MANAGEMENT OF HIGH RSC WATER IN SALT AFFECTED CONDITIONS UNDER RICE-WHEAT CROPPING SYSTEM

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Abstract

Use of saline sodic / sodic water for amelioration of salt affected soil or to irrigate the water requirement of crops has become vital for crop production. More area may be cultivated by irrigating with saline sodic or sodic water in semi arid to arid regions after proper management. Poor quality water can be used for crop production on a variety of soil after following the management practices like amendments and cultivation of salt tolerant crops. The deteriorated physical properties (bulk density, porosity, permeability, infiltration and hydraulic conductivity) due to such unfit water might be improved by proper management. Field studies were carried out at farmer field (Shirbagha) to assess the effect of brackish water on rice-wheat rotation with different management practices. Results revealed that the highest biomass and grains / paddy yield was obtained with canal water with 100% GR of soil followed by brackish water + 100 % GR of soil + GR of irrigation water on the basis of RSC. Results regarding pH_s, EC_e and SAR of soil at both soil depths (0-15) and (15-30 cm) showed that these parameters were reduced with (canal water + 100 % GR of soil) followed by (brackish water + 100 % GR of soil + GR on the basis of RSC of irrigation water and (Brackish water + 100 % GR of soil) and least reduction in pH_s, EC_e and SAR of soil was observed in control treatment.

Keywords: Brackish water, management practices, GR of soil, on the basis of RSC of water, rice-wheat

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Introduction

Pakistan has the largest canal system but limited supply in rivers is insufficient to irrigate the cropped area. The reduced fresh water supplies from canals have influenced the crop productivity and yields and dependence on underground water has been increased. Intensive cropping sequence to feed the ever increasing population of the country required more sources of water for agriculture. It is speculated that deficit in irrigation requirement might be reached 107 million acre feet up to 2013 in Pakistan and additional water is direly needed from other source that might be the underground water [7]. Unfortunately, it is estimated that about >70% of underground water have high EC and RSC [4, 14]. Use of unfit underground water for irrigation for crop production without management practices might enhance the salinity / sodicity hazards of soils [15]. Sole dependence on underground water deteriorates the soil chemical and physical properties (pH, EC_e, SAR, aeration, permeability, hydraulic conductivity and infiltration rate) [12]. Underground water having high soluble salts (EC) and dominance of Na^+ with carobonates or bicarbonates (SAR / RSC) affected the soil health and plant growth negatively. Continuous irrigation with high EC / SAR / RSC water results in accumulation of soluble salts and especially Na dominance on exchange sites damages the soil aggregation due to dispersion / clogging of pores and provide adverse environment for plant growth and thus crop productivity [8]. Although crops having different tolerance potential or threshold limits to saline / saline-sodic / sodic water yet the higher EC / SAR / RSC values than permissible limits adversely affected the crop growth [10, 12]. Comprehensive care and planned management practices should be followed to minimize the deleterious effects of unfit ground

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water. The menace of unfit ground water can be reduced by using management practices along with amendments either inorganic like gypsum, H_2SO_4 etc or organic like manures FYM, poultry manure, press mud etc. [13, 16, 20]. Keeping in view these considerations, the field studies were conducted to manage the brackish water at farmer field with different approaches in rice-wheat cropping system.

Materials and Methods

Three years experimentation was carried out at farmer field Shirbagha district Hafizabad district. Site was selected with brackish tube well and available canal water. Field was leveled, prepared and gypsum was applied as per treatment on a permanent layout followed by leaching with canal and brackish tube well water. Gypsum requirement (GR) was calculated on the basis of RSC of irrigation water and applied before transplantation of rice. Recommended dose of the fertilizer applied to rice was 110-90-70 and 120-90-70 NPK kg ha^{-1} for wheat. The treatments were tested in randomized complete block design (RCBD) are control (T_1), canal water + 100 % G.R. of soil (T_2), Brackish water + 100 % G.R of soil (T_3) and Brackish water + 100 % G.R of soil + GR of irrigation water on the basis of RSC (T_4). Soil and water samples were collected before initiation of experiment and after harvesting of each crop and analyzed for pH_s, ECe, SAR and G.R. Soil analysis for pH_s, EC_e, SAR, and G R and water analysis was carried out by the methods described by U. S. Salinity Lab. Staff [19]. Gypsum requirement of irrigation water was determined on RSC basis as reported by Eaton [6]. Soil texture was determined using hydrometer method Bouyoucos [3] while soil bulk density was measured by drawing undisturbed cores from 10-15 and 20-25 cm soil depths [2]. Data regarding yield components of rice and wheat were recorded and subjected to soil analysis using standard procedures as described by Steel *et al.* [18]. The differences among the treatment means were compared by the Duncan's multiple range tests (DMR) [5].

Results and Discussion

Field experiments following rice-wheat rotation were conducted at Shirbagha district Hafizabad to assess the brackish water at farmer fields. Soil samples were analyzed before initiation of experiment and after harvesting of each crop for pH_s, EC_e, and SAR is given in Table 1. Soil was sandy loam and moderately salt affected (0-15 cm) having pH_s: 9.12, EC_e: 7.60 dS m^{-1}, SAR: 77.0 (mmol $L^{-1})^{1/2}$ and GR 3.78 t $acre^{-1}$. Soil was sandy loam (15-30 cm) having pH_s: 8.99, EC_e: 5.95 dS $m^{-1}$and SAR: 59.92 (mmol $L^{-1})^{1/2}$. The bulk density was 1.69 Mg m^{-3} (10-15 cm) and 1.62 Mg m^{-3}(20-25 cm). The irrigation water used for rice-wheat cultivation was unfit for irrigation due to high RSC values (8.30 $mmol_c$ L^{-1}).

The data regarding biomass / paddy yield (Rice-2009) and soil analysis at harvest are presented in Table 2. Results revealed that biomass and paddy yield was increased significantly with the application of gypsum. The highest biomass was obtained (8.75 Mg ha^{-1}) with T_4 (brackish water + GR of soil and on the basis of RSC of irrigation water) while the maximum paddy yield (1.37 Mg ha^{-1}) with T_2 (canal water +100 % GR of soil). However T_4 (brackish water + GR of soil and on the basis of RSC of irrigation water) remained statistically non-significant with T_2 and T_3 for biomass and paddy yield than control i.e. 4.14 and 0.71 Mg ha^{-1}. The biomass and wheat grain yield (Wheat 2009-10) presented in Table 3 showed that canal water +100 % GR of soil (T_2) was found statistically better than T_3 (brackish water + 100 % GR of soil) for producing more biomass and grains (3.42, 1.33 Mg ha^{-1}). However, brackish water + GR of soil and on the basis of RSC of irrigation water (T_4) remained statistically non significant with T_2 and T_3 for biomass and grain yield. Post harvest soil analysis (0-15 cm) after harvesting of rice showed that soil pH, EC_e and SAR reduced due to application of gypsum and leaching. Soil pH_s, EC_e and SAR in the lower depth (15-30 cm) was increased during reclamation process. However, brackish water + 100% GR of the soil and brackish water + GR of soil+ irrigation water not only helped in reclamation of saline sodic soil but also in compensating the deleterious effect of brackish water for crop production and remained at par with T_2 (canal water +100% GR of soil).

The data regarding biomass / paddy yield (Rice-2010) and soil analysis at harvest are presented in Table 4. The highest biomass and paddy yield was obtained (11.24 and 2.0 Mg ha^{-1}) with canal water +100 % GR of soil followed by brackish water + GR of soil and on the basis of RSC of irrigation water i.e. 9.86 and 1.85 Mg ha^{-1} than control i.e. 5.48 and 0.84 Mg ha^{-1}. The biomass and wheat grain yield (Wheat 2009-10) presented in Table 5 showed that canal water +100 % GR of soil (T_2) was found statistically better than T_3 (brackish water + 100 % GR of soil) for producing more biomass and grains (4.32, 1.78 Mg ha^{-1}) and statistically at par with brackish water + GR of soil and RSC of irrigation water i.e. 4.16 and 1.68 Mg ha^{-1} than control i.e. 1.91 and 0.65 Mg ha^{-1}. Post harvest soil analysis (0-15 cm) showed that soil pH, EC_e and SAR reduced due to application of gypsum and leaching. Soil EC_e was almost at par with canal water (4.22 dSm^{-1}) and brackish water + GR of soil and irrigation water (4.26 dSm^{-1}). Soil pH_s, EC_e and SAR in the lower depth (15-30 cm) was increased than upper soil depth (0-15 cm). However, the application of gypsum on the basis of soil and also on the basis of irrigation water improved soil health status by reducing the EC_e and SAR and canal water has surpassed the soil health than brackish water with gypsum application. Data regarding biomass / paddy yield (Rice-2011) and soil analysis at harvest are presented in Table 6. The highest biomass and paddy yield was obtained (13.20 and 2.63 Mg ha^{-1}) with canal water +100 % GR of soil followed by brackish water + GR of soil and on the basis of RSC of irrigation water i.e. 11.43 and 2.41 Mg ha^{-1}. The biomass and wheat grain yield (Wheat 2010-11) presented in Table 7 showed that canal water +100 % GR of soil produced i.e. 4.97 and 2.22 Mg ha^{-1} and statistically at par with brackish water + GR of soil and RSC of irrigation water i.e. 4.83 and 2.12 Mg ha^{-1}. Post harvest soil analysis (0-15 cm) showed that soil EC_e and SAR was reduced due to gypsum application i.e.

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4.05 and 18.54 with canal water, 4.22 and 21.63 with brackish water+ GR of soil and 4.16 dS m^{-1} and 19.51 with Brackish water + 100 % G.R of soil and GR of irrigation water on the basis of RSC. Soil pH_s, EC_e and SAR in the lower depth (15-30 cm) was again increased than upper soil depth. However, the application of gypsum on the basis of soil and also on the basis of RSC of irrigation water improved soil status by reducing the EC_e and SAR.

Results of the three year experiments clearly showed the significance of canal and brackish water with gypsum application to sustain the yield of rice wheat crops. Results clearly demonstrated that canal water in combination with gypsum application on basis of soil GR proved better followed by brackish water with gypsum application on basis of GR of soil and water on RSC basis. Canal water usage with gypsum application @ 100% GR of soil proved better than the brackish water with 100% GR of soil and water on RSC basis and improved the crop yields. Poor quality water can be used for crop production on a variety of soils provided proper management practices coupled with chemical amendments are gypsum, FYM and salt tolerant crops [13]. Saifullah *et al.* [16] concluded that gypsum (25-50% of GR) with or without FYM / press mud along with recommended doses of fertilizer must used to sustain the productivity of rice-wheat system in areas having sodic ground water for irrigation [20]. Results are supported by the findings of Zaka [22] and Haq *et al.* [9] that application of gypsum on soil basis proved better if irrigation source is normal. Application of brackish water with the gypsum or other amendments on water RSC basis may further improve the crop yields. The improvement in soil parameters might be due to the amendments dissolution and root action in the soil during the crop growth [9, 20, 21, 22]. Azhar *et al.* [1] also reported that marginal to inferior quality of ground water might be due to higher EC, SAR, RSC, Na:Ca ratio and Mg:Ca ratio. Management of poor quality ground water by soil-water-crop management practices may promote the soil health and ultimately the crop yields. Sharma and Minhas [17] proposed that the management practices of irrigation water, amendments and cultural practices should be carried out to sustain the crop yields. Mehboob *et al.* [11] concluded that to maintain the soil health, the irrigation of unfit ground water should be checked carefully. However, if it is unavoidable to use the unfit underground water for irrigation purpose, then it must be used with proper management practices like land leveling, deep chiseling, flushing of soil profile and irrigation scheduling coupled with application of gypsum, acids / organic amendments like farm yard manure, poultry manure, press mud etc.

Studies clearly demonstrated that use of gypsum with canal and tube well water improved the soil for rice and wheat cropping system. Gypsum application on salt affected soils and having brackish water to irrigate must be carried out by applying gypsum not only on gypsum requirement of soil but also on the basis of RSC of water. The RSC of irrigation of water must be taken into account for soil health and crop yields

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Table 1. Initial Soil Status at Shirbagha.

<table>
<tr><th colspan="2">Parameters</th><th>Units</th><th colspan="2">Soil Depth (0-15 cm)</th><th>Soil Depth (15-30 cm)</th></tr>
<tr><td colspan="2">Soil Texture</td><td></td><td colspan="2">Sandy Loam</td><td>Sandy Loam</td></tr>
<tr><td colspan="2">Bulk density</td><td>(Mg m^{-3})</td><td colspan="2">1.69 (10-15 cm)</td><td>1.62 (20-25 cm)</td></tr>
<tr><td colspan="2">pH_s</td><td></td><td colspan="2">9.12</td><td>8.99</td></tr>
<tr><td colspan="2">EC_e</td><td>(dS m^{-1})</td><td colspan="2">7.60</td><td>5.95</td></tr>
<tr><td colspan="2">SAR</td><td>(mmol $L^{-1})^{1/2}$</td><td colspan="2">77.0</td><td>59.92</td></tr>
<tr><td colspan="2">G.R.</td><td>(t $acre^{-1}$)</td><td colspan="2">3.78</td><td>-</td></tr>
<tr><th colspan="6">Analysis of Irrigation Sources</th></tr>
<tr><td colspan="3">Tube well water</td><td colspan="3">Canal water</td></tr>
<tr><td>EC
(dS m^{-1})</td><td>RSC
($mmol_c$ L^{-1})</td><td>SAR
(mmol $L^{-1})^{1/2}$</td><td>EC
(dS m^{-1})</td><td>RSC
($mmol_c$ L^{-1})</td><td>SAR
(mmol $L^{-1})^{1/2}$</td></tr>
<tr><td>0.81</td><td>8.30</td><td>6.94</td><td>0.17</td><td>Nil</td><td>0.49</td></tr>
</table>

Table 2. Biomass and Paddy Yield (Mg ha^{-1}) and soil analysis as Affected by Canal and Brackish Water Irrigation with Amendments at Shirbaga

Treatments	RICE-2009							
	Biomass yield	Paddy yield	Soil Analysis at Harvest (0-15 cm)			Soil Analysis at Harvest (15-30 cm)		
	Mg ha^{-1}	Mg ha^{-1}	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$
T_1-Control	4.14 B*	0.71 B	8.95 A	5.86 A	49.17 A	8.98 A	6.25 A	49.95 A
T_2-Canal water + 100 % G.R. of soil	8.25 A	1.37 A	8.56 C	4.17 C	29.04 C	8.62 D	4.33 C	31.64 C
T_3-Brackish water + 100 % G.R of soil	8.16 A	1.35 A	8.76 B	4.85 B	33.30 B	8.83 B	4.90 B	36.00 B
T_4-Brackish water + 100 % G.R of soil + GR of irrigation water on the basis of RSC	8.75 A	1.30 A	8.69 BC	4.65 B	32.29 BC	8.73 C	4.73 BC	34.46 BC
LSD	0.6863	0.3159	0.1397	0.2374	4.288	0.0772	0.4122	3.6557

**Means sharing the same letter(s) in a column do not differ significantly at p<0.05 according to Duncan's Multiple Range Test.*

Table 3. Biomass and Grain Yield (Mg ha^{-1}) and soil analysis as affected by Canal and Brackish Water Irrigation with Amendments at Shirbaga

Treatments	WHEAT 2009-10							
	Biomass yield	Grain yield	Soil Analysis at Harvest (0-15 cm)			Soil Analysis at Harvest (15-30 cm)		
	Mg ha^{-1}	Mg ha^{-1}	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$
T_1-Control	1.83 C*	0.63 C	8.94 A	5.80 A	35.15 A	8.93 A	5.93 A	36.13 A
T_2-Canal water + 100 % G.R. of soil	3.42 A	1.33 A	8.55 C	4.07 B	26.13 B	8.60 B	4.30 B	28.14 B
T_3-Brackish water + 100 % G.R of soil	2.83 B	1.15 B	8.73 B	4.73 AB	29.15 B	8.79 AB	4.80 B	30.12 AB
T_4-Brackish water + 100 % G.R of soil + GR of irrigation water on the basis of RSC	3.25 AB	1.23 AB	8.68 BC	4.62 AB	28.80 B	8.69 B	4.70 B	29.12 AB
LSD	0.4934	0.1672	0.1570	1.2827	4.2418	0.1980	1.0261	7.5323

**Means sharing the same letter(s) in a column do not differ significantly at p<0.05 according to Duncan's Multiple Range Test.*

Table 4. Biomass and Paddy Yield (Mg ha^{-1}) and soil analysis as Affected by Canal and Brackish Water Irrigation with Amendments at Shirbaga

Treatments	RICE-2010							
	Biomass yield	Paddy yield	Soil Analysis at Harvest (0-15 cm)			Soil Analysis at Harvest (15-30 cm)		
	Mg ha^{-1}	Mg ha^{-1}	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$
T_1-Control	5.48 D*	0.84 D	8.64 A	4.80	29.55 A	8.63 A	4.93 A	31.45 A
T_2-Canal water + 100 % G.R. of soil	11.24 A	2.00 A	8.32 C	4.22	22.04 C	8.38 B	4.54 B	24.54 D
T_3-Brackish water + 100 % G.R of soil	8.33 C	1.64 C	8.54 B	4.39	25.62 B	8.56 A	4.42 B	27.12 C
T_4-Brackish water + 100 % G.R of soil + GR of irrigation water on the basis of RSC	9.86 B	1.85 B	8.49 B	4.26	22.34 C	8.51 AB	4.34 B	29.36 B
LSD	1.1647	0.1059	0.0845	NS	1.1599	0.1529	0.2481	1.1677

**Means sharing the same letter(s) in a column do not differ significantly at $p<0.05$ according to Duncan's Multiple Range Test.*

Table 5. Biomass and Grain Yield (Mg ha^{-1}) and soil analysis as affected by Canal and Brackish Water Irrigation with Amendments at Shirbaga

Treatments	WHEAT 2010-11							
	Biomass yield	Grain yield	Soil Analysis at Harvest (0-15 cm)			Soil Analysis at Harvest (15-30 cm)		
	Mg ha^{-1}	Mg ha^{-1}	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$
T_1-Control	1.91 C*	0.65 C	8.62 A	4.66 A	26.82 A	8.64 A	4.82 A	28.32 A
T_2-Canal water + 100 % G.R. of soil	4.32 A	1.78 A	8.29 B	4.20 C	21.25 C	8.32 D	4.28 C	23.14 C
T_3-Brackish water + 100 % G.R of soil	3.70B	1.59 B	8.52 B	4.36 B	24.08 C	8.55 B	4.40 B	25.40 B
T_4-Brackish water + 100 % G.R of soil + GR of irrigation water on the basis of RSC	4.16 A	1.68AB	8.48 C	4.24 C	22.15 B	8.49 C	4.32 C	27.10 AB
LSD	0.2534	0.1137	0.0321	0.085	1.2102	0.0251	0.0476	1.9373

**Means sharing the same letter(s) in a column do not differ significantly at $p<0.05$ according to Duncan's Multiple Range Test.*

Table 6. Biomass and Paddy Yield (Mg ha^{-1}) and soil analysis as Affected by Canal and Brackish Water Irrigation with Amendments at Shirbaga

Treatments	RICE-2011							
	Biomass yield	Paddy yield	Soil Analysis at Harvest (0-15 cm)			Soil Analysis at Harvest (15-30 cm)		
	Mg ha^{-1}	Mg ha^{-1}	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$
T_1-Control	5.62 D*	0.86 C	8.50 A	4.60 A	25.35 A	8.55 A	4.72 A	27.76 A
T_2-Canal water + 100 % G.R. of soil	13.20 A	2.63 A	8.27 C	4.05 C	18.54 C	8.30 C	4.20 C	20.50 C
T_3-Brackish water + 100 % G.R of soil	10.03 C	2.17 B	8.48 A	4.22 B	21.63 B	8.52 A	4.28 B	24.36 B
T_4-Brackish water + 100 % G.R of soil + GR of irrigation water on the basis of RSC	11.43 B	2.41 AB	8.44 B	4.16 B	19.51 C	8.46 B	4.24BC	22.77 B
LSD	0.1493	0.2381	0.0331	0.0921	1.0601	0.0404	0.0704	2.2549

**Means sharing the same letter(s) in a column do not differ significantly at p<0.05 according to Duncan's Multiple Range Test.*

Table 7. Biomass and Grain Yield (Mg ha^{-1}) and soil analysis as affected by Canal and Brackish Water Irrigation with Amendments at Shirbaga

Treatments	WHEAT 2011-12							
	Biomass yield	Grain yield	Soil Analysis at Harvest (0-15 cm)			Soil Analysis at Harvest (15-30 cm)		
	Mg ha^{-1}	Mg ha^{-1}	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$	pH_s	EC_e (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$
T_1-Control	1.90 C*	0.66 C	8.49 A	4.58 A	25.21 A	8.53 A	4.68 A	26.96 A
T_2-Canal water + 100 % G.R. of soil	4.97 A	2.22 A	8.25 C	3.96 C	18.09 C	8.28 C	4.15 C	19.72 C
T_3-Brackish water + 100 % G.R of soil	4.22 B	1.91 B	8.45 B	4.18 B	20.69 B	8.48 B	4.24 B	22.43 B
T_4-Brackish water + 100 % G.R of soil + GR of irrigation water on the basis of RSC	4.83 A	2.12 A	8.43 B	4.10 BC	19.27 BC	8.45 B	4.18 BC	21.68 BC
LSD	0.3626	0.1539	0.0300	0.1453	2.3503	0.0305	0.0866	2.2990

**Means sharing the same letter(s) in a column do not differ significantly at p<0.05 according to Duncan's Multiple Range Test.*