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COMPARATIVE SALINITY RESPONSES AMONG TOMATO GENOTYPES AND ROOTSTOCKS

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Abstract

Salinity is a major constraint limiting agricultural crop productivity in the world. However, plant species and cultivars differ greatly in their response to salinity. This study was conducted in a greenhouse to determine the response of 4 commercial tomato rootstocks, 21 cultivars and 8 candidate varieties to salinity stress. Seeds were germinated in peat and when the plants were at the fifth-true leaf stage, salt treatment was initiated except control treatment. NaCl was added to nutrient solution daily with 25 mM concentration and had been reached to 200mM final concentration. On harvest day, genotypes were classified based on the severity of leaf symptoms caused by NaCl treatment. After symptom scoring, the plants were harvested and leaf number, root length, stem length and diameter per plant were measured. The plants were separated into shoots and roots for dry matter production. Our results showed that, on average, NaCl stress decreased all parameters and the rootstocks gave the highest performance than genotypes. Among all rootstocks, three varieties (819, 2211 and 2275) and ten genotypes (Astona, Astona RN, Caracas, Deniz, Durinta, Export, Gökçe, Target, Yeni Talya and 144 HY) were selected as tolerant with slight chlorosis whereas the genotype Malike was selected as sensitive with severe chlorosis. Candidate varieties 2316 and 1482 were the most sensitive ones. Plant growth and dry matter production differed among the tested genotypes. However no correlation was found between plant growth and dry matter production. Rootstock Beaufort gave the highest shoot dry matter although Heman had highest root dry matter. Newton showed more shoot and root dry matter than other genotypes. It is concluded that screening of genotypes based on severity of symptoms at early stage of development and their dry matter production could be used as a tool to indicate genotypic variation to salt stress.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is the most prominent crop grown in greenhouses worldwide and in Mediterranean Region as well. The plants require high temperature and high photosynthetic active radiation conditions for optimal production. These conditions are typical for arid and semi-arid regions where soil and groundwater salinity are insidious problems (Cuertero & Fernandez, 1999). However, salinity is one of the most significant factors limiting agricultural crop productivity in these regions in the world (Flowers *et al.,* 1997) which occur due to low rainfall, high evaporation, native rocks, saline irrigation water, insufficient drainage and poor water management (Muns & Termaat, 1986).

Salinity affects the crop during both the vegetative and the reproductive stage and therefore causes reduction in plant growth and development with low water potential in the root medium (osmotic effect), too high internal ion concentration (ion excess/toxicity) and nutritional imbalance by depression in uptake and/or shoot transport (ion deficiency) (Levitt, 1980). Most of the salt stress in nature is due to sodium salts, particularly NaCl (Levitt, 1980; Muns & Termaat, 1986). High concentrations of Na^+ and Cl^- in the root medium saturation depress nutrient-ion activities and produce extreme rations of Na^+/Ca^{2+}, Na^+/K^+, Ca^{2+}/Mg^{2+} and Cl^-/NO_3^- (Grattan & Grieve, 1999). Osmotic effect resulting from salinity may cause disturbances in the water balance of the plant, including a reduction of turgor and an inhibition of growth, as well as stomatal closure and reduction of photosynthesis (Navarro *et al.,* 2000; Romero-Aranda *et al.,* 2001; Li & Stanghellini, 2001; Heuvelink *et al.,* 2003). As a result, plants become susceptible to osmotic and specific-ion injury as well as to nutritional disorders that may result in reduced yield and quality. These processes may be occurring at the same time, but whether they ultimately affects crops yield and quality depends on the salinity level, composition of salt, exposed period to salinity, the crop species and cultivars, the growth stage of plants and a number of environmental factors (Carjaval *et al.,* 1998; Del Amore *et al.,* 1999; Grattan & Grieve, 1999; Caro *et al.,* 1991).

When salt concentration reaches a harmful level to plant growth, a salinity condition is said to have developed. The degree to which growth and normal metabolism can be maintained is described as salt tolerance. Salt tolerance of vegetable crops varies considerably among species and depends upon the cultural conditions under which the crops are grown. Soil, water, plant and environment can affect the salt tolerance of a plant. Therefore, plant response to a given salt concentration cannot be predicted on an absolute basis but on relative performance basis. Vegetable crops tolerance to salinity is usually appraised in one of the three ways: the ability of plants to survive in saline conditions, the absolute plant growth or yield and the relative growth or yield in saline conditions as compared with non-saline conditions (Mangal & Singh, 1993).

The tomato plant is moderately tolerant to salinity stress (Ayers & Westcot, 1989; Maas, 1986,1990). Thus, Maas (1986) reported that a 50% yield reduction at an electrical conductivity of the saturated soil extract of 7.6 dS m^{-1}. It has been determined that salinity causes several kinds of damage such as growth inhibition, metabolic disturbance and quality losses in addition to yield reduction on tomato plants (Sanchez-Blanco *et al.,* 1991; Schwarz *et al.,* 1998; Navarro *et al.,* 2000; Li & Stanghellini, 2001; Romero-Aranda *et al.,* 2001; Tüzel *et al.,* 2003; Maggio *et al.,* 2007). As is seen, many investigations have been conducted to evaluate the effects of salinity on tomato. Also numerous attempts have been made to improve the salt tolerance of wild and commercial tomato crop through traditional breeding programs, more recently by biotechnological methods and by genetic transformation of plants (Sanches-Blanco *et*

al., 1991; Shannon *et al.,* 1987; Alian *et al.,* 2000). Especially plant breeding methods are time consuming, slow process, laborious and expensive approach and rely on existing genetic variability. Moreover, it is difficult to modify single traits that are probably multifunctionally controlled and commercial success has been limited. Use of physiological selection criteria can improve the probability of success by making empirical selection more efficient (Noble & Rogers, 1992).

In this context, screening at the earlier stage can be an easier method to determine salt tolerant genotypes. Besides, tolerance to NaCl by using screening method with large number of tomato genotypes was limited in literature. Our results can provide a potential for a genotypic variation for NaCl tolerance and be helpful in selecting the genotypes for further and detailed screening studies.

The main objective of this study was to determine the salt tolerance of commercial tomato rootstocks, cultivars and candidate varieties screening them on the basis of visual appearance and differential responses and the discuss the reliability of criteria indicating salt tolerances; and determination of effects of NaCl salinity on plant growth in seedling stage.

Material and Methods

This experiment was carried out in an un-heated greenhouse (Richel, PE covered bitunnel) at Faculty of Agriculture Ege University in the autumn season of 2004. Four commercially available rootstocks, eight candidate varieties and twenty-one cultivars of tomato were used as plant material (Table 1).

Table 1. Genotypes and their producer seed companies.

	Genotypes	Company		Genotypes	Company
Rootstocks	Beaufort	De Ruiter	**Cultivars**	Alida	Zeraim
	Heman	Sygenta		Astona	Nunhems
	Rootex	EnzaZaden		Astona RN	Nunhems
	Vigomax	De Ruiter		Beril	Rito
Candidate				Caracas	Zeraim Gerada
varieties	819	Çagdas		Deniz	Zeraim Gerada
	1414	Çagdas		Durinta	Western
	1482	Çagdas		Ecem	BATEM
	1483	Çagdas		Elif	Zeraim Gerada
	2211	BATEM*		Export	Golden
	2275	BATEM		Gökçe	Zeraim
	2316	BATEM		Halay 344	EnzaZaden
	2285	BATEM		Ikram	Sygenta
				Malike	Clause Tezier
				Newton	Sygenta
				Polaris	Golden
				Selin	Zeraim Gerada
				Target	De Ruiter
				Tülin	Zeraim Gerada
				Yeni Talya	De Ruiter
				144 HY	Hazera

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Seeds were sown into peat on 29 November 2004 and tomato seedlings at the second true leaf stage were transferred to other containers. Water and nutrient requirements of the plants were supplied with the nutrient solution having the following composition (mg L^{-1}): N 210, P 40, K 250, Ca 150, Mg 50, Fe 2, Mn 0.75, B 0.4, Zn 0.50, Cu 0.10 and Mo 0.05 (Day, 1991) and the plants were grown under non-saline conditions for 21 days. When the plants were at the fifth-true leaf stage, salt treatment was initiated excluding control treatment. The experiment was carried out with 6 plants. Three plants were used per genotype in each replication.

NaCl was added to nutrient solution with 25 mM NaCl concentration had been reached to 200 mM NaCl. The plants were grown for 10 days under 200 mM salt stress condition. 63-day old plants were classified for their salt tolerance by the visual appearance. Plants were rated for severity of salt susceptibility by 0-4 scale (Fig. 1). The scale was (0) normal green plants with fully expanded leaves; (1) green leaves with slight inward curly and dry leaves; (2) dry leaves from moderate to severe damages; (3) most leaves with drying damages; (4) all leaves of the plant with drying damages (Dasgan *et al.,* 2002). After scale scoring, the plants were harvested and leaf number, root length (length of the longest root), stem length and diameter per plant were measured. Furthermore the plants were separated into shoots (all leaves and stem) and roots for dry matter assimilation and dried at 65 °C using a thermo ventilated oven.

Analysis of variance (ANOVA) was carried out to determine any statistically significant differences. The experimental design was one factor randomized parcel with 3 replicates. Different letters in the tables represent significant variations according to the Fisher's protected least significant difference (LSD) test. Significance was set at $p \leq 0.05$.

Fig.1. The salinity scale classes used in experiment.

Results

Symptom score: The variation was not high in terms of tolerance to 200 mM NaCl treatment based on severity of leaf symptoms (Table 2). Among the tested genotypes, all rootstocks; candidate varieties namely 819, 2211 and 2275 and cultivars Astona, Astona RN, Caracas, Deniz, Durinta, Export, Gökçe, Target, Yeni Talya and 144 HY with 1.0 score were found tolerant genotypes followed by candidate varieties 1483 and 1414; cultivars Ikram, Polaris, Alida, Beril, Ecem, Elif, Halay 344, Selin and Tülin. All these genotypes were less affected from salt treatment than the others and showed no or only slight chlorosis. Candidate varieties 2316 and cultivar Malike were the most sensitive genotype to salinity stress with 2.7 score. Plants with scores between 1.0 and 2.7 showed mild tolerance to 200mM NaCl concentration.

Table 2. Leaf chlorosis and necrosis symptom score (0-4)* of 33 genotypes grown at 200 mM NaCl.

		Score			Score
Rootstocks	Beaufort	1.0 c	**Cultivars**	Alida	1.3 bc
	Heman	1.0 c		Astona	1.0 c
	Rootex	1.0 c		Astona RN	1.0 c
	Vigomax	1.0 c		Beril	1.3 bc
				Caracas	1.0 c
				Deniz	1.0 c
Candidate varieties	819	1.0 c		Durinta	1.0 c
	1414	1.3 bc		Ecem	1.3 bc
	1482	2.0 ab		Elif	1.3 bc
	1483	1.7 bc		Export	1.0 c
	2211	1.0 c		Gökçe	1.0 c
	2275	1.0 c		Halay 344	1.3 bc
	2316	2.7 a		Ikram	1.7 bc
	2285	1.0 c		Malike	2.0 ab
				Newton	1.3 bc
				Polaris	1.7 bc
				Selin	1.3 bc
				Target	1.0 c
				Tülin	1.3 bc
				Yeni Talya	1.0 c
				144 HY	1.0 c
$LSD_{(0.05)}$ 0.864**					

*All genotypes were scored by using 0-4 scores: 0: no or very slight, 1: slight, 2:mild, 3: severe, 4:very severe.

Plant growth: Plant leaf number was reduced by 23.3% with the salinity. In control treatment, candidate variety 1482 and rootstock Beaufort gave the highest leaf number as 11.0 and 10.0 number plant^{-1}, respectively. Least leaf number was obtained from 1414 and 2275 with 6.5 leaves per plant followed by Alida, Elif, Ecem, Halay 344, Polaris, Tülin, 2211 and 2285 with 7 leaves per plant. In saline conditions, Vigomax gave the highest leaf number with 8.3 leaves per plant followed by Beaufort, Durinta and Newton. Rootstock Rootex and cvs. Ecem, Malike, Polaris, Selin, 2211 and 2316 showed least leaf number per plant. On average, leaf numbers of cultivars was much more affected by NaCl treatment than the rootstocks. Rootstocks leaf number was reduced by 13.7% while in cultivars the reduction was 24.0% (Table 3).

Table 3. Plant growth parameters of 63 days old 33 genotypes grown in nutrient solution with (200 mM) and without (control) NaCl treatment.

		Leaf number (no plant^{-1})		Plant height (cm)		Root lenght (cm)		Stem diameter (cm)	
		-NaCl	+NaCl	-NaCl	+NaCl	-NaCl	+NaCl	-NaCl	+NaCl
Rootstocks	Beaufort	10.0 ab	7.3 ab	36.9 a	25.2 a	19.0 bcdefg	16.9 ab	0.390 fghi	0.357 ghijk
	Heman	8.0 cdef	7.0 bc	28.1 defghij	21.1 bcde	21.9 bc	15.8 abc	0.390 fghi	0.307 l
	Rootex	7.5 def	6.3 bcde	31.4 abcd	19.0 cdefgh	19.8 bcdef	17.9 a	0.320 i	0.317 kl
	Vigomax	8.0 cdef	8.3 a	27.4 defghijk	25.9 a	19.2 bcdefg	15.1 abcde	0.390 fghi	0.320 jkl
Cultivars	Alida	7.0 ef	6.0 cdef	22.0 klm	16.0 hijkl	23.4 b	12.5 cdefg	0.400 efghi	0.400 abcdefgh
	Astona	9.0 bcd	6.7 bcd	31.4 abcd	21.6 bcd	20.3 bcdef	11.4 efgh	0.515 ab	0.403 abcdefg
	Astona RN	8.0 cdef	5.7 def	23.3 hijklm	21.7 bc	20.5 bcde	10.3 fgh	0.405 defgh	0.393 bcdefghi
	Beril	8.0 cdef	6.0 cdef	31.1 abcde	16.0 hijkl	18.2 bcdefg	13.6 bcdef	0.470 abcdef	0.443 a
	Caracas	8.0 cdef	6.3 bcde	22.7 ijklm	16.8 ghijk	22.4 bc	12.6 cdefg	0.400 efghi	0.350 ijkl
	Deniz	8.0 cdef	6.0 cdef	34.1 abc	18.2 efghij	13.9 efg	11.3 efgh	0.495 abc	0.390 bcdefghi
	Durinta	8.5 bcde	7.3 ab	29.1 bcdefgh	19.9 cdef	19.9 bcdef	13.5 bcdefg	0.445 bcdefg	0.393 bcdefghi
	Ecem	7.0 ef	5.0 f	28.1 defghij	15.3 jkl	22.2 bc	15.4 abcd	0.400 efghi	0.370 defghi
	Elif	7.0 ef	6.0 cdef	25.8 defghijklm	18.2 efghij	20.0 bcdef	12.5 cdefg	0.430 cdefg	0.377 cdefghi
	Export	7.5 def	6.7 bcd	26.9 defghijkl	21.3 bcd	12.3 g	11.8 defgh	0.450 bcdefg	0.413 abcde
	Gökçe	8.0 cdef	5.7 def	25.3 efghijklm	18.7 defghi	21.2 bcd	10.6 fgh	0.420 cdefg	0.380 cdefghi
	Halay 344	7.0 ef	6.0 cdef	22.9 ijklm	16.9 fghijk	20.1 bcdef	11.2 efgh	0.385 ghi	0.367 efghij
	Ikram	8.5 bcde	6.7 bcd	30.4 bcdef	20.0 cdef	16.3 cdefg	10.5 fgh	0.550 a	0.417 abcd
	Malike	8.5 bcde	5.0 f	29.2 bcdefgh	15.3 jkl	17.5 bcdefg	11.1 fgh	0.485 abcd	0.393 bcdefghi
	Newton	8.5 bcde	7.3 ab	22.6 ijklm	18.8 cdefgh	17.1 bcdefg	10.0 fgh	0.445 bcdefg	0.393 bcdefghi
	Polaris	7.0 ef	5.0f	23.9 ghijklm	14.8 kl	17.4 bcdefg	9.9 fgh	0.390 ghi	0.393 bcdefghi
	Selin	7.5 def	5.0 f	26.3 defghijklm	18.8 cdefgh	20.7 bcde	13.3 bcdefg	0.445 bcdefg	0.403 abcdefg
	Target	9.0 bcd	5.7 def	24.6 fghijklm	21.1 bcde	19.9 bcdef	10.7 fgh	0.410 defgh	0.400 abcdefgh
	Tülin	7.0 ef	6.7 bcd	22.4 jklm	17.7 fghijk	13.5 fg	12.8 cdefg	0.405 defgh	0.395 abcdefghi
	Yeni Talya	7.5 def	5.3 de	24.2 ghijklm	19.2 cdefg	30.8 a	10.2 fgh	0.415 cdefg	0.353 hijkl
	144 HY	8.5 bcde	7.0 bc	24.9 fghijklm	15.6 ijkl	18.8 bcdefg	13.8 bcdef	0.480 abcde	0.353 hijkl
Candidate varieties	819	9.5abc	7.0 bc	28.4 cdefghi	26.1 a	13.8 efg	9.6 gh	0.470 abcdef	0.410 abcde
	1414	6.5 f	5.3 de	23.0 ijklm	19.1 cdefg	17.1 bcdefg	10.3 fgh	0.435 bcdefg	0.405 abcdef
	1482	11.0 a	5.3 de	29.7bcdefg	24.0 ab	20.4 bcdef	11.9 cdefg	0.445 bcdefg	0.420 abc
	1483	9.5 abc	6.7 bcd	35.0 ab	25.6 a	19.0 bcdefg	7.9 h	0.450 bcdefg	0.437 ab
	2211	7.0 ef	5.0 f	27.5 defghijk	15.7 ijkl	18.8 bcdefg	15.4 abcd	0.330 hi	0.320 jkl
	2275	6.5 f	5.7 def	21.2 lm	14.9 kl	14.7 defg	13.5 bcdef	0.390 fghi	0.360 fghijk
	2316	7.5 def	5.0 f	20.9 m	16.7 ghijk	20.6 bcde	12.3 cdefg	0.400 efghi	0.397 abcdefghi
	2285	7.0 ef	5.7 def	26.4 defghijklm	13.7 l	16.5 bcdefg	12.9 cdefg	0.385 ghi	0.350 ijkl
	LSD $_{(0.05)}$	1.841**	1.316**	5.940**	3.042**	7.026**	3.909**	0.083**	0.050**

*** indicates significant differences for $P \leq 0.001$.

Plant height was changed between 26.9 (Beaufort) and 20.9 (2316) cm in control treatment whereas it was between 26.1 (819) and 13.71 (2285) cm in 200 mM NaCl treatment. NaCl treated plants with 19.06 cm average height showed 29.03% reduction when compared with control plants. In salinity treatment rootstocks had 22.97% longer plants than cultivars and candidate varieties. Especially Vigomax and Beaufort gave the highest plant height. Among the cultivars and candidate varieties 819, 1483, Astona RN, Astona and Target were the highest ones (Table 3).

Yeni Talya with 30.8 cm showed the highest root length, while Export with 12.3 cm had the least length in control treatment. Among the rootstocks Heman was the highest root. In saline conditions, data was changed between 17.9 (Rootex) and 7.9 (1483) cm. Average decreases in root length of rootstocks (17.4%) caused by salt stress were less than cultivars and candidate varieties (35.2%). The average root length was 34.8% reduce in plants grown in nutrient solution with NaCl, compared to nonsaline plants (Table 3).

Among the tested plants, Ikram gave the thickest stem diameter (0.55 cm) followed by Astona and Deniz in nonsaline conditions. The thinnest stem diameter was measured on Rootex followed by 2211, 2285, Polaris and Halay 344. Stem diameter was reduced 10.37% when NaCl was applied to nutrient solution. As Beril in salt stress had thickest stem diameter with 0.443 cm, Heman gave the thinnest stem diameter with 0.307 cm (Table 3).

Dry matter production: Plants in control treatment, shoot and dry weight were found insignificant. However, in saline conditions shoot and root dry matter productions were statistically significant ($p \leq 0.01$). Among the tested rootstocks Beaufort gave the highest shoot dry matter even though Heman had highest root dry matter. Among the cultivars and candidate varieties Newton showed more shoot dry matter (1.09 g plant^{-1}) than others and followed by Beril, 1482, Astona, Ikram, 1483 and 2216. Average shoot dry matter was 1.06 and 0.81 in plants grown in nutrient solution with (200 mM) and without (control) NaCl. Decrease in shoot dry matter production caused by salt stress was 23.5%. When NaCl was not supplied, the average root dry matter was found as 0.19 g plant^{-1} and with NaCl it decreased to 36.8%. Heman and Newton gave the highest root dry matters with 0.16 g plant^{-1} followed by Durinta, Beril, Deniz, 2211 and 2316 (Table 4). Correlation between symptom scores of NaCl toxicity and shoot and root dry weight of plants could not be found significant (Fig. 2).

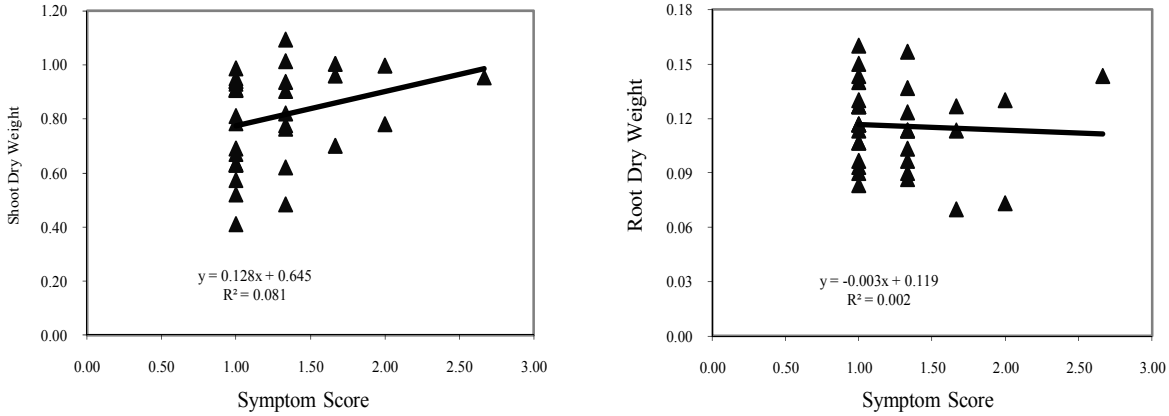

Fig. 2. Relationship between shoot and root dry matter production and symptom scores of NaCl toxicity.

Tomato genotypes showed significant differences in daily dry matter production especially under 200 mM NaCl salt stress. It has been range from 11.82 to 33.57 mg plant^{-1} in control, 9.05 to 19.84 mg plant^{-1} in salinity treatment. Astona produced the highest daily dry matter followed by 1483, 819 and Newton in nutrient solution without NaCl while Halay 344 showed the least dry matter production per day and 2275, Yeni Talya and Polaris were found close to it. 200 mM NaCl nutrient solution reduced daily dry matter production (26.19%) compared to control plants. In saline conditions, Heman and Ecem gave the least daily dry matter production while Newton had the highest dry matter production per day (19.84 mg plant^{-1}). Beril and Astona were followed by Newton with 18.25 and 17.67 mg daily dry matter per plant.

Discussion

Among the tested tomato genotypes there was not a large variation in terms of tolerance to salt stress, as judged from the severity of leaf symptoms caused by NaCl treatment. Symptom score was changed between 1.0 (tolerant) and 2.7 (sensitive). 2316, 1482, 1483, Malike, Ikram and Polaris were the most susceptible genotypes with greater leaf damage in saline (Table 1). Interestingly, the genotype Polaris and 2316 showed a very less decrease in shoot dry matter production like Alida, Caracas, Gökçe, Halay 344, Selin, Yeni Talya, 1414 and 2275. Also the genotype Heman, Astona and 144 HY with less leaf symptoms showed more reduction in growth (Table 2). These results indicate that scoring symptoms only for the severity of leaf symptoms cannot be reliable screening method in ranking genotypes for their tolerance to salt stress at early stage (Al-Karaki, 2000; Dasgan *et al.,* 2002). This screening method could be combined with other approaches such as shoot or root Na and Cl concentration of genotypes (Al-Karaki, 2000; Aktas *et al.,* 2006) or the root/shoot dry weight ratio (Cruz & Cuartero, 1990).

Table 4. Dry matter production of genotypes grown in nutrient solution with (200 mM) and without (control) NaCl treatment.

		Shoot dry weight (g plant^{-1})		Root dry weight (g plant^{-1})		Daily dry matter production (mg plant^{-1})	
		-NaCl	+NaCl	-NaCl	+NaCl	-NaCl	+NaCl
Rootstocks	Beaufort	1.28	0.95 abc	0.20	0.12 abcdefg	23.33 abcdef	16.93 abcdef
	Heman	0.91	0.41 j	0.18	0.16 a	17.22 bcdefg	9.05 k
	Rootex	0.88	0.63 ghij	0.16	0.13 abcdef	16.35 bcdefg	12.01 hijk
	Vigomax	1.03	0.78 bcdefg	0.18	0.10 cdefg	19.21 bcdefg	13.97 defghi
Cultivars	Alida	1.04	0.94 abcde	0.12	0.11 abcdefg	18.33 bcdefg	16.67 abcdef
	Astona	1.81	0.99 abc	0.31	0.13 abcdef	33.57 a	17.67 abcd
	Astona RN	1.29	0.91 abcdef	0.19	0.08 fg	23.49 abcdef	15.77 bcdefgh
	Beril	1.34	1.01 ab	0.22	0.14 abde	24.76 abcde	18.25 ab
	Caracas	0.72	0.67 fghi	0.15	0.13 abcdef	13.81 defg	12.65 ghijk
	Deniz	1.31	0.91 abcdef	0.24	0.14 abc	24.52 abcde	16.67 abcdef
	Durinta	1.10	0.94 abcd	0.23	0.15 ab	21.03 bcdefg	17.30 abcdef
	Ecem	0.94	0.48 ij	0.24	0.12 abcdef	18.65 bcdefg	9.63 k
	Elif	1.18	0.82 bcdefg	0.16	0.10 cdefg	21.19 bcdefg	14.55 bcdefghi
	Export	1.21	0.94 abcd	0.20	0.12 abcdefg	22.38 abcdefg	16.77 abcdef
	Gökçe	0.84	0.81 bcdefg	0.15	0.09 defg	15.63 bcdefg	14.34 cdefghi
	Halay 344	0.62	0.62 ghij	0.13	0.10 bcdefg	11.82 g	11.48 ijk
	Ikram	1.42	1.00 abc	0.23	0.13 abcdef	26.19 abc	17.94 abc
	Malike	1.18	0.78 bcdefg	0.21	0.13 abcdef	21.90 bcdefg	14.44 bcdefghi
	Newton	1.32	1.09 a	0.26	0.16 a	25.08 abcd	19.84 a
	Polaris	0.76	0.70 defghi	0.11	0.07 g	13.65 efg	12.22 hijk
	Selin	0.81	0.78 bcdefg	0.23	0.09 fg	16.51 bcdefg	13.70 efghij
	Target	1.03	0.91 abcdef	0.13	0.11 abcdefg	18.33 bcdefg	16.19 abcdefg
	Tülin	1.09	0.90 abcdef	0.19	0.11 abcdefg	20.32 bcdefg	16.14 abcdefg
	Yeni Talya	0.71	0.69 efghi	0.15	0.11 abcdefg	13.57 efg	12.65 ghijk
	144 HY	1.12	0.63 ghij	0.17	0.09 efg	20.48 bcdefg	11.43 ijk
Candidate varieties	819	1.45	0.93 abcde	0.20	0.11 abcdefg	26.11 abc	16.46 abcdefg
	1414	0.84	0.76 cdefgh	0.10	0.09 efg	14.92 cdefg	13.54 fghij
	1482	1.29	1.00 abc	0.24	0.07 g	24.13 abcdef	16.98 abcdef
	1483	1.44	0.96 abc	0.24	0.11 abcdefg	26.59 ab	17.04 abcdef
	2211	0.73	0.63 ghij	0.14	0.14 abc	13.81 defg	12.28 hijk
	2275	0.57	0.52 hij	0.25	0.12 abcde	13.02 fg	10.11 jk
	2316	1.02	0.95 abc	0.21	0.14 abc	19.44 bcdefg	17.41 abcde
	2285	0.82	0.57 ghij	0.15	0.13 abcdef	15.317 bcdefg	11.16 ijk
	LSD $_{(0.05)}$	ns	0.249**	ns	0.047**	11.421*	3.821**

* and ** indicate significant differences for $P \leq 0.05$ and 0.001, respectively, ns means nonsignificant.

It is well known that one of the first plant responses to salinity stress is a reduction in plant growth rate with associated reductions in leaf area available for photosynthesis. Subsequently, excessive accumulation of salts can lead to death of tissues, organs, and whole plants (Munns & Termaat, 1986). In 200 mM NaCl treatment, leaf number, seedling height, root height and stem diameter of 33 tomato genotypes were decreased as reported by other authors (Perez-Alfocea *et al.,* 1993; Yokas *et al.,* 2008). Root length has been found to be more adversely affected than shoot growth by an increasing supply of NaCl (Mills, 1989; Bourgeais & Guerrier, 1992; Sweby *et al.,* 1994). Similar results were obtained in this work: although both root and shoot growth were inhibited by salt, the effects were more pronounced on root growth. Vigomax and Beaufort showed the highest leaf number and plant height while Rootex showed the longest root length. Also Beaufort had the thickest stem diameter compared with other rootstocks. The observed positive effects of rootstocks were rootstock's vigorous root system which absorb water and nutrients more efficiently and may also serve as a supplier of endogenous plant hormones (Leonardi & Paratore, 1998; Romano & Paratore, 2001).

In this experiment, decreasing in root and shoot fresh weights in saline condition were 11.97 and 18.95%, respectively compared to control plants. This result was similar to that of Cruz and Cuartero (1990) who found that root growth in tomato appears to be less effected by salt than shoot growth. Other authors also reported that the root/shoot dry weight ratio may be an important parameter in salt tolerance of genotypes. In our results, any significant correlations were not detected between root/shoot dry weight and scores (data not shown). These may indicate that plant shoot and root dry weights were independent of salt tolerance at seedling stage of tomato plants as shown in this study, supported by Dasgan *et al.* (2002). Tomato genotypes grown under 200 mM NaCl showed significant variation in shoot and root dry weight and daily dry weight production (Table 3). However, significant relations were not found between shoot-root dry weights and the scale classes. Similar responses were reported by Al-Karaki, (2000) and Dasgan *et al.,* (2002).

It is concluded that plant growth and architect are changed according to genotypes. Rootstocks showed more vigor and vegetative growth depending on its own characteristics and rootstocks additionally could be useful tool for increasing the tolerance of plants to stress factors like salinity.

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References

Aktas, H., K. Abak and I. Cakmak. 2006. Genotypic variation in the response of paper to salinity. *Sci. Hortic.,* 110: 260-266.

Alian, A., A. Altman and B. Heuer. 2000. Genotypic difference in salinity and water stress tolerance of fresh market tomato cultivars. *Plant Sci.,* 152: 59-65.

Al-Karaki, G.N. 2000. Growth, water use efficiency and sodium and potassium acquisition by tomato cultivars grown under salt stress. *J. Plant Nutr.,* 23(1): 1-8.

Ayers, R.S. and D.W. Westcot. 1989. *Water Quality for Agriculture*. FAO Irrigation and Drainage Paper 29, Rome.

Bourgeais-Chaillou, P. and G. Guerrier. 1992. Salt-responses in *Lycopersicon esculentum* calli and whole plants. *J. Plant Physiol.,* 140: 494-501.

Caro, M., V. Cruz, J. Cuartero, M.T. Estan and M.C. Bolarin. 1991. Salinity tolerance of normal-fruited and cherry tomato cultivars. *Plant Soil,* 136: 249-255.

Carvajal, M., F.M. Del Amor, G. Fernandez-Ballester, V. Martinez and A. Cerda. 1998. Time course of solute accumulation and water relations in muskmelon plants exposed to salt during different growth stages. *Plant Sci.,* 138: 103-112.

Cruz, V. and J. Cuartero. 1990. Effects of salinity at several developmental stages of six genotypes of tomato (*Lycopersicon* spp), *In:* Cuarteroi, J., M.L. Gomez-Guillamon and R. Fernandez-Mun˜oz, (Eds.), *Eucarpia Tomato.* XIth Eucarpia Meeting on Tomato Genetics and Breeding Malaga-Spain, pp. 81-86.

Cuartero, J.R. and M. Fernandez. 1999. Tomato and salinity. *Sci. Hortic.,* 78: 83-125.

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

Day, D. 1991. *Growing in Perlite*. Grower Digest. No:12, Grower Publ, London, pp. 36 .

Del Amor, F.M., V. Martinez and A. Cerda. 1999. Salinity duration and concentration affect fruit yield and quality, and growth and mineral composition of melon plants grown in perlite. *HortScience,* 34: 1234-1237.

Flowers, T.J., A. Garcia, M. Koyama and A.R. Yeo. 1997. Breeding for salt tolerance in crop plants: the role of molecular biology. *Acta Physiol. Plant.,* 19: 427-433.

Grattan, S.T. and C.M. Grieve. 1999. Salinity mineral relations in horticultural crops. *Sci. Hortic.,* 78(1-4): 127-157.

Heuvelink, E., M. Bakker and C. Sthangellini. 2003. Salinity effects on fruit yield in vegetable crops: a Simulation Study. *Acta Hort.,* 609: 133-140.

Leonardi, C. and A. Paratore. 1998. Risposta alla salinita dell'acqua di piante innestate di pomodoro e melanzana. *Atti IV Giornate Scientifiche* SOI: 607-608.

Lewit, J. 1980. *Responses of Plants to Environmental Stresses.* Vol.: II. Academic Pres, New York, pp. 607.

Li, L.Y. and C. Stanghellini. 2001. Analysis of the effect of EC and potential transpiration on vegetative growth of tomato. *Sci. Hortic.,* 89: 9-21.

Maas, E.V. 1986. Salt tolerance of plants. *Applied Agricultural Research*, 1(1): 12-26.

Maas, E.V. 1990. Crop salt tolerance. *In:* Tanji K.K. (Ed.), *Agricultural Salinity Assessment and Management*. Am. Soc. Civil Engineers Manual on Engineering Practice, No. 71. Reston, VA. pp. 262–304.

Maggio, A., G. Raimondi, A. Martino and S. De Pascale. 2007. Salt stress response in tomato beyond the salinity tolerance threshold. *Environ. Ex. Bot.,* 59: 276-282.

Mangal, J.L. and K. Singh. 1993. Vegetable Crops: Part 2. In: *Advances in Horticulturae.* (Eds.): K.L. Chadha and G. Kalloo, Malhotra Publishing House, New Delhi, India.

Mills, D. 1989. Differential response of various tissues of *Asparagus officinalis* to sodium chloride. *J. Ex. Bot.,* 40: 485-491.

Munns, R. and A. Termaat. 1986. Whole-plant responses to salinity. *Aust. J. Plant Physiol.,* 13: 143-160.

Navarro, M.J., V. Martinez and M. Carvajal. 2000. Ammonium, bicarbonate and calcium effects on tomato plants grown under saline conditions. *Plant Sci.,* 157: 89-96.

Noble, C.L. and M.E. Rogers. 1992. Arguments for the use of physiological criteria for improving the salt tolerance in crops. *Plant Soil,* 146: 99-107.

Perez-Alfocea, F., M.T. Estañ, M. Caro and M.C. Bolarin. 1993. Response of tomato cultivars to salinity. *Plant Soil,* 150: 203-211.

Romano, D. and A. Paratore. 2001. Effects of grafting on tomato and eggplant. ISHS, *Acta Hort.,* 559: 149-153.

Romero-Aranda, R., T. Soria and J. Cuartero. 2001. Tomato water uptake and plant water relationships under saline growth conditions. *Plant Sci.,* 160: 265-272.

Sanchez-Blanco, M.J., M.C. Bolarin, J.J. Alarcon and A. Torrecillas. 1991. Salinity effects on water relations in *Lycopersicon esculentum* and its wild salt-tolerant relative species *L. pennellii*. *Physiol. Plantarum,* 83: 269-274.

Schwarz, D., R. Kuchenbuch and R. Munoz Carpena. 1998. Water uptake by tomato plants grown in closed hydroponic systems dependent on the EC level. *Acta Hort.,* 548: 323-328.

Shannon, M.C., J.W. Gronwald and M. Tal. 1987. Effects of salinity on growth and accumulation of organic and inorganic ions in cultivated and wild tomato species. *J. Amer. Soc. Hort. Sci.,* 112: 416-423.

Sweby, D.L., B.I. Huckett and M.P. Watt. 1994. Effects of nitrogen nutrition on salt stressed *Nicotiana tabacum* var Samsun *in vitro* plantlets. *J. Ex. Bot.,* 45: 995-1008.

Tuzel, Y., I.H. Tuzel and F. Ucer. 2003. Effects of salinity on tomato growing in substrate culture. *Acta Hort.,* 609: 329-335.

Yokas, I., L.A. Tuna, B. Burun, H. Altunlu, F. Altan and C. Kaya. 2008. Responses of the tomato (*Lycopersicon esculentum* Mill.) plant to exposure to different salt forms and rates. *Turk. J. Agric. For.,* 32: 319-329.

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