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Response of maize (*Zea mays* L.) to sodium chloride concentrations at early growth stages

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Abstract

The present study was conducted to investigate the effect of NaCl concentrations on seed germination and seedling growth of maize (*Zea mays* L.). Laboratory and pot experiments were conducted in 2014 using maize seeds obtained from Ministry of Agriculture Central Darfur State, Sudan. Ten seeds were germinated in Petri dishes containing filter paper of 9cm diameter, whereas in the pot experiment, five healthy seeds were allowed to germinate in plastic pots containing loamy soil. Treatments comprised of control (distilled water), 0.5%, 1.0%, 1.5% and 2% of sodium chloride (Na Cl). Treatments were arranged in completely randomized design (CRD) with 4 replications. Data recorded for the both experiments were subjected to analysis of variance (ANOVA). Least Significant Differences (LSD) method was used to test differences between treatments means at 5% and 1% probability levels. Results of the laboratory experiment showed that the number of germinated seeds was significantly affected by salinity level, especially by the higher salt concentration. Final germination percentage and seedling vigor index decreased with increasing salinity level. The highest seed germination percentage (97.5%) and seedling vigor index (2.49) were found with the control (0% NaCl) and the lower seed germination percentage (22.5) and seedling vigor index (0.05) were found with 2% concentration. Results indicated that the plumule length decreased significantly ($p \leq 0.01$) as concentration of NaCl increased. The radical length followed the same trend of the plumule length, it was decreased significantly ($p \leq 0.01$) as NaCl increased. Results of statistical analysis of pot experiments revealed that salinity made highly significant effects ($p \leq 0.01$) for the investigated traits. It was observed that the highest seed germination percentage (95%), seedling vigor index (23.3), plumule length (24.7 cm), radical length (26.2 cm) plumule fresh and dry weights (1.95 & 0.24 g/plant) and radical fresh and dry weights (1.66 &0.203 g/plant) were observed in 0%NaCl (control). No seeds germinated in the 1% and above NaCl treatments.

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Introduction

Maize or corn (*Zea mays* L.) occupies a key position as one of the most important cereals both for human and animal consumption. It is not only a food product, maize-derived products have been used in various aspects in our daily life. The crop is grown under various conditions in different parts of the world. The worldwide production of maize is 785 million tons; most maize production in Africa is under rain fed. In Sudan, maize is normally grown as a rain-fed crop in Kordofan, Darfur and in small irrigated areas in the Northern States (Ahmed and El Hag, 1999). In view of its increasing importance, improvement in agronomic characteristics of maize has received considerable attention in Sudan, especially in salt affected soils (Idris and Abuali, 2011). Soil salinity is one of the major environmental stresses that adversely affect plant growth and development. More than 800 million hectares of land throughout the world (approximately 7%) are salt affected, either by salinity (397 million ha) or the associated condition of sodicity (434 million ha) (FAO, 2005, Szabolcs, 1994, Zhu, 2001 and Sozharajan and Natarajan, 2014). The productivity of crops is adversely affected by high salt content in most of the soils (Alam *et al.*, 2000). Effects of salinity are more obvious in arid and semiarid regions where limited rainfall, high evapotranspiration, and high temperature associated with poor water and soil management practices are the major contributing factors (Azevedo Neto *et al.*, 2006). Salinity affects plants through osmotic stress and ion imbalance and toxicity (Munns and Tester, 2008). Osmotic effects are due to salt-induced decrease in the soil water potential. High salts inside the plant take time to accumulate before they affect plant function.

Plants have developed a wide range of mechanisms to sustain crop productivity under salt stress. Crops such as cotton and barley can produce acceptable yields at much greater soil salinity levels than crops such as corn and soybeans. This is because certain crops can make osmotic adjustments that enable them to extract more water from saline soil (USDA-NRCS, 2011). Germination and seedling characteristics are the most viable criteria used for selecting salt tolerant plants. One of the commonest experiments is to study germination of the seeds is application of NaCl to seed and seedling media (Khodarahmpour, 2013). Among the cereal species, maize (*Zea mays* L.) seems to be more sensitive to salt stress (Maas *et al.*, 1986). Salinity affects the crop adversely during germination and early growth stages (Carpici *et al.*, 2009). Much research on maize has been carried out in other agronomic charachters mainly taking into account the yield of grain, (Khatoon *et al.*, 2010, Sozharajan and Natarajan, 2014, Farsiani, and Ghobadi, 2009 and Abd El-Samad and Shadadd, 2013). However, there was a lack of information on the response of maize especially in early growth stagesunder semi-srid conditions in Sudan. With this economic importance and variability in salt tolerance among genotypes, a high-throughput method to screen salt tolerance and the development of maize varieties for salt tolerance for salt-affected areas is urgently needed.

The aim of this study was to evaluate germination parameters and early seedling growth of maize under different salinity conditions.

Materials and methods

Effect of salt stress induced by different levels of Na Cl on germination and early seedling development of maize was studied in 2014. A laboratory and pot experiments were conducted in Biology Laboratory and the Nursery of the Faculty of Forestry, University of Zalingei. Maize seeds were obtained from the Ministry of Agriculture Central Darfur State. Pretreatment germination and purity tests were done for the crop seeds. Germination percentage (GP) was calculated by the flowing equation:

GP = Number of germinated seeds / number of total seeds ×100 (Ilori *et al.*, 2012).

The treatments comprised of control (distilled water), 0.5%, 1.0%, 1.5% and 2% of sodium chloride (NaCl).The treatment solutions were prepared by solving NaCl in distilled water. Treatments were arranged in completely randomized design (CRD) with 4 replications.

Laboratory experiment

Each experimental unit included a Petri dish contains filter paper of 9 cm diameter with 10 seeds. 5 ml solution of each concentration was applied to each Petri dish as per treatment and the control plates received same volume of distilled water devoid of any salt. All Petri dishes were kept at room temperature .The counting of germinated seeds started from the 4th day after placing seeds .The seeds were considered germinated when radicals appeared and are visible enough to be counted. Germination count was made through the experimental period until all the seeds were either germinated and / or dead. *Pot*

Experiment

Five healthy seeds were allowed to germinate in plastic pots containing loamy soil; the planted seeds were irrigated with the test solution for the five treatments (distilled water 0.0% NaCl as control, 0.5%1%, 1.5% and 2%NaCl). From the 7^{th} day the germinated seeds were counted daily in specific time (at early morning). At that time, those seeds were considered germinated when the plumule was sprouted of the soil. Counting continued till there was no new germinated seeds appear. At the end of the experiment seedling length was measured from the soil surface to the newly grown leaf. Plants were removed from the pots carefully then the radical length was measured.

Parameters measured

The parameters measured include number of daily germinated seeds, germination percentage (calculated by the equation above), seedling length, root length and seedling vigor index (SVI).

Statistical analysis

The data recorded for the both experiments were subjected to analysis of variance (ANOVA) of complete randomized design (CRD). Least Significant Difference (LSD) method was used to test differences between treatments means at 5% and 1% probability level (Gomez and Gomez, 1984).

Results and discussion

Laboratory experiment

Results of the laboratory experiment showed that the number of germinated seeds was significantly affected by salinity level, especially by the higher salt concentrations (Fig. 1). The less number of germinated seeds during the germination period was obtained at 2% (2.3), for 1.5%, 1.0% and 0.5% NaCl concentrations, (3.3), (6.8) and (8.8) germinated seeds, respectively, were recorded compared to control (0% NaCl) which recorded (9.8). Results in (Table 1 and Fig.2) indicated that final germination percentage and seedling vigor index decreased with increasing salinity level.

Table 1. Effect of NaCl concentration on seed germination and seedling growth parameters.

Treatments	FGP	SVI	PL(cm)	RL(cm)
0%NaCl	97.5a	2.5a	2.6a	8.6a
0.5% NaCl	87.5b	1.0b	1.1b	2.9b
1% NaCl	67.5c	0.4c	0.5c	1.6c
1.5% NaCl	32.5d	0.1c	0.3d	0.6d
2% NaCl	22.5e	0.1c	0.2e	0.4d
C.V%	16.7	24.7	24.5	19.7
LSD	7.71**	0.31**	0.17**	0.43**

Note: * and ** indicate significant difference at 5% and 1% probability level respectively, FGP: Final germination percentage. PL: Plumule length .RL: Radical length.SVI: Seedling vigor index, PFW: Plumule fresh weight.PDW Plumule Dry weight. RFW: Radical fresh weight .RDW: Radical dry weight.

The differences between treatments were highly significant ($p \leq 0.01$). The highest seed germination percentage (97.5%) and seedling vigor index (2.49) were found with the control (0% NaCl) and the lower seed germination percentage (22.5) and seedling vigor index (0.05) were found with 2% concentration. Germination percentage and seedling vigor index decreased in 2% NaCl concentration by 76.9% and

98% from control for Germination percentage and seedling vigor index respectively, while the reduction in the other treatments from control were 66.7% ,30.8% and 10.3% in 1.5%,1.0% and 0.5% NaCl for germination percentage and 96.4%, 85.9% and 61.4% for seedling vigor index respectively.

Table 2. Result of variance analysis of germination percentage and seedling growth parameters.

	Mean square							
S.O.V.	FGP	SVI	PL(cm)	RL(cm)	PFW(g)	RFW(g)	PDW(g)	RDW(g)
Treatments	13.36*	79.11**	50.23**	31.18**	78.78**	32.5**	100**	16.28**
CV%	17.5	19.8	18.96	19.6	18.2	29.3	17.5	41.9
LSD(0.05)	11.71	2.46	2.76	3.20	0.20	0.26	0.022	0.046

Legends as in Table 1

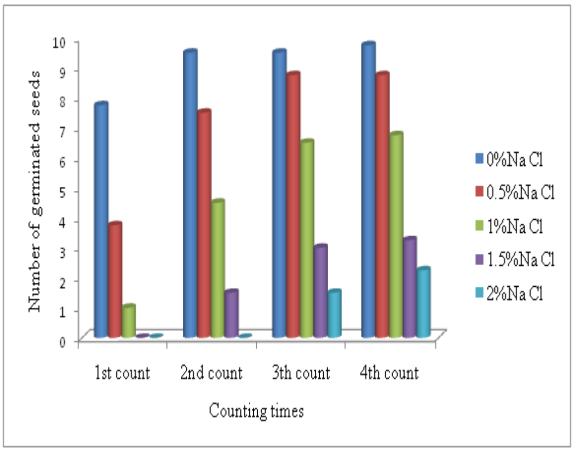

Fig. 1. Effect of Na Cl concentration on the number of germinated seeds.

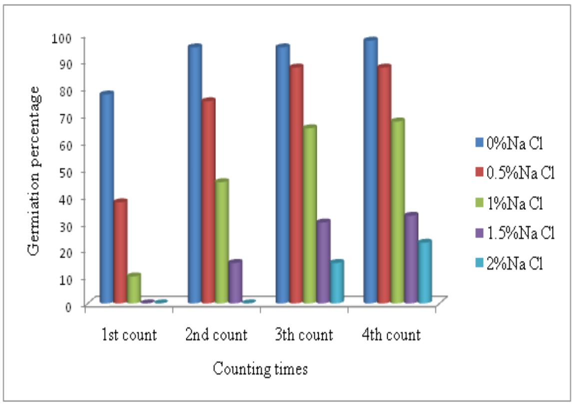

Fig. 2. Effect of Na Cl concentration on germination percentage.

The effect of salinity on seed germination was clearly demonstrated in this study, low level of salinity (control) increased germination percentage and seedling vigor index, these parameters decreased as the level of salinity increased. It was observed that salinity level above 1% NaCl delayed seed germination by 24 and 48 hours for 1.5% and 2% NaCl concentrations respectively, high salinity levels inhibit the seed germination significantly (Plate 1) .This agrees with previous records of Khodarahmpour1 *et al*, (2012) that maximum reduction in germination percentage (77.4%), germination rate (32.4%) and seed vigor (95%) of maize were obtained in highest level of salinity (240 mM). Similar results were obtained by (Arslan *et al,* 2013) that NaCl led to a decrease on germination rate and germination index of sorghum. Ibne Hoque *et al.*, (2014) found that Germination percentage (GP), germination speed (GS), germination index (GI, seed vigor index (SVI) and salt tolerance index (STI) were all decreased as the level of NaCl was increased**.** Verse to these results was recorded by Gharoobi *et al.*, (2012) that germination rate was not affected by osmotic potential. Considering germination percentage, only osmotic potential of -0.50 reduced germination percentages of corn seeds. Results in Table 1 indicated that the plumule length decreased significantly ($p \leq 0.01$) as concentration of NaCl increased. The tallest plumule was obtained by the control (2.6 cm) flowed by 0.5% (1.1 cm), 1.0% (0.5 cm), 1.5 %(0.3 cm) respectively, and the shortest one in 2% NaCl concentration (0.2 cm). The radical length followed the same trend of the plumule length it was decreased significantly ($p \leq 0.01$) as NaCl increased. These results agreed with (Khodarahmpour *et al.*, 2012) findings that maximum reduction in length of radical (79.5%), plumule (78%) and seedling length (78.1%) were obtained in highest level of salinity. Similar results were obtained by Radić *et al.*, (2007).

Plate 1. Effect of NaCl concentration on seed germination.

Pot experiment

Results of statistical analysis of pots experiment have been given in Table (2). Results of variance analysis revealed that salinity made highly significant effects ($p \leq 0.01$) for the investigated traits. It was observed that the highest seed germination percentage (95%), seedling vigor index (23.3), plumule length (24.7 cm), radical length (26.2 cm) plumule fresh and dry weights (1.95 & 0.24 g/plant) and radical fresh and dry weights (1.66 &0.203 g/plant) were observed in 0%NaCl (control). No seeds germinated in the 1% and above NaCl treatments, this might be attributed to the soil and environmental factors compared with controlled condition of the laboratory experiment. Results showed that all the parameters measured decreased with increasing salinity level, similar results were obtained by (Awad *et al.*, 2014; Khodarahmpour, 2013). Results indicated that maize is sensitive to salinity especially at germination stage, this confirmed by Maas *et al.*, (1986) statement that among the cereal species maize is seems to be more sensitive to salt stress. Ayres and Westcot (1985) reported that maize is a relatively sensitive to saline irrigation water. In the same line Ali *et al.,* (2014) recorded that the lower germination percentage (62.6% and 58.5%) was found with 1.5% NaCl concentration for sorghum and pearl millet respectively and no seeds germinated in the 2% NaCl treatment.

Conclusion

The current study indicates that the saline growth medium had an adverse effect on germination and growth parameters of maize. The growth inhibitory effect of Na Cl was more pronounced in 2% Na Cl as compared to the 0 and 0.5% Na Cl. Application of NaCl significantly decreased seed germination, germination percentage, seedling vigor index, plumule length, radical length, fresh and dry weights of plumule and radical of maize in laboratory and pot experiments. Salinity effect under field condition may not be the same due to the variation in environmental and soil condition, so field experiment should be conducted to confirm the results.

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