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Determination of salinity tolerance of some lentil (*Lens culinaris* M.) varieties

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Abstract

The salt (NaCl) tolerance of 5 lentil genotypes was investigated. Plants were grown at 5 different NaCl concentrations. Germination percentage, shoot and root length, shoot and root dry weight and salt tolerance percentage in the shoots and roots were evaluated. The salt tolerance index (STI) of the genotypes, expressed as the ratio of dry matter yield produced under the NaCl treatments compared to the control treatment, was found to be a reliable criterion for ranking genotypes for their tolerance to NaCl. Altın Toprak and Çağıl showed high levels of tolerance, and Yerli Kırmızı and Fırat-87 showed medium levels. Seyran-96 was the most susceptible genotype to NaCl.

Key words: Lentil, *Lens culinaris* M., salinity, NaCl, tolerance.

Introduction

Soil salinity is a major abiotic stress in plant production worldwide. This has led to research into salt tolerance with the aim of improving crop plants or soil reclamation [1]. 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 [2-7].

Due to increasing salinity problems both 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. Rather than a long-term breeding program, the determination of more tolerant varieties to grow in saline soils may be a short-term solution [8, 9].

Lentil (*Lens culinaris* M.) is considered a strategic crop under agronomic and food point of view, because of its role as possible component of the cropping systems in the Mediterranean areas and as a protein source for human and animal consumption [10-12]. The species is classified as salt sensitive [13] like many other leguminous crops. Selection for salinity resistance appears as a laborious and hazardous task and plant breeders are, therefore, seeking for quick, cheap and reliable ways to assess the salt-resistance of selected material. Determination of germination potential of seeds in saline conditions could appear as a simple and useful parameter for several reasons [14].

The research on varieties started with cool-season grain legumes: lentil (*Lens culinaris* M.), chickpea (*Cicer arietinum* L.) and faba bean (*Vicia faba*). These crops show little genetic diversity to salt tolerance, and therefore no information is available on varietal difference in salt tolerance [15]. Greenhouse experiments with nutrient solutions cannot be generalized to field conditions as was shown in a previous paper on lentils [12]. Grain legumes have multiple functions in the traditional farming systems as a source of human and animal food, and in the maintenance of soil fertility, particularly in dry rainfed areas [16]. Since grain legumes are salt sensitive, farmers do not consider growing them in a saline environment.

The first crop was lentil, for which no information on salt tolerance was available in literature. Lentil appeared to be very salt sensitive. At an EC_e of 2 dS/m, the yield reduction was about 20% and at an EC_e of 3 dS/m, 90–100%. The variety with the largest leaf area gave the highest yield. This crop should not even be grown under slightly saline conditions [12].

In this study, the effects of different NaCl concentration on seed germination and seedling growth of five lentil genotypes were studied.

Materials and Methods

Five lentil genotypes (Yerli Kırmızı, Seyran-96, Fırat-87, Altın Toprak and Çağıl) were grown in laboratory at the Cukurova University, Agriculture Faculty, Field Crops Department in Adana. In this study, distilled water (control) and four salt (NaCl) concentrations, 50, 100, 150 and 200 mg l^{-1}, were used.

Germination conditions: Seeds of each lentil genotype used in the experiment were surface-sterilized. Twenty five representative seeds per cultivar were placed on a filter paper in 9 cm Petri dish containing 3 cm^3 of distilled water (control) or 50, 100, 150 and 200 mg l^{-1} NaCl. The Petri dishes were hermetically sealed with Parafilm to prevent evaporation and then carefully kept in a humidity chamber at a temperature of 25±1°C under 8-h day length. The seeds were considered germinated when there was radicle protrusion through the seed coat.

Traits measured:

Germination percentage: Seven days after seeds were put into the Petri dishes, germinated seeds were counted and the germination percentage was calculated. Then 5 seedlings were left in each Petri dish to be evaluated for other traits.

Shoot and root length: Fifteen days after planting, the plants were separated into shoots and roots. The distances from crown to leaf tip and root tip were measured as shoot length and root length, respectively. The mean values in each replication were used for statistical analysis.

Shoot and root dry weight: The roots and shoots of plants in each replication were dried at 70°C until a constant weight was reached. Then root and shoot dry weights were measured and the dry weight of root and shoot per plant was calculated by dividing the total weight by the number of plants.

Shoot/root ratio was calculated for both length and weight by dividing shoot values by root values.
Salt tolerance index was calculated as total plant (shoot + root) dry weight obtained from 5 seeds grown on different salt concentrations compared to total plant dry weight obtained on normal concentration {[STI = (TDW at S_x/TDW at S_1) x 100], STI = salt tolerance index, TDW = total dry weight, S_1 = control treatment, S_x = x treatment} [8].

Experimental design and statistical analysis: The experimental design was a split plot with 4 replications; genotypes in the main plots and salt concentrations in the sub-plots. Data were analyzed SAS packet program.

Results

Germination percentage: Germination percentages declined with 150 and 200 mg l^{-1} NaCl treatments. At these NaCl concentrations, differences among the genotypes were significant. Yerli Kırmızı and Çağıl had germination percentage higher than 60% even with the 150 mg l^{-1} NaCl treatment, while only Seyran-96 had lower germination percentage with the same NaCl treatment. The germination percentage of Seyran-96 was also low with the 150 mg l^{-1} treatment. These results showed that 150 and 200 mg l^{-1} treatments can be used effectively to identify moderately and highly resistant genotypes, respectively (Table 1, Fig. 1).

Shoot and root length and shoot/root ratio: There were significant differences between genotypes in terms of shoot and root lengths. Increasing NaCl treatments resulted in a significant decrease in shoot elongation. Compared to the control (distilled water) plants, longer root lengths were recorded at higher salt concentrations except with the 200 mg l^{-1} treatment (Table 2). The shoot/root ratio of the more salt tolerant genotypes was 1.39-2.03 at the highest NaCl concentration. The decrease in root elongation starting from the 50 mg l^{-1} treatment was considered

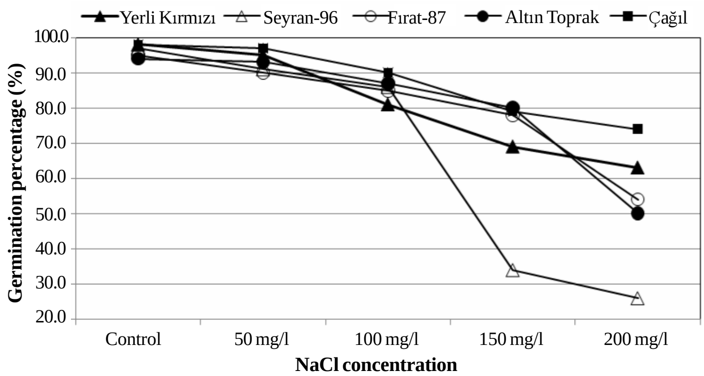

Figure 1. Germination percentage of 5 lentil genotypes in different salt concentrations.

Table 1. Germination percentage of 5 lentil genotypes germinated under different NaCl treatments.

	Germination percentage (%)				
Genotype	Control	50 mg l^{-1}	100 mg l^{-1}	150 mg l^{-1}	200 mg l^{-1}
Yerli Kırmızı	98.0	95.0	81.0	69.0	63.0
Seyran-96	97.0	91.0	86.0	34.0	26.0
Fırat-87	95.0	90.0	85.0	78.0	54.0
Altın Toprak	94.0	93.0	87.0	80.0	50.0
Çağıl	98.0	97.0	90.0	79.0	74.0
Mean	96.4	93.2	85.8	68.0	53.4
LSD	N.S.	N.S.	N.S.	22.10**	33.25**

*significant at P = 0.05 level; ** significant at P= 0.01 level; N.S.= Not significant.

Table 2. Shoot and root lengths and shoot/root ratios of 5 lentil genotypes grown with different NaCl treatments for 15 days.

	Control			50 mg l^{-1}			100 mg l^{-1}			150 mg l^{-1}			200 mg l^{-1}		
Genotype	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R
								(mm)							
Yerli Kırmızı	70.05	78.45	0.92	62.10	49.95	1.25	44.35	36.55	1.30	35.50	16.05	2.22	16.20	11.90	1.39
Seyran-96	50.65	49.90	1.24	35.90	37.70	1.05	33.55	28.25	1.22	11.95	10.00	1.20	9.40	9.95	0.97
Fırat-87	74.70	67.05	1.12	51.45	62.80	0.82	36.55	40.60	1.02	25.00	16.90	1.48	18.80	11.80	1.59
Altın Toprak	55.25	49.30	1.13	52.20	44.05	1.28	36.25	29.15	1.26	24.35	14.55	1.68	20.75	10.15	2.03
Çağıl	60.50	70.25	0.86	56.75	57.60	1.01	42.15	53.95	0.78	30.20	19.90	1.54	15.20	11.10	1.39
Mean	61.44	62.99	1.05	51.68	50.4	1.08	38.57	37.70	1.12	25.40	15.48	1.62	16.07	10.98	1.48
LSD(1%)	11.9**	28.8*	N.S.	16.0**	21.6*	N.S.	7.9**	23.1*	0.5*	13.4**	5.7**	0.8**	7.0**	N.S.	0.5**

*significant at P = 0.05 level; ** significant at P = 0.01 level; N.S. = Not significant.

an indicator that root growth was affected more quickly compared with the shoots.

Shoot and root weight and shoot/root ratio: Similar to the shoot elongation, shoot weight also decreased, starting from the 50 mg l^{-1} treatment. In accordance with the root elongation, average root dry matter production was significantly higher with the 50 and 100 mg l^{-1} treatments compared with 150 and 200 mg l^{-1} but was dramatically decreased by the 200 mg l^{-1} treatment. The average shoot/root ratio was 1.34 with control and gradually decreased to 1.20 and 1.17 with 50 and 100 mg l^{-1} NaCl treatments, respectively. The average shoot/root ratio was increased to 1.27 and 1.35 with 150 and 200 mg l^{-1} NaCl treatments, respectively (Table 3).

Salt tolerance index: Although genotypes responded similarly during the first 3 salt treatments, significant differences among the genotypes were obvious with the 150 and 200 mg l^{-1} treatments, concerning the salt tolerance index of genotypes (Table 4). The salt tolerance index varied between 9 and 37% with 150 mg l^{-1} and between 7 and 23% with 200 mg l^{-1}. Çağıl (23%) and Altın Toprak (20%) were the best performing genotypes with the 200 mg l^{-1} treatment; the other genotypes did not perform well, their salt tolerance indices ranged from 7 to 15%. The tolerance indices of genotypes with lower performances than Altın Toprak and Çağıl, except for Seyran-96, were above 20% with the 150 mg l^{-1} treatment. Among these, with the 200 mg l^{-1} treatment, Yerli Kırmızı and Fırat-87 resulted in lower indices (15%), and so these genotypes were evaluated as moderately tolerant. Seyran-96 resulted in the lowest indices (7%) and was evaluated as the least tolerant genotype.

Discussion

The results obtained in this study are consistent with previous findings that have indicated significant differences in the salt tolerance of lentil genotypes and their different responses to increasing salt concentrations [3, 8, 12, 14, 15]. Even though salt tolerance during germination differs from that at later stages of plant development [17, 18], good germination under saline conditions is essential because it is the first stage of plant growth. From this perspective, it is clear that Yerli Kırmızı and Çağıl with high germination percentages would have more advantages than the other genotypes that significantly lost their ability to germinate better.

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. When length and dry weight are considered as selection criteria, we advise that dry weight is 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 a more reliable selection criterion in this study.

Lentil is considered a very sensitive species to salinity, much more than other legumes such as broadbean and soybean [14]. However, there were variations between lentil genotypes in regard to STI under saline conditions. The highest STI at higher salt level (200 mg l^{-1}) was given by 'Çağıl' and the lowest belonged to 'Seyran-96'. It appears that the lentil genotypes Çağıl and Altın Toprak can perform well on saline treatments. These genotypes could be utilized not only in breeding programs to improve the saline resistance of the species but they could also be cultivated in environments where salinity of the soils is a frequent constraint.

Table 3. Shoot and root dry matter production and shoot/root ratios of 5 lentil genotypes grown with different NaCl treatments for 15 days.

	Control			50 mg l^{-1}			100 mg l^{-1}			150 mg l^{-1}			200 mg l^{-1}		
Genotype	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R
							(mg $plant^{-1}$)								
Yerli Kırmızı	8.01	5.44	1.48	5.78	6.31	0.92	4.49	5.25	0.89	2.57	2.12	1.20	1.81	1.33	1.39
Seyran-96	5.98	4.80	1.32	4.89	4.20	1.21	4.08	4.06	1.02	1.42	1.41	1.02	1.39	1.37	1.03
Fırat-87	8.00	6.08	1.37	7.33	5.39	1.37	3.58	2.48	1.44	2.43	1.64	1.53	2.41	1.37	1.75
Altın Toprak	5.88	4.02	1.43	5.67	4.00	1.48	4.05	3.00	1.37	2.59	1.73	1.48	2.27	1.48	1.56
Çağıl	7.56	7.01	1.10	6.77	6.53	1.04	5.48	4.91	1.12	2.94	2.62	1.12	2.24	2.15	1.04
Mean	7.09	5.47	1.34	6.09	5.29	1.20	4.34	3.94	1.17	2.39	1.90	1.27	2.02	1.54	1.35
LSD(1%)	1.6**	2.3*	N.S.	1.9**	2.1**	0.4**	1.1**	1.7**	1.0**	1.1**	0.7**	0.4**	0.7**	N.S.	0.5**

*significant at P = 0.05 level; ** significant at P = 0.01 level; N.S .= Not significant.

Table 4. The mean total (shoot and root) dry weight (TDW) and salt tolerance index (STI) values of 5 lentil genotypes grown with different NaCl treatments.

	TDW (mg)					STI (%)				
Genotype	Control	50 mg l^{-1}	100 mg l^{-1}	150 mg l^{-1}	200 mg l^{-1}	Control	50 mg l^{-1}	100 mg l^{-1}	150 mg l^{-1}	200 mg l^{-1}
Y.Kırmızı	13.18	11.49	7.89	3.24	1.97	100	87	60	25	15
Seyran-96	10.46	8.27	7.00	0.96	0.72	100	79	67	9	7
Fırat-87	13.38	11.45	5.15	3.17	2.04	100	86	39	24	15
A.Toprak	9.31	8.99	6.13	3.46	1.88	100	97	66	37	20
Çağıl	14.28	12.90	9.35	4.39	3.25	100	90	65	31	23
Mean	12.12	10.62	7.11	3.04	1.97	100	88	59	25	16
LSD(1%)	3.5**	3.1*	2.5**	1.6**	1.0*	N.S.	N.S.	22.3*	14.2**	9.3*

*significant at P = 0.05 level; ** significant at P = 0.01 level; N.S. = Not significant.

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