ROLE OF BRACKISH WATER IN THE RECLAMATION OF SALT AFFECTED SOILS

By

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ABSTRACT

The specific objective of this study was to observe the role of brackish water for reclaiming salt affected land. Experiment was carried out on a saline-sodic, non-gypsiferous soil. The treatments tried were: T1) Irrigations with pure tubewell water; T2) T1+Sub-soiling upto 45 cm; T3) T1+Gypsum @ 100% GR of soil; and T4) T1+Pressmud @ 25 tons ha^{-1}.

Wheat-rice crop rotation was practiced. Recommended doses of NPK (134 – 56 - 31 kg ha^{-1}) was applied. The infiltration rate of the soil increased in all the treatments at the end of the experiment. Maximum increase of 100% was recorded with the application of gypsum @ 100% GR of the soil. The pH of the soil in all the treatments at most of the soil depths increased by 1 to 3 percent at the end of the experiment except at a few soil depths where, it remained static. However, at the end of the experiment the pH ranged between 9.1 to 9.7. The soil EC_e decreased in all the treatments at all the soil depths whereas, in treatment 1 and 4, EC_e increased by 35 percent and 5 percent only at 60-90 cm soil depth, respectively. The SAR decreased in all the treatments at all the soil depths. In the upper 0-15 cm soil depth the SAR in all the treatments had higher values than the safe limit (13 mmol $L^{-1})^{1/2}$. The maximum wheat grain yield was obtained with the application of gypsum @ 100% GR of soil and was followed by T4 (pressmud application @ 25 tons ha^{-1}) in both the years. Due to very high salinity/sodicity as well as the continuous application of hazardous water, wheat 2003-04 and rice 2003, 2004 and 2005 could not survive. Application of gypsum @ 100% GR of soil with brackish water irrigations proved the best treatment to get the maximum possible yield i.e. 1983 percent more than the irrigations with pure tubewell water application.

1. INTRODUCTION

1.1 Background

Pakistan is predominantly an agricultural country. Agricultural sector being the lynchpin of the country's economy, continues to be the single largest sector and a dominant driving force for the growth and development of the national economy. This sector provides 80 percent of the Pakistan's export earnings and employs about 48.4 percent of the total labour force. Agriculture also accounts for 24 percent to the gross domestic products (GOP, Economic Survey 2003).

Crop production has to be increased in order to meet the food, fibre and shelter requirements of the increasing population. The shortage of fresh water and dry spell in most of the cultivated areas are compelling the farmers to use poor quality groundwater

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for crop production. Soil salinity/sodicity is another jeopardy for our agriculture. Recent survey conducted by SMO, WAPDA (2004) showed that more than 30 percent of the irrigated area of the country is affected by the menace of salinity/sodicity. This climity adversely affects the production of most of the agricultural crops of our country. In order to obtain the maximum possible crop yields and reclamation of these soils, physical, chemical and biological amendments are being practiced depending upon the nature and extent of the problem. Similarly, brackish water of varying intensity of salinity and sodicity can be amended accordingly. It is the dire need of the country to ensure the safe use of brackish drainage water for crop production and soil reclamation. For this purpose, a field study was planned to find out the solution of these problems by using the amendments such as gypsum, pressmud, and sub-soiling in the Mona Project area, Tehsil Bhalwal, District Sargodha.

1.2 Objectives of the study

The main objectives of this study were:

- To test the effectiveness of different amendments alongwith brackish water to reclaim the salt affected soils.
- To evaluate the use of gypsum, pressmud and sub-soiling for crop production.

2. METHODOLOGY AND DATA COLLECTION

2.1 Establishment of the Experiment

2.1.1 Experimental Site

The study was carried out in an area of 0.15 ha under the command of a farmer's tubewell. The selected field was abandoned/barren before the start of the experiment. The soil was saline-sodic, non-gypsiferous in nature. The site was located on Sargodha - Sher Muhammad Wala Road, about 1 km towards West of Sargodha Road. The selection of the study site was based on the availability of desired quality of tubewell water, saline-sodic field, cooperative farmer and easy accessibility.

2.1.2 Duration of Field Trial

The study was started with the sowing of wheat crop 2003-04 and continued for six crop seasons therefore, the study completed with the harvest of rice crop 2006. The main study indicators including soil infiltration rate, pH, soil salinity/sodicity, irrigation water quality and yields of rice and wheat crops were monitored during the study period.

2.1.3 Treatments Evaluated

Rice-wheat crop rotation alongwith the application of organic and inorganic amendments were used to avoid the ill effects of brackish water on saline-sodic soil. The treatments tested were as under:

T1 = Irrigations with brackish tubewell water;

T2 = T1 + Sub-soiling upto 45 cm;

T3 = T1 + Gypsum @ 100% GR of soil; and

T4 = T1 + Pressmud @ 25 tons ha^{-1}.

Each treatment was quadruplicated.

2.1.4 Layout of the Experimental Field

The field was barren, abandoned and had sporadic and sparse stand of salt bushes. After clearance of saline vegetation the field was intensively ploughed and planked. The entire field was divided into 16 equal plots of 15 m x 4.5 m (148th of a hectare). Strong bunds were constructed within the plots to avoid the overflow of irrigation water and interference of the treatments and also to facilitate the irrigation process. Layout plan of the experimental field is shown in Figure 2.1.

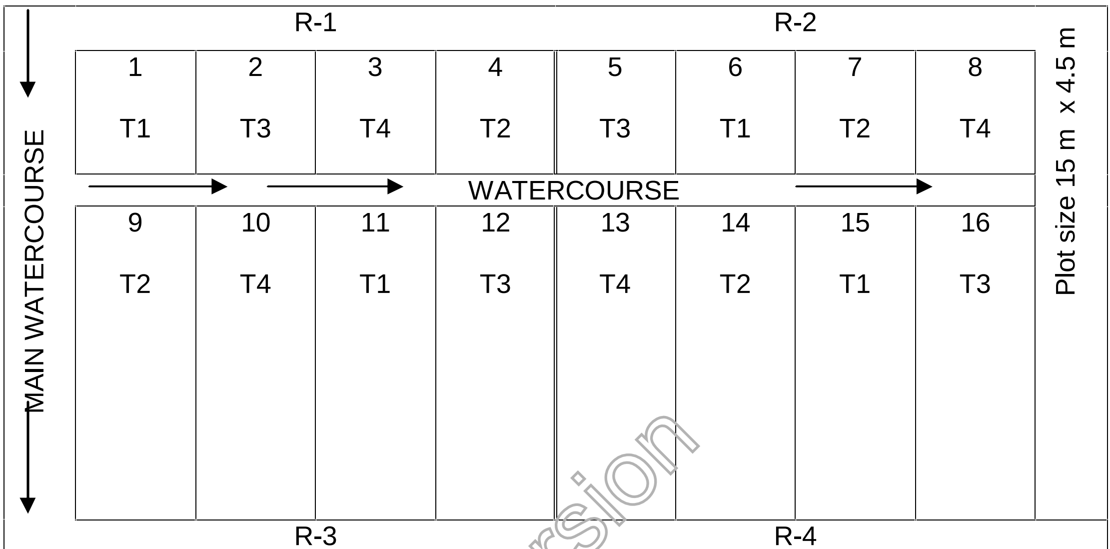

Figure 2.1 Layout Plan of the Experimental Field

2.2 Data Collection

2.2.1 Soil Texture

The soil samples were collected from 0-15, 15-30, 30-60 and 60-90 cm soil depths before the start of the experiment to determine the soil texture and chemical analysis. These samples were analysed in the Soil and Water Testing Laboratory, Mona Project, according to standard procedures of Bouyoucos, 1951. The physical properties of the experimental field are given in Table 2.1.

Table 2.1 Physical Properties of the Experimental Field

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class
0-15	26	42	32	Clay loam
15-30	18	48	34	Silty clay loam
30-60	08	50	42	Silty clay
60-90	04	52	44	Silty clay

2.2.2 Soil Infiltration Rate

The infiltration rate of each plot was measured in the beginning and just after the harvesting of each wheat crop by "Standard Ring Method" (Aronovici, 1955). The infiltration ring was hammered in the soil upto 15 cm depth and about 8 cm water was ponded in the ring. The readings were taken after three hours and mean of these readings was used to evaluate the infiltration rate of the soil under different treatments.

2.2.3 Quality of Irrigation Water

The tubewell water was used for irrigation according to the water requirements of both the crops. The quality of the tubewell water is given in Table 2.2.

Table 2.2 Quality of Irrigation Water

pH	TDS (ppm)	SAR $(mmolL^{-1})^{1/2}$	RSC (meL^{-1})
8.3	1779	23.2	4.8

2.2.4 Soil Salinity and Sodicity

The first soil sampling was done before the start of the experiment and later on after the harvest of each crop from 0-15, 15-30, 30-60 and 60-90 cm soil depths. Each sample was composited from three locations of each plot. These samples were analysed in the laboratory for pH, Electrical Conductivity of Saturated Extract (EC_e) and Sodium Adsorption Ratio (SAR) determinations. The chemical properties of the experimental field are given in Table 2.3.

Table 2.3 Chemical Properties of the Experimental Field

Depth (cm)	EC_e $(dS\ m^{-1})$	SAR $(mmol\ L^{-1})^{1/2}$
0-15	6.8 - 13.1	38.9 - 54.6
15-30	6.1 - 8.3	23.4 - 39.0
30-60	3.2 - 4.9	12.4 - 26.7
60-90	2.2 - 4.0	9.0 - 25.6

2.2.5 Sowing of Crops/Cultural Operations

Following the rice-wheat crop rotation, Super Basmati variety of rice and wheat variety of Inqlab-91 were sown at their respective time of sowing. Cultural practices carried out and inputs applied including ploughings, plankings, seed, irrigation, fertilizer, insecticide, weedicides and hoeing etc. are narrated in Table 2.4. Full dose of phosphorus and potash and half nitrogen was applied at the time of sowing whereas, the rest half nitrogen was applied with the 2nd irrigation to wheat crop and 45 days after transplanting of rice seedlings.

Table 2.4 Cultural Operations Carried Out at the Experimental Field

Operation	No./Quantity	
	Rice	Wheat
Ploughing	6	6
Planking	2	3
Date of sowing nursery	Last week of May	-
Seed rate	25 kg ha^{-1}	175 kg ha^{-1}
Date of transplanting/sowing	First week of July	2nd fortnight of November
Nitrogen	134 kg ha^{-1}	134 kg ha^{-1}
Phosphorus	56 kg ha^{-1}	56 kg ha^{-1}
Potash	31 kg ha^{-1}	31 kg ha^{-1}
Irrigations (No)	13	4

Rainfall (mm)	275	150

2.2.6 Yield Estimation

The crop yields were estimated on the whole plot basis and computed as yield kg ha^{-1}.

3. RESULTS AND DISCUSSION

This section deals with the observations and discussion about the field trial.

3.1 Changes in Soil Infiltration Rate

Initial infiltration rate of the soil was recorded before the start of the experiment when the field was lying barren before Rabi crop (wheat 2003-04). Subsequent infiltration rates were taken after the harvest of every Rabi crop i.e. in the month of May. The data given in Table 3.1 reveal that there was substantial increase in the soil permeability showing the improvement in the soil properties with the passage of time. The effect of different treatments on the soil infiltration rate is shown in Figure 3.1.

Table 3.1 Historic Soil Infiltration Rate

(mm hr^{-1})

Treatment	Year				% increase over T1
	2003 (initial)	2004	2005	2006	
T1 Irrigation with pure tubewell water	3	4	4	4	-
T2 T1 + Sub-soiling upto 45 cm	3	5	5	6	50
T3 T1 + Gypsum @ 100% GR of soil	4	7	8	8	100
T4 T1 + Pressmud @ 25 tons ha^{-1}	4	6	7	7	75
Average	3.5	5.5	6.0	6.3	57.5

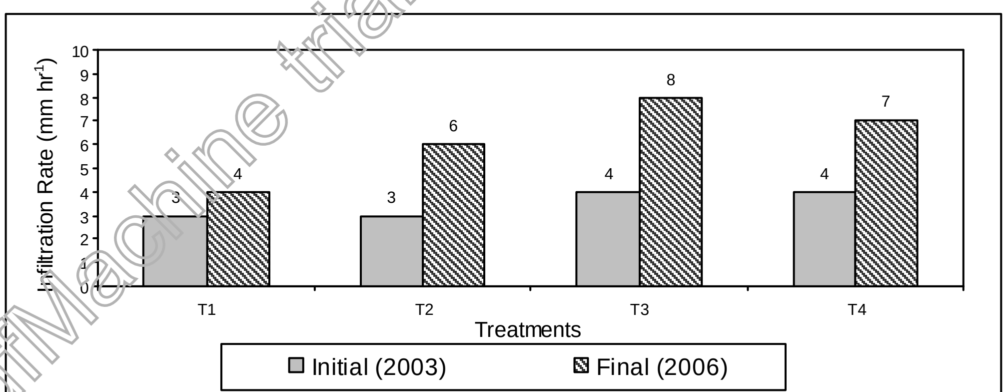

Figure 3.1 Effect of Different Treatments on Infiltration Rate of the Soil

The maximum increase in the infiltration rate of the soil was recorded in treatment 3 where gypsum was applied @ 100% GR of soil. The infiltration rate in this treatment was 100% more than the control. However, the infiltration rate of the treatment 2 and 4 was

50 and 75 percent more respectively than treatment 1. Treatment 2 did not show any improvement in the soil properties in the year 2005 as compared to 2004 which might be due to the greater cohesion of the clay particles. The average increase in the infiltration rate of the soil in the season 2006 depicted the improvement in the soil properties. However, the average increase in the infiltration rate was recorded as 57.5% over the treatment 1 and 80% increase than the average infiltration rate of the initial year. The application of marginal quality irrigation water alongwith gypsum @ 100% GR of soil proved the best treatment for the improvement in the soil properties. Haider et al. (1978) reported that infiltration rate of soil was significantly increased with the application of gypsum @ 100% GR of soil.

3.2 Changes in pH of the Soil

The effect of different treatments on the pH of the soil is shown in Table 3.2. The initial pH i.e. before the start of the experiment (Pre Wheat 2003-04) and final pH (Post Rice 2006) have been compared to observe the effect of treatments on the pH of the soil. The initial pH of all the treatments ranged between 9.4 to 9.5, 9.2 to 9.5, 9.2 to 9.3 and 9.0 to 9.1 at the soil depths of 0-15, 15-30, 30-60 and 60-90 cm respectively. After the harvest of rice crop 2006, the final pH ranged between 9.5 to 9.7, 9.3 to 9.5, 9.3 to 9.4 and 9.1 to 9.2 at the soil depths of 0-15, 15-30, 30-60 and 60-90 cm respectively. The data predicted that the pH increased in all the treatments at 0-15 cm soil depth except treatment 2 where it remained the same but at the depth of 15-30 cm the increase was more in sub-soiling treatment as compared to the other treatments. On overall basis, the change in pH at the time of final analysis ranged between nil to 3 percent. The initial and final pH of the experimental field remained more or less the same which is not suitable for the successful growth of the agricultural crops.

Table 3.2 Effect of Different Treatments on pH of the Soil

Treatment	Soil depth (cm)	pH: Pre-wheat 2003-04 (Initial)	pH: Post-rice 2006 (Final)	Percent increase over the initial
T1 Irrigation with pure tubewell water	0-15	9.4	9.7	+ 3
	15-30	9.3	9.3	-
	30-60	9.3	9.3	-
	60-90	9.1	9.2	+ 1
T2 T1 + Sub-soiling upto 45 cm	0-15	9.5	9.5	-
	15-30	9.2	9.5	+ 3
	30-60	9.3	9.4	+ 1
	60-90	9.0	9.2	+ 2
T3 T1 + Gypsum @ 100% GR of soil	0-15	9.5	9.6	+ 1
	15-30	9.5	9.5	-
	30-60	9.3	9.3	-
	60-90	9.1	9.2	+ 1
T4 T1 + Pressmud @ 25 tons ha^{-1}	0-15	9.5	9.7	+ 2
	15-30	9.4	9.5	+ 1

	30-60	9.2	9.3	+ 1
	60-90	9.1	9.1	-

3.3 Changes in Electrical Conductivity (EC_e) of the Soil

The electrical conductivity (EC_e) of the soil profile is based on the movement of soluble salts with water in the soil matrix. If the movement of water is restricted by soil crusting, hardening of soil layers, inadequate drainage etc. the soil salinity is developed and as such EC_e is increased and vice versa. On the other hand if the soil environment facilitates proper leaching, the EC_e could be managed even with marginal quality irrigation water. The tubewell water used for irrigation had the EC_e 2.8 dS m^{-1} and TDS 1779 ppm.

To determine the detailed soil salinity and sodicity status of the study field, composite soil samples were collected from 0-15, 15-30, 30-60 and 60-90 cm soil depths and analysis was performed in the Soil and Water Testing Laboratory of MREP. The data provided in Table 3.3 indicate that EC_e of the experimental field was much higher at the time of initial or pre-wheat 2003-04 season because the field was lying barren before the start of the experiment. The EC_e in the initial season varied from 10.7 to 13.0, 6.1 to 8.3, 3.4 to 4.9 and 2.2 to 3.1 dS m^{-1} in all the treatments at the soil depths of 0-15, 15-30, 30-60 and 60-90 cm respectively.

The maximum decrease (73 percent) in EC_e was recorded at 0-15 cm soil depth in the treatment where sub-soiling was done followed by the treatment where only pure tubewell water was applied (Table 3.3 & Figure 3.2). At 15-30 cm soil depth, the decrease was again the highest (72 percent) in the treatments where pure tubewell water alone and with pressmud @ 25 tons ha^{-1} were applied (Fig. 3.3). At 30-60 cm soil depth, the maximum decrease (51 percent) was also observed in pressmud application treatment (Figure 3.4). At the lowest depth (60-90 cm) the decrease in EC_e was the maximum (45 percent) in the treatment 3 where gypsum @ 100% GR of soil was applied (Figure 3.5). At this depth the increase in EC_e in untreated tubewell water alone (35 percent) and pressmud application (5 percent) was observed.

Table 3.3 Changes in EC_e of the Experimental Field after the Study

Soil depth (cm)	Treatment	EC_e (dS m^{-1}) Initial	Final	Percent change over the initial
0-15	T1	13.0	3.9	- 70
	T2	12.2	3.3	- 73
	T3	10.7	4.7	- 56
	T4	10.8	5.2	- 52
15-30	T1	7.5	2.1	- 72
	T2	7.6	2.3	- 70
	T3	6.1	2.1	- 66
	T4	8.3	2.3	- 72
30-60	T1	4.9	4.1	-16
	T2	3.5	2.2	- 37
	T3	3.4	2.2	- 35
	T4	4.3	2.1	- 51
60-90	T1	3.1	4.2	+ 35
	T2	3.0	2.3	- 23

	T3	2.9	1.6	- 45
	T4	2.2	2.3	+ 5

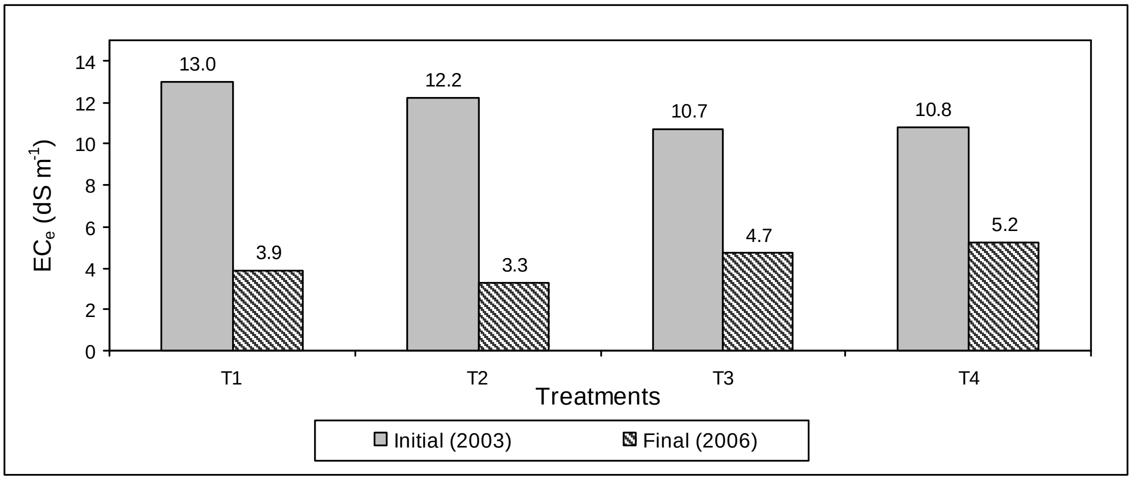

Figure 3.2 Effect of Different Treatments on EC_e at 0-15 cm Soil Depth

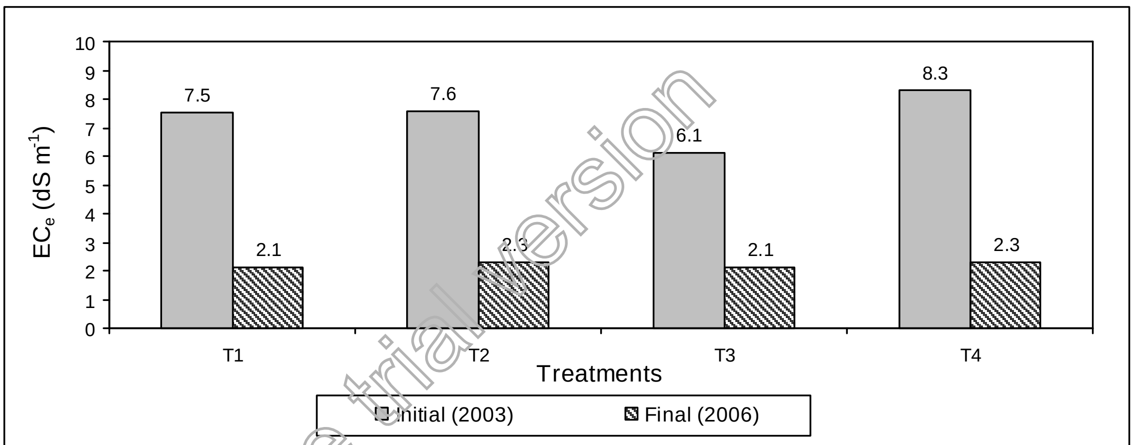

Figure 3.3 Effect of Different Treatments on EC_e at 15-30 cm Soil Depth

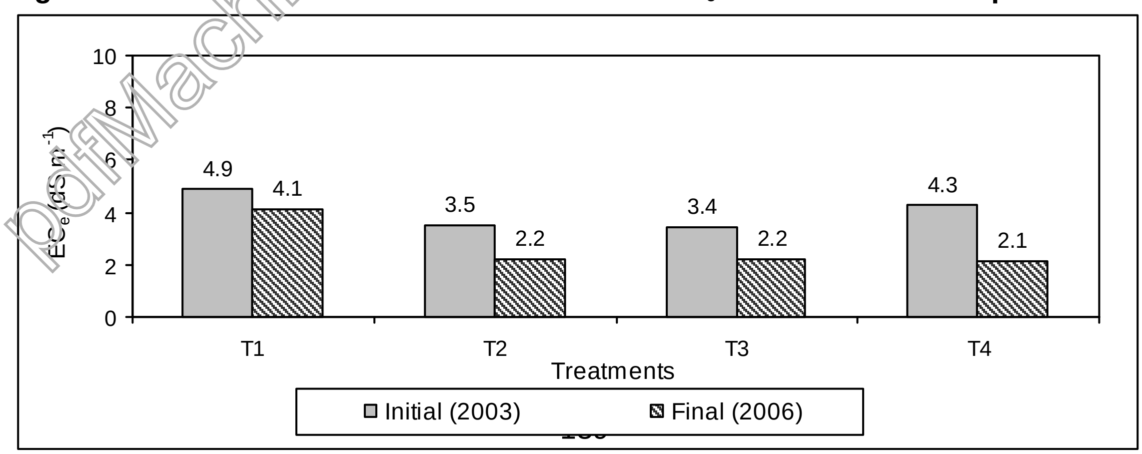

Figure 3.4 Effect of Different Treatments on EC_e at 30-60 cm Soil Depth

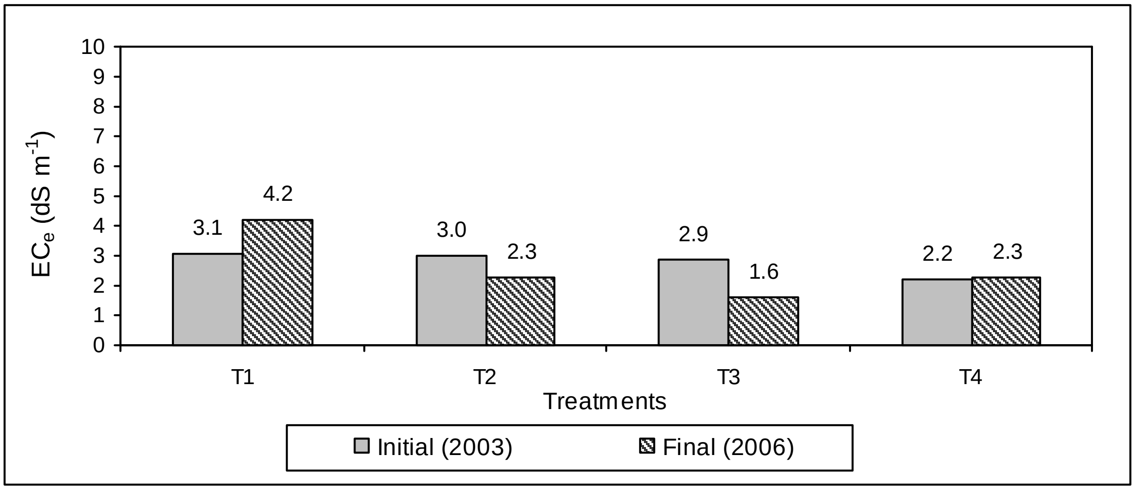

Figure 3.5 Effect of Different Treatments on EC_e at 60-90 cm Soil Depth

3.4 Changes in Sodium Adsorption Ratio (SAR) of the Soil

The effect of different treatments on soil sodicity has been shown in Table 3.4. The initial analysis of the experimental field indicates that the SAR of the experimental soil ranged between 38.9 to 53.8 (mmol $L^{-1})^{1/2}$ at 0-15 cm soil depth, 23.4 to 35.1 (mmol $L^{-1})^{1/2}$ at 15-30 cm soil depth, 12.4 to 19.8 (mmol $L^{-1})^{1/2}$ at 30-60 cm soil depth and 9.1 to 11.7 (mmol $L^{-1})^{1/2}$ at 60-90 cm soil depth in all the treatments under study. A tremendous decrease in the value of SAR in all the treatments at all the soil depths was recorded after the harvest of the first season crop (wheat 2003-04) because the soil was primarily barran and the salts leached down to the deeper layers with the application of water.

The comparison of initial and final values of SAR of all the treatments at different depths is narrated in Table 3.4 and Figure 3.6, 3.7, 3.8 and 3.9. The table shows that there was decrease in SAR values ranging between 6 to 64 percent in all the treatments at all the soil depths. The minimum decrease of 6 percent was noted at 60-90 cm soil depth in the treatment where pure tubewell water was used lone and the maximum decrease of 64 percent was recorded in sub soiling treatment at 0-15 cm and in pressmud treatment at 15-30 cm soil depth. In general the maximum decrease in SAR values was observed at 0-15 and 15-30 cm soil depths of all the treatments. At the end of the study the SAR values were much more than the safe limit at 0-15 cm soil depth in all the treatments whereas, values remained more or less within the safe limit (13 mmol $L^{-})^{1/2}$ at the lower depths. Haider et al. (1976) reported 29 to 72 percent decrease in SAR in pressmud treatment plots as compared with 5 to 32 percent in control plots at 0-15 cm soil depth whereas, Waheed (1971) found that leaching with gypsum efficiently brought down the

ESP.

Table 3.4 Changes in SAR of the Experimental Field after the Study

Soil depth (cm)	Treatment	SAR (mmol $L^{-1})^{1/2}$		Percent decrease over the initial
		Initial	Final	
0-15	T1	42.1	22.0	48
	T2	53.8	19.3	64
	T3	38.9	27.0	31
	T4	43.2	27.5	36
15-30	T1	26.2	11.5	56
	T2	25.2	15.3	39
	T3	23.4	11.5	51
	T4	35.1	12.8	64
30-60	T1	19.8	10.4	47
	T2	13.6	12.3	10
	T3	12.4	11.5	7
	T4	15.1	10.3	32
60-90	T1	11.7	11.0	6
	T2	10.5	9.1	13
	T3	11.7	9.0	23
	T4	9.1	8.4	8

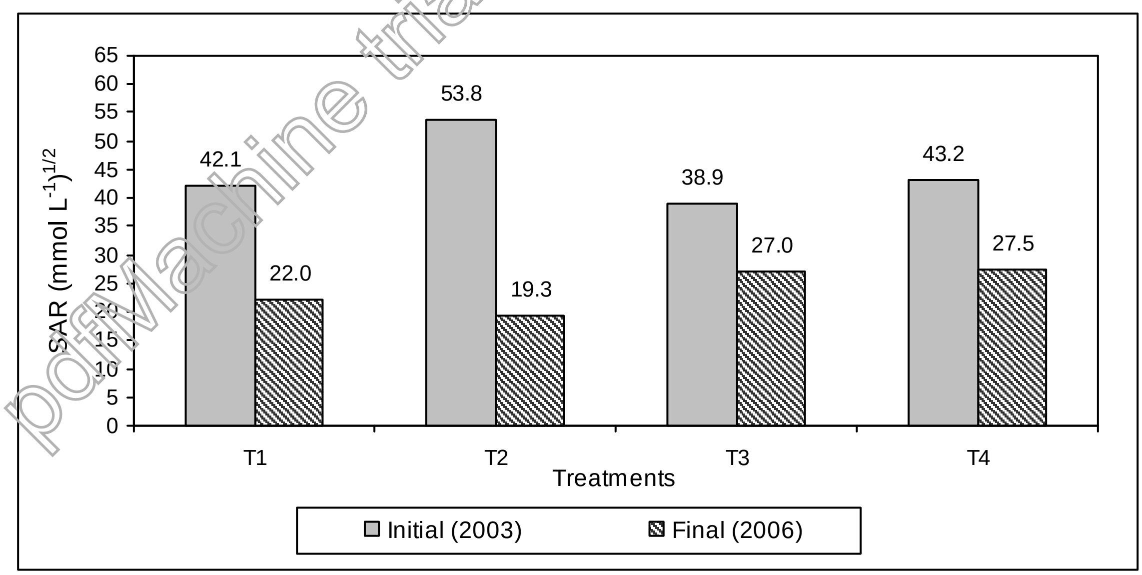

Figure 3.6 Effect of Different Treatments on SAR at 0-15 cm Soil Depth

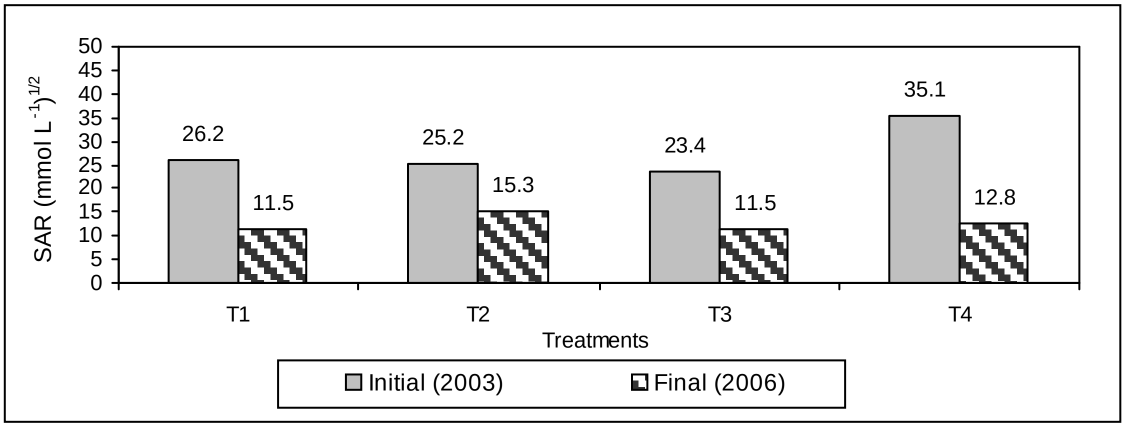

Figure 3.7 Effect of Different Treatments on SAR at 15-30 cm Soil Depth

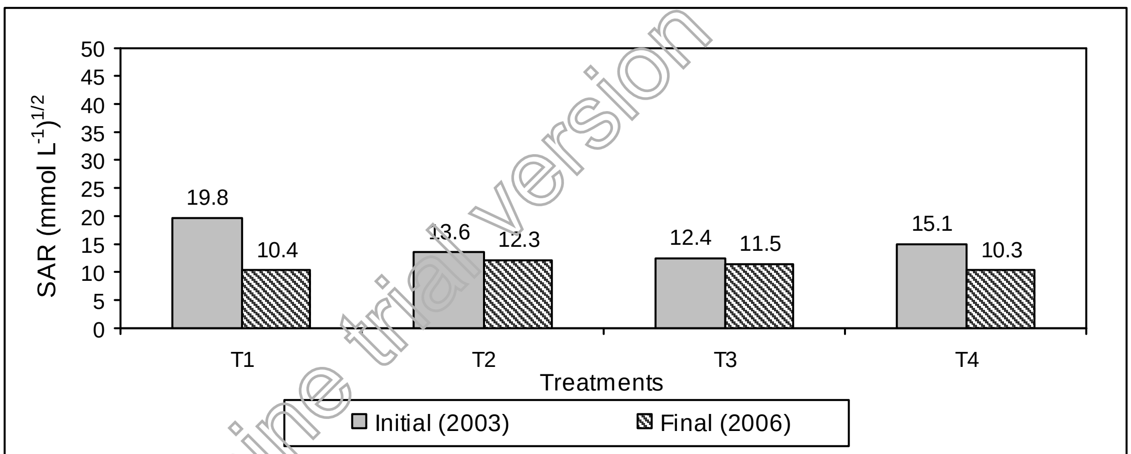

Figure 3.8 Effect of Different Treatments on SAR at 30-60 cm Soil Depth

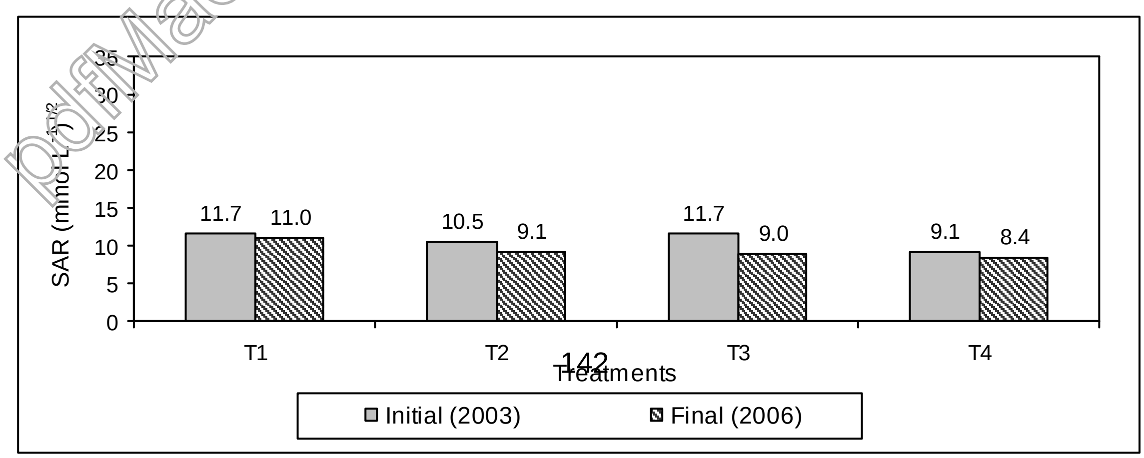

Figure 3.9 Effect of Different Treatments on SAR at 60-90 cm Soil Depth

3.5 Crop Yield

Due to high salinity and sodicity of the soil and continuous application of marginal quality water, wheat 2003-04 and rice 2004, 2005 and 2006 could not survive. The salts rapidly moved upward due to evaporation during the dry period (hot spell of weather) therefore, the plants scorched in all the treatments. During Rabi 2004-05, the wheat crop stand was patchy in all the treatments. The yield of wheat crop for the year 2004-05 and 2005-06 is given in Table 3.5.

The data reveal that the yield got by treatment-1 in both the seasons was the least (144 kg ha^{-1} and 48 kg ha^{-1} respectively).

Table 3.5 Effect of Different Treatments on the Wheat Grain Yield

(kg ha^{-1})

Treatment	Wheat grain (2004-05)	Wheat grain (2005-06)	% increase over control
T1 Irrigation with pure tubewell water	144	48	-
T2 T1 + Sub-soiling upto 45 cm	172	250	421
T3 T1 + Gypsum @ 100% GR of soil	502	1000	1983
T4 T1 + Pressmud @ 25 tons ha^{-1}	287	321	569

The reason for lowest yield in treatment 1 was that only the marginal quality tubewell water was used for irrigation purpose and no amendment was used. The application of gypsum @ 100% GR of soil gave the highest yield in both the seasons i.e. 502 kg ha^{-1} and 1000 kg ha^{-1} respectively. This treatment yielded 1983 percent more than the control and was almost double in the year 2005-06 as compared to the previous year (2004-05). It was followed by treatment 4 where pressmud @ 25 tons ha^{-1} was applied in both the seasons and was about 43% and 68% less than the yield of treatment 3 in the respective years (Figure 3.10). The general stand of the wheat crop by the treatment 3 and 4 for the year 2005-06 is clear from plate 1 and 2 respectively.

The wheat grain yields got by all the treatments in Rabi 2005-06 were almost in the same order as in Rabi 2004-05. The application of gypsum @ 100% GR of soil showed the improvement in the grain yield of saline-sodic soils. The grain yield obtained by gypsum application treatment was about 212 percent more as compared to pressmud application treatment in the last season of the study period.

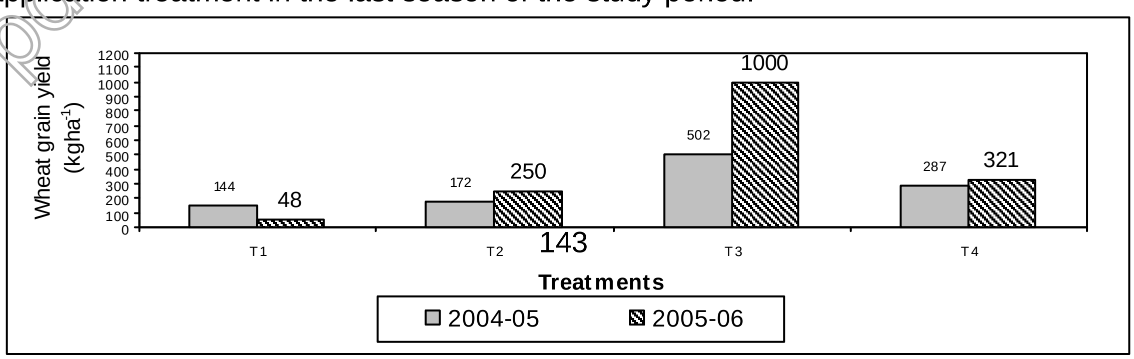

Figure 3.10 Effect of Different Treatments on the Wheat Grain Yield.

4. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations have been drawn on the basis of the field data of six crop seasons i.e. Rabi 2003-04 to Kharif 2006. The conclusions and recommendations are mainly based on soil characteristics such as salinity, sodicity, pH, soil permeability and crop yield. These are narrated as follows:

4.1 Conclusions

- None of the treatments showed any positive impact on the pH of the soil at any soil depth.
- Infiltration rate of the soil increased with the application of all the treatments but EC_e and SAR of the soil decreased in all the treatments at all the soil depths.
- Maximum increase in infiltration rate of the soil (100% more than the control) was with the treatment 3 where gypsum @ 100% GR of soil was applied.
- The decrease in SAR and EC_e was rapid initially in almost all the treatments at all the soil depths.
- Maximum wheat grain yield was obtained with the application of gypsum @ 100% GR of soil in both the seasons.
- Rice crop showed more susceptibility towards EC_e and SAR of the soil than wheat crop.

4.2 Recommendations

- Gypsum should be broadcast on the surface of the soil @ 100% GR of soil for rapid reclamation and the field should frequently be irrigated.
- Pressmud, the cheaper source of organic matter than gypsum can successfully be used for the reclamation of saline-sodic soils.

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