Pak. J. Agri. Sci., Vol. 50(2), 185-189; 2013
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

EFFECT OF SALINITY ON GRAIN YIELD AND GRAIN QUALITY OF WHEAT (*Triticum aestivum* L.)

Ghulam Abbas[1], Muhammad Saqib[1,*], Qaisir Rafique[1], M. Atiq ur Rahman[1], Javaid Akhtar[1], M. Anwar ul Haq[1] and M. Nasim[2]

[1]Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan;
[2]Soil & Water Testing Laboratory, Behawalpur, Pakistan
[*]Corresponding author's e-mail: drhmsab@yahoo.com

Salinity is one of the important stresses resulting in the reduction of growth and yield of different crops including wheat. In saline soils the concentration of Na^+ and Cl^- is higher accompanied with the decreased K^+: Na^+ ratio thus severely affecting the growth and yield of crops. The effect of salinity on the growth and yield of wheat is well documented, whereas there is very little information about salinity tolerance and grain quality of wheat. Present study was conducted to assess the effect of salinity on yield components, ionic relations and grain quality and to understand the relationship among these parameters. A pot experiment was conducted using wheat genotype Pasban-90. There were two treatments i.e. non-saline (0.33 dS m^{-1}) and saline (15 dS m^{-1}) with five replications. Salinity resulted in a significant reduction of the grain protein, fat and fiber contents. Similarly yield components were significantly reduced. Maximum reduction was noted in case of number of tillers $plant^{-1}$, followed by grain weight $plant^{-1}$. High Na^+ and low K^+, P concentration and K^+: Na^+ ratio was observed in the shoot, root and grain. This disturbed ionic composition seems to be apparent cause of yield reduction and deterioration of wheat quality under salinity.
Keywords: Salinity, wheat, grain yield, grain quality, *Triticum aestivum* L.

INTRODUCTION

Arid and semiarid regions of the world are being faced by soil salinization which is hampering crop growth in these areas. As a result of this menace, a large area of the arable land has become completely or partially non productive. Saline water and poor irrigation practices have converted good agricultural lands to barren lands. Soil salinization is one of the important abiotic stresses which results in the reduction of growth and productivity of the crops (Sairam *et al*., 2002). It affects crops mainly in two ways i.e. either by osmotic effect or by specific ion effect (Munns and James, 2003). Osmotic effect causes disruption in osmotic potentials, where as specific ion effect causes toxicity of different ions (Brady and Weil, 2002). High salt concentrations disturb the ionic homeostasis and produce reactive oxygen species (Saqib *et al*., 2008). This interference in homeostasis occurs at both the cellular and the whole plant levels. Various outcomes of these disturbed ionic and water homeostasis include molecular damage, growth restriction or even complete death of the plants (Zhu, 2001). It has been observed that in saline soils, the concentration of Na^+ and Cl^- is higher accompanied with the decreased concentration of K^+ and K^+:Na^+ ratio thus severely affecting the plant growth (Saqib *et al*., 2004).

Plants have developed different approaches to tackle the problem of salinity. They either exclude salts from their cells or tend to compartmentalize them into the vacuole (Parida and Das, 2005). Selective uptake of K^+ over Na^+ is a well recognized mechanism for salinity tolerance of the plants (Wenxue *et al*., 2003). Under saline conditions salt tolerant plants try to keep higher K^+ and lower Na^+ concentration in the cytosol. This is done by the regulation of the expression and activity of K^+ and Na^+ transporters (Zhu, 2003). Increased Na^+ efflux, K^+ influx and use of Na^+ for osmotic adjustment are the main strategies which plants use to sustain desirable K^+: Na^+ ratio in the cell (Zhu, 2003).

Wheat growth is affected by soil conditions and water availability (Akhkha *et al*., 2012; Iqbal *et al*., 2012). Wheat is a moderately salt-tolerant crop (Maas and Hoffman, 1977) and it has significant genotypic difference for salinity tolerance (Saqib *et al*., 2005). It is one of the important crops contributing to the daily protein and calories requirements of the people (FAO, 1985). It ranks first in acreage as well as production amongst all the cereals grown in Pakistan. Annual wheat production in Pakistan was 24214 thousand tons and area under cultivation was 8805 thousand hectares in 2010-11 (Ministry of Finance, 2011). Wheat production in Pakistan is quiet low in the salt-affected areas and yield losses up to 65% have been recorded in moderately saline soils (Shafi *et al*., 2010). Soil amelioration by addition of different amendments is one option (Kahloon *et al*., 2012). However, if genetic variability in wheat is explored extensively, the productivity of these saline areas would be increased to a great extent. The detrimental effects of salinity on the growth and yield of wheat are well documented whereas a little information is available regarding its effects on grain quality. In the past not much attention was given to study the effects of salinity on quality of grains. With the improved life style requirements for the high quality have also increased (Park *et al*., 2008). This study has been conducted to assess the effect of salinity on yield components, ionic relations and grain quality and to understand the relationship among these parameters.

MATERIALS AND METHODS

Growth conditions and treatment application: A pot experiment was conducted in the wire house of the Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad. Seeds of wheat (*Triticum aestivum L.)* genotype (Pasban-90) were obtained from the Saline Agriculture Research Centre, University of Agriculture, Faisalabad, Pakistan. The experiment was replicated five times in a completely randomized design. The plants were grown in pots filled with a sandy loam soil having pH 8.2. There were two treatments in the experiment i.e non-saline (0.33 dS m^{-1}) and saline (15 dS m^{-1}). Salinity level of 15 dS m^{-1} was created artificially by adding sodium chloride in the normal soil before filling in the pots. Each pot contained 10 kg of soil. The recommended doses of NPK fertilizers were used in the form of Urea, DAP and SOP in both saline and non saline treatments. Whole of the P and K and half of the N fertilizers were mixed in the soil while filling in the pots where as half of the N fertilizer was added at the booting stage. The soil filled pots were irrigated with tap water fit for irrigation. After one week when the soil became workable, it was hoed and softened with the help of a spatula. Five seeds were sown in each pot and after seedling emergence three plants were maintained in each pot by thinning. The pots were irrigated with tap water and plant protection measures were done according to the requirement. The plants were harvested at maturity.

Data collection: At maturity, plants were harvested and threshed manually. The data regarding plant height, grain yield, number of tillers per plant, spike length and number of spikelets per spike were recorded. The plant samples were dried at 65°C for 72 hours and ground to a fine powder. The dried and ground shoot, root and grain samples (0.5 g) were digested following the method of Wolf (1982). The filtered aliquot was used for ionic analysis.

Ionic analysis: Potassium and sodium were determined from the digested samples using flame photometer (Jenway PFP - 79). Phosphorus was determined by spectrophotometer (HITACHI U -1100).

Grain analysis for quality attributes including crude protein, fat and crude fiber: The percentage of protein was calculated by multiplying % nitrogen with the factor 6.25. Nitrogen in the sample was determined following Kjeldahl's method as described by Ryan *et al.* (2001).The crude fat content was determined by taking a weighed amount of sample and using petroleum ether as a solvent in a Soxhlet apparatus for 3-2 hours according to the procedure given in AACC (2000).

$$\text{Fat \%} = \frac{\text{Weight of fat in sample (g)}}{\text{Weight of sample (g)}} \times 100$$

The crude fiber was estimated by taking fat free weighed sample, first digesting it with 1.25% H_2SO_4 and then with 1.26% NaOH solution. The digested sample was filtered with the help of a muslin cloth by washing it with distilled water. The residue thus obtained was ignited in a muffle furnace at 550°C till a white residue was left. Fiber percentage was calculated with the help of following formula (AACC, 2000).

$$\text{Crude Fiber (\%)} = \frac{\text{Weight of ashed sample (g)}}{\text{Weight of sample (g)}} \times 100$$

Statistical analysis: The data collected was analyzed for the analysis of variance using completely randomized design (Steel and Torrie, 1980). The significance of differences among the means has been compared using the standard error.

RESULTS

Grain yield and yield components: Grain yield and yield components were decreased significantly by saline conditions as compared to non saline conditions (Table 1). The maximum percent reduction was noted for the number of tillers per plant (62.5%) followed by grain yield per plant (57.65%) and plant height (24.4%). The number of tillers per plant was 4.80 and 1.80 under non saline and saline conditions (15 dS m^{-1}), respectively. The grain yield per plant was 4.36 g in non-saline conditions against 3.54 g under stress condition. Plant height was 76.2 cm in normal conditions whereas in salt stress it was 57.6 cm. The number of spikelets per spike was 20 and 15.6, respectively under non-saline and saline soil conditions. The spike length was also decreased significantly and was 11.4 cm under normal soil conditions and 9.2 cm under saline soil conditions.

Table 1. Effect of salinity on grain yield and yield components of wheat

Parameters	Non Saline	Saline
Plant height (cm)	76.2a ±2.69	57.6b±2.18 (24.40)
Tillers per plant	4.80a±0.37	1.80b±0.2 (62.50)
Spike length (cm)	11.4a± 0.68	9.20b±0.58 (19.30)
Spikelets per spike	20.0 a±1.10	15.6b±0.93 (22.00)
Grain weight plant^{-1} (g)	8.36a ±0.24	3.54b±0.25 (57.65)

Values followed by the same letters in a row are not significantly different at $P < 0.05$ according to the Tukey test. Values in () show % reduction compared to non-saline.

Mineral composition of plant: Plant mineral composition is very important with respect to plant growth, health and produce quality. K^+: Na^+ ratio was decreased significantly in the shoots, roots as well as in the grains under saline soil conditions (15 dS m^{-1}) as compared to normal soil conditions (Fig.1). The concentration of K^+ was also decreased significantly due to salinity in all the parts of plant analysed whereas the concentration of Na^+ was increased significantly due to salinity in all the three parts (Fig. 2; data shown for K^+ alone). Percent reduction in K^+: Na^+ ratio was 45.2%, 58.97% and 43.47% in shoots, roots and grain respectively. Salinity resulted in significant reduction in the phosphorus concentration in shoots, roots and grain. The concentration of phosphorous was 0.50, 0.13 and 0.51 mmol g^{-1}dw in shoot, root and grain respectively under non saline conditions whereas under saline conditions concentrations of phosphorus were 0.30, 0.07 and 0.30 mmol g^{-1}dwt respectively in shoot, root and grain (Fig.3). The maximum reduction in the phosphorous concentration was found in the case of roots (44.45%) followed by grain (41.18%) and shoots (40%).

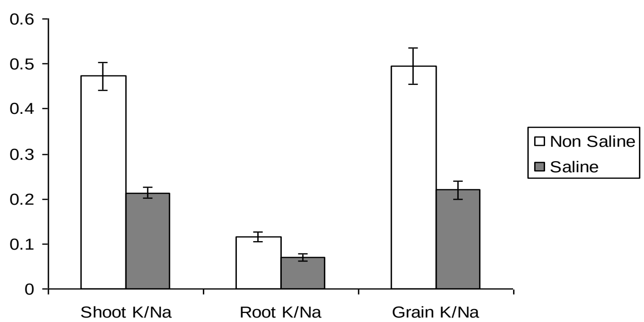

Figure 1. Effect of salinity on K^+/ Na^+ ratio of shoot, root and grain of wheat

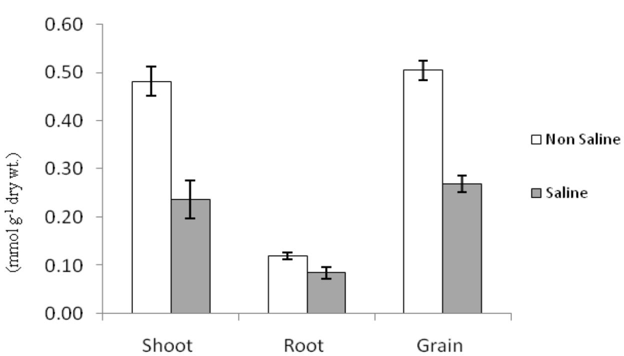

Figure 2. Effect of salinity on K^+ concentration (mmol g^{-1} dry wt.) of shoot, root and grain of wheat

Grain quality attributes: The quality parameters of grain i.e. protein, fat and crude fiber contents were also decreased significantly due to salinity (Fig.4). Under normal conditions protein, fat and crude fiber were 12.18%, 2.40% and 1.80%, respectively whereas under salt stress, the contents of protein, fat and crude fiber were reduced to 9.38%, 1.48% and 0.92%, respectively. The percent reduction in these parameters was 22.97%, 33.97% and 48.66%, respectively.

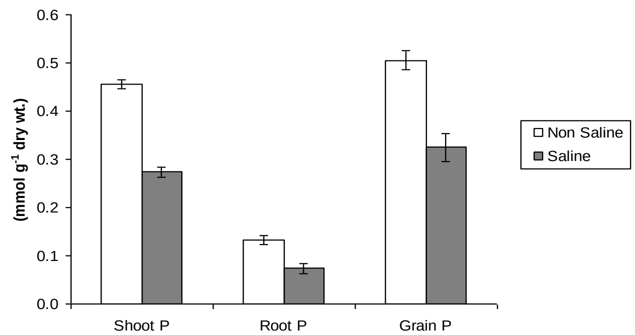

Figure 3. Effect of salinity on phosphorous concentration (mmol g^{-1} dry wt.) of shoot, root and grain of wheat

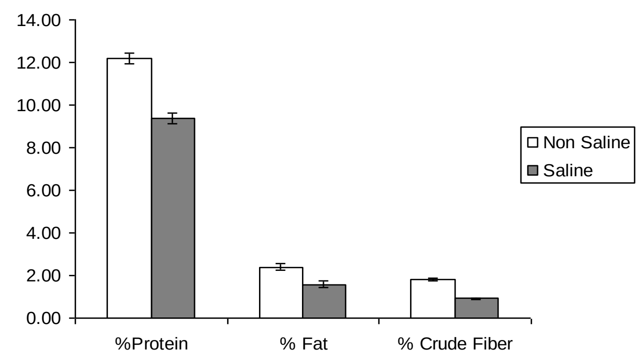

Figure 4. Effect of salinity on protein, fat and crude fiber content (%) of wheat grain

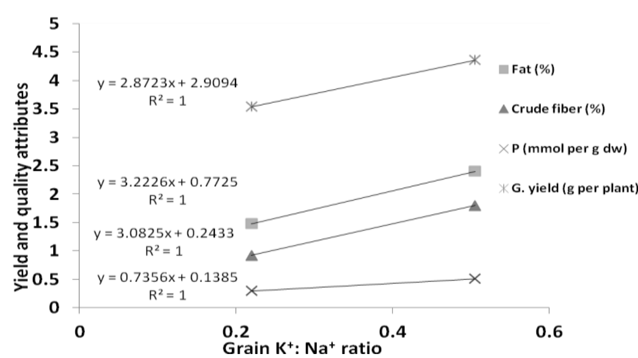

Figure 5. Relationship of grain K^+: Na^+ ratio with different quality attributes of wheat grain

DISCUSSION

Plant height, grain yield and yield components were reduced significantly with the application of salinity. Reduction in the grain yield and yield components due to salinity has also been observed by Saqib *et al*. (2004) and Ghogdi *et al.* (2012). Among the morphological attributes, maximum reduction was observed in number of tillers per plant which may be due to absorption of excessive salts by the plants, which ultimately affected the plant growth indirectly by decreasing the amount of photosynthates, water or other growth factors (Khathar and Kuhad, 1999). Due to higher concentrations of salts in the leaves different metabolic processes like photosynthesis and protein synthesis are negatively affected and result in the reduced grain weight (Ibrahim, 2003). Potassium to sodium ratio decreased significantly in shoot, root and grain which may be due to more uptake of sodium as compared to potassium which matches with the findings of Qureshi *et al.* (1991). A positive correlation exists between Na^+ exclusion and salt tolerance of many crops including wheat (Shafi *et al*., 2010; Ghogdi *et al*., 2012). In saline conditions there is passive Na^+ diffusion through damaged membranes and decreased efficiency of exclusion mechanism which results in high concentration of sodium in leaf sap (Leidi and Saiz, 1997). Potassium influx transporters mediated sodium influx into root cells (Rabhi *et al*., 2007) under saline conditions. High external Na^+ concentration interferes with K^+ absorption resulting in low root K^+ due to Na^+ antagonistic effect. The preferred uptake of K^+ is an important physiological mechanism of salinity tolerance in many crop plants. There was a positive relationship of grain yield and quality with the K^+: Na^+ ratio in this study which shows that a better ability of a plant to maintain favorable ionic composition helps it to tolerate saline conditions.

Grain protein, fat and fiber contents decreased significantly due to salinity. Katerji *et al*. (2005) found increased protein content in sensitive and decreased in tolerant genotype of wheat. While conducting an experiment on maize, Maqsood *et al*. (2008) reported that a decrease in protein and fiber content accumulation in maize grain is associated with salt stress. High external Na^+ concentration interferes with nitrogen absorption resulting in low protein concentration in the grains. The obtained results show that salinity not only reduces plant growth and yield but also causes a nutritional imbalance and deteriorates grain quality. Parida and Das (2005) mentioned that during the onset and development of salt stress within a plant, all the major processes such as photosynthesis, protein synthesis, energy production and lipid metabolism are affected. Deterioration in these processes would have lead to decreased yield and deteriorated quality of wheat grains due to salinity in the present study. Phosphorus concentration in shoot, root and grain were decreased under salinity. However this reduction was maximum in roots and minimum in grains. Phosphorous is very important with respect to nutrition and a decrease in phosphorous concentration not only decreases plant growth and yield but also show a poor nutritional value of the produce. The suppressive effects of soil salinity on metabolic activity of plants are well documented. Soil salinity causes the ionic imbalances which reduce the metabolic activities and water absorption in plants causing the deficiency of major plant nutrients (Irshad *et al.,* 2002).

Conclusion: Disturbed ionic homeostasis due to salinity caused a marked reduction in yield components of wheat accompanied with low potassium and phosphorus contents in shoot, root and grain. Likewise the quality parameters including grain protein, fat and fiber contents were also decreased in response to salinity.

REFERENCES

AACC. 2000. Approved methods of the American Association of Cereal Chemists, 10th ed., St. Paul, MN, USA.

Akhkha, A., T. Boutraa and A. Alhejely. 2011.The rates of photosynthesis, chlorophyll content, dark respiration, proline and abscicic acid (ABA) in wheat (*Triticum durum*) under water deficit conditions. Int. J. Agric. Biol. 13:215-221.

Brady, N.C. and R.R. Weil. 2002. The Nature and Properties of Soils (13th ed.), Prentice Hall, Upper Saddle River, NJ, USA.

FAO. 1985. FAO/WHO, energy and protein requirements, Technical Report Series No. 522. Rome, Italy.

Ghogdi, E.A., A.I. Darbandi and A. Borzouei. 2012. Effects of salinity on some physiological traits in wheat (*Triticum aestivum* L.) cultivars. Ind. J. Sci. Technol. 5:1906-1906.

Ibrahim, M. 2003. Salt tolerance studies on cotton. M.Sc (Hons.) Thesis, Inst. Soil and Environ. Sci., Univ. of Agric. Faisalabad, Pakistan.

Iqbal, M. , A.G. Khan, A.U. Hassan and M. Amjad. 2012. Soil physical health indices, soil organic carbon, nitrate content and wheat growth as influenced by irrigation and nitrogen rates. Int. J. Agric. Biol. 14:1-10.

Irshad, M., T. Honna, A. E. Eneji, and S. Yamamoto. 2002. Wheat response to nitrogen source under saline conditions. J. Plant Nut. 25:2603-2612.

Katerji, N., J.W.V. Hoorn, C. Fares, A. Hamdy, M. Mastrorilli and T. Oweis. 2005. Salinity effect on grain quality of two durum wheat varieties differing in salt tolerance. Agric. Water Manag. 75:85-91.

Kahlon, U.Z., G. Murtaza, A. Ghafoor and B. Murtaza. 2012. Amelioration of saline-sodic soil with amendments using brackish water, canal water and their combination. Int. J. Agric. Biol. 14:38-46.

Khatkar, D. and M.S. Kuhad. 1999. Short-term salinity induced changes in two wheat cultivars at different growth stages. Biolog. Plant. 43:629-632.

Leidi, E.O. and J.F. Saiz. 1997. Is salinity tolerance related to Na^+ accumulation in upland cotton seedlings? Plant Soil. 190:67-75.

Maqsood, T., J. Akhtar, M.R. Farooq, M.A. Haq and Z.A. Saqib. 2008. Biochemical attributes of salt tolerant and salt sensitive maize cultivars to salinity and potassium nutrition. Pak. J. Agri. Sci. 45:1-5.

Maas, E.V. and G.J. Hoffman. 1977. Crop salt tolerance current assessment. J. Irri. Drain. Div. Amer. Soc. Civil Eng. 103:115-134.

Ministry of Finance. 2011. Pakistan Economic Survey, Government of Pakistan, Finance Division, Economic Advisor's Wing, Islamabad. p. 13.

Munns, R. 2002. Comparative physiology of salt and water stress. Plant Cell Environ. 25:239-250.

Munns, R. and R.A. James. 2003. Screening methods for salinity tolerance: a case study with tetraploid wheat. Plant Soil. 253:201-218.

Parida, A.K. and A.B. Das. 2005. Salt tolerance and salinity effects on plants: a review. Ecotox. Environ. Safety. 60:324-349.

Park, S.H., J.D. Wilson and B.W. Seabourn. 2008. Starch granule size distribution of hard red winter and hard red spring wheat: Its effects on mixing and bread making quality. J. Cereal Sci. 3:1-8.

Qureshi, R.H., A. Aslam, G. Mustafa and J. Akhtar. 1991. Some aspects of physiology of salt tolerance in wheat (*Triticum aestivum*). Pak. J. Agri. Sci. 28:199-206.

Rabhi, M., C. Hafsi, A. Lakhdar, S. Hajji, Z. Barhoumi, M.H. Hamrouni, C. Abdelly and A. Smaoui. 2007. Evaluation of the capacity of three halophytes to desalinize their rhizosphere as grown on saline soils under non leaching conditions. Afr. J. Ecol. 47:463-468.

Ryan, J., G. Estefan and A. Rashid. 2001. Soil and Plant Analysis Laboratory Manual. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. 172 p.

Sairam, R.K., K.V. Rao and G.C. Srivastava. 2002. Differential response of wheat genotypes to long term salinity stress in relation to oxidative stress, antioxidant activity and osmolyte concentration. Plant Sci. 163:1037-1046.

Saqib, M., C. Zorb and S. Schubert. 2008. Silicon-mediated improvement in the salt-resistance of wheat (*Triticum aestivum*) results from increased sodium exclusion and resistance to oxidative stress. Fun. Plant Biol. 35:633-639.

Saqib, M., C. Zorb, Z. Rengel and S. Schubert. 2005. Na^+ exclusion and salt resistance of wheat (*Triticum aestivum*) are improved by the expression of endogenous vacuolar Na^+/H^+ anitporters in roots and shoots. Plant Sci. 169:959-965.

Saqib, M., J. Akhtar and R.H. Qureshi. 2004. Pot study on wheat growth in saline and waterlogged compacted soil: I. Grain yield and yield components. Soil Till. Res. 77:169-177.

Shafi, M., J. Bakht, M. J. Khan, M. A.khan and S. Anwar. 2010. Effect of salinity on yield and ion accumulation of wheat genotypes. Pak. J. Bot. 42:4113-4121.

Steel, R.G.D. and J.H. Torrie 1980. Principles and procedures of statistics. 2nd ed., McGraw Hill Book Co. Inc. New York, USA.

Wenxue, W., P.E. Bilsborrow, P. Hooley, D.A. Fincham, E. Lombi and B.P. Forster. 2003. Salinity-induced differences in growth, ion distribution and partitioning in barley between the cultivar Maythorpe and its derived mutant Golden Promise. Plant Soil. 250:183-191.

Wolf. 1982. A comprehensive system of leaf analysis and its use for diagnosis crop nutrient status. Comm. Soil Sic. Plant Anal. 13:1035-1059.

Zhu, J.K. 2001. Plant salt tolerance. Trends Plant Sci. 6:66-71.

Zhu, J.K. 2003. Regulation of ion homeostasis under salt stress. Curr. Opin. Plant Biol. 6:441-445.