

SCREENING OF MAIZE GENOTYPES AGAINST POOR QUALITY WATER IN SOLUTION CULTURE

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ABSTRACT

An experiment was conducted in solution culture to understand the response of dissimilar maize (*Zea mays* L.) genotypes against salinity in green house at Saline Agriculture Research Centre, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan. Maize plants at two leaf phase were transplanted at three different levels of water salinity [(T₁ (Control) T₂ [EC 2.0 dS m⁻¹, SAR 15.0 (mmol L⁻¹)^{1/2} and RSC 2.25 mmol_cL⁻¹] and T₃ [EC 4.0 dS m⁻¹, SAR 25.0 (mmol L⁻¹)^{1/2}, RSC 5.0 mmol_c L⁻¹]. The mixtures of four salts (NaHCO₃, Na₂SO₄, CaCl₂.2H₂O and MgSO₄.7H₂O) were used to formulate saline water levels through quadratic equation. Half strength Hoagland's nutrient solution was applied for nourishment throughout experiment. After 30 days of salinity evolution, maize plants were harvested and data for shoot fresh weight, root fresh weight, shoot dry weight root dry weight, shoot length and root length were recorded. From leaf juice Na⁺ and K⁺ contents were resolute and K⁺: Na⁺ proportion was calculated. All the growing components of maize varieties were significantly abridged owing to salinity effects and genotypic dissimilarity for salt lenience was also noticed between the maize varieties. The genotypes Sahiwal-2002 and Afgoi were classified as salt lenient genotype as these produced the highest shoot biomass (21.6 g and 17.3g) and retained higher K⁺: Na⁺(0.90 and 0.67) ratio, however Sadaf, FH-963 and FH-722 were categorized as salt sensitive genotypes and produced the least shoot weight (8.8 g, 7.7g and 7.9g) and could retain the lowest K⁺: Na⁺(0.34, 0.19 and 0.21) proportions under salinity.

KEYWORDS: *Zea mays*; genotypes; salinity; screening; water solution; Hoagland's nutrient solution; Pakistan.

INTRODUCTION

The salinity is a foremost problem in arid and semi-arid areas, where irrigation is crucial for growing of crops. Main cause of salinity in these areas is poor quality saline irrigation water and inadequate irrigation handling (24, 9). About 800 m ha area is pretentious by salinity all over the world (21).

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Geographically, Pakistan is located in the arid and semi arid regions of the world. Almost 6.67 m ha soil is affected through salinity in Pakistan which is nearly one third of the total cultured area of Pakistan (16). Higher amount of composite mineral salts existing in irrigation water reduce the growth of crops. Maize crop is a significant cereal used by human and animal and is grown up in different climatic environments of the world. Its grain has abundant nutritious value and maize grain oil is used for food purpose while maize green fodder comprises great proportion of protein (12). Maize is a cross pollinated crop and can have abundant variability for salt tolerance. In our country due to increasing significance of maize, progress in its agronomic parameters has received massive attention; still more work is required to recognize maize varieties for saline soils (3, 20). Selection of huge number of genotypes of maize is essential to find salt tolerant germplasm for breeding purpose to develop new salt tolerant and high yielding maize varieties. This methodology includes understanding the reaction of plants at different growing stages in salt stress conditions, as described by Ali *et al.* and Khan *et al.* (7, 15). It also conveys indications to plant breeders observing for plants of financial significance with better salinity tolerance. This technique is comparatively easy, economical, less time consuming and provides consistent results (27). Keeping in view above observations, current research work was performed to classify 15 maize genotypes in hydroponic culture to find out best salt tolerant maize genotypes on the basis of their growing performance and leaf sap ionic contents that can be further cultured on salt affected soils.

MATERIALS AND METHODS

A hydroponic research trial was conducted in green house at Saline Agriculture Research Center, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan. Seed of 15 maize (*Zea mays* L.) genotypes were collected from Maize Millet Research Institute (MMRI) Yousafwala, Sahiwal and from Maize Research Station, Ayub Agricultural Research Institute, Faisalabad. Good quality seeds of 15 maize varieties (FH-421, FH-810, FH-793, FH-722, FH-985, FH-763, Sahiwal-2002, Golden, EV-1098, Afgoi, EV-5098, Sadaf, EV-6089, EV-6098 and Agati 2002) were sown in trays containing pre-washed sand. Water was applied daily in these trays to keep best moisture contents for seed growth. When plant growth reached at two leaf phase (after seven days of sowing), the plants of all maize genotypes were transferred in holes of thermo pole sheet with the support of foam covered at shoot root connection, moving on 200 liter water volume iron tubs. These water filled iron tubs were wrinkled with polythene

sheet and contained half strength Hoagland's nutrient solution (14). Appropriate air was supplied by bubbling air through nutrient solution for eight hours a day by aeration pump. The nutrient solution was altered weekly. After one week of transplantation three levels of water salinity i.e., T1 [control], T2 [EC 2.0 dS m⁻¹, SAR 15.0 (mmol L⁻¹)^{1/2} and RSC 2.25 mmol_cL⁻¹] and T3 [EC 4.0 dS m⁻¹, SAR 25.0 (mmol L⁻¹)^{1/2} and RSC 5.0 mmol_c L⁻¹] were established. The mixtures of four salts (NaHCO₃, Na₂SO₄, CaCl₂.2H₂O and MgSO₄.7H₂O) were used to formulate these poor quality water levels. The pH of solution was maintained to 6.5±0.5. The experiment was conducted in CRD factorial arrangements with three replications. After 30 days of salinity development, the plants were harvested manually and washed with tap water once and twice with distilled water. Then their roots and shoots were separated and data for shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, shoot length and root length were noted. The leaf samples from the youngest fully expanded leaves were collected, washed with distilled water and frozen. The frozen samples were crushed and leaf sap was collected. Na⁺ and K⁺ contents were determined by flame photometer from the leaf sap and K⁺: Na⁺ ratio was computed. To evaluate the salt tolerance of the studied genotypes a scoring system (from 1-15) was used for each parameter. The genotype with the best performance for a parameter was awarded 15 score and the genotype with the poorest performance for a parameter was awarded 1 score (4). On the basis of this the genotype scoring maximum was called as a salt tolerant and the genotype with minimum scores was called as a salt-sensitive genotype. The data obtained were analyzed statistically using 'MSTAT-C' (28) and the means were compared by standard error (31).

RESULTS AND DISCUSSION

Shoot weight

Shoot fresh and dry weight of all the maize varieties is given in (Table 1). Maize genotype FH- 985 produced the highest shoot fresh weight in control treatment and followed by SWL- 2002 and FH -793. In saline water (T₂) and saline sodic water (T₃) treatments, higher shoot fresh and dry weight was noted in SWL -2002, followed by Afgoi and Agati-2002. The lowest shoot fresh and dry weight was noticed in FH-722 and FH- 963 correspondingly in both saline environments. The decline in shoot fresh and dry weights could be due to reduced osmotic potential of plant roots and ion toxicity (23). According to Cicek and Cakirlar (11) saline water application results in a substantial reduction in shoot length, shoot fresh and dry weights and leaf area of maize. Tuna *et al.*, (31) also stated that saline environments decrease the overall dry matter, chlorophyll content and relative water contents in maize.

Table 1. Shoot fresh and dry weights of maize genotypes after four weeks exposure to saline/saline sodic.

Maize genotypes	Shoot fresh weight (g)			Shoot dry weight (g)		
	Control	EC2.0 SAR 15RSC 2.25	EC 4.0 SAR 25 RSC 5.0	Control	EC 2.0 SAR 15 RSC 2.25	EC 4.0 SAR 25 RSC 5.0
FH-421	30.3 ± 1.76	17.2 ± 0.96	9.1 ± 0.66	4.1 ± 0.10	3.3 ± 0.09	1.9 ± 0.04
FH-810	39.0 ± 1.53	22.0 ± 1.16	10.5 ± 0.87	4.4 ± 1.10	3.3 ± 0.11	2.0 ± 0.12
FH-793	44.5 ± 1.61	19.7 ± 1.45	8.2 ± 0.53	3.6 ± 0.15	2.8 ± 0.07	1.8 ± 0.04
FH-722	38.0 ± 1.15	11.6 ± 0.77	7.9 ± 0.79	4.0 ± 0.08	2.9 ± 0.09	1.7 ± 0.03
FH-985	58.6 ± 1.45	22.6 ± 1.24	15.1 ± 0.78	4.8 ± 0.23	3.4 ± 0.03	2.2 ± 0.03
FH-963	36.7 ± 1.45	13.2 ± 1.28	7.7 ± 0.59	3.2 ± 0.07	2.6 ± 0.19	1.3 ± 0.04
SWL-2002	45.7 ± 1.45	29.3 ± 1.45	21.6 ± 1.44	6.2 ± 0.03	5.1 ± 0.10	3.8 ± 0.07
Golden	28.2 ± 0.44	19.7 ± 1.20	10.0 ± 0.58	4.6 ± 0.16	3.4 ± 0.05	2.1 ± 0.11
EV-1098	30.8 ± 1.09	18.3 ± 1.20	9.0 ± 0.58	4.2 ± 0.15	3.4 ± 0.18	2.2 ± 0.04
Afgoi	43.4 ± 1.45	26.0 ± 1.15	17.3 ± 0.2	5.0 ± 0.08	4.1 ± 0.09	2.8 ± 0.12
EV-5098	31.3 ± 0.88	17.6 ± 0.87	13.3 ± 0.88	3.9 ± 0.19	3.0 ± 0.04	2.0 ± 0.07
Sadaf EV-6089	26.0 ± 1.15	15.7 ± 1.20	8.8 ± 0.60	3.5 ± 0.16	2.9 ± 0.04	1.7 ± 0.06
EV-6089	36.3 ± 1.45	16.9 ± 1.16	12.1 ± 0.91	4.3 ± 0.07	3.9 ± 0.20	1.8 ± 0.07
EV-6098	35.1 ± 1.16	22.1 ± 1.16	13.1 ± 0.58	4.4 ± 0.12	3.3 ± 0.09	2.0 ± 0.07
Agati-2002	33.7 ± 1.45	23.7 ± 1.20	15.3 ± 1.20	4.7 ± 0.22	3.8 ± 0.19	2.7 ± 0.03

Each value is an average of 3 replicates ± SE

The maize growing parameters like shoot fresh and dry weights, root fresh and dry weights are usually linked with salinity lenience at initial growth phases of crops and can be used as screening/selection standards for salt tolerance (17). Data concerning root length and shoot length (Table 2) reveal that saline water stress caused strong adverse effect on shoot and root length of maize varieties. However, the influence of salinity varied considerably among maize genotypes.

Table 2. Root and shoot length of maize genotypes after 4 weeks exposure to saline/saline sodic water.

Maize genotypes	Root length (cm)			Shoot length (cm)		
	Control	EC2.0 SAR 15RSC 2.25	EC 4.0 SAR 25 RSC 5.0	Control	EC 2.0 SAR 15 RSC 2.25	EC 4.0 SAR 25 RSC 5.0
FH-421	25.0 ± 1.53	12.0 ± 1.15	7.7 ± 0.33	91.3 ± 1.45	48.7 ± 1.20	32.7 ± 1.86
FH-810	27.0 ± 1.15	14.7 ± 0.88	8.7 ± 0.33	96.0 ± 2.08	52.0 ± 1.53	38.3 ± 2.03
FH-793	22. ± 1.15	10.7 ± 0.88	6.7 ± 0.33	84.7 ± 2.03	38.3 ± 1.20	29.7 ± 1.76
FH-722	21.7 ± 1.20	11.0 ± 0.58	6.3 ± 0.33	86.3 ± 2.03	45.0 ± 1.73	29.0 ± 1.53
FH-985	30.0 ± 1.15	18.3 ± 1.20	10.7 ± 0.33	105.7 ± 0.88	57.0 ± 1.53	43.0 ± 2.31
FH-963	25.3 ± 1.20	11.7 ± 1.20	6.7 ± 0.33	80.3 ± 1.20	41.3 ± 1.76	22.0 ± 1.53
SWL-2002	28.3 ± 0.88	21.7 ± 0.88	18.0 ± 0.58	101.7 ± 2.03	64.0 ± 1.53	53.3 ± 0.88
GOLDEN	19.0 ± 1.15	13.3 ± 0.88	8.0 ± 0.58	90.0 ± 1.73	48.7 ± 1.45	38.7 ± 1.76
EV-1098	19.3 ± 0.88	14.3 ± 1.20	8.3 ± 0.33	85.7 ± 1.45	45.3 ± 1.20	34.0 ± 1.53
Afgoi	24.0 ± 1.15	16.7 ± 0.88	11.3 ± 0.33	97.7 ± 1.76	54.3 ± 1.76	44.7 ± 2.03
EV-5098	19.7 ± 0.33	15.0 ± 1.15	8.3 ± 0.33	88.3 ± 1.86	48.7 ± 1.76	37.0 ± 1.15
Sadaf	18.0 ± 0.58	12.3 ± 0.88	7.3 ± 0.33	72.0 ± 1.73	40.0 ± 1.15	28.0 ± 2.08
EV-6089	20.0 ± 0.58	13.3 ± 0.88	8.0 ± 0.58	76.7 ± 0.88	43.3 ± 1.86	33.0 ± 1.53
EV-6098	21.3 ± 1.45	13.0 ± 0.58	9.0 ± 0.58	91.3 ± 1.45	44.7 ± 1.76	36.3 ± 1.45
Agati-2002	22.7 ± 1.45	15.0 ± 0.58	9.3 ± 0.33	93.0 ± 1.15	53.3 ± 1.20	41.7 ± 1.45

Each value is an average of 3 replicates ± SE

Maximum root and shoot lengths were also recorded by SWL -2002 in saline situations. Saline water treatments caused a substantial reduction in root

fresh and dry weights as compared to control, however decrease in case of saline sodic water application was even higher (Table 3).

Table 3. Root fresh and dry weights of maize genotypes after four weeks exposure to saline/saline sodic water.

Maize genotypes	Root fresh weight (g)			Root dry weight (g)		
	Control	EC2.0 SAR 15RSC 2.25	EC 4.0 SAR 25 RSC 5.0	Control	EC 2.0 SAR 15 RSC 2.25	EC 4.0 SAR 25 RSC 5.0
FH-421	5.3 ± 0.08	3.8 ± 0.06	3.0 ± 0.06	0.85 ± 0.06	0.39 ± 0.03	0.18 ± 0.01
FH-810	7.8 ± 0.46	5.1 ± 0.14	3.6 ± 0.08	0.90 ± 0.01	0.52 ± 0.05	0.23 ± 0.01
FH-793	6.0 ± 0.14	4.3 ± 0.07	2.9 ± 0.05	0.73 ± 0.04	0.49 ± 0.05	0.17 ± 0.01
FH-722	5.4 ± 0.35	4.7 ± 0.26	3.1 ± 0.10	0.76 ± 0.04	0.40 ± 0.03	0.20 ± 0.01
FH-985	8.2 ± 0.55	5.50 ± 0.14	3.8 ± 0.25	1.10 ± 0.07	0.61 ± 0.02	0.29 ± 0.02
FH-963	5.8 ± 0.08	3.7 ± 0.12	2.8 ± 0.04	0.68 ± 0.02	0.34 ± 0.04	0.14 ± 0.02
SWL-2002	8.5 ± 0.34	7.2 ± 0.21	6.1 ± 0.24	1.20 ± 0.02	0.91 ± 0.03	0.56 ± 0.03
GOLDEN	6.7 ± 0.30	5.2 ± 0.32	3.8 ± 0.24	0.94 ± 0.09	0.01 ± 0.03	0.27 ± 0.02
EV-1098	6.7 ± 0.59	5.3 ± 0.26	4.0 ± 0.16	0.78 ± 0.03	0.54 ± 0.04	0.28 ± 0.01
Afghi	8.1 ± 0.53	6.4 ± 0.27	5.1 ± 0.16	1.14 ± 0.03	0.86 ± 0.03	0.47 ± 0.03
EV-5098	6.2 ± 0.24	4.9 ± 0.21	3.8 ± 0.20	0.97 ± 0.07	0.66 ± 0.09	0.28 ± 0.02
Sadaf	5.2 ± 0.16	3.8 ± 0.07	2.9 ± 0.04	0.75 ± 0.04	0.44 ± 0.02	0.19 ± 0.01
EV-6089	5.7 ± 0.33	4.7 ± 0.23	3.3 ± 0.06	0.76 ± 0.04	0.54 ± 0.08	0.28 ± 0.02
EV-6098	6.7 ± 0.35	4.9 ± 0.28	3.6 ± 0.06	1.08 ± 0.08	0.61 ± 0.05	0.25 ± 0.01
Agari-2002	6.0 ± 0.33	4.6 ± 0.28	3.5 ± 0.20	1.01 ± 0.08	0.52 ± 0.04	0.37 ± 0.02

Each value is an average of 3 replicates ± SE

Root weight

The highest root fresh and dry weights were noted in FH -985, SWL -2002 and Afgoi in control treatment but differ non-significantly. On the other hand in saline water (T2) and saline sodic water (T3), higher root fresh and dry weights were noted in SWL -2002, followed by Afgoi and least root fresh and dry weights were noted in FH-963, Sadaf and FH-421, respectively. Higher level of salts decreases all the growing parameters in maize plants (18, 10). Plant roots supplies all important nutrients from growth medium to growing parts of plant. Roots have direct connection with solution medium so root response conveys very important information for salt tolerance in crops. Root fresh and dry weights were considerably reduced in brackish water treatments. These results agreed with Akram *et al.* (6) who reported that root dry weight of maize hybrids reduced under salt stress. Similar results were also noted by Turan *et al.* (32).

Leaf ionic composition

Leaf ionic composition of maize genotypes/varieties depicted a significant rise in Na⁺ concentration and reduction in K⁺, Ca²⁺ concentration, K⁺: Na⁺ and Ca²⁺: Na⁺ ratios due to salinity stress (Fig. 1, 2, 3, 4 and 5). The genotypes also varied considerably for the uptake of Na⁺, K⁺ and Ca²⁺ in their leaf. In brackish water treatments, lowest leaf Na⁺ contents were found in SWL-2002

and Afgoi, while FH-722 uptake higher Na⁺ contents in leaf sap. These genotypes also differed considerably for the uptake of Na⁺ in their leaf sap (Fig. 1). Salt tolerant maize varieties uptake less shoot Na⁺ concentration which displays

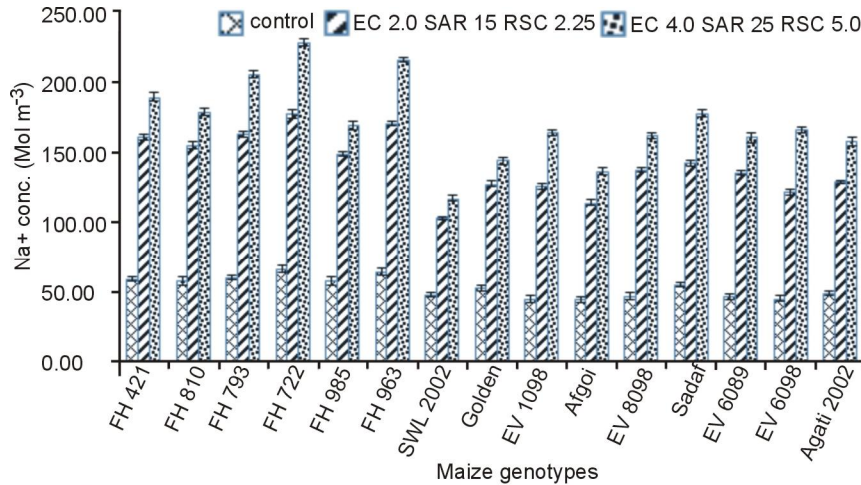


Fig. 1. Effect of saline/saline sodic water on Na⁺ concentration in leaf sap of maize genotypes.

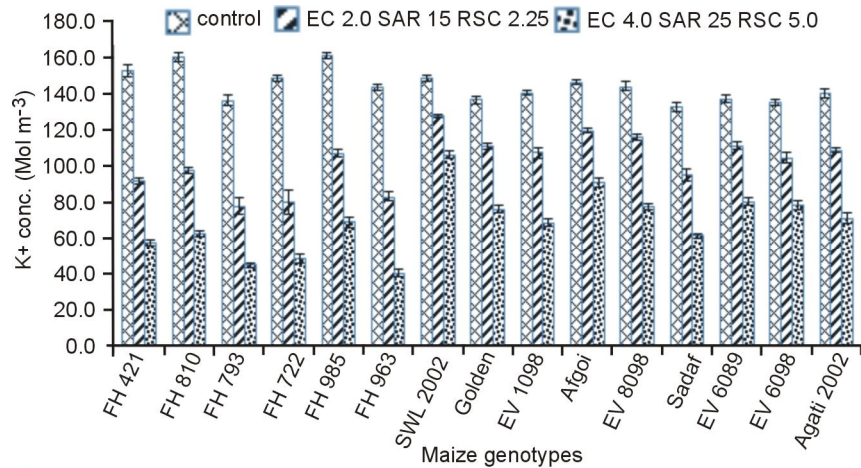


Fig. 2. Effect of saline/saline sodic water on K⁺ concentration in leaf sap of maize Genotypes.

that Na⁺ ion exclusion is definitely associated with salt tolerance. Similarly, Katerji *et al.* (14) and Arzani (8) reported that higher uptake of sodium ion in plant shoots cause nutrient imbalance, osmotic regulation and causes ion toxicity. The increase of toxic ions in plants is usually considered to be the major reason of growth decline under salt stress. The toxic concentrations of

Na^+ in plant cells exert numerous harmful effects on cellular processes and functions (25, 29). If excessive quantity of Na^+ cannot be capably confiscated in the vacuole, then these accumulated toxic ions in cytosol can cause a significant decrease in photosynthesis, chlorophyll contents, metabolic injury and ultimately the death of plant leaves (33). The results in case of K^+ and Ca^{2+} uptake in leaf was reverse by showing least K^+ and Ca^{2+} concentration at higher level of salinity and highest K^+ and Ca^{2+} contents were noticed in control treatments of all maize genotypes.

Two maize varieties (SWL-2002 and Afgoi) were capable in keeping highest K^+ (Fig. 2) and Ca^{2+} (Fig. 3) contents at all levels of salt stress and lowest K^+ and Ca^{2+} contents were noted in FH-793 and FH-722, respectively with a substantial variation between these genotypes. The increasing uptake of Na^+ contents and reducing K^+ concentration by increasing salinity caused reduction in $\text{K}^+ : \text{Na}^+$ ratio (Fig. 4). Higher potassium ion contents at high level of salinity caused in keeping highest $\text{K}^+ : \text{Na}^+$ ratio in leaf sap and showed superior growth in salt stress conditions. Mansour (19) and Zeng *et al.* (34) also reported that salt tolerant crops maintained higher $\text{K}^+ : \text{Na}^+$ ratios in tissues.

Salinity cause disturbance in uptake of K^+ ion and higher $\text{Na}^+ : \text{K}^+$ proportion in plant leaves results in salt injury (26). Higher potassium contents in leaf support cell osmotic regulation with comparatively less energy spending than uptake of compatible solutes. More than 50 plant enzymes need K^+ as co-factor and these enzymes are mostly susceptible to higher Na^+ and $\text{Na}^+ : \text{K}^+$ ratio (22, 31). Saline water stress caused dramatic increases in Na^+ contents and depicted substantial decrease in Ca^{2+} uptake. The higher uptake of Na^+ with upsurge in salinity caused reduction in $\text{Ca}^{2+} : \text{Na}^+$ ratio (Fig. 5). Highest $\text{Ca}^{2+} : \text{Na}^+$ proportion in brackish water treatments was found in the leaves of SWL-2002 and Afgoi, while lowest ratio was noted in FH-963 with a substantial variation between these genotypes. Similar results were reported by Akram *et al.* (5). The capability of plant genotypes to sustain higher amount of K^+ and Ca^{2+} and small concentration of Na^+ with in the leaves is one of the basic mechanisms relevant to expression of higher salt tolerance. Ahmed *et al.* (4) observed that there is negative correlation between shoot growth and Na^+ contents in leaves. Whereas it has been found in the present study that leaf K^+ and Ca^{2+} contents, $\text{K}^+ : \text{Na}^+$ and $\text{Ca}^{2+} : \text{Na}^+$ ratios have a positive correlation with shoot biomass. Maize hybrids with greater plant fresh, dry weights and K^+ contents in their leaves had depicted better salt tolerance (1).

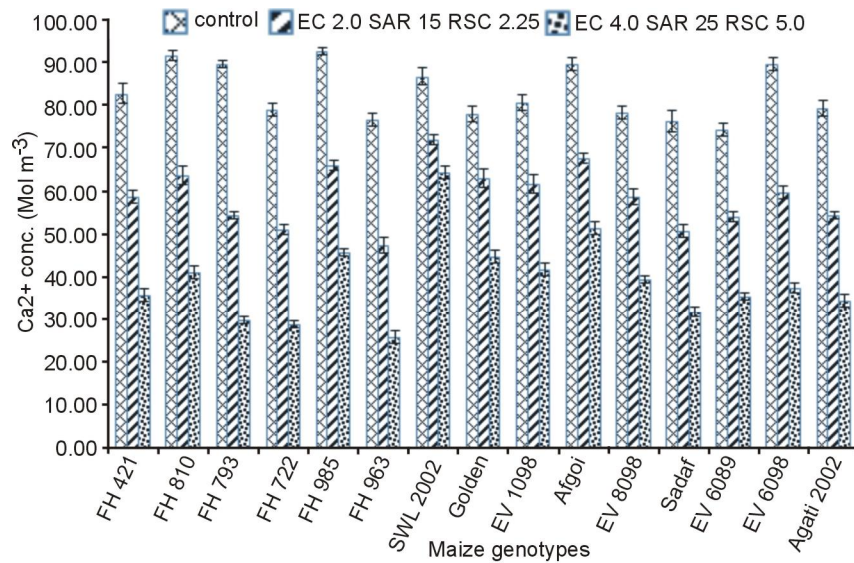


Fig. 3. Effect of saline/saline sodic water on Ca²⁺ Concentration in leaf sap of maize Genotypes.

The scores of genotypes in different growth parameters and their total score is depicted in Table 4. On the basis of these scores SWL-2002 and Afgoi have been acknowledged as tolerant and FH-985 moderately tolerant, while Sadaf, FH-963 and FH-722 as sensitive and moderately sensitive genotypes.

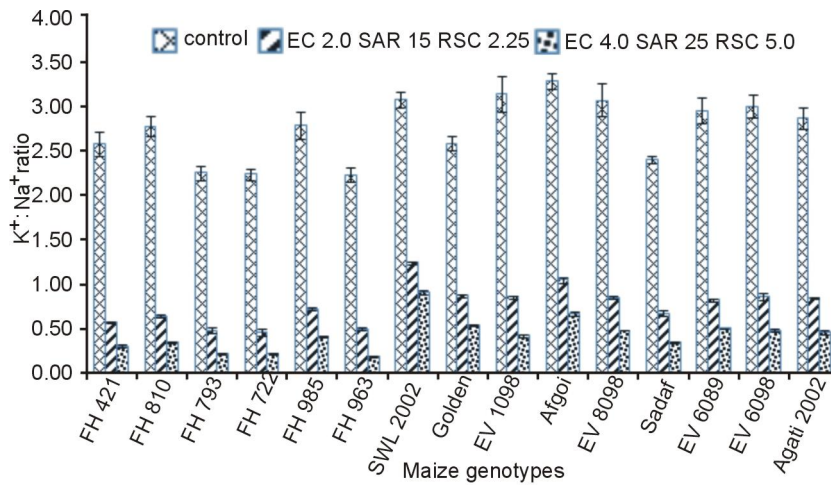


Fig. 4. Effect of saline/sodic water on K⁺: Na⁺ ratio in leaf sap of maize genotypes.

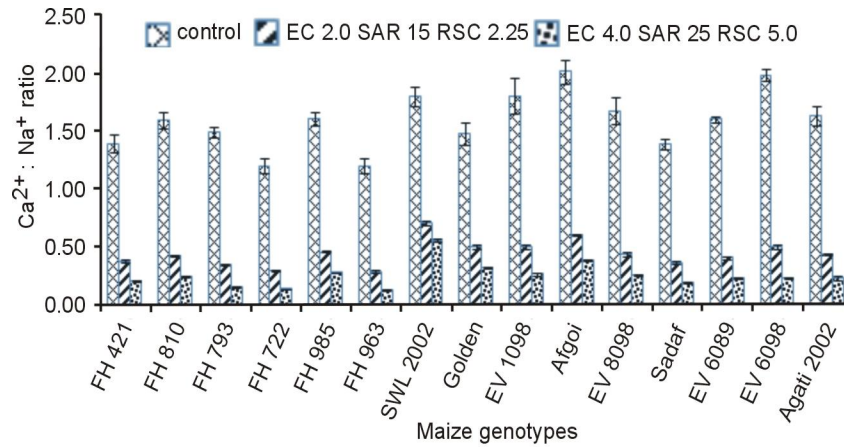


Fig. 5. Effect of saline/saline sodic water on Ca²⁺ : Na⁺ ratio in leaf sap of maize genotypes.

Table 4. The ranking of maize genotypes on the basis of their growth and leaf ionic composition.

Genotypes	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight	Shoot length	Root length	Leaf Na ⁺ conc.	Leaf K ⁺ conc.	Leaf Ca ²⁺ conc.	Leaf K ⁺ /Na ⁺ + ratio	Leaf Ca ²⁺ /Na ⁺ + ratio	Total score
FH-421	2	6	2	6	8	10	6	7	9	7	7	70
FH-810	10	8	12	8	11	12	7	9	12	8	8	105
FH-793	11	3	4	5	3	3	5	3	8	5	7	57
FH-722	3	4	5	5	5	2	3	5	5	4	5	46
FH-985	14	12	13	13	14	14	8	12	13	9	10	132
FH-963	4	1	3	4	2	9	4	4	4	4	4	43
SWL-2002	15	15	15	15	15	15	15	15	15	15	15	165
Golden	5	11	10	9	10	4	13	10	11	10	9	102
EV-1098	6	9	11	7	6	6	11	8	10	13	12	99
Afghi	13	14	14	14	13	13	14	14	14	14	14	151
EV-5098	7	5	8	11	9	7	9	13	9	12	11	101
Sadaf	1	2	1	5	1	1	8	6	5	6	6	42
EV-6089	8	10	6	7	4	5	10	11	6	12	8	87
EV-6098	9	7	9	12	7	7	8	12	8	11	13	109
Agari-2002	12	13	7	10	12	11	11	9	7	11	9	112

CONCLUSION

It can be concluded that selection at initial growth phases of maize genotypes in hydroponic culture is an easy and quick technique for determining genotypic variances in response to salinity. In this study, SWL-2002 and Afghi have been affirmed as tolerant, FH-985 moderately tolerant, Sadaf, FH-963 and FH-722 as sensitive and moderately sensitive genotypes, respectively.

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