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Amelioration of saline-sodic soil by flushing and leaching

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Abstract

A field experiment was conducted in saline -sodic soil [EC_e, 9.05-12.07 dS m^{-1}; pH_s, 8.95-9.36, Sodium Adsorption Ration (SAR), 95-134.5 (mmol $L^{-1})^{1/2}$ and Gypsum Requirement (GR) 9.30-13.70 Mg ha^{-1}] in split plot design at farmer field (Haveli Karim Dad, Pindi Bhattian District Hafizabad). The treatments included (i) amendments i.e. gypsum @ 50 and 100% soil GR and (ii) leaching / flushing with 8 and 12 inches of water (in two and three splits). The applied water (4 acre inches) was either left to leach down vertically (leaching) or drained out after 24 hours under gravitational force in a side channel (flushing) after gypsum application. Rice-wheat-rice rotation was followed during the study. The application of gypsum @ 100% GR significantly increased the biomass, paddy and wheat grain yield than gypsum application @ 50% GR. The effect of three leachings / flushings was significant in first rice crop than two leachings / flushings. The flushing proved helpful in reducing the EC_e of soil while vertical leaching accelerated the reclamation process.

Key words: Gypsum, flushing, leaching, *Triticum aestivum, Oryza sativa*

Introduction

Soil salinity / sodicity inhibits plant growth through complex reactions including osmotic effect, specific ion activity and nutritional imbalances (Qadir and Schubert, 2002). Gypsum ($CaSO_4$. $2H_2O$) is widely used on saline-sodic and sodic soils to replace the adsorbed sodium from the exchange site in order to reclaim the soil (Hussain *et al.*, 1986). Gypsum application is generally followed by heavy irrigations to dissolve the applied amendment to leach down the replaced sodium and to remove the soluble reaction products from the root zone. Dutt (1994) predicted that 52-72 cm of water was required to dissolve 16.15-23.90 tons of gypsum ha^{-1}, when applied through surface irrigation. Hussain and Hussain (1989) reclaimed saline-sodic soil by draining the water after standing on the surface over night. In this way, soil was free from salinity but sodicity persisted. Due to hard pan at certain depth, leaching of salts is a problem in fine textured sodic soils. The traditional reclamation technique "gypsum application followed by irrigation" is less effective to reclaim dense saline-sodic and sodic soils (Ghafoor and Muhammed, 1981; Ahmad and Qadir, 1995). Neither sub-soiling nor open ditch drainage proved helpful in reclamation under such conditions (Ilyas *et al.*, 1993). To cope with the problem, a technique involved mixing of gypsum with soil in standing water with cultivator followed by horizontal flushing of standing water to a nearby drain and a second flushing after 24 hours proved useful for reclamation. However, enough slope and a nearby drain are prerequisites which make the approach site-specific (Qadir *et al.*, 1998). Another method to get rid of excessive soluble salts in the solution is to flush out the surface water after the completion of reaction of gypsum with soil particles (Ahmad *et al.*, 1992). The present field study was conducted to determine the relative effectiveness of vertical leaching against surface flushing so that a technique can be devised that not only saves water but also can be adapted for problem soils where drainage is restricted.

Materials and Methods

Field experiment was conducted on sandy clay loam soil [EC_e, 9.05–12.07 dS m^{-1}; pH_s, 8.95-9.36; SAR, 95-134.5 (mmol $L^{-1})^{1/2}$; GR, 9.30-13.70 Mg ha^{-1}) in split plot design with three replications at Haveli Karimdad, Pindi Bhattian, District Hafizabad. The treatments were as under:

(A) Amendments

1. Gypsum @ 50% Soil GR
2. Gypsum @ 100% Soil GR

(B) Leaching / Flushing

L_1 = Vertical leaching with 8 inches water (in two splits)

L_2 = Vertical leaching with 12 inches water (in three splits)

F_1 = Horizontal flushing with 8 inches water (in two splits) drained after 24 hours

F_2 = Horizontal flushing with 12 inches water (in three splits) drained after 24 hours

The composite soil samples were collected from 0-15 and 15-30 cm depth and analyzed for pH_s, EC_e, SAR and gypsum requirement. Soil GR was determined by Schoonover's method (Schoonover, 1952). Gypsum was broadcast and mixed in the soil with shallow ploughing in

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the respective treatments according to 50 and 100% GR of 0-15 cm depth (Table 1). The applied water (4 acre inches measured through cut throat flume) was either left to leach down salts vertically or drained out after 24 hours under gravitational force in a side channel (flushing). Water application was completed through 2-3 irrigations as per treatment with 4-5 days interval. After completion of leaching / flushing process, rice variety Shaheen Basmati was transplanted. The rice - wheat - rice crop rotation was followed. Recommended dose of fertilizers (110-90-70 NPK kg ha^{-1}) to rice and wheat (120-90-70 NPK kg ha^{-1}) were applied along with other agronomic practices. The yield data were recorded at maturity and statistically analyzed using Duncan's Multiple Range Test (Steel and Torrie, 1984). The soil samples were collected from 0-15 and 15-30 cm depth after harvesting of each crop and analyzed for pH_s, EC_e and SAR by standard methods (U.S. Salinity Laboratory Staff, 1954).

Table 1. Gypsum requirement (Mg ha^{-1}) of original soil (0-15 cm)

Treatment	50 %	100 %
L_1	13.60	11.80
L_2	13.00	10.40
F_1	09.30	10.90
F_2	12.30	13.70

Results and Discussion

Effect of gypsum and flushing vs vertical leaching on the biomass, paddy and wheat grain yield

The application of gypsum @ 100% GR significantly increased biomass and grain yield of three crops when it was compared with 50% GR (Tables 2, 3 and 4). The low rate of gypsum (50% GR) proved inferior to higher rate and the differences in yield parameter could not be narrow during the growing period of crops. The differences between vertical leaching and horizontal flushing at the same rate of applied water were non significant. However, 12 inches water was superior over 8 inches during first two crops, when it was either applied to leach down the salts vertically or to remove through flushing. The effect of leaching/ flushing with either quantity of irrigation water was non significant for producing biomass and paddy yield of 3rd crop.

Hussain *et al.* (2000) reported 73% higher wheat grain yield in the treatment where irrigation water was flushed out 36 hours after gypsum application.

Effect of gypsum and flushing vs leaching on soil properties

Soil pH_s

Data regarding soil pH_s showed that gypsum application @ 100% GR was more effective than 50% GR in decreasing the soil pH_s of 0-15 and 15-30 cm soil depths (Figures 1 & 2). Irrespective of the rate of gypsum application, treatment L_2 was found better in decreasing pH_s of 0-15 cm soil depth with minor decrease in pH_s of the 15-30 cm soil depth after rice 2002. The significant effect in L_2 treatment might be due to ponded water which promoted gypsum dissolution, expediting the reclamation reactions and ultimately improvement of soil (Haq *et al*., 2001). The pH_s reduced to safe limit after the harvesting of wheat 2002-03 in the upper soil depth with gypsum application @ 100% GR in all the treatments while gypsum @ 50% GR reduced the pH_s of the soil to safe limit after harvesting of rice crop (2003) with L_2. The decrease in pH_s of 15-30 cm soil depth indicated gradual vertical removal of the reclamation reaction products in the soil profile.

Soil EC_e

The treatment effect on EC_e of soil is presented in figures 3 and 4. The data revealed that flushing in general, was more effective in reducing the EC_e of the soil as compared to leaching. Flushing disposed off the salts laterally that proved more effective technique over vertical leaching which in turn depends upon soil drainage. The EC_e reduced to safe limit in all the treatments after harvesting of rice 2002 because Ca^{2+} caused coagulation of soil and improved soil characteristics. However, the reduction in EC_e in L_1 treated plot was low with 50% gypsum application indicating the slow removal of soluble salts. The EC_e was less than 4 dS m^{-1} in all the treatments at both the depths with gypsum application @ 100% GR after harvesting wheat 2002-03 but when the gypsum was applied @ 50% GR, the EC_e reduced to the safe limit after harvesting of second rice crop in the 0-15 and 15-30 cm soil depths. The EC_e was higher in the lower depth than the upper depth showing the downward movement of soluble salts during reclamation process. The reduction in EC_e was found maximum after harvesting rice 2002 as compared to original values. However, after rice 2003, the surface depth remained within safe limits of less than 4 dS m^{-1}.

Soil SAR

The data regarding SAR is presented in figures 5 and 6. The reduction in SAR was more with gypsum @ 100% GR as compared to 50% GR. The vertical leaching of salts was more effective for reducing the SAR as compared to flushing as the process of gypsum dissolution continued.

Table 2. Biomass and paddy yield (Mg ha^{-1}) of rice 2002

Treatment	Biomass			Paddy		
	50%	100%	Mean	50%	100%	Mean
L_1	3.58 d*	6.55 a	5.06 B	0.91 d	1.43 b	1.17 B
L_2	4.75 b	6.58 a	5.66 A	1.12 c	1.58 a	1.35 A
F_1	3.75 cd	6.25 a	5.00 B	0.92 d	1.53 ab	1.22 B
F_2	4.48 bc	6.17 a	5.33 AB	1.18 c	1.62 a	1.40 A
LSD (Interactions leaching/ flushing)	0.7589		0.5357	0.1488		0.1052
Mean (Amendments)	4.14 B	6.39 A		1.04 B	1.54 A	
LSD (Amendments)	1.739			0.352		

*Means sharing similar letters are not statistically different at 5 % level of probability.

Table 3. Biomass and grain yield (Mg ha^{-1}) of wheat 2002-03

Treatment	Biomass			Grain		
	50%	100%	Mean	50%	100%	Mean
L_1	5.70 f*	7.75 cd	6.72 B	2.34 e	3.46 b	2.90 B
L_2	6.83 de	9.58 b	8.21 A	3.26 bc	4.63 a	3.94 A
F_1	5.95 ef	8.22 c	7.08 B	2.65 d	3.70 b	3.18 B
F_2	6.73 e	10.8 a	8.80 A	2.95 cd	4.95 a	3.95 A
LSD (Interactions leaching/ flushing)	0.9679		0.6844	0.4536		0.3207
Mean (Amendments)	6.30 B	9.10 A		2.80B	4.18 A	
LSD (Amendments)	1.873			0.987		

*Means sharing similar letters are not statistically different at 5 % level of probability.

Table 4. Biomass and paddy yield (Mg ha^{-1}) of rice 2003

Treatment	Biomass			Paddy		
	50%	100%	Mean	50%	100%	Mean
L_1	7.52 b*	10.51 a	9.01 NS	2.72 b	3.93 a	3.32 NS
L_2	7.56 b	10.54 a	9.05 NS	2.77 b	4.03 a	3.40 NS
F_1	7.53 b	10.57 a	9.05 NS	2.77 b	3.94 a	3.32 NS
F_2	7.57 b	10.60 a	9.08 NS	2.80 b	4.02 a	3.41 NS
LSD (Interactions leaching/ flushing)	0.1378			0.1258		
Mean (Amendments)	7.55 B	10.56 A		2.75 B	3.99 A	
LSD (Amendments)	2.103			0.675		

*Means sharing similar letters are not statistically different at 5 % level of probability.

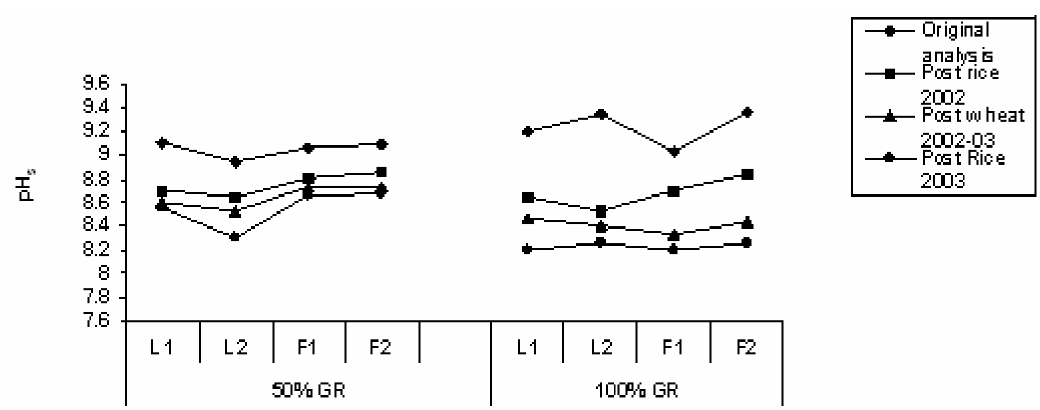

Figure 1. Original and post crop soil analysis for pH$_s$ (0-15 cm)

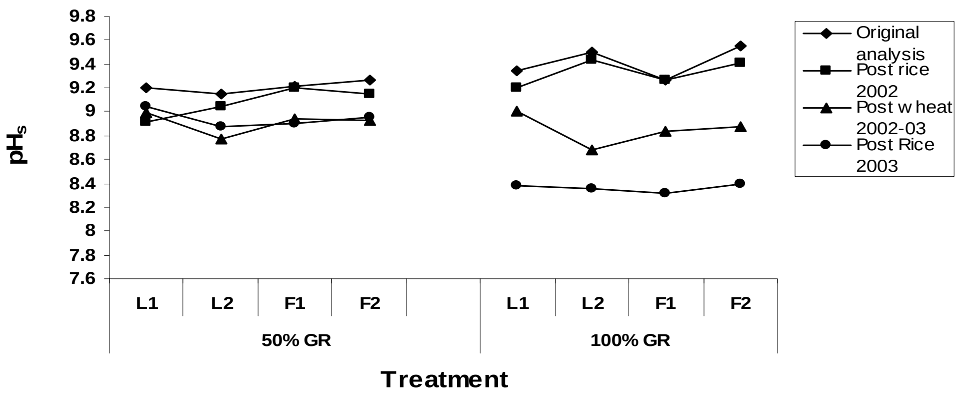

Figure 2. Original and post crop soil analysis for pH_s (15-30 cm)

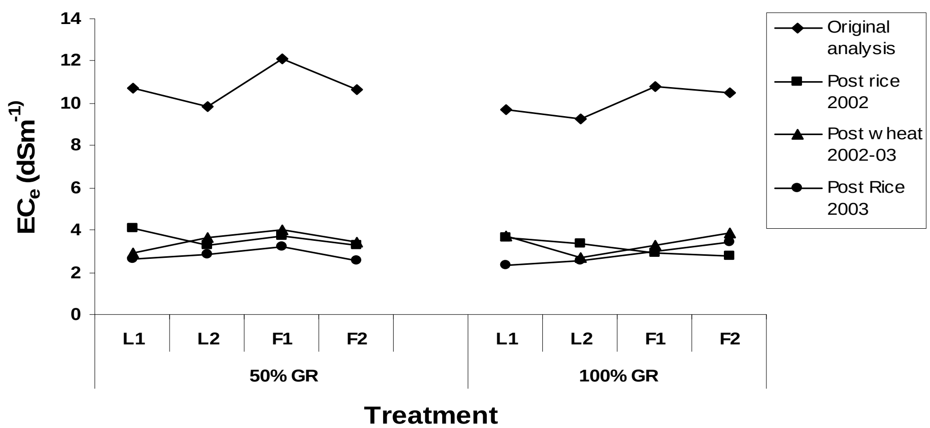

Figure 3. Original and post crop soil analysis for EC_e (0-15 cm)

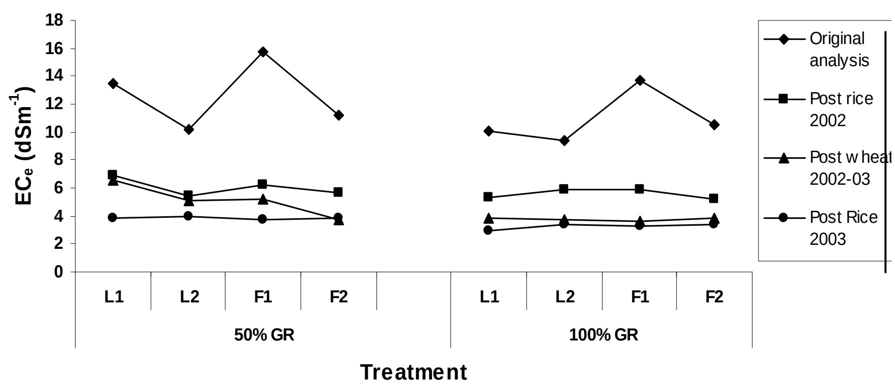

Figure 4. Original and post crop soil analysis for EC_e (15-30 cm)

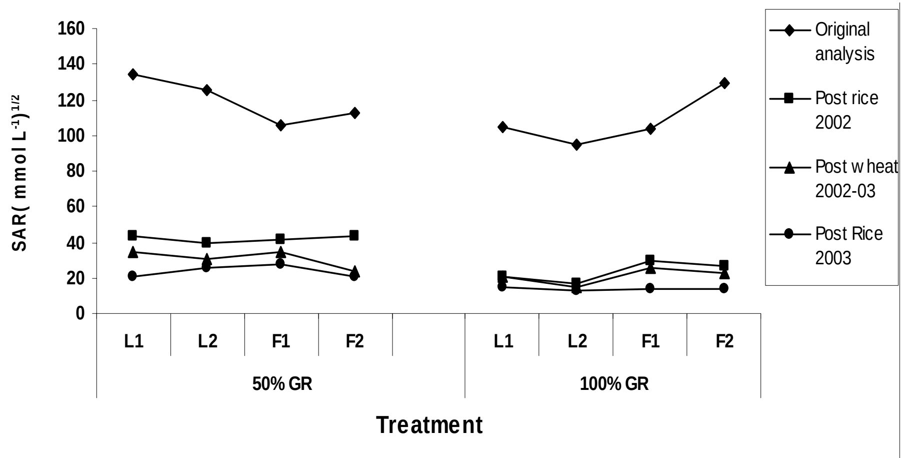

Figure 5. Original and post crop soil analysis for SAR (0-15 cm)

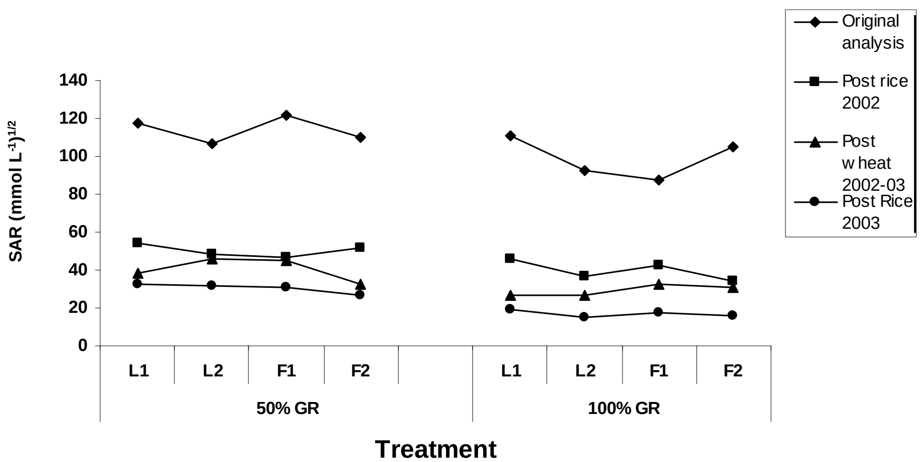

Figure 6. Original and post crop soil analysis for SAR (15-30 cm)

The decrease in SAR was due to removal of Na from the exchange complex. The flushing of irrigation water after 24 hours did not remove the salts quickly as the reaction of gypsum with exchange site was under way and only a small amount of exchangeable sodium salts were removed with flushed out water. The rate of decrease in SAR was greater in the upper soil depth than the lower depth. The SAR decreased in both soil depths after harvesting of second rice crop with the application of gypsum @ 100% GR irrespective of leaching vs. flushing indicating the completion of the reclamation process.

Niazi *et al*. (2000) also reported that maximum decrease in SAR was observed when soil was treated with 100% GR in one shot during the first wheat and rice cropping season. The rate of decrease in SAR enhanced with time and application of highest gypsum dose. But in case of 50% gypsum application, the rate of decrease in SAR was slower, however, gradual decrease in SAR was observed after harvesting of each crop.

Conclusion

Gypsum application @ 100% soil GR significantly increased the yield of crops than gypsum application @ 50 % soil GR. Flushing was more effective in reducing the EC_e of the soil as compared to leaching. However both were found useful for lowering the pH_s, and SAR to safe limits.

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