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RECLAMATION OF SALINE-SODIC SOILS UNDER RICE-WHEAT CROP ROTATION

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Abstract

A field experiment on a saline-sodic soil with pH 8.21-8.42, ECe 6.40-7.90 dSm^{-1} and SAR 17.79-23.46$mmol^{-1}$was carried out using five soil reclaiming treatments viz., leaching (Control), Farm yard manure (FYM) @ 10 tons ha^{-1}, Rice Husk (RH) @ 10 tons ha^{-1}, FYM+RH @ 5+5 tons ha^{-1} and Gypsum @ 100% soil requirement in a complete randomized block design with four replications. Rice variety SARSHAR and wheat variety TD-1 were sown in rotation. The effects of amendments were analyzed on soil physical and chemical properties as well as crop growth and yield. The results showed that all treatments including control significantly lowered the soil pH, ECe and SAR levels after rice harvest. After wheat harvest, however, the slight increase in pH and ECe were observed while, the SAR levels decreased further. Despite this increase, the pH and ECe remained significantly lowered than original levels. The treatment order of SAR decrease was T5>T4>T2>T3>T1. Although the inter treatment differences were significant but the plant height, grains $panicle^{-1}$ and 1000 grain weight were found the highest in T2 followed by T4. The highest grain yield kg ha^{-1} of wheat was observed in T4 followed by T1.

Introduction

Most of the irrigated agricultural land of Pakistan is under semi-arid to arid climate with very low annual precipitation. Due to this salt leaching in such soils is insufficient resulting in high salt accumulation on surface of soils. Nearly $8.331x10^6$ hectares fertile agriculture land of the country is saline and saline-sodic (Azhar & Tariq, 2003). Although, salt-affected soils contain sufficient moisture for plant growth, but it generally remains physiologically dry. From germination to maturity, all plant growth stages are adversely affected by salinity.

The saline-sodic soils with high sodium content are compact and generally form a hardpan on the soil surface (Rehman *et al*., 2002). This compactness prevents plant root proliferation and reduces salt leaching. Thus the reclamation of such soils with simple leaching by flooding remains ineffective. The application of gypsum enhances leaching by improving soil hydraulic conductivity (Ghafoor *et al.*, 1990). The gypsum application with or without organic manures for reclamation of different sodic and saline-sodic soils has proved profitable (Ghafoor *et al.*, 2001). Beside gypsum, the chemical amendments followed by leaching with canal water can reclaim saline-sodic soils (Biggar, 1996). The chemical amendments, being costly can be replaced successfully by organic manuring which has been found effective in increasing the crop yield and good physical health of soil (Ibrahim *et al*., 2000). This research study was conducted to assess the effect of various reclamation techniques for improving soil health and crop productivity on saline sodic soils.

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Materials and Methods

A field experiment was conducted on a silt-loam soil with saline-sodic properties during two successive crop seasons of 2004-2005 in a rice-wheat cropping system (Table 1). The five treatments were applied in a complete randomized block design with four replications. The treatments were as under:

T1 = Leaching with canal water
T2 = FYM (composted farmyard manure) @ 10 t ha^{-1}
T3 = RH (composted rice husk) @ 10 t ha^{-1}
T4 = FYM + RH (composted) @ 5 t ha^{-1} each
T5 = Gypsum @ 100 % of soil requirement.

FYM and RH were dumped separately and in combination in a 6 meter deep ditch for 45 days and were covered by thin plastic sheet in order to provide anaerobic conditions for decomposition. The compost manures and gypsum were mixed thoroughly in soils of their respective treatments before 20 days of rice transplantation. Treatments were irrigated twice during this period to facilitate the initial leaching of soluble salts. Rice variety SARSHAR was sown followed by wheat variety TD1 in rice-wheat crop rotation. Regarding fertilization, N at 120 Kg ha^{-1}, P at 50 K gha^{-1} and Zn 10 K gha^{-1} were applied to rice while only N at 140 K gha^{-1} and P 50 K gha^{-1} were applied to wheat.
The soil samples taken from a depth of 0–15 cm after each crop harvest from each treatment were analyzed for pH, ECe and SAR according to the methods given by Richard (1954). The data for plant height, grains per spike, 1000 grain weight and grain yield per hectare in kg was recorded and compared. The data were statistically analyzed for variance and individual mean differences by using LSD test at 5% probability level (Little & Hills, 1978).

Results and Discussion

Growth and yield of rice: In the present study leaching was considered as control because this practice is conventionally used for reclamation. In the rice crop the maximum plant height was found in FYM treatment (112.42 cm) followed by FYM+RH (111.17 cm) however, differences were non-significant. These treatments gave an increase of 12% and 10.8% respectively in plant height when compared with control. The lowest plant height (100.29 cm) was in control (leaching) which was statistically equal to (100.75 cm) gypsum treatment. Similarly, the number of grains $panicle^{-1}$ and 1000 grain weight were found higher in FYM treatment followed by RH+FYM (Table 2). FYM alone and in combination with RH produced significantly positive results to improve crop growth, but was not effective in increasing crop yield.

Grain yield on the other hand was maximum in RH+FYM and in gypsum treated plots. The yield increase of 4.6% in both these treatments over control was, however, non-significant. Gypsum treatment, along with FYM+RH not only caused a slight increase in crop yield but also improved soil properties (Table 4). These results are in conformity with those of Singh & Singh (1989) who reported that gypsum was more efficient than FYM and leaching in increasing rice yield on saline sodic soils. Singh (1990) also reported that gypsum significantly increased yield of rice and wheat over control.

Table 1. Soil pH, ECe, and SAR before treatment application

Treatments	pH	ECe (dS m^{-1})	SAR
Leaching	8.45	6.40	17.79
FYM	8.36	7.59	21.06
RH	8.32	7.30	18.83
FYM+RH	8.39	7.56	20.36
Gypsum	8.47	7.58	23.46
Mean	8.40	7.29	20.30
$LSD_{(0.05)}$	0.11	0.39	1.48

Table 2. Effect of various reclamation treatments on the growth and yield of rice crop. The values are mean of four replications

Treatment	Plant height (cm)	Grains $panicle^{-1}$	1000 grain weight (g)	Grain yield (kg ha^{-1})
Leaching	100.29	160.64	33.79	2700.00
FYM	112.42	174.47	39.15	3850.00
RH	107.92	168.70	33.34	3600.00
FYM+RH	111.17	172.20	35.99	4950.00
Gypsum	100.75	166.33	35.24	3850.00
Mean	106.51	168.67	34.70	3790.00
$LSD_{(0.05)}$	5.38	16.13	2.68	5.38

Growth and yield of wheat: The wheat crop attained highest plant height (81.50 cm) in FYM treatment, causing a 5% increase over control followed by FYM+RH while the lowest plant height (77.50 cm) was observed in control (Table 3). The treatments were however statistically non-significant. Gypsum and RH, on the other hand did not improve plant height.

Yield parameters such as number of grains per spike, 1000-grain weight and grain yield were all maximum in control (leaching) treatment. All other treatments significantly reduced number of grains per spike and 1000-grain weight. Per hectare grain yield was found significantly different in all treatments. It was maximum in gypsum followed by FYM+RH and minimum in leaching treatment (Table 3). The slight increase in yield parameters in control treatment may be attributed to more leaching of salts during rice crop. The rice wheat cropping system is common and characteristic to the salt-affected areas thus the wheat crop, sown after rice, often yields good results because of heavy salt leaching from root zone during rice. The high grain yield under gypsum can be the result of rich Ca availability which replaces the exchangeable Na from the soil exchange complex. The FYM along with RH increased grain yield perhaps because the FYM increased infiltration rate of soil.

Soil pH: Chemical properties of the soils taken at a depth of 0-15 cm before the treatment application indicate saline-sodic nature of the experimental site (Table 1). Physically the field had a hard and dark surface with patches of white salt crystals. There was a great variation in the pH levels in the soil which are characteristic of patchy soil conditions. After rice harvest a significant decrease in soil pH was observed (Table 4). The highest reduction was found in gypsum treatment followed by leaching. The effects of FYM, RH alone and their combination were also positive. After the harvest of wheat crop reduction in pH continued but at this time leaching has lesser effects than other treatments. The organic amendments were found effective perhaps because of the residual effects of these matters on soil pH status. The decrease in pH by gypsum could be because of Na^+ replacement with Ca. The organic materials release organic acids which cause mobilization of the native calcium present as $CaCO_3$ in soil. Zaka *et al*., (2003) reported similar results during agro-melioration of saline-sodic soils.

Soil ECe: The sharp decrease in ECe in all treatments was observed after the harvest of rice (Table 4) with salts leaching to permissible limits. Leaching was found most effective treatment and this could be due to more number of irrigations applied to the crop. Gypsum was found 2nd highest ECe reducing treatment. This was due to the replacement of Na^+, reduction in dispersion and increasing hydraulic conductivity as effects of gypsum. After the harvest of wheat although the ECe remained lower than the pre-treatment conditions however, it increased over the permissible limit in all treatments. This increase was due to the rise of water table in winter season and also less number of irrigations applied to leach down salts. The last irrigation to crop is applied before one month of harvest and this leads to the rise and accumulation of salts in upper surface layers of the soil. Similar results have been reported by Rehman *et al*., (2002). Similarly Zaka *et al*., (2003) found in their studies that during first year their was maximum decrease in ECe but later on its lowering remained slower (Rao *et al*., 1994).

Table 3. Effect of various reclamation treatments on the growth and yield of wheat crop. The values are mean of four replications.

Treatment	Plant height (cm)	Grains spike^{-1}	1000 grain weight (g)	Grain yield (kg ha^{-1})
Leaching	77.50	46.25	47.95	4025.00
FYM	81.50	41.00	47.03	4193.75
RH	78.25	42.50	44.37	4125.00
FYM+RH	79.50	42.50	45.57	4400.00
Gypsum	78.00	41.75	43.46	4650.00
Mean	78.95	42.80	45.68	4278.75
$LSD_{(0.05)}$	1.39	2.09	1.64	154.35

Table 4. Effect of various reclamation treatments on Soil pH, ECe, and SAR values after the harvest of rice and wheat crops.

Treatments	pH		ECe (dS m^{-1})		SAR	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
Leaching	8.21	8.05	2.33	4.38	9.81	7.33
FYM	8.29	7.96	2.89	4.33	9.94	5.78
RH	8.23	7.95	2.80	4.34	10.13	*7.28*
FYM+RH	8.32	7.98	2.63	4.28	8.82	5.66
Gypsum	8.20	7.95	2.68	4.33	7.83	4.07
Mean	8.29	7.98	2.67	4.22	9.31	6.02
$LSD_{(0.05)}$	0.11	0.11	0.31	0.31	1.48	1.48

Soil SAR: All the treatments reduced SAR significantly after rice harvest. Gypsum application was found highly effective in reducing SAR followed by FYM+RH treatment (Table 4). The results are in conformity with those reported by Ghafoor *et al*., (2001), Chaudhry *et al*., (2000) and Rehman *et al*., (2002). After the harvest of wheat the SAR reduction continued in the same manner with maximum reduction in gypsum treatment followed by FYM+RH treatment.

Conclusion

It is concluded from the results that rice growth and grain weight was improved by FYM alone and in combination with RH. But per hectare rice yield was, however, maximum in FYM+ RH and gypsum treated plots. Following wheat crop, the leaching significantly increased the number of wheat grains per spike and 1000-grain weight. The per hectare wheat yield, however was highest in gypsum treated plots.

After rice harvest soil pH, EC and SAR were decreased by all the treatments. Gypsum treatment followed by leaching was more effective in lowering pH and SAR. After wheat, reduction in pH continued but with lower effect by leaching while slight increase in ECe was observed.

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