve using pure KI (Mahesh et al., 1988).

Iodine content was calculated from the following formula:

$$\text{Dry Matter Content (\%)} = \frac{\text{Final dry weight of the sample}}{\text{Initial fresh weight of the sample}} \text{ X } 100$$

A_s – Change in A/min in sample; A_b, change in A/min in blank; m, slope of standard curve; d, dilution in ml

Phosphorus

One gram of sample was taken in digestion tubes and digested with 20-25 ml of triple acid mixture (Nitric acid (HNO_3): Concentrated Sulphuric acid (H_2SO_4): Perchloric acid ($HClO_4$): 9:1:3) till white fumes ceased and 5-6 ml aliquot was left. The volume was made to 100 ml with distilled water.

To 5 ml of the extract was added 5 ml of 5% nitric acid and 5 ml of Ammonium Molybdate-Vanadate Reagent (Ammonium Vanadate [1.25 g in 500 ml DW] and Ammonium Molybedate [25 g in 500 ml 1 N Nitric Acid] in 1:1). The intensity of the yellow color was measured at 470 nm against a blank containing 5 ml of triple acid, 5 ml of 5% nitric acid and 5 ml of Ammonium Molybdate-Vanadate Reagent. The concentration of phosphorus was calculated by plotting a standard curve using pure KH_2PO_4 (Jackson, 1973).

Agronomic characters

Days taken to 50% flowering: The number of days taken from sowing to 50% flowering was recorded.

Number of nodes on main stem: Number of nodes on main stem was counted.

Number of fruiting nodes on main stem: Number of fruiting nodes on main stem was counted.

Fruit length: Fruit length was taken in centimeters. Length of five randomly selected fruits was taken and average of these was computed.

Fruit width: Fruit width was taken in centimeters. Width of five randomly selected fruits was taken and average of these was computed. Width was taken from the center of fruit.

Average fruit Weight: The weight of five randomly selected fruits was recorded in grams and average was computed.

Total yield per plant: The total yield per plant in grams was obtained by summing up the weight of fruits of various pickings.

Marketable yield per plant: The marketable yield was recorded after excluding the weight of fruit infected by virus and fruit borer from the total yield.

Plant height at first picking: The plant height was measured from ground level to the tip of the main stem at first picking. The average height was computed and expressed in centimeters. Average heights of five plants were taken.

Plant height at final harvest: The plant height was measured from ground level to the tip of the main stem at final harvest. The average height was computed and expressed in centimeters. Average heights of five plants were taken.

Statistical methods

Experimental units were arranged factorialy in a randomized block design (RBD) with three replications. Mean ± S. D. was calculated and data was analyzed CRD at $p < 0.05$.

RESULTS AND DISCUSSION

Biochemical parameters

Crude protein

Effect of seed priming treatments and soaking durations on the crude protein was found to be statistically at par in okra fruit and has been reported in Table 1. Various priming sources and soaking durations cause significant increase in crude protein content of okra. Maximum increase was observed in T_2 followed by T_3 and T_1. Results of various soaking durations indicate that maximum crude protein content was observed in seeds soaked for 24 h followed by 30, 36 and 42 h, while minimum crude protein was observed in seeds soaked for 48 h. However, in their interaction, highest crude protein content was recorded in seeds soaked for 24 h in T_2 followed by T_3 and lowest crude protein was recorded in seeds which were soaked for 42 h in T_3. Okra is considered as high protein vegetable.

Total mineral

Mineral content was significantly affected by seed priming treatment and soaking durations. The data on the total mineral content has been presented in Table 2. Maximum mineral content was observed in T_2 followed by T_1 and T_3. Soaking durations, indicate that seeds soaked for 24 h duration showed maximum mineral content followed by 36 h, 30 h. In their interaction, maximum mineral content was recorded in seeds which were soaked for 24 h in T_2 followed by 36 h in T_2 and 36 h in T_1 while minimum was observed in seeds soaked for 42 h in T_3. Similar results were obtained by Oguntona (1998) that total mineral content in dry fruit of okra varies from 1.19-2.63%.

Dry matter

Olugbemi et al. (2010) reported that dry matter (DM) values increased in primed seeds as compared to non primed seeds. Primed seeds result in increased dry matter production at vegetative stage due to continuous gain in plant height, number of branches and uniform plant stand. Data presented in Table 3 showed that various seed priming treatments and soaking durations had significant effect on dry matter. Maximum dry matter was observed in T_2 followed by T_3 and T_1. However, in their interaction, highest dry matter was recorded in seeds which were soaked for 24 h in T_2 followed by 30 h

Table 1. Crude protein content in okra fruit in response to various soaking durations and seed priming treatments (%).

Soaking duration (h)	Treatment				
	Control	**T_1**	**T_2**	**T_3**	**Mean**
0	9.56±0.42	-	-	-	9.56
24	-	13.68±0.36	16.02±0.86	14.82±0.34	14.84
30	-	12.32±0.69	13.52±0.92	11.58±0.72	12.47
36	-	10.82±0.33	10.72±0.41	11.89±0.57	11.14
42	-	10.28±0.93	11.77±0.58	8.63±0.65	10.23
48	-	8.79±0.36	9.52±0.83	9.01±0.50	9.11
Mean	9.56	**11.18**	**12.31**	**11.19**	11.56
CD 5%	A=Seed priming treatments=0.265; B=soaking durations=0.343; A*B = 0.594				

Table 2. Total Mineral content in okra fruit in response to various soaking durations and seed priming treatments (%)

Soaking duration (h)	Treatment				
	control	**T_1**	**T_2**	**T_3**	**Mean**
0	0.38±0.05	-	-	-	0.38
24	-	2.36±0.12	2.95±0.08	1.94±0.09	2.42
30	-	2.08±0.09	2.45±0.10	1.30±0.13	1.94
36	-	2.56±0.05	2.68±0.14	1.49±0.10	2.24
42	-	2.38±0.11	1.15±0.09	0.58±0.08	0.87
48	-	1.40±0.10	1.96±0.06	0.63±0.14	1.02
Mean	0.38	2.16	2.24	1.19	1.86
CD 5%	A=Seed priming treatments=0.139; B=soaking durations=0.179; A*B=0.31				

Table 3. Dry matter in okra fruit in response to various soaking durations and seed priming treatments (%)

Soaking duration (h)	Treatment				
	control	**T_1**	**T_2**	**T_3**	**Mean**
0	4.08±0.31	-	-	-	**4.08**
24	-	6.43±0.26	7.96±0.24	6.10±0.36	**6.83**
30	-	5.88±0.42	7.30±0.44	6.50±0.24	**6.59**
36	-	6.80±0.27	5.12±0.49	5.40±0.49	**5.77**
42	-	6.24±0.40	5.98±0.53	6.95±0.23	**6.11**
48	-	5.05±0.46	5.96±0.17	6.14±0.128	**5.72**
Mean	4.08	6.08	6.46	6.22	6.25
CD 5%	A=Seed priming treatments=0.134; B=soaking durations=0.173; A*B=0.300				

in T_2 and lowest dry matter was observed in seeds which were soaked for 48 h in T_1.

Mucilage content

Mucilages are water soluble polysaccharides found in a wide variety of plants and their contents in okra genotype are reported to vary a great deal. The data on the mucilage content was found to be statistically at par in okra fruit and has been reported in Table 4. Various priming sources and soaking durations cause significant increase in mucilage content. Maximum mucilage content was observed with T_2 followed by T_3. Results of various soaking durations indicate that seeds soaked for 24 h duration recorded maximum mucilage content followed by 42, 30 and 36 h. Interaction effects due to seed priming treatment and soaking durations showed that maximum mucilage content was recorded in seeds soaked for 24 h in T_3 followed by 24 h in T_2 and minimum

Table 4. Mucilage content in okra fruit in response to various soaking durations and seed priming treatments (%).

Soaking duration (h)	Treatment				
	control	T_1	T_2	T_3	Mean
0	2.68±0.14	-	-	-	2.68
24	-	4.97±0.16	5.30±0.27	5.42±0.34	5.23
30	-	4.19±0.29	4.34±0.30	4.48±0.36	4.34
36	-	3.14±0.26	4.40±0.25	4.19±0.29	3.91
42	-	4.78±0.18	4.80±0.28	4.51±0.21	4.70
48	-	4.61±0.28	3.24±0.33	3.34±0.17	3.73
Mean	2.68	4.34	4.42	4.39	4.37
CD 5%	A=Seed priming treatments=NS; B=Soaking durations=0.150; A*B=0.260				

Table 5. Iodine content in okra fruit in response to various soaking durations and seed priming treatments (mg/kg)

Soaking duration (h)	Treatment				
	control	T_1	T_2	T_3	Mean
0	7.01±0.68	-	-	-	7.01
24	-	10.30±0.53	13.25±0.21	12.56±0.41	11.78
30	-	10.65±0.36	10.25±0.24	11.34±0.28	10.95
36	-	9.66±0.14	10.40±0.31	9.21±0.39	9.76
42	-	9.68±0.32	8.35±0.33	7.40±0.42	7.88
48	-	8.03±0.34	9.23±0.24	8.46±0.57	8.57
Mean	7.01	9.40	10.54	9.93	9.96
CD 5%	A =Seed priming treatments = 0.908; B = soaking durations = 0.117; A*B=0.203				

mucilage content was recorded in seeds soaked for 48 h in T_2.

Similar results were shown by Maurya and Kaufmann, (1978) that primed seeds showed higher mucilage content ranging from 3.40 to 5.93%.

Iodine content

Improvement in iodine content of primed seeds can be attributed to hydration and imbibitions. The data on the iodine content has been reported in Table 5. Maximum iodine content was recorded in T_2 followed by T_3. Results of various soaking durations indicate that maximum iodine content was observed in seeds soaked for 24 h followed by 30, 36 and 48 h, while minimum was observed in seeds soaked for 42 h. This result is supported by Basra et al. (2003) that iodine content is higher in primed seeds such as wheat.

The data on the phosphorus content have been reported in Table 6. With respect to phosphorus content, significant differences were noticed among seed priming treatments and soaking durations. Maximum phosphorus content was observed in T_2 followed by T_1 and T_3. Results of various soaking durations indicate that maximum phosphorus content was observed in seeds soaked for 24 h followed by 30 and 42 h, while minimum was observed in seeds soaked for 48 h. However, in their interaction, maximum phosphorus content was recorded in seeds soaked for 24 h in T_2 followed by 48 h in T_3 and minimum was recorded in seeds soaked for 36 h in T_1. This result is supported by Arif et al. (2005) who reported that priming increases the P content that supports early phase of crop development, synchronizes the germination process leading to enhanced final yield, especially in P deficient soil.

Agronomic characters

The data on the days to 50% flowering as influenced by various priming sources, soaking durations and their interactions has been presented in Table 7. Untreated control took maximum number of days to 50% flowering, while T_2 treated seeds took minimum number of days. Soaking duration treatment showed that highest number of days was taken in plot having seeds soaked for 36 h. Likewise, in their interaction maximum number of days to 50% flowering was recorded in un-primed seed and minimum was taken by seeds soaked for 24 h in T_2 followed by T_1. Similar results are also reported by Ullah et al. (2002 b) who noted that primed crops emerged

Table 6. Phosphorus content in okra fruit in response to various soaking durations and seed priming treatments (mg/kg)

Soaking duration (h)	Treatment				
	Control	T_1	T_2	T_3	Mean
0	0.65±0.02	-	-	-	0.65
24	-	1.68±0.05	2.25±0.09	1.09±0.07	1.67
30	-	1.47±0.08	1.72±0.04	1.49±0.04	1.56
36	-	0.98±0.04	1.21±0.07	1.35±0.03	1.18
42	-	1.55±0.06	0.94±0.05	1.09±0.09	1.19
48	-	1.37±0.05	1.24±0.04	1.86±0.08	1.02
Mean	0.65	1.41	1.47	1.38	1.42
CD 5%	A=Seed priming treatments=0.841; B=soaking durations=0.109; A*B = 0.188				

Table 7. Days taken to 50% flowering in okra in response to various soaking durations and seed priming treatments

Soaking duration (h)	Treatment				
	Control	T_1	T_2	T_3	Mean
0	34.86±1.29	-	-	-	34.86
24	-	26.86±1.56	24.30±1.98	27.00±1.08	26.05
30	-	31.00±1.07	27.00±1.03	34.20±1.02	30.73
36	-	34.00±1.87	29.23±1.25	31.06±1.71	31.43
42	-	31.46±1.84	28.63±1.57	28.96±1.21	29.68
48	-	31.59±1.58	31.23±1.63	31.00±1.03	31.27
Mean	34.86	30.98	28.08	30.44	29.83
CD 5%	A = Seed priming treatments = 0.308; B = soaking durations = 0.398; A*B = 0.689				

Table 8. Number of nodes on main stem of okra in response to various soaking durations and seed priming treatments.

Soaking duration (h)	Treatment				
	Control	T_1	T_2	T_3	Mean
0	9.55±0.41	-	-	-	9.55
24	-	13.91±0.28	15.86±0.33	13.44±0.58	14.40
30	-	11.08±0.82	14.54±0.67	11.92±0.51	12.51
36	-	11.96±0.53	12.65±0.71	11.85±0.61	12.15
42	-	10.94±0.72	10.43±0.66	10.84±0.81	10.73
48	-	10.63±0.52	10.71±0.83	9.43±0.86	10.67
Mean	9.55	11.70	12.84	11.49	12.01
CD 5%	A=Seed priming treatments=0.223; B=soaking durations=0.288; A*B = 0.500				

faster, flowered earlier and gave higher yield. Mauromicale et al. (2000) reported that osmopriming improved early flowering, maturity time and yield of summer squash (*Cucurbitapepo* L.).

Number of nodes and fruiting nodes on main stem is a major component which determines the final yield. Priming effect on seed emergence, seedling growth and seed vigour index have been translated to higher number of leaves and hence more number of nodes and fruiting nodes produced on main stem. The data on the number of nodes and fruiting nodes on main stem has been reported in Tables 8 and 9.

Various priming sources soaking durations as well as their interaction significantly increased the number of nodes and fruiting nodes on main stem. Maximum number of nodes and fruiting nodes on main stem was recorded in T_2 followed by T_1. Likewise, results of various soaking durations showed that maximum number of

Table 9. Number of fruiting nodes on main stem of okra in response to various soaking durations and seed priming treatments.

Soaking duration (h)	Treatment				
	Control	T_1	T_2	T_3	Mean
0	7.53±0.56	-	-	-	7.53
24	-	9.80±0.63	10.95±0.46	9.30±0.66	10.02
30	-	9.25±0.74	10.06±0.42	9.41±0.61	9.57
36	-	8.76±0.57	10.14±0.56	9.03±0.52	8.90
42	-	8.82±0.43	9.69±0.62	8.35±0.45	8.95
48	-	8.33±0.59	9.75±0.49	7.45±0.49	7.89
Mean	7.53	9.28	9.61	8.93	9.27
CD 5%	A=Seed priming treatments = 0.211; B = soaking durations = 0.273; A*B = 0.473				

Table 10. Fruit length of okra in response to various soaking durations and seed priming treatments (cm).

Soaking duration (h)	Treatment				
	control	T_1	T_2	T_3	Mean
0	7.85±0.61	-	-	-	7.85
24	-	9.59±0.72	9.85±0.78	11.91±0.55	9.72
30	-	10.27±0.74	12.95±0.67	11.03±0.41	11.61
36	-	9.13±0.78	9.62±0.59	10.35±0.71	9.38
42	-	9.68±0.51	9.23±0.70	8.54±0.91	9.46
48	-	9.22±0.77	9.46±0.86	9.08±0.52	9.34
Mean	7.85	9.58	10.22	10.18	9.90
CD 5%	A=Seed priming treatments = 0.489; B = soaking durations = 0.631; A*B = 1.093				

Table 11. Fruit width of okra in response to various soaking durations and seed priming treatments (cm).

Soaking duration (h)	Treatment				
	Control	T_1	T_2	T_3	Mean
0	0.81±0.03	-	-	-	0.81
24	-	0.84±0.06	0.93±0.03	1.05±0.06	1.16
30	-	0.95±0.04	0.98±0.05	1.09±0.04	1.02
36	-	0.99±0.07	0.89±0.06	0.86±0.08	0.88
42	-	1.13±0.08	1.09±0.04	0.97±0.07	1.03
48	-	0.97±0.02	0.92±0.05	0.87±0.02	0.90
Mean	0.81	0.98	0.92	1.01	0.92
CD 5%	A=Seed priming treatments=0.960; B=soaking durations=0.123; A*B = 0.214				

nodes and fruiting nodes on main stem was noted in plot in which seeds were soaked for 24 h, followed by plot in which seeds were soaked for 30 h. Minimum number of nodes and fruiting nodes on main stem was recorded in plot in which seeds were soaked for 48 h. In their interaction highest number of nodes and fruiting nodes on main stem was recorded in plot in which seeds were soaked for 24 h in T_2 followed by 24 h in T_1. Minimum number of nodes and fruiting nodes on main stem was noted in plot in which seeds were soaked for 48 h in T_3. Ullah et al. (2002 a) reported that priming increased yield parameters in raya like number of primary branches per plant and number of nodes and fruiting nodes on main stem.

Data presented in Tables 10 and 11 show that various soaking sources, durations and their interaction significantly enhanced fruit length and width. Maximum fruit length was recorded in plot in which seeds were soaked in T_2 and fruit width was recorded in plot in which seeds were soaked T_3. Similarly, results of various soaking

Table 12. Average fruit weight of okra in response to various soaking durations and seed priming treatments (g).

Soaking duration (h)	Treatment				
	control	**T_1**	**T_2**	**T_3**	**Mean**
0	9.71±0.72	-	-	-	**9.71**
24	-	11.39±0.66	13.51±0.57	11.04±0.42	**11.98**
30	-	10.97±0.45	12.46±0.50	10.75±0.56	**11.39**
36	-	10.51±0.59	11.32±0.54	10.28±0.49	**10.71**
42	-	9.99±0.35	11.18±0.34	10.44±0.68	**10.54**
48	-	9.67±0.53	10.03±0.56	8.78±0.62	**9.49**
Mean	**9.71**	**10.72**	**12.12**	**10.63**	**11.15**
CD 5%	A=Seed priming treatments = 0.337 B = Soaking durations = 0.436 A*B = 0.755				

Table 13. Total yield per plant of okra in response to various soaking durations and seed priming treatments (g).

Soaking duration (h)	Treatment				
	Control	**T_1**	**T_2**	**T_3**	**Mean**
0	92.32±3.56	-	-	-	92.32
24	-	125.31±4.18	132.50±4.72	128.32±4.80	128.71
30	-	120.65±4.49	128.96±5.41	118.36±4.79	122.66
36	-	115.65±4.80	123.40±5.45	107.56±5.54	115.54
42	-	121.30±3.60	125.30±3.19	104.30±4.89	111.97
48	-	109.82±5.40	105.36±4.83	106.23±3.86	107.16
Mean	92.32	115.56	123.10	112.95	176.61
CD 5%	A=Seed priming treatments = 0.249; B = soaking durations = 0.322; A*B = 0.558				

Table 14. Marketable yield per plant of okra in response to various soaking durations and seed priming treatments (g).

Soaking duration (h)	Treatment				
	Control	**T_1**	**T_2**	**T_3**	**Mean**
0	84.52±4.25	-	-	-	84.52
24	-	119.21±4.80	126.23±4.71	120.18±3.83	121.87
30	-	114.56±5.92	117.65±5.00	110.98±3.47	114.34
36	-	100.98±4.41	116.15±4.04	103.40±4.58	106.84
42	-	117.93±4.90	95.20±3.37	88.58±4.78	100.57
48	-	98.12±3.71	98.50±4.68	100.26±4.77	98.96
Mean	84.52	107.01	115.29	104.68	108.99
CD 5%	A=Seed priming treatments = 0.311; B = soaking durations = 0.401; A*B = 0.695				

durations showed that maximum pod length and width was recorded in the seeds soaked for 30 and 24 h soaking duration, while minimum was recorded in 48 h soaking duration. Similar results were shown by Harris et al. (2001) and Saikia et al. (2006) who documented larger ear production in wheat with osmopriming (10% PEG).

Data presented in Table 12 show that various priming sources and soaking durations had significant effects on average fruit weight of okra. Maximum fruit weight was noted in T_2 followed by T_1. Results of various soaking durations showed that maximum fruit weight was observed in plot in which seeds were soaked for 24 h. Similarly, in their interaction maximum fruit weight was recorded in seeds which were soaked for 24 h in T_2 followed by 30 h in T_2 and 24 h in T_1.

The data on the total yield and marketable yield per plant have been reported in Tables 13 and 14. Significantly maximum yield was recorded in T_2 followed by T_1 and T_3. Results of various soaking durations indicated that 24 h seed soaking gave the highest yield,

Table 15. Plant height at first picking of okra in response to various soaking durations and seed priming treatments (cm)

Soaking duration (h)	Treatment				
	Control	T_1	T_2	T_3	Mean
0	15.56±0.79	-	-	-	15.56
24	-	23.37±0.67	23.78±0.87	21.19±0.97	23.54
30	-	21.50±0.81	26.05±0.64	22.50±0.67	22.59
36	-	19.75±0.43	21.63±0.52	18.45±0.83	19.94
42	-	17.14±1.05	20.12±0.80	18.09±1.04	18.45
48	-	22.87±0.60	16.47±0.55	17.32±1.15	18.89
Mean	15.56	19.65	22.89	19.51	20.68
CD 5%	A = Seed priming treatments = 0.204; B = soaking durations = 0.264; A*B = 0.458				

Table 16. Plant height at final harvest of okra in response to various soaking durations and seed priming treatments (cm)

Soaking duration (h)	Treatment				
	Control	T_1	T_2	T_3	Mean
0	72.46±3.37	-	-	-	72.46
24	-	90.02±3.14	97.34±3.72	92.68±2.54	93.35
30	-	84.45±2.88	93.39±2.83	86.78±3.47	85.62
36	-	89.95±3.15	80.17±2.43	81.53±2.78	80.85
42	-	79.15±2.86	84.46±2.16	79.69±2.89	81.10
48	-	73.42±2.10	74.25±3.88	80.29±3.78	73.97
Mean	72.46	83.40	84.65	85.52	84.52
CD 5%	A=Seed priming treatments = 0.202; B=soaking durations = 0.261; A*B = 0.452				

followed by 30 and 36 h, while 48 h seed soaking resulted in the least yield. Likewise, in their interaction maximum yield was recorded in plot in which seeds were soaked for 24 h in T_2, followed by T_3. Minimum yield was recorded in plot in which seeds were soaked for 42 h in T_3. Ndunguru and Rajabu (2004) reported that seed priming improved yield in okra which may be attributed to early germination and better stand establishment. Zhang et al., (1998), Basra et al., (2003) and Arif et al., (2010) also reported that priming treatment significantly increased total biomass and resulted in higher yield in soybean and wheat.

The data on the plant height at first picking and at final harvest have been presented in Tables 15 and 16. The maximum plant height at first picking was observed in plot having seeds soaked in T_2, followed by T_1 and plant height at final harvest was observed in plot having seeds soaked in T_3. Results of various soaking durations indicated that the tallest plants were recorded in plot in which the seeds were soaked for 24 h, followed by plot with soaked seed of 30 h. Least plant height was recorded in control plot. The interaction results showed that plot having seed soaked in T_2 for 30 h and in T_2 for 24 h gave the longest plant at first picking and at final harvest. Unprimed seed plot had the shortest plants. Osmopriming causes significant increase in plant height in okra (Omran et al., 1980), tomato (Jagadish et al., 1994), and onion (Nalini et al., 2001). The increased plant height may be due to rapid cell division in meristematic region, number of cells and increase in cell elongation due to multiplication of various parts of the plant tissue, auxin metabolism, cell wall plasticity, permeability of cell membrane, cell enlargement and rapid cell elongation (Sandyrani et al., 2002). Sathiskumar (2005) has also reported that brinjal seed treated with osmopriming solution increased the plant height, number of of leaves per plant, fruit yield, fruit length and lesser number of days to 50% flowering as compared to control

Conclusions

It has been concluded from the research work that seed priming treatments resulted in increase biochemical parameters and yield of okra than un-primed seed. Maximum increase was observed with T_2 treatment, but both T_1 and T_3 treatments gave almost equal and better results than control treatment. Okra seed priming with T_2 treatment (osmo-priming with 5% PEG) for 24 h duration lead to better yield and biochemical quality parameter by tolerating adverse environmental effects. T_2 treatment can therefore be recommended to okra farmers.

Conflict of interests

The authors did not declare any conflict of interest.

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