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The evaluation of various soil conditioners effects on the amelioration of saline-sodic soil

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ABSTRACT

The soil salinity and sodicity collectively are the major problems in the soils of Pakistan and proved a continuous threat for the sustainability of agriculture. A pot study was planned to ameliorate such problematic soils and for this purpose different soil conditioners were used viz. gypsum @ 39.078 g pot^{-1} soil gypsum requirement, Citric acid (CA) @ 29.067 g pot^{-1}, H_2SO_4 @ 11.24 ml pot^{-1} and polyvinyl alcohol (PVA) @ 19.98 g pot^{-1} and control without any amendment and wheat was grown as a test crop. The results showed that maximum decrease in pH and SAR were 8.31 and 12.04 $(mmol\ L^{-1})^{1/2}$ by application of H_2SO_4 and citric acid respectively. Similarly H_2SO_4 and citric acid treatment show significant results related to crop growth and yield. The maximum plant height (63.33cm), number of tillers (4.63), photosynthetic rate (($2.83\ \mu molm^{-2}s^{-1}$), transpiration rate ($0.63\ molm^{-2}s^{-1}$), stomata conductance ($0.53\ molm^{-2}s^{-1}$), were by application of H_2SO_4. while the results related to grain yield were as maximum grain yield by H_2SO_4 was (15.67 g) and minimum grain yield was observed with control (6.73g). Moreover the decrease in grain yield was as H_2SO_4 (9.98 g) > citric acid (8.33 g) > PVA (7.36 g) > gypsum (6.12 g) > control (5.53g). From this experiment it was concluded that H_2SO_4 showed quick impact on soil physicochemical properties and growth parameters but gypsum and citric acid were long term and sustainable source to reclaim and to make saline-sodic soils more productive as compare to other soil conditioners.
Keywords: soil conditioners, amelioration, saline-sodic soil

1. Introduction

Soil salinity and sodicity are two major concerns of irrigated agriculture in arid and semiarid regions of the world. Water scarcity and aquifers having elevated levels of soluble salts and sodium are the major concerns that are bringing large areas under salinity (Qadir and Oster, 2004). Less precipitation and unmanaged use of water resources and excessive evaporation cause negative water balance in soil leading to salination and sodication. Soil degradation occurs in saline-sodic and sodic soils due to the dispersion of soil aggregates reducing water holding capacity and ultimately decreases the water uptake by the plants, and seedling germination and root penetration (Qadir and Schubert, 2002). Wheat is the staple food and largest grain source in our country. Wheat takes part 13.1% to the value in agriculture and 2.7% to GDP. An area of 8.805 mha was cultivated under wheat during 2010-11 and showing a decrease of 3.6% over last year area of 9.132 mha was cultivated under wheat with an annual production of 24.2 million tons (Pakistan Economic survey, 2013).

About 10 mha of the worlds irrigated land has been destroyed by salinity that reduces the crop yield. In Pakistan 6.67 mha of land is affected by varying extent of soil salinity and sodicity (Khan, 1998). Pakistan is facing acute shortage of good quality irrigation water for growing of crops due to shrinking capacity of canal water (Ghafoor *et al.*, 2001). During 2000-01 at canal head 103.5 MAF water was available which has been decreased up to 89.8 MAF in 2011-12 due to seepage of water. Groundwater is used as a supplementary source of irrigation due to shortage of canal water. Continuous use of poor quality water without any amendment has converted normal soil into saline and saline-sodic. In Pakistan ground water is pumped out, of which 70-75% is injurious to crops due to the high concentration of salts (Latif and Beg, 2004) on the basis of criteria of the Department of Agriculture, Punjab.

The rehabilitation of saline-sodic soils can be carried out by different physical practices (deep ploughing, sub soiling, sanding, profile inversion) and chemical practices such as gypsum, calcium chloride, limestone, sulphuric acid, iron sulphate, humic acid, Polyvinyl alcohol and Polyacrylamide, etc. Biological amelioration has two basic advantages for the reclamation of saline-sodic soil by improving the soil structure and permeability to enhance salt leaching (Matsumoto *et al.*, 1994). The efficacy of any method depends on its potential to remove and replace the soluble sodium (Na^+) by changing the ionic composition of soil solutions. Organic sources may include green manuring, peat, mulch, humic substances and farmyard manure. On the basis of their configuration and mechanisms to reclaim the saline-sodic soils, the soil conditioners are of different types, i.e. organic and inorganic, water soluble polymeric (polyvinyl alcohol) and hydrogen polymeric (polyacrylates, polyacrylamide etc) (Jhurry, 1997).

Currently soil conditioners are used due to cost effective and better mode of action. Soil conditioners having ability to improve the chemical and physical properties of sodic and saline-sodic soil i.e. pH_s, EC_e, and SAR, and physical properties as water holding capacity, infiltration rate, bulk density. Gypsum and crude sulfur are used as inorganic sources. Similarly charcoal of woody vinegars, EDTA and organic acids and polyamine carboxylic acid, hydrolytic polymeric anhydrate are used as soil conditioners (Yang and Wang, 2005). The gypsum is a cheapest and best source of calcium, which is a good established practice for the amelioration and management of sodic and saline-sodic soils (Bresler *et al*., 1982). Similarly H_2SO_4 is a good source to neutralize CO_3 and HCO_3 present in soil. A pot study was conducted with the following objectives by keeping in view the above given facts. To study the effect of different soil conditioners (gypsum, PVA, citric acid and sulfuric acid) for the amelioration of saline-sodic soil. To evaluate the growth response of wheat to different soil conditioners on saline-sodic soil.

2. Methods and materials

An experiment was carried out in soil and water chemistry laboratory green house in the institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad to evaluate efficiency of different soil conditioners to reclaim saline-sodic soil. A saline-sodic soil was collected from Proka Farm II, university of Agriculture, Faisalabad and brought to wire house in plastic bags. The soil was processed and stored in plastic bags some soil was taken to soil and water chemistry lab to analyze different pyhsico- chemical properties of soil before the conduct of experiment (Table 4.1).

Table 2.1: Physicochemical characteristics of pre - experiment soil (2013)

Soil Parameter	Values
Sand %	39
Silt %	30
Clay %	31
Texture	Loam
EC_e (dSm^{-1})	6.30
pH	8.35
CO_3^{-2} ($mmol_c\ L^{-1}$)	Absent
HCO_3^{-1} ($mmol_c\ L^{-1}$)	24
Cl^{-1} ($mmol_c\ L^{-1}$)	4.75
SO_4^{-2} ($mmol_c\ L^{-1}$)	0.23
Ca^{+2} + Mg^{+2} ($mmol_c\ L^{-1}$)	17.13
Na^{+} ($mmol_c\ L^{-1}$)	45
SAR $(mmolL^{-1})^{1/2}$!	13.53
ESP % **	17.5
SP % *	32.49
CEC ($Cmol_c\ Kg^{-1}$)	2.58
SGR ($g\ kg^{-1}$) #	6.5

* Saturation percentage, **Exchangeable sodium percentage, ! Sodium adsorption ratio, # Soil gypsum requirement

After the analysis soil @ 8 kg pot^{-1} was filled in each pot and treatments were applied as per design experiment. The soil was incubated at field capacity for two weeks period to sow the crop. The crop was harvested during 1st week of December and soil samples were taken to evaluate the effect of different treatments on different chemical properties of soil as discussed below.

3. Results and Discussions

3.1. Effect of conditioners on Soil properties

3.1.1. Soil pH_s affected by treatments

Post-harvest soil pHs was significantly affected by the soil conditioners (Fig. 3.1a) minimum pH was observed in T_3 (7.33) where H_2SO_4 was applied @ 11.24 ml / pot of soil while the decreasing order of soil pH remained as T_1 (8.34) > T_5 (8.33) >T_2 (8.33) > T_4 (8.32) > T_3 (8.27) , maximum percentage decrease in soil pH was recorded with T_3 (7.34 %) over control followed by T_2 (7.33 %), T_5 (7.32 %) and T_4 (7.26 %). Soil pH has great impact on controlling the dynamic of plant nutrients, especially accessibility of micronutrients such as Cu, Mn, Fe and Zn. Salt affected soils deteriorate as a result of changes in soil reaction (pH_s) and in proportions of certain cations and anions present in the soil solution and on the exchange sites. These changes lead to osmotic and ion-specific effect as well as to imbalances in plant nutrition, which may range from deficiencies in several nutrients to high level of sodium (Na+). Such changes have a direct impact on activities of plant roots and soil microbes, and ultimately on crop growth and yield (Mengel and Kirkby, 2001). Wang *et al*. (2011) reported similar results regarding to application of citric acid that, it decreased pH of soil by which availability of other nutrients increase in soil. Moreover our result corroborated to Ashworth (2007) reported that the decrease in pH by application of EDTA may be due to de-protonation of HCO_3^{-1} that cause reduction in pH of soil.

3.1.2. Effect of soil conditioners on soil EC_e (dSm^{-1})

After the harvest of applied treatment there was a significant change in soil electrical conductivity (EC_e) (Fig. 3.1b). The maximum decrease in EC_e was observed in T_2 (5.24 %) and T_5 (5.25%) over control (T_1). While in T_3 and T_4 increase in EC_e was examined being 5.37 and 5.98 %, respectively. The increase in EC_e by T_3 and T_4 might be due to increase in concentration of other ions that make salts with combination of opposite ions like NaCl salt formation (Ashworth, 2007). Rajpar and N. B. Sial, 2002 from his experiment resulted that by application of soil conditioner, polyacrylamide (PAM), there was slight effect of PAM on soil pH, ESP and SAR. While after harvesting of seedling EC_e was markedly increased.

3.1.3 Effect of soil conditioner on soil SAR (mmol $L^{-1})^{1/2}$

At the end of experiment reduction in SAR was observed (Fig. 3.1c). Maximum reduction in SAR was observed in T_4 (12.37%), followed by T_3 (12.07%) and T_2 (12.03%) over control T_1. Similarly, according to fig (3.1c) decreasing order in SAR was T_2 (13.03) > T_3 (13.07) > T_4 (13.38) > T_5 (14) > T_1 (14.24). This reduction in SAR may be due to reasonable amount of Ca^{+2} + Mg^{+2} in irrigation water, moreover , lime of the soil undergoes dissolution under influence of CO_2 released by plant roots and set Ca^{+2} free in this way favors Na - Ca^{+2} exchange which ultimately reduce SAR (Qadir and Oster, 2004). In calcareous sodic soils this effect is in part a sequence of the fact that growing roots of plants increase the partial pressure of CO_2, enhancing the dissolution of calcite. CO_2 concentration increase in soil atmosphere and CO_2 dissolve in water to form H_2CO_3. Dissolution of H_2CO_3 resulting H^+ and H_2CO_3 thus reacts with the soil $CaCO_3$ to increase Ca^{+2} concentrations in soil solution. In sodic soil, by application of chelating agents SAR reduce because Ca^{+2} remove Na^+ from exchange site, which come into soil solution and further leached down by application of heavy irrigation (Naidu *et al.*, 1993).

3.1.4. Effect of soil conditioners on soil ESP (%)

There were significant changes in exchangeable sodium percentage (ESP) observed after experiment in soil (Fig. 3.1d). The highest ESP was in T_2 (15.31) followed by T_3 (15.47), T_4 (16.03) and T_5 (16.95) over T_1 (17.02) control. It is well thought-out by many workers that poor structure and high concentration of sodium are main adverse physio-chemical features of sodic soils. This limit seedling emergence, plant growth and increase concentration of toxic ions in plants. Sodicity damage depends upon soil clay, extent of pH and ESP (Boem and Lavado, 1996).

3.2. Agronomic parameters of crop

3. 2. 1. Effect of soil conditioners on plant height (cm)

During experiment it was observed that soil conditioners also have positive effect on plant height (Fig. 3.2a). The results indicated that plant height was significantly increased in T_3 (63.33cm) followed by T_4 (59 cm), T_5 (56.16 cm), T_1 (53.33 cm) and T_4 (49.5 cm). Increase in plant height in T_3 is due to decrease in pH, because under low pH availability of nutrients especially Phosphorus increase, that is essential for proper growth of plant. Similarly the increase in plant height in T_2 due to improvement in physical properties of soil, that helps to improve plant growth. The lowest plant height was observed in control, while highest plant height was observed in T_3 and T_4 treatment respectively (Rashid *et al.*, 2009). The decrease in plant height under saline condition may be due to the accumulation of salts in plant tissues. The use of selected inorganic salts applied singly or applied mixture was reported to improve the root system leading to increase plant height. Many research results exposed that acid application like HCl and H_2SO_4 had significantly positive effect on tillering and plant height of wheat and help to reclaim saline-sodic soil. Our research result also related to (Rashid *et al.*, 2009) findings.

3.2.2. Effect of soil conditioners on number of tillers / plant

Good number of tillers in field is very important for good yield for any crop. There was significant effect of soil conditioners on number of tillers per plant (Fig. 3.2b). Statistical investigation shows that soil conditioners significantly ($P<0.05$) improved no of tillers per plant being maximum (4.33) in T_3 where as minimum (2.66) in control. Moreover decreasing order for number of tillers per plant was T_3 (4.33) > T_4 (4.00) > T_2 (3.66) > T_5 (3.66) > T_1 (2.66). Mean letters of T_3, T_2, T_5 and T_1 indicated that their response was relatively same and these treatments were not significantly differing from each other. Numerous studies have shown that tiller appearance is affected by salt stress. Same result were obtained in wheat crop by Rashid *et al.* (2009) in which they reported that number of tillers, spike length and number of spikelet's per spike, grains per spike were increased by application of gypsum compared to other amendments.

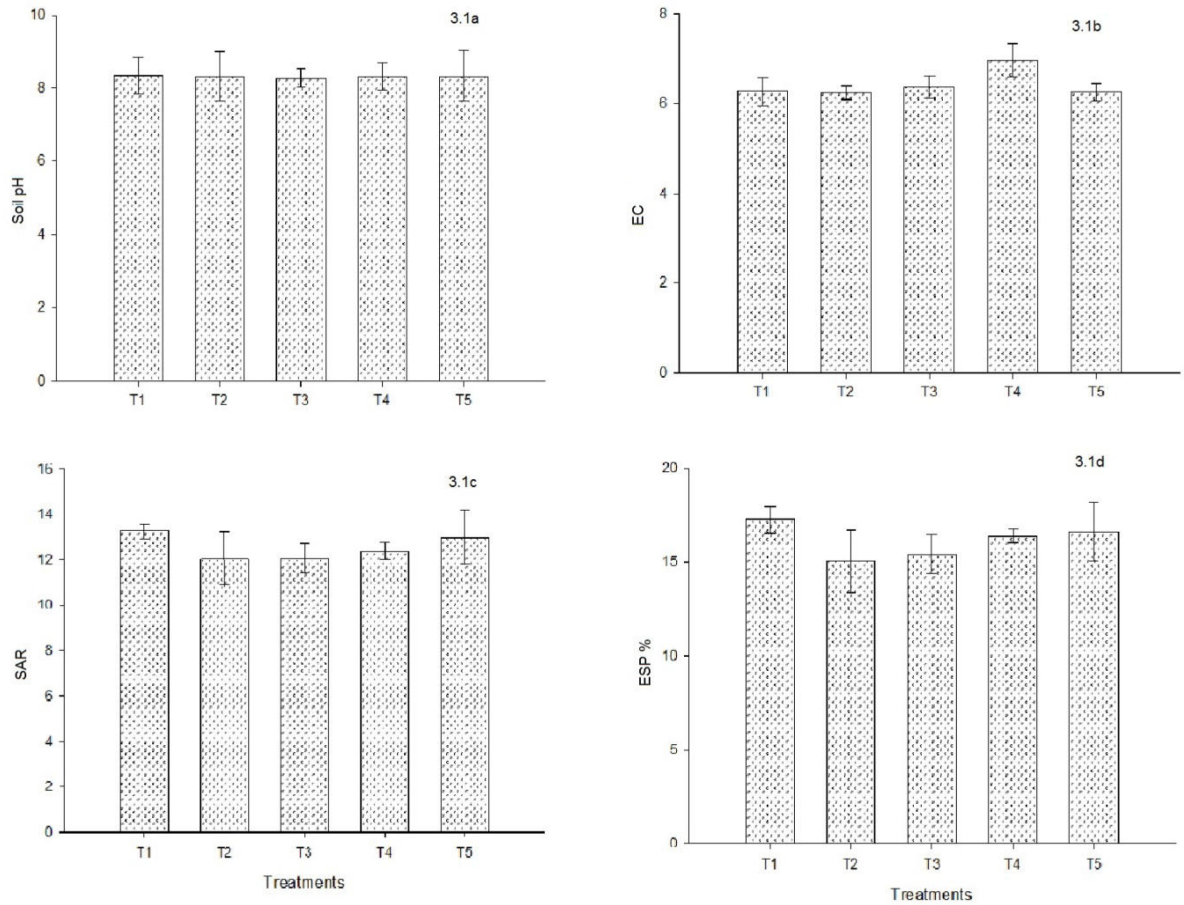


Fig. 3.1. Effectiveness of soil conditioners on Soil characteristics. T_1 = Control, T_2 = Gypsum, T_3 = H_2SO_4, T_4 = Citric Acid, T_5 = PVA

3.2.3. Effect of soil conditioners on number of spikes / pot

Many scientists reported that a plant having maximum number of spikes will produce maximum yield. After the harvest of crop, we observed that treatments have significant effect on no. of spikes / plant (Fig. 3.2c). The maximum number of spike / plant was observed with T_3 where citric acid was applied @ 29.067 g / pot of soil, while minimum number of spikes / plant was observed in pot with control. The effect of treatment T_5 was intermediate between T_1 and T_2 application. Results related to number of spikes / plant corroborated to (Mass, E.V and C. M. Grieve, 1990).

3.2.4. Effect of soil conditioners on spike length (cm)

There was significant improvement in spike length of wheat observed the harvest of applied treatments (Fig. 3.2d). Maximum spike length was observed with T_3 (9.16 cm), while minimum spike length was observed in T_4 (6.25 cm). The decreasing order in spike length was observed as T_3 (9.16 cm) > T_4 (8.16 cm) > T_5 (7.41 cm) > T_2 (6.83 cm) > T_1 (6.25 cm). Salinity has adverse effect on spike length, thousand grain weights, reported by Abro *et al*. (2009). Our resulted were correlated with findings of Rashid *et al*. (2009) in which they reported that no. of tillers, spike length and no. of spikelet per spike were increased by combine application of gypsum and acid.

3.2.5 Effect of soil conditioners on fresh weight (g)

The effect of soil conditioners on fresh weight of plant was significant (Fig. 3.2e). In this experiment maximum fresh weight (39.47 g) was observed with treatment (T_3), the minimum fresh weight (22.03 g) was observed with control (T_1). The decreasing order in fresh weight was observed as; T_3 (39.47 g) > T_4 (34.89 g) > T_2 (28.89 g) > T_5 (27.61 g) > T_1 (22.03 g). Poljakoff Mayber *et al.,* (1994) reported that with the increase in salinity, the reduction in fresh weight occur as compared to other crop fresh weight that grow in low salinity level. Our result collaborated to Moud. M. A and K. Maghsoudi. (2008) finding.

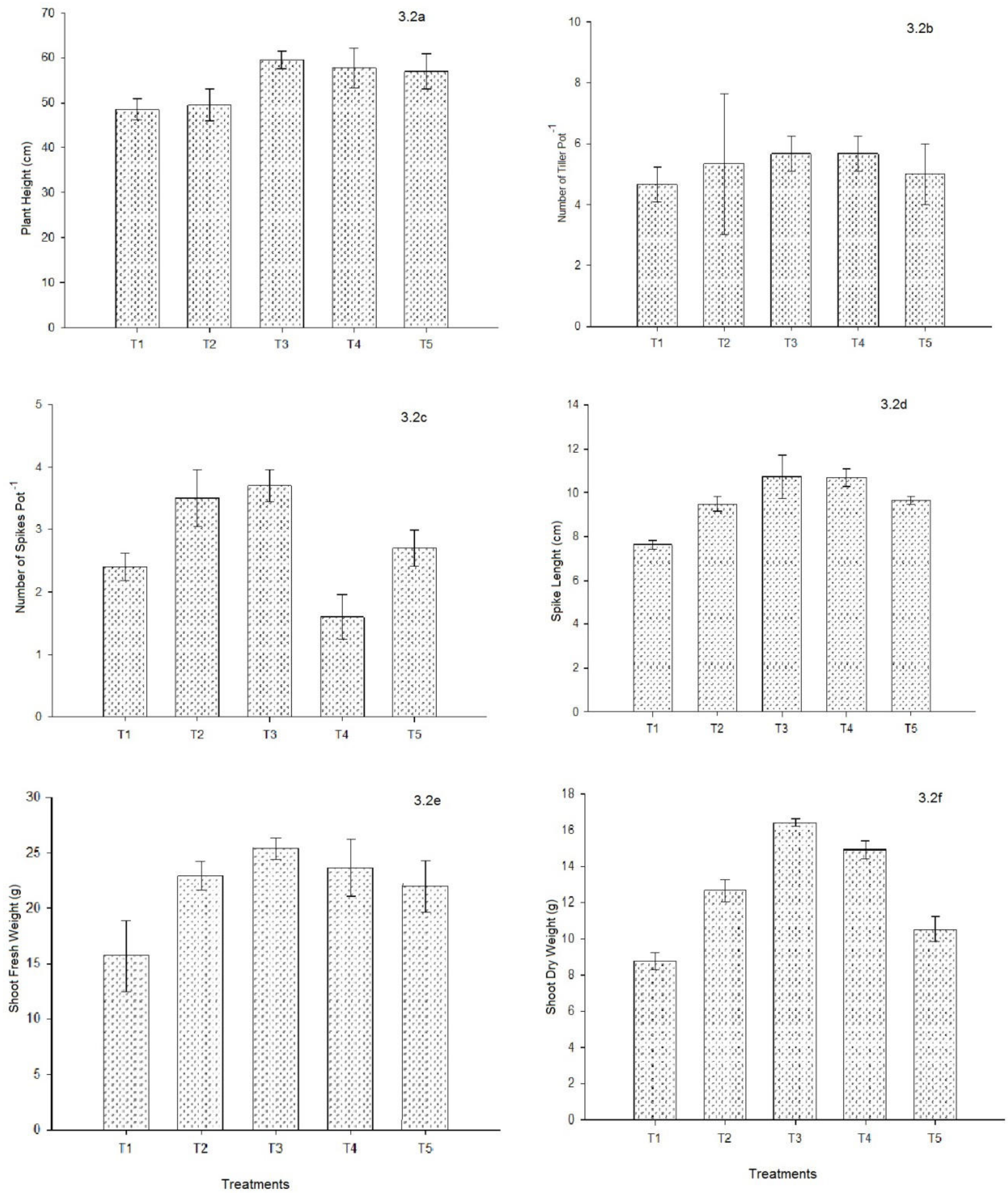


Fig 4.12: Effect of soil conditioners on agronomic parameters. T_1 = Control, T_2 = Gypsum, T_3 = H_2SO_4, T_4 = Citric Acid, T_5 = PVA

3.2.6 Effect of soil conditioners on shoot dry weight (g)

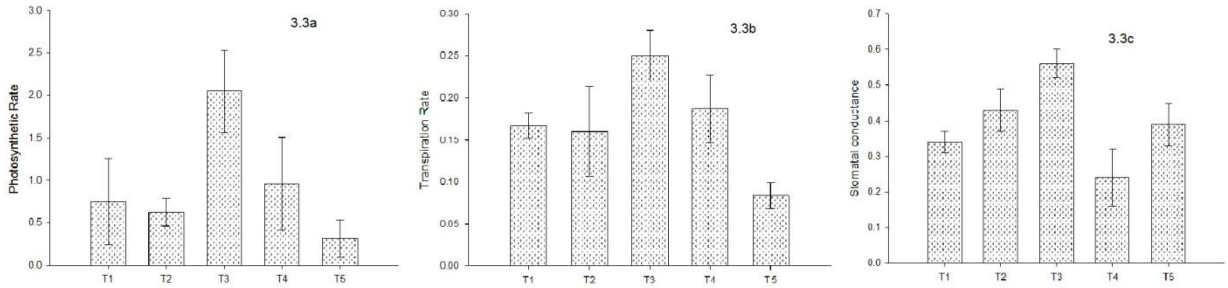
Shoot dry weight is important criteria for observing the performance of crop plants against salinity stress. After harvest of crop it was observed that the soil conditioners significantly affect the shoot dry weight (Fig. 3.2f). Maximum dry weight (37.56 g) was observed in T_3 as compare to other treatment while the minimum dry weight (14.42 g) was observed in control. However it also was observed by Iqbal and Ashraf (2007).

3.3. Physiological parameters of crop

3.3.1. Effect of soil conditioners on Photosynthetic Rate (µmol m^{-2} s^{-1})

Growth is known to be affected by various environmental and genetic factors to an extent which depends on species, variety as well as on plant's growing conditions. One of the main causes of reduced growth might be a reduction in the rate of photosynthesis (Ali *et al.*, 2005). The effect of soil conditioners treatment on photosynthetic activity was significant (Fig. 3.3a) maximum photosynthetic activity was observed with T_3 (15.83

µmol $m^{-2} s^{-1}$) while minimum activity was observed in T_5 (5.91 µmol $m^{-2} s^{-1}$) as compare to other treatments. Moreover the decreasing order of photosynthetic activity was T_3 (15.83 µmol $m^{-2} s^{-1}$) > T_4 (12.59 µmol $m^{-2} s^{-1}$) > T_1 (8.35 µmol $m^{-2} s^{-1}$) T_2 (7.35 µmol $m^{-2} s^{-1}$) > T_5 (5.92 µmol $m^{-2} s^{-1}$). The lowest photosynthetic activity in plants raised from T_4 might be associated with the loss of Rubp carboxylase / oxygenize (Koyro, 2006). In general photosynthesis is inhibited by salt stress that affects photosynthetic activity and chloroplast structure (Fidalgo et al. 2004). As due to application of acid the soil chemical properties changed (EC and pH) that affect photosynthetic activity, according to (Gerloff-Elias et al. 2005) the loss of photosynthesis activity may be due to increase in EC and pH of soil. Photosynthesis is inhibited in the presence of salinity through either reduction in stomata conductance (g_s) or such non stomata factors as a reduction in chlorophyll pigments to absorb enough light (Moradi and Esmail, 2007). Another possible factor contributing to decreased photosynthesis is the inhibitory effect of salt stress on the efficiency of translocation and assimilation of photosynthetic products. High concentration of Na^+ causes osmotic imbalance, membrane disorganization, reduction in growth, inhibition of cell division and expansion and reduction in photosynthetic rate (Mahajan and Tuteja, 2005).



3.3 Effect of soil conditioners on plant physiological characteristics. T_1 = Control, T_2 = Gypsum, T_3 = H_2SO_4, T_4 = Citric Acid, T_5 = PVA

3.3.2. Effect of soil conditioners on transpiration rate (µmol $m^{-2} s^{-1}$)

After the harvest of applied treatment there was a significant improvement in transpiration rate (Fig.3.3b). Minimum transpiration rate was observed with T_5 (0.3 $molm^{-2}s^{-1}$) while maximum transpiration rate was observed in treatment T_3 (0.6267 $molm^{-2}s^{-1}$) in which citric acid was applied to reclaim saline-sodic soil. Moreover the decreasing order of transpiration rate was T_3 (0.63 $molm^{-2}s^{-1}$) > T_4 (0.53 mol $m^{-2}s^{-1}$) > T_1 (0.46 $molm^{-2}s^{-1}$) > T_2 (0.38 $molm^{-2}s^{-1}$) > T_5 (0.30 $molm^{-2}s^{-1}$). It was reported by Kazuhiro *et al.* (2009) that salinity stress also decreased water potential and transpiration rate in wheat.

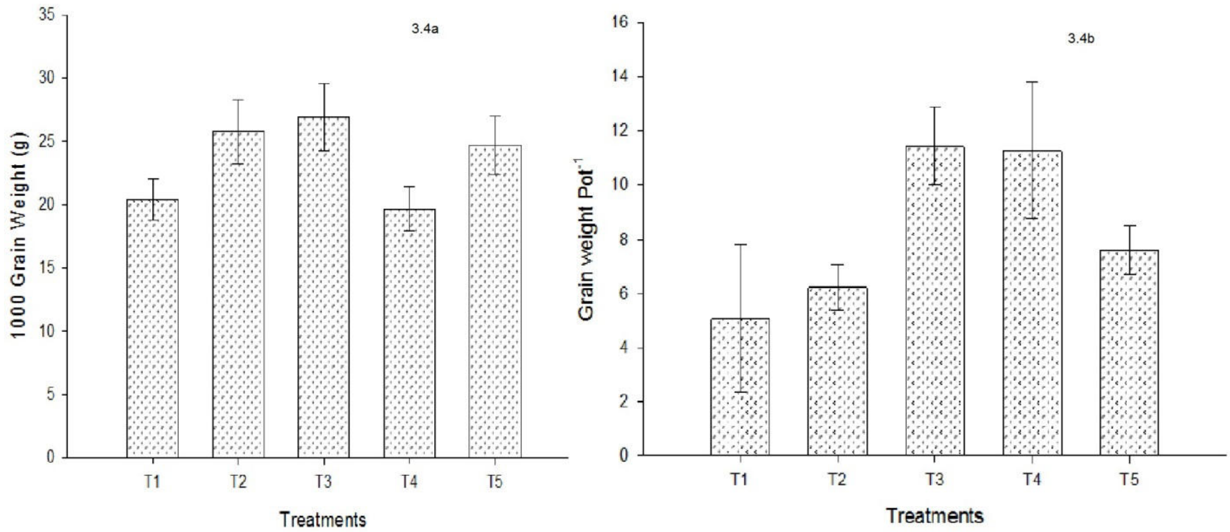
3.3.3 Effect of soil conditioners on stomata conductance

After harvest of applied treatments it was observed that there was significant improvement in stomata conductance (Fig. 3.3c). Maximum stomata conductance was observed with T_3 (0.52 $molm^{-2}s^{-1}$), while minimum stomata conductance was observed in T_4 (0.23 $molm^{-2}s^{-1}$) as compare to other treatments. Moreover the decreasing order of stomata conductance of treatment was as T_3 (0.52 $molm^{-2}s^{-1}$) > T_2 (0.41 $molm^{-2}s^{-1}$) > T_5 (0.36 $molm^{-2}s^{-1}$) > T_1 (0.32 $molm^{-2}s^{-1}$) > T_4 (0.23 $molm^{-2}s^{-1}$). The response to citric acid and gypsum treatment was different from each others, while the response of polyvinyl alcohol was somewhat similar to control. Kamboh *et al*. (2000) reported that salinity stress decrease water potential and transpiration rate and stomata conductance in wheat. They reported that with increase in salinity stress transpiration rate was decrease with decreasing water potential in wheat cultivar which develops stomata closure. Grover, (1993) also reported that with increasing salinity level the reduction in stomata conductance in wheat crop occur because long term exposure of wheat plants to salinity depress the rate of net CO_2 assimilation (A). These observations are in harmony with those of Ouerghi *et al*. (2000) who reported that in wheat at 100 mM of NaCl salinity, decrease stomata conductance led to limit photosynthesis.

3.4. Biological yield of crop

3.4.1. Effect of soil conditioners on 1000 grain weight (g)

The statistical analysis of data regarding 1000 grains weight as affected by different soil conditioners is presented in Fig 3.4a. Maximum 1000 grain weight, (26.9 g) / pot were observed with application of T_3. While minimum 1000 grain, (18.70 g) / pot was observed with applications of T_4. The decreasing order in 1000 grain was as T_3 (26.9 g) > T_2 (24.8 g) > T_5 (23.16 g) > T_1 (19.8 g) > T_4 (18.7 g). Maximum decrease in 1000 grain weight may be due to formation of less grains per spike, and less no of tillers per plant, according to (Mass, E.V. and C. M. Grieve, 1990) that salinity cause a large reduction on number of tillers per plant, plant height and also affect other physiological parameters of plant that ultimately reduce grain yield. Similarly according to Akhtar and Niazi., 1986 acid application like HCl and H_2SO_4 have significant effect on tillering and plant height, grain and straw yield of wheat.



3.4. Effect of soil conditioners on Biological yield (g / pot), T_1 = Control, T_2 = Gypsum, T_3 = H_2SO_4, T_4 = Citric Acid, T_5 = PVA

3.4.2. Effect of soil conditioners on grain weight Pot^{-1} (g)

The data regarding to grain yield is depicted by (Fig. 3.4b). Maximum grain yield was observed with treatment T_3 (9.98 g), while minimum grain yield was observed with treatment T_1 (5.53 g). Moreover the decrease in grain yield was as T_3 (9.98 g) > T_4 (8.32 g) > T_5 (7.36 g) > T_2 (6.12 g) > T_1 (5.54 g). By the application of H_2SO_4 and gypsum treatment there was a increase in grain yield as compare to other treatments that may be due to increase in grains / spike and 1000 grain weight. These results were collaborated to findings of Haq *et al*. (2007) and Rashid *et al*. (2009).

Conclusion

After harvest of crop it was observed that treatments have significant changes in soil chemical properties and also significantly improve crop yield. The maximum changes in chemical properties i.e. pH, EC_e and SAR were observed by application of T_3 and T_2. Similarly the maximum increase in grain yield was observed with treatment T_3 and minimum grain yield was observed with application of T_4, because it increases salinity level of soil as compare to other treatments. The decreasing order in grain yield was as T_3 (9.98 g) > T_2 (8.32 g) > T_5 (7.36 g) > T_1 (6.12 g) > T_4 (5.53 g). After observing the results related to soil conditioners we come to know that these improve soil chemical properties, to provide maximum crop yield. There is further need to conduct this experiment in field particularly to investigate the effect of H_2SO_4 and citric acid on physical changes of soil followed by other crop i.e. rice, maize and cotton etc.

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