COMPARISON OF GYPSUM AND POTASSIUM SILICATE FOR RECLAMATION OF SALINE SODIC SOIL

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ABSTRACT:- Relative efficiency of gypsum, potassium silicate and their combinations at different levels for reclamation of saline sodic soil was tested. Treatments were replicated thrice. All pots were arranged according to completely randomized design and treatments were applied to the soil according to treatment plan. Appropriate time was given to achieve the reclamation of saline sodic soil and relative efficiency was assessed through laboratory analysis. After this, rice seedling (Shaheen Basmati) was transplanted in all the pots i.e., 3 plants per pot. Necessary N, P and K fertilizers were applied at the recommended rate. After crop harvest, soil samples were taken for analysis of pH, electrical conductivity (EC), sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) of soil. All the amendments when used alone or in combination with each other improved the chemical parameters of soil. All levels of gypsum (100%, 75% and 50% G.R) proved effective in lowering pH, EC, SAR and ESP of saline sodic soil. Similar trend was observed with the use of all levels of potassium silicate (225, 150 and 75mg kg^{-1}soil) of soil. Combinations of gypsum and potassium silicate also remained better in this regard. The most effective treatment was application of the full required rate of gypsum.

Key Words: Rice; Soil Reclamation Gypsum; Potassium Silicate; Saline Sodic Soil; pH; EC; SAR; ESP; Pakistan.

INTRODUCTION

Salt affected soils are distinguished in three categories according to types of salts present; saline (soluble salts), sodic (exchangeable salts) and saline-sodic. These soils have poor soil health. The limiting factor in these soils is excess of salts (soluble, exchangeable or both) (Horneck et al., 2007). Soil chemical properties are badly deteriorated by these salts leading to their effect on plants. Salt affected soils are problem of dry and partially dry regions of the world. In these areas, water input (from any source) is not enough to take the salts away from root zones of the plants (Khan and Duke, 2001).

Pakistan with an area of 79.61 mha (World Bank, 2012) is located in dry and semi dry areas of the world. Salt affected soils considered to be major crisis of Pakistani agriculture. Various amendments are used for reclamation of saline sodic soils. Among these chemicals, gypsum is the most frequently used amendment for reclamation throughout the world and also in Pakistan. Being source of calcium it absorbs excess of sodium from saline, sodic or saline-sodic soils. Calcium plays important role in plant mechanisms. It is helpful for plants to fight with abiotic anxieties (Cha-um et al., 2011). Gypsum is easily accessible and inexpensive source of calcium. Its usefulness depends upon

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the fineness of the gypsum powder, its application method and efficiency of drainage structure (Ali and Kahlown, 2001).

Presently, there are some advances in the field of reclamation of salt affected soils. These include exogenous application of nutrients (silicon) (Raza et al., 2006). Silicon is valuable for plants in combating different biotic and abiotic stresses like diseases, pest attack and water deficiency, salts and metals toxicities (Ma, 2001). There are various means by which silicon assemble salinity tolerance in plants (Liang et al., 2007). Silicon boost salt tolerance in plants by rising water status of the plants (Romero -Aranda et al., 2006). Photosynthetic activity is vital for plant survival, silicon improves photosynthesis rate and keep ultra configuration of plant organelles (Shu and Liu, 2001) and provision of reactive oxygen species is reduced (Zhu et al., 2004). Silicon reduces the uptake of sodium and improves uptake of potassium in plants (Tahir et al., 2006), and improve potassium to sodium selectivity (Hasegawa et al., 2000).

The present study was thus conducted to check comparative effects of gypsum and potassium silicate on lowering chemical parameters of saline sodic soil and rehabilitation of these soils.

MATERIALS AND METHOD

A pot experiment was performed at study area of University College of Agriculture, University of Sargodha, Sargodha, on saline sodic soil [pH = 8.97, EC = 7.15 dS m^{-1}, SAR = 35.65]. Gypsum requirement of this soil was 6 t ha^{-1}. Gypsum and potassium silicate were applied to the pots according to treatment plan and 30 days were given to achieve the completion of reclamation process. To achieve complete leaching of soluble salts and exchangeable Na, a hole was provided in the pots. In this way, the leached water along with soluble salts and exchangeable Na escaped from all the pots. Completely randomized design with 11 treatments and 3 replications were pursued in this experiment. The treatments applied were as follows:

T_1= Control,
T_2= 100% G.R,
T_3= 75% G.R,
T_4= 50% G.R,
T_5= K_2SiO_3@ 225 mg kg^{-1} soil,
T_6= K_2SiO_3@ 150 mg kg^{-1} soil,
T_7= K_2SiO_3@ 75 mg kg^{-1} soil,
T_8= 75% G.R + K_2SiO_3 @ 150 mg kg^{-1} soil,
T_9= 75% G.R + K_2SiO_3 @ 75 mg kg^{-1} soil,
T_{10}= 50% G.R + K_2SiO_3@ 150 mg kg^{-1} soil,
T_{11}= 50% G.R + K_2SiO_3 @ 75 mg kg^{-1} soil.

Rice seedlings (Shaheen Basmati) were transplanted in all the pots (filled @ 14 kg soil) @ 3 plants per pot. Water was applied to rehabilitate soil, after rice transplanting sufficient irrigation (EC = 0.79; dS m^{-1}, TSS = 7.75 m mol_cL^{-1}; SAR = 4.8 (m $mol_cL^{-1})^{1/2}$) was given as crop demand. Necessary N, P and K fertilizers were applied at the recommended rate (100-70-70 kg ha^{-1}). Crucial agronomic practices were carried out when required. Half of the suggested nitrogen dose was applied at transplanting time while all phosphorus and potassium was applied at the same time. The remaining nitrogen was applied 15 days after transplanting. One month after transplanting, zinc sulfate was applied @ 10 kg ha^{-1}. At maturity, rice crop was harvested after recording necessary data regarding yield and yield components.

Soil samples from pots were obtained after crop harvest for chemical analysis of soil (pH, EC, SAR and ESP).

RESULTS AND DISCUSSION

Soil Reaction (pH)

It is important chemical property which determines the availability of nutrients to plant. Soil analysis indicates that application of gypsum and potassium silicate alone or in combination remained effective for lowering soil pH. All the treatments remained significant statistically in decreasing soil pH when compared with control (Figure 1). Maximum decrease in pH was noted in T_2 (100 %G.R), where pH was 8.16. Data indicated that application of gypsum proved superior to potassium silicate as the differences among gypsum treatments (T_2, T_3 and T_4) proved significant when compared with each other. On the other hand, use of potassium silicate at either rate also lowered the soil pH but differences among the value of analyzed pH for potassium silicate treatments (T_5, T_6 and T_7) were non-significant when compared with each other. However, the value of pH for T_5, T_6 and T_7 were 8.4, 8.5 and 8.6, respectively. Similar was the role of gypsum and potassium silicate combination. In this regard, lowest pH (8.4) was determined for T_8. However, all these four combinations (T_8, T_9, T_{10} and T_{11}) remained non-significant when compared with each other statistically.

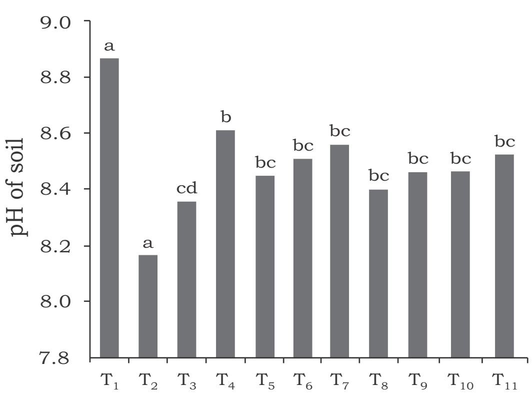

Figure 1. Effect of various levels of gypsum and potassium silicate on pH of soil (*Means followed by same letters do not differ significantly at P≤ 0.05*)

pH of saline sodic soils is high because of exchangeable Na^+ present on exchange sites. By application of gypsum to such soil pH of soils decreased. Gypsum gave Ca^{2+} and SO^{2-} ions; Ca^{2+} replaces Na^+ from exchange sites. This Na^+ reacts with SO^{2-} to form Na_2SO_4 which is soluble and leach out of soil profile. So, in this way pH of the soil is decreased (Brady and Weil, 2005). Potassium silicate is also helpful in decreasing pH of saline sodic soil as it contains silicon. Potassium silicate reacts with Na^+ on exchange sites and sodium silicate is formed. Thus, the pH of saline sodic soils decreased by application of potassium silicate. Results given by some other scientists like Ghafoor et al. (2001), Zaka et al. (2003), Murtaza et al. (1998), Tahir et al. (2006) and Cha-um et al. (2011) also supported these findings.

Electrical Conductivity (ECe)

It describes the total quantity of soluble salts present in a particular soil. Application of gypsum and potassium silicate at different levels decreased the EC of saline sodic soil. The difference among various treatments remained significant statistically when compared with control (Figure 2). Addition of gypsum at either rate (100%, 75% and 50%) decreases the EC of soil under test. Addition of the 100% G.R (T_2) decreased the soil ECe to the maximum level (2.96dSm^{-1}). Treatments T_2, T_3 and T_4 showed significant difference when compared with each other. Similar behavior of potassium silicate was noted in decreasing the ECe of soil. Maximum decrease in EC was noted in T_5. When compared with T_6 and T_7. Application of gypsum and potassium silicate in combination also proved effective in decreasing ECe of the soil but differences among treatments were assessed as non-significant with each other and significant when compared with control.

Saline sodic soils also contain excess of soluble salts which results in EC of soil. In saline sodic soils structure of soils deteriorate and become disperse, when gypsum is added. It improves the soil structure by replacing Na on exchange sites and turn soil structure to flocculate. In this way drainage of soils improved and leaching of salts becomes possible (Ghafoor et al., 2004). Similar mechanism was also carried out by silicon; its application resulted in increased root growth and activity, which caused increased nutrient recycling and more root actions. All this led to decreased compaction and more drainage of soils, so the excess of salts were leached out. Silicon also affects plant physiology, plants uptake salts and deposit them in their tissue. By this mechanism decrease in salt content of plants occur (Liang et al., 2007). This useful mechanism by silicon was demonstrated by lessened values of ECe in present experiment. These results are supported by Ghafoor et al. (2001; 2004); Zaka et al. (2003), Cha-um et al. (2011), Toma et al. (1999) and Chaudhry (2001).

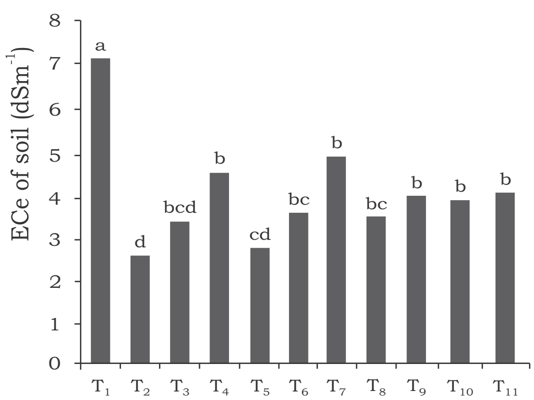

Figure 2. Effect of various levels of gypsum and potassium silicate on ECe of soil (*Means followed by same letters do not differ significantly at P≤ 0.05*)

Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP)

The SAR of soil is greatly influenced by application of amendments (gypsum and potassium silicate) at various levels alone and in combination. Statistical analysis of data showed that there is significant difference in capability of these amendments to reduce SAR of soil (Figure 3). Minimum decrease in SAR 34.84 (mmolL^{-1})$^{1/2}$ was observed in control. Maximum decrease in SAR was recorded in T_2 with value of 12.79 (mmolL^{-1})$^{1/2}$. T_5 also played its role effectively in decreasing SAR value to 15.28 (mmolL^{-1})^{½}. These values were followed by T_8 with SAR of 16.68 (mmolL^{-1})$^{1/2}$. Treatment T_3 and T_9 also decrease the SAR value to 18.48 and 18.27 (mmolL^{-1})^{½} and both were non-significant with each other. Similarly, T_6 also contributed much in decreasing SAR to 19.32 (mmolL^{-1})$^{1/2}$. Treatments

T_{10} and T_{11} decreased SAR to value of 20.55 and 21.61 $(mmolL^{-1})^{1/2}$, respectively and were statistically non-significant.

Similarly, T_4 and T_7 reduce SAR to 22.13 and 23.24 $(mmolL^{-1})^{1/2}$, respectively and remained non significant for each other. All three levels of gypsum and potassium silicate were useful in reducing SAR of saline sodic soil and proved highly significant with each other. Among different combinations of gypsum and potassium silicate; T_8 remained superior to all others. Application of gypsum increase the level of divalent cations (Ca + Mg) which decreased percentage of monovalent cation (Na) and hence leading to decrease in the value of soil SAR. Such sodium salts are more soluble in water and hence these were leached down. As a result of this process soil solution became dominant with Ca + Mg; although some quantity of sodium might be precipitated as carbonates and bicarbonates (Brady and Weil, 2005). In the same way use of potassium silicate was helpful in reducing soil SAR. The addition of potassium silicate changes the sodium potassium ratio on the exchange complex and sodium silicate is formed, this is more soluble in water and hence leached down in to the profile. Experimental results of Qadir et al. (2007), Khan et al. (2006), Ghafoor et al. (2001), Murtaza et al.(1998), Cha-um et al. (2011) and Richmond and Sussmam (2003) conform these findings.

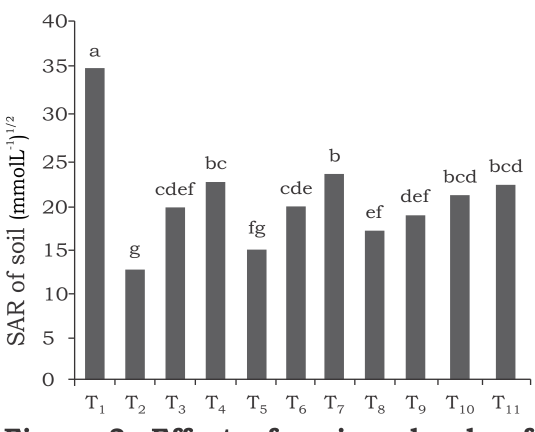

Figure 3. Effect of various levels of gypsum and potassium silicate on SAR of soil (*Means followed by same letters do not differ significantly at P≤ 0.05*)

The extent to which exchange complex of soil is saturated with Na is called exchangeable sodium percentage (ESP). Degree of sodication is characterized by this important parameter. It is numerical parameter calculated from SAR values because determination of sodium on exchange sites is a lengthy process (Kijne, 1998). Cation Exchange Capacity (CEC) which is produced by exchangeable sodium is a good indicator of alkalinity. Exchangeable sodium percentage of more than 15 is extremely harmful, 10-15 is moderately harmful and 5-10 is slightly harmful. High level of ESP causes dispersion of soil colloids which results in deterioration of soil structure. The equation for calculation of ESP from SAR is following (U.S. Soil Salinity Laboratory, 1954).

$ESP = (y/ (1+y))* 100,$

where,

$y = (0.01475\ SAR)-0.0126$

Similar to SAR, application of gypsum and potassium silicate proved useful for changing ESP of saline sodic soil. Statistical analysis indicated the significant difference among various treatments (Figure 4). Maximum decrease in ESP (14.92) was found in T_2 (100% G.R). Minimum decrease in ESP (33.31) was recorded

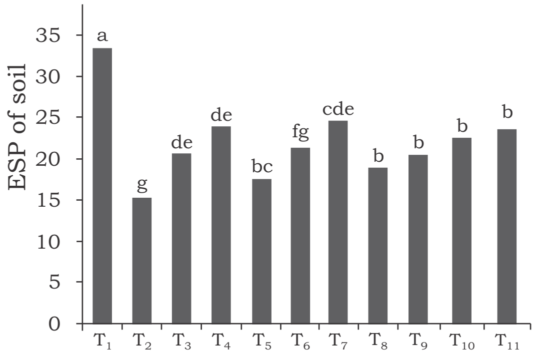

Figure 4. Effect of various levels of gypsum and potassium silicate on ESP of soil (*Means followed by same letters do not differ significantly at P≤ 0.05*)

in control. Highly significant decrease in ESP was also observed in T_5 and T_8 with value of 17.43 and 19.92, respectively, both were statistically non-significant. Similarly, T_3 and T_9 also play role in effective decrease of ESP and lowered it to 20.69 and 20.44, respectively, both were non-significant with each other. Treatments, T_{10} and T_{11} also lowered the ESP to 22.51 and 23.44, respectively and were noted as non significant with each other. T_4 and T_7 decreased ESP to 23.88 and 24.82, respectively. Various levels of gypsum and potassium silicate played effective role in reducing ESP and effect of these amendments was highly significant statistically. Among different combinations of gypsum and potassium silicate; T_8 was superior to all others.

ESP is derived from SAR, so similar pattern is adopted in its decrease as in SAR. Results of Matichenkov and Calvert (2002), Ghafoor et al. (2001), Zaka et al. (2003), Gong et al. (2003), Murtaza et al. (1998), Chengxiang et al. (2005) and Cha-um et al. (2011) also support these results.

It is thus concluded that although gypsum is the best amendment for the reclamation of saline sodic soil when applied @ 100% G.R. The results of the experiment proved that potassium silicate may be good substitute or alternate of gypsum when applied @ 225 mg kg^{-1} soil. Combination of gypsum @ 75% G.R + potassium silicate @ 150 mg kg^{-1} soil also proved successful treatment for the reclamation of saline sodic soils and subsequently growth of rice crop.

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