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SALT TOLERANCE DURING VEGETATIVE GROWTH IN CROSS OF TOMATO AND EFFECT OF CYTOPLASM IN RESPONSE TO SALT TOLERANCE

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Abstract

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The aim of the present study was the determination of salt tolerance differences among tomato crosses by using morphological, physiological parameters and the identification cytoplasm related to salt tolerance mechanisms during the vegetative stages of tomato. In the study, salt tolerant (40395, 40443, 47839) and salt sensitive (62573, 70452) tomato genotypes were used as plant material. Reciprocal crosses were made between salt tolerant and salt sensitive tomato genotypes. Cross combinations were exposed to 0 (control), 8 and 12 dS m^{-1} NaCl for 40 days. At the end of the experiment, the levels of leaf, stem and dry root weights and Ca^{2+}, K^+ and Na^+ concentrations were determined. The relationships between the levels of salinity and root, stem, leaf accumulation; and between K^+, Ca^{2+}, Na^+ and root, stem and dry leaf weights were investigated. Ca^{2+}/Na^+ and K^+/Na^+ ratios were also calculated. A tolerance index was calculated for every single genotype in root, stem and leaf dry weights and in the K^+/Na^+ and Ca^{2+}/Na^+ parameters of these organs.

In this study, tolerance index were used as a select salt tolerant tomato crosses at different salt concentrations. There was a large variation in root, stem and leaf dry weight and K^+/Na^+, Ca^{2+}/Na^+ TI among 12 cross combinations under increasing salinity. The highest tolerance index values were generally obtained from the combination of tolerant genotypes (40443, 47839 and 40395) and sensitive genotype 62573. Cytoplasm is another factor that plays an important role in the salt tolerance. Generally, in reciprocal crosses were made between a salt tolerant and a salt sensitive tomato genotypes; 40443, 47839, 40395 and 62573 cytoplasm positively affected tolerance index values and means which they were less affected by salinity.

Key words: tomato, genotypes, crossing, salt tolerance, cytoplasm

Introduction

Salinity affects almost every aspect of the physiology and biochemistry of plants and significantly reduces yield. As saline soils and saline waters are common around the world, great effort has been devoted to understanding physiological aspects of tolerance to salinity in plants, as a basis for plant

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breeders to develop salinity-tolerant genotypes. In spite of this great effort, only a small number of cultivars, partially tolerant to salinity, have been developed (Cuartero et al., 2006). Over the years, plant breeders have developed very productive cultivars of high quality, resistant to diseases and adapted to the demands of the market and of industry (Grandillo et al., 1999). New cultivars bred for salt tolerance has to not only be salt tolerant, but also achieve the same attributes of productivity and quality seen in modern cultivars (Cuartero et al., 2006).

The cultivated tomato (*Lycopersicon esculentum* Mill.) is in the family Solanaceae and is a widely distributed annual vegetable crop. Tomato is also valuable for breeding studies, because making crosses between wild and cultivated tomato plants is simple and its wild relatives provide a rich germplasm pool. Currently, the tomato crop is grown in a wide variety of climates ranging from the tropics to within a few degrees of the Arctic Circle (Foolad, 2004). Tomato production has been limited by a high level of salinity in the soil or irrigation water. Tomato is sensitive to moderate levels of salinity like most crop plants. All stages of plant development including seed germination, vegetative growth and reproduction show sensitivity to salt stress and economic yield is reduced under salt stress (Jones et al., 1986; Maas, 1986; Bolarin et al., 1993). Most research on tomato salt tolerance during vegetative stage was focused mainly on the physiological responses to salt stress (Foolad, 2004). There is a positive correlation between tomato yield and plant size during vegetative growth under salt stress (Bolarin et al., 1993; Pasternak et al., 1979), indicating the importance of salt tolerance during the vegetative stage.

Salinity stress results in a clear stunting of plants (Hernandez et al., 1995; Cherian et al., 1999; Takemura et al., 2002). Salt stress also results in a considerable decrease in the fresh and dry weights of leaves, stems, and roots (Hernandez et al., 1995; AliDinar et al., 1999; Chartzoulakis and Klapaki, 2000). Increasing salinity is accompanied by significant reductions in shoot weight, plant height, and number of leaves per plant, root length, and root surface area per plant in tomato. High salinity in the root zone severely impedes normal plant growth and development, resulting in reduced crop productivity or crop failure (Foolad, 2004). The physical growth parameters such as shoot fresh and dry weight, root fresh and dry weight are more correlated with crop salt tolerance at early growth stages and can be used as screening/selection criteria (Ibrahim, 2003). Bolarin et al. (1991), Foolad (1996) have indicated that shoot growth under salinity relative to control is the best practical indicator of salt tolerance in tomato.

The latter study suggested that tissue ion content and ion selectivity were good selection criteria for breeding for salt tolerance in tomato (Ahsan et al., 2000). Potassium selectivity over Na^+ was also reported as a good indicator of salt tolerance in a study of several genotypes of the cultivated and wild species of tomato (Cuartero et al., 1992). Salinity tolerance is genetically controlled and transmittable among genotypes. Whole plant performance might be more useful selection criteria for salinity tolerance than using a single trait high K^+/Na^+ ratio, Low Na^+. According to Foolad (1997) analysis of the parental, filial and backcross populations of a cross between a salt-sensitive tomato line (UCT5) and a salt-tolerant primitive cultivar (PI174263) indicated that growth under salt stress was positively correlated with leaf Ca^{2+} content and negatively correlated with leaf Na^+ content (Foolad,, 1997). Generation means analysis of these populations indicated that under salt stress, accumulation of both Na^+ and Ca^{2+} in the leaf was genetically controlled with additively being the major genetic component. The relationship between salt tolerance and leaf ion composition in the cultivated and three wild species of tomato prompted Saranga et al. (1993) to conclude that dry matter production under salt stress was positively correlated with K^+/Na^+ ratio. The genetics of physiological characters together with other tolerance components related to metabolic defenses against salinity have to be studied in order to advance the breeding of genotypes tolerant to salinity (Cuartero et al., 2006).

Two major approaches have been proposed and employed to minimize the deleterious effects of high soil/water salinity in agriculture (Epstein et al., 1980). First, a technological approach of implementing large engineering schemes for reclamation, drainage and irrigation with high-quality water. Although this approach has been effective in some areas, the associated costs are high and it often provides only a temporary solution to the problem. The second approach, genetically modifying domesticated crops by breeding and selection for improved salt tolerance. Breeding for salt-tolerant genotypes that can grow more efficiently than the conventional varieties under saline conditions (Foolad, 2004). The purpose of this study was the determination of salt tolerance differences among tomato crosses by using morphological, physiological parameters and the identification cytoplasm related to salt tolerance mechanisms during the vegetative stages of tomato.

Materials and Methods

The investigations were conducted under greenhouse conditions at the department of Horticulture and Soil Sciences at Uludag University. Two experiments (2005–2006) have been conducted with tomato genotypes.

Genetic materials: As genetic material, five tomato (*Lycopersicon esculentum* Mill.) genotypes were used. Tomato genotypes collected from different parts of Turkey and maintained by Aegean Agriculture Research Institute, Izmir.

Crosses: Reciprocal crosses were made between a salt tolerant (40395, 40443, 47839) and a salt sensitive (62573, 70452) tomato genotypes, *Lycopersicon esculentum* Mill. Plants from those genotypes have been grown under greenhouse conditions and kept until flowering and harvesting under optimal nutritional conditions. Manual crosses have been carried out using salt tolerant as pollen donor and salt sensitive (62573, 70452) tomato genotypes as pollen receptor. Pollen from each genotype was collected by breaking and mixing at least ten mature anther cones in a Petri dish. The flower of the female partner was emasculated just before anthesis. Pollination was made by rubbing the pollen obtained on the surface of the stigma of the emasculated flower (Yordanov et al., 1983; Shinohara, 1989).

Growth evaluation and salt stress treatment: twelve crosses seed were initially germinated in organically enriched peat with vermiculite cover to facilitate aerations, in open plastic trays. The average greenhouse temperatures were 17 and 25°C at night and day, respectively, but the atmospheric humidity was maintained at 70%. 35 days after germination, seedlings (3–4 true leaf) were transplanted into a 14cm plastic pots filled with peat: perlite (1:1 on volume basis) homogenous mixture. The transplanted plants were transferred to the greenhouse. The seedlings were grown in peat/perlite approximately for 40 days. When the plants had developed 3–4 true leaves (35 days after transplanting), applications of Hoagland solution containing 0 (control), 8 and 12 dS m^{-1} NaCl were started via drip irrigation. Plants were irrigated with their respective solution 1–2 times per day. It was attempted to keep the quantity of drainage water at 30–40% of the amount of nutrient solution applied. The electrical conductivity in the environment (pot, water, soil) was respectively 1.5 dS m^{-1} (control), 8±0.5 dS m^{-1} and 12±0.6 dS m^{-1}. The salt level was gradually increased over 4 days to avoid osmotic shock.

Plants were grown in a controlled greenhouse with day/night average temperature of 28.3°C, average relative humidity of 70.4%, and average photoperiod of 16 h. The experiments were conducted with 3 replicates. There was one plant in each pot (1 l), with 4 pots in each replicate.

Growth measurement: at the end of the experiments (forty days after transplanting), individual plants from both salt stress and non-stress treatments were harvested and plants were separated into root, stem and leaf. Plant materials were oven-dried at 70°C for two days and dry weights (DW) were determined (g).

Tissue ion analysis: Ca^{2+}, K^+ and Na^+ concentrations were also measured on nitric-perchloric acid digests of root, stem and leaf tissue by Eppendorf Elex model Fleymfotometry. A Ca^{2+}/Na^+ and K^+/Na^+ ratio was calculated.

In this study, Tolerance Index (TI)**,** developed by LaRosa et al. (1989) is used to show general attitude of genotypes towards NaCl concentrations, and, after eliminating differences, which may be a result of genotypic features, only to compare their performances against salt concentrations, which are applied. Tolerance Index is calculated for every genotype one by one in root (DWTI), stem (DWTI) and leaf (DWTI) dry weights and in Ca^{2+}/Na^+ and K^+/Na^+ parameters of these organs.

$$\textit{Tolerance Index (TI)} = 100 + \sum^{n} [X (Tx / T_0) 100]$$

Where
n= number of applications
Tx= value of the parameter as determined on stressed plants
T_0= value of the parameter as determined on plants without stress (control)

Statistical analysis: data were analyzed using MSTAT-C (version 2.1, Michigan State University, 1991) and Minitab 14.0 software. Analysis of variance (ANOVA) was conducted and significance of differences among treatment was tested using the least significant difference (LSD). Differences were declared significant at $P<0.05$ probability levels by the F test. The F-protected LSD calculated at 0.05 probability levels.

Results and Discussion

Growth response

In this study, the values of the dry weight of the 12 tested tomato crosses were found to be lowered with the rise of salinity level. Data presented in Table 1 shows that the dry weight obviously decreased in all cross combinations with salinity on comparing with control. This similar to the result obtained by Hajer et al. (2006), Maggio et al. (2006), Li and Stanghellini (2001), Cuartero and Fernandez-Munoz (1999). Furthermore, there is a positive correlation between tomato yield and plant size during vegetative growth under salt stress (Bolarin et al., 1993; Pasternak et al., 1979), indicating the importance of salt tolerance during the vegetative stage. The physical growth parameters such as fresh and dry shoot weight, fresh and dry root weight are more correlated with crop salt tolerance at early growth stages and can be used as screening/selection criteria (Ibrahim, 2003). In experiment, tolerance Index was calculated for every single cross in root (DWTI), stem (DWTI) and leaf (DWTI) dry weights parameters of these organs. Analysis of variance revealed that significant differences among the tested tomato crosses displayed a large variation in tolerance to treatments based on the Tolerance Index (TI). There was a large variation in root, stem and leaf dry weight TI between 12 genotypes under increasing salinity. The crosses [40443 x 62573] and [40395 x 62573] had the highest root, stem DWTI and leaf DWTI at all concentration levels, respectively. It was determined that the crosses, the most tolerant towards salt concentrations, thus had the highest TI. On contrary, the lowest root, leaf DWTI and stem DWTI were found in [70452 x 40443] and [62573 x 47839], respectively. The [70452 x 40443] and [62573 x 47839], however, were less under saline condition compared with the other ten crosses (Table 1, Figure 1A, 1B, 1C).

Ion accumulation

Salt stress causes extensive physiological and biochemical changes in plant. Between these changes, distribution in different organs of the plant's intake of ions like K^+, Ca^{+2} and Na^+ is emphasized (Aziz et al., 1999). In general, Ca^{+2} and K^+ concentrations decrease with salinisations (Cruz, 1990). In conditions which salt concentration is high, the plant gets more Na^+ ion than it needs (Levitt, 1980). Despite Na^+ ion has no effect on physiological incidents in the plant, K^+ and Ca^{+2} ions play key role. K^+ and Na^+ ion accumulation in tomato and eggplant tissues is important in salt tolerance and N^+ ion increases with salinity increase, despite K^+ ion amount decreases (Cruz et al., 2002; Dasgan et al., 2002; Yasar, 2003). Also in researches performed on the same subject it is determined that, the tomato kinds which keep Na^+ accumulation limited and of which K^+/Na^+ and Ca^{+2}/Na^+ ratios are high are salt tolerant and this parameter is reliable in salt tolerance (Rengel, 1992; Munns and James, 2003; Juan et al., 2005; Turhan et al., 2009). In addition that, Physiological criteria which have been suggested or used as potential indicators of salt tolerance and in tomato include tissue water potential, tissue ion content, K^+/Na^+ ratio, (Foolad, 2004; Ahsan et al., 2000). In this study, analysis of variance revealed that significant differences among the tomato crosses for tissues (root, stem and leaf) K^+/Na^+ and Ca^{+2}/Na^+. In

Table 1
Dry weight (DW, g) of values and their Tolerance index (TI) in root, stem, leaf tissue of tomato crosses, under different NaCl concentrations

Crosses	Root DW				Stem DW				Leaf DW			
	Control	8 dS m^{-1}	12 dS m^{-1}	TI	Control	8 dS m^{-1}	12 dS m^{-1}	TI	Control	8 dS m^{-1}	12 dS m^{-1}	TI
40395 x 62573	4.05 h	2.69 e	1.83 ab	1323.15 bc	6.54 bc	4.66 cd	2.90 a	1355.25 a-c	12.31 c-e	7.19 bc	6.72 ab	1380.09 a
40395 x 70452	4.43 c-e	2.83 c-e	1.62 c	1201.76 ef	6.00 d	4.05 e	2.22 de	1233.52 de	12.75 bc	7.01 bc	5.87 cd	1242.59 cd
40443 x 62573	4.29 e-g	3.60 a	1.74 a-c	1407.43 a	5.99 d	4.75 c	2.58 bc	1403.65 a	12.73 bc	7.52 bc	6.16 a-c	1317.87 a-c
40443 x 70452	4.10 gh	2.95 b-d	1.87 a	1370.98 ab	6.36 c	3.99 e	2.61 bc	1243.48 de	13.36 b	6.79 c	6.41 a-c	1233.55 cd
47839 x 62573	4.06 h	2.97 b-d	1.63 bc	1316.34 bc	6.35 c	4.74 c	2.62 bc	1347.15 a-c	11.67 e	6.94 bc	5.98 b-d	1366.47 ab
47839 x 70452	4.62 bc	2.81 de	1.65 bc	1169.82 ef	5.88 de	4.40 d	2.08 e	1274.32 cd	12.60 cd	7.05 bc	6.04 a-d	1274.01 a-d
62573 x 40395	4.72 b	3.57 a	1.83 ab	1321.27 bc	7.15 a	5.61 a	2.83 ab	1369.24 ab	12.21 c-e	7.62 b	6.33 a-c	1373.30 ab
62573 x 40443	4.36 d-f	3.02 bc	1.78 a-c	1296.31 cd	6.75 b	4.78 c	2.77 ab	1309.26 b-d	11.92 de	7.26 bc	5.94 cd	1342.09 a-c
62573 x 47839	4.51 cd	3.14 b	1.88 a	1308.87 bc	6.57 bc	4.73 c	1.71 f	1139.10 f	11.78 e	8.38 a	5.37 d	1373.53 ab
70452 x 40395	4.01 h	2.89 c-e	1.26 d	1210.33 e	6.32 c	4.58 cd	2.38 cd	1283.45 cd	14.23 a	7.36 bc	6.78 a	1240.73 cd
70452 x 40443	4.94 a	2.89 c-e	1.70 a-c	1133.19 f	6.66 b	4.44 d	2.81 ab	1290.25 b-d	14.30 a	7.68 ab	6.20 a-c	1199.97 d
70452 x 47839	4.21 f-h	2.80 de	1.58 c	1234.34 de	7.07 a	5.25 b	2.01 e	1185.31 ef	12.71 bc	7.51 bc	5.69 cd	1259.78 b-d

Means followed by the same letter are statistically not significant (Duncan's multiple range test, P=0.05)

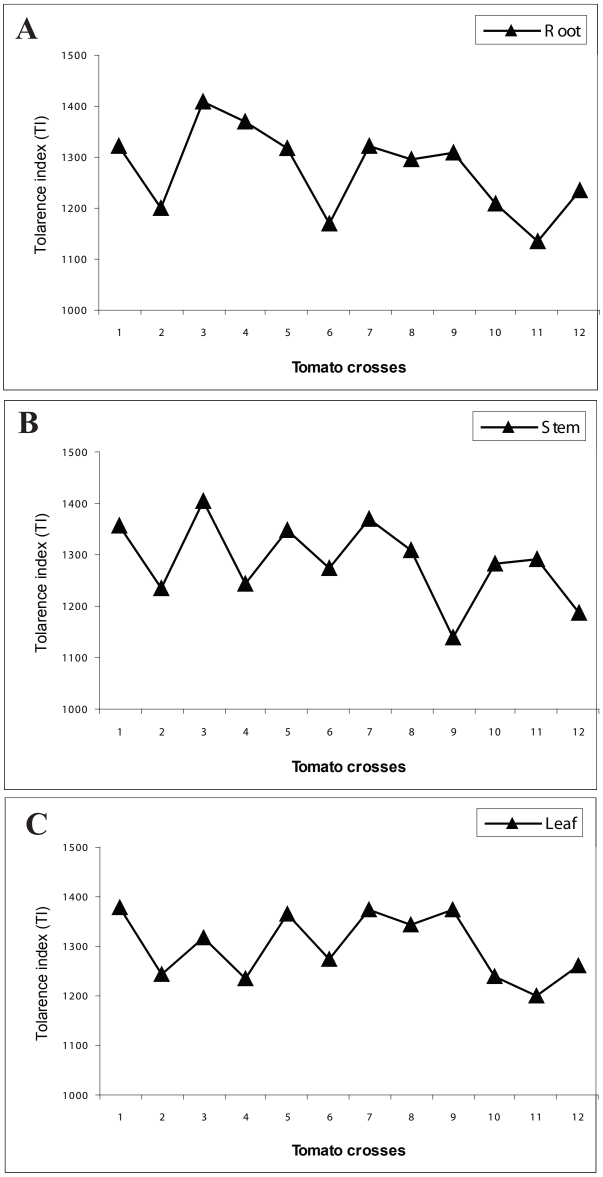

Fig. 1. Dry weights Tolerance index (TI) response of the tomato crosses on control and 8, 12 dS m^{-1} NaCl concentrations (A) root dry weight tolerance index, (B) stem dry weight tolerance index, (C) leaf dry weight tolerance index.
Tomato cross combinations were as follows: 1 (40395 x 62573), 2 (40395 x 70452), 3 (40443 x 62573), 4 (40443 x 70452), 5 (47839 x 62573), 6 (47839 x 70452), 7 (62573 x 40395), 8 (62573 x 40443), 9 (62573 x 47839), 10 (70452 x 40395), 11 (70452 x 40443), 12 (70452 x 47839)

comparison with the control plants, tissues of salt-treated plants accumulated more Na^+ but less K^+ and Ca^{+2}, resulting in lowered K^+/Na^+ and Ca^{+2}/Na^+ ratios. K^+/Na^+ and Ca^{+2}/Na^+ ratios are determined for the plant's root, stem and leaf parts separately. Tomato crosses with higher K^+/Na^+ and Ca^{+2}/Na^+ ratios tended to be rated in the higher TI showing less damage and those with lower K^+/Na^+ and Ca^{+2}/Na^+ in less TI. K^+/Na^+TI and Ca^{+2}/Na^+TI were used to characterize the overall tolerant of plant to salinity. In root tissue, cross [40443 x 62573] showed the highest root K^+/Na^+TI and Ca^{+2}/Na^+TI. In addition this result, cross [47839 x 62573], draw attention with root Ca^{+2}/Na^+TI that is higher than other crosses. It is obvious that the [40443 x 62573] and [47839 x 62573] crosses showed high degree of response to salinity conditions much more than the other ten crosses. On the contrary, the lowest root K^+/Na^+TI and Ca^{+2}/Na^+TI values were determined in [70452 x 40443] and [70452 x 47839] crosses, respectively (Table 2 and Figure 2A) and this combinations of [70452 X 40443] and [70452 X 47839] showed low tolerance.

Another plant tissue on which the effect of salt stress were observed was the stem. Similar results were obtained in stem K^+/Na^+TI and Ca^{+2}/Na^+TI. As shown in Table 3; all of salt treatment, stem's highest K^+/Na^+TI and Ca^{+2}/Na^+TI values were presented by the [47839 x 62573] cross, the lowest in [70452 x 47839] (K^+/Na^+TI) and [70452 x 40443] (Ca^{+2}/Na^{+1}TI) (Figure 2B). The relationship of TI with the concentrations of NaCl can be used as an indicator of salt tolerance. According to Turhan and Seniz (2010), TI could be used as a simple and effective method to select salt tomato cultivars.

Ahsan et al. (2000) suggested that ion content could be used as a breeding tool for selecting salt-tolerant genotypes. There for it is very important to know the extent of variation in Na^+, K^+ in leaves. In addition that, Leaf K^+ concentration and K^+/Na^+ ratio have been the most studied parameters related to salt tolerance in tomato (Cuartero et al., 1992; Cuartero and Fernandez-Munoz, 1999; Foolad, 2004). In different tomato crosses studied in work, the highest leaf K^+/Na^+TI and Ca^{+2}/Na^+TI appeared in the [62573 x 40443] cross, whereas the lowest were presented by [70452 x 47839] and [40443 x 70452], respectively. [62573 x 40443] tomato cross gave a good performance when it was treated by NaCl concentration (Table 4 and Figure 2C).

The effect of cytoplasm on salt-tolerance

In order to observe whether there is cytoplasmic effect on salt tolerance or not, reciprocal crosses were prepared with tolerant 40395, 40442, 47839 and sensitive 62573, 70452 tomato genotypes. Cross combinations were applied with different salt concentration (control, 8 and 12 dS m^{-1}). After the practice, the rate of K^+/Na^+ and Ca^{+2}/Na^+, dry weight was detected in root, stem and leaf tissue of combinations and Tolerance index values of these parameters were calculated. In this study, it was detected that cytoplasm has different effects on different index values. For example, it was detected that cytoplasm does not have an important effect on dry weight and root and leaf K^+/Na^+TI - Ca^{+2}/Na^+TI, stem Ca^{+2}/Na^+TI parameters of tolerant 40395 and sensitive 62573, whereas it has important effect on stem K^+/Na^+TI parameters. In other words, it was detected that cytoplasm of 40395 genotype had positive effect on stem Ca^{+2}/Na^+TI (Table 5).

It was found that cytoplasm has no effect on dry weight, root and stem K^+/Na^+TI parameters of [40395 x 70452] and [70452 x 40395] cross combinations obtained from 40395 genotype and sensitive 70452 reciprocal material. However, it was detected that cytoplasm has quite important effect on root, stem Ca^{+2}/Na^+TI, leaf K^+/Na^+TI and Ca^{+2}/Na^+TI; and this positive effect is caused by 40395 genotype in leaf K^+/Na^+TI and Ca^{+2}/Na^+TI, stem Ca^{+2}/Na^+TI; and by 70452 genotype in root Ca^{+2}/Na^+TI (Table 5).

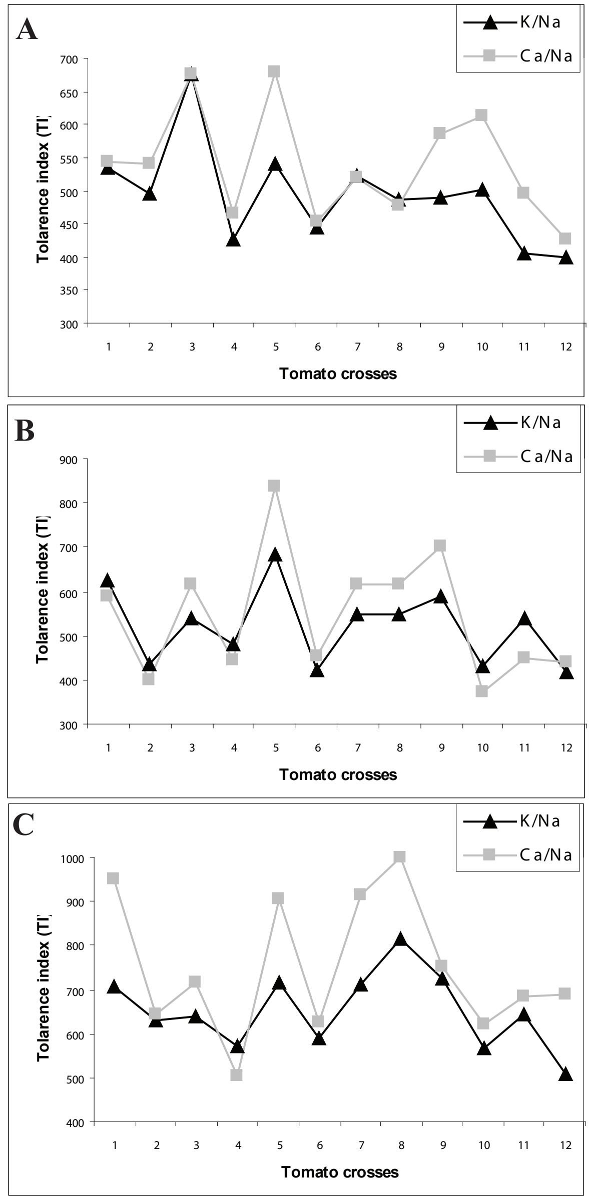

Fig. 2. K^+/Na^+ and Ca^{2+}/Na^+ ratios Tolerance index (TI) response of the tomato crosses on control and 8, 12 dS m^{-1} NaCl concentrations.
(A) root K^+/Na^+ and $Ca2^+/Na^+$ tolerance index,
(B) stem K^+/Na^+ and $Ca2^+/Na^+$ tolerance index,
(C) leaf K^+/Na^+ and $Ca2^+/Na^+$ tolerance index.
Tomato cross combinations were as follows: 1 (40395 x 62573), 2 (40395 x 70452), 3 (40443 x 62573, 4 (40443 x 70452), 5 (47839 x 62573), 6 (47839 x 70452), 7 (62573 x 40395), 8 (62573 x 40443), 9 (62573 x 47839), 10 (70452 x 40395), 11 (70452 x 40443), 12 (70452 x 47839)

In another material, 40443 tolerant genotype and 62573 sensitive genotype were reciprocal crossed. It was detected that cytoplasm has important effects on root and stem dry weight values and root and leaf K^+/Na^+ and Ca^{+2}/Na^+TI values. It was detected that these positive effects were especially caused from the cytoplasm of 40443 genotype in root and stem dry weight and K^+/Na^+ and Ca^{+2}/Na^+TI; and from the cytoplasm of 62573 genotype in leaf K^+/Na^+TI and Ca^{+2}/Na^+TI. Contrary to this, it was detected that cytoplasm has no effect on leaf dry weight and stem K^+/Na^+ and Ca^{+2}/Na^+ tolerance index (Table 5).

Cytoplasm does not important effect on root and stems dry weight, K^+/Na^+ (root, stem, leaf) and Ca^{+2}/Na^+ (leaf) tolerance index; on crosses obtained from reciprocal material between 40443 and 70452 tolerant and sensitive genotypes. It can be observed from Table 5 that these positive effects are caused by 40443 cytoplasm in root, dry weight and root K^+/Na^+; by 70452 genotype in stem; dry weight and K^+/Na^+, leaf; K^+/Na^+ and Ca^{+2}/Na^+ tolerance indexes.

With the reciprocal materials which are tolerant 47839 genotype and sensitive 62573 genotypes; combinations of [47839 x 62573] and [62573 x 47839] crosses were obtained. In these combinations, it was found that cytoplasm has important effects on the parameters other than root and stem dry weight and leaf K^+/Na^+ parameters. 47839 tol-

Table 2
Concentration of K^+, Ca^{2+}, Na^+, K^+/Na^+, Ca^{2+}/Na^+ and K^+/Na^+, Ca^{2+}/Na^+ Tolerance index (TI) in the root of the tomato crosses under different NaCl concentrations

Crosses	NaCl Concentration (dS m^{-1})															TI	
	Control					8					12						
	K^+	Ca^{+2}	Na^+	K^+/Na^+	Ca^{+2}/Na^+	K^+	Ca^{+2}	Na^+	K^+/Na^+	Ca^{+2}/Na^+	K^+	Ca^{2+}	Na^+	K^+/Na^+	Ca^{2+}/Na^+	K^+/Na^+	Ca^{2+}/Na^+
40395 x 62573	2.67	2.15	0.34	7.83 c	6.30 c	2.66	2.14	1.47	1.81 j	1.44 ij	1.79	1.59	2.74	0.65 q-s	0.58 o-s	535.52 bc	543.88 c
40395 x 70452	3.72	2.57	0.53	7.02 e	4.85 e	2.55	1.96	1.79	1.42 k-m	1.09 j-l	1.43	1.31	2.96	0.48 r-u	0.44 q-t	494.99 d	540.77 c
40443 x 62573	2.49	3.06	0.57	4.35 i	5.36 d	1.68	1.96	1.09	1.54 kl	1.80 hi	1.21	1.66	2.36	0.51 r-u	0.71m-r	675.29 a	676.10 a
40443 x 70452	2.75	2.66	0.48	5.77 h	5.59 d	1.24	1.80	2.00	0.62 q-t	0.90 l-o	1.11	1.04	2.56	0.44 s-u	0.41 r-t	426.27 f	466.29 ef
47839 x 62573	2.93	2.52	0.40	7.31 d	6.25 c	2.00	2.62	1.24	1.62 j-l	2.12 gh	1.46	1.63	2.11	0.69 p-r	0.78 l-r	541.70 b	678.68 a
47839 x 70452	3.32	3.07	0.55	6.03 g	5.58 d	1.35	1.60	1.66	0.81 pq	0.96 k-n	1.10	0.76	2.53	0.43 s-u	0.30 st	444.63 e	452.85 fg
62573 x 40395	3.58	2.97	0.40	8.98 a	7.46 b	2.68	2.08	1.61	1.66 jk	1.29 j-k	2.02	1.78	2.21	0.92 op	0.81 l-q	521.63 c	519.72 cd
62573 x 40443	3.32	3.36	0.39	8.50 b	8.64 a	2.21	2.11	1.97	1.12 no	1.07 j-m	2.00	1.99	2.15	0.93 op	0.93 k-o	487.09 d	478.12 ef
62573 x 47839	3.22	3.10	0.41	7.82 c	7.54 b	1.72	2.71	1.24	1.39 lm	2.19 g	1.53	1.54	2.38	0.64 q-s	0.64 n-s	490.42 d	585.77 b
70452 x 40395	3.76	2.26	0.56	6.79 e	4.09 f	2.58	1.84	1.99	1.29 mn	0.92 k-o	1.46	1.61	2.63	0.55 r-u	0.61 ns	502.86 d	612.72 b
70452 x 40443	3.35	2.43	0.55	6.15 g	4.51 e	1.82	1.56	2.66	0.69 p-r	0.59 n-s	1.01	1.49	3.07	1.61 u	2.10 p-t	404.42 g	496.93 de
70452 x 47839	3.65	2.98	0.57	6.47 f	5.29 d	1.29	1.76	2.05	0.63 q-s	0.86 l-p	1.19	0.61	3.09	0.38 tu	0.20 t	399.45 g	425.25 g

Means followed by the same letter are statistically not significant (Duncan's multiple range test, P=0.05)

erant genotype cytoplasm especially has especially more positive effect on leaf dry weight, root and stem K^+/Na^+ and Ca^{+2}/Na^+, leaf Ca^{+2}/Na^+ tolerance index when compared with 62573 sensitive genotype (Table 5).

Different salt concentrations were conducted on [47839 x 70452] and [70452 x 47839] cross combinations obtained from reciprocal material between 47839 tolerant genotype and other sensitive 70452 genotype. It was detected that cytoplasm has positive effects on stem dry weight, root and leaf tissues K^+/Na^+ and Ca^{+2}/Na^+ tolerance indexes and this effect was caused by 47839 genotype. On the other hand, as it can be observed from Table 5; there is no effect of cytoplasm on root and leaf dry weight, stem K^+/Na^+ and Ca^{+2}/Na^+ tolerance indexes.

It was seen on the entire cross combinations that while cytoplasm has important effect on an index value, it does not have such important effect on another index value in the same cross combination. Therefore using only one index value that is tolerant towards salt would show the effect of cytoplasm on salt tolerance better.

Conclusions

In this study, the dry weight obviously decreased in all crosses with salinity on comparing with control. The Na^+ concentration of the 12

Table 3
Concentration of K^+, Ca^{2+}, Na^+, K^+/Na^+, Ca^{2+}/Na^+ and K^+/Na^+, Ca^{2+}/Na^+ Tolerance index (TI) in the stem of the tomato crosses under different NaCl concentrations

Crosses	NaCl Concentration (dS m^{-1})															TI	
	Control					8					12						
	K^+	Ca^{+2}	Na^+	K^+/Na^+	Ca^{+2}/Na^+	K^+	Ca^{+2}	Na^+	K^+/Na^+	Ca^{+2}/Na^+	K^+	Ca^{2+}	Na^+	K^+/Na^+	Ca^{2+}/Na^+	K^+/Na^+	Ca^{2+}/Na^+
40395 x 62573	3.10	2.48	0.51	6.07 f	4.86 g	2.04	1.81	1.71	1.19 cd	1.06 c	1.99	1.20	1.82	1.10 a	0.66 bc	623.96 b	588.61 c
40395 x 70452	3.37	2.44	0.46	7.35 d	5.32 f	1.31	0.83	1.31	1.01 d	0.63 de	1.25	0.63	2.70	0.46 cd	0.23 d	435.51 f	397.60 e
40443 x 62573	3.47	3.02	0.43	8.13 c	7.06 a	2.37	2.62	1.23	1.93 b	2.13 b	1.34	1.49	2.01	0.67 bc	0.74 a-c	539.06 d	617.92 c
40443 x 70452	3.77	2.47	0.56	6.76 e	4.43 h	1.74	0.87	1.30	1.34 c	0.67 de	1.05	0.72	2.60	0.40 cd	0.28 d	480.56 e	446.09 d
47839 x 62573	4.15	2.49	0.47	8.94 b	5.37 ef	2.60	2.11	0.85	3.20 a	2.59 a	1.92	1.54	1.73	1.11 a	0.89 ab	685.64 a	835.72 a
47839 x 70452	4.50	2.61	0.52	8.70 b	5.03 g	1.57	0.95	1.16	1.35 c	0.82 d	1.01	0.88	2.98	0.34 d	0.29 d	421.93 f	452.41 d
62573 x 40395	3.58	2.54	0.46	7.89 c	5.60 de	2.26	1.86	1.67	1.36 c	1.12 c	1.85	1.69	1.78	1.04 a	0.95 a	546.78 d	614.74 c
62573 x 40443	3.33	2.87	0.42	7.88 c	6.80 b	2.51	2.84	1.30	1.93 b	2.19 b	1.57	1.39	2.31	0.68 bc	0.60 c	550.29 d	614.04 c
62573 x 47839	4.07	2.53	0.42	9.82 a	6.10 c	2.85	2.44	0.96	2.98 a	2.55 a	1.98	1.50	2.51	0.79 ab	0.60 c	590.32 c	702.38 b
70452 x 40395	3.51	2.50	0.43	8.19 c	5.81 d	1.51	0.70	1.38	1.09 cd	0.51 e	1.22	0.61	2.48	0.49 b-d	0.25 d	429.23 f	371.09 e
70452 x 40443	4.80	2.71	0.64	7.46 d	4.21 h	3.09	0.91	1.50	2.05 b	0.60 de	1.16	0.81	2.79	0.41 cd	0.29 d	537.10 d	448.01 d
70452 x 47839	4.36	2.75	0.54	8.05 c	5.08 g	1.39	1.10	1.39	1.00 d	0.79 d	1.13	0.73	2.56	0.44 cd	0.28 d	415.51 f	441.70 d

Means followed by the same letter are statistically not significant (Duncan's multiple range test, P=0.05)

Table 4
Concentration of K^+, Ca^{2+}, Na^+, K^+/Na^+, Ca^{2+}/Na^+ and K^+/Na^+, Ca^{2+}/Na^+ Tolerance index (TI) in the leaf of the tomato crosses under different NaCl concentrations

Crosses	NaCl Concentration (dS m^{-1})															TI	
	Control					8					12						
	K^+	Ca^{+2}	Na^+	K^+/Na^+	Ca^{+2}/Na^+	K^+	Ca^{+2}	Na^+	K^+/Na^+	Ca^{+2}/Na^+	K^+	Ca^{2+}	Na^+	K^+/Na^+	Ca^{2+}/Na^+	K^+/Na^+	Ca^{2+}/Na^+
40395 x 62573	4.30	3.24	0.54	7.93 c	5.97 de	3.29	3.00	1.12	2.95 b	2.69 b	1.71	2.71	1.61	1.06 bc	1.68 a	708.79 b	949.59 ab
40395 x 70452	4.13	3.49	0.63	6.62 e	5.58 fg	4.03	2.22	1.85	2.19 cd	1.20 g	1.29	2.07	2.04	0.63 f	1.02 d	629.32 c	641.94 e-g
40443 x 62573	4.77	3.82	0.70	6.84 e	5.46 g	3.27	3.00	1.55	2.12 c-e	1.95 d	2.20	2.28	2.78	0.79 d-f	0.82 e	637.28 c	715.22 cd
40443 x 70452	4.86	4.33	0.73	6.63 e	5.91 e	3.83	2.58	2.20	1.74 f	1.17 g	1.82	1.44	3.01	0.60 f	0.48 f	569.42 d	505.91 h
47839 x 62573	4.25	3.14	0.51	8.31 b	6.15 bc	3.22	2.98	0.93	3.47 a	3.21 a	2.11	2.75	2.28	0.92 c-e	1.21 c	717.75 b	903.47 b
47839 x 70452	4.60	3.99	0.59	7.78 cd	6.75 a	3.74	2.91	1.66	2.25 c	1.75 e	1.52	2.09	2.22	0.68 ef	0.94 de	588.59 d	626.42 fg
62573 x 40395	4.73	3.49	0.62	7.63 d	5.63 f	3.49	3.33	1.20	2.91 b	2.30 c	1.74	2.77	1.75	1.00 cd	1.59 ab	712.33 b	915.80 b
62573 x 40443	4.45	3.30	0.66	6.82 e	5.05 h	3.76	3.18	1.30	2.89 b	2.44 c	2.35	2.75	1.82	1.30 ab	1.51 b	817.14 a	998.06 a
62573 x 47839	4.26	3.41	0.54	7.85 cd	6.28 bc	4.07	2.89	1.71	2.38 c	1.69 e	2.89	2.85	1.90	1.53 a	1.50 b	727.06 b	753.08 c
70452 x 40395	4.65	3.72	0.61	7.66 d	6.13 cd	3.48	2.12	1.55	2.25 c	1.37 f	1.25	2.29	2.36	0.53 f	0.97 de	568.43 d	619.01 g
70452 x 40443	3.93	3.12	0.67	5.87 f	4.66 i	4.14	2.71	2.10	1.97 d-f	1.29 fg	1.74	2.41	2.92	0.60 f	0.82 e	645.24 c	685.08 d-f
70452 x 47839	5.43	3.78	0.60	9.05 a	6.31 b	3.49	3.57	1.83	1.90 ef	1.95 d	1.60	2.37	2.37	0.68 ef	1.00 d	508.15 e	688.0 de

Means followed by the same letter are statistically not significant (Duncan's multiple range test, P=0.05)

Table 5
Effect of genotypes cytoplasm in response to salt tolerance (DW, Dry Weight; TI, Tolerance Index)

Crosses	Root DWTI	Stem DWTI	Leaf DWTI	Root		Stem		Leaf	
				K/NaTI	Ca/NaTI	K/NaTI	Ca/NaTI	K/NaTI	Ca/NaTI
1) 40395 X 62573	1323.15	1355.25	1380.09	535.52	543.88	623.96**	588.61	708.79	949.59
7) 62573 X 40395	1321.27	1369.24	1373.30	521.63	519.72	546.78	614.74	712.33	915.80
2) 40395 X 70452	1201.76	1233.52	1242.59	494.99	540.77**	435.51	397.60**	629.32**	641.94**
10) 70452 X 40395	1210.33	1283.45	1240.73	502.86	612.72	429.23	371.09	568.43	619.01
3) 40443 X 62573	1407.43**	1403.65**	1317.87	675.29**	676.10**	539.06	617.92	637.28**	715.22**
8) 62573 X 40443	1296.31	1309.26	1342.09	487.09	478.12	550.29	614.04	817.14	998.06
4) 40443 X 70452	1370.98**	1243.48**	1233.55	426.27**	466.29	480.56**	446.09	569.42**	505.91**
11) 70452 X 40443	1133.19	1290.25	1199.97	404.42	496.93	537.10	448.01	645.24	685.08
5) 47839 X 62573	1316.34	1347.15**	1366.47	541.70**	678.68**	685.64**	835.72**	717.75	903.47**
9) 62573 X 47839	1308.87	1139.10	1373.53	490.42	585.77	590.32	702.38	727.06	753.08
6) 47839 X 70452	1169.82	1274.32**	1274.01	444.63**	452.85**	421.93	452.41	588.59**	626.42**
12) 70452 X 47839	1234.34	1185.31	1259.78	399.45	425.25	415.51	441.70	508.15	688.0

Significant between groups - ** - at P<0.01

tested tomato crosses was increased, whereas K^+, Ca^{+2}, Na^+ and K^+/Na^+, Ca^{+2}/Na^+ concentration decreased. Tolerance index values were calculated according to these findings. In this study, tolerance index used as a select tolerant salt tolerant tomato crosses at different salt concentrations. There was a large variation in root, stem and leaf dry weight and K^+/Na^+, Ca^{+2}/Na^+ TI among 12 cross combinations under increasing salinity. The highest tolerance index values were generally obtained from the combination of tolerant genotypes (40443, 47839 and 40395) and sensitive genotype 62573. For example, highest root, stem and leaf K^+/Na^+TI, Ca^{+2}/Na^+TI values were extracted from the [40443 x 62573], [47839 x 62573] and [62573 x 40443] crosses combination. Similar to results were obtained from DWTI.

Cytoplasm is another factor that plays an important role in the salt tolerance. It can be concluded that crossing, in between tolerant and sensitive tomato genotypes positively or negatively affected genotype cytoplasm. These affect were changed by the different tolerance index values being used. Generally, in reciprocal crosses were made between a salt tolerant and a salt sensitive tomato genotypes; 40443, 47839, 40395 and 62573 cytoplasm positively affected tolerance index values (root, stem, leaf; dry weight, K^+/Na^+, Ca^{+2}/Na^+ concentration) and means which they were less affected by salinity.

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