*Pak. J. Agri. Sci., Vol. 29, No. 4, 1992*

# BIOCHEMICAL RECLAMATION OF A CALCAREOUS SALINE-SODIC SOIL

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Effectiveness of chemical and biological methods for the reclamation of a calcareous saline-sodic soil (ECe = 9.1-15.2 dS $m^{-1}$; SAR = 27.4-43.5; pHs = 8.1-8.3; lime = 10.5-12.7%; texture = silt loam) was evaluated under field conditions. Two gypsum levels (No gypsum; gypsum @ 50% GR) were employed with four crop rotations (No crop, i.e. fallow; rice-wheat; Sesbania-barley; Kallar grass-alfalfa). Canal water (EC = 0.22 dS $m^{-1}$) was used for irrigation and leaching. The cropped treatments performed better than the non-cropped treatments in terms of soil reclamation at both the levels of gypsum application. The differences among the cropped treatments were not prominent. The cropped treatments completely reclaimed the soil within a year. The biomass production of all the species was more in the gypsum treated plots except Kallar grass where its yield decreased.

## INTRODUCTION

It is estimated that about 60% of the 6.22 million hectares of the salt-affected soils in Pakistan are saline-sodic (Muhammed, 1983). Majority of these soils contain lime ($CaCO_3$) at varying depths (Choudhri, 1972). These soils can be brought under cultivation after the use of certain amendments that supply soluble calcium either directly or indirectly by solubilising already existing insoluble fraction of the calcium as lime. But on account of certain limitations such as high cost of amendments and low permeability of the soils, the problem can not be tackled with complete success. A tangible line of approach and an equally important avenue to solve this problem may be the introduction of salt tolerant plant species habitat to this environment. These plant species may increase dissolution of lime in the presence of $CO_2$ evolved from the decomposition of organic matter and root respiration (Ahmad *et al.*, 1990) and their roots can improve soil permeability (Elkins, 1985). This means rehabilitation of these soils through biological means may need relatively low initial cost. Although a relatively slow process, yet it has a dual benefit of biomass collection and soil reclamation. The potential biotic materials reported suitable for such conditions may be Sesbania (Salim *et al.*, 1978; Sandhu and Qureshi, 1986), wheat (Tripathi and Pal, 1980; Qureshi *et al.*, 1983), barley (Khosla *et al.*, 1973), alfalfa (Rasmussen *et al.*, 1972), rice (Chhabra and Abrol, 1977; Ghafoor, 1984) and Kallar grass (Malik *et al.*, 1986).

A field experiment was carried out with the objectives: 1) To evaluate the effectiveness of Sesbania-barley, Kallar grass-alfalfa and rice-wheat rotations with and without gypsum in the reclamation of a calcareous saline-sodic soil and 2) To determine the comparative biomass production of the plant species.

## MATERIALS AND METHODS

The experiment was carried out on a calcareous silt loam saline-sodic soil at the Postgraduate Agriculture Research Station (PARS), University of Agriculture, Faisalabad during 1990-91. Soil characterization was done before the start of the experiment. The soil has been developed from mixed calcareous alluvial parent material. The surface down to 40 cm is clay loam to silt loams with an average pHs 8.2, lime 12.0% and cation exchange capacity (CEC) 10.8 cmol (+) $kg^{-1}$. This is underlain by silty material with yellow mottles and lime concretions. The soil is saline-sodic in nature and has great variation in $EC_e$ (9.1-15.2 dS $m^{-1}$) and SAR (27.4-43.5) in the upper 30 cm layer. The salinity/sodicity hazard decreases with depth. The soil is classified as Coarse loamy, mixed, calcareous, hyperthermic Natric Camborthids.

Eight treatments were run in triplicate in a randomized complete block design using a plot size of 6 m x 3 m (0.0018 ha).

**Treatments**

1. No gypsum + No crop (The treatment received irrigations equivalent to that of the rice-wheat rotation and the plots were kept fallow)
2. No gypsum + Sesbania-barley
3. No gypsum + Kallar grass-alfalfa
4. No gypsum + Rice-wheat
5. Gypsum @ 50% GR + No crop (same as in Treatment 1)
6. Gypsum @ 50% GR + Sesbania-barley
7. Gypsum @ 50% GR + Kallar grass-alfalfa
8. Gypsum @ 50% GR + Rice-wheat

After layout of the experiment, composite soil samples were collected from 0-15 cm and 15-30 cm depths of each plot. Agricultural grade gypsum powder (passed through a 70 mesh sieve and having 90% purity) was broadcasted on the soil surface in the plots under gypsum treatments @ 50% GR of the 15 cm surface layer and mixed into a depth of about 7 cm. Sesbania was sown in rows 30 cm apart with a seed drill while Kallar grass was planted as cuttings of the plants. Seedlings of rice cv. Basmati 385 were transplanted keeping row to row and plant to plant distance of 22.5 cm.

After harvesting Sesbania, Kallar grass and rice, the plots were prepared for barley, alfalfa and wheat cultivation. Wheat and barley were sown in rows 30 cm apart with a seed drill while alfalfa was broadcasted in the standing water. The NPK were applied as urea, single superphosphate (SSP) and sulphate of potash (SOP), respectively as a basal dose according to the individual crop requirements. Half of the N and full doses of P and K were applied at the time of sowing/transplanting, while the rest of the N was applied at the time of the second irrigation. Canal water (EC = 0.22 dS $m^{-1}$; SAR = 0.43) was used for irrigation. Experimental plots were irrigated according to the water requirements of the respective crop and the fallow plots were irrigated at a depth equal to that of the rice-wheat crop rotation. Two cuttings (biomass collection) of Sesbania, Kallar grass and alfalfa were taken. The weight of the harvested material was recorded just after the harvesting. Rice, wheat and barley were harvested at maturity and harvested material was sun-dried for six days and threshed manually to obtain the grain yield.

Composite soil samples were collected from each plot for 0-15 cm and 15-30 cm depths at three stages: 1. After the layout of the experiment, i.e. the original soil, 2. After harvesting of Sesbania, Kallar grass and rice, and 3. After harvesting of barley, alfalfa and wheat. These samples were air-dried, ground, passed through a 2 mm sieve and analyzed for pHs, $EC_e$ and SAR while the original soil samples were also analyzed for gypsum requirement by Schoonover's method for the upper 15 cm depth and lime percentage (Richards, 1954).

**Table 1. Effect of reclamation treatments on ECe (dS $m^{-1}$) of the soil**

| Treatment | Before start of the experiment | | After harvest of Sesbania, Kallar grass and rice | | After harvest of barley, alfalfa and wheat | |
|---|---|---|---|---|---|---|
| | D1 | D2 | D1 | D2 | D1 | D2 |
| No gypsum + No crop | 13.0 | 10.8 | 8.5 a | 7.5 a | 5.8 a | 6.5 a |
| No gypsum + Sesbania-barley | 12.5 | 10.6 | 1.8 de | 2.1 d | 1.2 f | 1.9 c |
| No gypsum + Kallar grass-alfalfa | 11.7 | 11.3 | 1.6 de | 3.0 c | 1.7 d | 1.8 cd |
| No gypsum + Rice-wheat | 13.7 | 12.1 | 2.0 d | 2.8 c | 2.1 c | 1.7 cde |
| Gypsum + No crop | 9.2 | 8.4 | 4.3 b | 4.9 b | 3.8 b | 3.9 b |
| Gypsum + Sesbania-barley | 10.0 | 9.1 | 2.8 c | 2.1 d | 1.6 de | 1.5 de |
| Gypsum + Kallar grass-alfalfa | 10.7 | 15.2 | 1.7 de | 2.0 d | 1.5 def | 1.6 cde |
| Gypsum + Rice-wheat | 9.6 | 11.9 | 1.5 e | 2.0 d | 1.3 ef | 1.4 e |

Means with different letter(s) in the last four columns differ significantly at P = 0.05.
D1 = 0-15 cm soil depth. D2 = 15-30 cm soil depth.

## RESULTS AND DISCUSSION

**Soil Reclamation:**

**Soil $EC_e$:** Analysis of the soil samples collected at different intervals indicates a decrease in $EC_e$ in all the treatments (Table 1). After the harvest, maximum decrease in $EC_e$ was observed in the Sesbania-barley rotation where no gypsum was applied but the decrease was comparatively low where Sesbania was grown along with gypsum application. The decrease in $EC_e$ by the Sesbania might be due to the more extensive and deeper root system of the crop which provided channels for the percolating water to carry away the soluble salts. The minimum decrease in $EC_e$ was observed in the treatment where only irrigation water at a depth equal to that of the rice-wheat rotation was applied in fallow plots. In general, the decrease in $EC_e$ was similar in Sesbania, rice and Kallar grass treatments with and without gypsum application but this decrease was more when compared with the fallow plots. The decrease in $EC_e$ in the cropped treatments receiving no gypsum was even more than the treatments where gypsum was applied and the plots were kept fallow. The reduction in $EC_e$ of the cropped treatments might have been hastened by the root action that improved soil permeability (Elkins, 1985). This helped leaching of soluble salts from the root zone (Abrol *et al.*, 1988; Ahmad *et al.*, 1990). The plant species also had a mulching effect, decreasing evaporation from the soil surface, and the capillary rise of soluble salts (Sandhu and Qureshi, 1986). Some fraction of salts could have been taken up by the plants. In the control (No gypsum + No crop), a little decrease in $EC_e$ probably was due to the leaching of salts by rain and irrigation water (Ahmad *et al.*, 1990).

gypsum and displacement of the exchangeable Na and subsequent leaching by irrigation and rain water. The decrease in SAR in the cropped treatments may be associated with valence dilution (Eaton and Sokoloff, 1935), Na uptake by the plants, Ca

**Table 2. Effect of reclamation treatments on SAR $(mmol\ L^{-1})^{1/2}$ of the soil**

| Treatment | Before start of the experiment | | After harvest of Sesbania, Kallar grass and rice | | After harvest of barley, alfalfa and wheat | |
|---|---|---|---|---|---|---|
| | D1 | D2 | D1 | D2 | D1 | D2 |
| No gypsum + No crop | 39.3 | 36.4 | 25.9 a | 30.9 a | 18.5 a | 24.3 a |
| No gypsum + Sesbania-barley | 33.1 | 32.5 | 7.5 d | 13.5 c | 4.2 e | 9.7 d |
| No gypsum + Kallar grass-alfalfa | 38.3 | 36.6 | 9.0 c | 12.4 cd | 6.2 c | 7.1 e |
| No gypsum + Rice-wheat | 42.7 | 38.1 | 6.9 d | 11.7 d | 5.8 d | 12.4 c |
| Gypsum + No crop | 30.6 | 27.8 | 17.3 b | 20.1 b | 13.6 b | 15.8 b |
| Gypsum + Sesbania-barley | 36.5 | 39.1 | 3.6 e | 10.0 e | 2.6 f | 4.8 f |
| Gypsum + Kallar grass-alfalfa | 40.4 | 38.7 | 3.4 e | 7.8 f | 3.0 f | 5.0 fe |
| Gypsum + Rice-wheat | 32.0 | 35.6 | 3.7 e | 8.8 f | 2.7 f | 3.5 g |

Means with different letter(s) in the last four columns differ significantly at $P = 0.05$.
D1 = 0-15 cm soil depth. D2 = 15-30 cm soil depth.

After harvesting wheat, barley and alfalfa, $EC_e$ of the soil (0-15 cm) was little affected because maximum salts have already been leached down. However, there was a small decrease in $EC_e$ of the 15-30 cm depth.

**Soil SAR:** After the harvest of first crops, efficiency of treatments in decreasing SAR without gypsum was in the descending order of rice = Sesbania > Kallar grass > fallow (Table 2). The decrease in SAR in the cropped plots was more than the gypsum treated fallow plots. The decrease in SAR in gypsum treated soil may be attributed to the increased soil solution Ca from the added supplied in the irrigation water and by dissolution of soil lime with pH reduction under the action of plant roots and soil microbial activity (Ahmad *et al.*, 1990). All the cropped treatments performed statistically at par when grown after the gypsum application.

**Soil pHs:** There was a slight decrease or no change in pHs in all the treatments except the control where pH increase at the end of the first season (Table 3). However, in the second season, there was no change in pHs in the control, alfalfa, and rice treatments when grown without gypsum application. Little or no change in pHs for all the reclamation treatments may be associated with the strong buffering capacity of the soil that resisted an appreciable change.

**Table 3. Effect of reclamation treatments on pHs of the soil**

| Treatment | Before start of the experiment | | After harvest of Sesbania, Kallar grass and rice | | After harvest of barley, alfalfa and wheat | |
|---|---|---|---|---|---|---|
| | D1 | D2 | D1 | D2 | D1 | D2 |
| No gypsum + No crop | 8.1 | 8.3 | 8.5 | 8.9 a | 8.5 a | 8.7 a |
| No gypsum + Sesbania-barley | 8.2 | 8.2 | 8.2 | 8.6 ab | 8.3 abc | 8.7 a |
| No gypsum + Kallar grass-alfalfa | 8.2 | 8.2 | 8.2 | 8.6 ab | 8.2 bcd | 8.6 ab |
| No gypsum + Rice-wheat | 8.2 | 8.2 | 8.3 | 8.3 bc | 8.4 ab | 8.7 a |
| Gypsum + No crop | 8.1 | 8.1 | 8.1 | 8.6 ab | 8.3 abc | 8.4 abc |
| Gypsum + Sesbania-barley | 8.2 | 8.3 | 8.0 | 8.3 bc | 8.2 bcd | 8.3 bc |
| Gypsum + Kallar grass-alfalfa | 8.2 | 8.2 | 8.0 | 8.1 c | 8.0 d | 8.3 bc |
| Gypsum + Rice-wheat | 8.2 | 8.1 | 8.1 | 8.0 c | 8.1 cd | 8.2 c |

Means with different letter(s) in the last columns differ significantly at $P = 0.05$.
D1 = 0-15 cm soil depth. D2 = 15-30 cm soil depth.

**Table 4. Performance of crops during reclamation of the soil**

| Crop | No gypsum | Gypsum |
|---|---|---|
| **Paddy/grain yields (t ha$^{-1}$)** | | |
| Rice | 1.77 | 2.53 |
| Wheat | 2.87 | 3.15 |
| Barley | 2.02 | 2.34 |
| **Straw yields (t ha$^{-1}$)** | | |
| Rice | 8.67 | 9.43 |
| Wheat | 6.02 | 6.76 |
| Barley | 5.02 | 5.63 |
| **Total biomass (t ha$^{-1}$)** | | |
| Sesbania | 45.9 | 49.4 |
| Kallar grass | 14.5 a | 7.2 b |
| Alfalfa | 17.4 | 20.8 |

Means with different letters in a row differ significantly at $P = 0.05$.

**Growth response of the plant species:** Biomass production of all the plant species was more in the gypsum treated plots except Kallar grass (Table 4). Increased biomass production with gypsum application may be due to the role of Ca to reduce the toxic effects of Na. However, the differences between the gypsum and non-gypsum treatments for crop yields were statistically non-significant. The growth of Kallar grass was reduced with gypsum application. This reduction in growth with gypsum application might be due to the reason that Kallar grass performs better in moderately saline-sodic soils rather than the normal soils because of its morphological adaptation to compensate the adverse effects of Na by excluding its excess quantity through the leaf salt gland.

## CONCLUSIONS

The results of the study indicate that calcareous, moderately saline-sodic and medium textured soils (like the one of this experiment) may be reclaimed effectively by starting the reclamation programme with crops like Sesbania (salt-tolerant), rice (high delta and sodium-tolerant) and Kallar grass (salt-tolerant + high delta), even without the prior application of gypsum to the soils. These crops can also produce substantial amount of biomass under the given soil conditions.

## ACKNOWLEDGEMENTS

The research was conducted under the Irrigation Systems Management/Research Project (Biotic and Chemical Reclamation of Sodic Soils) and was funded by the US-AID through PARC, Islamabad.

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