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Gypsum Application in Slots for Reclamation of Saline-Sodic Soils

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ABSTRACT

Traditionally, gypsum is applied to the soil surface to reclaim saline-sodic soils. The lower soil profile is left untreated. Therefore, the salts do not leach much to deeper depths, particularly in heavy textured soils. To address this issue, a field study in which gypsum was applied in slots for the reclamation of abandoned saline-sodic soils was conducted. The excavated soil was mixed with gypsum and slots were refilled. The field trials were conducted with maize-wheat-cotton-wheat crop rotation. Three treatments included were: T_1) Application of gypsum by broadcast method, T_2) Control (no gypsum application), and T_3) Application of gypsum in slots. The results showed that maximum increase in soil permeability by 220% occurred in slotted area; whereas, the infiltration rate increased by 152% with gypsum application by broadcast method. The electrical conductivity of soil (EC_e) decreased by 49 and 15% at 0-30 and 30-60 cm depths, respectively with gypsum applied by broadcasting. On the other hand, application of gypsum in slots reduced EC_e of slotted area by 51% at 0-30 and 25% at 30-60 cm depths. In case of slotting method, less salts were accumulated at 60-90 cm depth than that of broadcast method. Similarly, gypsum application by broadcast method reduced sodium adsorption ratio (SAR) of soil by 59% at 0-30 cm depth and 8% at 30-60 cm depth. At lower depth of 60-90 cm, SAR was increased by 24%. But gypsum application in slots decreased SAR by 72 and 46% at 0-30 and 30-60 cm depths, respectively. But SAR increased only by 11% at 60-90 cm depth. The gypsum application in slots also decreased the salinity and sodicity in inter slot area. Maximum crop yields were recorded from slotted area.

Key Words: Gypsum; Slots; Saline-sodic soils; Maize; Wheat; Cotton

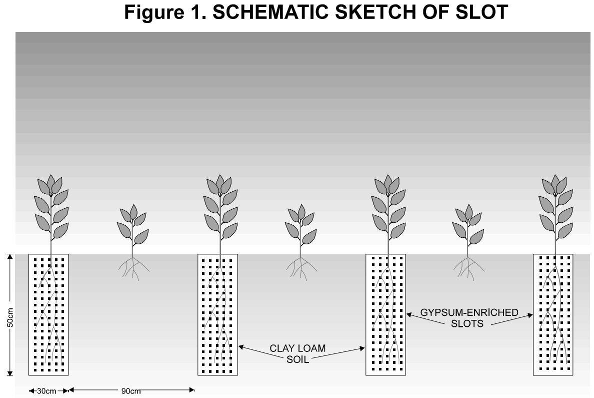
INTRODUCTION

The principal threats to the sustainability of irrigated agriculture in Pakistan are waterlogging and salinity. The salinity problem within the irrigated areas was assessed to be 4.21 Mha, which included 2.35 Mha of moderately to strongly saline areas (WAPDA, 1980). The reclamation of these soils needs ample quantity of fresh water that is already short in the country. Moreover, the clayey texture of salt-affected soils, particularly sodic soils also makes the reclamation of such soils very difficult due to low permeability. The chemical amendments like gypsum, sulfur, sulfuric acid etc. are recommended and applied to reclaim these soils. Traditionally, these amendments are applied to upper 0-30 cm soil depth irrespective of the type of soil texture below this depth. In this way, only the lower profile is not improved much in heavy textured soil. The salts do not leach to deeper depths. These salts again move upward quickly due to evaporation during dry period and increase salt contents in root zone. United States Department of Agriculture (USDA, 1958) emphasized sub-soiling or deep ploughing along with application of amendments to improve the structure of saline sodic and sodic soils. The application of amendments before leaching improved permeability and was found better than the leaching before the application of amendment (USDA, 1958; Loveday *et al*., 1970). The reclaiming efficiency of all amendments decreases with increasing soil depth and improvement is less in deeper layers (Sharma *et al*., 1981; Hussain *et al*., 1987; Chaudhary & Qureshi, 1990; Ramzan & Liaquat, 1991). In slotting technique, soil amendment is applied in slots instead of broadcast in soil. Slots are prepared by disturbing the soil to desired depth in narrow, parallel vertical bands, leaving inter slot area undisturbed. The slots are refilled with the excavated soil mixed with calculated quantity of amendment. Jayawardane and Blackwell (1985) studied that low yield of flood irrigated row crops on transitional red-brown earth was attributed to low infiltration rate and poor aeration. Owing to faster flow through the slots during irrigation, the slotted plots showed deeper wetting than the no gypsum and surface treated gypsum. Consequently, the surface soil layers between the slots were subjected to less wetting and better aeration than in the other plots. Infiltration rates showed two fold increase with addition of surface gypsum and a further two to three fold increase through the gypsum treated slots. In a similar experiment, Jayawardane and Blackwell (1986) evaluated the effects of gypsum slotting on infiltration rates and moisture storage in a swelling clay soil. The gypsum slotting increased the effectiveness of gypsum. The moisture flow was more and rapid in gypsum slotted soil than in other treatments. Slotting was effective and showed marked improvement in crop production. The infiltration rate was enhanced in the shallower and deeper soil profile. Slotting also decreased run off and hence, reduced erosion on slopping beds (Jayawardene *et al*., 1994). This study was undertaken with the specific objectives to evaluate the effectiveness of slotting technique for the reclamation of saline sodic soils and to suggest recommendations for the applicability of slotting technique.

MATERIALS AND METHODS

The study was conducted on 0.4 ha saline-sodic, silty clay loam field. The site was located about 9 km towards west of Mona Reclamation Experimental Project (MREP) office. The soil type, accessibility, availability of irrigation water and willingness of farmers were the main factors considered in the selection of sites. The field was divided in three equal plots providing one plot to each treatment. The dimension of each plot was 33 x 20 m. The following three treatments were tested in one replication with wheat-cotton crop rotation: T1= Application of gypsum by broadcast method; T2= Control (no gypsum application), and T3= Application of gypsum by slotting method. Fourteen slots were prepared in the plot allocated to treatment No. 3. These slots were dug manually. The schematic sketch of a slot is shown in Fig. 1. Each slot was

Figure 1. SCHEMATIC SKETCH OF SLOT



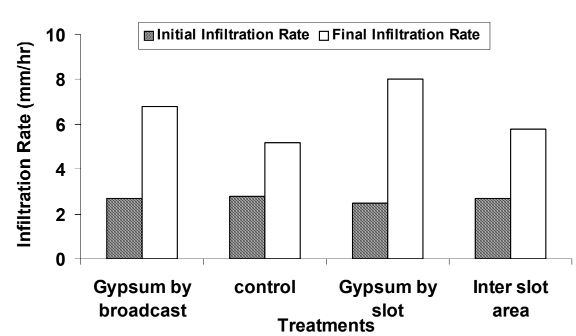
30 cm wide, 50 cm deep and 33 m long. The interslot area was 90 cm. The calculated quantity of gypsum for each site was mixed with soil. Then the slots were properly refilled with the gypsum mixed soil. The gypsum calculated on the basis of 100% gypsum requirement was applied in the field. The gypsum requirement was 1.7 ton per acre foot. About 270 kg of gypsum was broadcast in the T_1 plot.1 On the basis of gypsum requirement, the gypsum applied to each slot was 7 kg. This gypsum was mixed with the soil taken out of each slot. These slots were refilled with the gypsum mixed soils. After refilling, the slots area was properly leveled. After one year of the study, inter slot area was prepared for crop sowing manually and no amendment was applied in this area.

The soil infiltration rate of each plot was measured at the start of the experiment and later after harvesting wheat crop by Standard Ring Method (Aronovici, 1955). The readings were taken after 3 h and means of these readings were used to evaluate the infiltration rate of soil. Soil samples were collected from 0-30, 30-60 and 60-90 cm depths to determine the soil texture (Bouyoucas, 1951), bench mark electrical conductivity of saturated extract (EC_e) and sodium adsorption ratio (SAR) of experimental plots (U.S. Salinity Laboratory Staff, 1954). The subsequent samplings were taken after the harvesting of each crop to evaluate changes in these parameters. The samples were analyzed in the soil and water testing laboratory of Mona project. Appropriate seedbeds were prepared by ploughing and planking in plots of T_1 and T_2; whereas, the slot and inter slot area in plot of T_3 was prepared manually for crop sowing. The first crop of maize 1998 could not survive because this was the first crop in the abandoned field. The second crop of wheat 1998-99 established well and matured. After harvesting wheat, slot and inter slot areas were mixed with tractor cultivation. Then cotton, instead of maize, was cultivated in kharif season. The cotton crop germinated well and also matured successfully. Maize 1998 received 15 cm, wheat 1998-99 received 17, cotton 1999 received 11 and wheat 1999-2000 received 22 cm canal water irrigation. About 10, 12, 27 and 30 cm rain occurred during these crop seasons. The water table depth fluctuated from 1.5 to 2.8 m during the study. The average quality of groundwater was as TDS 850 ppm, SAR 14.5 and RSC 2.5. Per hectare crop yields were estimated on whole plot basis.

RESULTS AND DISCUSSION

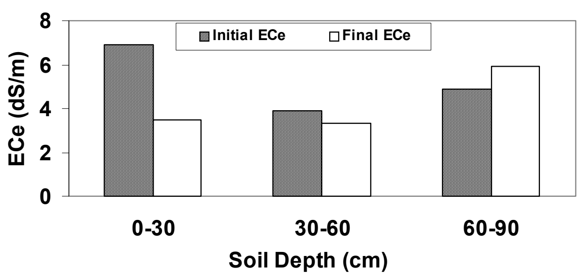
Changes in infiltration rate of soil. The pre-project infiltration rate of experimental plots ranged from 2.5 to 2.8 mm hr^{-1}. All the treatments significantly enhanced the permeability of soil at the end of the study (Fig. 2). The gypsum application by slotting method showed maximum increase by 220% (8.0 mm hr^{-1}) in infiltration rate. It was followed by 152% (6.8 mm hr^{-1}) increase with gypsum application by broadcast method. In inter slot areas, infiltration rate was increased by 115% (5.8 mm hr^{-1}). The increase in infiltration rate in the control plot was 86% (5.2 mm hr^{-1}). The infiltration rate in inter slot area without applying any amendment was increased because of the effects of gypsum in slot on adjoining areas, effect of roots etc. and management practices on slot as well as inter slot areas.

Fig. 2. Changes in soil infiltration rate with different treatments



Changes in electrical conductivity of soil. The soil salinity in terms of electrical conductivity of saturated extract (EC_e) indicated reduction with all the treatments at upper most depth of 0-30 cm. At second depths of 30-60 cm, except control, EC_e was also reduced with gypsum application by both the methods as well as in inter slot area. But at the lower most depth of 60-90 cm, none of the treatment showed reduction in EC_e It indicated the accumulation of salts in the lower root zone. However, the rate of reduction as well as increase varied with the treatments. Gypsum application by broadcasting method reduced EC_e by 49% at 0-30 cm depth and by 15% at 30-60 cm depth. There was 20% increase in EC_e at 60-90 cm depth (Fig. 3). The results indicated that although EC_e increased at 60-90 cm depth, but the change was quite less as compared with the changes at 0-30 and 30-60 cm depths. It showed that some salts were leached beyond 90 cm depth.

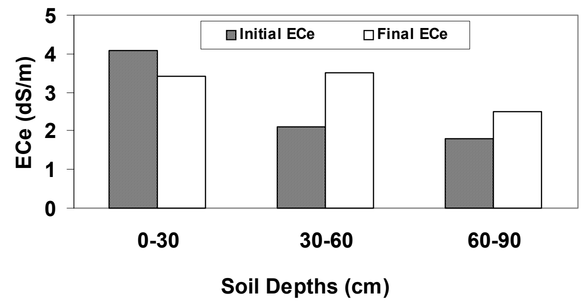
Fig. 3. Changes in soil ECe with gypsum application by broadcast method



The changes in EC_e in control plot (no gypsum application) indicated a reduction of only 17% at 0-30 cm depth; whereas, EC_e increased by 66% at 30-60 cm depth and by 39% at 60-90 cm depth (Fig. 4). The reduction at upper most depth was due to the irrigation and other management practices carried out for different crops. The application of gypsum in slots significantly reduced salinity at 0-30 and 30-60 cm depths (Fig. 5). This reduction was higher than the reduction recorded in gypsum application by broadcast method. At 0-30 cm depth, the EC_e reduced by 51%; whereas, 25% reduction was recorded at 30-60 cm depth. A slight increase of 14% was observed at 60-90 cm depth.

Comparing the changes in EC_e by gypsum application with broadcast method and gypsum application by slotting method, there were slight differences in the quantity of salt reduction at upper two depths and salt accumulation at lowest depth. In case of gypsum application by broadcast method, 64% EC_e was reduced at 0-60 cm depth and 20% EC_e was increased at 60-90 cm depth. On the other hand, gypsum application with slotting technique decreased EC_e by 76% at 0-60 cm depth and 14% EC_e was enhanced at 60-90 cm depth. This showed that more salts were leached below 90 cm depth with slotting technique as compared with broadcast technique. In inter slot area, 26% reduction in soil EC_e was recorded at 0-30 cm depth (Fig. 6). At second depth of 30-60 cm, 14% decrease was found whereas EC_e was enhanced by 47% at 60-90 cm depth.

Fig. 4. Changes in soil ECe with control



The gypsum by broadcast method was mixed in the upper 30 cm soil layer; whereas, the gypsum application by slotting technique was mixed in 50 cm soil layer in the slots. Therefore, it seemed imperative to evaluate the impact of different treatments on both salinity and sodicity of whole tested soil profile of 0-90 cm soil depth. The overall change in EC_e from 0-90 cm soil profile with different treatments was evaluated by taking the average EC_e of all depths at the start and end of the study (Fig. 7). The maximum reduction of 32% in EC_e of whole soil profile of 0-90 cm depth was recorded where gypsum was applied in slots. On the other hand, gypsum application by broadcast method decreased the EC_e of soil profile by 17%. About 11% reduction in EC_e in inter slot area occurred which was very close to broadcast method. About 15% increase in EC_e was observed in case of control, mostly due to the increase in EC_e at lower depths.

Changes in sodium adsorption ratio of soil. Gypsum application by broadcast method reduced SAR by 59% at 0-30 cm depth and by 8% at 30-60 cm depth (Fig. 8). At lower depth of 60-90 cm, SAR was enhanced by 24%. It showed that with broadcasting method, considerable quantity of sodium was deposited at 60-90 cm depth. The SAR in control plot reduced by 9% at 0-30 cm depth (Fig. 9). The SAR enhanced by 78% at 30-60 cm and by 40% at 60-90 cm depth. This showed that simple periodic irrigation along with other cultural operations was helpful in improving the sodicity of soil. There is a need to apply a suitable amendment for the reclamation of abandoned sodic soils.

In the slotted area, SAR was reduced by 72% at 0-30 cm depth (Fig. 10). The reduction in SAR at 30-60 cm was 46%. A slight increase of 11% was recorded at 60-90 cm depth. The results showed that although SAR slightly enhanced at 60-90 cm depth, but it was considerably lower than the level of SAR reduced at 0-60 cm depth. It indicated that a lot of sodium salts leached beyond the 90 cm soil depth. Moreover, at 60-90 cm depth, there was 24% increase in SAR with broadcast method showing 13 % more increase than in the slotting method at the this depth. This also revealed that the leaching of sodium salts to deeper depths with slotting method was achieved more than the broadcast method. The results showed that application of

Fig. 5. Changes in soil ECe in inter slot area

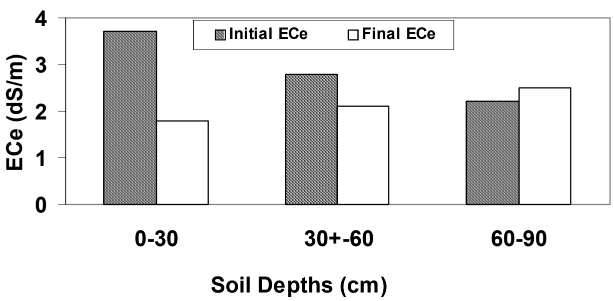


Fig. 6. Changes in ECe of 0-90 cm soil profile

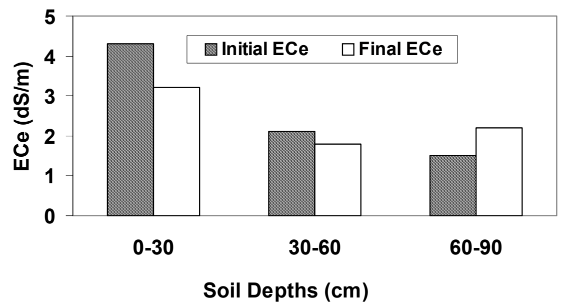


Fig. 7. Changes in soil SAR with gypsum application by broadcast method

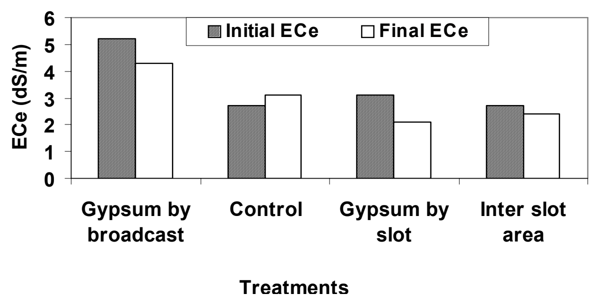


Fig. 8. Changes in soil SAR with control

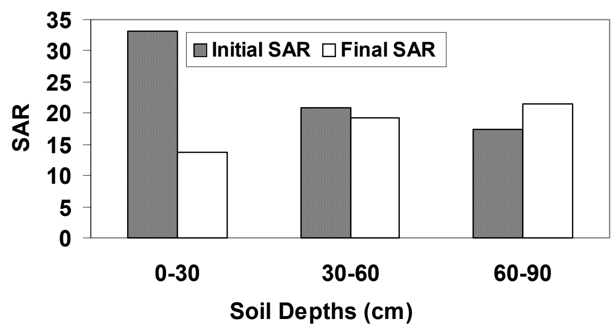


Fig. 9. Changes in soil SAR by gypsum application with slotting method

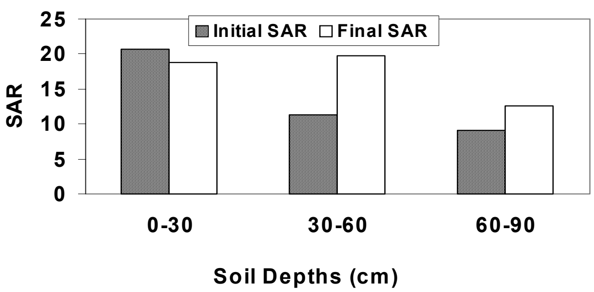


Fig. 10. Changes in soil SAR in inter slot area

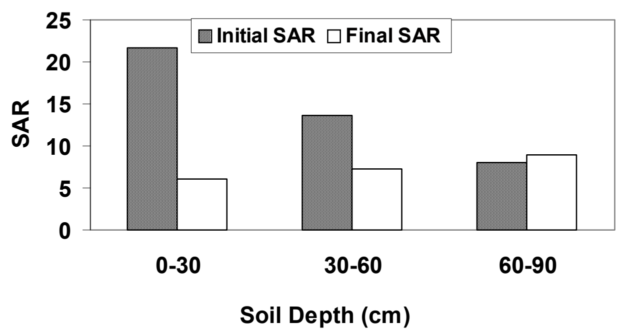


Fig. 11. Changes in SAR of 0-90 cm soil profile

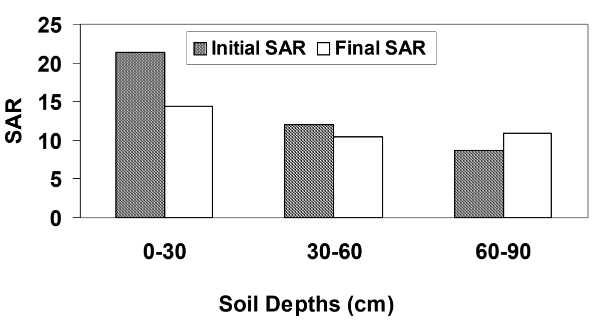
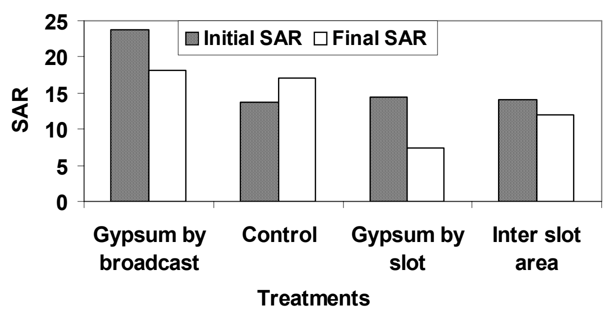


Fig. 12. Changes in SAR of 0-90 cm soil profile



gypsum to lower soil depth by slotting technique was useful in reducing the sodicity in upper as well as the lower soil profile of heavy texture. The reduction in SAR in inter slot area was not as much as in slotted area, but the trend was almost similar (Fig. 11). About 32 and 14% reduction in SAR was achieved at 0-30 and 30-60 cm depths, respectively. It indicated that the reduction was 6% higher than the 8% reduction recorded with broadcast method. At 60-90 cm depth, SAR was increased by 25%, which was almost close to the increase with broadcast method at this depth. It revealed that reclamation occurred in inter slot area without applying gypsum. Gypsum application by slotting technique decreased SAR by 47%; whereas, gypsum application by broadcast method reduced SAR by 24% (Fig. 12). The reduction in SAR in inter slot area was 16%. In case of control, 25% increase was recorded in 0-90 cm soil profile. It was concluded that with slotting technique, gypsum use was very effective in reducing the sodicity of soil profile.

Crop yields with different treatments. The experimental field was abandoned and had not been cultivated since long. The field had high salt constraints for the initial crops. The first experimental crop of maize of 1998 although germinated well, but could not survive mainly due to its sensitivity to salinity and sodicity. But next crop of wheat 1998-99 survived and gave production. The yield of wheat recorded from the slotted area was 4233 kg ha^{-1} and from broadcast method was 1106 Kg ha^{-1} (Table I). The yield from control and inter slot areas was 638 and 437 kg ha^{-1}. Cotton was cultivated instead of maize in kharif 1999. Maximum cotton yield of 863 kg ha^{-1} was recorded from slotting technique. The wheat yield achieved from slotting method was almost four times the yield with broadcast method. This indicated the effectiveness of both methods on crop production. The yield of second wheat crop was also higher in inter slot area than the yield from the control. This showed an improvement in inter slot area both in soil reclamation and crop production.

Table I. Effect of treatments on crop yields (kg ha^{-1})

Treatment	Wheat 1998-99	Cotton 1999	Wheat 1999-2000
Gypsum application by broadcast method	1106	439	1293
Control	638	229	719
Gypsum application by slotting method	4233	863	4625
Inter slot area	437	-	813

CONCLUSIONS

1. The application of gypsum by slotting technique reduced EC_e and SAR of slotted area more than application of gypsum by broadcast method; 2. In the case of slotting method, less salts were accumulated at 60-90 cm depth than the salt accumulated with broadcast method. In resalinization process the reduced quantity of salts at 60-90 cm depth would take more time and also the extent of salinity build-up would be less than those cases where salinity is higher at 60-90 cm depth. The gypsum application in slots also decreased soil salinity and sodicity in inter slot area indicating the reclamation effects of gypsum on adjoining; and 3. The maximum reduction in EC_e and SAR in the whole soil profile was recorded with slotting technique followed by broadcast method. The reduction in these parameters also took place in soil profile of slot area. The control treatment enhanced the salinity and sodicity in soil profile. Higher crop yields were recorded from slot area than any other treatment. More increase in wheat yield in the second season with slotting method indicated the effectiveness of the method on crop yield.

RECOMMENDATIONS

Application of gypsum in slots is more effective and economical in reclaiming the deeper depths of soil profile. Manually digging of slots is laborious, time consuming and expensive. Therefore, a suitable implement should be designed for slot digging and cultivation of slots. Slotting technique is the most beneficial for fine textured saline sodic soils.

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