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Original Article

Evaluation of genotypic behavior of maize under normal and salt affected soils

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Abstract

Soil salinity is one of the serious problems which posing severe threat to ecosystems under different environmental conditions throughout the world. Salinity is drastically affecting the productivity of agronomic crops particularly maize. Maize grain, being a rich source of protein, is a quality food for humans and healthy green fodder for animals. Experiment under randomized complete block design (RCBD) with four repetitions was conducted at Institute of Soil and Environmental Sciences (non-saline soil) and Proka Research Farm (saline soil), University of Agriculture, Faisalabad. Two maize genotypes (EV-78 and KS-64) were selected for their comparative performance under salt-affected and normal soil conditions. Physiological, growth and yield parameters of maize genotypes were significantly influenced under salt affected and normal soils. Under saline conditions, genotype EV-78 showed tolerant behavior as compared to genotype KS-64 because genotype EV-78 produced higher shoot fresh and dry weights, 100-grain weight and grain yield per hectare. Physiological parameters including photosynthetic rate, transpiration rate, sub-stomatal CO_2 concentration and stomatal conductance were also less affected in genotype EV-78 under saline soil conditions. Under non-saline soil condition, genotype EV-78 accumulated more potassium, phosphorus and nitrogen whereas concentrations of sodium and chloride were reduced. While genotype EV-78 accumulated higher concentrations of sodium and chloride under saline soil conditions. Genotype KS-64 showed more sensitive behavior to saline environment regarding economical yield.

Keywords: Salinity, Maize, Mineral nutrients, Stomatal conductance, Yield

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Introduction

Maize is one of the most important cereals that has been used for human and animal consumption for centuries and is cultivated in variety of soils in different regions of the world. Protein content and quality oil present in its grain has made maize a high value food. As compared to other cereals it has ability to endure salinity (Carpici et al., 2010). Soil salinity is posing a serious threat to the crop productivity in modern agriculture by reducing the yield of agricultural crops (Alam et al., 2000). Severity of soil salinity problem is evident from the fact that around 20% of cultured land all over the world and 33% irrigated land are salt-affected (Machado and Serralheiro, 2017). Impact of salt stress under semi-arid and arid areas is more threatening due to climatic conditions like erratic rainfall pattern, high temperature and evapotranspiration along with inappropriate management of soil and water resources (Azevedo et al., 2006). These areas are usually characterized with high temperature, insufficient rainfall, inadequate irrigation application, poor soil drainage and shallow underground water which ultimately boost the issue of soil salinity resultantly crop productivity is reduced (FAO, 2003).

Plants have adopted different mechanisms to sustain productivity under high amount of salts in soils. There is a varying level of salt tolerance among plant species and varieties (Ashraf and Foolad, 2007). Many physiological processes in plant like photosynthetic activity, ion uptake and movement, vacuolar compartmentalization and water contents may differ in diverse genotypes (Leidi and Saiz, 1997). Deferent genotypes under salt stress conditions showed varied response in plant processes as ion partitioning, transpiration efficiency, Na^+/ K^+ biasness, Na^+ exclusion, retaining of different ions in leaf sheath, ion apportioning, osmotic balance, timely flowering, shortened growing period and improvement in water use efficiency (Colmer and Flowers, 2006).

Plants have different protective mechanisms to cope with salinity problem that enable them to survive and complete their lifecycle. One of the ubiquitous mechanisms in plant is production of organic metabolites of low molecular weight which are commonly recognized as compatible solutes to overcome the problem of salinity (Serraj and Sinclair, 2002; Ashraf and Harris, 2004). Production of these metabolites in response to salt stress serves as osmolyte that enhances the capability of the cells to retain water stability without disrupting the usual functioning (Yancey et al., 1982). Osmoprotectants are particular molecules which are not highly charged, have maximum solubility and highly polar with big hydration shell (Sairam and Tyagi, 2004). Osmoprotectants facilitate osmotic adjustment in cells resultantly safeguarding sub-cellular structure and also reduce oxidative injuries due to the development of free radicals in response to high salt concentration (Demiral and Turkan, 2004).

Keeping in view the above discussion of the significance of maize and salinity, a field trail was conducted having the objectives to evaluate the impact of salt stress on growth, yield nutrient concentration (N, P, K) and photosynthetic performance of two maize genotypes.

Material and Methods

Experimental particulars

Current experiment was carried out at two different places i.e. at Research area of Institute of Soil and Environmental Sciences (normal soil) and Proka Research Farm (saline soil), University of Agriculture, Faisalabad. Soil sampling was done for different physio-chemical properties before sowing of crop (Table 1).

Table-1: Properties of salt affected soil used in the experiment

Parameters	Unit	Soil depth	
		0-30 cm	30-60 cm
ECe	dS m^{-1}	7.2-12.8	9.1-14.7
pHs	-	7.6-8.4	8.0-8.8
SAR	$[(mmol\ L^{-1})]^{1/2}$	4.8-13.9	8.3-15.7
Na^+	Ppm	25.39	13-53
Ca+Mg	Ppm	0.3-3.0	1.3-2.6
Saturation %age	%	13.2-22.7	13.8-20.39

Randomized complete block design (RCBD) accompanied by four replications with net plot size of 10 m × 5 m was used in the experiment. Seeds of two maize genotypes (EV-78 and KS-64) were collected from Ayub Agriculture Research Institute, Faisalabad-Pakistan and sown keeping P × P distance of 9 cm. Fine seedbed was prepared by deep ploughing followed by planking. Recommended dose of NPK was supplemented during the course of experimentation. Half dose of nitrogen with full dose

of phosphorus and potassium were supplemented at sowing time while the remaining half dose of nitrogen was supplemented at tasseling stage. Urea, SSP and SOP were used as the sources of NPK respectively. To reduce the infestation of stem borer in field, carbofuran at the rate of 20 kg ha^{-1} was applied on the top of the shoot after 35 days of emergence. All other agronomic practices including weeding and hoeing were performed as and when required.

Physiological parameters

Completely extended second leaf of particular maize plants before tasseling stage, was selected to record transpiration rate (m mole m^{-2} s^{-1}), photosynthetic rate (µmol m^{-2} s^{-1}), sub-stomatal CO_2 concentration and stomatal conductance with the help of IRGA.

Yield and its parameters

Meter rod was used to measure plant height (cm) at harvesting of crop. Fresh and dry weight of plants (kg ha^{-1}) were recorded by using electric balance after harvesting. After recording fresh weight from collected samples, these were dried under shade for 15 days to attain dry weight (kg ha^{-1}). Regarding the measurement of 100 grains weight (g) and grain yield (kg ha^{-1}) samples were collected from each plot and weighed by using electric balance. After the harvesting, number of cobs per hectare was calculated from both sites.

Nutrients accumulation in shoot

Plant samples that were collected for the estimation of nutrients were dried in oven at 65°C for 72 hours and their dry weights were recorded. Muffle furnace was used for ashing purpose of the samples. After ashing of samples, digestion was done in 2.5 ml 5M HNO_3 and made 50 ml volume with distilled water for ionic analysis. For the estimation of sodium (Na) and potassium (K) Sherwood – 410 flame photometer was used. For the estimation of Cl^{-1} Sherwood-926 Cl^{-1} analyzer apparatus calibrated in mg per liter was used. Spectrophotometer was used to estimate phosphorus (P) contents by using same filtrate. Digestion of ground plant material and mixture of 2 ml of sulfuric acid and hydrogen peroxide was done and distilled water was used to make the volume up to 100 ml. Kjeldahl apparatus was used for the estimation of N contents.

Statistical analysis

Data were statistical analyzed by using Statistix 8.1 software and differences amongst treatments' means were equated by using LSD test at 5% probability level as stated by Steel and Torrie (1983).

Results

Saline soil significantly reduced stalk fresh and dry weights, plant height, 100-grain weight, number of cons per hectare as compared to normal soil in maize hybrids (Table 2). Genotype EV-78 showed resistant behavior to saline soil as compared to KS-64. Genotype EV-78 statistically accumulated more biomass as compared to genotype KS-64. There was no significant difference among the genotypes regarding plant height, 100-grain weight, number of cobs per hectare and grain yield. Genotype EV-78 statistically performed better than genotype KS-64 under saline soil condition (Table 2) regarding growth and yield parameters. Genotype KS-64 showed sensitivity to salinity regarding plant height, 100-grain weight, number of cobs and grain yield.

Physiological parameters i.e. photosynthetic rate, transpiration rate, sub-stomatal CO_2 concentration and stomatal conductance were significantly reduced under saline soil conditions as compared to normal soil (Table 3). Genotype EV-78 comparatively showed superiority regarding physiological parameters over genotype KS-64. Genotype EV-78 performance was better on saline and normal soil than genotype KS-64 (Table 3).

Accumulation of mineral and essential nutrients in shoot was also significantly affected under saline condition. Higher concentrations of shoot sodium and chloride were observed under saline soil as compared to normal soil.

Table-2: **Performance of growth and yield parameters of two maize genotypes grown under normal and saline soils.**

Treatments	Stalk Fresh Weight	Stalk Dry Weight	Plant Height	100-Grain Weight	Number of Cobs	Grain Yield
A. Soil						
Non saline (NS)	684.5 A	186.86 A	56.21 A	17.33 A	1175 A	1715 A
Saline (S)	274.6 B	55.16 B	31.36 B	4.18 B	225 B	1216 B
LSD	135.27	49.71	16.69	9.36	309	139
B. Genotypes						
EV-78	672.5 A	178.9 A	48.46	11.38	700	1527
KS-64	286.5 B	63.11 B	39.11	10.12	700	1404
LSD	192.47	34.09	NS	NS	NS	NS
A×B Interaction						
NS×EV-78	903.6 A	273.63 A	62.52 A	18.99 A	1250 A	1737 A
NS×KS-64	465.3 B	100.1 B	49.90 B	15.66 A	1100 A	1693 A
S×EV-78	441.4 B	84.18 B	34.40 C	3.76 B	150 B	1317 B
S×KS-64	107.8 C	26.13 C	28.32 C	4.59 B	300 B	1116 B
LSD	274	38.92	9.64	6.27	367	245

Means sharing the same letter did not differ significantly at P = 0.05; NS = non-significant.

Table-3: **Performance of physiological parameters of two maize genotypes grown under normal and saline soils.**

Treatments	Photosynthetic Rate	Transpiration Rate	Sub-Stomatal CO_2 Concentration	Stomatal Conductance
A. Soil				
Non saline (NS)	20.22 A	12.0 A	81.49 A	0.14 A
Saline (S)	14.87 B	2.54 B	47.53 B	0.06 B
LSD	4.36	5.42	12.37	0.028
B. Genotypes				
EV-78	21.67 A	11.40 A	81.70 A	0.13 A
KS-64	13.42 B	3.14 B	47.32 B	0.07 B
LSD	3.82	4.61	18.43	0.316
A×B Interaction				
NS×EV-78	24.80	19.79 A	100.1 A	0.18
NS×KS-64	15.65	4.21 B	62.89 B	0.10
S×EV-78	18.55	3.00 B	63.31 B	0.07
S×KS-64	11.19	2.07 B	31.75 C	0.04
LSD	NS	9.25	21.74	NS

Means sharing the same letter did not differ significantly at P = 0.05; NS = non-significant.

Higher concentrations of shoot potassium, phosphorus and nitrogen were observed under normal soil as compared to saline soil. Genotype EV-78 showed statistically more accumulation of mineral nutrients as compared to KS-64. More concentrations of chloride and sodium were accumulated by genotype EV-78 under saline conditions comparatively. Maximum potassium concentration was recorded in shoot of genotype EV-78 under normal soil (Table 4).

Table-4: **Proximate analysis of two maize genotypes grown under normal and saline soils.**

Treatments	Shoot Potassium	Shoot Phosphorus	Shoot Nitrogen	Shoot Chloride	Shoot Sodium
A. Soil					
Non saline (NS)	31.85 A	54.79 A	1.61 A	0.645 B	1.08 B
Saline (S)	15.73 B	35.07 B	0.94 B	0.997 A	1.63 A
LSD	12.81	9.48	0.475	0.176	0.218
B. Genotypes					
EV-78	29.18 A	51.47 A	1.45 A	1.02 A	1.60 A
KS-64	18.39 B	38.39 B	1.10 B	0.63 B	1.11 B
LSD	4.374	8.148	0.187	0.329	0.374
A×B Interaction					
NS×EV-78	37.46 A	59.52	1.88	0.761 B	1.20 B
NS×KS-64	26.23 B	50.06	1.34	0.528 B	0.95 B
S×EV-78	20.90 B	43.41	1.02	1.27 A	1.99 A
S×KS-64	10.55 C	26.72	0.85	0.724 B	1.26 B
LSD	8.614	NS	NS	0.274	0.594

Means sharing the same letter did not differ significantly at P = 0.05; NS= non-significant.

Discussion

In this experimentation, saline conditions reduced the shoot fresh and dry weight as compare to non-saline or normal soil conditions in maize. Specific ion effect, osmotic stress and ionic imbalance reduced the fresh and dry weights of plant (Munns and Termaat, 1986; Romera and Alcantara, 1994). Kent and Lauchi (1985) reported that the deficiency of nutrients reduced the tissue development. Increase in salinity level due to ion toxicity of chloride and sodium ions decreased the fresh and dry weight of plants (Parveen and Qurashi, 1992; Munns, 1993; Shafaqat et al., 1998). Increase in salinity level also accelerated the leaves shedding resulting in decrease in shoot fresh weight in plants (Grieve et al., 1993). Different plant metabolic processes control the mechanism of growth in plants. Salinity affected the metabolic processes which decreased the dry shoot weight of plants (Cheesman, 1988). Imbalance nutrient concentration, solute suction at toxic level and use of metabolites increased the salinity level resultantly shoot dry weight decreased at drastic rate (Akhtar and Azhar, 2001). Excessive salts absorption and accumulation by cell wall altered the metabolic pathway which reduced the cell wall elasticity which resulted in reduction of shoot length and growth (Bavaresco et al., 2003; Yousfi et al., 2007). Early production of secondary cells and stiffness of cell wall caused lower turgor pressure which decreased leaf expansion, leaf area, leaf emergence and leaf growth (Kar et al., 2003).

Salt stress negatively influenced 100-grain weight and grains per spike which ultimately led to yield reduction in wheat crop (Ahmad et al., 1992). Khan et al. (2005) observed significant decline in number of grains per cob due to excessive salts in rhizosphere. Zaibunnisa et al. (2002) also observed decline in grain yield due salt stress in maize. Different yield parameters like grain weight and grain yield in different crops decreased in dry season when high transpiration rate resulted in high salt uptake by the plants. Environmental factors affected grain development which ultimately influenced degree of grain filling, spikelet fertility, grain size and grain weight (Sharif et al., 1999; Monsour et al., 2005). Reduction in physiological and yield parameters under saline soil conditions might be attributed to higher accumulation of sodium and chloride ions as compared to potassium ion in crop plants (Begum et al., 1992). Photosynthetic and transpiration rate were significantly reduced in plants grown under saline conditions (Ahmad et al., 2000; Sairam et al., 2002; Naheed et al., 2007). Reduction in photosynthetic activity and transpiration rate in crop plants could be attributed to decreased leaf area under salt stress conditions (Munns and Termaat, 1986).

Salt stress negatively influenced photosynthetic rate by causing closure of stomata which ultimately led to the reduced carbon dioxide concentration among cells (Stepien and Klobus, 2006).

Transpiration is a key physiological process in managing deposition of salts in shoot. Salt stress

strongly decreased transpiration rate through stomatal closure. However, stomatal closure proved to be a useful mechanism for salt tolerance in plants by decreasing salt uptake through roots (Moya et al., 1999; Storey and Walker, 1999).

Photosynthetic rate, rate of respiration, water use efficiency, carbon dioxide concentration in the cells and stomatal conductance were reduced in different cultivars grown under saline conditions. Carbon dioxide concentration at sub-stomatal stage decreased as salt concentration in rhizosphere increased due to less stomatal conductivity but due prolonged stomatal closure CO_2 increased due to less consumption in photosynthesis (Stoeva and Kaymakanova, 2008). Zhao et al., (2007) also reported that excessive accumulation of salts in root zone reduced the stomatal conductance as analyzed in current study (Table 2). Salts sensitive wheat varieties showed less stomatal conductance as compare to salt tolerant wheat varieties (Hendawy et al., 2005). The possible reason for decreased stomatal conductance was concentrated salt solution in root zone that restricted the absorption of water by roots. Moreover, reduced photosynthetic rate accredited to NaCl induced stomatal closure (Naheed et al., 2007). The finding of our experiment was similar to the results observed by Netondo et al. (2004), who stated that there was a linear relationship between CO_2 absorption and stomatal conductance in saline environment and decreased photosynthesis in sorghum under salt stress was due to stomatal conductance. Ashraf et al. (2003) reported that there was a strong relationship between stomatal conductance and water potential in leaf.

In current study accumulation of mineral nutrients in maize genotypes was significantly influenced by salinity (Table 4). On overall basis saline conditions significantly affected both genotypes. An important tool for identification of salinity tolerance in different crops is the determination of potassium concentration, as its concentration decreases due to increase in salinity level. Potassium is an important element for osmotic adjustment and also a major nutrient for plant growth and development and plants prefer K^+ as compared to Na^+. There is competition between Na^+ and K^+ for the entry in plant cells because they have same ionic radius and ionic hydration energy as well. Consequently, crop suffering from salt stress may suffer potassium deficiency and sodium toxicity. (Schachtman and Liu, 1999).

Sairam et al. (2002) and Anil et al., (2005) reported that K^+ concentration decreased in shoot due to increased salinity. Homeostasis is an important process in plants to bear the salt stress (Sairam et al., 2005). Under saline conditions sodium ion replaced the potassium in soil solution which caused disrupted protein functioning (Chinnusamy et al., 2005). Deficiencies of potassium and iron can be associated with each other (Rabhi et al., 2007).

As concerned with Phosphorus (P) contents the results are similar with the findings of Grattan and Grieve, (1999) who submitted the complex relation between phosphorus and salinity. Phosphorus concentration is associated with the photosynthetic rate but translation of fixed carbon into starch is decreased by phosphorus. Salt stress had detrimental effects on the uptake of P and ultimately reduced its availability (Grattan and Grieve, 1999). Increased chloride concentration under salt stress was reported by Jogeswar et al. (2006) and Kumar et al. (2008).

High salt concentration in soil persuaded the deposition of sodium and chloride ions in root and shoot as compared to potassium and calcium ions. High concentration of Cl^{-1} in leaves interrupted photosynthesis through the reduction in the activity of nitrate reductase (Xu et al., 2000). Ashraf and Leary (1994) in alfalfa reported the similar findings. Salt stress in high concentration of Na^{+1} and Cl^{-1} in shoot caused toxicity and salt injury in plants (Serrano et al., 1999). Toxicity due to high salt concentration in leaves and stem was mainly due to higher concentration of Na^{+1} and Cl^{-1} and decreased uptake of K^+ (Sharma, 1995).

Na^+ concentration can be used to determine the efficiency of crop in salt stress environment and ability of crop to tolerate the salts. On overall mean basis Na^{+1} concentration in shoot was significantly higher in salt stress conditions than in non-saline conditions (Table 4). Under high salt concentration higher concentration of Na^+ in plants was reported by Mansour et al. (2005) which resulted in ion toxicity due to disruption in translocation system (Iqbal and Ashraf, 2007). Higher leaf concentration of Na^+ proved toxic in plants (Serrano et al., 1999) and negatively affected the physiological and yield parameters of crop.

Conclusion

Salinity negatively affected the growth and yield of maize genotypes. Genotype EV-78 growth behavior was comparatively tolerant against salinity because growth and physiological parameters were less

affected by salinity. On the hand, genotype KS-64 was very sensitive to salinity because it produced low economic yield. It is suggested to cultivate genotype EV-78 on saline soils to get maximum benefits from saline soils rather than cultivation of genotype KS-64.

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References

Ahmad I, Iqbal N, Iqbal M, Aslam Z and Rasool E, 2000. Germination and seedling growth of rice under saline conditions. Pak. J. Biol. Sci. 3: 350-351.

Ahmad R, Zaheer SH and Ismail S, 1992. Role of Si in salt tolerance of wheat (*Triticum aestivum* L.). Plant Sci. 85: 43-50.

Akhtar J and Azhar FM, 2001. Response of cotton hybrids to NaCl salinity at seeding stage. Int. J. Agric. Biol. 3: 233-235.

Alam SM, Ansari A and Khan MA, 2000. Nuclear Institute of Agriculture, Tando Jam, available at http://www.pakistaneconomist.com/issue2000/issue 19&20/i7e3.htm.

Anil VS, Krishnamurthy P, Kuruvilla S, Sucharitha K, Thomas G and Mathew MK, 2005. Reduction of the uptake and distribution of Na^+ in shoots of rice (*oryza sativa* L.) variety pokkali: role of Ca^{+2} in salt tolerance response. Phys. Plant. 124: 451-464.

Ashraf M and Leary JWO, 1994. Does pattern of ion accumulation vary in alfalfa at different growth stages? J. Plant Nutr. 17: 1463-1476.

Ashraf M, Arfan M and Ahmad A, 2003. Salt tolerance in Okra: Ion relations and gas exchange characteristics. J. Plant Nutr. 26: 63-79.

Ashraf M and Foolad MR, 2007. Improving plant abiotic-stress resistance by exogenous application of osmoprotectants glycine betaine and proline. Environ. Exp. Bot. 59: 206–216.

Ashraf M and Harris PJC, 2004. Potential biochemical indicators of salinity tolerance in plants. Plant Sci. 166: 3-16.

Azevedo NAD, Prico JT, Eneas FJ, Braga de Abreu CE and Gomes-Filho E, 2006. Effect of salt stress on antioxidative enzymes and lipid peroxidation in leaves and roots of salt-tolerant and salt-sensitive maize genotypes. Environ. Exp. Bot. 56: 235–241.

Bavaresco L, Giachino E and Pezzutto S, 2003. Grapevine rootstock effects on lime-induced chlorosis, nutrient uptake and source-sink relationships. J. Plant Nutr. 7: 1451-1465.

Begum F, Karmmer JL, Falta QA and Maniruzzaman AFM, 1992. The effect of salinity on germination and its correlation with with K^+, Na^+ and Cl^- accumulation in germinating seeds of *Triticum aestivum*. Plant Cell Physiol. 33: 1009-1014.

Carpici EB, Celik N, Bayram G and Asik BB, 2010. Effects of salt stress on the growth, biochemical parameter and mineral element content of some maize (*Zea mays* L.) cultivars. Afr. J. Biotechnol. 9: 6937-6942.

Cheesman JM, 1988. Mechanism of salinity tolerance in plants. J. Plant Physiol. 87: 547-550.

Chinnusamy V, Jagendorf A and Zhu JK, 2005. Understanding and improving salt tolerance in two plants. Crop Sci. 45: 437-448.

Colmer TD and Flowers TJ, 2006. Use of wild relatives to improve salt tolerance in wheat. J. Exp. Bot. 57: 1059-1078.

Demiral T and Turkan I, 2004. Does exogenous glycinebetaine affect antioxidant system of rice seedlings under NaCl treatment? Plant Physiol. 161: 1089-1100.

FAO, 2003. Statistical Year Book. Rome (Italy): Available http://faostat.fao.org/ International Commission on Irrigation and Drainage (ICID): New Delhi, India. Accessed on: February 13, 2013.

Grattan SR and Grieve CM, 1999. Salinity-mineral nutrient relations in horticultural crops. Sci. Hort. 78: 127-157.

Grieve CM, Lesch SM, Mass EV and Francois LE, 1993. Leaf and spikelet primordial initiation salt stressed wheat. Crop Sci. 33: 1286-1290.

Hendawy SE, Hu Y and Schidfalter U, 2005. Growth, ion content, gas exchange and water relation of wheat genotypes differing in salt tolerance. Aus. J. Agric. Res. 56: 123-134.

Iqbal M and Ashraf M, 2007. Seed preconditioning modulates growth, ionic relations and photosynthetic capacity in adult plants of hexaploid wheat under salt stress. J. Plant Nutr. 30: 381-396.

Jogeswar G, Pallela R, Jakka NM, Reddy PS, Venkateswara Rao J, Sreeniwasulu N and Kishor PBK, 2006. Antioxidative response in different sorghum species under short term salinity stress. Acta. Phys. Plant. 28: 465-475.

Kar MB, Patro B, Sahoo S, and Patel SN, 2003. Response of hybrid cotton to moisture stress. Ind. J. Plant Physiol. 6: 427-430.

Kent LA and Lauchi A, 1985. Germination and seedling growth of cotton: salinity calcium interactions. Plant Cell Environ. 8: 115-119.

Khan MA, Abid M, Hussain N and Masood MU, 2005. Effect of phosphorous levels on growth and yield of maize (*Zea mays* L.) cultivars under saline conditions. J. Agric. Biol. 7: 511-514.

Kumar V, Shriram V, Nikam TD, Jawali N and Shitole MG, 2008. Sodium chloride induced changes in mineral nutrients and praline accumulation in indica rice cultivars differing in salt tolerance. J. Plant Nutr. 31: 1999-2017.

Leidi EO and Saiz JF, 1997. Is salinity tolerance related to Na^+ accumulation in upland cotton seeding? Plant Soil. 190: 67-75.

Machado RMA and RP Serralheiro, 2017. Soil salinity: Effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization. Horticulturae. 3: 30. doi:10.3390/horticulturae3020030

Mansour MMF, Salma KHA, Ali FZM and Hadid AFA, 2005. Cell and plant response to NaCl in *Zea mays* L. cultivars differing in salt tolerance. Gen. Appl. Plant Physiol. 31: 29-41.

Moya JL, Primo-Millo M and Talon M, 1999. Morphological factors determining salt tolerance in citrus seedlings: the shoot to root ratio modulates passive root uptake of transport in plants and fungi. University of Sydney. pp. 490-494.

Munns R, 1993. Physiological process limiting plant growth in saline soils. Some dogmas and hypotheses. Plant Cell Environ. 16: 15-24.

Munns R and Termaat A, 1986. Whole-plant responses to salinity. Aust. J. Plant Physiol. 13: 143-160.

Naheed G, Shahbaz M, Latif A and Rha ES, 2007. Alleviation of adverse effect of salt stress on rice (*Oryza sativa* L.) by phosphorous applied through rooting medium: growth and gas exchange characteristics. Pak. J. Bot. 39: 729-737.

Netondo GW, Onyango JC and Beck E, 2004. Sorghum and salinity: II. Gas exchange and chlorophyll fluorescence of sorghum under salt stress. Crop Sci. 44: 806-811.

Stoeva N and Kaymakanova M, 2008. Effect of salt stress on growth and photosynthesis rate of bean plants (*Phaseolus vulgaris* L.). J. Cent. Eur. Agric. 9: 385-392.

Parveen S and Qurashi RH, 1992. Toxicity levels of Na^+ and Cl^- in wheat leaves cell sap. Pak. J. Agric. Sci. 29: 148-152.

Rabhi M, Barhoumi Z, Ksouri R, Abdelly C and Gharasalli M, 2007. Interactive effect of salinity and iron deficiency in *Medicago ciliaris*. Res. Biol. 330: 779-788.

Romera FJ and Alcantara E, 1994. Iron deficiency stress response in cucumber roots. J. Plant Physiol. 105: 1133-1138.

Sairam RK, Rao KV and Srivastava GC, 2002. Differential response of wheat genotypes to long term salinity stress in relation to oxidative stress, antioxidant activity and osmolyte concentration. Plant Sci. 163: 1037-1043.

Sairam RK, Srivatava GC, Agarwl S and Meena RC, 2005. Difference in response to salinity stress in tolerant and susceptible wheat genotypes. Biol. Plant. 49: 85-91.

Sairam RK and Tyagi A, 2004. Physiology and molecular biology of salinity stress tolerance on plants. Curr. Sci. 86: 407-421.

Schachtman DP and Liu WH, 1999. Molecular pieces to the puzzle of the interaction between potassium and sodium uptake in plants. Plant Sci. 4: 281-287.

Serraj R and Sinclair TR, 2002. Osmolyte accumulation: can it really help increase crop yield under drought conditions? Plant Cell Environ. 25: 333-341.

Serrano R, Mullet JM, Rios G, De Marquez JA, Larrinoa I, Leube MP, Mendizabal I, Ahuir AP, Proft M, Ros R and Montesinos C, 1999. A glimpse of the mechanisms of ion homeostasis during salt stress. J. Exp. Bot. 50: 1023-1036.

Shafaqat MN, Mustafa G, Mian SM and Qurashi RH, 1998. Evaluation of physiological aspects of stress tolerance in wheat. Pak. J. Soil. Sci. 14: 85-89.

Sharif A, Rasool E, Nisar A and Sadiq M, 1999. Response of maize to NaCl salinity induced at various growth stages of crop. Pak. J. Biol. Sci. 2: 606-608.

Sharma SK, 1995. Effect of salinity on growth performance and internal distribution of Na^+, K^+ and Cl^- in *Vicia faba* L. Ind. J. Plant Physiol. 38: 69-72.

Steel RGD and Torrie JH, 1983. Principles and Procedures of Statistics. A Biometrical Approach. Mc Graw Hill, Book Inc., New York, USA. pp. 633.

Stepien P and Klobus G, 2006. Water relations and photosynthesis in *Cucumis sativus* L. leaves under salt stress. Biol. Plant. 50: 610-616.

Storey R and Walker RR. 1999. Citrus and salinity. Sci. Horti. 78: 39–81.

Xu G, Magen H, Farchitzkg J and Kafkai U, 2000. Advances in chloride nutrition in plants. Advan. Agron. 68: 97-150.

Yancey PH, Clark ME, Hans SC, Bowlus RD and Somero GN, 1982. Living with water stress: evolution of osmolyte systems. Sci. 217: 1214-1222.

Yousfi S, Sehli WM, Mahmoudi H, Abdelly C and Gharasalli M, 2007. Effect of salt on physiological responses of barley to iron deficiency. J. Plant Physiol. Biochem. 45: 309-314.

Zaibunnisa A, Khan MA, Flowers TJ and Malik R, 2002. Causes of sterility in rice under salinity stress. In: Ahmad, R. (Ed.), Prospects for Saline Agriculture. Kluwer, the Netherlands, pp. 177–187.

Zhao GQ, Ma BL and Ren CZ, 2007. Growth, gas exchange, chlorophyll fluorescence and ion content of naked oat in response to salinity. Crop Sci. 47: 123-131.

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Raza HMI: Managed the experiment while
Saqib M: Supervised the experiment.
Ahmad S: Provided technical input at every step.
Irshad S: Wrote the article
Khan S: Wrote the article.
Bukhsh A: Provided technical input at every step.
Wahid MA: Provided technical input at every step.
Bashir MI: Helps in data management and statistical analysis.