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Original Research Article

Effects of salinity stress on chickpea (*Cicer arietinum* L.) landraces during early growth stage

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ABSTRACT

Background: Salinity is one of the most serious abiotic stresses for crop plant growth. Chickpea grows under a wide range of climatic conditions and highly sensitive to salt stress. To determine the most tolerant genotype to salinity stress, an experiment was done as factorial form under completely block design (CRD) with three replications.
Methods: The experimental treatments were four NaCl salinity levels (0, 5dS/m, 10dS/m and 15dS/m) and five chickpea landraces (Dadi, Dido, Dida, Dimi and Soya).
Results: Results indicated that significant was observed in root length, shoot length, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, seedling shoot and root reduction traits in stress conditions. Dimi, Dido and Dadi were showed that high reduction in root length, shoot length, root length, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, seedling root and shoot in salinity conditions, respectively. The ANOVA for landraces and their interaction was found to be highly significant at ($p<0.001$) and ($p<0.05$) with all parameters. Landraces Dimi, Dido and Dadi were found salt tolerant but Soya was highly salt sensitive during seedling growth stage. Shoot dry weight had the most positive and significant correlation with root dry weight (r =0.987**). Seedling shoot reduction depicted a negative and significant correlation with total dry matter (r =-0.734**).
Conclusions: This study indicated that developing genetic variability by identifying salt tolerant landrace is one of the appropriate strategies used to overcome salinity problem in arid and semi-arid areas.

Keywords: Seedling, Salinity, Chickpea landrace

INTRODUCTION

Chickpea is the most important pulse crop in the world in terms of total production which is mostly grown in semi-arid regions and wide adaptability as a food grain.[1] It plays an important role in maintenance of the soil fertility through nitrogen fixation, particularly in the arid and low rainfall areas.[2] During early growth stage, it exposed to different aboitic stresses which limit its morphological growth and productivity. Among these factors, salinity and drought are the most sever factors that can affect agricultural production and productivity on worldwide especially in arid and semi-arid agro ecological zone.[3]

However, chickpea is sensitive to salinity stress, particularly during the early stages of growth and development. Seedling growth is the most critical life stage of crop plants and more sensitive to environmental salt stress during this period.[4] There has been reported a considerable variation observed among various genotypes in which the most susceptible ones fail to grow in just 25 mM NaCl but tolerant genotypes survives up to a maximum of 100 mM NaCl in hydroponics.[5] The higher levels of salt concentrations in the soil is raised due to high evaporation rate and insufficient rainfall during growing season, both lead to 8 to 10% yield losses globally. In Ethiopia about 10608 ha of total land is affected by salinity in semi-arid and arid regions which can reduce crop yield.[6] This research describes the effects of salinity on seedling growth of Chickpea landraces.

METHODS

The experiment was conducted in the traditional greenhouse at Bule Hora University, Oromia, Ethiopia from May to June, 2016. Five chickpea landraces were used in this experiment which was collected from three districts (Bule Hora, Yabello and Dire), purposively based on the production of chickpea landrace for several years on that areas. An experiment was carried out by modified procedures used by using plastic pots with width 15 cm at the base and 20 cm at the top and 18 cm height.[7] Chickpea landraces was treated with four different concentrations of salinity levels 0 (control), 5, 10, and 15 dS/m of NaCl which is dissolved in one liter of distilled water, respectively. Distilled water (0 dS/m) was used as a control. After the salt concentration is adjusted, about 2 kg of agricultural soil which is fertile, deep, well drained clay loam to silty loam soils with good water holding capacity was weighed and filled into 60 pots. Then, nine surface sterilized uniform seeds of each chickpea landraces were sown in the pots at uniform depth. Pots were arranged in a factorial based on a completely randomized design (CRD) placement and was replicated 3 times. The seedling growth parameters were obtained after 21st days of sowing and from each pot the seedling growth data was measured by using a draftsman ruler.[8]

Seedling parameters

The data was collected from shoot fresh weight, root fresh weight, root dry weight and shoot dry weight of the five seedlings were measured and expressed in gram as fresh condition for the first two parameters and also the next two parameters were expressed in gram after dried in oven dry at 70 ºC until a constant weight was reached. The above four parameters were measured on digital analytical balance.[9] And also, Seedling root reduction (SRR) and shoot reduction (SHR) were calculated according to the following formula, respectively.[10]

$$\text{Seedling root reduction } (\%) = \frac{\text{Root length of control} - \text{Root length of treatment}}{\text{Root length of treatment}} \times 100$$

$$\text{Seedling shoot reduction } (\%) = \frac{\text{Plant Height at control} - \text{Plant height at Saline condition}}{\text{Plant height at saline condition}} \text{ x } 100$$

Statistical analysis

Data analysis was carried out by SAS package where two way analysis of variance (ANOVA) and correlation analysis was employed. Whenever treatment differences are significant, means were separated by using the least significant difference (LSD) at 0.05 tests.

RESULTS

Analysis of variance showed that there were significant differences between salinity concentration levels. The results of this study revealed that various concentrations of NaCl had a significant effect on almost all measured traits for chickpea landraces. And also, analysis of variance showed that the interaction effects were significant for all investigated traits (Table 1).

Effect of salinity on chickpea agronomic traits

The experiment was carried out to observe the influence of salinity on the seedling growth of chickpea landraces. The results obtained indicated that the increment of salt concentration can cause delayed emergence of plumule and radicle as compared to control. At the early seedling stage, reduction in root length and shoot length clearly demonstrated genetic variation in vegetative growth responses to salinity among chickpea landraces.

Shoot length

Shoot length was affected significantly with increasing in the salinity level (Figure 1). The rate of reduction in shoot length at 15 dS/m NaCl in comparison with the control was detected in Dido with 19.87 cm, Dimi with 19.25 cm and Dadi with 18.96 cm.

Table 1: Analysis of variance on mean squares of measured traits of chickpea landraces under salinity stress.

Source of variance	DF	SHL	ROL	SHFW	ROFW	SHDW	RODW	SSHR	SRR	TDRM
SL	3	13.17**	122.08**	0.103**	0.14**	0.14**	0.01**	75.02^{ns}	1378.74**	2004.03**
Landraces	4	9.21**	88.03**	0.10**	0.11**	0.11**	0.00**	303.42**	1761.72**	136.82*
SL x Landrace	12	1.34	18.85	0.00	0.01	0.01	0.00	51.75	244.83	26.14
Error		0.22	3.07	0.00	0.00	0.00	0.00	8.45	39.99	5.23

ns,*, ** non-significance, Significant at 5% and 1% probability levels, respectively.

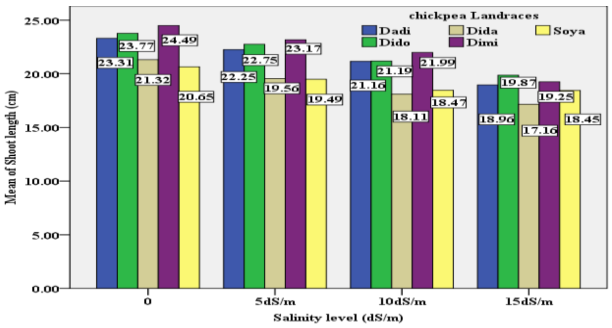

Figure 1: Effects of different salinity levels on shoot length of five chickpea landraces.

Root length

Maximum root length was observed in Dido, Dimi, Dadi and minimum was observed in Soya, Dida at 5, 10 and 15 dS/m of salinity level respectively (Figure 2).

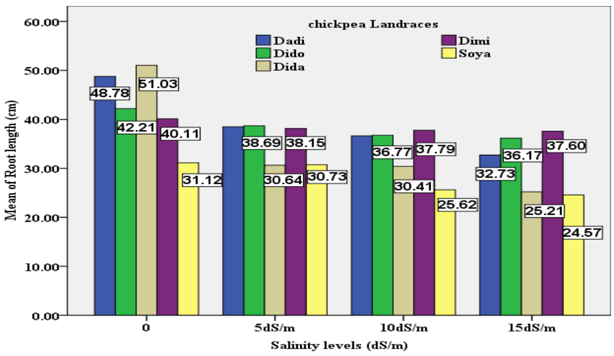

Figure 2: Effects of different salinity levels on Root length of five chickpea landraces.

Shoot fresh weight

The influence of salt stress on chickpea seedling becomes pronounced with higher salt concentrations (Figure 3). From the entire landraces considered, landraces Soya and Dida were the salt affected as compared to the control. In addition, landraces Dimi, Dido and Dadi were medium salt-affected landraces respectively.

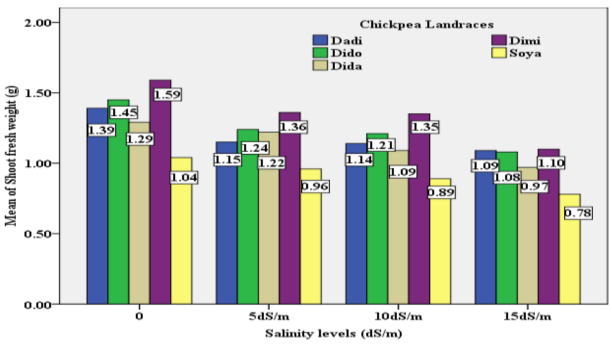

Figure 3: Effects of different salinity levels on shoot fresh weight of five chickpea landraces.

Root fresh weight

The analysis of variance (ANOVA) showed a significant variation among landraces ($p \leq 0.01$) for mean of root fresh weight (RFW). Landrace*treatment interaction effect was also significant reflecting all the landraces responding to different salinity levels with respect to mean root fresh weight (RFW). Increased salinity levels resulted in a decreased mean root fresh weight (RFW) in landraces Soya, Dida and Dadi. However, mean of root fresh weight (RFW), brought about no more influence in landraces Dimi and Dido by salt stress up to 15 dS/m (Figure 4).

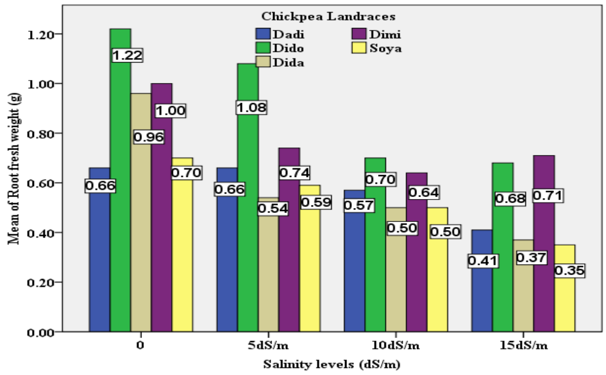

Figure 4: Effects of different salinity levels on root fresh weight of five chickpea landraces.

Root dry weight

The analysis of variance (ANOVA) confirmed that the presence of a significant variation in mean of root dry weight among landraces ($P \leq 0.01$). The root dry weight is highly decreased at 10dS/m and 15dS/m as salt concentration is increased when compared to control and salinity level 5 dS/m (Figure 5).

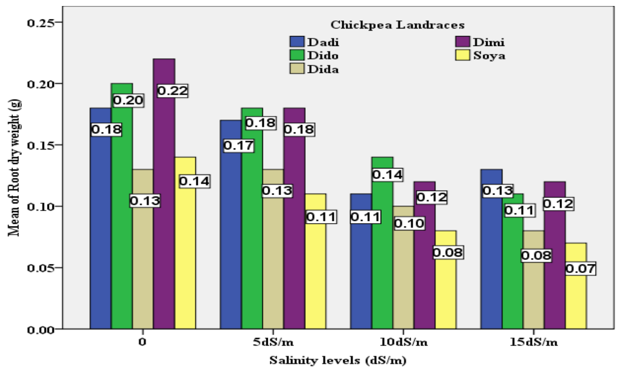

Figure 5: Effects of different salinity levels on root dry weight of five chickpea landraces.

Shoot dry weight

It was observed that in all landraces, there was a decrease in shoot dry weight because increment of salinity stress in certain landraces caused physiological disturbance in their cell membrane. Among the chickpea landraces, Dido and Dadi had the highest shoot dry weight at 10 dS/m and 15 dS/m as compared to control relatively. However, the maximum reduction in shoot dry weight was observed at the highest level, that is, 15 dS/m of salinity level (Figure 6).

Seedling root and shoot reduction

There is reduction of seedling root and shoot length in Dida and Dadi; Soya and Dimi as it was observed at 15 S/m salinity level in comparison with the left landraces.

Correlation analysis

Breeders always look for genetic variation among traits to select desirable traits. Some of these traits are highly associated among themselves and with seed yield components. The analysis of the relationship among these traits and their association with seed yield is essential to establish selection criteria.[11] Among chickpea landrace yield components shoot dry weight is highly correlate with root dry weight (r =0.987**). But shoot length is highly least correlated with seedling shoot reduction (r =-0.719 (Table 2).

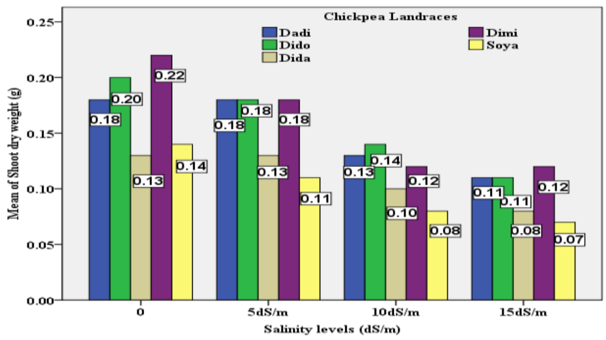

Figure 6: Effects of different salinity levels on shoot dry weight of five chickpea landraces.

Table 2: Correlation coefficients among studied agronomic traits of chickpea landraces under different salinity stress.

	GR	GP	PL	RAL	SHL	ROL	SHFW	ROFW	SHDW	RODW	SSHR	SRR	TDRW
GR	1	0.23	0.3	0.264	0.600**	0.433	0.323	0.351	0.209	0.176	-0.38	-0.133	-0.616**
GP		1	0.669**	0.850**	0.089	0.720**	0.648**	0.640**	0.849**	0.840**	-0.577*	-0.577*	0.621**
PL			1	0.542*	0.301	0.574*	0.771**	0.426	0.860**	0.834**	-0.609**	-0.379	0.757**
RAL				1	0.274	0.677**	0.596*	0.677**	0.739**	0.736**	-0.649**	-0.566*	0.738*
SHL					1	0.191	0.273	0.238	0.197	0.202	-0.719**	0.021	0.701**
ROL						1	0.770**	0.618**	0.685**	0.674**	-0.579**	-0.589**	0.611*
SHFW							1	0.642**	0.855**	0.860**	-0.668**	-0.41	0.594**
ROFW								1	0.711**	0.730**	-0.4	-0.654**	0.588*
SHDW									1	0.987**	-0.625**	-0.517*	0.740*
RODW										1	-0.624**	-0.510*	0.736**
SSHR											1	0.222	-0.734**
SRR												1	-0.264
TDRW													1

*, ** Significant at 0.05 and 0.01 probability levels, respectively.
GR=Germination Rate, GP=Germination Percentage, PL=Plumule Length, RAL=Radicle Length, SHL=Shoot Length, ROL=Root Length, SHFW= Shoot Fresh Weight, ROFW= Root Fresh Weight, SHDW= Shoot Dry Weight, RODW= Root Dry Weight, SSHR= Seedling Shoot Reduction SRR= Seedling Root Reduction, TDRW= Total Dry weight.

DISCUSSION

Analysis of variance for all seedling traits showed that the salinity levels and their interaction for shoot length, root length, root fresh weight, shoot fresh weight, root dry weight, shoot dry weight and seedling root and shoot reduction in chickpea landraces were found to be significant at 1% and 5% level (Figure 1-6) and reflecting that each landraces differently responded to salt stress with respect to all agronomic traits. However, the reduction was sharp at 10 dS/m and 15 dS/m salinity levels. On the basis of shoot length for the soils having 15 dS/m of salinity, the landraces Dido and Dimi can be recommended. Like other workers, results of this study also illustrated that salinity caused a reduction in crop shoot length. Landraces Dadi and Soya had medium shoot length. There is no reduction of seedling root length at 0dS/m salinity levels in comparison with the other salinity levels. According to found that the tolerant genotypes of chickpea had the higher growth rate under enhanced salt stress.[12] Consequently, physiological traits would be very useful in salinity tolerance improvement programs especially, shoot fresh weight which has shown a regular growth reduction compared to the controls. The findings of the present study are in accord with findings of who reported that the root length was more adversely affected compared to shoot length by salinity.[13] This is caused by the increasing salinity levels were more pronounced significantly decreased sharply at 10 dS/m and 15 dS/m of salinity concentration. The results were in partly accordance with, which reported that the fresh weight of root and shoot in seedlings were decreased by salinity stress.[14] Decrease in dry weight of root was noticed in chickpea relatively with the increment of salinity concentration.[15] And also the result is agreed with work of which noticed that the root dry weight of chickpea was decreased with the increment of salinity concentration.[16] Reduction in shoot and root length could be attributed to decrease in cell division, cell enlargement under salt stress.[5] It can be inhibited by interruption of water flow from xylem to the surrounding elongating cells leading to reduced number of branches. The reduction in total biomass could be due to either impaired reducing cyclin dependent kinase activity resulted in lesser cell division and vegetative growth reducing dry weight of shoot. The reduction in root and shoot development may be due to toxic effects of the Na^+ and Cl^- used as well as imbalanced nutrient uptake by the seedlings.[17] Significant reduction was occurred in seedling shoot height under different salinity levels. Similar results were scored in chickpea.[18] Salinity affects the seedling growth of chickpea by slow down or less mobilization of reserve foods, suspending the cell division, enlarging and injuring hypocotyls. This result is in agreement with similar research on Gina Cultivar by.[19]

The analysis of relationship among chickpea landrace traits and their association with seed yield is essential to establish selection criteria for salinity stress.[11] The correlation analysis showed a highly positive significant correlation between shoot dry weight (SHDW) and root dry weight (RODW) (=0.987**). Shoot length (SHL) was depicted a negative and significant correlation with seedling shoot reduction (SSHR) (=-0.719**). Strong positive correlation indicates that these traits can be used as a reliable criterion in selection of salt stress tolerant chickpea landrace. The results were in accordance with those of for sorghum landrace and for Chickpea.[20,21] The results of this experiment in chickpea landraces were in agreement with previous studies in which the concentration of Na^+ and Cl^- ions are negative correlation within physiological indices that salt cause direct injure to plant cells.[22] According to the current results, chickpea landraces at seedling stage are might be affected due to high concentration of salt in the soil solution at root zone which exceeds certain limits, and form toxic effects of Na^+ and Cl^- ions to chickpea metabolic pathway which interferes balanced absorption of essential nutrient ions from the soil.

CONCLUSION

This study showed increasing the amount of salt concentration caused a significant effect in seedling growth of some landraces. Salt tolerant genotypes may use their own morphological and physiological defensive mechanisms in order to survive themselves for perpetuate the next life cycle. Meanwhile, salt tolerant chickpea landraces on soil saline areas are recommended in case of giving sustainable economic value for the stake holders. To conclude, landrace crops have high resistant to salinity stress than released varieties. Therefore, this result recommends plant breeders Dimi, Dido and Dadi chickpea landraces would be tested at molecular level for further investigation.

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