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Evaluation of genotypic behavior of wheat *(Triticum aestivum* L.) in saline-sodic soil conditions

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Key words: Wheat genotypes, Salinity tolerance, SARC, Saline-sodic soil

Abstract

Salinity is one of the major constraints of the world that hampers the agricultural production. A relatively simple and practical way of improving crop yield and profitability to sustain food production on these problematic soils is to identify those genotypes that are tolerant to salinity and/or sodicity. To investigate the genotypic behavior of wheat against tolerance to high soil salinity and/or sodicity, a field experiment was conducted in saline-sodic soil using four different wheat genotypes i.e. SARC-1, SARC-2, SARC-3 and Pasban-90. The experiment was laid in a randomized complete block design (RCBD) with four replications. The treatments were categorized as T_1 (EC 3.71 dS m^{-1}), T_2(EC 5.85 dS m^{-1}) and T_3(EC 10.56 dS m^{-1}) on the basis of pre-sowing soil analysis. At harvest, the data regarding plant height, spike length, 1000-grain weight, total dry matter, No. of spikelets spike^{-1} and grain yield was recorded and analyzed statistically. Soil, leaf, grain and straw samples were also analyzed for N, P, K and Na^+ analysis. SARC-3 performed well on the basis of growth and physiological parameters compared with other genotypes. At high salinity i.e. at T_3 where EC level was in the range of 9.5-11.50 dS m^{-1}, it produced maximum spike length, 1000-grain weight, number of spikelets spike^{-1}, total grain weight and total dry matter weight. At the other two treatments its performance was also better than the other genotypes however further studies are needed to categorize the highest potential of these genotypes in saline-sodic soils.

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Introduction

The world population has 35% contribution in wheat as a principal food. Wheat, being the most important food grain of Pakistan has a share of 1.9% in GDP along with 9.6% in value adding in agriculture sector. The total area of Pakistan, in 2016, cultivated under wheat was 9052 thousand hectares and the total production was 25.633 million tones with an average yield 2845kg ha^{-1} (Economic Survey of Pakistan, 2016).

Saline soils have become major problems for the world including Pakistan which reduced agricultural production drastically (Hasegawa *et al.*, 2000; Ashraf and Foolad, 2007). Total land of the world has more than 6% salinity having 20% of irrigated land area (Heidari and Heidarizadeh, 2003; FAO, 2008) and this problem is usually occur in arid to semi-arid regions of the world (Schleiff, 2008). In Pakistan, about 6.68 million hectare soils are saline and/or sodic where this salinity and/or sodicity are the major constraints to agricultural production and this saline area constitutes about 26% of the irrigated land (Rashid *et al.*, 2009). In Pakistan, salinity is converting annually about 40,000 hectares of cultivated land into unfertile. It is reported that one third of irrigated area has been affected by salinity and this saline area is increasing day by day very rapidly (Ahmad *et al.*, 2006; Ashraf *et al.*, 2008). Globally, this dangerous trend of saline area has been increasing about 1% every year (FAO, 2006). Saline soils are easy to reclaim than the sodic and saline-sodic soils whose reclamation is very difficult, time consuming and expensive. For the reclamation of such soils, not only the soluble salts may have to leach down and sodium replacement is required but the physical conditions of the soil may also be improved (Hussain *et al.*, 2000).

Plant growth may also be reduced by salts significantly. These salts affect the growth by reducing the water potential or by interfering with nutrient uptake. Generally, yields of many crops can be affected by more than 2600 mg L^{-1} (4 dS m^{-1}) concentrations of these salts (Kahlown and Azam, 2003).

Although, for all the crops, salts greatly reduces their growth and yield but different crops show different responses against this salt stress and these variations are due to variation in the physiological, morphological and biochemical processes occurring within the plant species (Singh and Chatrath, 2001).

Salt tolerance in crops may have its greatest advantage for agriculture as subsoil salinity has become a major threat to crops growing on soils with natural salinity in all semi-arid regions of the world and this threat even stands after managing all other agronomic constraints such as balance nutrition, nutrient deficiency and disease resistance etc. (Pitman and Lauchli, 2002). For the crops growing on salt-affected soils, new sources of salinity tolerance are needed. This salinity tolerance in crops would be particularly effective in the areas with subsoil salinity (Rengasamy, 2002).At salinity level of 100 mMNaCl (about 10 dS m^{-1}) in the field, the yield of wheat will be marginally low compare to other crops like rice (Maghsoudi and Maghsoudi, 2008).

A relatively simple and practical way of improving crop yield and profitability on these problem soils is to identify those genotypes that are tolerant to salinity and/or sodicity (Heidari and Heidarizadeh, 2003; Harsharn *et al.,* 2004). The results obtained by Ahmad *et al.* (2005) for wheat genotypes grown under controlled and field condition, respectively indicated that K^+/Na^+ discrimination rather than Na^+ alone has been used as a potential criterion for salt-tolerance screening at both conditions. In contrast, the study of Zeng *et al.* (2002) and El-Hendawy *et al.* (2005) found that weight and number of grain per plant may not be suitable as screening criteria for salt tolerance of rice and wheat under control condition. However, Ahmad *et al.* (2005) reported that both traits may serve as screening criteria for salt tolerance of wheat genotypes under field conditions. The main objective of this research was to find out those wheat genotypes which can tolerate salts at higher concentrations by investigating the variations in wheat genotypes for their tolerance to high soil salinity and/or sodicity and the relative agronomic as well as physiological parameters associated with salt tolerance.

Materials and methods

Seed

Four wheat genotypes SARC-1, SARC-2, SARC-3 and Pasban-90 were grown in four plots with four replications.

Experimental site

Experiment was performed at Proka Farm, University of Agriculture, Faisalabad, under field conditions.

Treatments

After doing pre-sowing soil analysis 3 treatments were made on the basis of electrical conductivity of soil extract (EC_e) i.e. T_1 (EC 3.71 dS m^{-1}), T_2 (EC 5.85 dS m^{-1}) and T_3 (EC 10.56 dS m^{-1}).

Experimental design

Randomized Complete Block Design (RCBD) was used in the experiment.

Fertilizer application

Recommended dose of NPK @ 120-90-60 kg/ha was applied to every plot. The source of NPK fertilizer was Urea, DAP and SOP respectively. The whole dose of N fertilizer was applied in two splits while P and K were applied as basal dose.

Seed sowing

Seeds of each genotype were sown by using drill method keeping row-row distance at 22.5cm.

Soil

Initially 8 (4 from each depth) soil samples were taken from each plot randomly at a depth of 15 and 30 cm. After air drying these samples, they were grinded and sieved through a 2mm mesh sized sieve. Then the analyses of these samples were performed for pre-sowing physiochemical characteristics of the soil, whose results are shown in the Table 1.

Growth parameters

Plant height

Plant height was measured in centimeters by using a meter rod at crop maturity.

Spike length

Spike length was measured by using a meter rod at harvesting stage of the crop.

No. of spikelets spike^{-1}

Total no. of spikelets spike^{-1} was calculated after harvesting of crop.

Total dry matter

Wheat was harvested at maturity stage and total dry matter was taken by using an electric balance.

Total grain weight

Total grain weight was taken by using an electric balance at the time of harvesting.

1000-grain weight

1000-grain weight was also taken at the time of harvesting by using an electric balance.

Statistical analysis

The data was analyzed statistically (using $\alpha = 0.05$) using a computer based program MStat-C and Microsoft Excel®. Comparison among different means of genotypes and salinity were made by using ANOVA at 5% probability (Steel *et al.,* 1997).

Results and discussion

Plant height (cm)

Data regarding plant height (average of four replications) revealed that different wheat genotypes showed significant variations (Fig. 1) and by increasing levels of salinity/sodicity, plant height was decreased considerably. Maximum plant height was observed at T_1 (EC 3.71 dS m^{-1}) when synchronized with the other two treatments: T_2 (EC 5.85 dS m^{-1}) and T_3 (EC 10.56 dS m^{-1}).Reduction in plant height with increasing salinity level is similar to the findings of Naseem *et al.* (2000) and Naseem *et al.* (2008). Higher concentrations of salts within the plant body changes the metabolic activities of the cell wall due to which various materials deposits within the cell wall and elasticity of the cell wall is greatly decreased. Secondary cell appears sooner, which becomes rigid and ultimately the turgor pressure of the cell is decreased which lowers down the cell enlargement efficiency. Due to these processes plant height remains small (Saqib *et al.,* 2002).

Table 1. Physiochemical characteristics of the soil.

Parameter	Unit	Value
Sand	%	58.65
Silt	%	24.15
Clay	%	17.20
Textural class	---	Sandy Loam
pH_s	---	8.53
EC_e	dS m^{-1}	3.43-11.30
Saturation Percentage	%	31.37
Soluble CO_3^{2-}	me L^{-1}	Absent
Soluble HCO_3^-	me L^{-1}	3.34
Soluble Cl^-	me L^{-1}	19.86
*SO_4^{2-}	me L^{-1}	14.30
Soluble Ca^{2+} + Mg^{2+}	me L^{-1}	5.06
Soluble Na^+	me L^{-1}	30.43
Soluble K^+	me L^{-1}	2.31
SAR	$(mmol\ L^{-1})^{1/2}$	14.56-26.43

Spike Length (cm)

Wheat genotypes showed significant variation regarding the data of spike length (Fig.2) and by increasing levels of salinity/sodicity, spike length was decreased considerably. Maximum spike length was seen at T_1 (EC 3.71 dS m^{-1}) as compared to other treatments. The results of spike length are similar with the findings of Singh *et al.,* 1994.

With increasing concentrations of salts, the decrease in the spike length was due to reduction or competition of ionic uptake under saline conditions that creates more absorptive conditions for these salts due to which uptake of essential nutrients i.e. N & K required for plant growth is highly decreased which ultimately affects the plant growth.

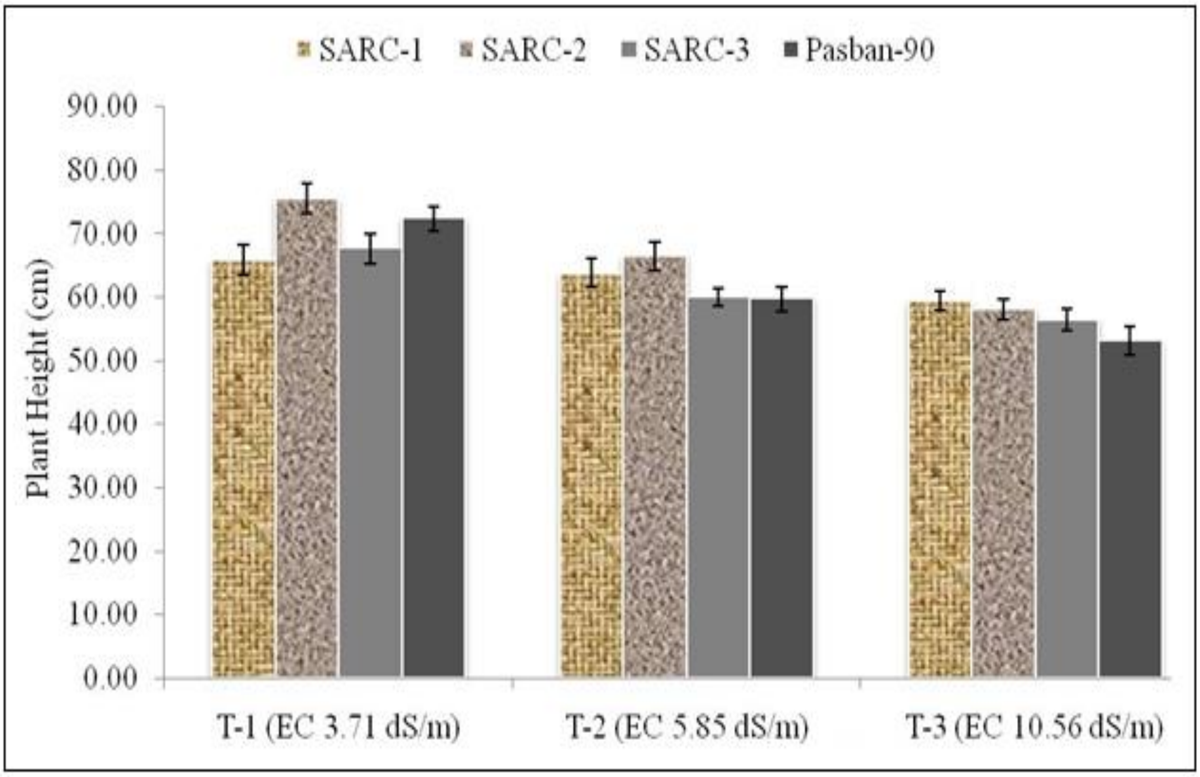

Fig. 1. Plant height (cm) of wheat in saline-sodic soil conditions.

Number of spikelets Spike^{-1}

Data regarding number of spikelets spike^{-1} revealed that different wheat genotypes showed significant variations (Fig. 3) and by increasing levels of salinity/sodicity, number of spikelets spike^{-1} was decreased considerably.

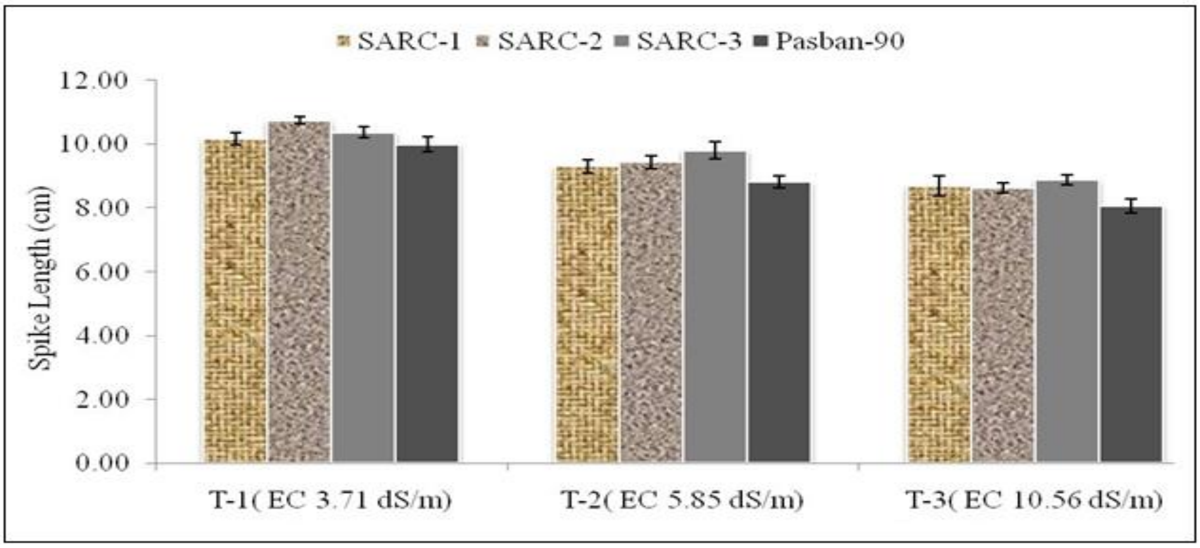

Fig. 2. Spike length (cm) of wheat in saline-sodic soil conditions.

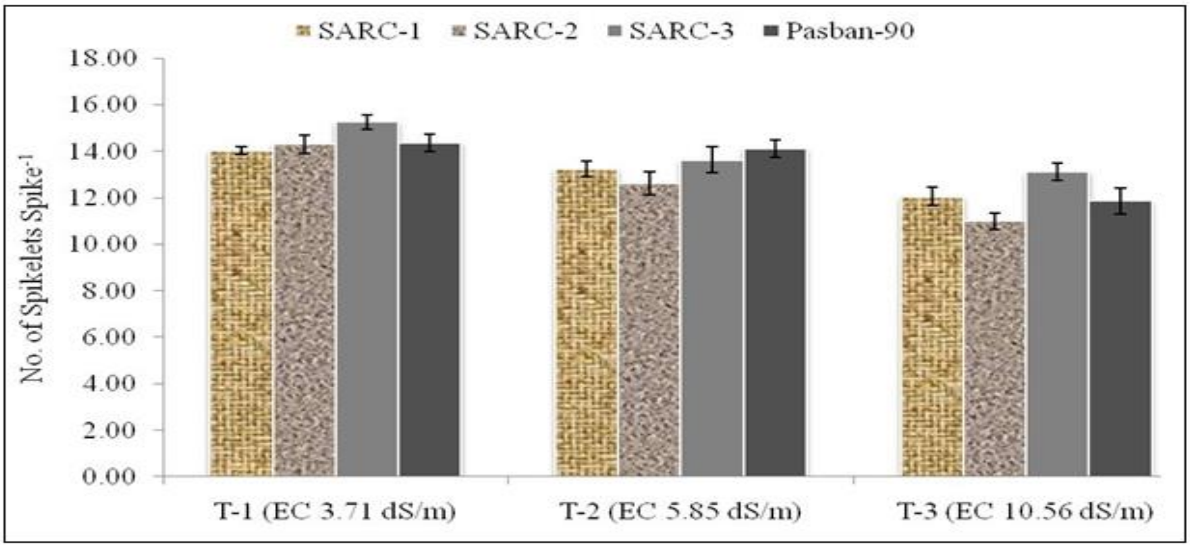

Fig. 3. No. of Spikelets per spike of wheat in saline-sodic soil conditions.

The causes of reduction in growth and number of spikelets under saline-sodic soil conditions may be the shrinkage of cell contents, less development and differentiation of plant tissues, lack of balanced nutrition and damage to membrane integrity (Kent and Lauchli, 1985) and this higher concentrations of salts may also limits the reproductive development and spikelet initiation during spike emergence and ultimately the number of spikelets per spike are reduced (Mans and Rawson, 2004).

1000-grain weight (g)

On the basis of overall treatment effect, the maximum 1000 grain weight was seen at T_1 (EC 3.71 dS m^{-1}) as compared to other treatments (Fig. 4). The results of the experiment are also in accordance with the results of Munns *et al.,* 2006.

The reduction in the 1000-grain weight of all the genotypes with increasing salt concentrations was due to the excessive uptake of sodium and chloride.

This excess led to decreased uptake of other nutrients such as NO_3^- which are required for proper growth and development of plants when there will be less availability of nutrients to plants there will be reduction in growth and yield of the crops. During such stress initially plant growth is affected due to disturbance in the osmotic cells of plants osmotically by soil salinity but later on salt toxicity and high EC_e become the main reason for the low yield (Saqib *et al.,* 2006; Katerji *et al.,* 2009).

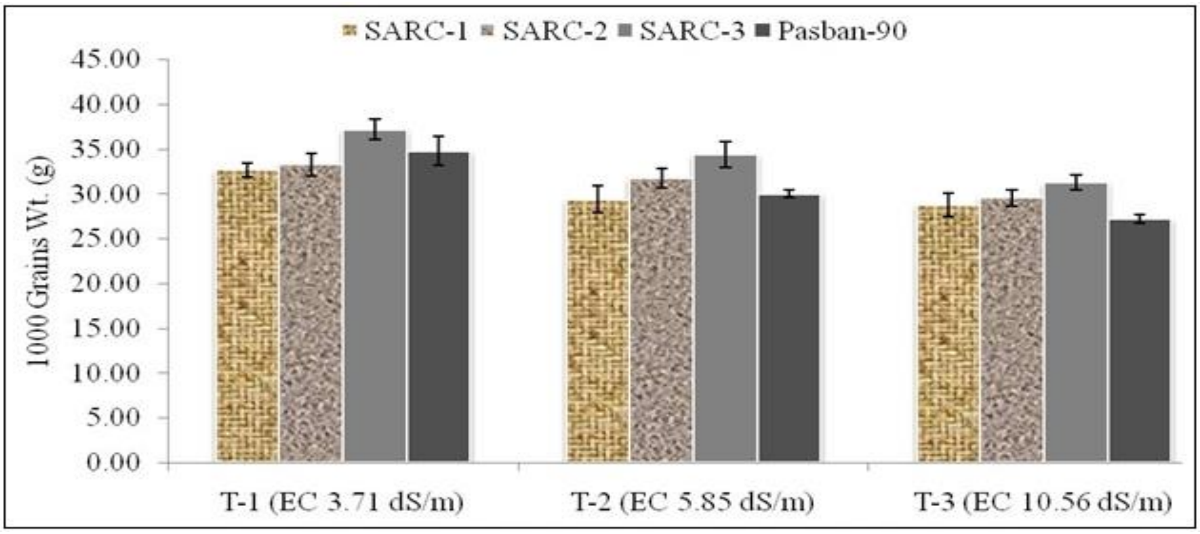

Fig. 4. 1000-grain (g) weight of wheat in saline-sodic soil conditions.

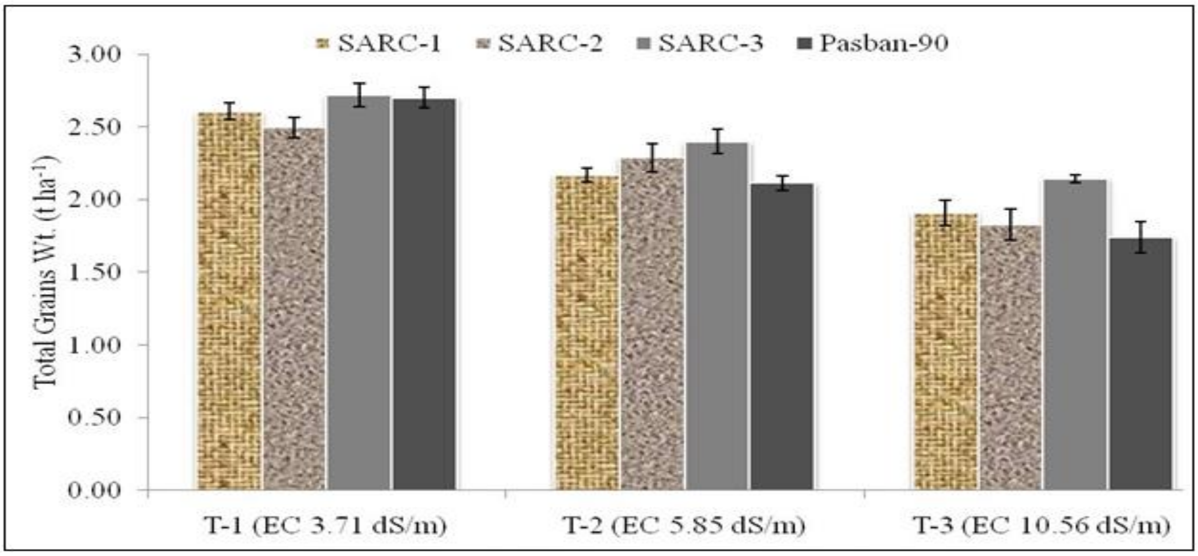

Fig. 5. Total grain weight (t ha^{-1}) of wheat in saline-sodic soil conditions.

Total grain weight (t ha^{-1})

Maximum total grain weight was seen at T_1 (EC 3.71 dS m^{-1}) when synchronized with the other two treatments: T_2 (EC 5.85 dS m^{-1}) and T_3 (EC 10.56 dS m^{-1}) (Fig. 5). The reduction in the grain yield of all the genotypes with the increasing salt concentrations was might be due to leaf wilting and senescence which reduces the light interception area of the plant resultantly less photosynthesis occur ultimately grain yield is decreased (Ashraf and Bhatti, 2000). According to Majeed *et al.* (2010) plant's growth and development is greatly affected by salt stress due to which grain yield is also reduced. The results of the experiment are also in accordance with the results of Munns *et al.,* 2006. The causes of reduction in grain yield may also be excessive uptake of sodium and chloride affecting the uptake of other essential nutrients i.e. nitrate, required for proper growth and development of the crop.

The results of the experiment are also in accordance with the results of Munns *et al.,* 2006.

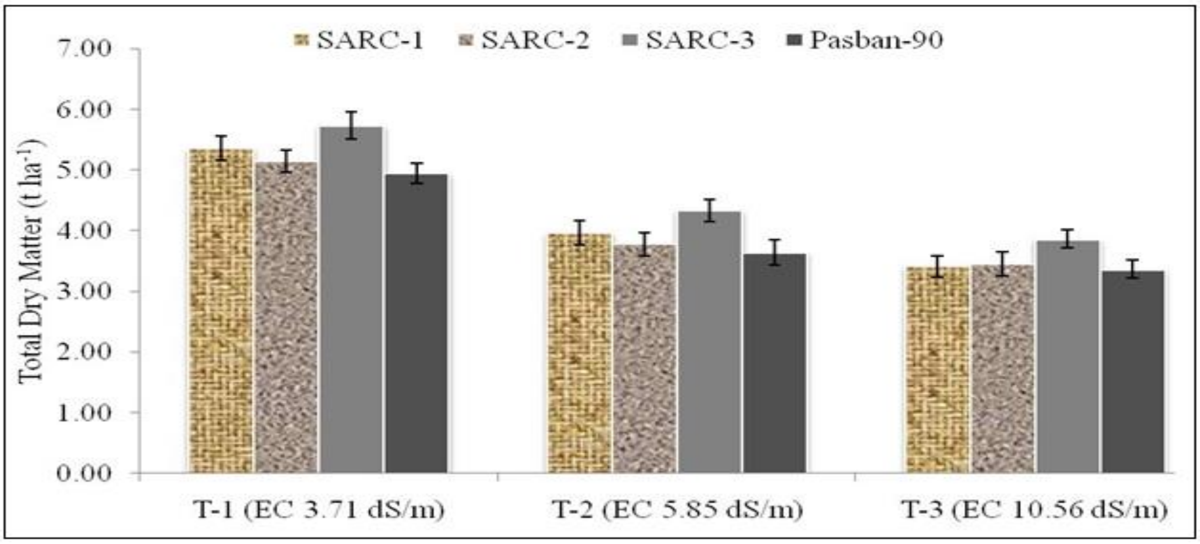

Fig. 6. Total dry matter (t ha^{-1}) of wheat in saline-sodic soil conditions.

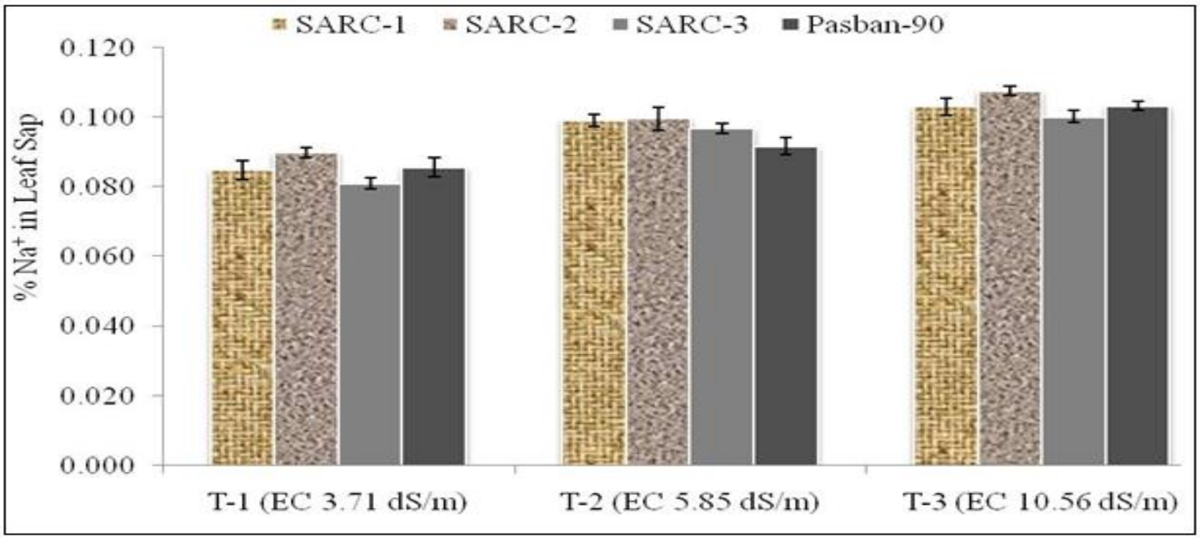

Fig. 7. %Na^+ in leaf sap of wheat in saline-sodic soil conditions.

Total dry matter (t ha^{-1})

In case of total dry matter, statistically there was a significant change at each level of salinity/sodicity and the behavior of all the genotypes was also found varied with the treatment variations (Fig. 6).The results of total dry matter are similar to the findings of Naseem *et al.* (2000) Din and Flowers, (2002) and Morant *et al.* (2004) that fresh weight of shoot and total dry matter is decreased by the increase of salt concentration within the soil.

Reduction in the total dry matter with increasing salinity may also be due to direct inhibitory effect of salts on Calvin cycle enzymes by which photosynthetic activity of the plant is reduced, causing less total dry matter.

Sodium concentration (%) in leaf sap of wheat

Data regarding sodium concentration in leaf sap (average of four replications) revealed that different wheat genotypes showed significant variations (Fig. 7) and by increasing levels of salinity/sodicity, sodium concentration in leaf sapwas also increased considerably.

Results of the experiment are very much similar to the results of El-Hendawy *et al.*(2005) and Saqib *et al.* (2006).

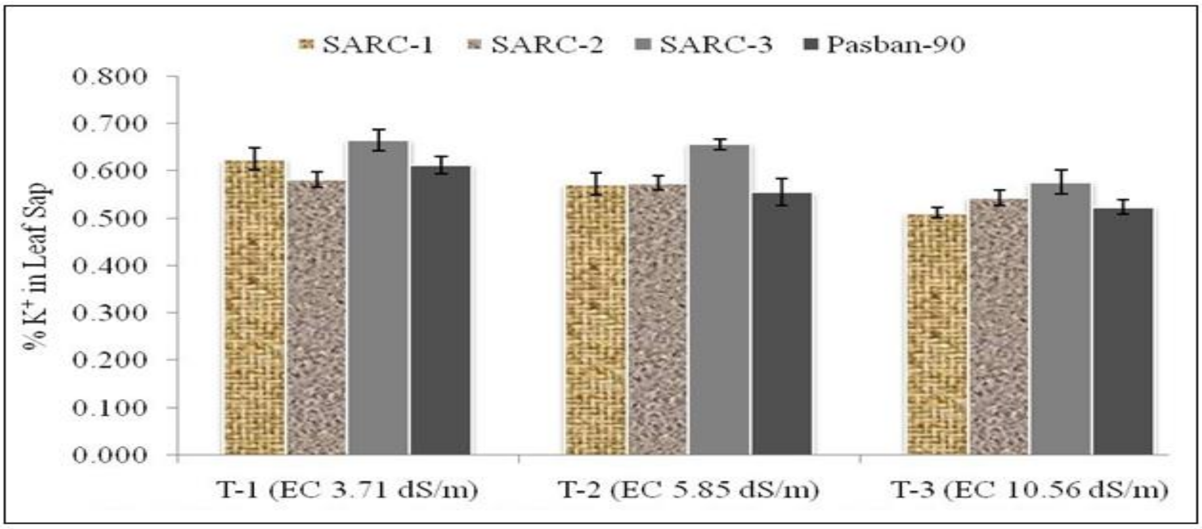

Fig. 8. %K^+ in leaf sap of wheat in saline-sodic soil conditions.

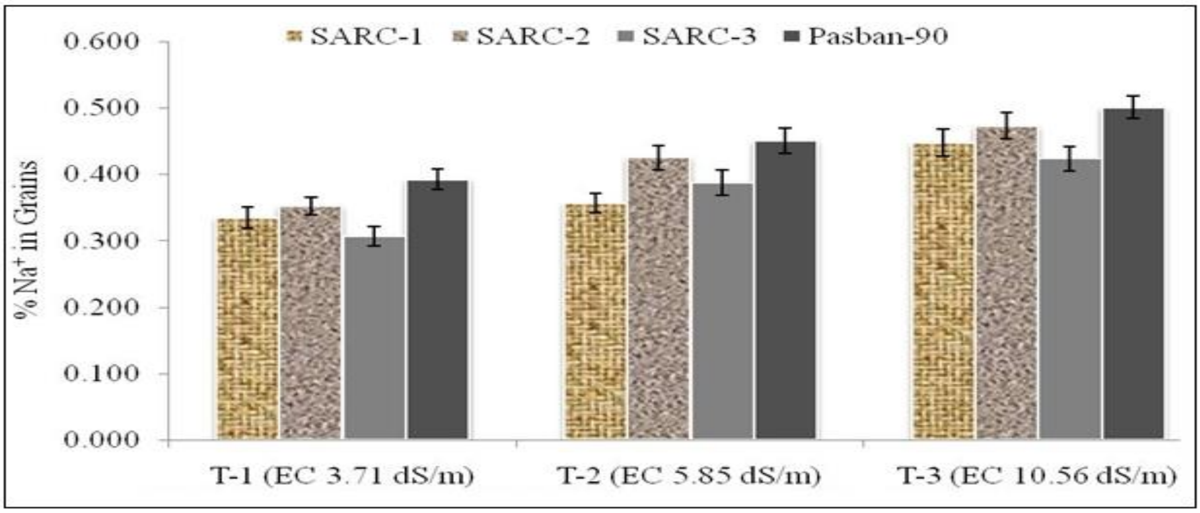

Fig. 9. %Na^+ in grains of wheat in saline-sodic soil conditions.

The increase in the sodium percentage of leaf sap of all the genotypes with increasing salt concentration indicates a significant positive relationship between sodium and potassium uptake. Higher amount of sodium in leaf sap with increasing salinity may also be due to increased sodium concentration in soil solution and higher uptake of sodium by plants may be due to higher osmotic pressure created for osmotic adjustment. About 50 percent fresh weight of shoot and root is lost due to high concentrations of Na^+ and Cl^- in the leaf sap (Parveen and Qureshi, 1992).

Potassium concentration (%) in leaf sap of wheat

Maximum potassium concentration in leaf sap was seen at T_1 (EC 3.71 dS m^{-1}) when synchronized with the other two treatments: T_2 (EC 5.85 dS m^{-1}) and T_3 (EC 10.56 dS m^{-1}) (Fig 8). Flowers and Hajibagheri (2001) concluded from their experiments that more dry matter production, higher K^+ and nitrogen contents within the plant body and less uptake of Na^+ and Cl^- are very important characters responsible for salt resistance. Reduction in K^+ concentration with increasing salts is in accordance with the findings of Schachtman and Munns (1992).

They reported that K^+ concentration in thin xylem sap decreases when the concentration of NaCl in the soil solution is about 100 mol m^{-1}. For the plants being resistance against salty conditions K^+ uptake at higher concentrations is an essential physiological mechanism (Flowers and Hajibagheri, 2001). Sodium toxicity hinders the plant growth therefore, in salt tolerant plants, the phenomenon of Na^+ exclusion is more prominent and they contain greater amount of K^+ in their leaf sap as compared to sensitive ones (Munns *et al.,* 2000; Tester and Davenport, 2003; Saqib *et al.,* 2004b; 2005a).

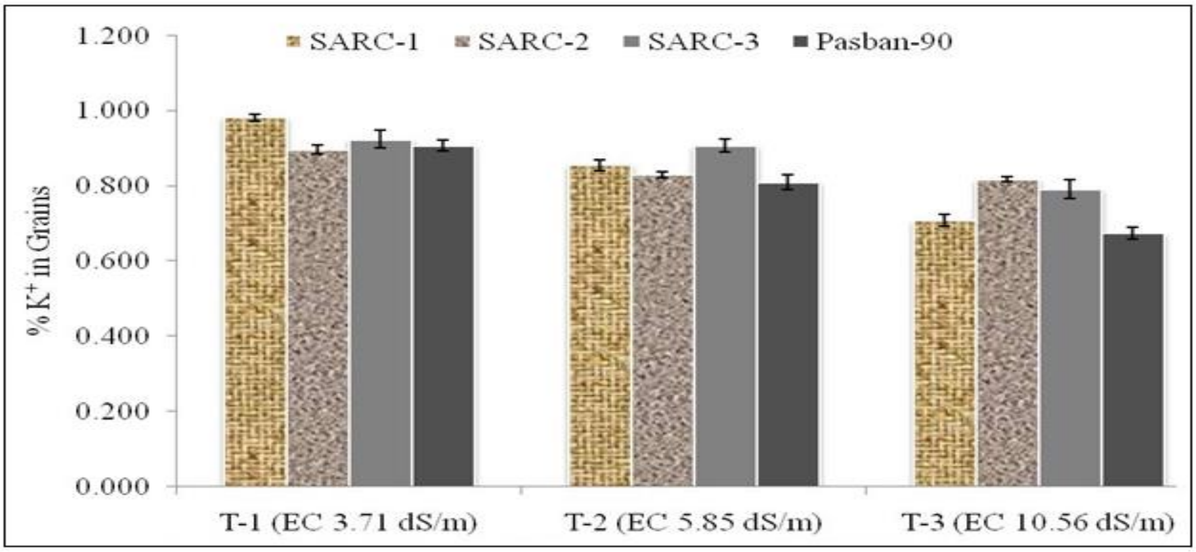

Fig. 10. %K^+ in grains of wheat in saline-sodic soil conditions.

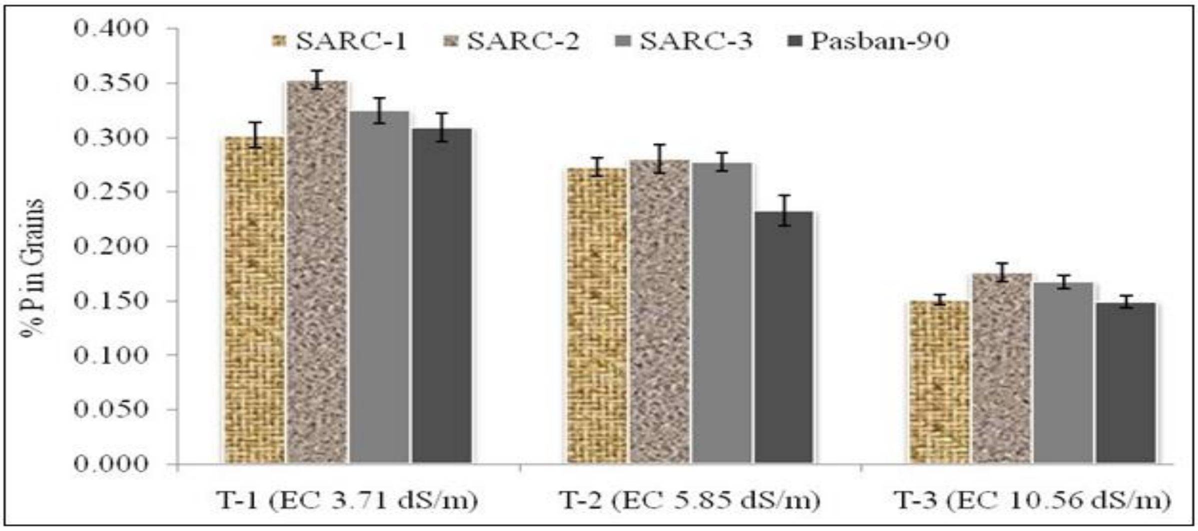

Fig. 11. %P in grains of wheat in saline-sodic soil conditions.

Sodium concentration (%) in grains of wheat

On the basis of overall treatment effect, the maximum sodium concentration in grains was seen at T_1 (EC 3.71 dS m^{-1}) when synchronized with the other two treatments: T_2 (EC 5.85 dS m^{-1}) and T_3 (EC 10.56 dS m^{-1}) (Fig. 9). Results of the experiment are very much similar to the results El-Hendawy *et al.,* (2005) and Saqib *et al.,* (2006). Sodium toxicity hinders the plant growth therefore in salt tolerant plants, the phenomenon of Na^+ exclusion is more prominent and they also contain greater amount of K^+ in their leaf sap as compared to sensitive ones (Munns *et al.,* 2000; Tester and Davenport, 2003; Saqib *et al.,* 2004b; 2005a).

This increased concentration in leaf sap ultimately stored in the grains after passing from leaf sap and other parts of the plant through xylem and phloem and the concentration of sodium in xylem and phloem may also vary from variety to variety (Netondo *et al.,* 2004: Davenport *et al.,* 2005: Huang *et al.,* 2006).

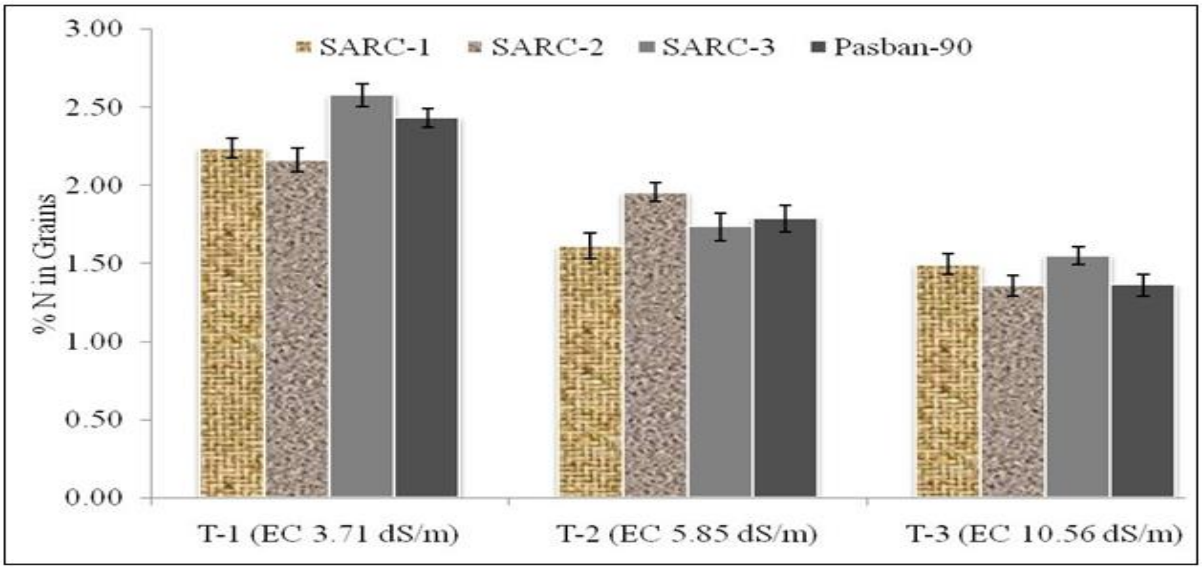

Fig. 12. %N in grains of wheat in saline-sodic soil conditions.

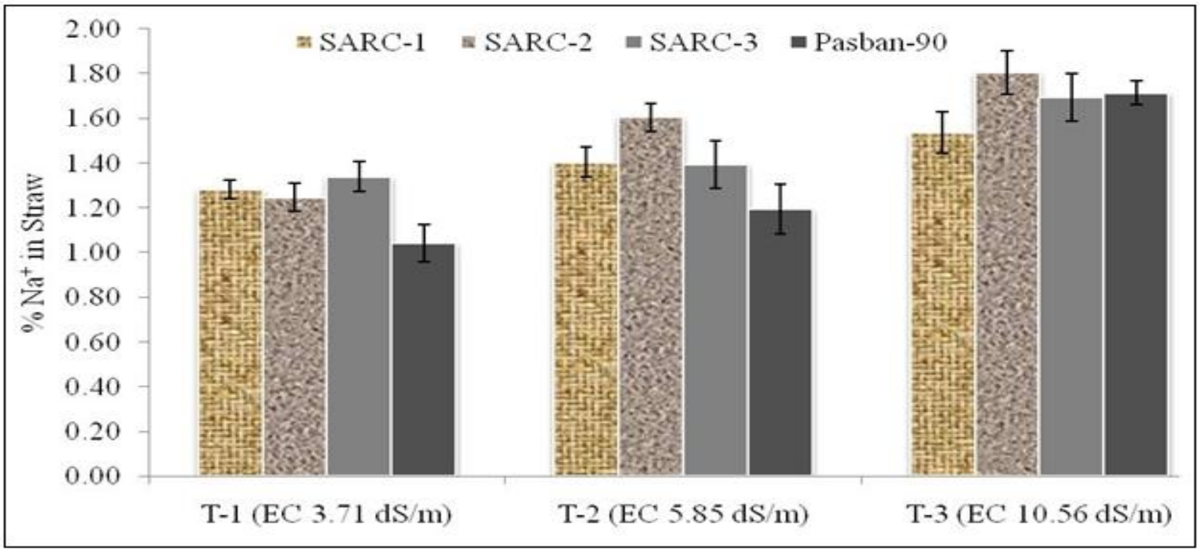

Fig. 13. %Na^+ in straw of wheat in saline-sodic soil conditions.

Potassium concentration (%) in grains of wheat

On the basis of overall treatment effect, the maximum potassium concentration in grains was seen at T_1 (EC 3.71 dS m^{-1}) as compared to other treatments (Fig. 10).Flowers and Hajibagheri (2001) concluded from their experiments that more dry matter production, higher K^+ and nitrogen contents within the plant body and less uptake of Na^+ and Cl^- are very important characters responsible for salt resistance in plants. Sodium toxicity hinders the plant growth therefore in salt tolerant plants, the phenomenon of Na^+ exclusion is more prominent and they contain greater amount of K^+ in their leaf sap as compared to sensitive ones (Munns *et al.,* 2000; Tester and Davenport, 2003; Saqib *et al.,* 2004b; 2005a). The higher concentration of sodium in soil solution suppresses the uptake of potassium, due to which concentration of potassium is reduced in plant parts and ultimately less potassium is transferred from plant parts to grains (Munns *et al.,* 2003; Asch *et al.,* 2000; Chen *et al.,* 2007).

Phosphorus Concentration (%) in Grains of Wheat

Maximum phosphorus concentration was observed in grains at T_1 (EC 3.71 dS m^{-1}) (Fig. 11). The results of this research are very much similar to Botella *et al.,* (1997) that phosphorus, potassium, calcium and magnesium concentrations are greatly reduced with increasing salinity in wheat varieties. Phosphorus is very much important for plants as it is directly used in the formation of ADP, NAD, and NADP which are the main energy sources for plant metabolism and it also plays a vital role in photosynthesis. Increasing salinity in the soil favors the sodium uptake by plants due to which nutritional imbalance takes place.

Reduced uptake of phosphorus with increasing salt concentration might be due to this nutritional imbalance and ultimately less phosphorus reaches to the grains (Munns, 2002; Munns *et al.,* 2006; Munns and Tester, 2008).

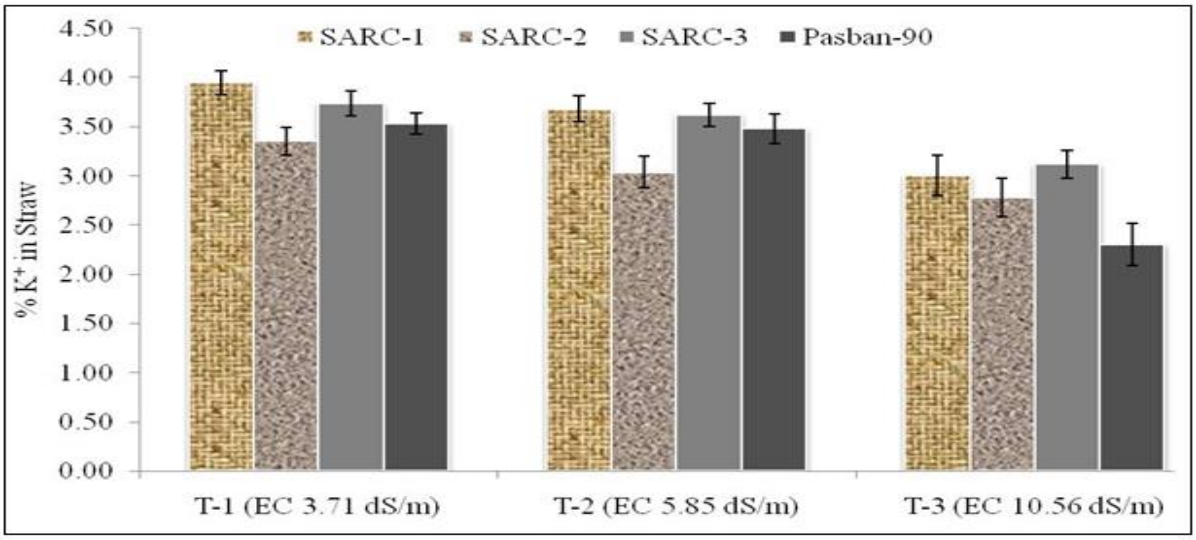

Fig. 14. %K^+ in straw of wheat in saline-sodic soil conditions.

Nitrogen concentration (%) in grains of wheat

Maximum nitrogen concentration in grains was seen at T_1 (EC 3.71 dS m^{-1}) (Fig. 12).These results of the experiment highly correlates with the conclusions of Ozer *et al.,* (2004) and Svoboda and Haberle (2006) that negative interaction between salinity and nitrogen uptake exists. Salinity acts as limiting factor for plant growth (Burger and Celkova, 2003; Orak and Ateş, 2005; Supanjani and Lee, 2006). Saline soils are generally deficient of nitrogen (Albassam, 2001; Flores *et al.,* 2001; Abdelgadir *et al.,* 2005) and under saline environment N availability is greatly reduced to plants (Bhandari *et al.,* 1972). Increasing concentration of NaCl causes a decrease in the uptake of N, K, Fe and Cu and Zn concentrations (Murat *et al.,* 2007) and in saline environments nutrient uptake is greatly reduced due to low water potential in the rooting medium (Tabatabaei, 2006).

Sodium concentration (%) in straw of wheat

Maximum amount of sodium in straw was seen at T_1 (EC 3.71 dS m^{-1}) as compared to other two treatments (Fig. 13) The increase in the sodium percentage in straw of all the genotypes with increasing salt concentration indicates a significant positive relationship between sodium and salinity (El-Hendawy *et al.,* 2005; Saqib *et al.,* 2006). Higher amount of sodium in straw with increasing salinity might also be due to increased sodium concentration in soil solution and higher uptake of sodium by plants. Sodium toxicity hinders the plant growth therefore, in salt tolerant plants, the phenomenon of Na^+ exclusion is more prominent and they also contain greater amount of K^+ in their leaf sap as compared to sensitive ones (Munns *et al.,* 2000; Tester and Davenport, 2003; Saqib *et al.,* 2004b; 2005a).

Potassium Concentration (%) in Straw of wheat

On the basis of overall treatment effect, the maximum potassium concentration in straw was seen at T_1 (EC 3.71 dS m^{-1}) when synchronized with the other two treatments: T_2 (EC 5.85 dS m^{-1}) and T_3 (EC 10.56 dS m^{-1}) (Fig 14).

Flowers and Hajibagheri (2001) also concluded from their experiments that more dry matter production, higher K^+ and nitrogen contents within the plant body and less uptake of Na^+ and Cl^- are very important characters responsible for salt resistance.

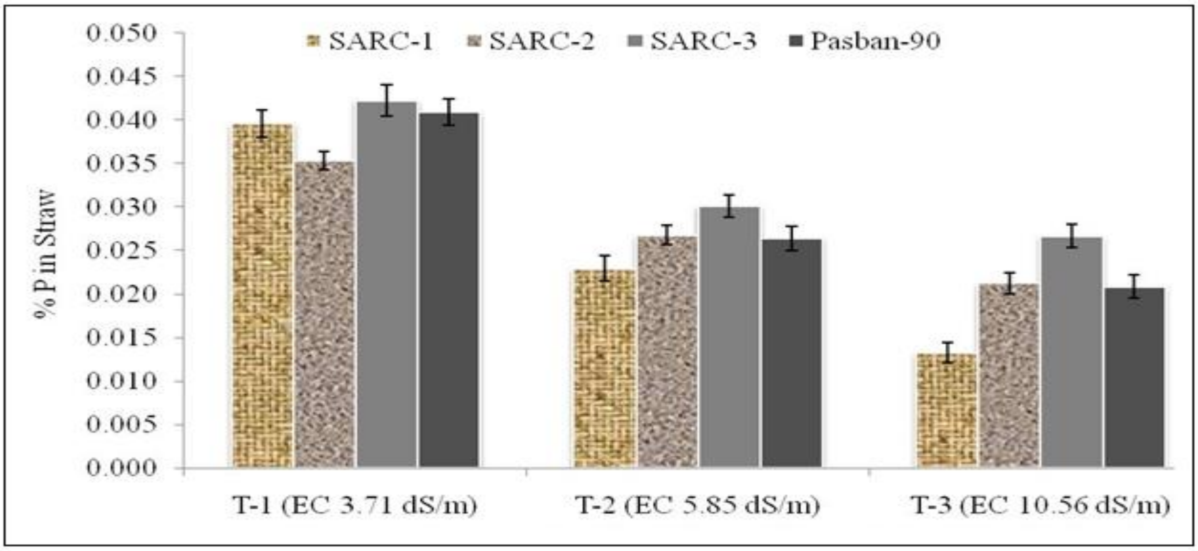

Fig. 15. %P^+ in straw of wheat in saline-sodic soil conditions.

Phosphorus concentration (%) in straw of wheat

Higher phosphorus concentration in straw was seen at T1 (EC 3.71 dS m-1) (Fig. 15). Increasing salinity in the soil favors the sodium uptake by plants due to which nutritional imbalance takes place. Reduced uptake of phosphorus with increasing salt concentration might be due to this nutritional imbalance and ultimately less phosphorus reaches to the plants i.e. straw (Munns, 2002; Munns *et al.,* 2006; Munns & Tester, 2008).

Conclusion

From the overall results of this experiment it could be concluded that the genotype SARC-3 is better regarding growth and physiological parameters comparing with other genotypes of wheat in saline-sodic soil conditions however further studies are needed to categorize the highest potential of these genotypes in saline-sodic soils.

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