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Genetic Variations of Triticale Genotypes in Different NaCl Concentrations

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Abstract

In this study, rate of germination and emergence and seedling characters (shoot and root length, fresh and dry weight) of three triticale cultivars and ten triticale lines were tested under various salt (NaCl) concentrations. Salt tolerance index was calculated from total dry weight. The results showed that root and shoot length, fresh weight and dry weight decreased as NaCl concentration increased. Significant differences among the genotypes were obvious with all NaCl concentration, concerning the salt tolerance index of genotypes. Karma-2000 and Mikham 2002 appeared to be more tolerant to salt stress than the others. TRT 121 and TRT 142 were seemed to promising lines for salt tolerance.

Key words: Salt tolerance, triticale, seedling characters.

INTRODUCTION

Breeders and farmers aim to get higher seedling establishment in crops, but some biotic and abiotic stresses reduce it in field conditions. Salt and drought stress are considered among most important abiotic stresses that limit plant growth and development. These abiotic stresses occur in field condition due to lack of some environmental components. The uncertainty of rainfall is immediately after plant emergence, leading to early season drought in rainfed farming systems [13]. Another most negative effect on seed germination is soil salinity [34].

Seed germination is usually the most critical stage in seedling establishment, determining successful crop production [2]. Crop establishment depends on interaction between seedbed environment and seed quality [8, 19]. Factors adversely affecting seed germination may include sensitivity to drought stress [33], and salt tolerance [27, 30]. Earlier growth stages are more sensitive to salinity than subsequent ones [20]. The stand, subsequent growth and final yield of crop plants are decreased when the moisture supply is limited. Seeds sown in seedbeds having unfavorable moisture because of limited rainfall at sowing time yield, in poor and unsynchronized seedling emergence [15,25], affecting the uniformity of plant density with negative effects on yield. Salinity has also been identified as the major seedbed factor influencing establishment in arid and semi-arid regions [2]. Germination and seedling growth are reduced in saline soils with varying responses for species and cultivars [6, 16]. Salinity may also affect the germination of seeds by creating an external osmotic potential that prevents water uptake.

Saline soils are widespread in arid and semiarid regions of the world. This problem may be a result of basins with limited or no access to rivers due to diverse soil properties, unsuitable irrigation practices, poor drainage and high evaporation. Salinity is one of the main problems that negatively affect soil fertility and limit plant production [10, 29].

Salinity can be alleviated through either soil reclamation or growing tolerant crops. However, soil reclamation is a very expensive process, and hence the cultivation of tolerant species and varieties is the most practical solution when the salinity is low. It is well known that there are significant genotypic differences with respect to salt tolerance between and within plant species [1, 35, 12]. Due to increasing salinity problems in Turkey and in many other countries around the world, breeding for salinity needs more attention. Besides genetic resources, the use of efficient selection criteria would help breeders. However, it is difficult to say that the breeders have efficient selection criteria and tools for improvement of salt tolerant varieties.

Triticale (x Triticosecale Wittmack) is a cereal crop, high yielding and well adapted to extreme cold, drought and acidic soils, and grown in almost all geographic regions where the parental species are grown [7]. In many semi-arid and arid parts of the world, including Turkey, salt accumulation in the soil profile due to high evapotranspiration is common [24, 28]. One of the major environmental stres factors adversely affecting uniform germination is salinity in arid and semi-arid regions [11]. Salt accumulation in soils affects plant growth to different degrees [4], however, in the same saline environment; different plant species may exhibit different growth response [23]. A prerequisite for successful production is stand establishment.

The ability of a seed to germinate and emergence under salt stress indicates that it has genetic potential for salt tolerance, at least at this stage in the life cycle. This does not necessarily indicate that a seedling started

under salt stress could continue under salt stress and that the plant could complete its life cycle [26]. Tolerance of salinity at germination and emergence is, however, a highly desirable trait. For this reason, use of germination and emergence as a first indicator of salt tolerance seems valid. Many researchers have reported that several plants are sensitive to high salinity during germination and the seedling stage [17, 32, 15]. The reason of the sensitivity to salinity is not fully understood. Some researchers have indicated that the main reason for germination failure was the inhibition of seed water uptake due to a high salt concentration [9, 22], whereas others have suggested that germination was affected by salt toxicity [21, 19]. Although preliminary studies on the salt tolerance of triticale have been conducted [14, 18], the responses of newly released triticale to salinity are not well known. Francois et al [14] found that 7.3 dS m-1 reduced triticale yield by 2.8%. In addition, Karim et al [18] indicated that triticale cultivars gave different responses to varying NaCl (0-200 mM). Furthermore, the relative importance of the osmotic or toxic effects of NaCl on seed germination is not clear in triticale.

MATERIALS AND METHODS

Plant Material and Growth Conditions

Triticale cultivars Tatlıcak 97, Karma 2000, Mikham 2002 and ten triticale lines were used as materials. The experiment was conducted with four salt concentrations, 75 mM, 150 mM, 200 mM and 250 mM and distilled water as a control. Three replicates of three seed from each genotypes was planted in pots. Pots kept on outdoor to observed reaction under natural conditions. Beginning from planting, plants were irrigated everyday with 25 ml each of respective test solution for seventeen days.

Traits Measured

Germination and Emergence Percentage: Emergence was measured daily take than each replication and seven days after seeds were planted, emerged plants were counted and germination and emergence percentage was calculated. A seedling was considered emerged if the first foliar leaf had emerged from the pore of the coleoptile and accepted as germinated of every emerged seeds.

Shoot and Root Lengths and Fresh Weights: Seventeen days after planting, the plants were harvested and measured. Shoot and root lengths separated from crown to leaf tip and root tip. Roots were measured from the stem base to maximum length. Shoots were measured from the base to tip. After than, the roots and shoots of plants in each replication were weighted particularly.

Shoot and Root Dry Weights: The roots and shoots of plants in each replication were dried at 70 ° C for 48 h in an oven. Then root and shoot dry weights per plant were measured. The mean values were used for statistical analyses.

Salt Tolerance Index: This was calculated as total plant (shoot + root) dry weight obtained from 100 seeds grown on different salt concentrations compared to total plant dry weight obtained on normal concentration {[STI = (TDW at Sx / TDW at S1) x 100], STI = salt tolerance index, TDW = total dry weight, S1 = control treatment, Sx = x treatment).

Statistics

A randomized complete block design was used with a factorial arrangement of treatments (cultivar and NaCl level) with 3 replications. Data were analyzed by using Excel computer program and mean separation was accomplished by least significant difference (LSD) test at $P<0.05$.

This study was conducted to determine the effect of NaCl on the seedling growth of triticale cultivars on germination and, genetic variations in salt tolerance of triticale genotypes at different NaCl concentrations.

RESULTS

Germination and Emergence

In each level of NaCl, 100 % final germination was obtained for all cultivars and lines. The effect of increasing NaCl levels on final germination percentage was essentially the same for all cultivars and lines. All cultivars and lines germinated at all levels of NaCl, but germination time differed relative to cultivars and NaCl. Increasing NaCl level delayed germination time rather than affecting the final germination percentage. Related to this, emergence rate affected of increasing NaCl levels sameway.

Shoot and Root Length

There were significant differences between genotypes in terms of shoot and root lengths. Mean root length varied between 8,9-285,3 mm for various NaCl concentrations (Table 1). Increasing NaCl treatments resulted in a significant decrease in root length. The longest root length was detected on the control of TRT 142. As expected, the controls had the longest root length, while the shortest value was at 250 mM NaCl concentrations. Generally, root length decreased as NaCl concentration increased. Genotypes TRT 51, 69, 110,142 had the longest roots averaged over five salinity levels (Table 1).

Table 1. Shoot and root lenghts of triticale genotypes grown with different NaCl treatments

	0		75		150		200		250		Mean	
Genotypes	S	R	S	R	S	R	S	R	S	R	S	R
						(cm)						
TRT 51	16,93	18,67	9,70	11,53	8,57	11,87	2,00	6,60	0	3,70	7,44	10,47
TRT 55	15,07	20,30	9,83	10,13	8,07	7,10	0,00	4,10	0	4,93	6,59	9,31
TRT 69	16,50	24,83	9,90	11,80	8,13	9,00	0,00	4,97	0	4,47	6,91	11,01
TRT 90	13,80	17,40	10,90	9,90	9,13	7,43	1,07	5,70	0	5,43	6,98	9,17
TRT 110	14,27	17,13	9,00	15,50	6,10	12,23	3,73	5,80	0	2,30	6,62	10,59
TRT 119	13,83	17,97	11,13	7,63	8,53	7,33	2,47	6,13	0	5,27	7,19	8,87
TRT 121	13,10	16,57	10,97	11,83	8,67	8,57	4,40	7,07	0	4,50	7,43	9,71
TRT 136	15,43	16,43	11,73	15,17	4,83	6,50	4,83	9,23	0	2,37	7,36	9,94
TRT 142	13,93	28,53	9,17	12,83	3,87	8,33	4,57	6,63	0	2,93	6,31	11,85
TRT 148	15,90	19,77	10,17	8,50	9,67	7,20	5,83	9,13	0	4,60	8,31	9,84
TATLICAK 97	14,20	18,63	9,87	11,63	7,40	7,37	4,20	8,03	0	1,97	7,13	9,53
KARMA 2000	11,83	16,07	10,17	9,17	7,70	8,87	5,30	6,77	0	4,03	7,00	8,98
MİKHAM 2002	10,33	9,17	8,30	7,93	7,27	8,27	2,73	5,53	0	0,87	5,73	6,35
Mean	14,24	18,57	10,06	11,04	7,53	8,47	3,16	6,59	0	3,64	7,00	9,66

Root	CV= 7	LSD_{NaCl}=0,91	$LSD_{cult.}$=1,46	$LSD_{int.}$=3,27
Shoot	CV=4	LSD_{NaCl}=0,35	$LSD_{cult.}$=0,56	$LSD_{int.}$=1,25

The highest shoot length was determined from TRT 51 in control, TRT 136 in 75 mM NaCl concentration, TRT 148 both in 150 and in 200 mM NaCl concentration. No shoot length was recorded for all cultivars in 250 mM NaCl concentration (Table 1). Shoot length was severely influenced by salt stress and increasing NaCl treatments resulted in a significant decrease in shoot elongation. The decrease in shoot elongation starting from 75 mM NaCl concentration was considered an indicator that shoot growth was affected more quickly compared with the roots (Figure 1).

Figure 1. Effects of increasing NaCl concentrations in triticale genotypes at seedling characters.

Shoot and Root Fresh Weight

The average root weight was 209,31 mg at control and gradually decreased to 11,05 mg with increasing NaCl treatments (Table 2). Differences determined among the cultivars were significant. Although the cultivars showed different responses to all NaCl concentration, the highest value were observed from TRT 148 in 250 mM NaCl concentration as root weight. Similar to the shoot elongation shoot weight also decreased, starting from 75 mM NaCl concentration. Shoot weight was obtained from all genotypes tested up to 200 mM NaCl concentration exception of TRT 55 and TRT 69.

Table 2. Shoot and root fresh weights of triticale genotypes grown with different NaCl treatments

	0		75		150		200		250		Mean	
Genotypes	S	R	S	R	S	R	S	R	S	R	S	R
(mg.plant^{-1})												
TRT 51	373,87	245,17	116,67	128,77	71,87	62,90	21,07	29,23	0	12,23	116,70	95,66
TRT 55	283,50	243,57	103,80	99,40	71,20	66,40	0,00	6,80	0	8,60	91,70	84,95
TRT 69	384,37	308,77	118,30	94,80	66,90	66,80	0,00	12,93	0	6,80	113,91	98,02
TRT 90	235,70	200,20	107,50	107,00	82,47	79,17	16,50	22,10	0	10,50	88,43	83,79
TRT 110	254,27	223,70	105,43	140,03	52,70	72,70	33,33	30,03	0	6,67	89,15	94,63
TRT 119	245,27	213,73	116,83	103,03	81,97	75,03	33,90	30,90	0	9,13	95,59	86,36
TRT 121	199,70	167,30	179,07	121,17	76,67	62,33	33,67	47,67	0	9,00	97,82	81,49
TRT 136	296,00	215,67	163,63	128,70	43,17	46,17	43,83	40,73	0	5,93	109,33	87,44
TRT 142	204,53	214,53	116,40	107,57	39,23	54,73	38,13	37,87	0	11,27	79,66	85,19
TRT 148	312,73	214,13	146,53	111,80	85,27	80,83	49,07	42,63	0	33,50	118,72	96,58
TATLICAK 97	301,20	223,57	145,80	122,53	72,57	64,97	37,80	23,30	0	6,67	111,47	88,21
KARMA 2000	179,63	143,97	156,80	134,83	65,73	73,87	44,43	23,93	0	19,67	89,32	79,25
MİKHAM 2002	146,10	106,73	133,93	92,90	76,53	82,83	28,97	23,23	0	3,73	77,11	61,88
Mean	262,84	209,31	131,59	114,81	68,17	68,36	29,28	28,57	0	11,05	98,38	86,42

Root	CV= 9	LSD_{NaCl}= 9,83	$LSD_{cult.}$=15,85	$LSD_{int.}$=35,45
Shoot	CV= 5	LSD_{NaCl}= 7,17	$LSD_{cult.}$=11,57	$LSD_{int.}$=25,87

Shoot and Root Dry Weight

Root and shoot dry weight showed a similar trend to that of fresh weight, depending on the decline in seedling fresh weight, dry weight decreased with increasing NaCl treatments (Table 3). With increasing NaCl concentrations, total dry weight of genotypes decreased between 35-47 %, meanly (Table 4).

Table 3. Shoot and root dry weights of triticale genotypes grown with different NaCl treatments

	0		75		150		200		250		Mean	
Genotypes	S	R	S	R	S	R	S	R	S	R	S	R
(mg.plant^{-1})												
TRT 51	42,07	28,33	18,8	21,07	13,57	15,8	6,43	6,93	0	4,60	16,17	15,35
TRT 55	38,90	35,30	18,6	18,77	14,4	13,47	0,00	3,63	0	5,53	14,38	15,34
TRT 69	47,80	29,97	42,6	16,93	20,23	14,53	0,00	4,53	0	4,00	22,13	13,99
TRT 90	32,73	30,33	22,17	18,10	15,93	13,8	3,20	4,8	0	6,37	14,81	14,68
TRT 110	31,60	25,93	14,77	16,87	10,57	13,87	8,20	7,93	0	3,57	13,03	13,63
TRT 119	32,07	28,93	20	18,10	15,23	16,47	8,03	13,53	0	5,70	15,07	16,55
TRT 121	27,50	26,73	26,3	18,30	14,57	13,5	7,90	11,93	0	5,37	15,25	15,17
TRT 136	36,73	28,70	25,63	19,27	8,8	13,57	9,37	9,87	0	3,30	16,11	14,94
TRT 142	23,77	22,73	17,93	15,50	8,2	12,47	8,40	10,03	0	7,27	11,66	13,60
TRT 148	39,50	26,27	25,03	20,87	14,7	15,3	10,37	12,03	0	7,93	17,92	16,48
TATLICAK 97	36,73	30,73	25,4	22,57	14	15,63	8,17	11,47	0	2,50	16,86	16,58
KARMA 2000	24,33	25,57	25,6	22,40	12,3	15,97	10,03	8	0	5,27	14,45	15,44
MİKHAM 2002	21,80	23,17	22,83	20,77	15,2	15,77	7,07	9,67	0	0,87	13,38	14,05
Mean	33,50	27,90	23,51	19,19	13,67	14,63	6,71	8,80	0	4,79	15,48	15,06

Root	CV= 8	LSD_{NaCl}=1,58	$LSD_{cult.}$=2,55	$LSD_{int.}$=5,70
Shoot	CV= 14	LSD_{NaCl}=2,92	$LSD_{cult.}$=4,71	$LSD_{int.}$=10,54

Salt Tolerance Index (STI)

Significant differences among the genotypes were obvious with all NaCl treatments, concerning the salt tolerance index of genotypes (Table 4). The salt tolerance index between 48-97% with 75 mM NaCl concentration and 2-15% with 250 mM NaCl concentration. TRT 119, 121, 142,148, Karma 2000 and Mikham 2001 were the best performing genotypes with 200 mM NaCl concentration (above the 30 %), the other genotypes did not perform well had salt tolerance indices ranged from 6-29% (Table 4). TRT 55 was the most affected by NaCl concentrations. Karma 2000 and Mikham 2001 were the best performing genotypes averaged over the all NaCl concentrations.

Table 4. Total dry weights (TDW) and salt tolerance index (STI) of triticale genotypes grown with different NaCl treatments

	TDW (mg)					STI (%)					
Genotypes	**0**	**75**	**150**	**200**	**250**	**0**	**75**	**150**	**200**	**250**	Mean
TRT 051	70,40	39,87	29,37	13,37	4,60	100	50	38	5	7	31
TRT 055	74,20	37,37	27,87	3,63	5,53	100	48	73	6	5	25
TRT 069	77,77	37,17	57,13	4,53	4,00	100	64	47	13	10	33
TRT 090	63,07	40,27	29,73	8,00	6,37	100	62	52	35	9	33
TRT 110	57,53	31,63	24,43	16,13	3,57	100	82	49	39	10	33
TRT 119	61,00	38,10	31,70	21,57	5,70	100	69	29	35	5	40
TRT 121	54,23	44,60	26,50	21,40	5,37	100	57	42	19	7	45
TRT 136	65,43	44,90	18,67	22,93	3,30	100	55	42	28	6	34
TRT 142	46,50	33,43	18,23	20,87	7,27	100	72	39	45	16	43
TRT 148	65,77	45,90	30,00	22,40	7,93	100	70	46	34	12	40
TATLICAK	67,47	47,97	29,63	19,63	2,50	100	71	44	29	4	37
KARMA	49,90	48,00	28,27	18,03	5,27	100	96	57	36	11	50
MİKHAM	44,97	43,60	30,97	16,73	0,87	100	97	69	37	2	51
Mean	61,40	40,98	29,42	16,09	4,79	100	69	48	28	8	37

TDW	CV=8	LSD_{NaCl}= 3,25	LSD_{cult} = 5,24	LSD_{int} = 11,71
STI	CV=6	LSD_{NaCl}= 4,39	LSD_{cult} = 7,09	LSD_{int} = 15,85

DISCUSSION AND CONCLUSIONS

Final germination percentage was not noticeably changed by NaCl concentration, but germination time was increased as NaCl level increased. Similar results were noted in several crops [3, 5, 11, 19]. Increasing NaCl level delays germination time rather than affecting final germination percentage, in agreement with Van Hoorn [32], who determined that an increase in salt concentration delayed germination time in several crops. These results also revealed that the levels of NaCl used in this study did not have a toxic effect on germination although they had a detrimental effect on the rate of germination. Our findings showed that NaCl had grater inhibitory effects on seedling growth than on germination because no significant decrease in germination in all genotypes was observed.

Root and shoot length decreased with increasing NaCl, begining from 75 mM NaCl levels. Furthermore, the shoots were more sensitive than the roots as the NaCl increased. These results are similar to those reported by Atak et al [3], who found that the root parts were less affected than the shoots in triticale. It was reported that root growth in triticale was much beter than that in rye and wheat plants in varying (0, 75 and 150 mM NaCl) salt treatments [31].

Shoot and root lengths did not always relate to shoot and root weights. Although some genotypes had long shoots and roots, thin and unbranched, they could not produce sufficient dry weight. In the contrast, some genotypes had relatively short shoot and root lengths, but high dry weight since they produced thick and branched shoots and roots. For this reason, when length and dry weight are considered as selection criteria, we advise that dry weight be the primary selection criterion. It is anticipated that in addition to higher dry weight, longer and stronger root and shoot development will allow more successful selection for high salt tolerance. However, as selection criteria, the length and weight measurements taken from single plants can be considered appropriate only when there is a high germination percentage. For these reasons, the salt tolerance index, which is a function of both germination percentage and total dry weight, was determined to be a more reliable selection criterion in this study.

It appears from the results that there is significant differences among genotypes for all traits. Also there was a wide range of variation for each trait. The significant differences between genotypes under the five salinity levels, the wide range of variation within each salinity level and the significant “genotype x salinity level” interaction are important signals for potential use of the studied characteristics as selection criteria for salinity tolerance at the seedling stage. This might save breeders time in the future as they can screen a large number of genotypes at the seedling stage.

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