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Original Research

GENETIC ASSOCIATION AMONG MORPHOLOGICAL TRAITS OF *ZEA MAYS* SEEDLINGS UNDER SALT STRESS

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Abstract: *Zea mays is an important cereal crop which has been used by human from last thousands of years as grain crop. It is very sensitive for drought, heat, cold, salinity and heavy metals toxicity. For evaluating corn for salt stress we have conducted an experiment in the greenhouse of IMBB, University of the Lahore. Four maize genotypes were selected for our research work, viz., B-316, EV-1097Q, Raka-poshi and Sahiwal-2002 under the treatments of salt were kept as following: control, 0.2Molar NaCl, 0.5Molar NaCl, 0.7Molar NaCl and 1Molar NaCl. The selection of genotypes for high shoot and root length under treatments 0.5Molar NaCl, 0.7Molar NaCl may be fruitful for the improvement of crop production and productivity. It was found from results that the B-316 performed better under all stress treatments for seedling traits as compared with EV-1097Q and Sahiwal-2020 maize genotypes. The results showed that higher genetic advance and heritability was recorded for both root length and shoot length. The significant and positive correlation was recorded among root length, shoot length, root dry weight and shoot dry weight. The regression analysis showed that the higher contribution for shoot length was found for root length. It was concluded from our study that the selection of maize genotypes may be fruitful on the basis of root length and shoot length to improve grain yield under salt stress conditions.*

Keywords: *Zea mays*, salt stress, genetic advance, regression analysis, root length

Introduction

The maize (Zea *mays* L.) as one of an important leading cash and food crops in the world occupied a significant role and position among all of the cultivated crop cultivars of cereal plants (Boomsma et al., 2009). The cultivation or growing of maize is a symbolic of the green revolution which has played an important and pivotal role for fulfillment of nation food and nutrient requirements. It is one of the most important among all of the worldwide fodder as well as food crop plants; in terms for its cultivated crop area which is 0.973 m ha along with production of grain is 3.707 m tones however it has productivity potential up to 3805 kg ha^{-1} (Anonymous, 2018). It has ability to be grown as below as sea level up to 5000 m of altitude along with the areas where the rainfall is in the 300-1130 mm range. The grain availability for maize is increasing due to increasing population affects since (Ali et al., 2012; Buckler et al., 2009). The growing area of maize has been decreasing through every year while very low expectation of increasing area and production in coming future. Therefore, there is an urgent requirement or need for vertical or continuous increase for fodder and grain yield/hectare for insuring the household and livestock food and fee security throughout the world (Edreira and Otegui, 2012; Mustafa et al., 2013; Mustafa et al., 2018). It has been noted that the current climatic effects caused a change in the relation for wheat has become inconclusive along with the model dependent in maize growth, development, grain productivity and yield (Farooq et al., 2015; Saif-ul-malook et al., 2014). It has been found form various research works on climatic changing effects that the increase in temperature and rainfall are interlinked with each other, the increase in the temperature is also causing drought along with salt stress in the temperate, tropical and subtropical regions of the world, there is an average increase in temperature up to 3-4°C till end of 21st century throughout the world and South East Asia continent (Gavaghan et al., 2011; Khalil et al., 2020; Mazhar et al., 2020; Zubair et al., 2016). The present study was carried out to evaluate the effects of salt stress on maize seedling morphological traits and association among them.

Materials and methods

For evaluating maize for salt or NaCl stress, we have conducted an experiment in the greenhouse of Institute of Molecular Biology and Biotechnology, The University of Lahore, Lahore. Four maize genotypes were selected for our research work, *viz.*, B-316, EV-1097Q, Raka-poshi and Shawil-2002. The seeds of selected wheat genotypes were sown in 56 pots. Each of the pot was in triplicate for each of the maize genotype. The treatments of salt were kept as following: T0 (control no any type of treatment), T1 (0.20Molar NaCl), T2 (0.5Molar NaCl), T3 (0.7Molar NaCl) and T4 (1Molar NaCl). The seeds were sown and after germination, the seedlings were given stress treatments after one week of germination. The salt treatment was carried out through the application of 200ml water to normal or control plants while 100ml to the plants under salt stress. The seedling data was recorded for diverse morphological traits, *viz*., leaf area, roots per plant, dry root weight, root length, shoot length, shoot dry weight. The recorded data was analyzed statistically through the analysis of variance (ANOVA) techniques through using the SPSS23.1 software.

Results and discussions

It was found from results that the all of the maize genotypes showed 100% survival under control conditions while it was found that by increasing salt concentrations the performance of maize genotypes for survival under salt stress was decreased. The genotype B-316 showed better survival under all stress conditions. It was also found from results that du tot increasing salt stress the survival of maize genotypes was decreased. The results from table 2 showed that there were significant differences among the treatments, genotypes and the interactions of treatments and genotypes. It was found that the lower coefficient of variance was recorded for all of the studied traits which revealed that there was consistency among the results of all studied traits (Ashraf et al., 2020; Khalil et al., 2020; Mazhar et al., 2020). The lower coefficient of variance also indicated that the results were reliable for the selection of resistance genotypes of maize against salt effects. The average leaf area under all of the studied traits was recorded as 5.821±0.0112cm^2, while average roots per plant (7.017±0.0106), dry root weight (0.372±0.0011g), dry shoot weight (0.3423±0.0012g), root length (19.231±1.2352cm) and shoot length (8.123±0.0235cm) were recorded. It was indicated from results that the higher root length and shoot length under effects of salt revealed the plant tolerance and the chance of selecting maize genotypes against salt stress. The higher genetic advance was recorded for dry shoot weight (12.383%), root length (19.231%) and shoot length (27.469%) while higher heritability was recorded for all of the studied traits especially dry shoot weight (91.242%), root length (94.235%) and shoot length (96.245%). The higher genetic advance and heritability revealed that the selection may be fruitful to improve grain yield and production of maize under salt stress conditions.

Table 1. Survival percentage of maize genotypes under different salt stress conditions

Treatments	B-316	Raka-poshi	EV-1097Q	Sahiwal-2002
Control (T0)	100	100	100	100
0.2Molar NaCl (T1)	93.24	88.34	93.25	92.23
0.5Molar NaCl(T2)	90.57	82.24	87.26	89.34
0.7Molar NaCl (T3)	89.47	79.56	83.75	81.46
1Molar NaCl (T5)	86.34	77.43	80.24	78.65

Table 2. Genetic components for morphological traits of maize seedlings

Source	LA	RPP	DRW	DSW	RL	SL
Replication	0.0004	0.0267	0.0192	0.0014	0.0041	0.0028
Genotypes	6.0246*	8.1911*	17.671*	2.0171*	9.9432*	8.2231*
Treatments	0.3215 *	7.2451*	6.924*	11.013*	7.7023*	14.2280*
Genotypes × treatments	0.1420 *	3.123*	9.0241*	6.0151*	11.1026*	9.4014*
Error	0.0022	0.0011	0.0711	0.0018	0.0011	0.0031
Grand Mean	5.821	7.017	0.372	0.34231	19.231	9.261
Coefficient of variance (%)	2.37	3.232	3.56	5.432	6.213	8.123
Standard Error	0.0112	0.0106	0.0011	0.0012	1.3241	0.0235
Genetic advance	8.541	7.252	7.391	12.383	17.2443	27.469
Broad sense heritability	89.234	87.535	90.128	91.242	94.235	96.245

* = Significant at 5% probability level, DRW = dry root weight, FRW = fresh root weight, RL= root length, SL = shoot length, RPP = roots per plant, LA = leaf area

The results from table 3 indicated that the higher shoot length of B-316 was found higher under control and 1Molar NaCl treatment (8.560cm, 8.556cm) respectively, root length (19.360cm) under 1Molar NaCl, leaf area (5.770cm^2), number of roots (6.660), shoot dry weight (0.290g) and root dry weight (0.281g) under 0.7Molar NaCl concentration. The higher shoot length (9.710cm) of Raka-poshi was

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found along with higher root length (22.140cm) and leaf area (6.950cm^2) under 1Molar NaCl, while, number of roots (6.660) and shoot dry weight (0.360g) under 0.7Molar NaCl and root dry weight (0.350g) under 0.2Molar NaCl concentration. The higher shoot length (8.66cm) of EV-1097Q was found along with higher root length (22.560cm) and leaf area (7.10cm^2) under 0.5Molar NaCl, while, number of roots (7.860) and shoot dry weight (0.330g) under 0.2Molar NaCl and root dry weight (0.332g) under 1Molar NaCl concentration. The higher shoot length (9.622cm) of Sahiwal-2002 was found along with higher root length (18.464cm) and leaf area (7.453cm^2) under 0.2Molar NaCl, while, number of roots (7.564), shoot dry weight (0.321g) and root dry weight (0.327g) under 1Molar NaCl concentration. The higher root length under salt stress conditions indicated that the plants showed tolerance against salt stress and helped to improve shoot length of maize seedlings under salt stress conditions (Mazhar et al., 2020; Mupangwa et al., 2007; Mustafa et al., 2013). The selection of maize genotypes on the basis of higher root length and shoot length may be helpful to improve the salt stress tolerance in maize genotypes and selected genotypes may be used for the development of maize hybrids and synthetic varieties (Ali et al., 2013; Ali et al., 2016; Masood et al., 2015).

Table 3. Mean comparison for maize genotypes under different salt concentrations

Genotypes	Treatments	SL	RL	LA	NR	SDW	RDW
B-316							
	Control (T0)	8.560a	18.660b	4.670b	6.660a	0.280b	0.275b
	0.2Molar NaCl (T1)	7.550b	18.200c	4.680b	6.460b	0.275c	0.276b
	0.5Molar NaCl(T2)	8.558a	18.660b	4.660b	6.660a	0.278c	0.280a
	0.7Molar NaCl (T3)	8.560a	19.260a	5.770a	6.660a	0.290a	0.281a
	1Molar NaCl (T5)	8.559a	19.360a	5.750a	6.560b	0.290a	0.269c
Raka-poshi							
	Control (T0)	7.679c	19.540b	5.920b	6.610b	0.350b	0.329c
	0.2Molar NaCl (T1)	9.710a	17.040c	5.850b	7.710a	0.360a	0.350a
	0.5Molar NaCl(T2)	8.706b	17.140c	5.840b	7.710a	0.358b	0.348b
	0.7Molar NaCl (T3)	8.709b	17.140c	5.860b	7.610a	0.360a	0.349b
	1Molar NaCl (T5)	7.679c	22.140a	6.950a	6.610b	0.338c	0.341b
EV-1097Q							
	Control (T0)	9.667a	17.360c	6.040c	7.960a	0.328b	0.339a
	0.2Molar NaCl (T1)	8.66b	17.36c	6.06c	7.86a	0.33a	0.33c
	0.5Molar NaCl(T2)	7.64c	22.56a	7.15a	6.96b	0.309c	0.331c
	0.7Molar NaCl (T3)	7.641c	22.36a	7.15a	6.86b	0.308c	0.333c
	1Molar NaCl (T5)	8.662b	18.16b	6.26b	6.86b	0.33a	0.332b
Sahiwal-2002							
	Control (T0)	7.522d	17.24c	6.346b	7.454a	0.332a	0.322c
	0.2Molar NaCl (T1)	9.622a	18.464a	7.453a	7.324b	0.321b	0.314d
	0.5Molar NaCl(T2)	9.612b	16.758d	6.354b	6.243c	0.311b	0.325b
	0.7Molar NaCl (T3)	7.521d	18.256b	6.453b	7.564a	0.321b	0.327a
	1Molar NaCl (T5)	8.532c	16.885d	7.543a	7.345b	0.301c	0.311e

DRW = dry root weight, DSW = dry shoot weight, RL= root length, SL = shoot length, RPP = roots per plant, LA = leaf area

The results from table 4 revealed that there was a significant correlation between number of roots and leaf area, dry root weight, and root length. The positive and significant correlation was found between leaf area and dry root weight, root length and number of roots per plant. The root length was significantly and positively correlated with leaf area, shoots length, number of roots per plant, dry root weight, dry shoot weight while negatively and significantly correlated with dry shoot weight. The shoot length was positively and significantly correlated with dry shoot weight and root length. The significant and positive correlation of root length, shoot length, dry root weight indicated that the selection of maize genotypes for improving grain yield and productivity under salt stress conditions may be helpful (Ali et al., 2014; Ali et al., 2011; Saif-ul-malook et al., 2014).

Table 4. Correlation among morphological traits of maize

Traits	LA	RPP	DRW	DSW	RL
RPP	0.7654*				

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DRW	0.3776*	0.6769*			
DSW	0.0344	-0.0834	-0.0553		
RL	0.5867*	0.7863*	0.8536*	-0.3739*	
SL	-0.6556	0.0463	-0.2038	0.7948*	0.8948*

* = Significant at 5% probability level, DRW = dry root weight, FRW = fresh root weight, RL= root length, SL = shoot length, RPP = roots per plant, LA = leaf area

The regression analysis was carried out to find out the contribution of different traits to improve shoot length (Table 5), it was found that the higher contribution for improving shoot length was recorded for root length (7.544) followed by dry shoot weight (3.113) and leaf area (1.231) while negative contribution was reported for dry root weight (-1.130) and number of root per plant 9-0.003). The positive contribution indicated that the shoot length will also be increased due to increase in the root length, leaf area and dry shoot weight. The coefficient of determination was recorded as 68.23% while revealed that selection of maize genotypes may be helpful to improve grain yield and production under salt stress conditions however the process of selection may be delayed for more improvements in traits of maize genotypes (Ali et al., 2016; Buckler et al., 2009; Khalil et al., 2020; Tahir et al., 2020). The regression equation predicted may be written as Y = 1.217+7.544(RL)=1.231(LA)-1.130(DRW)+3.113(DSW)-0.003(RPP)

Table 5. Regression analysis for shoot length among morphological traits of maize

Traits	Coefficients	Standard Error	t Stat	Partial R^2	Lower 95%	Upper 95%
RL	7.544	0.0023	-0.0231	0.8643	0.0023	0.036
LA	1.231	0.0112	0.2324	0.3352	-0.0351	0.3524
DRW	-1.130	0.0212	1.3643	0.1356	-0.0235	0.3235
DSW	3.113	0.0232	-5.5356	0.0133	1.3156	2.3532
RPP	-0.003	0.104	0.4903	0.6235	-0.0235	0.0546

Y = 1.217, Multiple R^2= 0.8534, R^2 = 0.6823, Adjusted R^2 = 0.6424, Standard Error = 0.0231 DRW = dry root weight, FRW = fresh root weight, RL= root length, RPP = roots per plant, LA = leaf area

Conclusions

It was concluded from our study that the B-316 performed better under all stress treatments for seedling traits as compared with EV-1097Q and Sahiwal-2020 maize genotypes. The correlation and regression analysis showed that the selection of maize genotypes for improving grain yield and production under slat stress conditions on the basis of root length, shoot length and shoot dry weight may be fruitful.

Conflict of interest

The authors declare absence of any conflict of interest.

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