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Management of Saline Sodic Soil Irrigated with Brackish Ground Water Employing Gypsum and Soil Ripping

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ABSTRACT

A long term field study by growing two wheat and two rice crops in succession was conducted to evaluate the effectiveness of gypsum application and soil ripping to manage saline-sodic soil irrigated with brackish ground water in Pindi Bhattian area, district Hafizabad. The soil was clay loam in texture. The original pH, EC_e and SAR of the soil were 8.9, 5.25 dS m^{-1} and 49.9, respectively and the brackish water had EC_w 1.4 dS m^{-1}, SAR 8.7 (m mol/L)$^{1/2}$ and RSC 4.8 me L^{-1}. Two gypsum levels i.e. control and gypsum @100 % GR and no ripping, single ripping and double ripping were tested in farmer's fields. Reduction in EC_e and SAR were treated as the indicators to evaluate the effectiveness of different treatments. Significantly higher wheat grain yield was recorded when double ripping along with 100% GR was applied. Increase in wheat yield over control was 55% during the year 1996-97. Highest paddy yield (1.52 Mg ha^{-1}) was recorded when single ripping along with gypsum @ 100% GR was applied. Gypsum x ripping interaction significantly ($P<0.05$) decreased the EC_e below salinity threshold in all the treatments except control. SAR was significantly decreased below 15 in treatments which received double ripping + gypsum application and single ripping + gypsum application. Crop yield data indicated that gypsum application in conjunction with ripping is much more effective than either of the two treatments alone.

Key Words: Saline sodic soil; Brackish ground water; Gypsum; Soil ripping

INTRODUCTION

The reclamation of sodic and saline-sodic soils is more difficult, time consuming and expensive than those of saline soils. The reclamation of such soils involves not only the leaching of soluble salts and sodium replacement but also improvement of their soil physical conditions. Under these adverse soil physical conditions, the movement of water, air and root penetration into the soil is restricted (Voorhees, 1977). Plant roots do not function properly in compacted soil due to limited root soil volume caused by increased mechanical resistance of the soil which might result in decreased nutrient and water uptake (Hussan & Adhikari, 1994). With the continuous irrigation of sodic soils with brackish tubewell waters, the problem is further aggravated. To overcome this problem, good drainage is a pre-requisite for successfully managing salt-affected soils because hard pan generally exists in saline-sodic heavy textured soils. To achieve good drainage and improvement of soil physical condition, Agricultural Mechanization Research Institute (AMRI), Multan developed a ripper which can effectively be utilized. The practice of opening up the soil to more than 1.5 m depth with the use of ripper has the advantages of loosening the hard soil layer which facilitates the leaching of salts in the process of reclamation. It may also enhance the process of replacing Na^+ by Ca^{2+} on the exchange complex by gypsum application. Since the ripper was not previously tried on dense saline-sodic soils, this particular study was conducted to investigate its utility under the field conditions. Results on the effectiveness of gypsum on soil amelioration, offsetting the harmful effects of brackish irrigation water and yield of four successive crops are discussed in this paper.

MATERIALS AND METHODS

A field experiment was laid out to evaluate the efficiency of ripping and gypsum application to manage a saline-sodic soil using moderately saline but highly brackish water during 1996 to 1998 in Pindi Bhattian area, district Hafizabad. Soil was ripped off by ripper, designed by AMRI, Multan, driven by a bulldozer. Ripping depth was 1.52 m and intertine space was 2 m. Rice (cv. IR-9) was grown in saline-sodic, clay loam soil , having pH 8.9, EC_e 5.25 dS m^{-1}, SAR 49.9. Gypsum requirement of the soil was 5.25 Mg ha^{-1}. Highly brackish underground water with slight to moderate degree of salinity restriction, having EC_w 1.4 dS m^{-1}, SAR 8.7 and RSC 4.8 $mmol_c\,L^{-1}$, was used to raise two rice and two wheat (Inqalab-91) crops. The treatments under investigation were as under:

T_1 = Control (No ripping + No gypsum application)
T_2= No ripping + 100% GR
T_3 = Single ripping + No gypsum
T_4 = Single ripping + 100% GR
T_5 = Double ripping + No gypsum
T_6 = Double ripping + 100% GR

After layout of the experiment, gypsum application was made and thoroughly mixed. Plot size was 10x30 m^2. The study was organized using split plot design. Composite soil samples were collected from each plot to determine pH, EC_e and SAR. Rice seedling of 35 days age were transplanted by keeping row to row and hill to hill distance of 22.5 cm. A basal dose of N, P_2O_5 and K_2O @ 100-70-70 kg ha^{-1}, respectively was applied. Half of N as urea and full dose of P_2O_5, K_2O were applied at the time of transplanting rice seedling. Zinc @ 20 kg ha^{-1} was also applied. Harvesting was done at maturity. Crop growth characteristics viz. paddy and straw yields were recorded. After rice harvesting, composite soil samples were collected from each plot. These were analyzed for pH, EC_e and SAR according to the methods of Page *et al.* (1982).

After the rice crop, the field was prepared for wheat sowing. Wheat cv. Inqalab-91 was sown by using seed rate of 100 kg ha^{-1} with row to row distance of 20 cm. A basal dose of N, P_2O_5, K_2O @ 150-100-50 kg ha^{-1}, respectively was applied. Half of N and full dose of P_2O_5 and K_2O were applied at the time of sowing. The rest of N was applied with the second irrigation. Harvesting was done at maturity and crop growth characteristics *viz*. grain and straw yield were recorded. The grain, paddy and straw yield data from both rice and wheat experiments were statistically analyzed (Steel & Torrie, 1980). The second crop of rice in 1997 followed by second crop of wheat were grown in the field with the same layout and other practices/inputs.

RESULTS AND DISCUSSION

A. Crop Yield Data. Application of gypsum significantly ($P<0.05$) increased wheat grain yield during 1996-97 (Table I). Maximum wheat grain yield of 1.79 Mg ha^{-1} was achieved by the application of gypsum @100% GR. Similarly residual ripping effect on wheat grain yield was also found significant ($P<0.05$). Maximum wheat grain yield of 1.79 Mg ha^{-1} was realized from double ripping treatment (Table I). These results are in accordance with Schmidit *et al*. (1994), who reported increase in depth of soil disturbance, reduced soil strength and greatly increased grain yield of wheat. Furthermore, Barret *et al*. (1993) mentioned that improvements in productivity of Atriplex species under saline conditions are achieved by deep ploughing to reduce sub-soil compaction. Gypsum x ripping interaction effect was also found statistically significant ($P<0.05$). Maximum wheat grain yield of 1.98 Mg ha^{-1} was recorded when double ripping along with 100% GR was applied. Increase in wheat yield over that from the control was 55, 44, 25 and 22% by the application of double ripping + gypsum application @ 100% GR, single ripping + gypsum application @ 100% GR, double ripping and gypsum application @ 100% GR, respectively.

Table I. Effect of ripping and gypsum application to soil on wheat grain yield (1996-97)

Treatments	No ripping	Single ripping	Double ripping	Means
No Gypsum	1.28 d	1.27 d	1.60 c	1.38 B
100 % GR	1.56 c	1.84 b	1.98 a	1.79 A
Mean	1.42 C	1.56 B	1.79 A	

Wheat straw yield during 1996-97 was significantly ($P<0.05$) increased by gypsum application (Table II). Maximum wheat straw yield of 1.99 Mg ha^{-1} was recorded by the application of gypsum @ 100% GR. Similarly wheat straw yield was also significantly affected by ripping treatments. Maximum straw yield of 2.05 Mg ha^{-1} was obtained where double ripping was done. This increase in yield as compared to control was 17%. Gypsum application x ripping interaction effect was also found significant ($P< 0.05$). Maximum straw yield of 2.15 Mg ha^{-1} was obtained as a result of double ripping along with gypsum application (@ 100% GR). Increase in wheat straw yield over that from control treatment was 1.7, 13, 11, 20, 25% by the application of single ripping, double ripping, gypsum (100% GR), single ripping + gypsum (100% GR) and double ripping + gypsum (100% GR), respectively.

Table II. Effect of ripping and gypsum application to soil on wheat straw yield (1996-97)

Treatments	No ripping	Single ripping	Double ripping	Means
No Gypsum	1.73 bc	1.91 ab	1.95 ab	1.86 B
100 % G R	1.76 bc	2.07 ab	2.15 a	1.99 A
Mean	1.74 C	1.99 B	2.05A	

Wheat grain yield during 1997-98 was significantly ($P<0.05$) affected by gypsum application (Table III). Maximum wheat grain yield of 1.79 Mg ha^{-1} was recorded when gypsum (100% GR) was applied. Residual effect of ripping on wheat grain yield (1997-98) was found non-significant. Ripping x gypsum application interaction effect was found significant. Maximum grain yield of 2 Mg ha^{-1} was obtained when 100% gypsum requirement was applied. Single ripping + gypsum (100% GR) and double ripping + gypsum (100% GR) treatments were at par with gypsum (100%

Table III. Effect of ripping and gypsum application to soil on wheat grain yield (1997-98)

Treatments	No ripping	Single ripping	Double ripping	Means
No Gypsum	1.23 b	1.21 b	1.5 ab	1.31 B
100 % GR	2.00 a	1.69 ab	1.68 ab	1.79 A
Mean	1.61 A	1.45 B	1.59 A	

GR) application only.

Wheat straw yield during 1997-98 was again significantly affected by gypsum application (Table IV). Maximum wheat straw yield (1.90 Mg ha^{-1}) was obtained by the application of gypsum @ 100% GR. While ripping did not significantly affect the wheat straw yield, gypsum x ripping interaction effect was significant. The treatment effect followed the pattern: 100% GR + No ripping > 100% GR + single ripping = 100% GR + double ripping > double ripping > single ripping < control. The increase in wheat straw yield when gypsum @100% GR applied was 60% higher as compared to control.

Table IV. Effect of ripping and gypsum application to soil on wheat straw yield (1997-98)

Treatments	No ripping	Single ripping	Double ripping	Means
No Gypsum	1.33d	1.32d	1.62 c	1.42 B
100 % G R	2.10 c	1.80 b	1.80 a	1.90 A
Mean	1.71 A	1.56 B	1.70 A	

Paddy yield during 1997 was significantly ($P<0.05$) affected by gypsum application (Table V). Maximum paddy yield of 1.39 Mg ha^{-1} was recorded by the application of 100% GR. This increase in yield due to 100% GR over control was 85%. Similarly ripping effect was also found significant ($P<0.05$). Maximum paddy yield of 1.17 Mg ha^{-1} was achieved when soil was double ripped. This increase in yield due to double ripping over control is 37%. However, no significant difference was recorded between single and double ripping treatments. Gypsum x ripping interaction effect was statistically significant ($P<0.05$). The maximum paddy yield of 1.52 Mg ha^{-1} was realized when single ripping along with 100% GR was applied. This treatment was statistically at par with 100% GR + double ripping. Increase in paddy yield over that from the control treatment was 56, 53, 102, 171 and 170% by the application of single ripping, double ripping, gypsum @ 100% GR+ no ripping, gypsum @ 100% GR+ single ripping, gypsum @ 100% GR+ double ripping, respectively. The favourable ameliorative effect of gypsum application and improvement in soil physical conditions due to ripping helped in efficient leaching of salts. This is also confirmed by the reduction in EC_e and SAR. These results lend support to the findings of

Table V. Effect of ripping and gypsum application to soil on paddy yield-1997

Treatments	No ripping	Single ripping	Double ripping	Means
No Gypsum	0.56c	0.88b	0.84bc	0.755B
100 % GR	1.13c	1.52a	1.51a	1.39A
Mean	0.85b	1.20A	1.17A	

Sharma *et al*. (1996), Rashid *et al*. (1986) and Akram *et al*. (1994).

Second rice crop after gypsum application during 1998 gave significantly ($P<0.05$) higher paddy yield (Table VI). Maximum paddy yield of 2.11 Mg ha^{-1} was recorded where 100% GR was applied in 1997.

Table VI. Effect of ripping and gypsum application to soil on paddy yield-1998

Treatments	No ripping	Single ripping	Double ripping	Means
No Gypsum	0.68 c	0.99d	1.50cd	1.05B
100 % GR	1.24 c	2.30b	2.80b	2.11A
Mean	0.96 C	1.65B	2.15A	

The increase in paddy yield due to gypsum application was 100% over control. Ripping effect on paddy yield was also significantly ($P<0.05$) increased. However, the paddy yield in case of single ripping and double ripping treatments was statistically at par. Gypsum x ripping interaction effect was also found significant. The maximum paddy yield of 2.82 Mg ha^{-1} was obtained where gypsum @ 100% GR along with double ripping was applied. This increase in paddy yield was 311% over control treatment. The trend in paddy yield was as under:

Table VII. Effect of soil ripping and gypsum application on pH at crop harvest

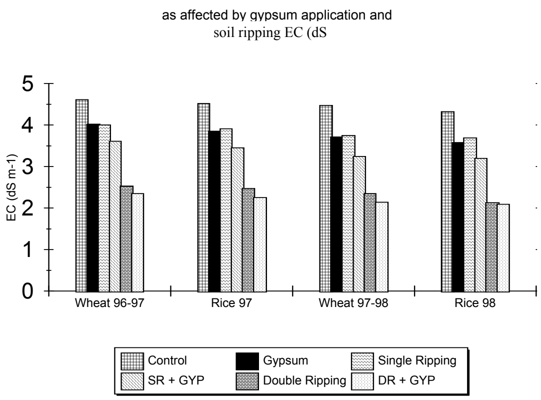
Crops	No ripping		Single ripping		Double ripping	
	0	100 % GR	0	100 % GR	0	100 % GR
Wheat-1996-97	8.48	8.58	8.58	8.48	8.51	8.41
Rice-1997	8.81	8.51	8.54	8.41	8.51	8.38
Wheat 1997-98	8.88	8.50	8.51	8.40	8.80	8.38
Rice –1998	8.80	8.48	8.50	8.39	8.48	8.88

Gypsum @ 100% GR+ double ripping> Gypsum @ 100% GR+ single ripping> Gypsum @ 100% GR> double ripping> single ripping> control. The higher paddy yield with gypsum application could be because of soil improvement. Probably enhancement of soil permeability due to Ca and ripping might have helped in efficient leaching of salts.

B. Soil Properties. Soil pH was recorded before the initiation of study and it was 8.9 at both depths (0-15 cm and 15-30 cm). Soil pH was recorded after the harvest of each crop. Neither application of gypsum nor ripping had any significant decrease in soil pH (Table VII). As soil pH is affected by a strong buffering capacity of soil, therefore the ameliorative effects of experimental treatments and deleterious effects of brackish water neutralized each other. These finding are in line with that Rashid *et al.*(1994). EC_e value before the initiation of the experiment was 5.25 and 4.95 dS m^{-1} at 0-15 cm and 15-

30 cm, respectively. Gypsum application as well as soil ripping (Fig. 1) significantly decreased soil electrical conductivity. After the harvest of wheat (1996-97), significant reduction ($P<0.05$) in soil electrical conductivity was recorded. Maximum decrease in EC_e (2.38 dS m^{-1}) was noticed in double ripping + gypsum

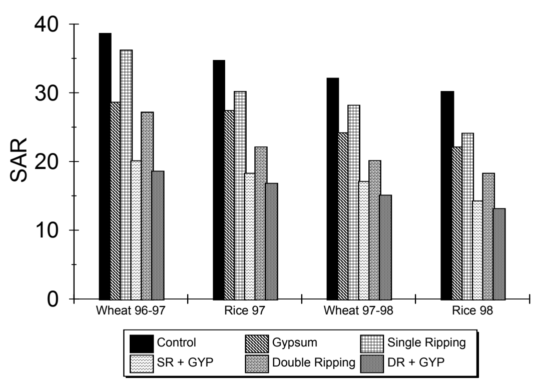
Fig. 1. Electrical conductivity as effected by gypsum application and soil ripping



(100% GR) treatment as compared to EC_e 4.61 dS m^{-1} in control treatment. Decrease in EC_e was recorded in all the treatment. The EC_e reduction pattern is as under.

Double ripping + gypsum (100% GR) < Double ripping < single ripping + gypsum (100% GR) < gypsum < single ripping (100% GR) < control.

Fig. 2. SAR as effected by gypsum application and soil ripping



After the rice (1997) harvest, further decrease in EC_e was recorded. The pattern of reduction of EC_e was as above. Double ripping along with gypsum (100% GR) was most effective and EC_e value recorded was 2.25 dS m^{-1} as compared to 4.52 dS m^{-1} in control treatment. After the wheat 1997-98 and rice-98 harvest further decline in EC_e was noticed. After the harvest of rice-98, EC_e recorded from all the treatments except control was much below than salinity threshold EC_e (4 dS m^{-1}). Perhaps rapid dissolution of calcium and ripping might have improved soil permeability, which helped in leaching of soluble salts below the root zone. These results are in line with Yasin *et al*. (1998) and Rashid *et al.* (1986).

Sodium adsorption ratio (SAR) before the initiation of the experiment was 49.9 and 47.8 at 0-15 cm and 15-30 cm, respectively. Both the application of gypsum and ripping significantly ($P<0.05$) decreased the SAR (Fig. 2). Maximum reduction in SAR was recorded in double ripping + gypsum (@ 100% GR) treatment which was 18.61 (52%) as compared to control treatment (38.64). The reduction pattern is SAR was as under:

Double ripping+ Gypsum (100% GR) < Single ripping + Gypsum (100% GR) < Double ripping < Gypsum< Single ripping< control.

After the rice harvest (1997), residual effect of gypsum and ripping significantly decreased SAR ($P < 0.05$). Maximum reduction in SAR again recorded in treatment receiving double ripping + gypsum (100% GR) application. The SAR reduction pattern in different treatments was same as observed after wheat (1996-97) harvest. This pattern in yield reduction continued during the course of investigation i.e. after wheat (1997-98) and rice (1998) harvest. Further decline in SAR value was recorded. Both double ripping + gypsum application and single ripping + gypsum treatments registered maximum decrease in SAR which were below SAR threshold value. The SAR reduction might be due to removal of adsorbed sodium. These findings are in line with those of Yasin *et al.* (1998) and Chaudhry *et al*. (1994).

CONCLUSIONS

Firstly, the utility of soil ripping has been indicated which along with gypsum application improved the crop yields as well as the soil properties. Secondly the experimental treatments may offset the deleterious effects of marginal quality tube-well waters.

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