EFFECT OF SALINE GROUNDWATER ON GROWTH, FODDER YIELD AND ION CONTENT OF VARIOUS MAIZE (*ZEA MAYS* L.) CULTIVARS

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ABSTRACT: *Water scarcity is a global issue, especially in arid and semiarid regions. Saline groundwater is increasingly being used to mitigate this shortage even though it has threats of increasing soil salinity and producing plant salt toxicity. Comparing the response of cultivars of one species to salinity is essential for their recommendation in particular saline area. The objective of this study was to evaluate and screen out salt tolerant maize cultivars under different levels of saline groundwater for vegetative growth, fodder yield, and ion accumulation in maize plants. A greenhouse pot experiment was conducted at Sindh Agriculture University, Tandojam, Pakistan. Ten different maize cultivars (Hicorn, Agaiti-2002, Margalla, Akbar, Sahiwal 2002, EV-5098, EV-3001, EV-1098, EV-6098 and EV-4001) were irrigated with saline groundwater. Water salinity levels were EC 0.4 (canal water, control), 2.0, 4.0, 6.0 and 8.0 dS* m^{-1}*. The data showed that water salinity levels significantly decreased height of the plants and fodder yield. The significant variations were observed in growth among different maize cultivars; where EV-1098 and Agaiti-2002 were observed as salt-tolerant by accumulating lesser contents of* Na^+ *and* Cl^- *and maintaining higher* K^+ *in plants. Whereas, cultivars EV-4001 and Akbar accumulated more* Na^+ *and* Cl^- *and less* K^+ *in plants and were identified as salt-sensitive. Soil salinity enhanced remarkably by the application of saline ground water and increased the contents of soluble cations (*Na^+*), anions (*Cl^- *and* SO_4^{-2}*), SAR and ESP in soil. This study had shown that maize cultivars EV-1098 and Agaiti-2002 could be grown successfully with saline irrigations for higher fodder production.*

Key Words: fodder yield, groundwater, maize cultivars, salt tolerance, soil salinity

INTRODUCTION

Groundwater has become an important water resource and its increasing demand in agriculture, domestic and industrial uses ranks it as a resource of strategic importance. Approximately 4430 cubic kilometers of fresh water resources are abstracted annually, of which 70% are used in agriculture, 25% in industry and 5% in household [1]. Groundwater exploitation has enabled many farmers to supplement their irrigation requirements. The main problems with groundwater quality in Pakistan is salinity, the concentrations of total dissolved solids (TDS) are higher, often upto >3000 mg l^{-1}, in groundwater's from the interfluve areas between the major river and canal tracts. Salinity is more widespread in the lower reaches of the Indus Plain. The TDS values are typically lower (<1000 mg l^{-1}) in groundwaters from below the active river channels as a result of dilution by local river and canal recharge to the aquifers [2]. There are large numbers of saline groundwater pockets in the canal command areas of Pakistan. In Punjab 23 percent of the area has hazardous groundwater quality, while it is 78 percent in Sindh [3].

One reason for crop yield decline is abiotic stresses [4]. Among others, salt stress may cause considerable production losses worldwide [5]. Yield potential of annual crops was declined by 51–82 % due to stressful environments including salinity [6]. Salinity exposes plants to an environment with toxic levels of ions and with reduced water availability. Salinity occurs naturally in arid and semi-arid regions and as water salinization is occurring globally for a number of reasons. Perhaps surprisingly, irrigation is a major cause of salinity. Agricultural production is mainly reliant on water but non availability of fresh water caused a disproportionate increase of salts in the soil profile that affects crop yields and the choice of crop to be grown [7] Salty water could be a substitute of good quality water but its long use, in the absence of management deteriorates soil [8]. Suitable management of saline water and choice of salt-tolerant genotypes would lessen harmful effects of salts on soil characteristics and crop yield [9]. In Pakistan's Indus basin, the demand-oriented variation in the irrigated agricultural sector formed a gap between demand and supply of canal water [10]. Under such situation, the exploitation of groundwater is widely started by the growers as an alternate of canal water [11].

Forage maize (*Zea mays* L.) is a nutritious fodder and is the richest source of livestock feed. This crop can be grown under irrigated areas with wide range of climate throughout the year for fodder purpose it is a short-duration crop and is ready for harvesting in about 8-10 weeks after sowing [12]. Maize is recognized as moderately salt sensitive [13]. There exists a threshold that differs with species and with cultivar within species. It is relatively difficult to calculate variations in salt tolerance between closely related species, due to reason that decline in growth is related to the period of time over which the plants have grown in saline conditions. A significant decline in rate of growth was observed during a short time in salinity but the decrease may be the same for species that have different reputations for salt tolerance [14]. Reducing the spread of salinization due to saline water and exploration of salt tolerant genotypes and their adaptation in saline condition are, therefore, concern of universal significance. Looking the severe shortage of canal water and over pumping of saline groundwater in Pakistan, the studies were carried out to explore the variability in maize cultivars tolerance under saline water and its effect on plant performance and soil properties.

MATERIALS AND METHODS

Study area

Experiment was conducted at the glasshouse of the Department of Soil Science, Sindh Agriculture University, Tandojam, Pakistan (Latitude 25o 25’ 28” N, and Longitude 68o 32’ 25” E). Ten maize cultivars (Hicorn, Agaiti-2002, Margalla, Akbar, Sahiwal 2002, EV-5098, EV-3001, EV-1098, EV-6098 and EV-4001) were assessed for their salt-tolerance under different saline groundwater levels. The salinity levels of ground water were; control (canal water with EC 0.4 dS m^{-1}), 2, 4, 6 and 8 dS m^{-1}. The experimental design was factorial randomized complete block deign with 03 replicates.

Preparation of saline water levels*:* The desired saline water levels were prepared by mixing the canal water with poor quality groundwater.

Pot Preparation

The fertile (plow layer) soil was collected from agricultural soil. Ten kg pot^{-1} air dried soil was placed in earthen pots. Ten seeds of every maize cultivar were sown in every pot. After emergence, 5 seedlings were allowed to grow in each pot up to tasselling. The pots were given irrigation water as per treatments and on the basis of crop requirement. Nitrogen in the form of urea (46% N) and Di ammonium phosphate (DAP) at the rate of 130 kg N ha^{-1} was applied in three equal splits, at time of sowing, 1^{st} irrigation and 2^{nd} irrigation. Phosphorus from DAP (N 18%, P_2O_5 46%) and K from Sulphate of potash (K_2O 60%) were applied at the rate equal to 80 and 40 kg ha^{-1}, respectively at the time of sowing.

Soil analysis

Soil samples were collected before sowing and after harvest of crop. Soil texture (pre sowing) was determined by Bouyoucous Hydrometer method [15] organic matter by Walkely-Black method [16], EC (1:2 soil water extract using digital conductivity meter Model Hi-8333, pH (1:2 soil water extract using Suntex pH meter, Model SP-34, soluble Na^+ and K^+ through EEL-flame photometer, standardized with a series of Na^+ or K^+ solutions [17] , soluble Ca^{2+} and Mg^{2+} by titrating the saturation extract against EDTA solution [17], and Cl^- by titration with $AgNO_3$ solution [17].

Plant analysis

Earlier to tasseling, the fully developed leaf below whorl from all the replications of each treatment were sampled and processed for the analysis of Na^+ and K^+ using Acid wet digestion method [18] and Cl^- by dry ash method [19].

Statistical Analysis. The data were analyzed statistically through SPSS software (v. 12). Treatment means were compared through Duncan’s Multiple Range Test [20] at a p level of 0.05.

RESULTS AND DISCUSSION

Saline groundwater effects on height and fodder yield of maize cultivars

Increase in salinity of water beyond EC 2.0 dS m^{-1} significantly reduced the height of plants and dwarf plants (31.44 cm) were observed under EC 8.0 dS m^{-1} (61 % decrease over control). Application of canal water (EC 0.4 dS m^{-1}) and brackish water with EC 2.0 dS m^{-1} recorded taller plants (80.41 and 79.19 cm, respectively). Regarding cultivars performance, EV-1098 and Agaiti-2002 had taller plants (62.41 and 62.22 cm, respectively), both of these cultivars were at par with each other. Among the 10 tested maize cultivars EV-4001 and Akbar were found more sensitive to saline and recorded dwarf plants (52.42 and 52.49 cm, respectively). The results of the study had shown that all the tested cultivars irrigated with canal water (EC 0.40 dS m^{-1}) or water quality having EC 2.0 dS m^{-1} significantly increased height of maize plants as compared to rest of the treatments (Table I). This means that all maize cultivars can grow well at low salinity level. On the other hand drastic decline in the plant height were recorded at high water salinity levels this might be due to the adverse effects of specific ion concentration which exceeds their threshold and become toxic. The results of this experiment are supported by the findings of other scientists. They reported that application of saline water significantly enhanced salt build up in soil and adversely affected growth parameters of crop [21]. Canal water application along with saline water decreased soil salt build up and enhanced growth of crop plants. Plant height of maize decreased significantly as salinity increased and early flowering cultivars were more salt- tolerant than late flowering cultivars[22,23] .

The statistical results for green fodder yield showed significant differences among cultivars at different saline water levels and their interaction. The results of the study revealed that increasing water salinity significantly decreased average green fodder yield. The minimum fodder yield (52.11 g 5 $plants^{-1}$) was recorded from the plants irrigated with saline groundwater having EC 8.0 dS m^{-1} (66.88 % decrease over control). The maximum green fodder yield (152.74 and 152.24 g 5 $plants^{-1}$) was observed with the application of canal water and EC 2.0 dSm^{-1}, respectively. The difference between these two treatments were non-significant.

The results for performance of maize cultivar showed that EV-1098 and Agati-2002 were salt tolerant and produced more green fodder (115.12 and 115.10 g 5 $plants^{-1}$, respectively) as compared to EV-4001 and Akbar which produced less green fodder yield (103.91 and 103.20 g 5 $plants^{-1}$, respectively). The interaction of cultivars x water qualities recorded higher values of this trait when all cultivars received canal water or water quality with EC 2.0 dS m^{-1} (Table-I). These findings agree with the reports of [18] who reported that saline water effects over early flowering cultivars were less than that on late flowering cultivars and major factor associated with salinity tolerance was genetic potentiality of the genotype. Maize is an important crop for fodder as well as grain production and is a relatively sensitive to saline irrigation water showing 50 % reduction in yield at EC 3.9 dS m^{-1} [24]. Similarly [25] while investigating the effects of irrigation water (differing in salt concentration (4.8 to 12 dS m^{-1}) indicated that considerable reduction in fresh and dry fodder yield was observed in Bajra at EC levels above 8 dS m^{-1}.

TABLE I. Effect of saline groundwater on height, green fodder yield and ionic (Na, Cl, K) concentration of maize cultivars

Saline groundwater levels EC (dS m^{-1})	Plant height (cm)	Green fodder yield (g pot^{-1} (5 plants))	Na^+ (%)	Cl^-(%)	K^+(%)
0.4	80.41a	152.74a	0.262e	0.434e	2.418a
2.0	79.19a	152.24a	0.363d	0.504d	1.995b
4.0	56.10b	115.08b	0.913c	0.809c	1.481c
6.0	41.13c	74.88c	1.704b	1.166b	0.995d
8.0	31.44d	52.12d	2.496a	1.652a	0.510e
LSD (0.05)	1.041	3.066	0.0198	0.0114	0.0198
Cultivars					
Hicorn	57.85b	109.56b	1.156b	0.918b	1.497b
Agaiti-2002	62.22b	115.11a	0.935c	0.773c	1.674a
Margalla	57.85a	109.33b	1.156b	0.918b	1.495b
Akbar	52.49c	103.20c	1.345a	1.056a	1.246c
Sahiwal-2002	57.75b	109.59b	1.154b	0.910b	1.499b
EV-5098	57.79b	109.03b	1.150b	0.912b	1.489b
EV-3001	58.01b	109.77b	1.152b	0.910b	1.495b
EV-1098	62.41a	115.13a	0.925c	0.771c	1.682a
EV-6098	57.77b	109.47b	1.150b	0.900b	1.491b
EV-4001	52.42c	103.92c	1.352a	1.060a	1.229c
LSD (0.05)	1.472	4.335	0.0279	0.016	0.0279
Significance					
Saline ground water(S)	***	***	***		
Cultivars(C)	***	***	***		
SX C	***	***	***		

*** Significant at *P*=0.05

Means followed by similar letters do not differ significantly at P=0.05.

Saline groundwater effects on chemical composition of cultivars

Sodium and Chloride

The Na^+ and Cl^- content in straw of different maize cultivars were recorded higher with the use of saline water especially in higher salinity levels of groundwater. The maximum Na^+ and Cl^- (2.49 and 1.65%) concentration was noted in the plants treated with water EC 8.0 dS m^{-1} (852.67 and 280.64 % increase over control respectively), followed by water quality with EC 6.0 dS m^{-1}. The lower values of Na^+ and Cl^- were exhibited in the plants irrigated with canal water or EC 2.0 dS m^{-1}; the difference between these treatments were non-significant. Among the tested cultivars, EV-4001 and Akbar accumulated more Na^+ (1.35 and 1.34%) and Cl^- (1.06 and 1.05%). However, EV-1098 and Agaiti-2002 recorded less Na^+ and Cl^- accumulation (Tables I). The increasing salinity of water exhibited significant increases in Cl^- concentration of leaf and provoked noticeable inhibition on growth and yield [26]. [27] compared responses of a salt-tolerant (Denghai 11) and a salt-sensitive cultivar (Yangnuo 1) and concluded that maize cultivars with different tolerance ability to salt stress represented different responses. The salt-tolerant maize at normal condition had smaller uptake rates of Na^+ and Cl^- than the salt-sensitive maize, which meant that the salt-tolerant cultivar might have superior utilization efficiency of nutrients and could uphold the equilibrium of nutrients in plants and accordingly get better its tolerance to salt stress. Highest salt regime (120 mol NaCl m^{-3}) caused a significant increase in Cl^- concentration of the maize plant [28].

Effect of saline water on potassium content of plant straw

The K^+ content in maize straw increased with the application of canal water (EC 0.4 dS m^{-1}) which recorded K^+ 2.41% followed by saline water with EC 2.0 dS m^{-1} which exhibited 1.99% K^+. However, application of saline water with higher EC of 8.0 dS m^{-1} recorded less values of K (79% decrease over control). Among the 10 tested maize cultivars, EV-4001 (1.22%) and Akbar K^+ (1.24%) accumulated less K^+. The higher accumulation of K^+ (1.68%) was noted in EV-1098 followed by Agaiti-2002 (1.67%) (Table I).The increased soil salinity encouraged by irrigation with saline water also increased the Na^+ content, but decreased the K concentration [29]. Regarding maize response to saline water, [30] reported that salt stress induced Na^+ and Cl^- accumulation while it reduced K^+ levels in shoots of maize cultivars. The increase in Na^+ and Cl^- and the decrease in K^+ concentration was greater in sensitive maize cultivars than in tolerant.

Saline groundwater effects on some chemical properties of soil

The results of the soil analysis for EC, soluble cation and anions under saline water showed highest EC (4.47 dS m^{-1}), soluble Na^+ (33.48 meq L^{-1}), Cl^- (31.19 meq L^{-1}), SO_4 (10.78 meq L^{-1}), SAR (15.81) and ESP (20.43) under the application of saline groundwater with EC 8.0 dS m^{-1}. However, soluble K^+ (2.68 meq L^{-1}) was higher in the treatment where soil received canal water (Table II).

Table II. Effect of saline groundwater on chemical properties of soil at the end of experiment

Saline groundwater levels EC (dS m^{-1})	EC (dS m^{-1})	Na^+ (meq L^{-1})	K^+ (meq L^{-1})	Cl^- (meq L^{-1})	$SO4^{2-}$ (meq L^{-1})	SAR	ESP
0.4	1.10e	6.18E	2.68a	5.76e	5.73e	4.60e	6.39e
2.0	1.49d	10.97d	2.58b	8.78d	6.76d	7.57d	10.12d
4.0	2.68c	18.67c	2.43c	17.54c	7.64c	10.49c	13.77c
6.0	3.86b	27.81b	2.19d	26.14b	9.61b	13.84b	17.97b
8.0	4.47a	33.48a	1.97e	31.19a	10.78a	15.81a	20.43a
S.E	0.011	0.115	0.013	0.106	0.042	0.038	0.063
LSD 0.05	0.0301	0.3214	0.0360	0.2951	0.1172	0.1050	0.1745

Means followed by similar letters do not differ significantly at P= 0.05.

The limited irrigation water supply coupled with high pumping cost and salinity hazards, makes it more important and should be used efficiently and judiciously. Different salts are present in saline irrigation water in arid and semi arid regions of world [31] which can increase salinity [8] in the plant root zone. The soaring Na^+ and Cl^- contents in soil solution is generally the main cause of the saline stress and the consequent slower growth is an adaptive feature for plant survival because it allows plants to rely on multiple resources to combat stress. The findings of the present investigation are in confirmation with those of [32] and [33] that the presence of salts in irrigation water influences most of the chemical soil characteristics such as soil EC, soluble ions and SAR. Contents of soluble Ca^{2+}, Mg^{2+} and Na^{+} sharply increased as salinity level of irrigation water increased up to 4 dS m^{-1} [34]. Increasing irrigation water salinity resulted in a significant increase in sweet corn root zone salinity [35].

CONCLUSION

Saline water affected growth and fodder production of maize cultivars at different extents. Cultivars exposed to low saline water levels had the uttermost height, green fodder yield and lowest accumulation of toxic ions (Na^{+}, Cl^{-}) in plant. The increases in salinity levels (EC 4, 6, 8 dS m^{-1}) significantly lowered the agronomic traits and increased concentration of Na^{+} and Cl^{-} in soil and plant. This study suggests that cultivars EV-1098 and Agaiti-2002 could be grown successfully with poor quality groundwater for higher fodder production.

ACKNOWLEDGEMENTS

Authors are thankful to National Coordinated Maize, Sorghum and Millet Programme, National Agriculture Research Council (NARC), Islamabad, Pakistan for providing seeds of fodder maize cultivars used in this study.

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