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Screening of Tomatoes for Their Resistance to Salinity and Drought Stress

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Abstract
In the study, 55 tomato genotypes have been investigated for their responses against salinity stresses in 48 day old early plant growth stage. For these purposes, several morphological and physiological measurements and analysis have been done in stressed plants. Shoot and root dry weights, plant height, leaf number, leaf area, relative water content, stomatal conductance, leaf osmotic potential, leaf water potential, shoot K, Ca and Cl concentrations were measured and analyzed. Salt and drought tolerant and sensitive (intolerant) genotypes have been found out according to the responses of the tomato genotypes to the above mentioned morphological and physiological parameters. At the end of the study, the fifty-five tomato genotypes were classified as tolerant, mildly tolerant or susceptible. Shoot dry weight, plant total leaf area, leaf water potential, leaf osmotic potential, stomatal conductance, K, Ca, Na and Cl concentrations in shoot and root, K/Na, Ca/Na, membrane injury index and visual appearance of damages were more relevant parameter for screening studies.
Keywords: Stress, saline, water, tolerance, selection, breeding

1. Introduction

Limited water supply in the Mediterranean region and all over the World is a major problem in irrigated agriculture. The progressive salinization of irrigated agricultural areas threatens the future of agricultural lands. Low rainfall, high evapotranspiration, salt deposits, saline irrigation water and inappropriate irrigation treatments causes "salinity problem" to appear in agricultural areas. Most of the agricultural crops are susceptible and cannot survive under conditions of high salinity and drought, their growth is hindered with decreased yields (Dasgan and Koc, 2009; Kuşvuran, 2012). Salinity reduces the ability of plants to absorb water, becaouse of low water potential around root system causing a reduction in growth rate similar to those caused by water stress. Uptake and accumulate of aboundan salt ions such as Na and Cl are toxic for the plants. These ions can affect other mineral elements uptake through competitive interactions or by affecting the ion selectivity of membranes, which nutrient deficiencies in plants. In the presence of excess NaCl, some nutritional disturbances are expected, resulting in high ratios of Na/Ca and Na/K. Possible reduction of yield in drought can be slowing down of all physiological process (Cabello et al., 2009). Food productivity is decreasing due to the effect of salinity, drought and other various abiotic stresses on crop plants (Mahajan and Tuteja 2005). World population is increasing at an alarming rate and is expected to reach about six billion by the end of year 2050. Selection and breeding of the cultivars that can grow and produce economic yield under the saline and drought conditions are low costing permanent and complementary alternative solutions to minimize their detrimental effects of on crop production (Epstein et al., 1980; Dasgan et al., 2002; Dasgan and Koc, 2009). Genetic variability within a species is a valuable tool for screening and breeding for high salt tolerance. In breeding programs for tolerance to salt stress, large number of genotypes should be considered in screening for a reasonable genetic variation. The availability of genetically based variation is essential for bringing rapid improvement in salinity tolerance of a crop through rapid selection and breeding (Hanif et al., 208). In the present study, 55 tomato genotypes have been screened for their tolerance to NaCl and drought at young plant stage based on some physiological and morphological mechanisms.

2. Materials and Methods

2.1. Plant Culture and growth conditions

Fifty-five tomato genotypes, were used as plant material (Table 1 and 2). Tomato plants were grown under salinity and drought for 27 days. Plants were grown in a growth chamber at 22 / 18ºC and a 16 h photoperiod, 60% relative humidity for 48 d. The amount of photosynthetically active radiation (PAR) received by the upper plant surfaces was 300 mol m^{-2} s^{-1}. Seedlings were transplented into the vermiculite substrate in 2 liters plastic pots. For each genotype, 3 independent plants in one pot were used as one replication and 4 replicates were used. The design of the study was completely randomized. Plants were irrigated by the full strength nutrient solution in ppm concentrations of 177.2 N; 52.70 P; 240.44 K; 53.46 Mg; 120.30 Ca; 3.36 Fe; 0.85 Mn; 0.45 B; 0.50 Zn;

0.10 Cu; 0.05 Mo. The amount of nutrient solution applied in the treatments was determined based on daily measured drainage fraction from the base of the pots (Dasgan et al. 2009). Range of drainage fraction was kept about 20% during the experimental period. The tomato plants were grown without salt and drought up to 3 true leaf stage (21 day old plant). Then, NaCl was added with 50 mM increments on every day until the final concentration of 200 mM. Plants were subjected to the salt during 27 days. Similarly drought stress were performed gradually during 4 days, later on the terminal drought was continued for 27 days. In order to screen tolerant and susceptible tomato genotypes, some physiological measurements and analysis were realized; plant height, leaf number, shoot and root dry weights, leaf area, leaf relative water content, leaf osmotic potential, leaf water potential, stomatal conductance, Na, K, Ca, and Cl concentrations of the shoot samples in salt as previously described (Akhoundnejad, 2011).

2.2. Leaf area

Leaf area was measured 48 days old plants on three plants from each replicate with a LICOR 3100 leaf area meter.

2.3. Stomatal conductance

Stomatal conductance of the youngest fully developed leaves was measured by a Delta-T Devices AP4 Porometer. Measurements were made on three plants in each pot in the morning (10.30–11.30 a.m.) at a steady photon flux density ([300 mol m-2 s-1), while leaf temperature varied between 20-22ºC.

2.4. Relative water content

In order to minimize leaf age effects, samples for relative water content (RWC) were always collected from mid-section of the plant. In per sampling, leaves were weighed and then immediately floated in double distilled water in Petri dishes. Dry weights of discs were then measured after drying at 80_C for 24 h. Relative water content of the discs was calculated as (Kafi and Rahimi, 2011) : where f.wt, d.wt, and t.wt are the leaf fresh, oven dried, and turgid weights, respectively. RWC = (FW-DW)/ (TW-DW)

2.5. Osmotic potential

To determine the osmolality, 1 g of fresh weight from fully expanded leaves were homogenized in a mortar and completed to 20 ml with distilled water. After extract filtration in a millipore, the sap was utilized to determine the osmolality (c) using a freezing point osmometer (Gonotec Osmomat 030, Germany). The osmotic potential was determined using the formula: ψ_s (MPa) = -c (mosmol kg^{-1}) × 2.58 ×10 $^{-3}$, according to the Van't Hoff equation (Silva et al., 2010).

2.6. Leaf water potential (MPa)

It was measured in a pressure chamber, brand Plant Water Status Console, model 3005-1412 (Soilmoisture Equipment Corp., Goleta, California, USA. Measurements were done with the third leaf from the tip of the plants (Kusvuran, 2012).)

2.7. Determination of sodium, potassium, calcium and chlorine in leaf tissue

Leaves and roots were washed once with tap water and twice using deionized water. They were then dried in a forced-air oven at 65 ºC for 48 hours and were ground (40 mesh sieve) for elemental analysis. Ground samples were dry-shed in a muffle furnace at 550 ºC for 6 h. The ash was then dissolved in 0.1 M HCl (hydrochloric acid) solution. K, Ca and Na concentrations were determined using an atomic absorption spectrophotometer (Jones, 2001). Tissue Cl concentration in ground samples was determined according to the titrimetric procedure with silver nitrate.

2.8. Statistical analysis

ANOVA was performed on the data with the Jump program for Windows package.

3. Results and Discussion

Fifty-five tomato genotypes were categorised according to their salt and drought responses in three different groups; tolerant, mild tolerant and susceptible (Table 1 and 2). Among the 55 genotypes 10 genotypes were tolerant to both salinity and drought stresses. These genotypes were AG 2134, SC 2121, 1009-18, 1048-16, FER, *S. pimpinellifolium,* Lignon S2- RHT 9, Lignon S1-RHT 10, TR47882, TR49449. For salinity response, 14 genotypes were tolerant, 31 genotypes were moderate tolerant and 10 genotypes were susceptible. For the drought responses, in the same amount by chance, 14 genotypes were tolerant, 31 genotypes were moderate tolerant and 10 genotypes were susceptible. In order to screen tomatoes for salinity and drought stresses, among the 27 parameters (Table 3) the most relevant ones were shoot dry weight, plant total leaf area, leaf water

potential, leaf osmotic potential, stomatal conductance, K, Ca, Na and Cl concentrations in shoot and root, K/Na, Ca/Na, membrane injury index and visual appearance of damages by scale evaluation (Table 3). Dasgan et al. (2002) reported that visual apperance, Na concentration, K/Na and Ca/Na ratios of the shoot, those are physiological characters determining salinity tolerance, indicate significant importance to estimate the ion selective mechanism of the genotype, however the parameters related shoot and root dry weight of the plants grown saline condition, seem to be independent of salt tolerance at the seedling stage of tomato plant. Kusvuran (2012) suggested that leaf water potential, osmotic potential and stomatal conductance can be used for assessing and screening melon genotypes for their tolerance to salinity and drought stresses during their young plant stage. It might be argued that "Does the early plant stage screening give an idea for the mature plant stage?" The performance of young plants based on the above mentioned physiological parameters under saline and drought stress conditions has been considered enough predictive of the response of the adult plants in field (Qureshi 1990; Akhoundnejad 2011, Dasgan and Akhoundnejad 2012; Dasgan et al., 2012, Suyum et al., 2012; Dasgan et al., 2015a and b).

4. Conclusion

The screening parameters, shoot dry weight, plant total leaf area, leaf water potential, leaf osmotic potential, stomatal conductance, K, Ca, Na and Cl concentrations in shoot and root, K/Na, Ca/Na ratios, membrane injury index, at young plant stage in this study could contribute great effectiveness in reducing the number of genotypes in a feasible time in a large germplasm for future screening works including reproductive stage in the field or greenhouse.

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References

Cabello, M.J., Castellanos, M.T., Romojaro, F., Martinez-Madrid, C. & Ribas, F. (2009). "Yield and quality of melon grown under different irrigation and nitrogen rates", *Agricultural Water Management* **96**, 866–874.

Kusvuran, S. (2012). "Effects of drought and salt stresses on growth, stomatal conductance, leaf water and osmotic potentials of melon genotypes (*Cucumis melo* L.)", *Afr. J. Agric. Res*. **7(5),** 775-781.

Dasgan, H.Y., Kusvuran, S., Aydoner, G., Akyol, M., Akhoundnejad, Y.,Bol, A. &Abak, K. (2012), "Screening for salinity and drought tolerance in melons", *Proceedings of the Xth EUCARPIA meeting on genetics and breeding of Cucurbitaceae,* pages: 497-502.

Suyum, K., Dasgan, H.Y., Sarı, N., Kuşvuran, S., Aydoner, G., Akyol, M., Akhoundnejad, Solmaz, I. & Bol, A. (2012), "Genotypic variation in the response of watermelon genotypes to salinity and drought stresses", *Proceedings of the Xth EUCARPIA meeting on genetics and breeding of Cucurbitaceae,* pages: 392-397.

Dasgan, H.Y., Akhoundnejad, Y., Coban, G., & Kusvuran, S. (2015a), "The physiological parameters to compare for drought between early stage in pot and mature stage in field for melons", *Procedia Environmental Sciences,* **29**: 269.

Dasgan, H.Y., Akhoundnejad, Y., Coban, G., & Kusvuran, S. (2015b), "Comparison of physiological parameters for drought in tomatoes between early stage in pot and mature stage in field", *Procedia Environmental Sciences* **26**, 128-129.

Akhoundnejad Y. (2011). Determination of the field performance of the some selected tomato genotypes against to the drought stres. Cukurova University, Institute of Basic and Applied Sciences. *MSc thesis*, Code no: 4129, page 111

Dasgan HY, Akhounfnejad, Y., Aydoner, G., Bol, A. & Unlu, M. (2012), "Field performans of the some selected melon genotypes against to drought stress", *Proceedings of the 9th National Vegetable Symposium*. Konya-Turkey. 428-432.

Dasgan, H.Y., Aktas, H., Abak, K. & Cakmak, I. (2002), "Determination of screening techniques to salinity tolerance in tomatoes and investigation of genotype responses", *Plant Sci*. **163,** 695-703.

Dasgan H.Y & Koc S. (2009), "Evaluation of salt tolerance in common bean genotypes by ion regulation and searching for screening parameters", *J. Food Agric. & Environ*.**7 (2)**, 363-372.

Kafi, M.&Rahimi, Z. (2011), "Effect of salinity and silicon on root characteristics, growth, waterstatus, proline content and ion accumulation of purslane (*Portulaca oleracea* L.)", *Soil Science and Plant Nutrition* **57**, 341—347.

Jones, JB Jr (2001, "Laboratory guide for conductivity soil tests and plant analysis", CRC Press, Taylor and Francis Group, NW.

Mahajan S.&Tuteja N. (2005), "Cold, salinity and drought stresses: an overview", *Aust. J. Plant Physiol*., **13**, 1–13.

Hanif, M., Noor, E., Murtaza, N., Quayyum, A.&Malik, W. (2008), Assessment of variability for salt tolerance at seedling stage in *Gossypium hirsitum* L",. *J. Food Agric. & Environ*. **6(1)**, 134-137.

Epstein, E., Norlyn, J.D., Rush, D.W., Kingsbury, R.W., Kelly, D.B., Gunningham, G.A.& Wrona, A.F. (1980), "Saline cultures of crops: A genetic approach", *Science* **210**, 399-404.

Silva E.N., Ribeiro R.V., Ferreira-Silva S.L., Viégas R.A.&Silveira J.A.G. (2010), "Comparative effects of salinity and water stress on photosynthesis, water relations and growth of Jatropha curcas plants", *J Arid Environ* **74 (10),** 1130-1137.

Table 1. Salinity response of the tomato genotypes have been determined and classified as 3 levels: tolerantt, mild tolerant and susceptible.

Genotype Code	Tolerant Genotypes	Genotype Code	Mild-Tolerant Genotypes	Genotype Code	Susceptible Genotypes
Tom-1	AG 2134	Tom-4	Invictus	Tom-11	Cambell 37
Tom-2	SC 2121	Tom-5	Pearson	Tom-17	Super G.H.E.S.58
Tom-15	T-2 improved	Tom-6	Rio Fuego	Tom-26	1009-6
Tom-18	Lignon C.19.18	Tom-7	WC 156	Tom-121	Lignon S3 RHT 18
Tom-29	1009-18	Tom-9	Falcon	Tom-123	Marmande
Tom-32	1048-16	Tom-10	H 2274	Tom-139	TR47820
Tom-41	FER	Tom-12	Rio Grande	Tom-151	TR49644
Tom-43	*S. pimpinellifolium*	Tom-14	Cambell 33	Tom-162	TR68513
Tom-115	Lignon S2, RHT 9	Tom-19	Roza (Orijinal)	Tom-163	TR68516
Tom-116	Lignon S1 RHT 10	Tom-22	1071-35	Tom-167	TR61697
Tom-141	TR47882	Tom-24	1071-32		
Tom-150	TR49449	Tom-27	1009-16		
Tom-157	TR48932	Tom-30	1009-9		
Tom-164	TR68517	Tom-31	1048-34		
		Tom-34	1048-27		
		Tom-36	51/2 Nolu Hat		
		Tom-44	*S. Hirsitum*		
		Tom-106	Karaduvar		
		Tom-114	Lignon S5, RHT 8		
		Tom-118	ACE VF 55, RHT 12		
		Tom-120	Birecik Yerli, RHT 17		
		Tom-140	TR47865		
		Tom-143	TR40351		
		Tom-148	TR40397		
		Tom-161	TR55711		
		Tom-165	TR62573		
		Tom-170	TR63233		
		Tom-171	TR66330		
		Tom-174	TR52376		
		Tom-176	TR52414		
		Tom-177	TR52428		

Table 2. Drought response of the tomato genotypes have been determined and classified as 3 levels: tolerant, mild tolerant and susceptible.

Genotype Code	Tolerant Genotypes	Genotype Code	Mild-Tolerant Genotypes	Genotype Code	Susceptible Genotypes
Tom-1	AG 2134	Tom-6	Rio Fuego	Tom-4	Invictus
Tom-2	SC 2121	Tom-9	Falcon	Tom-5	Pearson
Tom-12	Rio Grande	Tom-10	H 2274	Tom-7	WC 156
Tom-19	Roza (Orijinal)	Tom-11	Cambell 37	Tom-14	Cambell 33
Tom-29	1009-18	Tom-15	T-2 improved	Tom-17	Super G.H.E.S.58
Tom-32	1048-16	Tom-22	1071-35	Tom-18	Lignon C.19.18
Tom-41	FER	Tom-24	1071-32	Tom-123	Marmande
Tom-43	*S. pimpinellifolium*	Tom-26	1009-6	Tom-157	TR48932
Tom-44	*S. Hirsitum*	Tom-27	1009-16	Tom-162	TR68513
Tom-114	Lignon S5, RHT 8	Tom-30	1009-9	Tom-163	TR68516
Tom-115	Lignon S2, RHT 9	Tom-31	1048-34		
Tom-116	Lignon S1 RHT 10	Tom-36	51/2 Nolu Hat		
Tom-141	TR47882	Tom-34	1048-27		
Tom-150	TR49449	Tom-106	Karaduvar		
		Tom-118	ACE VF 55, RHT 12		
		Tom-120	Birecik Yerli, RHT 17		
		Tom-121	Lignon S3 RHT 18		
		Tom-139	TR47820		
		Tom-140	TR47865		
		Tom-143	TR40351		
		Tom-148	TR40397		
		Tom-151	TR49644		
		Tom-161	TR55711		
		Tom-164	TR68517		
		Tom-165	TR62573		
		Tom-167	TR61697		
		Tom-170	TR63233		
		Tom-171	TR66330		
		Tom-174	TR52376		
		Tom-176	TR52414		
		Tom-177	TR52428		

Table 3. Physiological parameters of 48 day old tomato plants grown under saline and drought stresses during 27 days.
The data on the table is mean of 55 tomato genotypes.

Screening parameters	Control	Salinity	Drought	Changes in salinity relative to control (%)	Changes in drought relative to control (%)
Plant height (cm)	32.00	24.3	19.01	-24.06	-40.59
Number of leaf (leaf/plant)	12.88	10.53	6.96	-18.25	-45.96
Shoot fresh weight (g/plant)	32.38	24.3	15.7	-24.95	-51.51
Shoot dry weight (g/plant)	3.60	2.85	1.83	-20.83	-49.17
Root fresh weight (g/plant)	19.97	17.82	13.06	-10.77	-34.60
Root dry weight (g/plant)	1.89	1.76	1.52	-6.88	-19.58
SPAD reading	41.23	51.39	51.2	24.64	24.18
Leaf area (cm^2/plant)	652.23	313.61	395.68	-51.92	-39.33
Relative water content (%)	78.49	66.21	59.95	-15.65	-23.62
Leaf water potential (-MPa)	-0.11	-0.16	-0.41	45.45	272.73
Leaf temperature (^oC)	21.27	23.5	23.24	10.48	9.26
Stomatal conductance (mmol $m^{-2}s^{-1}$)	186	139.38	88.82	-25.06	-52.25
Osmotic potential (-MPa)	-0.21	-0.56	-0.26	166.67	23.81
Potassium in shoot (%)	4.45	3.55	4.09	-20.22	-8.09
Potassium in root (%)	2.36	1.98	0.97	-16.10	-58.90
Calcium in shoot (%)	1.50	1.21	1.17	-19.33	-22.00
Calcium in root (%)	0.36	0.28	0.33	-22.22	-8.33
Sodium in shoot (%)*	1.10	3.5	-	218.18	-
Sodium in root (%)*	1.03	2.2	-	113.59	-
Chloride in shoot (%)*	0.84	6.62	-	688.10	-
Chloride in root (%)*	0.47	3.31	-	604.26	-
K/Na ratio in shoot*	4.37	1.07	-	-75.51	-
K/Na ratio in root*	2.8	0.93		-66.79	
Ca/Na ratio in shoot*	1.48	0.36	-	-75.68	-
Ca/Na ratio in root*	0.41	0.13	-	-68.29	-
Membrane injury index (%) **	-	25.5	13.65	-	-
Visual appreance scale***	-	3.05	2.85	-	-

*: Salt treatment only, **: Control included for membrane injury index calculation.
***: Visual appreance scale from 1 to 5 and 1 is the best and 5 is the wors