INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES
IJPAES
Volume-4, Issue-3, July-Sept-2014 ISSN 2231-4490

Coden : IJPAES www.ijpaes.com
Received: 10th April-2014 *Revised: 28th April-2014* *Accepted: 5th May-2014*
Research article

EVALUATION OF DIFFERENT OKRA GENOTYPES FOR SALT TOLERANCE

Tahira Abbas[2], Muhammad Aslam Pervez[1], C. M. Ayyub[1], Muhammad Rashid Shaheen[1*], Sana Tahseen[1], Muhammad Adnan Shahid[2], Rashid Mukhtar Bilal[2] and Abdul Manan[1]

[1]Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.
[2]College of Agriculture, University of Sargodha, Sargodha, Pakistan.
*Corresponding Author: rashid_uaf2004@yahoo.com Phone: +92-333-6329065

ABSTRACT: An experiment was executed using twenty different Okra genotypes of unknown salt tolerance potential submitted to saline regime, with the objective to categorize them into salt tolerant, moderately tolerant and sensitive groups, on the basis of their salinity-tolerance capacity. The tested genotypes were exposed to different germination and emergence trials under a range of salinity levels i.e., 0, 2, 4, 6 and 8 dS m^{-1}. Germination tests revealed that salt stress significantly reduced final germination percentage, germination index, energy of germination and embryo axis length. Okra seeds subjected to salt stress depicted delay in mean germination time and increased time to 50% germination. The germinated seedlings followed an attenuating pattern in terms of seedling root and shoot length and fresh and dry weight. The emergence tests of okra seeds portrayed a declining trend in emergence percentage, seedling biomass (fresh and dry) and seedling root and shoot length. On the basis of these attributes, the okra genotypes OH-713, OH-139, OH-138, OH-2324 and OH-001 were among the most tolerant group and medium tolerant group included OH-597, MD-02, OH-152. Lower medium tolerant group was formed by PMF-Beauty, PusaSwani, JKOH-456, OH-809, MF-04 whereas the sensitive genotypes included Kiran, Okra-1548, Ikra-3, Sabzpari, Okra-7100, Sitara-9101, Okra-7080. From the findings of this research trial, it can be extracted that germination and emergence tests are the significant screening tools for evaluating the okra genotypes at early growth stages under salt-stress.

Keywords: Salinity; Okra; Germination; Emergence; Genotypes

INTRODUCTION

Salinity is the buildup of soluble salts by which saline soils are formed [1]. Gama et al. [2] reported that plants growing under saline conditions are affected in three ways: reduced water potential in root zone causing water deficit, phytotoxicity of ions such as Na^+ and Cl^- and nutrient imbalance [3] depressing uptake and transport of nutrients. Sodium and chloride which are the major ions produce many physiological disorders in plants [4], but chloride is the most dangerous because NaCl liberates almost 60% more ions into the soil solution than Na_2SO_4[5]. Excess of these salts also enhances the osmotic potential of soil matrix as a result of which water intake by plants is restricted [6,7]. Due to the accumulation of Cl^-, relative salt tolerance has been linked to water use efficiency [8,9] and transpiration [10]. Inspite of upper plant parts, salinity also affects root growth and physiology and ultimately their function of nutrient uptake [11]. Salt stress causes multifarious drastic effects in plants and among these factors production of reactive oxygen species (ROS) is a common phenomenon [12]. In saline environment, plant growth is affected by complex interaction of hormones, osmotic effects, specific ion effects and nutritional imbalances, probably all occur simultaneously [13]. In okra, it affects the leaf growth, photosynthesis, mineral nutrition, stomatal conductance, transpiration, water and ion transport and increases sugars, amino acids and different ions along with acute effects on yield and quality. Okra (*Abelmoschusesculentus*L. Moench) is an annual vegetable of the tropical and subtropical areas. Almost all parts of okra plant are consumed, like fresh okra fruits are used as vegetable, roots and stems are used for clearing the cane juice [14] and leaves and stems are used for making fiber and ropes [15].

Okra like other crops in Pakistan faces a dual menace of biotic and abiotic stresses. Our canal system cannot fulfill the farmers' crop irrigation requirements. So, to fulfill these needs our farmers pump out the underground brackish water and use it for irrigating their fields. On the other hand, addition of effluents to canals makes it more salty and unfit for irrigation. Due to high ratio of toxic salts, plants observe osmotic and specific ion injuries as well as nutritional disorders that result in reduced yield and quality. So there is a dire need to develop and identify the salt tolerant genotypes of vegetables, necessary to feed ever growing population of Pakistan. Keeping in view the importance of okra and utilization of salt affected soils for crop production, a study was initiated to screen out twenty locally available cultivars on the basis of their salt tolerance potential.

MATERIALS AND METHODS

Seeds of 20 different okra genotypes from Ayyub Agriculture Research Institute, Faisalabad were collected. The germination tests were accomplished in Petri dishes in a seed incubator. Seeds were disinfected with 15% sodium hypochlorite solution. Each Petri dish had twenty five seeds in double Whattman filter paper, soaked with relevant salt solution to maintain the desired salinity level. Distilled water was used as control. The embryo axis length, fresh and dry weight of germinated seedlings, germination index, mean germination time, final germination percentage, energy of germination and time to 50% germination were recorded.

Germination Tests

Final germination percentage and germination index were calculated according to Association of Official Seed Analysts [16]. Mean germination time was calculated following Ellis and Roberts [17]. Time to 50% germination was calculated according to Coolbear et al. [18] modified by Farooq et al.[19]. Energy of germination followed [19] and embryo axis length was measured following [20].

Emergence Tests

For emergence test, seeds were sown in plastic pots placed in lath house of Institute of Horticultural Sciences, University of Agriculture, Faisalabad. Twenty seeds per pot were sown having Astatula fine sand (hyperthermic, uncoated typicquartzipsamments) individually as growth medium. The sand had pH of 6.0-6.5, with field capacity (7.2%) and incipient wilting at 1.2 % (Volume basis). NaCl at different concentrations (0, 2, 4, 6 and 8 dS m^{-1}) was applied before sowing of seeds, while 0.5 strength Hoagland solution was used as nutrient solution. The seedlings were watered according to the need by observing the moisture contents of sand.

Salinity application

Sodium chloride (NaCl) at different concentrations (0, 2, 4, 6 and 8 dS m^{-1} and dS/m = conductivity of 1 mmho/cm) was applied before sowing. The salinity level was maintained frequently by assessing the salt level, using EC meter. Control was without salt stress and irrigated only with half strength Hoagland solution.

Emergence percentage

Seeds of 20 okra genotypes were sown in plastic pots. Each pot carried 20 seeds and there were three pots per treatment. Half strength Hoagland solution was used as nutrient medium. Desired salinity levels (2, 4, 6 and 8 dS m^{-1}) were created before the sowing of seeds. The number of seeds emerged (4.0 cm) from sand were counted and emergence percentage was calculated by using the following formula

$$\text{Emergence percentage} = \frac{\text{Number of seeds emerged}}{\text{Total number of seeds sown}} \times 100$$

Shoot and root samples were collected for the estimation of various indicators of salt stress after 20 days of emergence. These indicators comprised of shoot length, root length, shoot fresh & dry weight and root fresh & dry weights.

Measurement of shoot and root lengths

After twenty days of growth, the seedlings were up rooted and washed with distilled water to remove the foreign particles of sand. Shoot length of five randomly selected seedlings from each replicate was measured in centimeters (cm) from the base of hypocotyls to the tip of the shoot with the help of meter rod. Root length of five randomly selected seedlings from each replicate was measured in centimeters (cm) from the base of hypocotyls to the tip of the longest root with the help of meter rod. The average of each replication was calculated.

Measurement of plant fresh and dry biomass

After the measurement of root and shoot lengths, the seedlings were wrapped with filter paper to remove any drop of water present on their leaves and shoots.

Then digital balance was used for the calculation of fresh weights. For dry weights, the five randomly selected plants from each replicate were taken in paper bags and then placed in oven (Memmert-110, Schawabach) and dried at 70 ^{o}C for a week. The dry weights of both root and shoot were calculated on digital balance and average fresh and dry weight of each replicate was taken.

Experimental design and statistical analysis

Experiment was designed following Complete Randomized Design (CRD) with two factor factorial arrangements.Collected data were analyzed statistically by employing the Fisher's analysis of variance technique and significance of treatments were essayed by using HSD (Tukey Test). Statistical analysis and correlations between variables were also estimated by using Statistix 8.1.

RESULTS

Effect of salt stress on final germination percentage

Salt stress significantly reduced the final germination percentage (FGP) in all tested okra cultivars but the highest reduction in final germination percentage was noted in plants exposed to 8.0 dS m^{-1}NaCl stress followed by 6.0, 4.0 and 2.0 dS m^{-1}NaCl (Table-1). Plants grown under non saline condition exhibited highest germination percentage as compared to those submitted to various salinity levels. The statistical comparison of means established OH-139, OH-2324 and OH-713 as the most tolerant cultivars followed by OH-001 and OH-138, being statistically at par. It was also clearly figured out from Table-1 that Ikra-3, PMF-beauty and Sitara-9101 showed the most sensitive behavior in terms of FGP among all the cultivars.

The ranking of cultivars (Table-2) on the basis of % reduction over the control depicted that, cultivars like OH-713, OH-139, OH-2324, OH-138, OH-001 and OH-597 can be categorized as the highly salt tolerant while Pusasawani, OH- 809, Okra-7080, Okra-1548, Ikra-3 and Sitara-9101 as sensitive ones. The remaining cultivars were between the highly salt sensitive and tolerant genotypes.

Table-1.Overall comparison of means of different attributes of 20 okra cultivars at different salinity levels

Cultivars	FGP	GI	MGT	T50	EG	EAL	EP	SFW	SDW	SSL	SRL
IKRA-3	65.65f	5.55e	1.74ef	0.80e	60.95de	4.65gh	75.27cde	5.79abc	2.03c	6.66de	3.05e
JKOH-456	77.67de	6.92c	1.54fg	0.74ef	66.25c	9.62a	79.62bc	5.05c	2.14bc	6.53de	4.63ab
KIRAN	74.32e	8.06b	1.76ef	0.81e	62.83de	8.02bc	76.45cd	5.24c	2.09c	5.13ef	4.58a
MD-02	82.14c	8.35b	1.99e	0.82e	75.64b	5.56de	79.83bc	5.60abc	1.90d	8.52bc	4.88a
MF-04	73.05e	6.92c	1.84ef	0.85e	69.27c	5.73de	76.75cd	5.44bc	2.15bc	8.02c	4.69ab
OH-001	85.83ab	9.16ab	2.65bc	1.01c	83.33ab	9.88a	81.59b	4.82cd	2.77a	9.10b	3.31d
OH-138	87.40ab	8.12b	1.31g	0.59f	82.54b	7.88c	82.36ab	6.62a	2.82a	8.05c	4.50ab
OH-139	89.94a	5.65e	2.93b	0.64f	89.43a	6.49cde	86.83a	6.26a	2.99a	8.98b	3.66c
OH-152	80.12c	8.19b	1.61f	0.75ef	72.02b	8.07bc	77.49c	5.93ab	2.21b	8.56bc	3.86b
OH-2324	88.02a	9.42a	2.19d	1.28b	86.67ab	9.39ab	82.72ab	6.32a	2.74a	6.67de	4.77a
OH-597	82.80c	4.33f	4.05a	2.79a	64.48de	5.07efg	82.01ab	5.95ab	2.85a	10.06a	3.59c
OH-713	91.26a	9.10ab	1.51fg	0.61f	90.26a	9.18b	86.32a	5.49bc	2.76a	9.82a	3.86b
OH-809	71.27ef	7.31bc	1.78ef	0.84e	58.75e	7.89c	77.37c	5.40bc	2.39b	6.43de	4.61ab
OKRA-1548	70.20ef	6.47cd	2.19d	0.98d	55.58e	4.40gh	76.75cd	4.89cd	2.41b	7.13d	2.28f
OKRA-7080	70.67ef	6.52cd	2.71bc	1.06c	55.15e	4.11ghi	71.44e	4.79cd	1.76de	4.95ef	4.53ab
OKRA-7100	74.41e	7.33bc	2.47c	0.94d	66.33c	3.64hij	71.09e	4.58d	2.29b	5.39e	3.45cd
PMF-BEAUTY	68.92f	6.53cd	2.04de	0.84e	61.53de	4.69efg	72.78e	5.91ab	1.97d	8.00c	4.71a
PUSA SAWANI	70.83ef	6.60cd	2.23cd	0.91d	58.87e	4.00ghi	81.44b	5.98ab	2.30b	7.05d	4.16b
SABZ PARI	73.40e	5.74e	1.63f	0.82e	62.53de	5.64de	74.16cde	4.69d	1.76de	4.50f	3.09e
SITARA-9101	63.22f	6.41cde	2.63bc	1.06c	60.23de	4.85efg	73.14e	5.22c	1.52e	7.03d	3.92b

The abbreviations used are FGP: final germination percentage, GI: germination index, MGT: mean germination time, T50: time to 50% germination, EG: energy of germination, EAL: embryo axis length, EP: emergence percentage, SFW: seedling fresh weight, SDW: seedling dry weight, SSL: seedling shoot length, SRL: seedling root length.

Effect of salt stress on germination index

The germination index (GI) of tested okra cultivars depicted that it decreased significantly in response to salinity magnitude as maximum decrease in GI was noted under 8.0, followed by 6.0, 4.0 and 2.0 dS m^{-1}NaCl. All cultivars submitted to saline conditions, had minimum values for germination index than plants grown under non-saline conditions. The overall comparison of means in Table-1 exposed OH-2324 as the cultivar with maximum GI, while OH-001 and OH-713 showed the similar GI value. Minimum value for this attribute was recorded with OH-597. Some of the cultivars (OH-139, OH-713, OH-138, OH-2324, OH-001 and OH-152) were noted to possess excellent tolerance against saline conditions while PMF-beauty, Ikra-3, Pusasawani, Okra-1548, Sitara-9101, Okra-7080 were noted to be highly sensitive to salinity.

Table-2 Overall Ranking of okra cultivars at different salinity levels on the basis of percentage variation in different attributes

Cultivars	FGP	GI	MGT	T50	EG	EAL	EP	SFW	SDW	SSL	SRL	Cumulative	Ranks*
IKRA-3	18	16	16	13	11	17	15	17	16	15	10	164	16
JKOH-456	9	11	13	10	9	9	8	12	11	10	7	109	9
KIRAN	10	9	11	13	12	10	14	13	15	14	13	134	13
MD-02	7	8	6	7	6	8	7	6	8	7	6	76	7
MF-04	13	12	9	12	8	13	13	11	13	12	11	127	12
OH-001	5	6	3	5	4	5	4	7	5	4	3	51	5
OH-138	4	4	2	3	5	3	5	4	3	4	2	39	3
OH-139	2	1	5	2	2	1	1	1	2	2	1	20	2
OH-152	8	5	8	8	7	7	9	8	7	6	4	77	8
OH-2324	3	3	1	4	3	4	3	2	4	5	8	40	4
OH-597	6	7	4	6	6	6	6	5	6	3	5	60	6
OH-713	1	2	1	1	1	2	2	3	1	1	3	18	1
OH-809	16	10	7	11	13	11	10	12	12	11	14	127	12
OKRA-1548	17	16	15	12	15	15	12	16	14	13	12	157	14
OKRA-7080	16	18	12	17	14	16	18	18	20	18	18	185	19
OKRA-7100	12	16	19	16	10	14	19	19	17	17	17	176	17
PMF-BEAUTY	14	14	10	9	11	12	11	10	9	8	9	117	10
PUSA SAWANI	15	15	14	10	13	15	5	9	10	9	8	123	11
SABZ PARI	11	13	18	15	10	12	17	15	18	16	16	161	15
SITARA-9101	19	17	17	14	13	17	16	14	19	17	15	178	18

The abbreviations used are FGP: final germination percentage, GI: germination index, MGT: mean germination time, T50: time to 50% germination, EG: energy of germination, EAL: embryo axis length, EP: emergence percentage, SFW: seedling fresh weight, SDW: seedling dry weight, SSL: seedling shoot length, SRL: seedling root length. *Rankings were based on evaluation of each parameter with number 1 being the most tolerant cultivar

Effect of salt stress on mean germination time (days)

The plants grown under NaCl environment exhibited the delay in germination as compared to those under NaCl conditions. In present study a continuous increase in mean germination time (MGT) was noted with the increasing salinity concentrations from 2.0 dS m^{-1} to 8.0 dS m^{-1}.The interaction between salinity and cultivars was also significant ($p \leq 0.05$).

The statistical comparison of means of all cultivars under various saline conditions showed that OH-138 followed by OH-713 demonstrated minimum MGT (Table-1). It may be hypothesized that salinity application delayed the germination of okra varieties in general. The varieties varied in their response to this aspect as six of them (OH-2324, OH-713, OH-138, OH-597, OH-139 and MD-02) were observed to be highly tolerant but the other six (JKOH-456, Pusasawani, Okra-1548, Ikra-3, Sitara-9101, Sabzpari and Okra-7100) proved to be highly susceptible to salinity (Table-2). The remaining cultivars were categorized in between these extreme saline conditions.

Effect of salt stress on time to 50% germination (days)

Results regarding the time required for 50% seed to germinate indicated that salinity stress had enhanced the time for 50% seed germination. The comparison of means of different cultivars at various saline concentrations revealed that OH-597 took maximum time for 50% seed germination which was followed by OH-2324.

The cultivars like OH-138, OH-139 and OH-713 demonstrated significantly at par behavior by taking minimum time for 50% seed germination. As depicted in Table 4.2, Cultivars (OH-713, OH-139, OH-138, OH-2324, OH-001 and OH-597) can be ranked among salt tolerant group as they exhibited maximum salt tolerance for this attribute while Okra-1548, Ikra-3, Sabzpari, Okra-7100, Sitara-9101 and Okra-7080 were awarded the higher ranks because of their poor performance and grouped under the most sensitive category.

Effect of salt stress on energy of germination

Salinity had decreasing effect on energy of germination (EG), therefore a remarkable decrease in EG was noted in tested okra cultivars. Statistically compared means of all cultivars demonstrated that highest values of EG was noted with OH-713 and OH-139, which were statistically at par with OH-2324, OH-001, OH-138and MD-02. Minimum EG was established by OH-809, Okra-1548, Okra-7080 and Pusasawani, being statistically at par.

Based on ranking regarding the energy of germination, it can be concluded that cultivars i.e. OH-713, OH-139, OH-2324, OH-001, OH-138 and MD-02 had maximum while Kiran, Sitara-9101, Pusasawani, OH-809, Okra-1548 and Okra-7080 had minimum tolerance against salinity.

Effect of salt stress on embryo axis length (cm)

Salt stress significantly reduced the embryo axis length (EAL) in all tested okra cultivars but the highest reduction in embryo axis length was noted in plants subjected to high salt stress (8.0 dSm^{-1} NaCl), followed by 6.0, 4.0 and 2.0 dS m^{-1}NaCl. The interaction between salt stress and cultivars was significant ($p\leq0.05$). The statistical comparison of means regarding EAL established that maximum EAL was noted in JKOH-456 and OH-001 statistically at par with OH-2324 and OH-713. Least EAL values were noted in Okra-7080, Pusasawani and Okra-7100.

On the basis of % reduction in embryo axis length over the control, cultivars like OH-139, OH-713, OH-138, OH-2324, OH-001 and OH-597 can be categorized as the highly salt tolerant while Okra-7100, Pusasawani, Okra-1548, Ikra-3, Sitara-9101 and Okra-7080 as sensitive ones. The remaining cultivars were between the highly salt sensitive and tolerant ones.

Effect of salt stress on emergence percentage

The data on emergence percentage (EP) of tested okra cultivars reflected that increasing salt stress had remarkably decreased emergence because maximum decrease in emergence was noted under 8.0, followed by 6.0, 4.0 and 2.0 dS m^{-1}NaCl. All cultivars grown under saline conditions had minimum values for emergence than plants grown under non-saline conditions. The statistically compared means of cultivars regarding EP revealed the top position of OH-713 and OH-139, statistically at par with OH-138, OH-597 and OH-2324. However, the cultivars like Okra-7080, Okra-7100, Sitara-9101 and PMF-beauty attained the lowest emergence percentage (Table 4.1). Based on the data regarding emergence percentage it can be concluded that plants grown under NaCl conditions witnessed significant reduction in emergence but cultivars (OH-713, OH-139, OH-138, OH-2324, OH-001 and OH-597) demonstrated excellent salinity tolerance potential while Okra-1548, Ikra-3, Sabzpari, Okra-7100, Sitara-9101 and Okra-7080 were highly sensitive to salt stress.

Effect of salt stress on seedling fresh weight (g) and dry weight (g)

The seedlings of plants grown under +NaCl environment exhibited a decline in fresh weight as compared to those under –NaCl conditions, furthermore, in present study this decrease was proportionate to the increase in salinity levels from (2.0 dS m^{-1}) to higher (8.0 dS m^{-1}).The interaction between salinity and cultivars was significant ($p\leq0.05$). A conclusion can be made that under +NaCl conditions cultivars i.e. OH-139, OH-713, OH-2324, OH-138, MD-02 and OH-597 had high salt tolerance potential but Sabzpari, Okra-1548, Okra-7100, Ikra-3 and Okra-7080 were highly sensitive to salt stress.

Results regarding the seedling dry weight (SDW) indicated that salinity stress had decreased the seedling dry weight. Statistically compared means of all cultivars under various salinity levels established the prominent position of OH-713, OH-597, OH-2324, OH-138, OH-139 and OH-001 which were found to be statistically at par. Sitara-9101 attained the lowest mean value for SDW.

Effect of salt stress on seedling shoots length (cm) and root length (cm)

Salt stress had inhibiting effect on seedling shoot length (SSL), therefore a significant reduction in seedling shoot length was noted in investigated okra cultivars. The comparison of means reflected that maximum SSL was noted with OH-597 and OH-713 (Statistically at par) while lowest SSL value was recorded with Sabzpari. Based on above findings regarding the seedling shoot length, it can be concluded that cultivars i.e. OH-713, OH-139, OH-597, OH-138, OH-001 and OH-2324 had maximum while Okra-1548, Ikra-3, Sabzpari, Okra-7100, Sitara-9101, and Okra-7080 had minimum salt tolerance potential.

Salt stress caused a significant reduction in the seedling root length (SRL) of all tested okra cultivars (Table 4.31). Cultivars i.e. OH-138, OH-713, OH-001, OH-139, JKOH-456 and OH-152 had maximum while Sitara-9101, OH-2324, Sabzpari, OH-809, Okra-7100 and Okra-7080 had minimum salt tolerance potential.

DISCUSSION

In present investigation, twenty okra cultivars were submitted to different salinity regimes in order to categorize them into salt tolerant, moderately tolerant and highly salt sensitive categories on the basis of various growth attributes at seedling stage. Salinity significantly limited the germination and emergence percentage. This reduction in germination and emergence may be associated with the reduced water absorption capacity of germinating seeds under saline regimes. Our results also confirmed the findings of Song et al. [21]; Zhang et al. [22]; Zehraet al.[23] who observed a marked reduction in germination of *Suaeda salsa, Chloris virgate*, *Digitariasanguinalis* and *Phragmiteskarka*, respectively. It can be claimed that germination and emergence can be regarded as good indicators of salt stress and can be a reasonable criteria to categorize the tested okra cultivars into salt-tolerant and non-tolerant categories. Shahidet al. [20] reported that salt stress inhibited the growth of radical and plumule so it ultimately resulted in reduced emergence.

The mechanism of inhibition of germination and seedling growth by NaCl, may be related to radical emergence due to insufficient water absorption, or may be ascribed to toxic effects on the embryo [24]. Uhvits[25] observed in alfalfa plants that seeds absorbed an insufficient amount of water and accumulated a large amount of Cl when osmotic pressure of the substrate was increased by salinity and as a result, the seeds emerged slowly which became restricted at higher salinity level. Waiselet al. [26] found that increasing salinity concentration often causes osmotic or specific ion toxicity which may reduce or cease seed germination. Reduction in germination of plants by increasing salinity levels has been described by numerous authors [27-30]. It can be extracted that salt stress limits the seed germination by reducing the water absorption capacity of seeds, inducing ion toxicity and ionic imbalance within cell cytoplasm and disturbing the protein activity of seeds grown under saline conditions. The cultivars OH-713, OH-139, OH-2324 and OH-138 showed the high salt tolerance potential regarding the germination, which indicates that these cultivars may accumulated less ratios of toxic ions (Na and Cl) in their tissue, thus absorbed the maximum beneficial ions and moisture contents which facilitated the enzymatic and protein activities necessary for growth and development. Whereas, the remaining okra cultivars specially Pusasawani, Okra-1548, Ikra-3, Sitara-1901, Okra-7080 and Okra-7100 could not hindered the entry of Na^+ and Cl^- in their tissues, and these toxic ions may reduced the water up-taking potential of seeds and disturbed the enzymatic activities essential for growth related metabolic processes.

Salt stress also hindered the emergence of seedlings in present study, which can also be attributed to the reduced elongation of coleoptile due to low water potential of growing medium. Therefore, seedlings under saline conditions cannot develop well due to less growth of coleoptile and root. The cultivars i.e. OH-713, OH-138, OH-139 and OH-2324 having good seedling establishment under saline conditions, so were assigned under tolerant category. The reduction in embryo axis length may also a strong reason for poor seedling establishment and reduced emergence percentage. It is reported that excessive entry of toxic ions (Na and Cl) into the plant seeds tissues inhibit radical and plumule growth by disintegrating their tissues [31,32], therefore it could be the cause of reduced emergence percentage in tested okra cultivars exposed to salt stress. Our results regarding the emergence percentage are in accordance with the findings of Patel et al. [33,34], Goodman et al.[35] and Katerjiet al. [32]. Salt stress also reduced other growth attributes like seedling shoot length, seedling root length, seedling fresh weight and seedling dry weight in tested okra cultivars, which showed that a strong negative correlation existed between these attributes and salinity. Since, in present study salinity inhibited various growth aspects, so it could have been due to the inhibiting effect of salt stress on growth-related hormones or PGRs. The best performance of OH-713, OH-139, OH-2324 and OH-138 indicated that these cultivars had well maintained their PGRs activity due to less accumulation of toxic ions, therefore they showed less reduction in growth attributes in response to salt stress. Whereas, the cultivars like Okra-7080, Okra-7100, Okra-1548, Ikra-3 and Pusasawani presented the highest reduction in growth attributes which may be linked with high negative effect of salinity on the functioning of PGRs, stimulating the growth and development. In current study, high salinity in root zone may be involved in reducing the water potential, which indirectly resulted in reduced cell turgidity. Due to this reduced cell turgidity the cell differentiation and cell elongation get decreased, which lead to inhibition of growth in tested okra cultivars grown under saline conditions. Since, all the tested okra cultivars, exposed to salt stress showed the significant reduction in growth attributes as compared to those grown under non-saline control conditions, therefore these parameters can be used as a screening criteria for salt tolerance.

The cultivars (OH-713, OH-139, OH-138 and OH-2324) showing less decrease in growth parameters (germination, emergence, root/shoot length and plant biomass) were categorized as salt-tolerant cultivars while Okra-7080, Okra-7100, Okra-1548, Ikra-3 and Pusasawani with maximum decline in these attributes were placed in salt sensitive category. The high growth of tolerant okra cultivars (OH-713, OH-139, OH-138 and OH-2324) could have been due to the excellent maintenance of cell turgor and PGRs activity in response to salt stress. On the basis of this experiment it can be concluded that reduction in germination percentage, emergence percentage, seedling shoot length, seedling root length, seedling fresh weight and seedling dry weight was highly associated with salt stress and these can serve as an effective tool for the assessment of salt tolerance potential of okra cultivars. Literature also depicts that these attributes can be used as screening tools for salinity tolerance potential [36-38]. The screened salt-tolerant okra cultivars like OH-713, OH-139 and OH-138 having excellent genetic capacity to tolerate the excessive salts in root zone, can be cultivated on marginal saline lands.

REFERENCES

[1] Levy, Y. and Syvertsen, J.P. 2004. Irrigation water quality and salinity effects in citrus trees.Hortic.Rev. 30:37-82.

[2] Gama, P.B.S., Inanana, S., Tanaka, K. Nakazawa, R. 2007. Physiological response of common bean (*Phaseolus vulgaris* L.) seedlings to salinity stress.Afr. J. Biotechnol. 6:79-88.

[3] Ashraf, M. and Foolad, M.R. 2007. Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environ. Exp. Bot. 59:206-216.

[4] Romero-Aranda, R.,Moya, J.L., Tadeo, F.R., Legaz, F. and Primo-Millo, E. 1998. Physiological and anatomical disturbances induced by chloride salts in sensitive and tolerant citrus: beneficial and detrimental effects of cations. Plant Cell Environ. 21:1243-1253.

[5] Rachmilevitch, S., Cousins, A.B. and Bloom, A.J. 2004. Nitrate assimilation in plants shoots depends on photorespiration. Proc. Nat. Acad. Sci. 101:11506-11510.

[6] Garcia-Sanchez, F., Jifon, J., Carvajal, M. and Syvertsen. J.P. 2002.Gas exchange, chlorophyll and nutrient contents in relation to Na^+ and Cl^- accumulation in 'Sunburst' mandarin grafted on different rootstocks.Plant Sci. 162:705-712.

[7] Garcia-Sanchez, M.R., Bernet, P., Puchades, J., Gomez, E.A. andAsins, M.J. 2002. Evaluation of salt tolerance of five citrus rootstocks using screening technique.Aust. J. Agric. Res. 53:653-662.

[8] Syvertsen, J. and Levy, Y. 2005. Salinity interactions with other abiotic and biotic stresses in citrus.University of Florida, Indian River Research and Education Center, Ft. Pierce, FL.

[9] Kuo-Tan, L. and Syvertsen, J.P. 2005. Mechanical harvesting has little effect on water status and leaf gas exchange in citrus trees. Florida Dept. of Citrus.Florida Agricultural Experiment Stations, Journal Series No.R-10706.

[10] Moya, L.J., Gomez-Cadenas, A., Primo-Millo, E. and Talon, M. 2003. Chloride absorption in salt-sensitive Carrizo citrange and salt-tolerant Cleopatra mandarin citrus rootstocks is linkedto water use. J. Exp. Bot. 54:825-833.

[11] Apse, M.P. and Blumwald, E. 2007. Na^+ transport in plants.FEBS Letters. 581:2247-2254.

[12] Ashraf, M. 2009. Biotechnological approach of improving plant salt tolerance using antioxidants as markers.Biotechnol. Adv. 27:84-93.

[13] Arbona, V., Macro, A.J.,Iglessias, D.J., Lopez-Clements, M.F., Talon, M. and Gomez-Cadnas, A. 2005. Carbohydrate depletion in roots and leaves of salt-affected potted *C. clementina* L. Plant Growth Regul. 46:153-160.

[14] Chauhan, D.V.S. 1972. Vegetable production in India.RamPrasadandsons, Agra, India.

[15] Jideani, V.A. and Adetula, H.O. 1993. The potential of okra seed flour for weaning foods in West Africa.Ecol. Food Nutr. 29:275-283.

[16] Association of Official Seed Analysists. 1983. Seed vigor testing handbook. Contribution no. 32 to the and book on seed testing. Association of Official Seed Analysis. Springfield.

[17] Ellis, R.A. and Roberts, E.H. 1981. The quantification of ageing and survival in orthodox seeds.Seed Sci. Technol. 9:373-409.

[18] Coolbear, P., Francis, A. and Grierson, D. 1984. The effect of low temperature pre-sowing treatment under the germination performance and membrane integrity of artificially aged tomato seeds.J. Exp. Bot. 35:1609-1617.

[19] Farooq, M., Basra, S.M.A., Hafeez, K. and Ahmad N. 2005. Thermal hardening: a new seed vigor enhancement tool in rice. J. Integr. Plant Biol. 47:187-193.

[20] Shahid, M.A., Pervez, M.A, Balal, R.M., Mattson, N.S., Rashid, A., Ahmad, R, Ayyub, C.M. and Abbas, T. 2011. Brassinosteroid (24-epibrassinolide) enhances growth and alleviates the deleterious effects induced by salt stress in pea (*Pisumsativum*L.).Aus. J. Crop Sci.5 (5):500-510.

[21] Song, C.P., Guo, Y., Qui, Q.S., Lambert, G., Galbraith, D.W., Jagendorf, A. and Zhu, J.K. 2004. A probable Na^+ (K^+)/H^+ exchanger on the chloroplastenvelope functions in pH homeostasis and chloroplast development in*Arabidopsis thaliana*. Proc. Nat. Acad. Sci.USA 101:10211-10216.

[22] Zhang, H., Irving, L.J., Tian, Y. and Zhou, D. 2012. Influence of salinity and temperature on seedgermination rate and the hydrotime model parameters for the halophyte, *Chlorisvirgata*, and the glycophyte, *Digitariasanguinalis*.South Afr. J. Bot.78:203-210.

[23] Zehra, A., Gul, B., Ansari, R. and Khan, M.A. 2012.Role of calcium in alleviating effect ofsalinity on germination of *Phragmiteskarka* seeds. South Afr. J. Bot.78:122-128.

[24] Azza, M.A.M., EL-Quensi, E.M.F. and Farahat, M.M. 2007. Responses of ornamental plants and woody trees to salinity.World J. Agric. Sci. 3(3):386-395.

[25] Uhvits, R. 1964. Effects of osmotic pressure on water absorption and germination of alfalfa seeds.Am. J. Bot. 33:278-285.

[26] Waisel, Y., Agami, M. and Shapira, Z. 1982. Uptake and transport of ^{86}Rb, ^{32}P, ^{36}Cl and ^{22}Na by four submerged hydrophytes.Aquat. Bot. 13:179-186.

[27] Breen, C.M., Everson, C. and Rogers, K. 1997. Ecological studies on *Sporobolusvirginicus* (L.) Kunth with particular reference to salinity and inundation. Hydrobiol. 54:135-140.

[28] El-Tayeb, M.A. 2005. Response of barely grains to the interactive effect of salinity and salicylicacid.J. Plant Growth Regul. 45:215-224.

[29] Abdul Karim, M.D., Utsunomiya, N. andShigenaca, S.H. 1992.Effects of sodium chloride on germination and growth of Hexaploid Triticale at early seedling stage.*Japn*. J. Crop. Sci. 61: 279-284.

[30] Abbad, A., El Hadrami, A. and Benchabane, A. 2004. Germination responses of the Mediterranean saltbush (*Atriplexhalimus* L.) to NaCl treatment.J. Agron. 3: 111-114.

[31] Qu, X.X., Huang, Z.Y., Baskin, J.M. and Baskin, C.C. 2008. Effect of temperature, light and salinity on seed germination and radical growth of the geographically widespread halophyte shrub *Halocnemumstrobilaceum*. Ann. Bot. 101:293-299.

[32] Katerji, N., Mastrorilli, M, Lahmer, F.Z. and Oweis, T. 2012. Emergence rate as a potential indicator of crop salt-tolerance.Eur. J. Agron.38: 1-9.

[33] Patel, A.D, Bhensdadia, H. andPandey, A.N. 2009. Effect of salinisation of soil on growth, water status and general nutrient accumulation in seedlings of *Delonixregia* (Fabaceae).Acta Ecologica Sinica. 29:109-115.

[34] Patel, N.T., Gupta, A. andPandey, A.N. 2010. Salinity tolerance of *Avicennia marina* (Forssk.)Vierh from Gujarat coasts of India. Aquat. Bot. 93:9-16.

[35] Goodman, A.M, Ganf, G.G., Maier, H.R. and Dandy, G.C. 2011.The effect of inundation and salinity on the germination of seed banks from wetlands in South Australia. Aquat. Bot. 94: 102-106.

[36] Dasgan, H.Y, Aktas, H, Abak, K. and Cakmak, I. 2002. Determination of screening techniques to salinity tolerance in tomatoes and investigation of genotype responses.Plant Sci.163:695-703.

[37] Tlig, T, Gorai, M. and Neffati, M. 2008. Germination responses of *Diplotaxisharra* to temperature and salinity. Flora. 203:421-428.

[38] Guan, Y.J., Hu, J., Wang, X.J. and Shao, C.X. 2009. Seed priming with chitosan improves maize germination and seedling growth in relation to physiological changes under low temperature stress. J. Zhejiang Univ. Sci. 10:427-433.