



Assessment of Salinity Tolerance in the Selected Genotypes of Cotton

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ABSTRACT

In order to evaluate the salinity tolerance of cotton genotypes, 14 selected genotypes together with a commercial cultivar (as control) were compared in laboratory and farm in during the 2014-2015 growing season. The aim of this study was recognition salinity tolerant genotypes at the germination stage and found the relationship between laboratory and farm conditions to reduce costs and minimize the time needed to improve tolerance to salinity. The laboratory study was performed as a factorial experiment based on a completely randomized design with three replications. The first factor was salinity at 3 levels (0, 8 and 16 ds/m) and the second factor was genotypes selected from 180 imported varieties using a two-step selection in previous experiments. The measured traits include the percentage of germination (Ger%), stem length (SL), root length (RL), stem wet weight (SWW), stem dry weight (SDW), root wet weight (RWW), root dry weight (RDW), stem tissue water content (SWC), root tissues water content (RWC), seedling wet weight (SLWW), seedling dry weight (SLDW) and whole plant water content (PWC). Results showed that there are significant differences among studied genotypes for the mentioned traits at a 5 or 1 percent level. Salinity treatments have reduced the length of stem, root and wet weight of cotton seedlings. The TJ189 genotype showed higher performance for GER (91.6), also TJ178 for SL (51.6) and TJ169 for RL (70.5). For SWW and RWW, genotypes TJ120 and TJ183 with 362.4 and 53.6 mg were higher than the control cultivar, respectively. Tj82 the most seed cotton yield and Golestan the most earliness have among the 15 genotypes.

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1. Introduction

In Iran, the cotton cultivation area is approximately 100000 hectares and there are some limitations to increasing this area. So, cotton production has been reduced and needs to introduce new cotton cultivars tolerant to abiotic stress (Rahemi *et al.*, 2018).

Salinity stress is one of the first abiotic stresses that plants encounter and is one of the most important environmental stresses that influence the whole plant growth cycle (Garratt *et al.*, 2002). The tolerance degree to salinity is different in germination and seedling stages in different plant species. An increase in salinity may reduce the germination percentage, depending upon the type and level of salinity and also plant species. However, there is no general regulation for

plant tolerance in the germination stage and even a highly tolerant plant may demonstrate severe susceptibility in this growth stage. In some species, including cotton, the susceptibility in the germination stage is higher than that in the node formation stage (Fathi Sadabadi *et al.*, 2017).

Azad *et al.* (2017) showed that the effect of salinity was significant ($P < 0.01$) on all studied traits except the ratio of the length of root and shoot. Increasing of salinity stress condition from 70 to 210 mM was decreased germination percentage, germination rate, fresh weight and dry, root length and shoot, seedling length, longitudinal, and the weighted power toward control, but the longitudinal power index increased (Azad *et al.*, 2017).

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Cotton has a higher tolerance threshold than other industrial crops. However, developing new cotton genotypes with better tolerance to higher concentrations of salt can be quite promising for cultivation in regions with saline soils. There are desirable variations in diploid (*G. herbaceum*) and tetraploid (*G. hirsutum*) species for salt tolerance (Ghajari et al., 2001).

Kornejadi evaluated various salt-tolerant cotton cultivars at the seedling stage and showed that upon increasing the salt level, there was a reduction in all the measured traits when compared to the control conditions. Differences in salinity×genotype interaction effects were significant at 5% for leaf area, leaf dry weight and ratio of root/shoot dry weight. These results represent different responses of cotton cultivars in salinity levels for an index of salt sensitivity (Kornejadi et al., 2004).

Mirghasemi (2012) evaluated 7 cotton genotypes in saline (Anbarolum research station) and non-saline (Karkandeh-Kordkoy research station) conditions and determined the tolerant genotypes by studying the morphological and physiological characteristics of the cotton plants. Results of the combined analysis showed that the Coker*349 cultivar produced a higher yield with 1623 and 3616 kg.ha⁻¹ and earliness of 77 and 89 percent in saline and non-saline states, respectively (Mirghasemi et al., 2012).

To understand more about the effects of salinity on α -amylase and protease activities and the relationship of metabolism in the germination period of cotton cultivars, performed an experiment using 3 cultivars and demonstrated that salinity had significant effects on germination stages and the wet weight of all cotton cultivars (Ashraf and Ahmad, 2000).

Sixteen cotton cultivars in Pakistan belonging to upland (*G. hirsutum* L.) and desi (*G. arboreum* L.) were studied to work out comparative salt tolerance at the germination stage. Four different salinity levels viz. 0.25%, 0.5%, 0.75% and 1.0% were raised by mixing NaCl, MgSO₄ 7H₂O CaCl₂ 2H₂O: NaHCO₃ (9:8:2:1). Increasing salinity levels delayed seed germination rather to inhibit this biological process. This delay was signed up to 48 hours. However, the onward delay was insignificant in most of the cotton cultivars. Sixty percent or more germination in 1% salinity level after 48 hours of incubation period was selected as the criteria to compare the salt tolerance at germination.

Upland cotton cultivars B557, Rehmani, K68, Niab 78, Sarmast, Qalandari and desi cotton cultivars Rohi, Ravi and SK 10/19 appeared as most salt-tolerant under 1% salinity level at germination (Jafri and Ahmad, 2002).

Soil salinity effects were studied in cotton (*Gossypium hirsutum* L.) under four levels of salinity [EC=0.6 (control) EC=6.3, EC=12.3 and EC=16 dsm-l]. Salinity stress decreased stem and root length, organic material and chlorophylls (a, b and a+b) contents in Siokra (resistant) and Sahel (semi-resistant) cultivars. Salinity not only increased in the content of proline, soluble sugars, and soluble proteins but also decreased peroxides activity in Siokra leaves significantly. In both cultivars, Na⁺, Cl⁻, and K⁺ concentration increased significantly in the leaves, indicating that salinity resistance was not associated with the ability of the plants to restrict uptake and accumulation. Na⁺ accumulation in the Sahel was higher than in Siokra (Rezaei et al., 2004).

Six F1 progenies and their parents were planted in Kashmar Cotton Research Station (non-saline location) and Saadaldin region (Saline location) in a randomized complete block design with three replications in 2003. Results showed that the variance of genotypes for boll weight in a non-stress environment, and seed cotton yield and number of plants per plot in stress conditions, were significant. Also, the effect of specific combining ability for boll seed cotton weight in a non-stress environment and the plant number per plot in stress conditions were significant. It was also significant for seed cotton yield under stress conditions (Taberian et al., 2006).

Ghasemi and Hamidi (2013) Studied the callus formation potential of immature embryo, hypocotyl and root explants of Sahel, Sepid, No. 200, Barbadense and Khordad cotton cultivars were investigated on Murashiq and Skoog (MS) basal medium containing various hormonal combinations of 2, 4-Dichlorophenoxy acetic acid (2, 4-D) and 6-Benzylamino purine (BAP). The relative growth rate of calli showed a significant reduction in all explants and cultivars with increasing NaCl densities, as, the control treatment (without NaCl) has the highest relative growth rate with 51.6%, and the lowest relative growth rate of 20.6% was observed on MS medium containing 3 mg/l NaCl.

The effects of soil salinity on fatty acid composition, antioxidative enzyme activity, lipid peroxidation, and

photosynthesis in functional leaves were studied during the flowering and boll-forming stages of two cotton cultivars including CCRI-44 (salt-tolerant) and Sumian 12 (salt-sensitive), grown under different soil salinity conditions. These results suggested that salt stress caused DBI reduction and decreased the photochemical conversion efficiency of solar radiation and, thereby resulting in lower net photosynthetic rates (Zhang et al., 2013).

This study aimed to identify salinity tolerant genotypes at the germination stage and to find the relationship between laboratory and farm conditions to reduce costs and minimize the time needed to improve tolerance to salinity.

2. Materials and methods

In order to consider germination rates of treatments under salinity stress, a factorial experiment based on a completely randomized design with three replications was conducted at the Cotton Research Institute of Iran laboratory in 2014. The experiment factors included salinity treatment at three levels (0, 8, 16 ds.m⁻¹) and 15 selected genotypes of cotton (14 genotypes introduced from Tajikistan and 1 control). Cotton seeds were first soaked at 20% sodium hypochlorite for 10 min and then the number of 100 seeds were cultured between two layers of paper towel in which 10 rows. Pure NaCl was used for obtaining the necessary EC in related salinity treatments and the salt was calculated as gr.l⁻¹ and each sample was moistened with 20 ml of this solution. The rolled papers were put vertically until the extra water drained out. Then, the rolled papers inside two layers of a plastic bag were put into a germinator regulated at 25°C with 16/8 hour light/dark. Three, six and nine days after culturing, the germinated seeds with more than two mm root length were accounted and five seedlings of each sample were selected for measuring the wet and dry weight of shoots and roots. Seedlings were put into paper envelopes and then put for 48 hours into a 78°C oven for measuring dry weight. Traits include germination percentage (GER), shoot length (SL), root length (RL), shoot wet weight (SWW), shoot dry weight (SDW), root wet weight (RWW), root dry weight (RDW), seedling wet weight (SLWW), seedling dry weight (SLDW) and tissue water content (TWC) were measured.

$$GER\% = \frac{n}{N} * 100 \quad (1)$$

$$TWC = \frac{SLWW - SLDW}{SLWW} * 100 \quad (2)$$

Where n was the number of seedlings that emerged in each count and N was the number of total seedlings that emerged (Maguire, 1962).

Length of root and shoot were measured using a ruler and root wet weight was measured using a sensitive scale after cutting above soil organs. After measuring, the root and shoot were put into paper envelopes and their weight was written separately on the envelopes.

The field experiments were performed in a randomized complete block design with three replications. Planting was performed using a 20×80 cm pattern in the second half of May in 2014-2015. The characteristics included: plant height (PLH), number of bolls (NOB), boll weight (BOW), seed cotton yield (SCY) and earliness (EAR). Five random plants were randomly selected, and all data was recorded only from the selected plants. Harvesting was done after removing half a meter from up and down rows.

ANOVA was done and mean comparisons of traits were done using Duncan's multiple range tests. Software MSTATC and SAS (9.1) and also Excel were used for data analysis and drawing graphs, respectively.

3. Results and discussion

Results of analysis of variance show significant effects of salinity on all measured traits. The genotypes differed at 5 or 1% level for Ger%, SL, RL and RDW, while these differences were not significant for the other traits (Table 1). The salinity×genotype interactions for all traits except RL and SWW were significant in expressing the existence of various reactions of genotypes at different salinity levels (Table 1).

Mean comparison of traits demonstrated significant differences among different levels of salinity, so that, by increasing salinity level, an obvious decrease has happened in most traits. For instance, by increasing the salinity level, SL reduced from 45.6 to 29.3 mm and RL reduced from 67.1 to 45.5 mm. Moreover, SDW, RDW and SLW showed considerable reduction (Table 2).

Table 1. Mean squares of traits related to the germination of cotton genotypes in different salinity conditions.

Source of variation	df	Ger (%)	SL (mm)	RL (mm)	SWW (mg)	SDW (mg)	RWW (mg)	RDW (mg)	SLWW (mg)	SLDW (mg)
Salt		517.1**	3485.1**	6707.9**	257878.2**	5229.8**	18850.9**	67.3**	412251.1**	6427.2**
Genotype	2	413.1**	287.1**	588.8*	5746.8 ^{ns}	147.3 ^{ns}	363.2 ^{ns}	8.8**	7562.4 ^{ns}	177.5 ^{ns}
Salt * genotype	14	112.1**	179.6**	312.1 ^{ns}	6957.1 ^{ns}	148.7*	497.8*	4.9*	9601.3*	172.4**
Error	28	55.7	87.4	276.1	4644.2	90.8	262.7	2.2	5256.7	103.1
C.V.	90	8.8	23.7	22.8	24.2	23.3	23.5	23.2	22.1	22.2

Ger=Germination percentage, SL=Shoot length, RL=Root length, SWW=Shoot wet weight, SDW=Shoot dry weight, RWW=Root wet weight, RDW=Root dry weight, SLWW=Seedling wet weight and SLDW=Seedling dry weight. ns, *, **: not significant, significant at 5 and 1%, respectively.

Table 2. Mean comparisons of traits related to the germination of cotton genotypes at different salinity levels.

Treatment	Ger (%)	SL (mm)	RL (mm)	SWW (mg)	SDW (mg)	RWW (mg)	RDW (mg)	SLWW (mg)	SLDW (mg)
Salt 1 (S=0)	87.7 ^a	45.6 ^a	67.1 ^a	331.5 ^a	50.1 ^a	69.2 ^a	6.03 ^a	400.8 ^a	56.1 ^a
Salt 2 (S=8)	82.9 ^b	43.1 ^a	66.4 ^a	303.9 ^a	43.3 ^b	52.5 ^b	4.58 ^b	356.4 ^b	47.9 ^b
Salt 3 (S=16)	81.2 ^b	29.3 ^b	45.5 ^b	185.8 ^b	28.6 ^c	28.5 ^c	3.61 ^c	217.4 ^c	32.6 ^c

Ger=Germination percentage, SL=Shoot length, RL=Root length, SWW=Shoot wet weight, SDW=Shoot dry weight, RWW=Root wet weight, RDW=Root dry weight, SLWW=Seedling wet weight and SLDW=Seedling dry weight. In each column, means with a similar letter has not significantly different.

Table 3. Mean comparisons of cotton genotypes at different salinity conditions for traits related to the germination.

Genotype	Ger (%)	SL (mm)	RL (mm)	SWW (mg)	SDW (mg)	RWW (mg)	RDW (mg)	SLWW (mg)	SLDW (mg)
TJ8	89.8 ^{ab}	41.6 ^{bc}	49.4 ^{bc}	263.4 ^{ab}	35.5 ^{bc}	55.1 ^{ab}	3.99 ^d	318.4 ^{abc}	39.4 ^{bc}
TJ20	86.5 ^{abc}	40.0 ^{bc}	62.2 ^{ab}	309.9 ^a	44.3 ^{ab}	52.5 ^{ab}	4.99 ^{bcd}	362.4 ^a	49.3 ^{abc}
TJ57	63.8 ^e	28.6 ^d	42.2 ^c	231.5 ^b	38.2 ^{abc}	41.3 ^b	3.42 ^d	272.8 ^c	41.7 ^{bc}
TJ82	77.6 ^d	44.2 ^{ab}	62.6 ^{ab}	276.6 ^{ab}	38.1 ^{abc}	44.4 ^b	4.21 ^{cd}	321.2 ^{abc}	42.2 ^{bc}
TJ124	86.6 ^{abc}	38.8 ^{bc}	57.7 ^{abc}	262.8 ^{ab}	40.0 ^{abc}	41.7 ^b	3.95 ^d	304.5 ^{abc}	43.9 ^{abc}
TJ135	82.1 ^{bcd}	33.6 ^{cd}	49.4 ^{bc}	277.4 ^{ab}	42.7 ^{abc}	47.1 ^{ab}	3.71 ^d	324.5 ^{abc}	46.4 ^{abc}
TJ139	86.6 ^{abc}	44.1 ^{ab}	64.7 ^{ab}	281.2 ^{ab}	37.5 ^{abc}	42.6 ^b	3.79 ^d	323.8 ^{abc}	41.3 ^{bc}
TJ168	83.5 ^{a-d}	38.1 ^{bcd}	55.5 ^{abc}	302.2 ^{ab}	39.5 ^{abc}	56.3 ^{ab}	5.90 ^{ab}	358.6 ^a	45.4 ^{abc}
TJ169	85.3 ^{a-d}	42.3 ^{abc}	70.5 ^a	258.2 ^{ab}	33.5 ^c	55.2 ^{ab}	5.65 ^{abc}	313.2 ^{abc}	39.2 ^c
TJ174	82.1 ^{bcd}	39.5 ^{bc}	68.1 ^{ab}	293.1 ^{ab}	45.5 ^{ab}	63.5 ^a	4.99 ^{bcd}	356.6 ^{ab}	50.5 ^{abc}
TJ178	89.8 ^{ab}	51.6 ^a	69.4 ^a	305.4 ^{ab}	42.7 ^{abc}	51.2 ^{ab}	6.85 ^a	356.7 ^{ab}	49.6 ^{abc}
TJ183	85.6 ^{abc}	34.1 ^{bcd}	64.3 ^{ab}	252.2 ^{ab}	47.6 ^a	51.1 ^{ab}	5.94 ^{ab}	303.4 ^{abc}	53.6 ^a
TJ185	88.3 ^{ab}	43.1 ^{abc}	63.6 ^{ab}	273.2 ^{ab}	40.9 ^{abc}	49.6 ^{ab}	4.89 ^{bcd}	322.9 ^{abc}	45.8 ^{abc}
TJ189	91.6 ^a	33.6 ^{cd}	55.2 ^{abc}	302.9 ^{ab}	46.3 ^a	54.4 ^{ab}	4.54 ^{bcd}	357.3 ^{ab}	50.8 ^{ab}
Golestan	80.0 ^{cd}	36.3 ^{bcd}	59.4 ^{abc}	231.2 ^b	39.4 ^{abc}	45.1 ^b	4.19 ^{cd}	276.2 ^{bc}	43.6 ^{abc}

Ger=Germination percentage, SL=Shoot length, RL=Root length, SWW=Shoot wet weight, SDW=Shoot dry weight, RWW=Root wet weight, RDW=Root dry weight, SLWW=Seedling wet weight and SLDW=Seedling dry weight. In each column, means with a similar letter has not significantly different.

In other research reported that salinity resulted in a reduction of the Shoot Dry Weight (SDW), Total Dry Weight (TDW) Leaf Area (LA) and Plant Water Content (PWC) in cotton (Basal et al., 2006). Similar results were reported that increasing salinity is effective in the reduction of Ger%, SL, SWW, SDW, RWW and RDW of cotton seedlings (Ibrahim et al., 2007).

The reaction of cotton cultivars was different from levels of salinity stress. An increase in salt stress caused

a significant reduction in the germination characteristics of studied cotton cultivars (Taghizadeh et al., 2018).

Although significant differences were not observed among genotypes for some traits in the ANOVA table, it seems that the non-significant differences might be due to salinity×genotype interaction. Therefore, the positive and negative effects of treatments were neutralized and the F test was not able to show differences among genotypes. Nevertheless,

differences among genotypes were significant at 5% using Duncan's multiple range test (Table 3).

The highest germination percentage was seen in the genotype TJ189 with 91.6% and the least germination was observed in TJ57 only with 63.8%. The longest shoot and root were 51.6 and 70.5 mm and were observed in genotypes TJ178 and TJ169, respectively. However, genotypes TJ20 and TJ183 with 309.9 and 47.6 mg showed the highest SWW and SDW, respectively.

The genotype TJ174 with 63.5 mg and genotype TJ178 with 6.85 mg displayed the highest RWW and RDW, respectively.

Genotypes TJ20 and TJ168 with 362.4 and 358.6 mg SLWW and genotype 183 and TJ189 with over 50 mg RDW were superior to the other genotypes and Golestan control cultivar, respectively (Table 3).

Higher root volume and higher absorption of water and nutrition from a larger area of soil are effective characteristics of salinity stress tolerance (Garratt, Janagoudar et al., 2002). Generally, the cultivars tolerant to drought and salinity have more root volume, lengthier root and more root/shoot ratio in comparison with the sensitive cultivars (Wittenmayer and Merbach, 2005). According to these criteria genotype, TJ178 was superior to the other genotypes. There is a considerable amount of loss of water content in the plant tissues subjected to salinity stress due to an increase in the

plant osmotic pressure. Therefore, the relatively high salinity (16 ds.m^{-1}) limits the plant growth and development by decreasing the water content of plant tissues (Fig. 1).

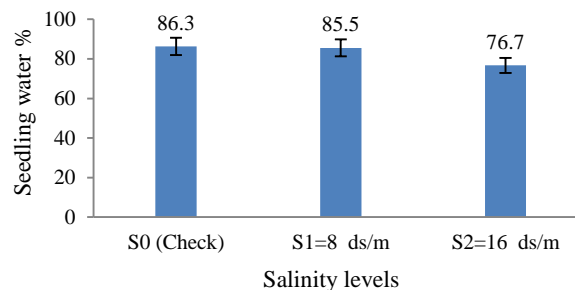


Figure 1. Comparison of seedling water percentage at different levels of salinity.

3.1. Phenotypic correlation

Calculation of the correlation coefficient among traits in Table 4 showed that Ger% has a positive and significant relationship with SL($r=0.322$) and RL($r=0.277$), which means that genotypes with better germination have better growth and their shoot and root lengths will subsequently increase. Moreover, better germination caused better root development in these genotypes. The reason behind this conclusion is having positive and significant relationships between G% with RWW and RDW that finally resulted in increasing the dry weight of seedlings.

Table 4. Correlation coefficients of the considered traits in early maturity of cotton genotypes at different levels of salinity.

Correlation coefficient	Ger (%)	SL (mm)	RL (mm)	SWW (mg)	SDW (mg)	SWC (%)	RWW (mg)	RDW (mg)	RWC (%)	SLWW (mg)	SLDW (mg)
SL (mm)	0.322**										
RL (mm)	0.277*	0.703**									
SWW (mg)	0.418**	0.534**	0.438**								
SDW (mg)	0.311**	0.395**	0.465**	0.772**							
SWC (%)	0.298**	0.563**	0.523**	0.592**	0.437**						
RWW (mg)	0.352**	0.651**	0.605**	0.614**	0.628**	0.370**					
RDW (mg)	0.349**	0.556**	0.624**	0.505**	0.519**	0.391**	0.711**				
RWC (%)	0.247*	0.563**	0.516**	0.546**	0.525**	0.899**	0.541**	0.334**			
SLWW (mg)	0.433**	0.597**	0.505**	0.984**	0.794**	0.585**	0.741**	0.585**	0.583**		
SLDW (mg)	0.335**	0.442**	0.516**	0.781**	0.992**	0.457**	0.678**	0.619**	0.531**	0.813**	
PWC (%)	0.296**	0.571*	0.534**	0.582**	0.457**	0.996**	0.403**	0.395**	0.925**	0.583**	0.476**

Ger=Germination percentage, SL=Shoot length, RL=Root length, SWW=Shoot wet weight, SDW=Shoot dry weight, SWC=Shoot water content, RWW=Root wet weight, RDW=Root dry weight, RWC=Root water content, SLWW=Seedling wet weight and SLDW=Seedling dry weight.

ns, *, **: not significant, significant at 5 and 1%, respectively.

Correlation between SL and RL ($r=0.703$), SWW ($r=0.534$) and RWW($r=0.352$) were positive and significant. Also, SL has a direct and significant

relationship with SLWW ($r=0.597$). There were similar correlations for RL with these traits that emphasize the role of root in shoot development.

Shoot wet weight had a maximum correlation with SLWW ($r=0.984$), which is quite logical since a similarly positive and significant relationship is observable in a correlation between SDW and SLDW (0.992). Although correlation coefficients of RWW and RDW with all the other traits were significant ($P<0.001$), the correlation between RDW and RWC (0.334) and between RDW and PWC (0.395) were not so strong. The relatively high correlation between RL with RWW (0.605) and RDW (0.624) proves that any increase in RL can produce higher RWW and RDW. Because of the positive and significant correlation, SLWW and SLDW (0.813) were under the influence of SWW and SDW (0.772). Correlations between PWC with all traits were significant at 5 or 1%. However, it showed a maximum correlation with SWC (0.996) and RWC (0.925).

3.2. Analysis of variance

ANOVA for plant population shared significant differences at 5 or 1% level among the studied genotypes for most traits in years and locations (Table

5). Also, genotype×location interaction was significant for the cotton seed yield. This trait had various performances in different locations probably. Therefore, a single genotype cannot be introduced for planting in all areas and a proper genotype should be recommended for each region distinctively because genotype performance was different in studied regions (Fig. 2).

According to the results, most of the studied traits in the first year were superior to those observed in the second year. The best locations were as follows Hashemabad, Gonbad and Anbarolum for measured traits (Table 6).

The mean characteristics in different genotypes were compared using the Duncan method at a probability level of 5%. The highest plants belonged to genotype 11 with an average height of more than 101 cm and the shortest plants belonged to genotype 15, with an average of 65 cm. Genotypes 6 and 10 showed maximum length and number of sympodial branches at 21.6 and 13.9, respectively.

Table 5. Combined analysis of variance cotton genotypes in three regions (2014-2015).

Source of variation	df	Plant height	Sympodial length	Sympodial number	Boll number	Boll weight	Cotton seed	Earliness
Mean of squares								
Year (Y)	1	6962.6**	121.8 ^{ns}	75.4**	275.6**	51.7**	52169618.2**	541.3 ^{ns}
Location (L)	2	39584.7**	2211.2**	953.1**	2002.4**	84.9**	5255849.4**	19372.2**
Y*L	2	5078.5**	382.2**	207.1**	44.1*	4.44*	2912257.8**	11573.4**
Rep (Y*L)	12	2398.9	109.5	61.2	16.9	1.41	1798450.1	560.2
Genotype (G)	14	1848.7**	85.2**	23.1**	19.2*	1.24*	657325.1*	357.5 ^{ns}
Y*G	14	305.1 ^{ns}	41.9 ^{ns}	11.1 ^{ns}	6.55 ^{ns}	0.75 ^{ns}	108821.4 ^{ns}	564.2 ^{ns}
L*G	28	543.6 ^{ns}	48.1 ^{ns}	15.7 ^{ns}	11.1 ^{ns}	0.87 ^{ns}	366582.8*	287.2 ^{ns}
Y*L*G	28	317.4 ^{ns}	39.1 ^{ns}	6.75 ^{ns}	9.22 ^{ns}	0.84 ^{ns}	171824.2 ^{ns}	726.7**
error	269	509.3	41.3	10.9 ^{ns}	11.6 ^{ns}	0.71	340591.2	384.6
C.V		27.3	25.4	27.9	23.4	21.2	21.2	26.3

ns: not significant differences *: Significant at the 5% level ** Significant at the 1% level.

Table 6. Comparing the mean of traits in different years and locations.

		Plant height (cm)	Sympodial length (cm)	Sympodial number	Boll number	Boll weight (gr)	Cotton seed (Kg/h)	Earliness (%)
year	2014	87.7 ^a	18.8 ^a	12.3 ^a	8.84 ^a	4.42 ^a	2306 ^a	75.7 ^a
	2015	77.5 ^b	17.4 ^a	11.2 ^b	6.82 ^b	3.54 ^b	1428 ^b	72.9 ^a
Location	HashemAbad	101.4 ^a	23.2 ^a	15.5 ^a	13.2 ^a	4.76 ^a	2711 ^a	80.4 ^a
	Anbarolum	59.9 ^c	13.1 ^c	9.4 ^b	4.78 ^b	2.89 ^c	802 ^c	57.6 ^b
	Gonbad	86.3 ^b	18.3 ^b	10.4 ^b	5.44 ^b	4.28 ^b	2087 ^b	84.9 ^a
Year*Location	Y1 * L1	101.3 ^a	21.8	14.3 ^b	13.5 ^a	4.96 ^a	3249 ^a	89.6 ^a
	Y1 * L2	73.6 ^c	15.9 ^d	10.9 ^d	5.9 ^d	3.53 ^d	1351 ^e	44.2 ^e
	Y1 * L3	87.9 ^b	18.6 ^b	11.7 ^c	7.6 ^c	4.76 ^b	2319 ^b	84.9 ^b
	Y2 * L1	101.5 ^a	24.2 ^a	16.7 ^a	13.1 ^b	4.56 ^b	2173 ^c	71.3 ^c
	Y2 * L2	46.3 ^d	10.2 ^e	7.9 ^f	3.6 ^e	2.26 ^e	254 ^f	70.9 ^d
	Y2 * L3	84.7 ^b	17.9 ^c	9.1 ^e	3.8 ^e	3.81 ^c	1855 ^d	84.9 ^b

In each column means with a similar letter has not significantly different.

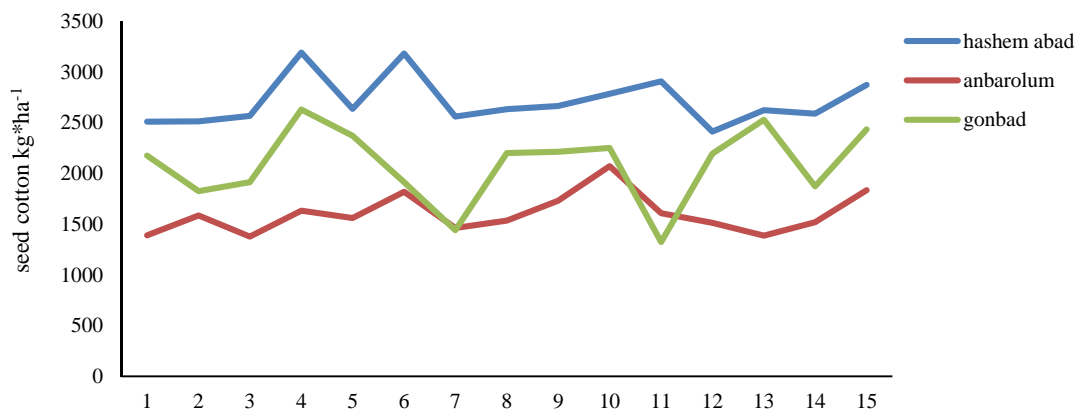


Figure 2. Performance changes in cotton genotypes in different areas.

The greatest number of bolls per plant was obtained in treatment 4 (9.72). Tj82 had the most yields among the 15 genotypes studied, which had the highest average seed cotton yield of 2220 kg per hectare. This point was important that the best performance of a single plant was produced at 50 grams per plant. But in terms of earliness that was calculated from the portion

of the first harvest to total performance, Golestan (check) was earlier than others because 81 percent of the performance of this genotype was achieved in the first harvest (Table 7). Early maturity in cotton is calculated from the ratio of the first harvest to the total product.

Table 7. Comparing the mean of traits of cotton genotypes (2014-2015).

Treatment	Genotype	Plant High (cm)	Symphodial Length (cm)	Symphodial Number	Boll Number	Boll Weight (gr)	Seed Cotton (Kg/h)	Earliness (%)
1	TJ8	74.4 ^{cde}	17.1 ^{ab}	10.3 ^b	7.01 ^{ab}	4.05 ^{abc}	1759 ^{abc}	79 ^a
2	TJ20	75.7 ^{cde}	16.2 ^{ab}	10.7 ^b	7.28 ^{ab}	3.49 ^c	1708 ^{bc}	71 ^a
3	TJ57	67.9 ^{de}	16.5 ^{ab}	10.8 ^b	7.03 ^{ab}	3.77 ^{abc}	1688 ^{bc}	68 ^a
4	TJ82	91.1 ^{abc}	20.6 ^a	13.1 ^{ab}	9.72 ^a	4.27 ^{ab}	2220 ^a	76 ^a
5	TJ124	87.2 ^{a-d}	16.3 ^{ab}	12.2 ^{ab}	8.02 ^{ab}	3.93 ^{abc}	1942 ^{abc}	79 ^a
6	TJ135	84.1 ^{a-e}	21.6 ^a	11.5 ^{ab}	9.19 ^a	3.92 ^{abc}	2040 ^{abc}	66 ^a
7	TJ139	85.8 ^{a-d}	20.9 ^a	12.3 ^{ab}	7.18 ^{ab}	3.87 ^{abc}	1555 ^c	72 ^a
8	TJ168	77.8 ^{b-e}	16.6 ^{ab}	10.6 ^b	7.53 ^{ab}	4.25 ^{ab}	1857 ^{abc}	68 ^a
9	TJ169	88.9 ^{abc}	17.3 ^{ab}	12.8 ^{ab}	7.18 ^{ab}	3.37 ^{bc}	1938 ^{abc}	75 ^a
10	TJ174	97.1 ^{ab}	17.2 ^{ab}	13.9 ^a	7.31 ^{ab}	4.09 ^{abc}	2103 ^{ab}	77 ^a
11	TJ178	101.3 ^a	19.6 ^{ab}	13.1 ^{ab}	8.41 ^{ab}	4.23 ^{ab}	1680 ^{bc}	70 ^a
12	TJ183	83.3 ^{a-e}	19.4 ^{ab}	11.1 ^b	7.34 ^{ab}	3.63 ^{bc}	1774 ^{abc}	73 ^a
13	TJ185	84.4 ^{a-e}	20.3 ^a	12.3 ^{ab}	8.52 ^{ab}	3.93 ^{abc}	1914 ^{abc}	74 ^a
14	TJ189	74.1 ^{cde}	18.7 ^{ab}	10.6 ^b	6.16 ^b	4.47 ^a	1727 ^{abc}	77 ^a
15	Golestan (check)	65.1 ^e	13.9 ^b	11.4 ^{ab}	9.51 ^a	4.06 ^{abc}	2116 ^{ab}	81 ^a

In each column, means with a similar letter has not significantly different.

Salinity disables some hormones, as well as the effects on membrane permeability, reducing seed vigor. Therefore, the germination percentage with increased salinity has been decreasing. Also, in stress, salinity color and sodium ions because of negative osmotic potential, disrupt seed hydrolysis processes and create ion toxicity, as a result, reducing dry weight root and stem (Munns et al., 1986).

Generally, decreasing all traits with increasing salinity level has been shown, which is consistent with research Basal et al. (2006) and Ibrahim et al. (2007) reported that salinity leads to a decrease in stem length and the water content in the cotton seedling.

Varghese et al. (1995) stated that the percentage of germination, root length, aerial part, and seedling vigor is reduced with increasing salinity intensity.

Kornejad (2002), Line et al. (1997) and Rezaee et al. (2015) showed that increased salinity affected reducing the percentage and speed of germination, shoot length, and the weight of dry stems, and fresh weight of stems and roots in seedlings. The results of these researches are consistent with our results.

The length and number of sympodial branches in cotton are very important because it affects by the formation of bolls on fruiting branches directly. Thus, sympodial branches, as components of the performance, can have a positive role in forming bolls and increasing cotton yield.

Also, the number of bolls in the plant is significant because cotton has a self-regulation model in stress conditions so that it can retain the portion of leaf to time by falling flowers and bolls. On the contrary, the maximum performance would be produced if the conditions were provided by increasing the number of bolls per plant (Sadabadi et al., 2018).

4. Conclusion

The findings of this study revealed that by increasing salinity level, an obvious decrease in the most measured traits, including the percentage of germination (Ger%), stem length (SL), root length (RL), stem wet weight (SWW), stem dry weight (SDW), root wet weight (RWW), root dry weight (RDW), stem tissue water content (SWC), root tissues water content (RWC), seedling wet weight (SLWW), seedling dry weight (SLDW) and whole plant water content (PWC) has happened (Table 2).

Also, the field experiments showed that genotypes had significant performances in different years and locations. Tj82 the most seed cotton yield and Golestan the most earliness have among the 15 genotypes (Table 7).

Conflict of interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

All authors had an equal role in study design, work, statistical analysis and manuscript writing.

Informed consent

The authors declare not to use any patients in this research.

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References

- Ashraf M., Ahmad S. 2000. Genetic effects for yield components and fibre characteristics in upland cotton (*Gossypium hirsutum* L.) cultivated under salinized (NaCl) conditions. *Agronomie* 20(8). <https://doi.org/10.1051/agro:2000168>
- Azad H, Fazeli-Nasab B, Sobhanizade A. 2017. A study into the effect of jasmonic and humic acids on some germination characteristics of rosselle (*hibiscus sabdariffa*) seed under salinity stress. *Iranian Journal of Seed Research* 4(1):1-18 (In Persian). <https://doi.org/10.29252/yujs.4.1.1>
- Basal H., Demiral M.A., Canavar O. 2006. Shoot biomass production of converted race stocks of upland cotton (*Gossypium hirsutum* L.) exposed to salt stress. *Asian Journal of Plant Sciences*. 5(2): 238-242. <https://doi.org/10.3923/ajps.2006.238.242>
- Fathi Sadabadi M., Ranjbar G.A., Zangi M.R., Kazemi Tabar S.K., Najafi Zarini H. 2017. Evaluation salt tolerance in earliness genotypes of Cotton (*Gossypium hirsutum*) at seedling stage. *Journal of Crop Breeding* 9(22): 109-116. <https://doi.org/10.29252/jcb.9.22.109>
- Garratt L.C., Janagoudar B.S., Lowe K.C., Anthony P., Power J.B., Davey M.R. 2002. Salinity tolerance and antioxidant status in cotton cultures. *Free Radical Biology and Medicine* 33(4): 502-511. [https://doi.org/10.1016/S0891-5849\(02\)00838-9](https://doi.org/10.1016/S0891-5849(02)00838-9)
- Ghajari A.G., Zangi M., Azad G. 2001. Evaluation of tetraploid seed germination at different levels of salinity. Final Reports Cotton Research Institute of Iran.
- Ghasemi B.K., Hamidi A. 2013. Study of callus formation and salinity tolerance in different explants of cotton (*Gossypium sp.*) cultivars in vitro. Final Reports Cotton Research Institute of Iran.
- Ibrahim M., Akhtar J., Younis M., Riaz M., Anwarul-Haq M. Tahir M. 2007. Selection of cotton (*Gossypium hirsutum* L.)

- genotypes against NaCl stress. *Soil and Environment* 26(1): 59-63.
- Jafri A.Z., Ahmad R. 2002. Comparative performance of upland and desi cotton cultivars at germination stage of growth under different salinity levels. *Journal of Research (Science)* 13: 161-166.
- Kornejadi A., Galeshi S., Zeinali E., Zangi M. 2004. Evaluation of cotton genotypes resistance to salinity in the germination stage. *Agricultural Sciences and Technology* 18: 109-125.
- Lin H., Salus S., Schumaker S. 1997. Salt sensitivity and the activity of the H⁺ -ATPase in cotton seedling. *Crop Science* 37(1): 190-197. <https://doi.org/10.2135/cropsci1997.0011183X003700010032x>
- Maguire J.D. 1962. Speed of germination-aid in selection and evaluation for seedling emergence and vigor. *Crop Science* 2:176-177. <https://doi.org/10.2135/cropsci1962.0011183X000200020033x>
- Munns R., Termaat A. 1986. Whole-plant responses to salinity. *Australian Journal of Plant Physiology* 13: 143-160. <https://doi.org/10.1071/PP9860143>
- Mirghasemi S.J., Sohrabi B., Gharanjiki A.R., Gajari A.G. 2012. Comparison of yield and yield components of cotton cultivars by direct seed planting and seedling transplanting methods in saline regions.
- Rahemi M.R., Eskandari A., Moghiseh E., Mozaffari K., Rahimi M., Amiripari M., Jankuloski L., Hussain M., Malek M., Alishah O. 2018. Evaluation of new cotton mutant cultivars for adaptation to climate change in Iran.
- Rezaei M., Khavari-Nejad R., Fahimi H. 2004. Physiological response of cotton (*Gossypium hirsutum* L.) plants to soil salinity. *Pajouhesh-va-sazandegi in agronomy and horticulture* 17 (62): 81-89.
- Rezaee S., Ramazani Moghaddam M.R., Bazrgar A.B. 2015. Cottonseed germination as affected by salinity and priming. *Indian Journal of Fundamental and Applied Life Sciences* 5(1): 312-318.
- Sadabadi M. F., Ranjbar G., Zangi M., Tabar S.K., Zarini H.N. 2018. Analysis of stability and adaptation of cotton genotypes using gge biplot method. *Trakia Journal of Sciences* 16(1): 51-61. <https://doi.org/10.15547/tjs.2018.01.009>
- Taherian M., Solouki M., Rezaei A., Ramezani M.R., Siasar B. 2006. Estimation of the effects of Genes Controlling seed cotton yield and yield components in upland cotton under salinity and normal conditions. *Seed and Plant* 22(2): 141-151.
- Taghizadeh N., Ranjbar G.A., Nematzadeh G.A., Ramazani Moghaddam M.R. 2018. Evaluation of Salinity Tolerance in allotetraploid Cotton (*Gossypium* sp.) Genotypes, Using Multivariate Statistical Methods and Stress Tolerance Indices at Germination Stage. *Iranian Journal of Seed Research* 4(2): 93-110. <https://doi.org/10.29252/yujs.4.2.93>
- Varghese S., Patel K.V., Gohil M.D., Bhatt P.H., Patel G. 1995. Response of OT 11 leant cotton (*Gossypium herbaceum*) to salinity at germination stage. *Indian Journal of Agriculture Science* 65: 823-825.
- Wittenmayer L., Merbach W. 2005. Plant responses to drought and phosphorus deficiency: contribution of Phyto hormones in root related processes. *Journal of Plant Nutrition and Soil Science* 168(4): 531-540. <https://doi.org/10.1002/jpln.200520507>
- Zhang L., Zhang G., Wang Y., Zhou Z., Meng Y., Chen B. 2013. Effect of soil salinity on physiological characteristics of functional leaves of cotton plants. *Journal of plant research* 126(2): 293-304. <https://doi.org/10.1007/s10265-012-0533-3>

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