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Effects of Tillage Implements in Combination with Gypsum Applications on the Reclamation of Saline-Sodic Soils

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ABSTRACT

This study was conducted to investigate the effects of tillage implements in combination with gypsum applications on the reclamation of saline-sodic soils. The reclamation rate was greater with 75 than 50% gypsum applications. Subsoiler was found to be the most effective tillage implement for accelerating the reclamation process.

Key Words: Gypsum; Tillage; Saline-sodic soils

INTRODUCTION

The total salt-affected area in the Indus plain is about 5.8 million hectare (m ha), out of which about 2.93 m ha is under cultivation. Out of the cultivated salt-affected soils, about 0.6 m ha has saline-sodic patches (Rafique, 1990). Saline-sodic soil restricts the hydraulic properties due to dispersion, translocation and deposition of clay platelets in the conducting pores as the dominant mechanism. Maximum improvement in hydraulic conductivity is only possible with simulated subsoiling and gypsum-saturated solution (Shahid, 1993). Sodium dominated soils have problems of poor aeration and low hydraulic conductivity, both of which are responsible for oxygen stress to plants and problems of leaching of salts during reclamation. Moreover, dense or hard layers may develop in the subsoil portion of saline-sodic soils due to clay illuviation and/or accumulation of lime in the sub-soil (Hassan *et al*., 1990). Sodic soils have low infiltration rates because they contain little soluble calcium. The use of gypsum on saline-sodic and sodic soils improves the infiltration rate and helps in leaching the salts into the lower layers (Qureshi & Barrett-Lennard, 1998). Gypsum is easily available and is the cheapest source of soluble calcium in Pakistan.

Cultivation increases the mulchability and infiltration rate and helps in leaching the salts and reclaiming the saline soils. Pratharpar and Qureshi (1999) evaluated the effect of pre-monsoon surface cultivation for the reclamation of saline soils by using a numerical model SWAP-93. It was found that with a water table at one meter or below, abandoned saline soils could be reclaimed by pre-monsoon surface cultivation within few years. However, deep ploughing and chiselling alone are not helpful to reclaim saline-sodic soils because the soil slumps again on wetting and becomes hard after drying (Qureshi & Barrett-Lennard, 1998). Therefore, gypsum applications in combination with the proper tillage implement is pre-requisite for the reclamation of saline-sodic soils.

This paper reports the results of experiments conducted to investigate the nature and depth of hard layer in order to select the proper tillage implement and suitable chemical amendments for the reclamation of saline-sodic soils.

MATERIALS AND METHODS

Tillage implements employed in this study for breaking the hard pan were sub-soiler, chisel plough, disk plough and narrow-tine cultivator. The experimental field was divided into two blocks A and B, each having 12 plots. In block A, gypsum @ 75% of the gypsum requirement and in block B, gypsum @ 50% of the gypsum requirement were applied. Four tillage treatments were replicated thrice in a RCBD and data on the following parameters were taken: (i) soil penetration resistance, (ii) bulk density, (iii) infiltration rate, (iv) chemical properties before and after the treatments and (v) emergence of wheat.

The soil penetration resistance was measured with a cone penetrometer along the soil profile and the bulk density was measured with a tube sampler up to a depth of 60 cm with 15 cm increment. Infiltration rate was measured with a double ring infiltrometer. Soil samples were collected up to the depth of 150 cm with 15 cm increments, before and after the treatments, and were analyzed for ECe, pH, ESP and SAR.

After the tillage treatments and application of the amendments, experimental field was flooded. At field capacity, wheat was sown and the emergence was counted on 7, 14, and 21 days after the 1st irrigation. The data presented are the average of the two plots A and B except for infiltration rate and wheat emergence.

RESULTS AND DISCUSSION

Soil penetration resistance. The soil penetration resistance is an important soil physical property that greatly affects the germination, emergence and growth of crop seedlings. The penetration resistance of the soil ploughed with subsoiler was the least as compared to the other implements used (Fig. 1). This is due to the more porosity of the soil. The soils ploughed with chisel and disk plough show almost the same resistance. However, the soil ploughed with cultivator reflects high penetration resistance and shows about 5% more resistance than the resistance offered by the soil ploughed with subsoiler.

Bulk density. Bulk density is an important soil physical property and is a function of soil texture, structure, porosity and organic matter content. Bulk density as a function of depth for the plots ploughed with different implements is shown in Fig. 2. Bulk density (BD) at 15 cm depth was almost the same for all the tillage implements. Similar to the penetration resistance, BD increases with depth and sub-soiled plot shows the smallest BD as compared to the other implements. The reason for small BD was the ability of the subsoiler to penetrate to a relatively greater depth.

Infiltration rate. Infiltration rate is the rate of water movement from the soil surface into the soil and is influenced by the soil properties and the moisture gradient. Table I shows the effect of different tillage implements on the infiltration rate of the soil. The average infiltration rate (AIR) was the highest in plots, ploughed with subsoiler and chisel plough, most probably due to the more permeability of the soil. The plots ploughed with disk plough and the cultivator has about 9 and 15% less infiltration rate than the subsoiler and the chisel plough. Similarly, the subsoiler and chisel ploughed plots have higher moisture content than the disk plough and cultivator plots. The higher infiltration rate of sub-soiled and chisel ploughed plots than the disk plough and cultivator ploughed plots is due to the fact that they shatter and penetrate deep into the soil thereby making the soil more porous.

Chemical properties. An improvement in soil physical properties alongwith the application of chemical amendments helps to leach the salts. Figs. 3 to 6 show the salinity profiles as a function of depth. It is obvious from these figures that reclamation took place at quite accelerated rate i.e. ECe decreased from 29.60 to 4.75 dS m^{-1} (85%), pH 8.1 to 7.43 (8.27%), ESP 115 to 18 (84.34%), and SAR 92.21 to 13.92 (84.90%). The trend of ECe, pH, ESP and SAR was almost reversed after the treatments. Since the soil has been kept abandoned for a long time, the movement of water from the water table and its subsequent evaporation at the soil surface led to an increase in salinity level at the soil surface. When the soil was ploughed and chemical amendments were applied, leaching of salts took place and the salts moved down to the lower depths thus decreasing the salts at the soil surface. These figures also suggest that a combination of physical methods and chemical amendments could help to reclaim the saline-sodic soils rapidly. Armstrong *et al.* (1996) also studied the seasonal movement of salts in saline-sodic grassland and arable clay soils in England. They found that during the winter rains, the water moving through the macro pores uniformly leached the salt from the soil profile to a depth of 1.2 m. However, in the late summer the salt content of the grassland and arable soils had increased again by 11 and 35%, respectively compared with their early spring salinity levels. This suggests that the soil reclamation is a continuous process and should be operated as a system for effective salinity management.

Table I. Effect of tillage implements on the infiltr–ation rate of soil

Treatments	AIR ($mm\ hr^{-1}$) Block A	Moisture content (%)	AIR ($mm\ hr^{-1}$) Block B	Moisture content (%)
Subsoiler	20.57	19.12	18.50	18.35
Chisel plough	20.39	18.81	13.80	15.74
Disk plough	18.57	14.58	11.73	15.60
Cultivator	17.36	14.00	10.75	13.87

AIR= Average infiltration rate

Table II. The effect of tillage implements on the germination of wheat

Treatment	GC per m^2 after 7 days		GC per m^2 after 14 days		GC per m^2 after 21 days	
	A	B	A	B	A	B
Subsoiler	21	15	43	23	49	25
Chisel plough	17	13	31	19	38	19
Disk plough	15	8	28	14	27	13
Cultivator	7	6	17	8	19	9

GC= Germination count; A and B are the blocks

Emergence. Table II shows the effect of tillage implements on the germination of wheat. In sub-soiled plot of block A, the germination was significantly higher than chisel ploughed, disk ploughed and cultivated plots, respectively. Similar type of results were observed in block B with poor emergence than block A. Higher germination in sub-soiled plots is due to the reason that, subsoiler shattered the soil well which increases the permeability of the soil greater as compared to the other treatments i.e. more leaching of salts took place in sub-soiled plots than that of other treatments. The reclamation effect is greater in block A than B. Variation in emergence in block A and B may be due to the difference

Fig. 1. Effect of tillage implements on the penetr–ation resistance of soil

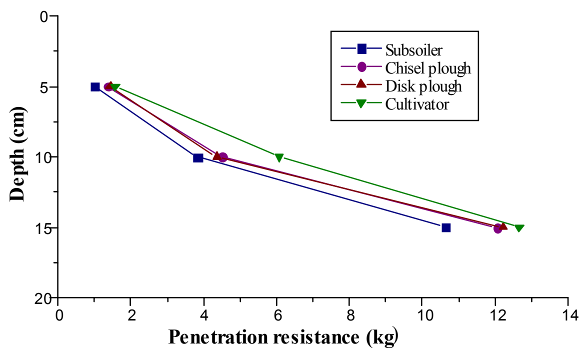


Fig. 2. Effect of tillage implements on the bulk density of soil

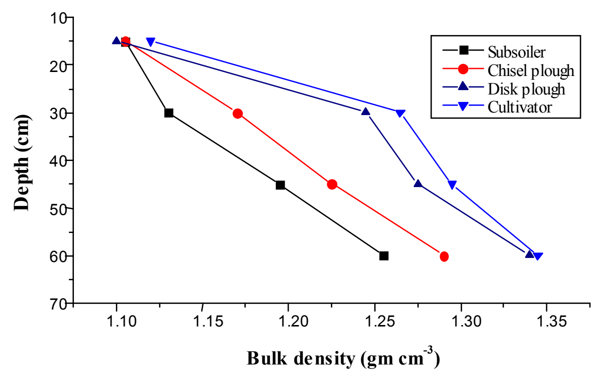


Fig. 3. Electrical conductivity of soil before and after treatments

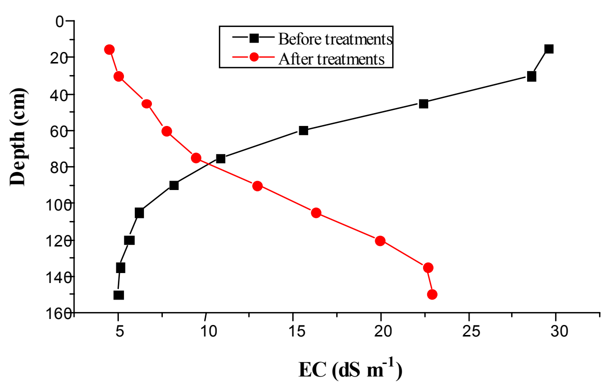


Fig. 4. pH of soil before and after treatments

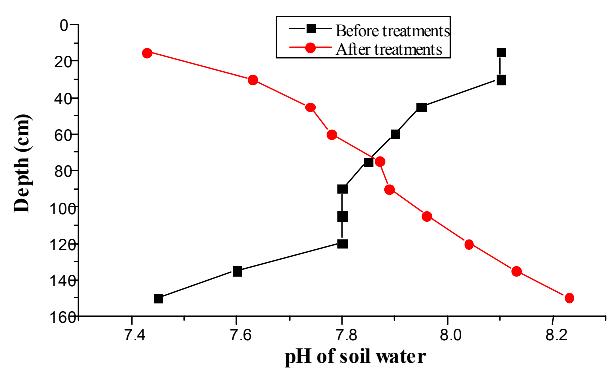


Fig. 5. ESP of soil before and after treatments

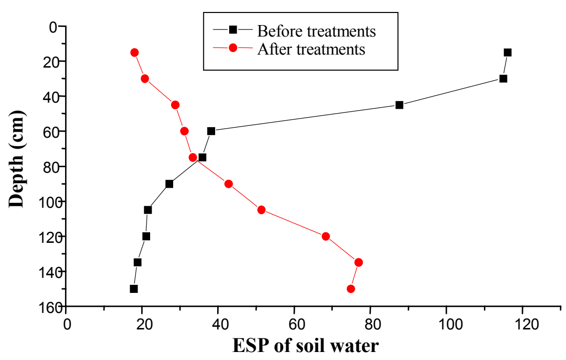
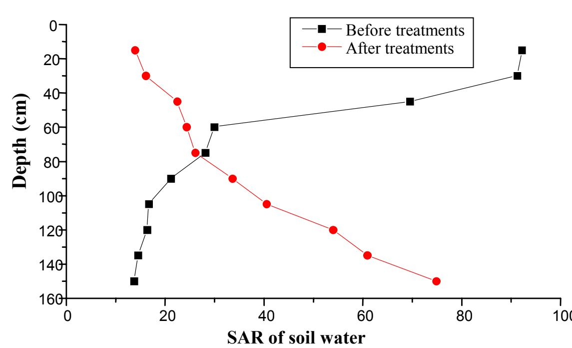


Fig. 6. SAR of soil before and after treatments



in the application of gypsum in both blocks.

Over all germination was poor because of salinity and sodicity of soil and abundance of soil for a long period. Another possible reason for poor germination may be the less applications of amendments than the 100% requirement.

CONCLUSIONS

The existence of hard layer at certain depth resists the reclamation of saline-sodic soils. Physical or chemical methods alone are insufficient for the reclamation of such soils. However, a combination of physical and chemical methods could accelerate the reclamation process. Subsoiler is the most effective tillage implement since it breaks hard pan effectively, increases the porosity of soil and causes more salt leaching. Wheat emergence was maximum in sub-soiled plots followed by chisel plough, disk plough and cultivator. The reclamation rate was greater in plots having 75% gypsum applications than that of 50%.

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