Abiotic Stress Tolerance in Maize (*Zea mays* L.) at Early Growth Stage

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Abstract

Abiotic stress is environmental factor adversely affecting early growth and yield in Pakistan including world. Maize (*Zea mays* L.) is an important cereal crop which is a principal source of food and is grown extensively in Pakistan and other areas of the world. The laboratory experiment was conducted in Completely Randomized Design with treatments viz; 00 control, 100, and 150 *mM* NaCl including three replications in the Department of Food Science and Technology,Hamdard University, Karachi, Pakistan**.** Maize seedlings were treated with 00*mM* control, 100 and 150 *mM* NaCl solution. The results showed minimum seed germination (61.66%), root and shoot length (16.67 and 4.23mm), fresh weight root and shoot (0.36 and 0.39mg), dry weight root and shoot (0.11 and 0.08mg), under 150*mM* NaCl stress. In the variation of time period and salinity levels are significantly (<0.05) affected upon the seedling growth in the maize. The highest seed germination (87.77%), root and length (43.47 and 17.25mm), fresh weight root and shoot (1.29 and 0,98mg), dry weight root and (0.35 and 0.26mg), observed at 96 hours. However, significantly (<0.05)highest seed germination (64.44%), while lowest root and shoot length (4.62 and 1.1mm), fresh weight root and shoot (0.30 and 0.24mg), seedling dry biomass (yield) of root and shoot (0.09 and 0.06mg) were also significantly (<0.05) higher at 24 hours as compared to control and other treatments with effect by interaction of time duration and salinity stress.

Keywords

Abiotic stress, growth, maize, seedling, yield.

1. INTRODUCTION

Maize *(Zea mays* L.*)* also known as corn, is a large grain plant first domesticated by indigenous people in Mexico about 10,000 years ago. Maize is an important cereal crop in the world, which is the basic need of food and oil for human consumption. It is also widely used for feed and

industrial raw material. Maize ranks third in world production following wheat and rice for the area and production. It is also used as feed for livestock throughout the world but this crop is normally susceptible to salt stress. Salinity is the most important abiotic stress that inhibits growth and productivity of crop and it is one of the world's oldest and most widely distributed environmental challenges. Due to excessive concentration of soluble salts in the soil which suppresses plant growth (Zaki,2011). Increased salinity is a stringent problem and a major limiting factor for crop production around the globe (Wahid *et al.,* 2007). Among the cereal species maize *(Zeamays* L.*)* seems to be sensitive to salt stress (Maas *et al.,*1986). It is being increasingly cultivated in Pakistan on a large scale for fodder and grain purpose. Its cultivation area is expanding to area having high potential for accumulation of salts. It is important to develop new varieties with high genetic capacity to salinitystress tolerance. (Mohammadi *et al.,*2008). Seed sowing generally considered the first critical and most sensitive stage in the life cycle of plants and are frequently exposed to unfavorable environmental conditions that may compromise the establishment of seedling (Fiqueiredo-e-Albuquerque and Carvalho, 2003; Misra and Dwivedi, 2004). Changes in plants that are stressed by salinity has been repeated, many plants undergo osmotic regulation when they are exposed to salt stress by increasing the negativity of the osmotic potential of the leaf sap (Rodriguez *et al.,*1997; Gama *et al*., 2007, Stoeva, 2008). The effect of salt on plants growth evident as a connection between the reduced plant length and the raised in sodium chloridelevels (Beltagi *et al*., 2006; Mustard and Renault, 2006; Gama *et al*., 2007; Jamil *et al.,* 2007; Houimli *et al.,* 2008;Rui *et al*., 2009; Memon *et al*., 2010). Many studies have shown that the fresh and dry weight of the shoot system are affected, either negatively or positively, by change in salinity concentration, type of salt present or type of plant species (Jimenez *et al*., 2002; Jamil *et al*., 2005; Niaz *et al.,* 2005, Saqib *et al*., 2006, Turan *et al.,*2007, Saffan, 2008, Rui *et al.,* 2009, Taffouo *et al.,* 2010, Memon *et al.,* 2010). The salinity tolerance is not a simple attribute, but it is an outcome of various factors that depend on different physiological interactions, which are difficult to determine. The morphological appearance presented by the plant in response to salinity, may not be enough to determine its effect, so it is important to recognize other physiological and chemical disorders as well as the interaction between these various salinity stresses (Munns, 1993, Munns, 2002, Neumann,1997, Yao, 1998 Hasegawa *et al,* 2000). In the present study, the response of abiotic stress tolerance at early growth stage in maize has been adhered.

2. MATERIAL AND METHODS

The present investigation was conducted at the Department of Food Science and Technology, Hamdard University, Karachi.Seeds of Maize (Pakafgoi) variety were acquired from Agriculture Research Institute (ARI) Tandojam.The experiment was conducted under optimal laboratory condition by Complete Randomized Design (CRD). The treatments with three replications were applied for different salinity levels 00 control, 100 and 150 *mM* NaCl and different time duration for 24, 48, 72 and 96h of incubation at 25ÚC±2,by testing on maize variety (Pakafgoi).

2.1. SEED PREPARATION

Approximately (20gPakafgoi) maize seeds

were surface sterilized with (2%) Sodium hypochlorite to avoid any fungal infection during germination for 5-15 minutes and washed thoroughly with distilled water (Khan, 1980). The experiment was conducted under controlled conditions for determining the early seedling growth behavior. Ten seeds were placed between two layers of blotting paper in petri dish 9cm diameter. Seven *ml* solution of 100 and 150 *mM* NaCl was treated to each petri dish. Petri dishes were covered with lid and incubated at 35ÚC ± 2. The petri dishes were kept in controlled incubator tor 24, 48, 72 and 96h. Then after 24hrs germination percentage (GP) was observed, root and shoot lengths were recorded in control and treated groups (<1mm). This experiment was done in 24hrs till 96hrs and obtained readings each time duration germination% measured by following equation.

$$\text{Germination\%} = \frac{\text{Number of germinated seeds}}{\text{Number of total sown seeds}} \times 100$$

Seed germination (%),shoot length (mm), root and shoot growth rate (mm/h), root and shoot fresh weight (mg), root and shoot dry weight (mg).

2.2. STATISTICAL ANALYSIS

The data recorded was subjected to analysis of variance (ANOVA) of complete randomized design (CRD). Least significant difference (LSD) method was used to test differences between treatment means at 5% probability level.

3. RESULTS

The percentage of seed germination of Pakafgoi at 100 and 150 *mM* and mean germination time are presented in Table-1. The highest seed germination (90%) wasobserved in control (non-treated) followed by (89 and 61%) at 100 and150 *mM* NaCl solutions.

Table 1. Effect of different salinity levels on seed germination (%) of maize at different duration of time.

Salinity treatment (NaCl)	Germination periods (h)				
	24	48	72	96	Mean
Control	80.0	90.0	93.3	100	90.167 A
100	73.3	90.0	92.3	93.3	89.167 A
150	40.0	66.6	70.1	70.0	61.667 B
Mean	64.44 B	82.2 A	85.56A	87.78 A	

	Salinity	Time duration	Time duration X Salinity
SE	4.09	4.73	8.19
LSD 5%	8.49	9.81	16.9

The shoot length mm at different salinity levels 100 and 150 *mM* at different duration of time 24, 48, 72 and 96h are presented in Table-2. The highest shoot length (8.8mm) was observed at control (non-treated) followed by (5.3 and 4.2mm) 100 and 150*mM* respectively. The time duration showed significant effect on salinity levels. The significantly (P<0.50) highest shoot length (17.25mm) at 96h and the lowest shoot length was (1.11mm) recorded at 24h respectively. Interaction with time duration and salinity remained significantly effective on shoot as concentration increases shoot length decreases.

Table 2. Effect of various salinity levels on shoot length (mm) at different duration of time.

Salinity treatment (NaCl)	Germination periods (h)				
	24	**48**	**72**	**96**	**Mean**
Control	2.00	4.44	4.82	12.1	8.84 A
100	0.66	1.08	3.70	13.1	5.38 A
150	0.66	2.33	2.36	6.5	4.23 A
Mean	1.11 B	2.62 B	3.63 B	17.25 A	

	Salinity	**Time duration**	**Time duration Salinity**
SE	3.95	4.56	7.90
LSD 5%	8.20	9.47	16.4

Table-3 shows the different sodium chloride concentrations 100 and 150 *mM* at various time duration 24, 48, 72 and 96h on fresh weight root of maize. The highest fresh weight of root (0.84mg) was observed at control (non-treated) followed by (0.76 and 0.36mg) at 100and 150*mM* levels. Whereas, the maximum fresh weight of root was(1.29mg) at 96h and the minimum (0.30mg) was found at 24h. The root fresh weight significantly(P<0.50) responded on the interaction of time duration and salinity. Whereas the results of fresh weight of shoot at various concentrations of NaCl 100 and 150 *mM* and different time duration 24, 48, 72 and 96h presented in Table-4. The highest fresh weight shoot (0.70mg) was observed at control (none-treated), followed by (0.44 and 0,39mg) when treated with 100 and 150*mM* concentrations. However, the significantly (P<0.50) highest fresh shoot weight(0.98mg) at 96h and the lowest shoot fresh weight (0.24mg) were obtained at 24h respectively. The interaction of time duration into salinity suggested significantly affect the shoot fresh weight.

Table 3. Effect of several salinity concentrations on fresh weight of root (mg) at different duration of time.

Salinity treatment (NaCl)	Germination periods (h)				
	24	**48**	**72**	**96**	**Mean**
Control	0.41	0.51	0.89	1.76	0.84 B
100	0.36	0.48	0.73	1.65	0.76 A
150	0.14	0.15	0.22	0.46	0.36 A
Mean	0.30 c	0.41 c	0.61 B	1.29 A	

	Salinity	**Time duration**	**Time duration X Salinity**
SE	0.05	0.06	0.10
LSD 5%	0.10	0.12	0.21

Table 4. Effect of different salinity levels on fresh weight of shoot (mg) at different duration of time.

Salinity treatment (NaCl)	Germination periods (h)				
	24	**48**	**72**	**96**	**Mean**
Control	0.33	0.45	0.67	1.84	0.70 A
100	0.21	0.27	0.42	0.35	0.44 B
150	0.18	0.25	0.38	0.76	0.39 C
Mean	0.24 D	0.32 C	0.49 B	0.98 A	

	Salinity	**Time duration**	**Time duration X Salinity**
SE	2.33	2.69	4.66
LSD 5%	4.85	5.58	9.66

The results of dry weight roots showed different concentrations of NaCl 100 and 150 *mM*and different time duration 24, 48, 72 and 96h presented in Table-5. The highest dryweight root(0.24mg) was observed at control (non-treated) followed by (0.20 and 0.11mg) at 100 and 150*mM* NaCl concentrations. The significantly (<0.05) maximum dry weight root (0.35mg) at 96h and minimum dry weight of root was recorded (0.09mg) at 24h, respectively. The interaction of time duration into salinity affects the root dry weight in maize.

Table 5. Effect of diverse salt concentrations on dry weight of root (mg) at different duration of time

Salinity treatment (NaCl)	Germination periods (h)				
	24	**48**	**72**	**96**	**Mean**
Control	0.11	0.14	0.18	47	0.24 B
100	0.11	0.15	0.24	38	0.20 A
150	0.05	0.07	0.20	36	0.11 C
Mean	0.09 D	0.12 C	0.18 B	0.35 A	

	Salinity	**Time duration**	**Time duration X Salinity**
SE	0.01	0.01	0.02
LSD5%	0.02	0.02	0.04

Table-6 depicts the outcome of dry weight shoot at various concentrations of NaCl 100 and 150 *mM* and different time duration 24, 48, 72 and 96h. The maximum dry weight shoot was observed (0.16mg) at control (non-treated) followed by (0.14 and 0.08mg) when 100 and 150mM concentrations were applied to maize seedlings.

Whereas, the higher dry weight shoot (0.26mg) at 96h and the lowest dry weight shoot (0.06mg) recorded at 24h, respectively. The interaction of time duration and salinity adversely affects dry weight shoot. The variety of Pakafgoi showed germination (89 and 61%), shoot length noted (5.3 and 4.2mm), fresh weight root (0.76 and 0.36mg), fresh weight shoot (0.44 and 0,39mg), dry weight root (0.20 and 0.11mg) and dry weight shoot (0.14 and 0.08mg) noted at 100 and 150*mM* NaCl concentrations as compared to control (non-treated). Interaction with time duration and salinity remained effective as salinity level increases germination %, shoot length, fresh weight root, shoot, dry weight root and shoot decreases.

Table 6. Effect of different salinity levels on dry weight of shoot (mg) at different duration of time.

Salinity treatment (NaCl)	Germination periods (h)				
	24 h	48 h	72 h	96 h	Mean
Control	0.08	0.10	0.15	0.31	0.16 A
100	0.08	0.10	0.16	0.32	0.14 A
150	0.04	0.05	0.08	0.15	0.08 B
Mean	0.06 D	0.08 C	0.13 B	0.26 A	

	Salinity	Time duration	Time duration X Salinity
SE	2.72	3.14	5.44
LSD 5%	5.64	6.51	0.01

4. CONCLUSION

It is concluded that highest seed germination (89%) and lowest (61%) on 100 and 150*mM* NaCl solution as compared to control (non-treated).The maximum seed germination (87.7%) at 96h and the lowest 64.4% recorded at 24h time duration, respectively.The highest shoot length (5.3mm) and lowest shoot length (4.2mm) was recorded when treated with 100 and 150*mM* NaCl concentrations,respectively as compared to control (non-treated). Highest fresh weight root and shoot was (1.29mg) and (0.44mg) was calculated at 100 and 150*mM* concentrations respectively.The highest dryweight root and shoot (0.20mg) and (0.14mg). Whereas, lowest dry weight root and shoot (0.11mg) and (0..08mg) noted at 100and 150*mM* NaCl concentrations, respectively as compared to control (non-treated).The maximum dry weight root(0.35mg) and dry weight shoot (0.98mg) was obtained at 96h time duration. However, overall interaction of time period and salinity could suggest that if the concentration of NaCl increases the germination and seedling growth will be affected adversely. The maize variety Pakafgoi recommended to be grown in field condition having soil EC less than 100 *mM*.

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