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FIELD STUDIES ON THE RECLAMATION OF THE GANDHRA SALINE-SODIC SOIL

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A field experiment on the reclamation of the Gandhra sandy clay soil was conducted during 1981-83 on a permanent layout following the randomized complete block design with rice-wheat rotation being irrigated with marginal saline-sodic tubewell water. The results indicated that the subsoiling in combination with gypsum is better than gypsum alone, while subsoiling is better than control for chemical reclamation as well as for rice productivity. For wheat, gypsum alone was slightly better than subsoiling + gypsum. In terms of cost economics, subsoiling + gypsum provided the maximum gross income followed by gypsum, subsoiling and the control. However, gypsum treatment gave the highest net income followed by subsoiling + gypsum, subsoiling and the control.

INTRODUCTION

Being situated in the arid and semiarid subtropical zones, salinity and sodicity are amongst the dominant soil problems in Pakistan that cause serious reduction in crop production. The salts in such soils originate mainly from the parent material causing fossil salinity/sodicity while secondary or man-made saline/sodic soils have been formed due to unscientific use of land water resources. About 6.22 million hectares of the salt-affected soils occur in Pakistan. Nearly 80% of the salt-affected soils of the Punjab and 60% of that of Pakistan are saline-sodic (Muhammed, 1983) and are not easily reclaimable because of low permeability to canal water.

There are two possible approaches for utilizing these problem soils: (1) make the soil environment suitable for successful and healthy crop growth, (2) develop plant species that can grow successfully in inhospitable soil environment. Nevertheless, the two approaches are complementary and are not

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mutually exclusive. The reclamative techniques include the physical, chemical, biological, hydrotechnological, electrochemical methods and combinations of these techniques. Rasmussen (1973) conducted field experiments and found that gypsum alongwith subsoiling (70 cm deep) and ploughing (55 cm deep) with moulboard plough were successful for reclaiming salt-affected soils while subsoiling only was observed to be less effective for soil reclamation and for the growth of alfalfa interseeded with small grain crops of wheat and barley. In a pot experiment, Kausar and Muhammed (1972) compared chemical and biological methods of reclamation and found gypsum to be the most effective. According to Muhammed and Khaliq (1975), gypsum treatment took less time for passing 120 cm water through the soil columns as compared to sulphur, presumed and FYM. Only a limited number of field experiments have been conducted in Pakistan on the reclamation of saline-sodic soils inspite of the fact that saline-sodic soils cover a major part of salt-affected soils in the Indus Plains. Zaidi *et al.* (1968) and Chaudhry *et al.* (1982) have published results of field experiments on the reclamation of saline-sodic soils. Most of these studies indicated need for further farm level investigations on the comparison and economics of reclamation of saline-sodic soils with gypsum application based on gypsum requirement (GR) test.

There is no single method universally applicable for reclaiming all types of salt-affected soils because of their complexity and nature of formation. Therefore, the present study was undertaken on a Gandhra saline-sodic soil at farm level to find the most practical and economical method for its reclamation.

MATERIALS AND METHODS

The Gandhra sandy clay soil was selected at Chak No. 44/R.B., Kotla Kahluwan near Shahkot, Tehsil and District Sheikhupura for conducting the experiment. The soil was deep. It belonged to Halic Camborthids, fine loamy, mixed calcareous, Hyperthermic family of international soil toxonomy. Following treatments were replicated in randomized complete block design on a permanent layout with rice-wheat rotation on all the treatments having 32 x 14 m gross plot size :

Control : Simple leaching with saline-sodic tubewell water.

Subsoiling (SS) : 50 ± 5 cm deep furrows were drawn crosswise, 120-150 cm apart with single tine subsoiler during January, 1981.

Gypsum (Gyp) : Seventy to 100 mesh gypsum of about 90% purity at 100% GR (half of the 100% GR of 0-30cm soil depth) was broadcast and mixed with surface 10cm soil with cultivator at the end of February and beginning of March, 1981. No correction was made for 90% purity of gypsum powder.

Subsoiling + gypsum (SS+Gyp) : Combination of subsoiling and gypsum treatments given above.

Tubewell water of marginal quality was applied for leaching and irrigating crops throughout this study. It had, on the average, an EC = 1.8 mmhos/cm, CO_3+HCO_3 = 11.38 me/l, Cl = 3.42 me/l, Ca+Mg = 4.22 me/l, Na^+ = 14.28 me/l, RSC = 7.16 me/l and SAR = 9.8. Composite soil samples from 0-15 and 15-30 cm depths were taken from three randomly selected sites per subplot before application of treatments and after harvesting each crop and were analyzed according to the standard methods (Black, 1965). Thirty to forty days old, 2-3 rice seedlings/hill, were transplanted without puddling the soil, while wheat was planted in "Wadd Water" (residual moisture from rice) each year by broadcasting about 100 kg seed/ha. The fertilizer rates, time of their application, sowing and harvesting dates are given in Table 1. All the other cultural practices were carried out uniformly in all the plots. Half the dose of N as urea and total P_2O_5 as single superphosphate were applied at the time of sowing/transplanting of crops. $ZnSO_4$ at 12.4 kg/ha was top dressed on 3.9. 1981, 25 9.1982 and 18.8.1983, respectively, while Diazinan 22.25 kg/ha was top dressed on 31.8.1981 to rice 1981 and on 15.9.1983 to rice crop of 1983. One spray of 2.47 kg Sevin-85/ha was carried out on 24.10.1983 against the infestation of leaf folder/roller, hairy caterpillar and rice stem borers. The ground water table remained within 1.5-2.2 meters during the course of study.

RESULTS AND DISCUSSION

Application of gypsum alone or in combination with subsoiling to the Gandhra sandy clay soil reduced the exchangeable sodium percentage (ESP) and pH of the saturated soil paste (pH_s) to values significantly lower than those of subsoiling and the control (Table 2), while all the treatments were equally effective for decreasing the electrical conductivity by the harvest of rice in 1983.

Table 1. *Fertilizer rates (kg/ha), dates of sowing and harvesting of crops on the Gandhra saline-sodic soil series*

S. No.	Crop	Sowing/ transplanting	N		P_2O_5	Harvesting
			Split I	Split II		
1.	Rice, IRRI-6 (1981)	3rd week of July, 1981	49	49 (28 8.1981)	99	2nd week of November, 1981
2.	Wheat, LU-26 (1981-82)	3rd week of December, 1981	74	74 (18.2.1982)	90	2nd week of May, 1982
3.	Rice, IRRI-6 (1982)	4th week of July, 1982	62	62 (5.9.1982)	99	2nd & 3rd week of November, 1982
4.	Wheat, LU-26S (1982-83)	2nd week of December, 1982	74	74 (20.1.1983)	111	2nd week of May, 1983
5.	Rice, KS-282 (1983)	1st week of August, 1983	74	49+49 (24.8.1983) and (15.9.1983)	111	3rd week of November, 1983

Table 2. *Role of various treatments in chemical reclamation of Gandhra saline-sodic soil series*

Seasons	Treatment means				Depth means		S .E.	
	Cont.	SS	Gyp	SS + Gyp	D_1	D_2	Treat.	Depth
				$EC_e \times 10^3$				
Original soil	14.6	15.0	17.2	13.2	14.8	15.2	—	—
Post rice, 1981	.8a	4.9ab	3.8b	5.6a	5.4	4.6	0.45*	0.33NS
Post wheat, 1981-82	.8	6.2	5.0	5.2	5.8	5.3	0.37NS	0.26NS
Post rice, 1982	6.8a	.4b	4.4c	4.8bc	5.6	5.1	0.25**	0.17NS
Post wheat, 1982-83	6.0a	.0ab	4.7b	4.6b	5.0	5.2	0.37*	0.26NS
Post rice, 1983	3.5	4.0	3.2	3.2	3.6	3.5	0.24NS	0.17NS
				Exchangeable sodium percentage				
Original soil	59.6	65.0	65 6	76 0	66.1	67.1	—	—
Post rice, 1981	45.1a	38.2b	30.6bc	31.1c	33.5b	39.0a	1.73**	1.22**
Post wheat, 1981-82	49.4a	45.2a	33.0b	32.6b	37.0b	43.2a	1.71**	1.21**
Post rice, 1982	37.6a	35.1a	23.2b	22.2b	26.7b	32.3a	1 49**	1.05**
Post wheat, 1982-83	42.2a	36.2b	24.6c	24.0c	28.6b	35.0a	1.74**	1.23**
Post rice, 1983	34.6a	33.0a	19.4b	16.3b	23.2b	28.4a	1.28**	0.91**
				pH_s				
Original soil	9.0	8.7	8.5	8.7	8.8	8.6	—	—
Post rice, 1981	8.6a	8.6a	8.2b	8.1b	8.2b	8.4a	0.08*	0.06*
Post wheat, 1981-82	8.8a	8.8a	8.4b	8.4b	8.5b	8.6a	0.04**	0.03*
Post rice, 1982	8.8a	8.8a	8.5b	8.4b	8.5b	8.8a	0.07*	0.05**
Post wheat, 1982-83	8.6a	8.6a	8.2b	8.2b	8.4b	8.5a	0.05**	0.03*
Post rice, 1983	8.6a	8.5a	8.2b	8.2b	8.3b	8.5a	0.08*	0.05**

Figures followed by the same letter (a) are not statistically different at P = 5%; * = Significant at P = 5%; ** = Significant at P = 1%; NS = Non-significant.

The reduction in ESP was more after rice in 1981 than after wheat in 1981-82. The reduction in ESP with subsoiling and simple leaching (control) was due to "valence dilution" as explained by Eaton and Sokoloff (1935), and also due to Ca + Mg supplied in tubewell irrigation water as well as in single superphosphate. Chemical soil improvement (pH & ESP) was slowed down significantly with increasing depth and time in all the treatments.

Chaudhry *et al.* (1982) concluded that gypsum at 100% GR+20 tons FYM/ha was the best treatment for the chemical soil improvement and growth, while growing *Leptochloa fusca* and 20 cm deep tillage were the least efficient treatments.

Application of gypsum alone or in combination with subsoiling improved paddy to straw ratio (Table 3), indicating grain formation to be more sensitive to salinity and especially to sodicity than the vegetative growth. This fact was also supported by the data on sterility percentage (not presented here) which was higher in the control and subsoiling treatments than gypsum treated plots. In fact, there was no paddy yield from the first rice crop in the untreated plots (control).

For wheat production the effectiveness of these treatments was very similar to that for rice crops although rice is considered to be a better crop during the reclamation of saline-sodic soils especially for the fine textured ones. Generally, both for chemical soil improvement and crop productivity, gypsum and subsoiling + gypsum treatments were statistically superior to subsoiling and control with non-significant differences among gypsum vs. subsoiling + gypsum and subsoiling vs. control. Rasmussen (1973) obtained similar results.

Reclamation of the Gandhra and similar soils is quite expensive, time consuming and difficult because of their fine texture and high ESP level (Table 3). During the present experiment, the cost of gypsum was recovered from the three crops sown after the application of the treatments (Table 4). After five crops, the gross income was the highest from subsoiling + gypsum treatment followed by gypsum, subsoiling and control, while the net income was higher from gypsum than subsoiling + gypsum treatment due to higher GR of the latter. The use of gypsum becomes much more attractive and economical if appreciation in the value of land due to reclamation is considered (Singh, 1980). The improved soil

Table 3. *Crop response to reclamation treatments on Gandhra saline-sodic soil series*

Treatment	Rice				Wheat			
	Irrigation[1] (cm)	TDM ——kg/ha——	Paddy	Paddy / Straw	Irrigation[1] (cm)	TDM ——kg/ha——	Grain	Grain / Straw
	IRRI-6 (1981)				LU-26 (1981-82)			
Control	162.7	34b	0	—	61.0	280b	64b	0.30
Subsoiling	174.7	1060b	314b	0.42	61.0	406b	105b	0.35
Gypsum	184.7	4568a	1618a	4.56	61.0	4363a	1399a	0.47
Subsoiling + Gypsum	190.7	4960a	1827a	0.68	61.0	3254a	1184a	0.57
S.E.	—	594.4**	218.7**	—	—	575.6**	193.6**	—
	IRRI-6 (1982)				LU-26S (1982-83)			
Control	121.7	1780b	838b	0.89	67.6	2235b	804b	0.56
Subsoiling	127.7	1821b	899b	0.98	67.6	2468b	1061b	0.74
Gypsum	169.7	3808ab	2054a	1.17	67.6	9380a	3769a	0.67
Subsoiling + Gypsum	162.7	5189a	2817a	1.18	67.6	9353a	3548a	0.61
S.E.	—	747.7*	308.8**	—	—	1219.9**	526.7	—
	KS-282 (1983)							
Control	137.6	6406	2598	0.68				
Subsoiling	146.6	6871	2763	0.68				
Gypsum	148.6	8178	4050	0.98				
Subsoiling + Gypsum	162.6	8925	3969	0.80				
S.E.	—	1568.6NS	527.9NS	—				

1. Irrigation water includes rainfall as well; figures followed by the same letter (s) are not statistically different at $P=5\%$. * = significant at $P=5\%$; ** = significant at $P=1\%$; NS = non-significant.

Table 4. *Economics of reclamation of Gandhra saline-sodic soil series*

Treatments	GR[1]	Expenditure (Rs/ha)	Income[2] (Rs/ha)						
			Rice (1981)	Wheat (1981-82)	Rice (1982)	Wheat (1982-83)	Rice (1983)	Gross	Net
Control	16.3	—	00	123	1,152	1,501	3,715	6,491	6·491
Subsoiling[3]	18.5	370	385	194	1,231	1,894	3,993	7,697	7,327
Gypsum[4]	18.8	5,640	2,017	2,436	2,798	6,872	5,724	19,847	14,207
Subsoiling+gypsum	22.7	7,180	2,238	2,001	3,836	6,548	5,644	20,267	13,087
Rate (Rs/40 kg)		Grain	49.00	58.00	53.00	64 00	55.00	—	—
		Straw	—	5.50	1.75	6 00	1.50	—	—

1. Gypsum requirement tons per hectare.
2 Calculated by multiplying the yield with the rates.
3. At the rate of Rs 370/- per hectare.
4. At the rate of Rs. 300/- per ton.

health as a result of amendment application may last 4-10 years (Elgabaly, 1970 and Obrejanu *et al.*, 1970) under average management. This further makes the use of gypsum favourable for the soil reclamation. Also, the marginal saline-sodic water (similar to one used in this study) can be used successfully for growing wheat and rice during reclamation. The use of such waters will increase the dissolution rate of applied gypsum and thus accelerate the reclamation of saline-sodic soils for reasonable crop yield.

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