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Genetic variability for salt tolerance in maize seedlings

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ABSTRACT. Maize is very sensitive for abiotic environmental stress conditions involving drought, heat and salt stress as important stress conditions. For this purpose a study was planned to conduct in greenhouse of Institute of Molecular Biology and Biotechnology, University of the Lahore to determine effects of salt stress on maize seedling growth. For our study we have selected four maize varieties viz., B-316, EV-1097Q, SH-2002 and FH-810. The seed of each variety were sown in triplicate pots with all irrigation requirements in equal manners. The results revealed that there were significant differences among the treatments of NaCl concentrations (0.2 mM, 0.4 mM, 0.6 mM, 0.8 mM and 1 mM) along with control and maize genotypes used for research evaluation and the interactions among the maize genotypes and salt concentrations applied. The average maize seedling length was recorded as 22.646 ± 1.2025 cm and length of roots was recorded as 22.609 ± 2.0135 cm. It was found that the performance of all of four maize genotypes was variable for all studied traits. The results showed that the genotype B-316 showed higher root and shoot length which indicated that B-316 was higher salt tolerant genotype and may be used as salt tolerant genotype to improve grain yield per plant in maize. The genotype EV-1097Q has shown poor performance for all of the studied traits which indicated that it was salt sensitive maize genotype. It was revealed from results that the performance of maize varieties/genotypes was highly affected under the treatment of higher salt concentration. The performance of maize genotypes under lower NaCl concentration was higher while intermediate for intermediate treatment of salt concentrations. The higher genetic advance was found for shoot length (45.254%) and root length (41.971%) while higher heritability as reported for leaf are (98.132%), roots per plant (94.351%) and root length (96.345%). The higher genetic advance and heritability for root length indicated that the selection of maize genotypes for salt stress may be helpful to improve yield under stress conditions. It was suggested from our study that the use of B-316 as salt tolerant genotype could be useful for improving yield of grain and production under the salt stress environment.

Keywords: Maize; Salt stress; NaCl; Abiotic; Root length; Shoot length

INTRODUCTION

Maize has an important and significant position among existing plant cropping systems for Pakistan maize growing areas. Maize ranks as third after the rice and wheat crops for grain yield and production of country. The estimate for yield in Pakistan is about 70% production which is used indirectly or directly in food while the rest of its production is used for starch formation also in poultry industries for feed formation. Maize grain was constituted about grain protein, grain oil, grain crude fibre, grain starch, embryo as 9.7396%, 4.85%, 9.4392%, 71.966%, 11.77% respectively while the fodder contains acid detergent fibre, nutrients detergent fibre, cellulose, dry matter, crude protein, moisture as 22.988%, 51.696%, 28.797%, 40.178%, 26.845%, 10.353%, 9.095% respectively (Ali et al., 2014 a, b, c). In Pakistan the maize is grown or cultivated for two times in each of the year as autumn as well as spring seasons of country. With an active involvement for multinationals in the country, the growing or cultivation of the spring maize which has been improved or increased as compared with previous years. However, the climatic as well as the soil conditions in Pakistan has been most responsive and adaptive for corn or maize grain production however the yield of grain is still very low in Pakistan as compared with other maize growing countries of the world. There has been a need for recognizing a suitable and executive technique for maize cultivation which can resist salt and drought stress environmental conditions (Ali et al., 2012a; Ali et al., 2013b). The maize has higher water demands which can give higher grain production even when the water, mineral and other soil nutrients have become sufficient in amount and avail to plants easily, the maize plant is also very sensitive for salt and water deficit of moisture stress environment (Jabeen et al., 2008, Ali et al., 2013a; Ali et al., 2012b; Pandey et al., 2000) along with other stress environments like cold, heat, salt and alkaline conditions at anthesis period of plants (Ali et al., 2011 b, c; Ahsan et al., 2013; Anjum et al., 2014; Pandey et al., 2000; Golparvar et al., 2006).

MATERIALS AND METHODS

Maize is a cereal crop which is grown throughout whole world for its grain and other byproducts. Maize is very sensitive to abiotic or environmental stress conditions involving drought, heat, cold and salt stress as important stress conditions. For this purpose a study was planned to conduct in greenhouse of IMBB (Institute of Molecular Biology and Biotechnology), University of Lahore to estimate effects of salt stress on maize seedling growth. For our study we have selected three maize varieties viz., B-316, EV-097Q, SH-2002 and FH-810. Seed from selected maize genotype was used to grow in 54 pots, filled with 2 kg pure washed sand. The sand was mixed with 500 mg/kg of NaCl in each of the pot except of the control pots for maize sowing. The seed of each variety were sown in triplicate pots with all irrigation requirements in equal manners. To carry out our research work we have used following sets for treatment of NaCl: T0. Control or no any salt treatment, T1 (0.2 m Molar NaCl), T2 (0.4m Molar NaCl), T3 (0.6 m Molar NaCl), T4 (0.8 m Molar NaCl) and T5 (01 m Molar NaCl). The treatment of salt or NaCl was applied after the germination of maize seeds and data was recorded for various seedling traits. The treatment was applied and again data was recorded after one week of salt application. The data recorded for two times from two weeks was pooled to carried analysis of variance and all pairwise comparisons for maize varieties and treatments of salt. Data was recorded for various morphological traits including the leaf area, roots per seedling, dry root weight, root length, shoot length, shoot dry weight, shoot water contents and root water contents. The recorded data which was statistically analyzed through using analysis of variance techniques (Steel et al., 1997) by using SPSS23.1 software.

RESULTS AND DISCUSSION

Shoot length

The results from Table 1 revealed that there was significant differences among the treatments of NaCl concentrations (0.2 mM, 0.4 mM, 0.6 mM, 0.8 mM and 1 mM) along with control (no NaCl application) and maize genotypes used for research evaluation and the interactions among the maize genotypes and salt concentrations applied. The results also indicated that there was lower coefficient of variation (0.82%) recorded for length of shoots of corn under effects of various salt concentrations which indicated that the consistency of results was higher and predications may be useful for length of shoot in corn under salt stress to use as response variable. The genetic advance was found 45.245% while heritability was 89.232% was recorded for shoot length. The higher genetic advance and heritability indicated that the shoot length may be helpful to improve stress tolerance in maize under stress conditions. The average length of shoot in corn genotypes was recorded as 22.646 ± 1.2025 cm under all salt concentration applications. The higher shoot length under salt concentration indicated that the maize genotypes showed tolerance against salt stress and tends to improve plant growth and development even under salt stress environment (Katerji et al., 1996; Katerji et al., 1994 and Turan et al., 2010).

The results as given in Figure 1 showed that there was higher seedling length of maize genotype FH-810 under 0.6 mM NaCl (24.54 cm). The results about SH-2002 showed that there was higher seedling length under the application of 0.4 mM NaCl (24.23 cm) concentration followed by 0.8 mM NaCl (25.34 cm) and 1 mM NaCl (25.24 cm). The maize genotype B-316 showed higher seedling length under the application of 0.6 mM NaCl (25.74 cm) concentration followed by 0.8 mM NaCl (25.64 cm) and 0.4 mM NaCl (25.84 cm) while lowest under the application of 1 mM NaCl (21.84 cm). The results showed that the genotype B-316 showed higher seedling length under application of different salt concentrations as compared with both of the other FH-810 and SH-2002 which showed B-316 as more salt tolerant genotype and hence may be used for improving grain yield and productivity of maize under salt affected soil (Khayatnezhad and Gholamin 2011; Ali et al., 2017; Maas, 1995).

Table 1. Analysis of variance table for morphological traits of maize seedlings

Sources	DF	Shoot length (cm)	Roots per plant	Root length (cm)	Leaf area (cm^2)	Shoot water contents (%)	Root water contents (%)
Replications	2	0.1667ns	0.0318ns	0.0881ns	0.00075ns	0.0993ns	0.0629ns
Treatments	5	26.363*	1.6158*	64.0019*	7.9883*	1.2754*	0.6827*
Genotypes	3	5.5317*	0.46702*	0.4833*	0.6085*	14.4850*	18.6432*
Treat×Gen	15	0.0017*	0.00002*	0.0001*	0.00005*	0.7876*	0.0850*
Error	35	0.0342	0.00897	0.0197	0.00020*	0.1814	0.0772
Grand Mean		22.646	9.5617	22.609	8.3443	84.905	79.508
Standard Error		1.2025	0.3452	2.1035	1.0105	3.5012	3.0054
Coefficient of variation		0.82%	0.99%	0.62%	0.17%	0.50%	0.35%
Genetic Advance		45.245%	32.101%	41.971%	29.451%	27.174%	26.952%
Heritability		89.232%	94.351%	96.345%	98.132%	87.356%	88.896%

* = Significant at 5% probability, ns = Non Significant

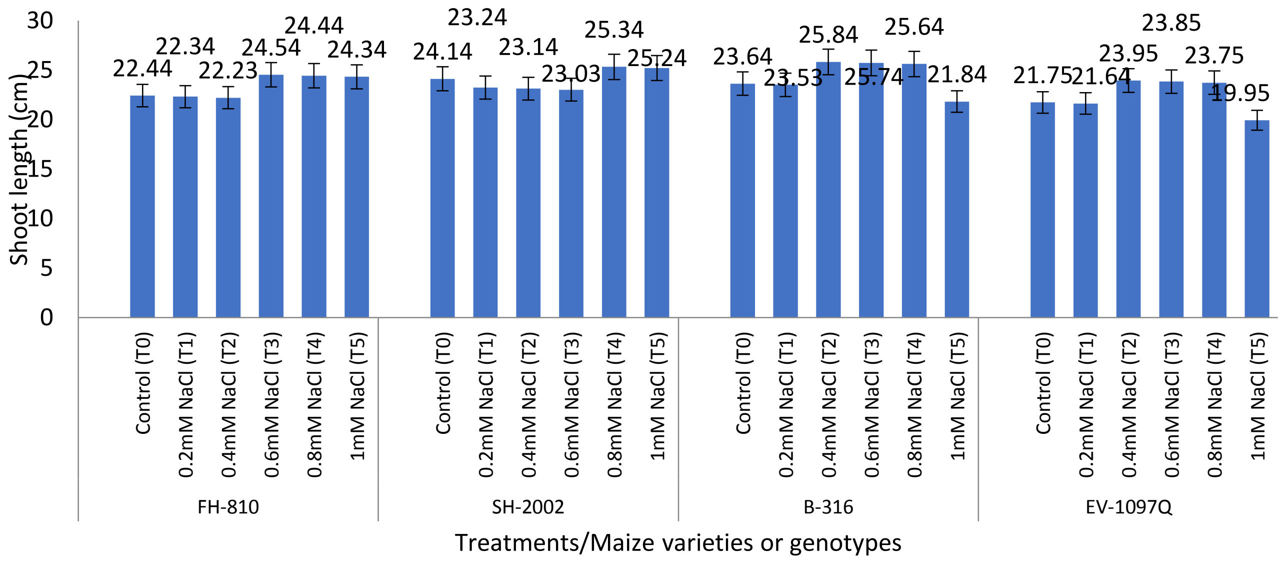

Figure 1. Shoot length of maize seedlings under different applications of NaCl concentrations

Root length

The results from Table 1 showed significant difference for all studied parameters. The results also indicated that there was lower coefficient of variation (0.62%) recorded for length of corn roots under effects of various salt concentrations which indicated that the consistency of results was higher and predications may be useful for length of corn roots under salt stress to use as response variable. The average length of root in corn genotypes was recorded as 22.609 ± 2.0135 cm under all salt concentration applications. The genetic advance was recorded as 26.952% and heritability 88.896% for root length. The higher genetic advance and heritability for length of root under salt concentration showed that maize or corn genotypes showed tolerance against salt stress (Maas, 1995; Munns, 1993 and Chaabane, 2011). The results as given in Figure 2 showed that there was higher seedling length of maize genotype FH-810 under 0.6 mM NaCl (24.84 cm) concentration followed by 1 mM NaCl (24.74 cm) and 0.8 mM NaCl (24.64 cm). The results about SH-2002 showed that there was higher seedling length under the application of 0.8 mM NaCl (25.02 cm) concentration followed by 1 mM NaCl (24.82) and control (25.24 cm). The maize genotype B-316 showed higher length of roots under the application of 0.4 mM NaCl (25.24 cm) concentration followed by 0.8 mM NaCl (25.14 cm) and 0.6 mM NaCl (25.04 cm). The results showed that the genotype B-316 showed length of roots under application of different salt concentrations as compared with both of the other FH-810 and SH-2002 which showed B-316 as more salt tolerant genotype and hence may be used for improving grain yield and productivity of maize under salt affected soil (Khayatnezhad and Gholamin 2011; Ali et al., 2016; Maas, 1995).

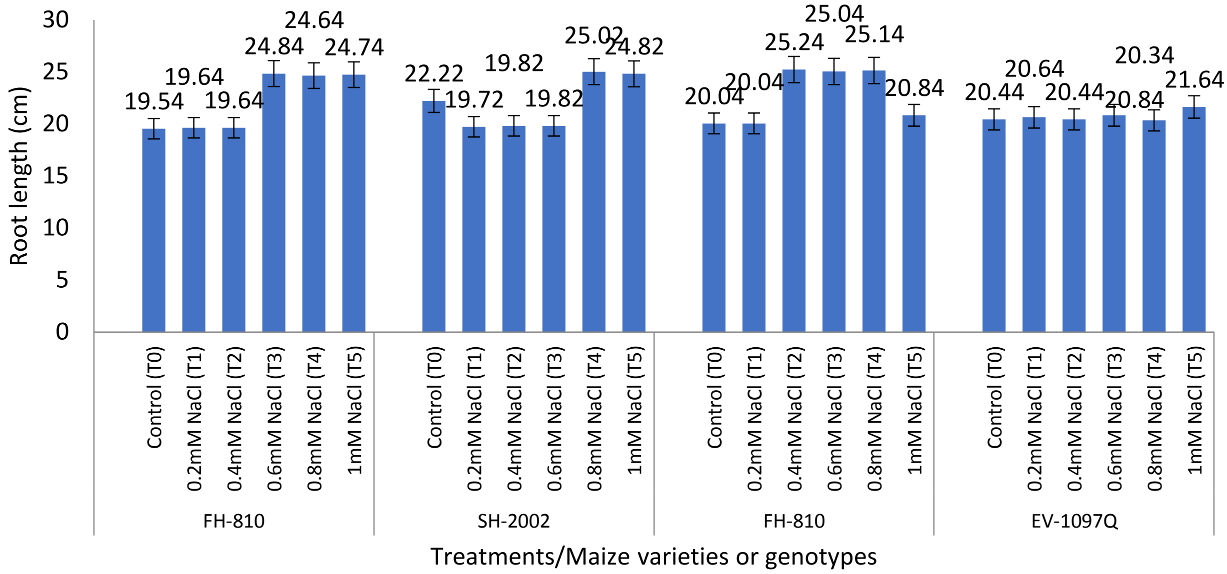

Figure 2. Root length of maize seedlings under different applications of NaCl concentrations

Roots per plant

The results from Table 1 indicated significant difference for all studied parameters. The results also indicated that there was lower coefficient of variation (0.99%) recorded for roots/plant of corn under effects of different salt concentrations which indicated that the consistency of results was higher and predications may be useful for roots/plant of corn under salt stress to use as response variable. The average roots/plant of corn genotypes was recorded as 9.5617 ± 0.3452 under all salt concentration applications. The genetic advance was recorded as 32.101% and heritability 94.351% for root length. The higher genetic advance and heritability for roots per palnt under salt concentration indicated that the maize genotypes showed tolerance against salt stress and tends to improve plant growth and development even under salt stress environment (Ahsan et al., 2013; Munns, 1993 and Chaabane, 2011). The results as given in Figure 3 showed that there was higher seedling length of maize genotype FH-810 under control and 0.2 mM NaCl (10.34) concentration followed by 0.4 mM NaCl (10.24). The results about SH-2002 showed that there was higher roots/plant of corn under the application of 0.2 mM and 0.4 mM NaCl (10.39) concentration followed by 0.6 mM NaCl (10.29). The maize genotype B-316 showed higher roots/plant of corn under the application of control and 0.4 mM NaCl (10.64) concentration followed by 0.2 mM NaCl (10.54). The results showed that the genotype B-316 showed higher roots/plant of corn under application of different salt concentrations as compared with both of the other FH-810 and SH-2002 which showed B-316 as more salt tolerant genotype and hence may be used for improving grain yield and productivity of maize under salt affected soil (Khayatnezhad and Gholamin 2011; Ali et al., 2013; Ali et al., 2014ab).

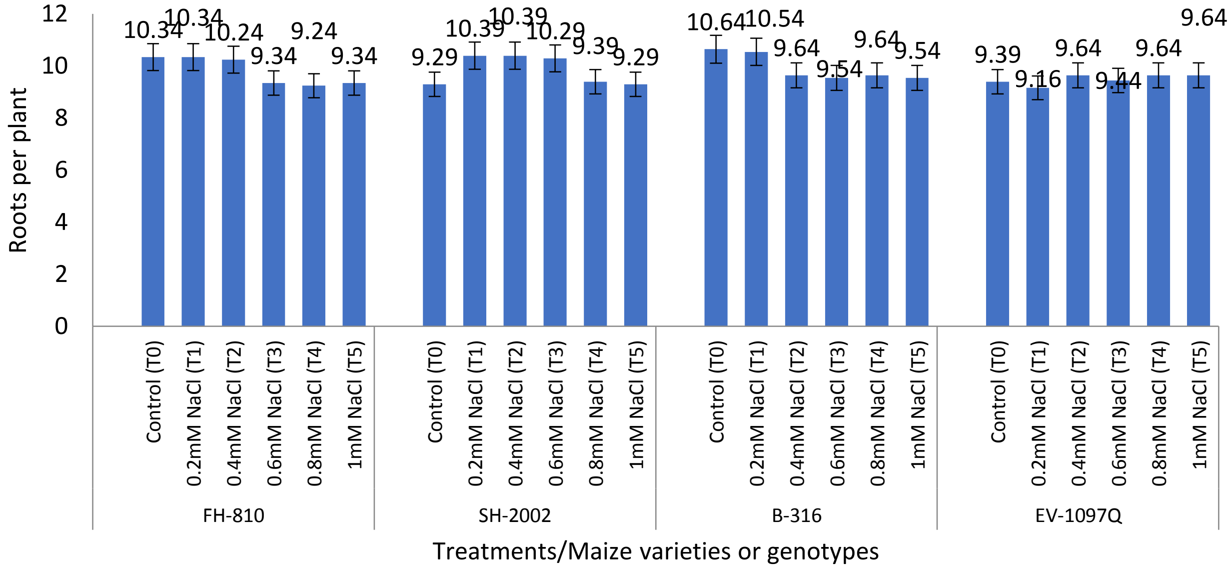

Figure 3. Roots per plant of maize seedlings under different applications of NaCl concentrations

Leaf area

The results from Table 1 indicated significant differences for all studied parameters. The results also indicated that there was lower coefficient of variation (0.17%) recorded for leaf area of maize under effects of different salt concentrations which indicated that the consistency of results was higher and predications may be useful for leaf area of maize under salt stress to use as response variable. The average leaf area of maize genotypes was recorded as 8.3443 ± 1.0105 cm^2 under all salt concentration applications. The genetic advance was recorded as 29.451% and heritability 98.132% for root length. The higher genetic advance and heritability for leaf area under salt concentration indicated that the maize genotypes showed tolerance against salt stress which may help in selecting higher yielding maize genotypes against stress conditions (Ali et al., 2011ab; Ali et al., 2012a, 1993 and Chaabane, 2011). The results as given in Figure 4 showed that there was higher seedling length of maize genotype FH-810 under 1 mM NaCl (9.47 cm^2) concentration followed by 0.6 mM and 0.8 mM NaCl (9.46 cm^2). The results about SH-2002 showed that there was higher seedling length under the application of 0.8 mM and 1 mM NaCl (9.63 cm^2) concentration followed by control NaCl (8.60) while lowest seedling length was recorded under treatment of 0.4 mM NaCl (8.52 cm^2). The maize genotype B-316 showed higher leaf area under the application of 0.8 mM NaCl (9.84 cm^2) concentration followed by 0.6 mM and 0.4 mM NaCl (9.83 cm^2). The results showed that the genotype B-316 showed higher leaf area under application of different salt concentrations as compared with both of the other FH-810 and SH-2002 which showed B-316 as more salt tolerant genotype and hence may be used for improving grain yield and productivity of maize under salt affected soil (Khayatnezhad and Gholamin 2011; Hussain et al., 2102; Maas, 1995).

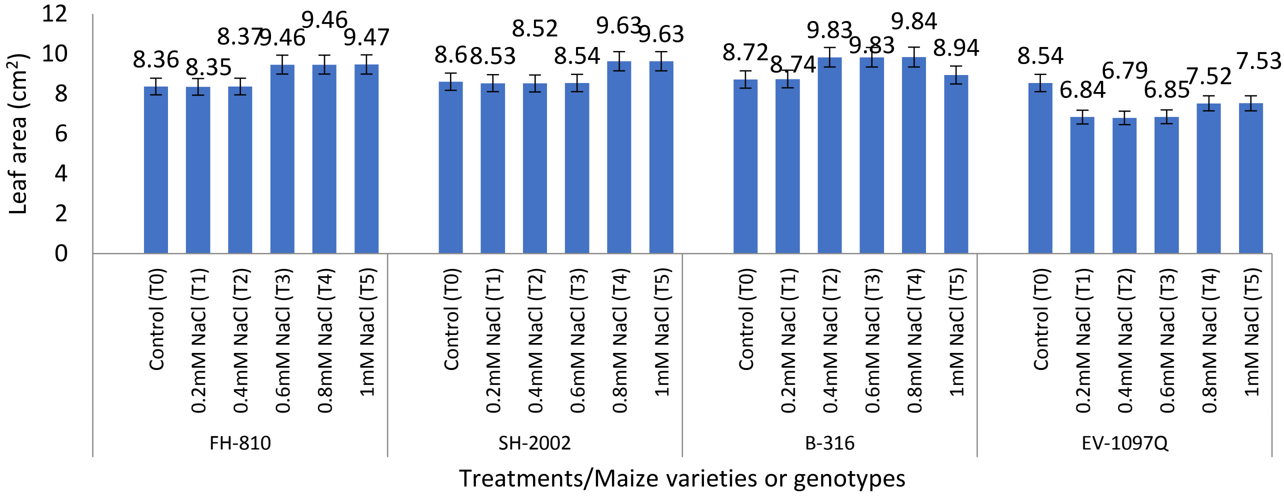

Figure 4. Leaf area of maize seedlings under different applications of NaCl concentrations

Shoot water contents

The results from Table 1 indicated significant differences for all studied parameters. The results also indicated that there was lower coefficient of variation (0.50%) recorded for shoot water contents of maize under effects of different salt concentrations which indicated that the consistency of results was higher and predications may be useful for shoot water contents of maize under salt stress to use as response variable. The average shoot water content of maize genotypes was recorded as 84.905 ± 3.5012% under all salt concentration applications. The genetic advance was recorded as 27.174% and heritability 87.356% for root length. The higher genetic advance and heritability for shoot water content under salt concentration indicated that the maize genotypes showed tolerance against salt stress (Maas, 1977; Munns, 1993 and Chaabane, 2011). The results as given in Figure 5 showed that there was higher seedling length of maize genotype FH-810 under 0.6 mM NaCl (82.73%) concentration followed by 0.8 mM NaCl (82.65%). The results about SH-2002 showed that there was higher seedling length under the 0.8 mM NaCl (80.99%) concentration followed by 1 mM NaCl (80.89%). The maize genotype B-316 showed higher shoot water content under the application of 0.4 mM NaCl (82.13%) concentration followed by 0.6 mM (82.12%). The results showed that the genotype FH-810 showed higher shoot water content under application of different salt concentrations as compared with both of the other which showed FH-810 as more salt tolerant genotype and hence may be used for improving grain yield and productivity of maize under salt affected soil (Husain et al., 2013; Jabeen et al., 2008; Khan et al., 2009; Kang et al., 2014).

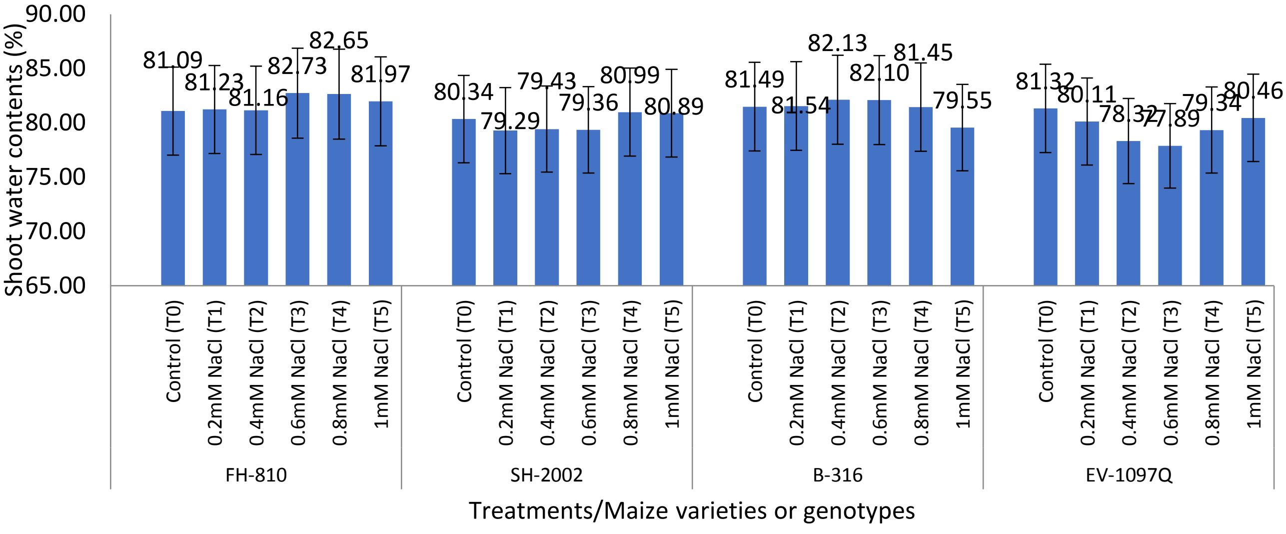

Figure 5. Shoot water contents of maize seedlings under different applications of NaCl concentrations

Root water contents

The results from Table 1 indicated significant differences for all studied parameters. The results also indicated that there was lower coefficient of variation (0.35%) recorded for root water contents of maize under effects of different salt concentrations which indicated that the consistency of results was higher and predications may be useful for root water contents of maize under salt stress to use as response variable. The average root water content of maize genotypes was recorded as 79.508 ± 3.0054% under all salt concentration applications. The genetic advance was recorded as 26.952% and heritability 88.896% for root length. The higher genetic advance and heritability for root water content under salt concentration indicated that the maize genotypes showed tolerance against salt stress (Kanwal, et al., 2019; Munns, 1993 and Chaabane, 2011). The results as given in Figure 6 showed that there was higher seedling length of maize genotype FH-810 under 0.8 mM NaCl (85.52%) concentration followed by 0.6 mM NaCl (85.50%). The results about SH-2002 showed that there was higher seedling length under control (84.09%) concentration followed by 1 mM NaCl (83.60%). The maize genotype B-316 showed higher root water content under the application of 0.2 mM NaCl (83.82%) concentration followed by 0.4 mM (83.79%). The results showed that the genotype FH-810 showed higher root water content under application of different salt concentrations as compared with both of the other which showed FH-810 as more salt tolerant genotype and hence may be used for improving grain yield and productivity of maize under salt affected soil (Azizi et al., 2006; Kang et al., 2003; Hou et al., 2014; Chai et al., 2014; Ali et al., 2014c).

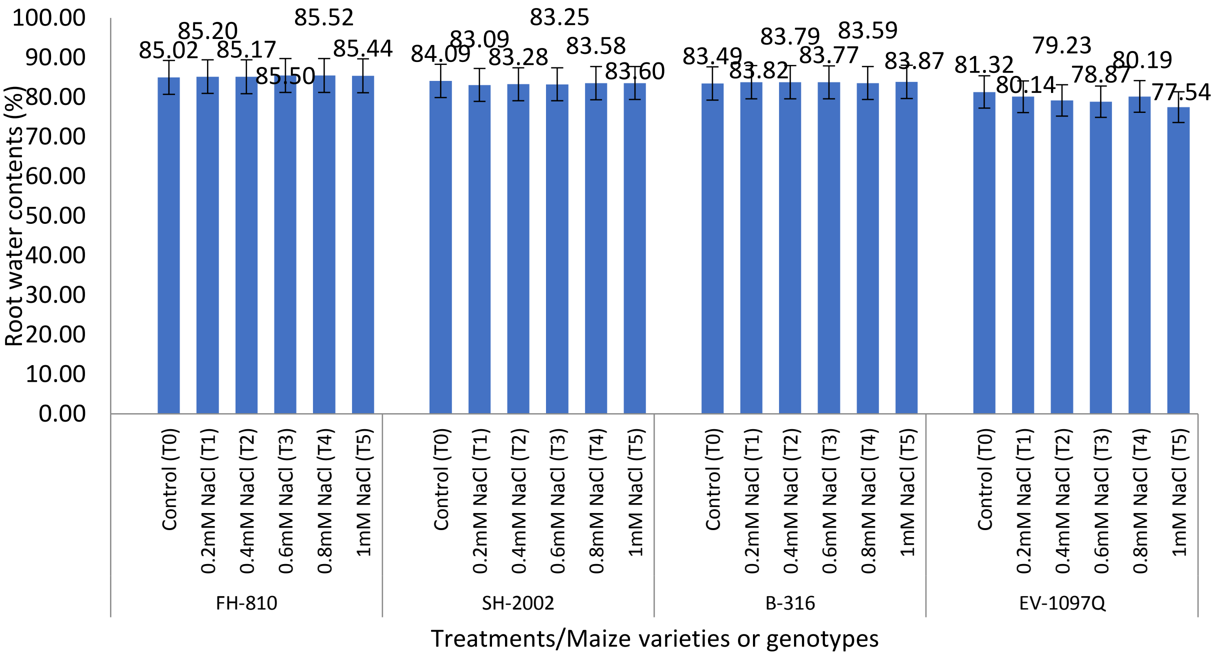

Figure 6. Root water contents of maize seedlings under different applications of NaCl concentrations

Correlation

It was found from Table 2 that significant correlation was found for leaf area with roots per plant, root length, shoot length and shoot water contents. The shoot length showed higher and positive correlation with roots per plant and shoot water contents. The shoot water contents showed strong positive correlation with root length and root water contents. The correlation of seedling traits indicated that the shoot and root length may be used for the selection of higher yielding maize genotypes under salt stress conditions. The higher shoot and root length caused to increase photosynthetic rate in leaves and accumulation of organic matters in seedling body due to which the growth and development of maize seedlings improved even under salt stress conditions (Ali et al., 2016; Ali et al., 2014a; Ahsan et al., 2013; Anwar et al., 2013; Araus et al., 2002; Aslam et al., 1999).

Table 2. Correlation analysis among morphological traits of maize seedlings

Traits	Leaf area	Roots per plant	Root length	Shoot length	Shoot water contents
Roots per plant	0.4341*				
Root length	0.6532*	0.2092			
Shoot length	0.0452	0.2861*	0.2093		
Shoot water contents	0.3231*	0.4298*	0.9024*	0.3142*	
Root water contents	0.2084	-0.2556	-0.2542	0.2435	0.4762*

* = Significant at 5% probability

CONCLUSION

The higher genetic advance and heritability for root length indicated that the selection of maize genotypes for salt stress may be helpful to improve yield under stress conditions. It was suggested from our study that the use of B-316 as salt tolerant genotype could be useful for improving yield of grain and production under the salt stress environment.

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