Research Article

Screening of different maize (*Zea mays* L.) genotypes against salinity under hydroponics

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Citation

Munaza Batool, Muhammad Saqib, Muhammad Abdul Qayyum, Muhammad Jan, Syeda Amber hameed, Ahmad Kamran Khan, Athar Khaliq, Tayyaba Naz, Arif Hussain and Shafqat Nawaz. Screening of different maize (*Zea Mays* L.) genotypes against salinity under Hydroponics. Pure and Applied Biology. Vol. 9, Issue 1, pp1118-1129. <http://dx.doi.org/10.19045/bspab.2020.90117>

Received: 03/10/2019

Revised: 31/12/2019

Accepted: 07/01/2020

Online First: 30/01/2020

Abstract

Growth and development of a crop or even cultivars within a species of a crop respond to soil salinity since germination. Twenty the most growing varieties of maize (*Zea mays* L.) genotypes were used in this study. The sterilized and healthy seeds of twenty maize genotypes were sown in trays containing two inches' layers of gravel. The experiment comprised two levels i.e 100 mM NaCl was developed step wise with NaCl salt, whereas no salt was added in control for hydroponic experiment, designed in two factorials Complete Randomized Design (CRD) with three replications on four cultivars with the design of experiment was completely randomized with five replicates and factorial arrangement. Results showed that the highest shoot fresh and dry matter was produced by EV-5098 whereas the minimum shoot fresh and dry weight was produced by Pak-afgooe due to higher accumulation of Na⁺ in its leaves and lower concentration of K⁺ and K⁺: Na⁺ ratio which depreciated its performance. There is a significant increase in Na⁺ concentration while concentration of K⁺ and K⁺: Na⁺ ratio is significantly decreased under saline conditions. Results indicated that root and shoot length, number of leaves plant-1, fresh and dry mass production varied with NaCl stress which indicating that some cultivars of maize seedlings are highly susceptible to concentrated NaCl.

Keywords: Hydroponic; Maize; NaCl stress; Root length; Sensitivity and shoot length

Introduction

After wheat and rice, maize (*Zea mays* L.) is the third most important cereal crop in Pakistan. Salt-affected area in the world, is

1128 million hectare (Mha) [1], 226 Mha of land are irrigated [2]. Farmers grow maize (*Zea mays* L.) as an essential food grain in all climates from warm to tropical prevailed in

various parts of the world. World maize production was approx. 1067 million tons, in 2016 [3]. The stressful abiotic conditions such as water and salinity stresses and cold temperature, reduces its performance in terms of production, while the crop meets up human diet with the nutritional quality of the grain [4]. Therefore, study on the efficient technique can be developed for the purpose tolerance of maize cultivars to salinity through evaluation and selection of maize cultivars is a great necessity [5]. Salinity effect the crop is flexible at altered growth stages [6]. For resistance to salinity and drought at the seedling stage a very high genotypic variability in maize cultivars exists. For resistance to drought and salinity stresses diverse genotypes of the crop have also been selected [7]. At the germination stage maize crop transported high amount of Na^+ and Cl^- to the growing part of shoot and in course of time, Ca^{2+} and K^+ concentrations decreased in the tissues located in embryonic part [8]. Osmotic ion and oxidative stress are the effect of salinity on plant growth. Glycophytes and halophytes got adjusted

osmotically with the increase in accumulated solutes in inorganic and organic forms [9] which finally causes larger decrease in cell solute potential than external salinity. This may be recognized to balancing the accumulated organic solutes in the cytosol with the solute potential of the ions-dominated-vacuoles [10]. A progressive correlation between the adaptation to stress and osmolyte accumulation has been well documented. By different authors molecular mechanism of salt tolerance has been well accepted [11]. Therefore, present study was conducted to Screen out the different maize (*Zea Mays* L.) genotypes against salinity under Hydroponics conditions.

Materials and methods

Growing site

This research experiment was started in the airport campus of the Ghazi University Dera Ghazi Khan Punjab, Pakistan. The climate condition of the study area was hot summer (25- 50 °C) and cold winter (0-21 °C) with very low rainfall rate. Twenty varieties were selected on the basis of most cultivated varieties in our project area (Table 1).

Table 1. List of tested genotypes

Sr. No. 1	Tested varieties	Sr. No. 1	Tested varieties
1	Sahiwal 2002	11	32-B-33
2	Monsento6142	12	8711
3	8441	13	Ev-5098
4	FH-985	14	Etc
5	Monsento6542	15	FH-793
6	EV-78	16	FH-782
7	Sadaf	17	EV-77
8	EV-1098	18	32-M-15
9	32-T-16	19	6525
10	Pak-Afgoee	20	6143

Growing condition

In this study twenty genotypes of maize (*Zea mays* L.) were used. The healthy and sterilized seeds were sown in trays containing two inches' layers of gravel. After transplanting salinity level which was required i.e. 100 mM NaCl was developed step wise with NaCl salt, whereas in control no salt was added. The pH of solution was maintained between 5.5 and 6.5 with dilute solution of HCl and/or NaOH solution.

Data collection

After four weeks of transplanting plants were harvested and the data regarding

1-root/ shoot lengths,

2-root/shoot fresh and dry weights,

3-and ion contents (Na^+ and K^+) of the dry plant material was determined.

Analysis

The data were collected was analyzed using an appropriate statistical package. The design of experiment was completely randomized with five replicates and factorial arrangement.

Results

Shoot and root growth

Salt stress resulted in a significant weakening in shoot fresh and dry weights of all the maize genotypes (Fig. 1 & 2). The difference between treatments, genotypes and their interaction was significant for mutually these parameters. In the saline treatment they differed significantly from one and other however in the control treatment, genotypes did not differ significantly however in. Like root growth salinity caused the corresponding decline in the shoot growth as well (Fig. 3 & 4). For both root fresh and dry weights the main effects as well as their interaction were significant. Shoot and root length was also decreased due to salinity stress (Fig. 5 & 6). Although genotypes did not differ significantly from each other, however the treatments have significant

effect for shoot. *Ev-5098* produced more shoot and root length at 100 mM NaCl level as related to other genotypes and it was also statistically significant from all others. The salt stress and genotypes have significant effect on relative shoot fresh weight (Fig. 7). *Pak-afgoee* showed the minimum relative shoot fresh weight while the maximum relative shoot fresh weight was observed in *Ev-5098* that was 42 %.

Leaf ionic composition

Leaf Na^+ concentration increased significantly in all the genotypes due to Salinity (Fig. 8). The interactive as well as individual effects of genotypes and treatment were found significant. The comparison of all the genotypes under salinity treatment (100mM NaCl) indicated that *Ev-5098* and *Ev-78* stored significantly lower Na^+ as compared to other genotypes. In this treatment, the maximum Na^+ concentration ($0.7 \text{ mmol g}^{-1} \text{dwt}$) was found in the leaves of *Pak-afgoee*. At the same salinity level leaf Na^+ concentration was $0.68 \text{ mmol g}^{-1} \text{dw}$ in *Monsento-6525*. The concentration of K^+ as against of Na^+ decreased significantly at 100mM NaCl salinization (Fig. 9). The individual effects of treatments and genotypes as well as their interaction were found significant. In control treatment K^+ concentration was the higher than 100 mM NaCl. The comparison of genotypes at control and salinity level showed that *Ev-5098* accumulated more K^+ in leaf as compared to other genotypes. At 100 mM NaCl, leaf K^+ concentration was $0.38 \text{ mmol g}^{-1} \text{dwt}$ in *Ev-5098* where as in case of *Pak-afgoee* it was $0.25 \text{ mmol g}^{-1} \text{dwt}$. The $\text{K}^+ : \text{Na}^+$ ratio was the higher in control treatment than in 100 mM NaCl treatment. *FH-985* had higher $\text{K}^+ : \text{Na}^+$ ratio than all other genotypes under control treatments while *Ev-5098* had higher $\text{K}^+ : \text{Na}^+$ ratio than all other genotypes under saline conditions (Fig. 10).

Figure 1. Shoot fresh weight of different maize genotypes against NaCl salt stress

Figure 2. Shoot dry weight of different maize genotypes against NaCl salt stress

Figure 3. Root fresh weight of different maize genotypes against NaCl salt stress

Figure 4. Root dry weight of different maize genotypes against NaCl salt stress

Figure 5. Shoot length of different maize genotypes against NaCl salt stress

Figure 6. Root Length of different maize genotypes against NaCl salt stress

Figure 7. Relative shoot fresh weight of different maize genotypes against NaCl salt stress

Figure 8. Shoot Sodium concentration of different maize genotypes against NaCl salt stress

Figure 9. Shoot potassium concentration of different maize genotypes against NaCl salt stress

Figure 10. Shoot potassium to sodium ratio of different maize genotypes against NaCl salt stress

Discussion

This hydroponic study was directed to evaluate different maize genotypes for leaf ionic composition and their growth performance in response to salinity. This study shows that salt stress has a negative effect on the growth of all the genotypes of maize as there was a significant reduction in their growth parameters under salt stress (100 mM NaCl). According to [12] salinity is a primary environmental factor decreasing plant growth and yield. Decline in plant growth as a result of salinity condition has been reported in many species [13-15]. High salinity concentration interrupts several physiological processes of plants, which effects in reduction in plant growth and development [16]. Salinity decreases water potential in the maize leaves, plant height and stem dry mass [17]. It also affects xylem water transport, leaf elongation, root length and root hydraulic conductivity of maize [18, 19]. According to [20] salt stress significantly reduces the leaf area of maize, shoot length, fresh and dry weight of shoots with increasing intensity of salt stress.

The results of the present study indicated that under salinity concentration of K^+ and K^+ : Na^+ ratio is significantly decreased while there is a significant increase in Na^+ concentration. Under salinity accumulation of the toxic ions (Na^+) has been also observed earlier [21, 22]. In plants the main reason of growth reduction under salinity is the the presence of toxic Na^+ and Cl^- [23]. [24] showed that there is a negative relationship among the biomass of aerial organs and Na^+ content. So, in this study similar relationship has also been found (Fig. 11). [25] stated that salt tolerant maize genotypes have low shoot Na^+ concentration which shows that exclusion of Na^+ is positively related to salt tolerance in maize. Under salinity a high

Na^+/K^+ ratio in the tissues, disturbance of K^+ nutrition results in salt injury in many plants [25-28]. High concentration of potassium in leaf enables osmotic regulation with relatively less energy expenditure than the accumulation of compatible solutes [29, 30]. For more than 50 plant enzymes the K^+ is essential as a co-factor and these enzymes are mostly affected by high Na^+ and low K^+/Na^+ ratios [31].

Within saline treatment, genotypic variation has also been observed, the minimum shoot fresh and dry weight was produced by Pak-afgoee whereas the highest shoot fresh and dry matter was produced by EV-5098 due to higher accumulation of Na^+ in its leaves and lower concentration of K^+ and K^+ : Na^+ ratio which deteriorated its performance. Different genotypes also showed different relationship between growth and leaf ionic composition. Plant species and their genotypes differ greatly in growing under salt stress conditions [32, 33]. Maize is a major cereal crops and is relatively sensitive to salinity [34, 35] and this sensitivity depends upon the genotype [36]. Halperin *et al.* [36] reported 40% decline in dry weight of maize genotype when exposed to 100 mM NaCl salinity. According to [37], the maize genotype *Zea mays* L. proved to be more resistant than the Pioneer-3578. Maize genotypes G2 and SRO73 have been observed as more salt tolerant maize cultivars than the other in a long-term experiment [38, 39]. Saline environment results in a greater increase in cytoplasmic Na^+ content in the salt sensitive variety than in the resistant variety [40]. According to Hollington [41] salt resistant variety contains low Na^+ and high K^+ content as compared to salt sensitive variety. On the basis of these results Ev-5098 has been selected as salt tolerant and Pak-afgoee as salt sensitive maize genotypes.

Figure 11. Relationship between leaf Na⁺ and shoot dry weight (g plant⁻¹) of different maize genotypes

Conclusion

Twenty maize genotypes were evaluated in Hoagland's nutrient solution under treatments i.e. control and 100 mM NaCl. Regarding results of growth and ionic relations, significant differences were recorded among the maize genotypes. Results of this study revealed that salt tolerant genotypes (EV-5098) produced more shoot fresh and dry weights, had less accumulation of Na⁺ and showed higher K⁺:Na⁺ ratio, whereas less shoot fresh and dry weights and high accumulation of Na⁺ and lower K⁺:Na⁺ ratio was noted in the salt sensitive (Pak-afgoee).

Authors' contributions

Conceived and designed the experiments: M Batool, M Saqib & S Nawaz, Performed the experiments: M Batool, Analyzed the data: A Khaliq, T Naz & A Hussain, Contributed materials/ analysis/ tools: MA Qayyum & M Jan, Wrote the paper: M Batool, SA Hameed & AK Khan.

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