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SHORT RESEARCH ARTICLE

Assessing the effect of salinity stress on root and shoot physiology of chickpea genotypes using hydroponic technique

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Abstract

A study was conducted in chickpea under hydroponics using best available water or saline water of EC_{iw} 9 dS m^{-1} to assess the salt tolerance at early seedling stage. As compared to control a less than 25 % reduction in root length was observed in the genotype, CSG 8962, BG 1103, S7, ICCV 10, KWR 108 and JG 16 whereas ICC4463 showed maximum reduction (60.67%) under salinity. These genotypes also showed more proline, low Na^+/K^+ ratio and greater root and shoot water potential which might impart tolerance against salinity. Greater than 75% salt tolerance index was also shown by these genotypes. Stress tolerance index was found positively correlated with higher root length, higher proline accumulation, low Na^+/K^+ ratio and higher root/shoot water potential. The genotypes, S7, KWR 108, JG-16, CSG 8962 and ICCV10 have the potential to perform satisfactorily under salt stress and can be used for future chickpea breeding programme.

Keywords: Chickpea, hydroponic technique, Na^+/K^+, root length suppression, salinity

Introduction

Chickpea (*Cicer arietinum* L.) is an important pulse crop and salinity badly strikes the quality and quantity of chickpea grains (Kaur et al. 2021). The response of chickpea genotypes towards salinity varies with respect to the stage of the plant and the duration of salinity along with genotypic and environmental variations. The present work was focused to evaluate the chickpea genotypes at seedling stage for salt tolerance in hydroponics. Plant roots are the first organ that senses the salinity first due to its direct contact with the salt environment. The present investigation was carried out to study the morphological and physiological changes induced by salinity on chickpea root and shoot traits.

Ten chickpea genotypes namely, CSG 8962, BG 1103, S7, DCP 92-3, ICCV 10, KWR 108, BG 256, K 850, JG 16, ICC 4463 were chosen for the study using hydroponic culture technique at ICAR-Central Soil Salinity Research Institute, Karnal during 2020. Pre-germinated seeds were shifted on the seed holding trays floating in the water tanks containing best available water with the desired proportions of nutrient solution. After 7 days of growth period, seedlings were exposed to salinity by shifting them to a tank containing water of EC_{iw} 9 dS m^{-1} keeping the control in the best available water. Length, fresh and dry weight was measured after 15 days of saline treatments. Chlorophyll content was measured in leaves and physiological traits *viz.*, water potential, osmotic potential, proline content and ion analysis were measured in root and shoot. SAS software (Version 9.3, SAS Institute Inc., USA) was used for statistical data analysis. Mean differences were compared at 5% probability level using TUKEY's Honest Significant Test and Pearson's correlation analysis was done using PAST software (version 4.03).

The results showed that salinity reduced the length of root/shoot of the genotypes when compared with respective controls (Fig. 1). Decline in root-shoot length might be due to arrested cell growth and limited nutrient availability because salinized plants first experience osmotic stress which limits water uptake, cell expansion and later ion toxicity finally creating nutrient imbalance (Kumar et al. 2019). Fresh and dry weight of root and shoot also showed decreasing trend (Table 1). Reduction in the fresh/dry weight is a common phenomenon due to the disturbances in physiological and metabolic activities of the plants. The reduction in the shoot fresh and dry weight may be due to decreased leaves number and leaf area as reported earlier (Buttar et al. 2021; Kumar 1 et al. 2020). Salinity induced reduced water uptake and increasing solute concentration in the root zone leads to declined water potential (ψ_w) and osmotic potential (ψ_s). Higher WP and OP were recorded in shoots than roots (Table 2). Lowering of WP in root and shoots might be due to enhanced accumulation of toxic ions i.e., Na^+ and Cl^- which interferes with other physiological and biochemical attributes (Soni et al. 2021) and increase in the values of osmotic potential (ψ_s) might be related to the tolerance ability of genotypes to adjust physiological drought conditions caused by salinity to maintain pressure potential and to absorb more water from the rhizosphere. Significant variability (p<0.001) was noted among the chickpea genotypes for chlorophyll content (Fig. 2). Salinity stress reduced the chlorophyll content by 12.21%, with minimum reduction in genotype CSG 8962 (5.36%) followed by JG 16 (5.60%) and KWR 108 (6.32%), whereas maximum reduction was noted in ICC 4463 (35.54%). Salt toxicity resulted in the burning of chickpea leaves and authors suggested that salinity might have degraded many pigments contained within the plant including chlorophyll (Mann et al. 2019). Significant variability's (p<0.001) were noted for proline accumulation among genotypes. Higher accumulation of proline was observed in shoots (124.42 and 270.25 µg g^{-1}) than roots (109.78 and 160.06 µg g^{-1}) under control as well as stress conditions, respectively (Table 3). Proline is an osmoprotectant, an antioxidant, a cell compartment stabilizer and in any one way it might have helped the chickpea plants to combat with the stressful atmosphere created by salinity (Sanwal et al. 2018; Sanwal et al. 2021; Khamesi et al. 2020). It was noted that roots had the higher Na^+/K^+ values than shoots (Table 3). Roots Na^+/K^+ was 0.40 under control and 0.87 under salinity stress with maximum in JG 16 and ICC 4463 (0.50) under control conditions and under salinity conditions in ICC 4463 (1.35) (Table 3). In shoot (Table 3), no significant variability in Na^+/K^+ was seen under

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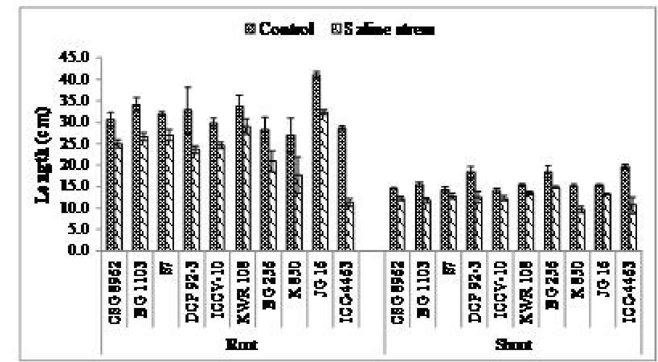

Fig. 1. Effect of saline water irrigation (ECiw–9 dS m^{-1}) on root and shoot length (cm)

Table 1. Effect of saline water (EC_{iw}-9 dS m^{-1}) on morphological traits of chickpea genotypes

Genotypes	Root fresh weight (mg)		Root dry weight (mg)		Shoot fresh weight (mg)		Shoot dry weight (mg)	
	Control	EC_{iw}–9 dS m^{-1}	Control	EC_{iw}–9 dS m^{-1}	Control	EC_{iw}–9dS m^{-1}	Control	EC_{iw}–9 dS m^{-1}
CSG 8962	428.90	340.67	42.67	35.33	597.20	476.60	74.33	57.00
BG 1103	757.20	512.33	71.67	50.33	883.50	685.67	107.00	72.67
S7	761.00	583.67	71.00	55.00	811.17	685.71	103.67	82.00
DCP 92-3	569.11	342.17	50.67	33.33	711.53	467.68	70.33	47.00
ICCV 10	480.90	362.07	45.00	34.33	429.07	349.73	47.33	36.67
KWR 108	688.50	548.67	68.33	52.33	701.05	582.67	77.33	60.33
BG 256	601.10	417.10	59.33	40.00	808.80	563.00	86.00	61.33
K 850	382.67	266.33	42.33	28.33	664.83	405.23	67.67	40.33
JG 16	479.83	372.67	47.33	38.67	586.30	467.57	62.67	49.00
ICC 4463	395.67	134.56	37.33	17.00	576.33	243.67	63.67	30.00
G.M.	554.49^A	388.02^B	53.57^A	38.47^B	676.98^A	492.75^B	76^A	53.63^B
CV (T)	13.53		8.30		12.69		14.84	
CV (G)	6.24		6.24		7.16		7.08	
LSD (T)	70.82		4.24		82.40		10.68	
LSD (G)	57.19		5.58		81.42		8.93	
LSD (T × G)	103.66		8.56		135.96		15.94	

Means with at least one letter common are not statistically significant (p<0.05) using TukeysTest, G.M. = General mean

Table 2. Effect of saline water (EC_{iw}-9 dS m^{-1}) on water potential and osmotic potential of chickpea genotypes

Genotypes	Water potential (-MPa)				Osmotic potential (mmol/kg)			
	Root		Shoot		Root		Shoot	
	Control	EC_{iw}–9 dS m^{-1}	Control	EC_{iw}–9 dS m^{-1}	Control	EC_{iw}–9dS m^{-1}	Control	EC_{iw}–9 dS m^{-1}
CSG 8962	0.72	1.10	1.06	2.60	324.33	487.33	427.33	606.00
BG 1103	0.73	1.28	0.84	2.88	313.00	533.67	435.00	660.67
S7	0.77	1.18	0.89	2.84	368.67	520.67	458.67	618.00
DCP 92-3	0.97	1.45	1.13	3.65	321.33	527.33	433.00	692.67
ICCV 10	0.71	1.18	1.48	2.59	353.00	538.67	445.33	623.00
KWR 108	0.68	0.85	0.80	2.46	316.00	477.33	452.00	554.33
BG 256	1.04	1.14	1.07	3.53	324.00	517.33	449.67	657.00
K 850	0.87	1.28	0.99	3.52	299.00	405.00	409.67	665.00
JG 16	0.63	0.66	0.81	2.76	326.33	419.33	414.33	567.67
ICC 4463	0.86	1.22	1.20	3.93	262.00	439.33	395.00	637.00
G.M.	0.8^B	1.13^A	1.03^B	3.07^A	320.77^B	486.6^A	432^B	628.13^A
CV (T)	9.30		6.05		4.22		1.99	
CV (G)	6.71		3.99		4.90		2.40	
LSD (T)	0.10		0.14		18.91		11.68	
LSD (G)	0.13		0.16		38.45		24.77	
LSD (T × G)	0.20		0.25		54.80		35.14	

Means with at least one letter common are not statistically significant (p<0.05) using Tukeys Test, G.M.=General mean

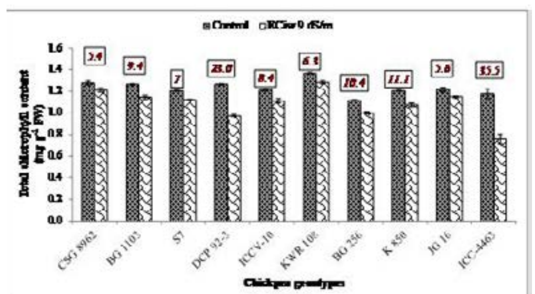

Fig. 2. Effect of saline irrigation on total chlorophyll content (mg g-1FW) of chickpea genotypes

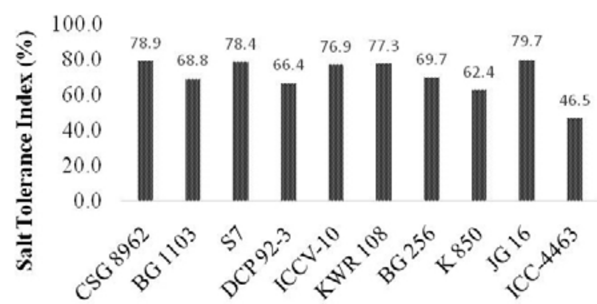

Fig. 3. Salt tolerance index of different chickpea genotypes

Table 3. Effect of saline water (EC_{iw}-9 dS m^{-1}) on proline content (µg g^{-1}FW) and Na^+/K^+ of chickpea genotypes

Genotypes	Proline (µg/g FW)				Na^+/K^+			
	Root		Shoot		Root		Shoot	
	Control	EC_{iw}–9 dS m^{-1}	Control	EC_{iw}–9 dS m^{-1}	Control	EC_{iw}–9dS m^{-1}	Control	EC_{iw}–9 dS m^{-1}
CSG 8962	102.68	140.87	128.29	301.60	0.47	0.72	0.09	0.34
BG 1103	96.30	144.69	126.90	297.61	0.24	0.90	0.08	0.36
S7	121.57	229.41	129.36	340.68	0.43	0.66	0.10	0.32
DCP 92-3	112.43	132.54	110.07	221.47	0.35	0.90	0.09	0.39
ICCV 10	105.11	187.35	112.95	311.32	0.45	0.70	0.08	0.31
KWR 108	95.11	189.07	126.25	319.92	0.24	0.69	0.08	0.30
BG 256	120.01	148.57	130.44	273.59	0.39	0.97	0.08	0.31
K 850	119.13	142.71	127.84	204.50	0.44	0.88	0.08	0.42
JG 16	122.95	164.72	124.20	246.19	0.50	0.94	0.06	0.33
ICC 4463	102.52	120.18	127.87	185.61	0.50	1.35	0.09	0.43
G.M.	109.78^B	160.06^A	124.42^B	270.25^A	0.40^B	0.87^A	0.08^B	0.35^A
CV (T)	1.9745		7.3027		11.5742		22.2649	
CV (G)	3.7980		3.9974		15.9868		12.0513	
LSD (T)	2.96		16.01		0.08		0.05	
LSD (G)	9.97		15.34		0.20		0.05	
LSD (T × G)	13.68		25.91		0.28		0.09	

Means with at least one letter common are not statistically significant (p<0.05) using Tukeys Test, G.M.=General mean

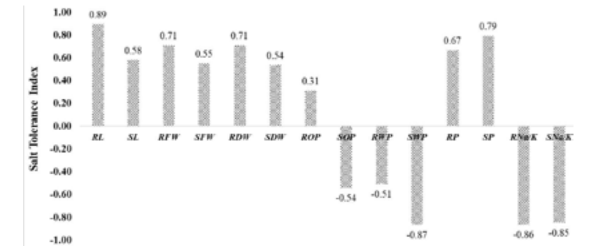

Fig. 4. Correlation between STI and morphological & physiological traits. RL: Root Length, SL: Shoot Length, RFW: Root Fresh Weight, SFW: Shoot Fresh Weight, RDW: Root Dry Weight, SDW: Shoot Dry Weight, ROP: Root Osmotic Potential, SOP: Shoot Osmotic Potential, RWP: Root Water Potential, SWP: Shoot Water Potential, RP: Root Proline, SP: Shoot Proline, RNa/K: Root Sodium to Potassium ratio, SNa/K: Shoot Sodium to Potassium ratio

control condition, but under saline conditions lower Na^+/K^+ was recorded in KWR 108 (0.30) and higher in ICC 4463 (0.43). Na^+/K^+ is an important trait to identify the salt tolerance of the crops and the maintenance of low Na^+ concentration is a vital aspect of stress tolerance. Na^+/K^+ ratio has been used as a criterion for distinguishing salt tolerant and salt sensitive chickpea genotypes. The genotypes that were able to manage low Na^+/K^+ ratio were categorized as tolerant and vice versa (Sanwal 1 et al. 2021). Salt tolerance index STI) was calculated on dry weight the basis (Mann et al. 2019) and five genotypes namely JG-16, CSG 8962, S7, KWR 108 and ICCV10 had more than 75 % salt tolerance index (Fig. 3). The correlation of STI with the different studied traits showed a significant positive association with root length, root fresh weight, root dry weight and root & shoot proline content while high negative correlation with root and shoot Na^+/K^+ ratio and water potential (Fig. 4). Briefly, it is concluded that S7, KWR 108, JG-16, CSG 8962 and ICCV10 genotypes can further be evaluated under field conditions for validation and can be involved in crop breeding as donors.

Authors' Contribution

Conceptualization of research (SKS, AM); Designingof the experiments (GK, SKS, AK); Contribution ofexperimental materials (SKS); Execution of field/labexperiments and data collection (GK, NK); Analysisof data and interpretation (AK, NK); Preparation ofmanuscript (GK, SKS, AK).

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