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The effects of salt stress on seed germination of some maize (*Zea mays* L.) genotypes

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Abstract

Maize (*Zea mays* L.) is the plant which has high seed capacity for seed germination but germination ability under salt stress is scarce. To study effect of salt stress on maize seed germination ability experiment with 2 hybrids and 2 local maize population was conducted. It was analyzed the effect of different NaCl concentrations of 50 , 100 , 200 and 400 mM NaCl, and 50 100, 200 and 400 mM $CaCl_2$. The experimental design was random block with four replications and four treatments. Maize seeds were prepare for these purposes and after that they are located in seed germinator in temperature 22-25 °C. For each genotype were placed 25 seeds for each treatment with the double filter paper in 125 mm. The seed germination has varied depending on the treatments. The lowest germination was determined in high concentration on 400 mM for both salts (NaCl and $CaCl_2$). At all maize genotypes high salinity of 200, 400 mM of both NaCl and $CaCl_2$ caused decrease in seed germination. Hybrid genotypes and local maize populations treated by 400mM showed significantly (LSDp=0.01) lower germination ability.

Key words: maize, populations, stress, salt, seed germination

Introduction

Maize is the important cereal crop which is the basic need of food and oil for human intake. 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. Salinity is defined as the presence of an 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). Most of the water on the Earth contains about 30 g of sodium chloride per litre. This can make the Earth a really salty planet. This salt has affected, and is still affecting, the land on which crops might be grown (Flowers and Yeo, 1995; Munns, 2002). Salinity is also a threat to our food supply since most crop plants will not grow in high concentrations of salt. Only halophytes grow in concentrations of sodium chloride higher than 400 mM. Consequently, there is currently enough food for the world population but more than 800 million people are chronically undernourished (Conway, 1997). Growth of the human population by 50%, from 6.1 billion in mid-2001 to 9.3 billion by 2050, means that crop production must increase if food security is to be ensured, especially for those who live on about $1 per day (Flowers, 2004), cited by Zaki, 2011). The salt stresses affect badly to the plant morphology, functioning and homeostasis, and decrease the plant biomass (Parvaiz, 2014). 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. Salt stress had adverse effects on the functioning and metabolism of plants considerably hinders the productivity (Khan and Srivastava, 1998). Salinity has diverse outcome on plants; for example salt in the soil solution diminishes the accessibility of water to the roots and the salt reserved in the plant will raise to poisonous points in several tissues of plants (Munnus et al., 1995).

Salinity has an adverse effect on seed germination of many crops by creating anosmotic potential outside the seed inhibiting the absorption of water, or by the toxic effect of Na+ and Cl^- (Khajeh-Hosseini et al., 2003). Therefore, the objective of this investigation was to evaluate the effects of salt stress on seed germination of some maize hubrids and local maize population with a view to a better understanding of the mechanisms of salt tolerance in these genotypes.

Material and methods

Measurement of germination and physiological characteristics of seeds

The seeds of hybrid maize genotypes (BC-678 and BC-408) originating from Botinec Institute-Croatia, and seed of Local Maize Populations (LMP-3 and LMP-4) from Kosova, were used as testing material. The experiment included four 4 maize genotypes seeds treated with 50, 100, 200 and 400 mM NaCl and $CaCl_{2,}$ respectively as well as control treatment. Then, seeds were incubated in a germination chamber at 25 °C. For each genotype 25 seeds were used for each treatment. The seed germination ability were analyzed according to ISTA rules. The experiment was laid out in completely randomized block design with four replications. Then, the total germination percentage was calculated after ten days of seed germination.

The germination index and Mean Germination Time were calculated as $GI=\Sigma(\frac{GtGt}{TtTt})$ and $MGT=\Sigma(\frac{GtxTt}{\Sigma Gt})$, respectively (Zhang et al., 2007; Kaya et al., 2008; AOSA, 1983)

where G_t is the number of germinated seeds on Day t**,** T_t is time corresponding to G_t in days. While the Final germination Percent (FGP) was culculed as following formula:

$FGP=(\frac{Ng}{Nt}$ x 100)

where; Ng is total number of germinated seeds,

Nt is total number of evaluated seeds.

Statistical analyses:

The SPSS-19 software was applied to analyze the data. Statistical analysis was performed using a one way ANOVA (for P< 0.05). Based on the ANOVA test results, a Duncan test for mean comparison was performed, for a 95% confidence level.

Results and discussion

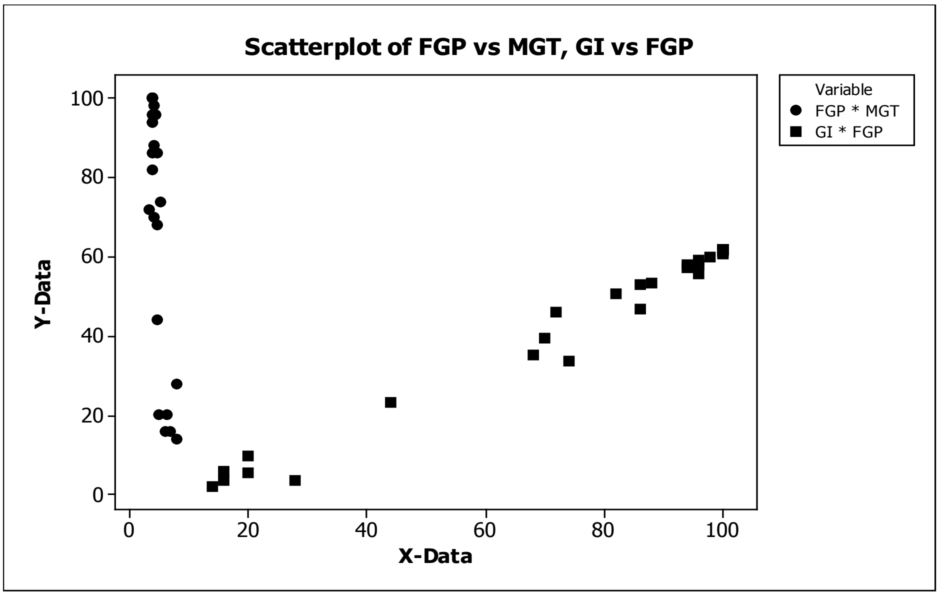
Examination of variance showed that salinity level has high effects on the studied parameters. Moreover, the differences of salinity level had significant effect on all parameters tested at LSDp=0.05 level of probability. The data on the effects of different concentrations and tretaments on maize seed germination are shown in Table 1.

Table 1. Effects of various salt concentrations on germination percentage in maize seed

Maize genotypes	Treatments	FGP(%)*		MGT*		GI*	
		NaCl	$CaCl_2$	NaCl	$CaCl_2$	NaCl	$CaCl_2$
BC-678	Control	98^{B}	96^{B}	4.01^{C}	4^{C}	59.36^{AB}	59.26^{AB}
	50 mM	100^{A}	100^{A}	4^{C}	4^{C}	61.73^{A}	61.73^{A}
	100 mM	100^{A}	100^{A}	4^{C}	4^{C}	61.73^{A}	61.73^{A}
	200 mM	100^{A}	96^{B}	4^{C}	4.09^{C}	61.73^{A}	57.88^{B}
	400 mM	44^{C}	16^{D}	4.62^{B}	6.88^{A}	23.10^{C}	3.58^{C}
Average		88.4	81.6	4.12	4.41	53.53	48.83
BC-408	Control	100^{A}	100^{A}	4^{D}	4^{D}	61.73^{A}	61.73^{A}
	50 mM	100^{A}	100^{A}	4^{D}	4^{D}	61.73^{A}	61.73^{A}
	100 mM	100^{A}	100^{A}	4^{D}	4^{D}	61.73^{A}	61.48^{A}
	200 mM	100^{A}	96^{A}	4.02^{D}	4^{C}	61.03^{A}	55.83^{B}
	400 mM	74^{B}	20^{C}	5.26^{B}	6.50^{A}	33.61^{C}	5.23^{D}
Average		94.8	83.2	4.25	4.51	55.96	49.2
LMP-3	Control	98^{B}	100^{A}	4.01^{C}	4^{DE}	59.36^{AB}	61.73^{A}
	50 mM	100^{A}	100^{A}	4.04^{DE}	4^{DE}	60.53^{A}	61.35^{A}
	100 mM	94^{A}	98^{A}	4.02^{DE}	4.10^{CD}	57.30^{A}	59.87^{A}
	200 mM	72^{B}	68^{B}	3.42^{D}	4.67^{BC}	46.11^{B}	35.31^{C}
	400 mM	20^{C}	28^{C}	5.04^{B}	7.94^{A}	9.74^{D}	3.66^{E}
Average		96.8	96.4	4.1	4.94	46.6	44.38
LMP-4	Control	100^{A}	88^{BC}	4^{D}	4.07^{DE}	61.73^{A}	53.39^{B}
	50 mM	86^{C}	82^{C}	4^{E}	4^{E}	53.08^{B}	50.49^{B}
	100 mM	94^{AB}	96^{A}	4^{E}	4.13^{DE}	58.02^{A}	57.91^{A}
	200 mM	86^{C}	70^{D}	4.61^{C}	4.19^{D}	46.77^{C}	39.51^{D}
	400 mM	16^{E}	14^{E}	6.17^{B}	7.88^{A}	5.93^{E}	2.03^{F}
Average		56.64	52.4	4.55	4.85	45.1	40.66

*FGP as Full Germination time ; MGT as Mean Germination Time (days) ; GI as Germination Index.

The results showed that full germination time (FGT) were significantly influenced by salinity levels at (LSDp=0.05). At all maize genotypes, including local maize populations, high salinity of 200 and 400 mM NaCl or $CaCl_2$ caused decrease in seed germination. Results for FGT, for maize genotype which are sensitive to the high concentration of salt (NaCl and $CaCl_2$) was characterized LMP-4, which had the lowest germintaion on value 16%. If compare with hybrids (BC-678 and BC-408), the differences were highest (>50%). Results are given in Table 1. The different findings range of salt concentrations of NaCl and $CaCl_2$ was reported by Yohannes and Abraha, 2013, which varied from 10 till 94.5%). For FGT the mean concentration with NaCl showed maximum germination (83.9 %), while the average values for maximum germination for $CaCl_2$ was 78.4%. The differences between them were +5.5%. Obtained results of Kazem et al., (2011) at some different maize hybrids for FGT were on average values from 79 till 99%. The results obtained from this study suggested that increased salt stress results in NaCl and $CaCl_2$ has a direct influence on the seed germination capacity and other parameters. The study revealed that mean germination time (MGT) using different solutions can have significantly impact in seed performance by increasing of concentration. The hybrid BC-678 had lowest MGT in NaCl and $CaCl_2$ salt concentration, on average 4.12 and 4.41 days, respectivelly. The highest MGT for NaCl and $CaCl_2$ concentration had local maize populations (LMP-4), 4.55 days while for $CaCl_2$ and LMP-3was 4.94 days. If we make a comparison for MGT between maize genotypes BC-678, LMP-4 and LMP-3, the differences were significant. The differences between them to the two levels of concentration NaCl and $CaCl_2$ were +0.43 and +0.53 days respectively. Msuya and Stefano (2010), analysed some maize hybrids for MGT and obtained



Graph 1. Scatter plot of seed maize germination

results from 3.18 till 3.39 days. The wide variation was observed for the germination index (GI). The obtained results of GI showed high variation between studied maize genotypes. The high value for the GI (treatment with NaCl) obtained genotype BC-408 (55.96), while the lowest value obtained LMP-4 (45.1). The difference between them was +10.86, significantly higher. With high level concentration of $CaCl_2$ hybrid BC-408 had GI 49.2, while the lowest value was obtained at LMP-4 (40.66). The difference between them was +8.54, with high significance.

The proportion and differences between FGP, MGT, GI and FGP was analysed and full conection between them was obtained.

Conclusions

The differences were expressed on the basis of treatments and was affected by genotypes. The study involving NaCl and $CaCl_2$ application indicated that maize seed is sensitive on high salt concentration and in generall, inhibits seed germination. The high salt concentration of NaCl and $CaCl_2$ had a direct impact on traits FGP, MGT and GI. But, the other treatments with lower salt concentrations had nonsignificant effect. It was characteristic of the hybrid BC-408 that it exhibited higher average values for almost all traits under study. This study has allowed a better knowledge of the different salt concentration in maize seed.

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