Effects of Salt Stress on the Germination, Water Content and Seedling Growth of *Zea mays* L.

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ABSTRACT

Salt stress is one of the most severe environmental factors that reduces and limits growth and development of plants. The aim of this experiment is to examine the effect of NaCl on the germination, water content and seedling growth of Zea mays L. Seeds of Zea mays were germinated in Petri-dishes which had been lined with Whatman No 1 filter papers. The filter paper in each of the Petri-dishes allocated to the control was moistened with ten milliliters of distilled water while that of the Petri-dishes allocated to the other treatments were moistened with ten milliliters of 10mm, 20mm and 30 mm concentrations of the NaCl solution. The germination percentage, water absorption of the seeds, water content of the seedlings and the growth parameters were determined according to conventional methods. The germination and growth parameters of NaCl treated seedlings were significantly inhibited at $P < 0.05$. The inhibition of the germination percentage, germination rate, water content, growth and biomass accumulation of the seedlings were observed to increase significantly with increasing NaCl concentration.

Keywords: *Zea mays, salt stress, inhibition, water content, germination, seedling growth.*

INTRODUCTION

As a sessile organism, plants often experience abiotic stress like salinity, drought, high or low temperature, flooding, metal toxicity, ozone, UV-radiations, herbicides, etc., which pose a serious threat to the crop production (Bhatnagar-Mathur, Vadez and Sharma, 2008; Ahmad and Prasad, 2012a, Ahmad and Prasad, 2012b). Zhu (2001) states that nearly 20% of the world's cultivated area and nearly half of the world's irrigated lands are affected by salinity. According to Mahajan and Tuteja (2005), increased salinity of agricultural land is expected to have destructive global effects. Baccio, Navari-Izzo and Izzo (2004) state that the introduction of salt tolerant plants is one of the ways to utilize the waste saline water and lands. The salt tolerance of plants varies with the type of salt and osmotic potential of the medium (Kayani and Rahman, 1988). It is reported that plants growing under saline conditions are affected in three ways: reduced water potential in root zone causing water deficit, phytotoxicity of ions such as Na^+ and Cl^- and nutrient imbalance depressing uptake and transport of nutrients (Munns, 2002a). Maize (*Zea mays* L.) is the third most important cereal in the world after wheat and rice, and grows under a wide range of climatic conditions (Khodarahmpour, 2011). It is used as food for human consumption as well as food grain for animals (Moussa, 2001). It is moderately sensitive to salinity and considered as the most salt-sensitive of the cereals (Ashraf and McNeally, 1990). Among the stages of the plant life cycle, seed germination and seedling emergence and establishment are key processes in the survival and growth of plants (Hadas, 2004). It is well established that salt stress has negative correlation with seed germination and vigor (Rehman, Harris, Bourne and Wilkin, 2000).

According to Khan and Weber (2008), higher level of salt stress inhibits the germination of seeds while lower level of salinity induces a state of dormancy. Salinity has many-fold effects on the germination process: it alters the imbibitions of water by seeds due to lower osmotic potential of germination media (Khan and Weber, 2008), causes toxicity which changes the activity of enzymes of nucleic acid metabolism (Gomes-Filho *et al*., 2008), alters protein metabolism (Dantas, De SaRibeiro and Aragão, 2007), disturbs hormonal balance (Khan and Rizvi, 1994) and reduces the utilization of seed reserves (Othman, Al-Karaki, Al-Tawaha and Al-Horani, 2006). Seed germination, seedling emergence, and their survival are particularly sensitive to substrate salinity (Baldwin, Mckee, and Mendelssohn, 1996). Grieve and Suarez (1997) observe that high levels of soil salinity can significantly inhibit seed germination and seedling growth due to the combined effects of high osmotic potential and specific ion toxicity.

Germination rate and the final seed germination according to Hadas (1977), slow down with the decrease of the water movement into the seeds during imbibitions. High salinity may inhibit root and shoot elongation due to the lower water uptake by the plant (Werner and Finkelstein, 1995). Demir and Arif (2003) state that the root growth was more adversely affected as compared to shoot growth by salinity. According to McKensie and Leshen (1994), the effect of salinity on plant water relations, nutritional imbalance and ion toxicity are responsible for the inhibition of growth and as a consequence decrease in plant yield. Rehman, Harris, Bourne and Wilkin (1996) state that intolerance to salinity may result in physiological and biochemical disorders which prevent or delay germination or cause abnormal seedlings. Generally the growth of plant is reduced by salinity but may vary from species to species in their tolerance (Munns and Termaat, 1986). Therefore, the objective of this study is to examine the effect of salt stress on the germination, water content and seedling growth of *Zea mays* L.

MATERIALS AND METHOD

The seeds of the test plant were selected randomly on the basis of uniformity of size. The selected seeds were then soaked for five minutes separately in 5% sodium hypochlorite to prevent fungal infection and they were rinsed for about five minutes in running tap water. Ten of the seeds were placed in each of the clean oven dried Petri-dish which had been lined with a Whatman No 1 filter paper. The filter paper in each of the Petri-dishes allocated to the control was moistened with ten millilitres of distilled water while that of the Petri-dishes allocated to the other treatments were moistened with ten millilitres of the appropriate concentrations of the salt solution. The Petri-dishes were incubated at room temperature for two weeks. Emergence of one millimeter of the radicle was used as the criterion for germination. Water uptake was recorded for 12 hours. Water uptake percent was calculated by the formula according to Mujeeb-ur-Rahman, Umed, Mohammad and Shereen (2008).

$$WU = \frac{W_2 - W_1}{W_1} \times 100$$

Where: W_1 = Initial weight of seed
W_2 = Weight of seed after absorbing water in a particular time.

Germination percentage (GP) was calculated according to the International Seed Testing Association (ISTA) method:

$$GP = \frac{number\ of\ normally\ ger\min ated\ seeds}{total\ number\ of\ seeds\ planted} \times 100$$

Germination rate (GR) was determined by the following equation (Sarmadnia, 1996):

$$GR = \frac{X_1}{Y_1} + \frac{X_2 - X_1}{Y_2} + \cdots \frac{X_n - X_n - 1}{Y_n}$$

Where X_n is the number of germinated seeds at the *n*th day and
Y_n *is* the number of days from sowing until the *n*th sowing time.

The tissue water content (TWC) was calculated according to the formula of Black and Pritchard (2002)

$$TWC = \frac{Fresh\ weight - dry\ weight}{Fresh\ weight} \times 100$$

The plumule length, radicle length, radicle fresh weight and plumule fresh weight of each plant were determined according to conventional methods. The data obtained were analysed by Analysis of Variance (ANOVA) to determine significant ($P< 0.05$) effects. The significant differences between means were determined using Duncan's Multiple Range Test DMRT.

RESULTS AND DISCUSSION

The percentage germination of the control was 80% while that of the 10mm, 20mm and 30mm NaCl regimes were 54%, 36% and 20% respectively. The percentage germination increased as the salt concentration decreased. ANOVA showed that the reduction of the germination of the seeds by the different salt solutions was significant at $P < 0.05$. There was significant difference among the germination of the seeds in the 10mm, 20mm and

30mm NaCl regimes. Decrease and delay in germination in saline medium have also been reported by Rahman, Kayani and Gul (2000) and Mirza and Mahmood (1986). According to Mujeeb-ur-Rahman, Umed, Mohammad and Shereen (2008), salinity affects germination in two ways: there may be enough salt in the medium decrease the osmotic potential to such a point which retard or prevent the uptake of water necessary for mobilization of nutrient required for germination; the salt constituents or ions may be toxic to the embryo. Cramer, Alberico and Schmidt (1994) suggest that ion ratios are important in determining relative toxicities of various ions and can provide insight into ion antagonisms. According to Wilson, Lesch and Grieve (2000), the increase in salinity shortens this ratio and probably caused injury to embryo. The control had the highest germination rate of 2.50 this was followed by that of the 10mm NaCl regime which was 1.45. Water uptake by the seeds decreased with increase in salinity of the medium. According to Khan and Weber (2008), salinity alters the imbibitions of water by seeds due to lower osmotic potential of germination media. The reduction in water absorption into the seeds could be responsible for the decrease in the germination and germination rate of *Zea mays* observed in this study.

The radicle and plumule length were reduced by the application of the salt solution. This was consistent with the finding of Munns and Termaat (1986) who state that the growth of a plant is generally reduced by salinity. The result showed that the salt solutions reduced the water content of the test crop. Water content of the seedlings decreased with increasing salt concentration. Osmotic effects of salt on plants are the result of lowering of the soil water potential due to increase in solute concentration in the root zone. The accumulation biomass in the control test crop was significantly higher than that of the seedlings in the NaCl regimes. This was consistent with the finding of Gururaja-Rao *et al*. (2005) who state that salinity decreased biomass production.

Table 1: Effect of NaCl on the Germination and Growth of *Zea mays*

Treatments	% Germination	Germination rate	Radicle length (cm)	Plumule length (cm)
Control	80 ± 1.58[a]	2.50 ± 0.16[a]	10.50 ± 0.32[a]	8.95 ± 0.63 [a]
10mm	54 ± 2.65[b]	1.42 ± 0.09[b]	5.80 ± 0.34[b]	6.60 ± 0.31[b]
20mm	36 ± 0.63[c]	1.31 ± 0.06[b]	3.50 ± 0.32[c]	4.00 ± 0.32[c]
30mm	20 ± 0.63[d]	0.58 ± 0.12 [c]	2.10 ± 0.09[d]	3.60 ± 0.32[c]

Values within columns followed by same letter are not significantly different at 5% level of probability as determined by Duncan's multiple range test ± SE

Source: Experimentation, 2012

Table 2: Effect of NaCl on the water absorption and water content of *Zea mays*

Treatments	Water absorption %	Tissue water content %
Control	30.33 ± 1.58[a]	70.00 ± 0.63[a]
10mm	20.49 ± 0.63[b]	62.64 ± 1.15[b]
20mm	22.36 ± 1.26[b]	45.15 ± 1.58[c]
30mm	18.76 ± 0.94b	34.69 ± 1.26[d]

Values within columns followed by same letter are not significantly different at 5% level of probability as determined by Duncan's multiple range test ± SE

Source: Experimentation, 2012

Table 3: Biomass accumulation in *Zea mays* as affected by the different concentrations of NaCl

Treatment	Radicle fresh weight (g)	Plumule fresh weight (g)	Radicle dry weight (g)	Plumule dry weight (g)
Control	1.17 ± 0.31^{a}	2.53 ± 0.31a	0.10 ± 0.02^{a}	0.28 ± 0.01^{a}
10mm	1.00 ± 0.06^{a}	2.25 ± 0.33^{a}	0.06 ± 0.01^{b}	0.21 ± 0.01^{b}
20mm	0.32 ± 0.02^{b}	1.81 ± 0.07^{b}	0.03 ± 0.01^{c}	0.17 ± 0.01^{c}
30mm	0.10 ± 0.11^{b}	1.24 ± 0.11^{b}	0.01 ± 0.01^{c}	0.11 ± 0.02^{d}

Values within columns followed by same letter are not significantly different at 5% level of probability as determined by Duncan's multiple range test ± SE.

Source: Experimentation, 2012

Table 4: Analysis of variance results to show the effect of NaCl on germination, water absorption and water content of *Zea mays*

Parameter	Source of Variation	df	F	Sig.
Germination Percentage	Between Groups	3	254.943	.000
	Within Groups	16		
	Total	19		
Germination rate	Between Groups	3	65.684	.000
	Within Groups	16		
	Total	19		
Water absorption	Between Groups	3	19.362	.000
	Within Groups	16		
	Total	19		
Water content	Between Groups	3	174.429	.000
	Within Groups	16		
	Total	19		

Source: Experimentation, 2012

Table 5: Analysis of variance results to show the effect of NaCl on the growth of *Zea mays*

Parameter	Source of variation	df	F	Sig.
Plumule length	Between Groups	3	35.508	.000
	Within Groups	16		
	Total	19		
Radicle length	Between Groups	3	164.232	.000
	Within Groups	16		
	Total	19		
Plumule Fresh Weight	Between Groups	3	4.059	.025
	Within Groups	16		
	Total	19		
Radicle Fresh Weight	Between Groups	3	35.450	.000
	Within Groups	16		
	Total	19		
Plumule Dry Weight	Between Groups	3	56.622	.000
	Within Groups	16		
	Total	19		
Radicle Dry Weight	Between Groups	3	20.734	.000
	Within Groups	16		
	Total	19		

Source: Experimentation, 2012

CONCLUSION

Results of this experiment showed that different levels of NaCl have significant effect on seed germination and early seedling growth of *Zea mays*. Considering the retardatory effects of NaCl on the germination and growth of *Zea mays*, important features like increased germination capacity have to be explored in programs to select and/or develop tolerant cultivars that are able to remain productive at saline soils to make possible the utilization of waste saline water. Future research should be directed towards elucidating the physiological, biochemical and molecular basis involved in regulating growth and carbon reallocation during salinity stress.

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