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Response of some chickpea (*Cicer arietinum* L.) genotypes to salt stress conditions

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Abstract

The salt (NaCl) tolerance of 5 chickpea genotypes was investigated. Plants were grown in 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. İnci, Aydın-92 and FLIP 98-55C showed high levels of tolerance and İzmir-92 medium levels. FLIP 98-63C was the most susceptible genotypes to NaCl.

Key words: Chickpea (*Cicer arietinum* L.), salinity, NaCl, tolerance.

Introduction

Soil salinity predates human civilization and is probably a cause of the breakdown of the ancient Sumerian civilization [1]. Today salinity remains a major abiotic stress that adversely affects crop productivity and quality [2]. Salinity affects about 6% of the world's land area, much of which is important to agriculture. Over 800 million ha of land throughout the world are salt-affected either by salinity or by the associated condition of sodicity [3]. Most of this salinity, and all of the sodicity, is natural. However, a significant proportion of recently cultivated agricultural land has become saline due to clearing of natural vegetation or irrigation. Of the current 230 million ha of irrigated land, 45 million ha are salt affected [3].

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 also 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 [4, 5].

Chickpea was domesticated in association with other crops of wheat, barley, rye, peas, lentil, flax and vetch [6, 7], and with sheep, goats, pigs and cattle [8], as part of the evolution of agriculture in the Fertile Crescent 12,000–10,000 years ago [9, 10].

Chickpea is a cool season crop mostly grown in the semi-arid regions of the world. In these regions salinity is one of the major constraints for yield production [11-14]. Breeding for salinity tolerance is the most economic and environmentally acceptable option to improve chickpea production on saline soils [15-18].

Numerous studies have been conducted on the management and identification of saline tolerant crops such as cotton or cereals [19-21]. Limited attention has been given to legumes and forages, which are known to have low tolerance to salinity. As for most legumes, germination of chickpea is relatively less affected by salinity than subsequent seedling growth [22]. Kumar [23] also indicated that later stages of chickpea growth were more sensitive than earlier stages. The sensitivity of all chickpea genotypes increases with plant growth and greater salinity [16, 24, 25]. Over the years a large number of legume germplasm accessions have been screened for salt tolerance including chickpea [16, 26], *Vicia faba* L.[27], *Phaseolus acutifolius* A. Gray [28] and *P. vulgaris* L. [29]. However, few salt-tolerant genotypes were identified. Preliminary screening of 211 chickpea accessions (mini-core collection) [30] and another of 143 accessions of *P. vulgaris* landraces from diverse geographical sources and wild relatives [31] resulted in the identification of presumptively more salt tolerant genotypes. In the case of chickpea, a comparison of sampling strategies based on geographical sources, to our knowledge, has not been done. Identification of a large number of salt tolerant accessions will provide a wide genetic variability to ensure a better chance of breeding salt tolerant chickpea varieties. 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 [32].

The objective of the present study was to determine the effects of different NaCl concentration on seed germination and seedling growth of five chickpea genotypes.

Materials and Methods

Five chickpea genotypes (İnci, İzmir-92, Aydın-92, FLIP 98-63C and FLIP 98-55C) were grown in laboratory at the Çukurova 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 chickpea genotype used in the experiment were surface-sterilized. Twenty five representative seeds per cultivar were placed on a filter paper in 9 cm Petri dishes 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 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: Of each chickpea genotypes 25 seeds were placed in Petri dishes for germinating the seeds. Germinated seeds were counted after seven days of putting seeds in the Petri dishes, and germination percentage was calculated. Seedlings were discarded from the Petri dishes and only 5 seedlings were left in for studying the further characteristics.

Shoot and root length: The 5 remaining seedlings in each Petri dishes were used for measuring the shoot and root characteristics. After 15 days of putting seeds in the Petri dishes, the seedlings were separated into roots and shoots. The distances from crown to leaf tip and root tip were measured as shoot length and root length, respectively.

Shoot and root dry weight: The root and shoot weights of each seedling were measured by drying the roots and shoots at 70°C. The drying process continued untill the constant weight was obtained. The average dry weights of root and shoot of each plant seedling were measured by divividing the total weight by total number of seedlings.

Shoot/root ratio: This was calculated for both length and weight by dividing shoot values by root values.

Salt tolerance index: Sal tolerance index is the ratio of total dry weight at control treatment and dry weight at salt concentration. Salt tolerance index was calculated from the following formula [4]: STI = (TDW at S_x / TDW at S_1) x 100], where STI is salt tolerance index, TDW is mean of total dry weight, S_1 refers control treatment and S_x for x treatment.

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 by SAS packet program.

Results

Germination percentage: By using 150 and 200 mg l^{-1} NaCl treatments reduced germination percentages. During these concentrations, differences among the genotypes were significant. İnci and FLIP 98-55C had germination percentages higher than 60% even with the 150 mg l^{-1} NaCl treatment, yet only FLIP 98-63C had lower germination percentages with the same NaCl treatment. The germination percentage of FLIP 98-63C 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).

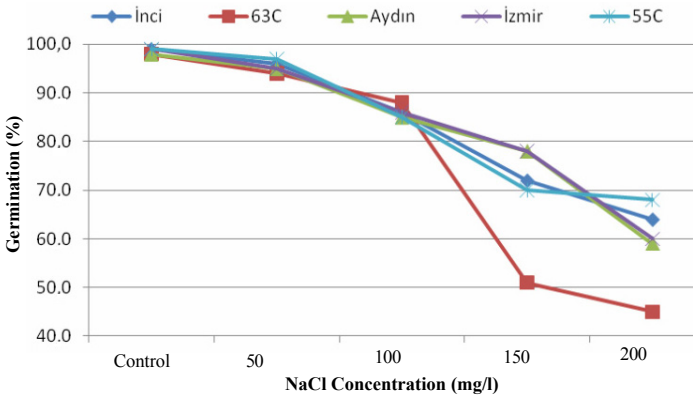

Figure 1. Germination percentage of 5 chickpea genotypes in different salt concentrations.

Shoot and root length and shoot/root ratio: When shoot and root lengths are taken into consideration, there were important differences between genotypes. A significant decrease in shoot elongation was observed resulting from increasing NaCl treatments. Longer root lengths were recorded at higher salt concentrations except with 200 mg l^{-1} treatment (Table 2), when compared to the control (distilled water) plants. The shoot/root ratio of the salt tolerant genotypes was 0.90-1.26 at the highest NaCl concentration. The decrease in root elongation starting from the 50 mg l^{-1} treatment was considered as an indicator that root growth was affected more quickly compared with the shoots.

Shoot and root weight and shoot/root ratio: Starting from the 50 mg l^{-1} treatment, the weight of shoot also decreased, which is smilar to the shoot elongation. In accord with the root elongation, with the 50 and 100 mg l^{-1} treatments, average root dry matter production was significantly higher with the 50 and 100 mg l^{-1} treatments when compared with 150 and 200 mg l^{-1}. However, it was dramatically decreased by the 200 mg l^{-1} treatment. After the shoot/root ratio was controlled, it was 1.08 and it gradually decreased to 1.06 with 50 mg l^{-1} NaCl treatments. Then, the average shoot/root ratio was increased to 1.09 and 1.10 with 100 and 150 mg l^{-1} NaCl treatments, respectively. Finally, again average shoot/root ratio was decreased to 1.06 with 200 mg l^{-1} NaCl treatment (Table 3).

Salt tolerance index: In spite of the similar responses of genotypes during the first 3 salt treatments, it was obvious to see differences among the genotypes with the 150 and 200 mg l^{-1} treatments, regarding the salt tolerance index of genotypes (Table 4). The salt tolerance index differed between 20.3 and 32.0% with 150 mg l^{-1} and 16.7 and 25.0% with 200 mg l^{-1}. Although the best performing genotypes with the 200 mg l^{-1} treatment were İnci (25%), Aydın-92 (23.7%) and FLIP 98-55C (23.7%), the other genotypes did not perform well - their salt tolerance indices ranged from 16.7% to 19.0%. The tolerance indices of genotypes with lower performances than İnci, Aydın-92 and FLIP 98-55C were above 30% with the 150 mg l^{-1} treatment, except for FLIP 98-63C. Among these, with the 200 mg l^{-1} treatment, İzmir-92 resulted in lower indices (19.0%), and so this genotype was evaluated as moderately tolerant. FLIP 98-63C caused the lowest index (16.7%), and was evaluated as the least tolerant genotype.

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

	Germination Percentage (%)				
Genotypes	Control	50 mg l^{-1}	100 mg l^{-1}	150 mg l^{-1}	200 mg l^{-1}
İnci	99.0	96.0	86.0	72.0	64.0
İzmir-92	99.0	95.0	86.0	78.0	60.0
Aydın-92	98.0	95.0	85.0	78.0	59.0
FLIP 98-63C	98.0	94.0	88.0	51.0	45.0
FLIP 98-55C	99.0	97.0	85.0	70.0	68.0
Mean	98.6	95.4	86.0	69.8	59.2
LSD =	N.S.	N.S.	N.S.	13.57**	14.05*

*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 chickpea 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}		
Genotypes	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R
								(mm)							
İnci	110.98	106.88	1.04	99.45	96.58	1.04	90.48	89.15	1.02	74.48	76.25	0.98	54.03	48.83	1.12
İzmir-92	112.43	101.35	1.11	97.38	86.18	1.13	71.25	65.75	1.12	61.23	51.78	1.21	46.73	38.13	1.26
Aydın-92	114.10	99.48	1.15	98.95	90.98	1.09	80.23	76.90	1.05	68.13	62.68	1.10	51.83	44.88	1.16
FLIP98-63(	109.90	101.08	1.09	102.60	100.08	1.03	80.75	75.55	1.07	79.05	66.50	1.21	40.78	45.25	0.90
FLIP98-55(	110.70	100.88	1.09	102.38	92.78	1.11	76.43	70.53	1.08	59.95	49.18	1.24	40.23	35.00	1.18
Mean	111.62	101.93	1.10	100.15	93.32	1.08	79.83	75.58	1.07	68.57	61.28	1.14	46.72	42.42	1.12
LSD =	N.S.	N.S.	0.09*	N.S.	11.46*	0.12*	12.5*	14.38*	N.S.	11.88*	17.22**	0.24*	N.S.	11.87*	0.33*

*Significant at P= 0,05 level; ** significant at P= 0,01 level; N,S,= Not significant.

Table 3. Shoot and root dry matter production and shoot/root ratios of 5 chickpea 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}		
Genotypes	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R	Shoot	Root	S/R
								(mg $plant^{-1}$)							
İnci	21.98	20.63	1.07	15.76	14.64	1.07	13.14	11.48	1.17	9.47	8.75	1.09	8.75	7.94	1.11
İzmir-92	22.91	21.63	1.07	18.73	18.34	1.02	8.71	8.70	1.00	8.60	7.63	1.15	6.98	6.95	1.01
Aydın-92	20.57	18.82	1.10	16.83	15.59	1.08	11.26	11.43	0.99	8.56	7.50	1.14	8.23	7.49	1.10
FLIP98-63C	22.00	20.34	1.08	16.24	15.41	1.06	13.40	11.60	1.17	8.75	8.20	1.07	8.17	7.51	1.09
FLIP98-55C	22.66	21.43	1.06	15.65	15.14	1.04	14.11	12.94	1.10	9.03	8.85	1.03	7.61	7.50	1.01
Mean	22.02	20.57	1.08	16.64	15.82	1.06	12.12	11.23	1.09	8.88	8.18	1.10	7.95	7.48	1.06
LSD =	N.S.	N.S.	N.S.	N.S.	3.27*	N.S.	3.50*	3.56*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*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 chickpea of 5 genotypes grown with different NaCl treatments.

Genotypes	TDW (mg)				STI (%)			
	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}
İnci	42.18	30.43	24.63	18.25	16.68	100	69.6	50.1	30.7	25.0
İzmir-92	44.09	37.07	17.43	16.23	13.93	100	79.9	33.9	28.5	19.0
Aydın-92	38.60	32.43	22.70	16.05	15.70	100	78.4	49.2	32.0	23.7
FLIP98-63C	41.49	31.65	25.03	16.95	15.68	100	71.0	52.4	20.3	16.7
FLIP98-55C	43.65	30.80	27.05	17.88	15.13	100	67.9	52.5	28.7	23.7
Mean	42.00	32.48	23.37	17.07	15.42	100	73.3	47.6*	28.0	21.6
LSD =	N.S.	6.64*	6.87*	N.S.	N.S.	N.S.	N.S.	17.17*	6.81*	7.98

*Significant at P= 0,05 level; ** significant at P= 0,01 level; N.S.= Not significant.

Discussion

In this study salt tolerance of different chickpea genotypes was measured. There was significant difference in the response of chickpea genotypes to the applied concentration of NaCl. The results obtained in this study are also consistent with previous findings that have indicated significant differences in the salt tolerance of chickpea genotypes and different responses to increasing salt concentrations [4, 32-3 4]. Even though salt tolerance during germination differs from that at later stages of plant development [35, 36], good germination under saline conditions is essential because it is the first stage of plant growth. From this perspective, it is clear that İnci and FLIP 98-55C 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 more effective parameter as a 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. FLIP 89–57C (drought-tolerant) senesced and flowered earlier, whereas ILC 3279 (drought-sensitive) responded differently with new leaf growth and flowers and a delay in senescence[34]. Salinity reduces plant height, leaf number, leaf, stem and root dry weights, and seed emergence [37, 38]. There were reductions in fresh and dry weights of leaves and roots in a range of genotypes treated with 40 mol/m^3 NaCl [39].

There were variations between chickpea genotypes in regard to STI under saline conditions. The highest STI at higher salt level (200 mg l^{-1}) was given by 'İnci' and the lowest belonged to 'FLIP 98-63C'. It appears that the chickpea genotypes İnci, Aydın-92 and FLIP 98-55C can perform well under saline conditions. Genotypes CSG 8977, CSG 8962 and CSG 8943 had the best yield under saline conditions [40]. Genotypic variation for salinity tolerance was attributed to differences in uptake and distribution of sodium and chloride ions [40].

Chickpea is usually cultivated in dry and semidry regions. However, in some parts of the world, it is also grown under irrigation condition. Due to this reason, the salinity is the main problem concerned with chickpea cultivation in dry and semidry as well as in irrigated areas. Although chickpea is less resistant to salinity compared to cereals, it is more more resistant among the other edible pulses. Therefore, chickpea could be included as a preferable pulse in crop rotations program in salin areas.

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