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Use of Chemical Amendments for Reclamation of Saline-Sodic Soils

MANZOOR AHMAD, NAZIR HUSSAIN†, M. SALIM AND B.H. NIAZI
National Agricultural Research Centre, Park Road, Islamabad–Pakistan
†Soil Salinity Research Institute, Pindi Bhattian, Hafizabad–Pakistan

ABSTRACT

The experiment was conducted at farmer's field on a saline-sodic soil to compare the reclamation effect of different doses of gypsum and equivalent amounts of $CaCl_2$ (industrial bye-product). The treatments were applied and wheat crop was sown in the year 1996-97. Further, to study the residual effect of both the chemicals, two crops, each of rice and wheat, were sown after wheat 1996-97. There was a significant yield increase by gypsum and $CaCl_2$ in both wheat and rice as compared to control. Equivalent amounts of $CaCl_2$ and gypsum gave almost similar grain yield in wheat. Grain yield was significantly higher in gypsum treated plots than the respective $CaCl_2$ treated plots in rice, while there was no difference in wheat. Soil SAR, EC_e and pH decreased by both the chemicals but $CaCl_2$ proved less effective as compared to gypsum in lowering the SAR and EC_e .

Key Words: Sodic soil; Industrial waste; Gypsum; Calcium chloride; Wheat; Rice

INTRODUCTION

About 3.2 million hectares of agricultural land in Pakistan is classified as saline-sodic and sodic in nature (Muhammed, 1990). These soils are characterized by a pH > 8.5; $EC_e \leq 4.0$ dS m^{-1} and ESP > 15. The dominant cation on the exchange complex of these soils is Na^+ due to which they suffer a deterioration in physical conditions. A soluble source of Ca^+ is essential for reclamation of such soils, which is helpful in removing harmful Na^+ from the exchange complex (Richards, 1954; Muhammed, 1990), and is subsequently leached down from the root zone as drainage water. Gypsum being the soluble source of calcium is most commonly used to reclaim sodic soils. It improves soil water infiltration by enhancing electrolyte concentration (Oster, 1982; Gupta *et al.,* 1985).

Chaudhary and Abaidullah (1988) reported that gypsum applied @ 100% gypsum requirement (GR) was more effective in reducing the soil electrical conductivity (EC) and sodium adsorption ratio (SAR) than the equivalent amount of $CaCl_2$. In a field experiment conducted on a highly sodic silty loam soil (EC_e = 1.2 dS m^{-1}, pH=10.2, ESP = 55.3 and GR = 8.4 me $100g^{-1}$); application of gypsum at all levels significantly increased yield of rice and wheat over control (Singh, 1990). With the application of 12 t ha^{-1} of gypsum and other suitable cultural practices during the reclamation of a dense sodic soil, pH_s decreased from 10.2 to 9.1 (Rao *et al.,* 1994); and EC_e decreased from 2.1 to 0.8 dS m^{-1} during the first year of reclamation. Later on, the effect of the amendment was still evident but the rate of amelioration was slow.

Calcium chloride (an industrial bye-product) has been reported to be equally good amendment but is not popular as reclament in Pakistan. This paper compares the relative efficiency of gypsum and calcium chloride for reclamation of sodic soils and yield of wheat and rice.

MATERIALS AND METHODS

The experiment was conducted on a farmer's field on saline-sodic calcareous soil near the Soil Salinity Research Institute, Pindi Bhattian (Texture = clay loam, EC_e =7.72 dS m^{-1}, pH = 9.0, SAR = 30.1, GR = 6.5 t ha^{-1}). Crop rotation was wheat-rice-wheat. Rice (Pb-95) and wheat (Inqlab-91) were planted in this study. Recommended doses of fertilizer were applied to rice (100 - 70 - 50 NPK kg ha^{-1}) and wheat (120 - 100 - 50 NPK kg ha^{-1}). Canal water was not available for irrigation for this experiment. Hence, both the crops were grown with tube well water of marginal quality (Ec_{iw} = 0.84 dS m^{-1}, SAR = 8.86, RSC = 4.25 me L^{-1}) throughout the season.

The experiment was laid out according to split plot design and had three replications. Plot size was 15 x 10 meters. Treatments applied were: T_1 = Control; T_2 = gypsum equivalent to 100 % GR; T_3 = gypsum equivalent to 150% GR; T_4 = gypsum equivalent to 200% GR; T_5 = Calcium chloride equivalent to 100% GR; T_6 = Calcium chloride equivalent to 150% GR; T_7 = Calcium chloride equivalent to 200% GR. The experiment was started in Rabi, 1996-97 and continued up to Rabi, 1998-99. Three wheat crops and two rice crops were grown to maturity during this period. Effect of these treatments was recorded on wheat and rice yields. Soil samples were collected at the time of harvesting of each crop and were analyzed for EC_e, pH and SAR. Data were statistically analyzed and Duncan's Multiple Range test was applied to examine significant differences between the treatment means (Little & Hills, 1978).

RESULTS AND DISCUSSION

Grain yield. There was a significant yield increase by gypsum and $CaCl_2$ in both wheat and rice as compared to control (Table I). Equivalent amounts of $CaCl_2$ to those of gypsum gave almost similar grain yield of all the three wheat crops. Wheat yield increase noted in gypsum applied @ 150 and 200% of GR were statistically similar but higher than gypsum @ 100% GR. In the subsequent two crops of wheat, gypsum at 100 and 150% GR gave similar yields but gypsum @ 200% of GR gave significantly higher yield as compared to the lower doses. Yield of wheat noted, in case of $CaCl_2$ equivalent to 200% GR was also better. Value cost ratio (VCR) calculated for first wheat crop with gypsum @ 100% GR was 2.46. The cost of applied gypsum (@100% GR) was recovered in the first wheat crop in the shape of increased grain yield. However, this treatment could not be compared with equivalent amount of $CaCl_2$, which was received as a free input.

In rice (Kharif 1997 and 1998), grain yield was significantly higher in gypsum treated plots than the respective $CaCl_2$ treated plots. This might be due to slightly better chloride tolerance of wheat as compared to rice (Anonymous, 1980). Yield reduction in rice by salinity produced by a mixture of salts ($CaCl_2$ and NaCl) was 50% at 8 dS m^{-1} i.e. approximately 95 me L^{-1} of chlorides (Chapman, 1975), while in wheat 30% yield reduction was noted at 100 me L^{-1} in solution culture experiments. Based on these studies, rice has been classified as medium tolerant and wheat as high tolerant to salinity and chloride toxicity. Other workers have classed wheat and rice as medium tolerant and sensitive to salinity, respectively (Mass, 1993). Hence, better performance of wheat in $CaCl_2$ treated soil could be due to its better tolerance to salinity and chlorides present in the root zone. Ahmad *et al.* (1986) reported that in a sodic soil, treatment of soil with HCl @ 100% GR, resulted in the highest yield and yield components in IRRI-6 and Basmati-370 rice. This was obviously due to formation of $CaCl_2$ as a result of HCl reaction with native $CaCO_3$ of the soil. Greater mobility and leaching of $CaCl_2$ in soil under wheat and restricted leaching in puddled soil under rice might be responsible for this differential behavior of $CaCl_2$ on wheat and rice yield. In 1997, gypsum at 200% GR gave significantly higher paddy yield as compared to the lower doses while the effect of different $CaCl_2$ doses was non-significant. In 1998, rice yield was significantly higher at 200% gypsum as well as its equivalent $CaCl_2$.

Long-term reclamation effect was visible up to 5th crop after application of these amendments. Grain yields of wheat 1998-99 and rice 1998 were almost similar to wheat 1996-97 and rice 1997, respectively. Rao *et al.* (1994) obtained 1.5 and 4.0 t ha^{-1} wheat and rice, respectively after reclamation of a barren, sodic and unproductive soil with gypsum @12 t ha^{-1}. After nine years of reclamation, this yield level was successfully maintained in both the crops.

EC_e of soil. All the three gypsum treatments significantly decreased the EC of the soil in 1996-97 (LSD = 0.31); although differences amongst gypsum doses were non-significant (Table II). During this year, $CaCl_2$ proved less effective as compared to gypsum and $CaCl_2$ equal to 200% GR was the least effective treatment. In the subsequent years, differences between the treatments became less clear. However, with continuous cropping, there was a tendency for decrease in EC. Decrease in EC in 1998-99 was about 29-40% as compared to wheat 1996-97 in gypsum treated plots. In $CaCl_2$ treated plots, the decrease in EC_e in the year 1998-99 was about 33-46% as compared to the initial year of reclamation. Even in control, there was a gradual decrease in EC_e and in 1998-99, it was about 12% lower than the initial year i.e. 1996-97.

Table I. Effect of gypsum and $CaCl_2$ on grain yield of wheat and rice (t ha^{-1})

Treatments	Wheat 96-97	Rice 97	Wheat 97-98	Rice 98	Wheat 98-99
Control	2.30 d*	1.62 d	2.15 c	1.66 d	2.23 d
T1	3.58 c	3.08 b	3.86 b	3.27 b	3.98 c
T2	4.17 a	3.16 b	3.88 b	3.32 b	3.95 c
T3	4.25 a	3.41 a	4.36 a	3.51 a	4.45 a
T4	3.50 c	2.62 c	3.79 b	2.42 c	3.83 c
T5	4.00 b	2.66 c	3.88 b	2.46 c	4.15 b
T6	4.25 a	2.74 c	4.50 a	3.55 a	4.30 ab

Table II. Effect of gypsum and $CaCl_2$ on EC_e (dS m^{-1}) of soil

Treatments	Wheat 96-97	Rice 97	Wheat 97-98	Rice 98	Wheat 98-99
Control	6.17 a*	5.90 a	5.75 a	5.60 a	5.44 a
T1	5.20 d	4.90 a	4.45 b	4.05 b	3.67 b
T2	5.07 d	4.85 b	4.30 bc	3.75 cd	3.24 cd
T3	5.17 d	4.87 b	4.25 bc	3.60 d	3.09 d
T4	5.58 c	4.95 b	4.39 bc	3.90 bc	3.75 b
T5	5.84 bc	4.80 b	4.30 bc	3.85 bcd	3.36 c
T6	5.92 ab	4.70 b	4.18 c	3.70 cd	3.14 cd

* Figures sharing the same letters are significantly similar to each other at $p < 0.05$; T1= Gypsum @ 100% GR; T2= Gypsum @ 150% GR; T3= Gypsum @ 200% GR; T4= $CaCl_2$ @ 100% GR; T5= $CaCl_2$ @ 150% GR; T6= $CaCl_2$ @ 200% GR

$CaCl_2$ is more soluble in water than gypsum and may result in increased electrolyte concentration (Oster, 1982) in the soil solution and hence should be comparatively more effective in reducing EC of the soil. The salt concentration in soil after wheat 1996-97 however, showed an opposite trend. In the subsequent years the performance of both the reclaments was similar. Higher doses of these chemicals were slightly more effective in reducing the EC than their respective lower doses. After nine years of reclamation with gypsum @ 12 t ha^{-1} and cropping (rice-wheat-rice) of a highly sodic soil, there was a 95% decrease in EC of a sodic soil (Rao *et al.,* 1994). Decrease in EC_e by these amendments was possibly due to improved hydraulic conductivity due to which salts were leached down more effectively (Richards, 1954; Oster, 1982).

pH of Soil. Both gypsum and $CaCl_2$ reduced the soil pH significantly (LSD = 0.12*) in the year 1996-97 as compared to control (Table III). Maximum reduction in pH occurred at the highest dose of gypsum as well as $CaCl_2$. Residual effect of both the amendments was observed in the subsequent crops. Decrease in pH for gypsum and equivalent amount of $CaCl_2$ @ 200% GR was only 2.2 and 1.5%, respectively in the year 1998-99 as compared to the year 1996-97. Effect on pH was similar in other two doses of gypsum and $CaCl_2$. Rao *et al.* (1994) reported that in a highly sodic soil, gypsum @ 12 t ha^{-1} caused 16% decrease in pH in nine years but the major decrease occurred in the first year of reclamation. Decrease in pH could be due to removal of excess Na^+ from the soil and/or addition of sulfur in case of gypsum, which contains about 19% sulphur (Chapman, 1975).

Table III. Effect of gypsum and $CaCl_2$ on pH_s of soil

Treatments	Wheat 96-97	Rice 97	Wheat 97-98	Rice 98	Wheat 98-99
Control	8.84 a*	8.82 a	8.80 a	8.78 a	8.76 a
T1	8.62 b	8.60 b	8.59 b	8.58 b	8.57 b
T2	8.57 bc	8.54 b	8.50 bc	8.43 bc	8.38 c
T3	8.49 c	8.46 b	8.43 bc	8.36 c	8.30 c
T4	8.68 b	8.60 b	8.52 bc	8.48 bc	8.42 c
T5	8.59 bc	8.55 b	8.50 bc	8.40 bc	8.31 c
T6	8.48 c	8.42 b	8.38 c	8.37 c	8.35 c

* Figures sharing the same letters are significantly similar to each other at $p< 0.05$; T1= Gypsum @ 100% GR; T2= Gypsum @ 150% GR; T3= Gypsum @ 200% GR; T4= $CaCl_2$ @ 100% GR; T5= $CaCl_2$ @ 150% GR; T6= $CaCl_2$ @ 200% GR

SAR of soil. Significant reduction in SAR of the soil was noted in all tested doses of gypsum as well as $CaCl_2$ in the year 1996-97 (Table IV). Gypsum was more effective in decreasing the soil SAR as compared to $CaCl_2$. Lowest SAR was noted @ 200% gypsum and its equivalent amount of $CaCl_2$. Decrease in SAR and residual effect of both the amendments in the subsequent years was quite obvious. Reduction in SAR in 1998-99 was about 32% in gypsum @ 200 and 29% at equivalent amount of $CaCl_2$ as compared to the year 1996-97. Similar trend was also found at the other two tested doses of gypsum as well as $CaCl_2$. Decrease in SAR of the soil was caused by a decrease in sodium and an increase in calcium after reclamation with gypsum.

Table IV. Effect of gypsum and $CaCl_2$ on SAR of soil

Treatments	Wheat 96-97	Rice 97	Wheat 97-98	Rice 98	Wheat 98-99
Control	28.30 a*	26.25 a	25.30 a	24.80 a	24.72 a
T1	20.81 bc	18.75 b	17.65 b	16.55 b	15.48 b
T2	18.23 d	15.20 d	14.10 de	13.25 de	12.76 d
T3	17.36 d	14.30 d	13.22 e	12.35 e	11.84 e
T4	22.14 b	19.25 b	17.30 bc	16.40 b	15.90 b
T5	19.43 cd	17.30 bc	16.20 c	14.50 c	13.45 c
T6	17.84 d	15.70 cd	14.60 d	13.55 cd	12.73 d

* Figures sharing the same letters are significantly similar to each other at $p< 0.05$; T1= Gypsum @ 100% GR; T2= Gypsum @ 150% GR; T3= Gypsum @ 200% GR; T4= $CaCl_2$ @ 100% GR; T5= $CaCl_2$ @ 150% GR; T6= $CaCl_2$ @ 200% GR

Chaudhary and Abaidullah (1988) reported that gypsum applied @ 100% GR was more effective in reducing the soil EC and SAR than the equivalent amount of $CaCl_2$. The SAR reduction in our experiment in case of the amendments (@ 100 % GR) was almost similar and gave identical results. It has been reported that non-calcareous soils are very sensitive to the type of chemical amendment added. In the calcareous soils, gypsum and $CaCl_2$ behave similarly (Shainberg *et al.,* 1982).

From the foregoing discussion, it can be concluded that gypsum as well as $CaCl_2$ are equally effective for reclaiming sodic soil. For rice cultivation, it is comparatively less effective due to the harmful effect on the yield of rice. Long-term effect of $CaCl_2$ was nearly comparable to that of gypsum with regard to crop yield and soil reclamation except the effects on SAR. In this experiment, a VCR of 2.46 was noted for the first wheat crop and the cost of applied gypsum (@100% GR) was recovered in the first wheat crop in the shape of increased grain yield.

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