African Journal of Biotechnology Vol. 10(9), pp. 1559-1565, 28 February, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB10.1525
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Enhanced fodder yield of maize genotypes under saline irrigation is a function of their increased K accumulation and better K/Na ratio

I. Rajpar[1]*, I. Jandan[1], Zia-ul-hassan[1], G. M. Jamro[1] and A. N. Shah[2]

[1]Department of Soil Science, Sindh Agriculture University Tandojam-70060, Sindh, Pakistan.
[2]Department of Agronomy, Sindh Agriculture University Tandojam-70060, Sindh, Pakistan.

Accepted 10 January, 2011

Poor quality irrigation water adversely affects the growth and yield of crops. This study was designed to evaluate the growth, fodder yield and ionic concentration of three promising maize (*Zea mays* L.) genotypes under the influence of varying quality irrigation water, with different salinity levels. The genotypes, such as EV-1097, Kisan and Akbar were irrigated with usable (electrical conductivity, EC 1.5 dS m^{-1}), marginal (EC 3.0 dS m^{-1}), poor (EC 4.5 dS m^{-1}) and very poor (EC 7.0 dS m^{-1}) quality irrigation water. The increasing adverse effects on various growth and yield variables of all three genotypes were observed with the increasing water salinity. Also, soil EC, SAR and ESP values increased linearly with increasing salinity levels of irrigation water. Poor quality irrigation water affected all the growth variables and yield of maize. Increasing concentrations of sodium and chloride ions, coupled with decreasing concentration of potassium, in flag leaf of maize was observed in response to increasing salinity of irrigation water. The genotypic variation among the three maize genotypes to saline water irrigation was in order of EV-1097 > Kisan > Akbar. The better fresh fodder yield of maize genotypes under poor quality irrigation water was a function of their enhanced accumulation of potassium (K) and better K/Na ratio. The study concluded that, the genotype EV-1097 is a better choice for the maize growers under saline water irrigation condition.

Key words: Maize (*Zea Mays* L.), fodder yield, saline irrigation, K accumulation, K/Na ratio.

INTRODUCTION

The global population would cross over 9.0 billion by 2050 (FAO, 2010) and this would definitely create pressure on crop production, especially cereals. This ever increasing population of world will also result in the increase in the need for water, which is the scarcest resource globally due to continuous drying of rivers as a result of global warming (Rahman, 2010). To cope with the alarming situation, there is a dire need to find out practicable solutions for sustainable irrigation management. Use of poor quality irrigation water is a centuries old business. The techniques in using poor quality irrigation water include reverse osmosis, supplementing with good quality canal water, using amendments, using various agronomic and cultural practices and tailoring saline-resistant crop species and their varieties (Gupta, 1990). Identifying salt-resistant crops and their varieties that are best suited for sustainable production under poor quality irrigation water is now a well-established technique (Qureshi and Barret-Lennard, 1998). The genotypic variation among crop species and their varieties have been exploited in almost all cereal crop species, namely, rice (Bhattacharya and Mishra, 1979), wheat (Zahid and Afzal, 2002), pearl millet (Kumawat et al., 1995), sweetcorn (Pasternak et al., 1995) and maize (Narwal et al.,

---

*Corresponding author. E-mail: irajpar@yahoo.com. Tel: +92 22 276 5870. Fax: +92 22 276 5300.

Abbreviations: K, Potassium; **Na,** sodium; **SAR,** sodium adsorption ratio; **DAS,** days after sowing; **EC,** electrical conductivity; **ESP,** exchangeable sodium percentage.

1995; Hasegawa et al., 2000; Abid et al., 2003). Maize is one of the most important cereal crops that are grown in almost all parts of the world. In Pakistan, maize is grown in all the four provinces as a food and fodder crop. Several fodder maize genotypes, such as Akbar, Agaiti, Kisan, EV-109, etc. are most commonly cultivated for fodder production in lower Sindh that is, Hyderabad, Thatta, Mirpur Khas, Badin and Tando Allahyar. Although, some of these maize genotypes (Akbar, Agaiti, etc) are already categorized for their salt-tolerance exposed to soil and water salinity (Gandahi, 2010), few high yielding maize genotypes still need to be evaluated for their tolerance to saline irrigation water. Moreover, despite the recent reports of increasing potassium (K) deficiency in Pakistani soils (Zia-ul-hassan et al., 2008), a negligible amount of potassium fertilizer (<1.0 kg K_2O ha^{-1}) is used in Pakistan which favors K mining from soils and affects the growth of maize plants (Nawaz et al., 2006). This study aimed at investigating the influence of usable (EC <1.5 dS m^{-1}), marginal (EC 3.0 dS m^{-1}), poor (EC 4.5 dS m^{-1}) and very poor quality (EC 7.0 dS m^{-1}) irrigation waters on the growth and fodder yield of three maize genotypes, which includes Kisan, EV- 1097 and Akbar.

MATERIALS AND METHODS

This pot study was conducted in a wire-house, under natural conditions at the Sindh Agriculture University, Tandojam, Sindh, Pakistan (Latitude: 25° 25'60 N, Longitude: 68° 31'60 E). The experiment was conducted in a 4 X 3 factorial randomized complete block design (RCBD) with three replications. The soil under study was collected from Latif Experimental Farm and filled in plastic pots of 15 kg capacity, containing drainage holes at bottom. The soil filled pots were then placed on wooden benches. Three maize genotypes Kisan, EV-1097 and Akbar were tested in the experiment. The seed of the above maize genotypes was sown in each pot at 1 cm depth. After 15 days of sowing (DAS), seedlings were thinned to grow five plants in each pot up to 60 days. The four types of desired irrigation water quality were obtained by mixing good quality canal water with poor quality ground water. These four irrigation water treatments of varying quality include: Ti, usable (electrical conductivity, ECi1.5 dS m^{-1}); T2, marginal (ECi 3.0 dS m^{-1}); poor, (ECi 4.5 dS m^{-1}); and T3, very poor (ECi 7.0 dS m^{-1}). The volume of water applied to plants was calculated on the basis of field capacity. A blanket dose of recommended nitrogen (N) as urea (N 46% N) and phosphorus (P) as diammonium phosphate, DAP (18% N, 46% P_2O_5) were applied to the crop. The soil under study was analyzed before sowing and after harvesting of maize by following the recommended methods for texture (Bouyoucos hydrometer method as described by Kanwar and Chopra, 1959), organic matter (Walkley-Black method as suggested by Rowell, 1994), pH (using Suntex digital pH meter), electrical conductivity (using Lab-960 digital EC meter), soluble Na^+ and K^+ (both by Flame Photometery following the methods suggested by USSL, 1954) and Ca^{2+} and Mg^{2+} (both by titration method prescribed by USSL, 1954). Soluble anions (CO_3^{-2}, HCO_3^- and Cl^- by titration and SO_4^{2-} by calculation as: SO_4^{2-} meq L^{-1} = TSS – (CO_3^{-2} + HCO_3^- + Cl^-) all expressed in meq L^{-1} (USSL, 1954). Sodium adsorption ratio (SAR) was calculated as suggested by Rowell (1994). The experiment was stopped 60 days after sowing (DAS) and the plants were harvested by cutting at soil level to record their height (cm), stem girth (cm), green and dry leaves per plant and fresh and dry fodder yield per plant. Flag leaf samples were secured from each treatment for ion analysis. The leaf samples were oven dried and processed to determine Na^+, K and Cl^- using Dry-ash method (Rowell, 1994). The statistical analyses were performed by using MINITAB version-13. The treatment means were separated by using the least significance difference test at alpha 0.05.

RESULTS

The soil under study (Table 1) was heavy in texture (57% clay), free from salinity hazards (ECe 1.60 dS m^{-1}), non-sodic (SAR 1.94 and ESP 1.63), alkaline in reaction (pH 7.76) and poor in fertility (0.67% organic matter). The values for various soil variables remained same when analyzed after the harvesting of maize. However, the values of EC, SAR and ESP increased. The plant height was significantly ($p < 0.05$) affected by water quality, genotypes and their interaction (Table 2). The plants receiving marginal, poor and very poor quality waters were 6, 11 and 12% shorter in height, respectively, when compared with the height of plants cultivated with good quality water. Generally, the genotype EV-1097 produced taller plants than Kisan and Akbar irrespective of water quality. The number of green leaves per plant was significantly ($p < 0.05$) affected by water quality, genotypes and their interaction (Table 3). The number of green leaves per plant recorded on maize genotypes was highest when the crop was irrigated with good quality usable water (EC 1.5 dS m^{-1}), while the number of green leaves per plant reduced when water salinity increased. The lowest number of green leaves per plant was recorded when water salinity increased to 7.0 from 1.5 dS m^{-1}. On overall basis, under the effect of various irrigation water quality treatments, genotype EV-1097 produced more green leaves than Kisan and Akbar. The genotype Akbar was more sensitive to very poor quality irrigation water (EC 7.0 dS m^{-1} EC). However, it performed better under lower levels of water salinity. The number of dry leaves per plant was significantly ($P < 0.05$) affected by water quality, genotypes and their interaction (Table 4). Increasing water salinity increased the number of dry leaves per plant. The number of dry leaves per plant was highest for the treatment where plants were irrigated with very poor quality water (EC 7.0 dS m^{-1}). In terms of number of dry leaves, the genotype Akbar was more affected than those of Kisan and EV-1097 when exposed to water salinity. The interaction of water quality and genotypes also confirmed this observation. The results regarding stem girth of maize genotypes irrigated with saline water (Table 5) indicated that, the stem girth was significantly ($p < 0.05$) affected by water quality, genotypes as well as their interaction. The stem girth of maize plants decreased with increasing water salinity. With respect to genotype performance, the genotype EV-1097

Table 1. Selected soil chemical properties recorded after harvesting of maize crop irrigated with saline water.

Water quality	EC_i (dS $m^{-1)}$	Soil properties			
		EC_s (dS m^{-1})	pH	SAR	ESP
Usable	1.5	1.87	7.86	3.11	3.40
Marginal	3.0	2.10	7.75	4.56	5.59
Poor	4.5	2.52	7.59	6.18	8.05
Very poor	7.0	3.92	7.42	8.47	11.52

Table 2. Effect of water quality (EC_i dS m^{-1}) on height (cm) of three maize genotypes.

Water quality (WQ)	EC_i (dS $m^{-1)}$	Genotypes			Mean
		EV-1097	Kisan	Akbar	
Usable	1.5	85.50	81.04	79.23	81.92
Marginal	3.0	80.38	76.15	74.18	76.90
Poor	4.5	77.51	72.54	68.68	72.91
Very poor	7.0	68.84	62.01	57.42	62.75
Mean		78.05	72.93	69.88	-

Significance, S.E.D and L.S.D; WQ, 0.301 and 0.620; genotypes, 0.261 and 0.537; WQ and genotypes, 0.522 and 1.0076.

Table 3. Effect of water quality (EC_i dS m^{-1}) on number of green leaves plant^{-1} produced by three maize genotypes.

Water quality (WQ)	EC_i (dS $m^{-1)}$	Genotypes			Mean
		EV-1097	Kisan	Akbar	
Usable	1.5	6.86	6.46	6.0	6.44
Marginal	3.0	6.46	6.33	5.86	6.22
Poor	4.5	5.93	5.53	5.06	5.51
Very poor	7.0	3.86	3.60	3.00	3.48
Mean		5.78	5.48	4.98	---

Significance, S.E.D and L.S.D; WQ, 0.0026 and 0.0053; genotypes, 0.0034 and 0.007; WQ and genotypes, 0.1019 and 0.2099.

achieved maximum stem girth, followed by Kisan and Akbar genotypes. The stem girth of EV-1097 in almost all water quality treatments was better than those of Kisan and Akbar. The data on fresh fodder yield produced by three maize genotypes irrigated with different quality waters are given in Table 6. It depicts that, the fresh fodder yield was significantly ($p < 0.05$) affected by all three sources of variance, including water quality, genotypes and their interaction. The production of fresh fodder yield was significantly decreased with increasing water salinity. On overall basis, under the influence of various water quality treatments, genotype EV-1097 produced more fodder yield than other two genotypes. The interaction of two sources of variance indicated that, the genotype EV-1097 gave maximum fresh fodder yield of maize while the genotype Akbar gave minimum. The latter genotype was affected most when it was irrigated with very poor quality irrigation water (EC 7.0 dS m^{-1}). The data on dry fodder/straw yield of maize genotypes irrigated with different quality waters are presented in Table 7. The results indicated that, the effect of water quality, genotypes and their interaction on straw yield of maize was significant ($p < 0.005$). Increasing water Salinity significantly decreased straw yield of maize. On the other hand, as affected by various water quality treatments, genotype EV-1097 produced maximum straw yield while the genotype Akbar produced low dry fodder/ straw yield plant^{-1}. The data regarding accumulation of Na, K, Cl and K/Na ratio in flag leaves are given in Tables 8, 9, 10 and 11. The effect of water quality, genotypes and their interaction was significant ($p < 0.05$) for all ions (Na, K, Cl) and K/Na ratio. As expected, increasing water

Table 4. Effect of water quality (EC_i dS m^{-1}) on number of dry leaves $plant^{-1}$ produced by three maize genotypes.

Water quality (WQ)	EC_i (dS m^{-1})	Genotypes			Mean
		EV-1097	Kisan	Akbar	
Usable	1.5	6.53	6.86	7.66	7.02
Marginal	3.0	6.73	7.33	7.43	7.33
Poor	4.5	7.26	7.66	8.26	7.73
Very poor	7.0	8.46	8.60	9.13	8.73
Mean		7.25	7.61	8.25	--

Significance, S.E.D and L.S.D; WQ, 0.0588 and 0.1211; genotypes, 0.0509 and 0.1048; WQ and genotypes, 0.1019 and 0.2099.

Table 5. Effect of water quality (EC_i dS m^{-1}) on stem girth (cm) of three maize genotypes.

Water quality (WQ)	EC_i (dS m^{-1})	Genotypes			Mean
		EV-1097	Kisan	Akbar	
Usable	1.5	3.86	3.86	3.65	3.79
Marginal	3.0	3.47	3.36	3.06	3.30
Poor	4.5	3.22	2.85	2.79	2.95
Very poor	7.0	2.83	2.35	2.17	2.45
Mean		3.34	3.10	2.92	--

Significance, S.E.D and L.S.D; WQ, 0.0506 and 0.1042; genotypes, 0.0438 and 0.0902; WQ and genotypes, 0.0876 and 0.1804.

Table 6. Effect of water quality (EC_i dS m^{-1}) on fresh fodder yield (g $plant^{-1}$) produced by three maize genotypes.

Water quality (WQ)	EC_i (dS m^{-1})	Genotypes			Mean
		EV-1097	Kisan	Akbar	
Usable	1.5	27.93	23.33	20.46	23.91
Marginal	3.0	20.80	18.20	17.06	18.68
Poor	4.5	18.06	16.13	14.93	16.37
Very poor	7.0	13.66	12.66	10.73	11.68
Mean		19.86	17.33	15.80	--

Significance, S.E.D and L.S.D; WQ, 0.253 and 0.5211; genotypes, 0.219 and 0.4513; WQ and genotypes, 0.438 and 0.9026.

salinity increased the accumulation of Na and Cl ions and decreased K and K/Na ratio of the flag leaves of all the three maize genotypes studied. However, under the effect of various water quality treatments, genotype EV-1097 accumulated less Na and Cl and had high K accumulation and K/Na ratio. The genotype EV-1097 exhibited greatest (1.96) K/Na ratio under very poor quality irrigation water (EC 7.0 dS m^{-1}) whereas genotype Akbar had lowest (0.68%) K/Na ratio. The relationship between fresh fodder yield of maize genotypes and accumulation of K and Na and K/Na ratio in the flag leaves were was ascertained. The correlation analysis elucidated significant ($p < 0.05$) relationship of maize fodder yield with K accumulation (0.99*) of flag leaves of maize genotypes and their K/Na ratio (r = 0.99*). No relationship of Na accumulation of flag leaves of maize genotypes was found with K accumulation and K/Na ratio of flag leaves of maize. Moreover, the relationship of Na was not significant with the fresh fodder yield of maize genotypes.

DISCUSSION

Compared to usable (EC_i 1.5 dS m^{-1}) water, maize plants

Table 7. Effect of water quality (EC_i dS m^{-1}) on dry straw yield (g $plant^{-1}$) produced by three maize genotypes.

Water quality (WQ)	**EC_i (dS m^{-1})**	**Genotypes**			**Mean**
		EV-1097	**Kisan**	**Akbar**	
Usable	1.5	8.13	6.93	4.66	6.57
Marginal	3.0	6.60	5.93	4.13	5.55
Poor	4.5	6.00	5.66	3.80	5.15
Very poor	7.0	3.40	3.00	2.73	3.22
Mean		6.03	5.00	3.83	-

Significance, S.E.D and L.S.D; WQ, 0.0889 and 0.1832; genotypes, 0.0770 and 0.1586; WQ and genotypes, 0.154 and 0.317.

Table 8. Effect of water quality (EC_i dS m^{-1}) on Na (%) determined in flag leaves of three maize genotypes.

Water quality (WQ)	**EC_i (dS m^{-1})**	**Genotypes**			**Mean**
		EV-1097	**Kisan**	**Akbar**	
Usable	1.5	0.899	0.768	0.681	0.783
Marginal	3.0	1.217	0.957	0.811	0.995
Poor	4.5	1.507	1.304	1.188	1.333
Very poor	7.0	1.34	1.44	1.82	1.773
Mean		1.395	1.192	1.076	-

Significance, S.E.D and L.S.D; WQ, 0.0122 and 0. 0253; genotypes, 0. 0106 and 0. 0219; WQ and genotypes, 0. 0212 and 0. 0438.

Table 9. Effect of water quality (EC_i dSm^{-1}) on K (%) in flag leaf of three maize genotypes.

Water quality (WQ)	**EC_i (dS m^{-1})**	**Genotypes**			**Mean**
		EV-1097	**Kisan**	**Akbar**	
Usable	1.5	2.50	2.445	2.37	2.44
Marginal	3.0	2.19	2.300	2.14	2.21
Poor	4.5	2.01	1.875	1.805	1.89
Very poor	7.0	1.52	1.32	1.03	1.29
Mean		2.031	1.968	1.881	-

Significance, S.E.D and L.S.D; WQ, 0. 0086 and 0. 0179; genotypes, 0. 0075 and 0. 0155; WQ and genotypes, 0. 0150 and 0. 0310.

irrigated with 3.0, 4.5 and 7.0 EC_i (dS m^{-1}) waters were 6, 11 and 12% shorter in height, respectively (Table 3). This suggests that, maize plants are sensitive to hazardous quality waters and increasing water salinity decreases plant height. These results are supported by some recent studies (Gandahi et al. 2009), which elucidated that saline irrigation water reduces plant height of maize crop. The number of leaves per plant is a morphological trait of maize, generally influenced by genetic makeup, given inputs, soil fertility status and water quality used for irrigation purpose. Compared to good quality water (EC_i 1.5 dS m^{-1}), maize plants irrigated with 3.0, 4.5 and 7.0 EC_i (dS m^{-1}) waters had 3.4, 14.4 and 47% fewer green leaves (Table 4), respectively and 5, 10 and 24% more dry leaves, respectively (Table 5). This suggests that, saline water significantly dries up green leaves, rather than decreasing the total number of leaves per plant. The results of some early studies on this subject (Rajpar, 1999) are in line with these findings which depicted that, salts stress badly affects the photosynthetic activities. In the present study, maize plants irrigated with marginal, poor and very poor quality water exhibited 13, 22 and 35% decrease in their stem girth (Table 6). This clearly indicates that, saline water beyond EC_i 1.5 dS m^{-1} adversely affects stem development. A drastic and notable decrease in stem girth was observed when water

Table 10. Effect of water quality (EC$_i$ dSm^{-1}) on Cl$^-$ (%) in flag leaves of three maize genotypes.

Water quality (WQ)	EC$_i$ (dS m^{-1})	Genotypes			Mean
		EV-1097	Kisan	Akbar	
Usable	1.5	0.763	0.746	0.686	0.733
Marginal	3.0	0.983	0.916	0.893	0.931
Poor	4.5	1.136	1.086	1.056	1.093
Very poor	7.0	1.740	1.713	1.690	1.714
Mean		1.155	1.115	1.0817	-

Significance, S.E.D and L.S.D; WQ, 4.242 and 8.738; genotypes, 04.898 and 10.089; WQ and genotypes, 2.449 and 5.044.

Table 11. Effect of water quality (EC$_i$ dS m^{-1}) on K/Na ratio in the flag leaves of three maize genotypes.

Water quality (WQ)	EC$_i$ (dS m^{-1})	Genotypes			Mean
		EV-1097	Kisan	Akbar	
Usable	1.5	2.787	3.185	3.491	3.15
Marginal	3.0	1.799	2.404	2.639	2.28
Poor	4.5	1.333	1.437	1.519	1.43
Very poor	7.0	1.13	0.92	0.57	0.73
Mean		1.662	1.937	2.098	-

Significance, S.E.D and L.S.D; WQ, 0.0426 and 0.0879; genotypes, 0.0369 and 0.0761; WQ and genotypes, 0.0739 and 0.1523.

EC$_i$ (dS m^{-1}) was raised from 1.5 to 7.0. Compared to usable quality water, plants grown with marginal, poor and very poor quality water gave 22, 32 and 51% less green (Table 7) and 16, 22 and 51% less dry fodder yield, respectively (Table 8). Such behavior of maize plants can be attributed to smaller plants and reduced stem girth under saline irrigation condition. These adverse impacts of saline waters on maize plants were possibly due to higher concentration of cytotoxic ions (Na and Cl) and lower concentration of K and narrow K/Na ratio, determined in the flag leaves of maize genotypes (Table 9, 10, 11 and 12). There are several evidences (Gorham, et al., 1985; Glenn, et al., 1999; Rajpar, et al., 2007), indicating that under saline condition Na competes with K hence plants uptake and accumulate more Na than K. Also, the absorption of Na by plants is passive, whereas K is actively absorbed by plants. In another study, Medeiros et al. (2003) used saline and alkaline water with high concentration of Cl and Na and observed significant increase in the uptake of Cl and Na by maize plants. Turan et al. (2009) also reported that, NaCl significantly decreased dry mass and increases Na and Cl concentration in maize plants. The correlation analysis suggested that, the better fresh fodder yield of maize genotypes under poor quality irrigation water was a function of their enhanced accumulation of K and better K/Na ratio. Accordingly, the performance of genotype EV-1097 was found better while Akbar seemed to be more sensitive than Kisan. This observation was in line with the K accumulation and K/Na ratio of these maize genotypes. These results are further confirmed by a number of other studies, including Pasternak et al. (1995), who also evaluated salt-tolerance in 14 sweet corn cultivars using fresh (EC$_i$ 1.2 dS m^{-1}) and saline (EC$_i$ 6.2 dS m^{-1}) water and reported that, salinity affects yield and almost all yield contributing variables. Similarly, Hasegawa et al. (2000) studied the effect of salts stress on the growth and development of maize plants and concluded that, the higher concentration of Na and Cl in soil solution is generally, the main cause of the reduced growth and even death of plants. Contrarily, the correlation analysis suggested that, the reduction in the fresh fodder yield of maize genotypes under poor quality irrigation water was not related to their Na accumulation. This contradiction of results might be related to the alteration of genetic behavior among the maize genotypes used in these studies.

Conclusion

The results of the present study elucidated that, the irrigation water salinity beyond 4.5 dS m^{-1} is not favorable for growing maize genotypes under study, except EV-1097. The better fresh fodder yield of maize genotypes under poor quality irrigation water was a function of their enhanced accumulation of K and better K/Na ratio. The study concluded that, the genotype EV-1097 is a better choice for the maize growers under saline water irrigation condition. Further field studies are recommended to validate these results.

ACKNOWLEDGEMENTS

WE are grateful to Prof. A.N. Laghari for improving the language of this manuscript. This research and publication is funded by Sindh Agriculture University, Tandojam, Pakistan through Higher Education Commission Funded Project, "Centre for Bio-saline Agriculture"

REFERENCES

Abid M, Hassan A, Ghafoor A (2003). Brackish water for irrigation: IV Effects on yield of maize and saturated hydraulic conductivity of soil. J. Res. Sci. 14: 17-26.

Bhattacharya RK, Mishra B (1979). Present position on the studies of salt-tolerant rice varieties in India and their problems. Curr. Agric. 3: 73-79.

FAO (2010). Global agriculture towards 2050. High-Level Expert Forum, Rome 12-13 October, 2009.

http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/ HLEF2050_Global_Agriculture.pdf [Accessed on September 28, 2009].

Gandahi AW (2010). Integrated saline water management in maize fodder production. PhD. Thesis. Department of Soil Science, Sindh Agriculture, University, Tandojam.

Gandahi AW, Wagan MR, Yosup MK, Oad FC, Rajpar I, Siddiqi MH (2009). Water quality effect on fodder maize and soil characteristics. Sarhad. J. Agric. 25: 217-223.

Glenn EP, Brown JJ, Blumwald EJ (1999). Salt-tolerance and crop potential of halophytes. Crit. Rev. Plant Sci. 18: 227-255.

Gorham JE, McDonnell, Budrewicz E, Wyn Jones RG (1985). Salt tolerance in the Triticeae: Growth and salt accumulation in leaves of *Thynopyrum bessarabicum*. J. Exp. Bot. 36: 1021-1031.

Gupta IC (1990). Management practices. *In*: Use of saline water in agriculture. Revised Edition. Oxford & IBH Publishing Co. PVT. LTD., New Dehli. pp. 255-293.

Hasegawa PM, Bressan RA, Zhu JK, Bohnert HJ (2000). Plant cellular and molecular responses to high salinity. Annu. Rev. Plant Biol. 51: 463-499.

Kanwar JS, Chopra SL (1959). Practical Agriculture Chemistry. S. Chand and Co. New Delhi. pp. 130-131.

Kumawat GL, Lal P, Chhipa BR, Kumar A (1995). Effect of salinity and sodicity of water used for supplemental irrigation on morpho-physiological parameters and yield of pearl millet. Plant Physiol. Biochem. 18: 43-46.

Medeiros JF, Lisboa RS, Oliveira M, Silva MJ, Alves LP (2003). Effect of salinity stress on seedling growth of maize. Rev. Bras. Engenharia Agrícola Ambiental, 7: 469-472.

Narwal RP, Singh M, Gupta AP (1995). Influence of cadmium enriched sewage water on growth and nutrient content of corn. Ann. Biol. Ludhiana, 11: 158-163.

Nawaz I, Zia-ul-hassan, Ranjha AM, Arshad M (2006). Exploiting genotypic variation among fifteen maize genotypes of Pakistan for potassium uptake and use efficiency in solution culture. Pak. J. Bot. 38: 1689-1696.

Pasternak D, Sagih M, DeMalach Y, Keren Y, Shaffer A (1995). Irrigation with saline water under desert conditions XI. Salt tolerance in sweet-corn cultivars. Agric. Water Manage. 28: 325-334.

Qureshi RH, Barret-Lennard EG (1998). Saline Agriculture for Irrigated Land in Pakistan. A handbook. ACIAR, Canberra, Australia.

Rahman A (2010). Seawater for Agriculture: advances in reverse osmosis. The Daily Dawn, Newspaper, 16 May 2010.

Rajpar I (1999). The effects of sodicity on the growth and yield of wheat. Ph.D. Thesis, University of Wales, Bangor, UK.

Rajpar I, Khanif YM, Saad MS (2007). Salt tolerance in *Andrographis paniculata*. J. ISSAAS. 13: 1-9.

Rowell DL (1994). Soil Science Methods and Applications: (ed.). Rowell DL. Longman Group, UK.

Turan MA, Elkarim AHA, Taban N, Taban S (2009). Effect of salt stress on growth, stomatal resistance, proline and chlorophyll concentrations in maize plant. Afr. J. Agric. Res. 4: 893-897.

United States Salinity Laboratory (1954). Diagnosis and Improvements of Saline and Alkali Soils. United States Department of Agriculture, handbook No. 60.

Zahid P, Afzal M (2002). Screening of wheat cultivars against salinity. Pak. J. Soil Sci. 21: 7-10.

Zia-ul-hassan, Memon KS, Memon M, Arshad M (2008). Quantifying the effect of temperature on ammonium bicarbonate diethylene triamine penta-acetic acid extractable potassium and developing a novel correction factor to express the data. Commun. Soil Sci. Plan. 39: 3047-3056.