Pak. J. Agri. Sci., Vol. 39 (3), 2002

MANAGEMENT OF BRACKISH WATER FOR CROP PRODUCTION UNDER ARID AND SEMI-ARID CONDITIONS

*G. Murtaza, **S.H. Shah, *A. Ghafoor, *S. Akhtar and **N. Mahmood
*Department of Soil Science, University of Agriculture, Faisalabad-38040 (Pakistan)
** Water Management Research Centre, University of Agriculture, Faisalabad.

For sustainable crop production, changing the soil or water chemistry so as to counter the adverse effects of brackish water is good option. This is normally accomplished by soil- or water- applied amendments such as gypsum. The other option is of blending or cycling saline and non-saline waters, which has merits to reduce the potential hazards. The biological/organic amendments improve soil physical conditions, which are expected to deteriorate by the use of brackish water.
A field experiment was conducted on a non saline-non sodic sandy loam soil (EC_e = 1.31-1.76 dS m', pH, = 8.47-8.61. SAR 5.50-7.4 L infiltration rate = 0.6-0.8 cm h', bulk density = 1.56-1.61 Mg m"3 for the upper 15 cm soil depth) to evaluate the growth response of cotton crop to different soil and water treatments. Treatments included: T1 (canal water). T₁ (tube well water having EC = 3.38 dS m', SAR ~ 16.43 and RSC" = 5.57 mmol, L'l), T, (cyclic use, i.e. one canal and one tube well water). T1 (tube well water as such FYM @ 25 Mg ha' annually) and T; (tube well water + gypsum @ water gypsum requirement. i.c. decrease of WRSC to about (0). During the first year of experimentation. seed cotton yield was not significantly affected by the applied treatments and was in the order: T, > T, > T1 > T; > T_1. The number of boils picked per plant was in the order: T2 > T.j > T1 T, > T, and differed non-significantly. The wheat grain yield was significantly affected by the treatments and the order was T1 > T,. T, • T_1 T_2 The EC and SAR increased after wheat 2001-02 harvest. While pH, was not increased over the original respective values.
Key words: Management. brackish water. blending, cycling, amendment

INTRODUCTION

Pakistan have the largest continuous gravity flow canal system for irrigation but is falling short due to increased cropping intensity (Mohtadullah et al., 1993: Ghafoor, 1999) and increased demand over the years. Most of the agriculturally important areas fall under arid climate where average annual rainfall is 7-25 cm. which is not enough even for a single crop without artificial irrigation. The major constraint of low production in Pakistan is considered the limited canal supplies for irrigation. At present, the canal net work could supply one cusec of water for 350 acres in Pakistan compared to 70 acres in USA (Ansari, 1995).

Ground water of different qualities is being used to make up the shortage of good quality waters for crop production. At certain places. this practice has lead to soil and drainage water contamination by a variety of pollutants. Salinity and sodicity are the principal water quality concerns in irrigated areas receiving such waters (Ayars and Tanji, 1999). Attempts have been made in the past to minimize the adverse effects of poor quality irrigation waters via their cyclic/serial or blended use (Rhoades, 1984). Such efforts may help to slow down the rate of soil degradation and improve crop production (Sheng and Xiuling. 1997: Rhoades, 1998).

It has been reported that 70-75 % of the pumped ground water in the country is brackish in nature (Malik et al., 1984) and its continuous use with out proper management and amendment is making the soils scdic. Rafiq (1990) estimated that about 3 mha have developed surface salinity/sodicity due to the use of such poor quality tube well waters. These waters can be used efficiently for irrigation if proper management practices are applied (Ghafoor et al., 200 I and 1997: Qadir et al., 200 I).

The use of brackish water could increase the area under irrigated agriculture. Recent studies and evaluations indicate that waters previously thought unsuitable for irrigation can often be used successfully for longer periods without hazardous consequences for crops or soils. Use of such water would not only permit the horizontal expansion of irrigated agriculture but would also reduce drainage disposal and associated environment problems (Rhoades, 1983). Therefore. the present study was planned with the following objectives:

1. To monitor the effect of brackish water on physical and chemical properties of a non saline-non scdic soil.
2. To test different water management strategies of brackish water for cotton and wheat crops on long term basis.
3. To evaluate the economics of different water management practices.

MATERIALS AND METHODS

The study was initiated during summer 200 I following a cotton-wheat crop rotation at the research farm of Water Management Research Centre. University of Agriculture. Faisalabad. The experiment was conducted on a permanent lay-out having plot size 11.25 m x 24.00 m following Randomized Complete Block Design (RCBD) with three replications. After laying out the experiment, composite soil samples were drawn from 0-15, 15-30 and 30-60 cm of each experimental plot and were analysed for its various characteristics following methods described by the U.S. Salinity Lab. Staff (1954). Physical characteristics (infiltration rate, bulk density and soil strength) and chemical properties (pH", EC_e, SAR) were determined before applying the treatments. Seed bed was prepared for cotton crop and seed rate was 20 kg ha", and 35 cm plant to plant and 65 cm row to row distance was maintained.

Recommended doses of fertilizers (N : P10, : K10 @ 125 : 55 : :i:i kg ha·', respectively) were applied. HalfofN as urea, and full doses of P as single superphosphate and K as potassium sulphate were applied at the time of sowing. The remaining nitrogen was applied with 2nd and 3rd irrigations in equal splits. The depth of floodwater in each plot was measured with flume and a total of 6 irrigations (each of 3") were applied. The treatments were:

I1 Canal water alone (CW)

T, Tube well water alone

T, Cyclic use: one canal and one tube well water Irrigation

I Tube well water as such, FYM (a) 25 Mg ha' annually.

I, Tube well water ; Gypsum ((/',water gypsum requirement ((iR eq. to WRSC)

The crop growth characteristics (No. of boils picked per plant and seed cotton yield) were recorded and statistically analysed. After cotton harvest, composite soil samples were taken from each plot similar to that at the start of the experiment. The field was prepared for wheat 200 I and 100 kg ha' 1 seed rate was used by maintaininu 20 cm row to row distance. Recommended doses 'of fertili/er~ (N: P1O,: K10 @ 125: 55: 55 kg ha', respectively) wen: applied. HalfofN as urea, and full doses of P as single superphosphate and K as potassium chloride were applied at the time of sowing. The remaining nitrogen was applied with 2nd and 3rd irrigations in equal splits. The amount of water applied was measured with the help of flume and 4 irrigations (each of 3") were applied. The crop growth characteristics (tillering, plant height and grain and straw yields) were recorded. The data collected were analysed statistically and treatment differences were evaluated by using LSD test (Steel and Torrie, 1980).

REsLJLTS AND DISCUSSION

Quality of tube well water

The tube well water quality (FC 3.38 dS m', SAR 16.43 and RSC 5.57 mrnol, L·1) is almost the same during a period of one year of the present studies. It is expected that high EC, SAR and RSC of this water might give rise soils problems like permeability/infiltration, particularly if used continuously for longer period since the soil under investigation is moderately coarse texture and have good internal drainage.

Physical characteristics of soil

The water movement into and through soils is of particular importance for managing poor quality waters for crop production both on the productive and salt-affected soils. The physical characteristics of experimental field is normal (Table I). After the harvest of wheat 2001-02, the treatment differences were significant, i.e. the bulk density was maximum in T, and minimum for T1 Since the most common bulk density values range between 1.0-1.8 Mg m .' (Brady, 1990) for normal soils, it appears that the bulk density in all the treatments was not problematic during the first year experimentation. The infiltration rate decreased in 1'1 and 1', but increased with other treatments (Table 4) and was maximum with 1'5 followed by 1'1 and 1'1 This observation was very much clear when the field was irrigated for cotton 2002 and the plots receiving gypsum and FYM came one day earlier on "wattar" condition. The crust strength was not affected by the applied treatments.

Chemical characteristics of soil

Before the start of experiment, pH", EC_c and SAR of soil were normal (Table 2) which slightly increased by the harvest of cotton 2001 (first crop). However, non-significant effects of treatments were observed on pH, (T2~TI > T,~T4 >1'5) and EC_c (T5~T2~T4>TI~T,) of soil for all the depths except EC_c at 30-60 cm where the treatment order was: T, > 1'1 > T1 > 1'2 > 1'5 (Table 3). The SAR values in 0-15 and 30-60 cm depths increased non-significantly with the applied treatments probably due to less time of brackish water irrigation to single crop on this soil having good internal drainage owing to moderately coarse texture. The SAR values in 15-30 cm depth were significantly affected and the treatment order was: 1'5 (9.41) > 1'1 (10.40) > 1', (12.05) = 1'2 (12.05) > 1'4 (13.63) indicating Na accumulation from the applied brackish water. The treatment differences are expected to become prominent 2-3 years latter since there was a small increase in EC_c and SAR of soil.

After the harvest of wheat 2001-02, the pl-l, values were lowest for 1'5 and 1'1 followed by 1'4, 1'2 and T, for the 0-15 cm with non-significant treatment effect at 15-30 cm depth. While treatments differed significantly regarding pl-l, of 30-60 cm depth with ascending treatment order 1', > T4 > 1'2 > 1'1 > 1', (Table 5). However, pl-l, remained below 8.5 and similar to that of the original soil. The EC_c values increased significantly (Table 5) which was due to prolonged dry period during this season. Only two canal water irrigations were applied to 1'1 and 1'1 because of canal closure, the rest two were of the brackish water to grow the crop. The EC_c increased significantly and ascending order of treatments was: 1'1 > 1', > T, > T4> 1', for the 0-15 cm, the treatments have non-significant effect at 15-30 cm depth, while at 30-60 cm depth treatments have significant effect and ascending order was: 1', > T1 > Te > 1'4 > 1'5. Similar changes in EC_c in response to irrigation with brackish water have been reported by Rhoades (1993) and Ghafoor et a!'. (1997).

The post-wheat 2001-02 soil attained SAR values> 13 which is the lower limit for the sodic soils (U.S. Salinity Lab. Staff, 1954). The effect of treatments on SAR at 0-15 cm soil was significant and remained in the ascending order 1'1 > 1', > 1', > 1'2 > T4. The SAR at 15-30 and 30-60 cm depths was non-significantly affected by the applied treatments. An increase in SAR with all the treatments could be due to the application of tube well (brackish) water having SAR 16.43 and RSC 5.57 mrnol, L'I.

Table I. Physical characteristics of ori,ginal soil (April 2001)

Treatment	Infiltration rate (cm h-1)	Bulk density (Mg m') at depth (cm)			Soi I strength (k Pa)"	Soi I crust (kPa)*
		10-15	20-25	30-35		
T1 Canal water alone (CW)	0.80	1.58	1,66	1,57	6.26	3.79
T, Tube well water alone (TW)	0.75	1,61	1,61	1,58	5.96	3.56
1, Cyclic use: CW&TW alternatively	0.60	1,56	1,63	1,56	6.01	:1.78
T~ TW' FYIV1." !(P 25 Mg ha' annually	0.75	1.56	1,60	1.56	6.53	~.1)
T, TWvGypsum eq. to WRSC	0.60	I.60	1,58	1.54	5.12	3.54

"Moisture contents (%): T1c5.46. Te =c5)22. '1',=6.17. '1'1=2.72. '1,= 3.97

**FY M : Farm yard manure

Table 2. Chemical properties of original soil before start of the experiment (April 200])

Treatment	pl l, at depth (cm)			EC (dS m') at depth (cm)			SAR (mmol L-1)le at depth (cm)		
	0-15	15-30	30-60	0-15	15-30	30-60	0-15	15-30	30-60
T1	8.47	8.33	8.11	1,40	1,91	2.67	6.00	6.32	4.38
T.	8.54	8.53	8.10	1,76	1,99	3.63	7,41	7.58	6.70
'1',	8.50	8.62	8.33	1,31	1,34	2.12	5.50	6,41	6.3\
11	8.58	8,45	8.27	1,38	2.06	2.54	6.76	6.27	7.77
T,	8.61	8.50	8.24	1,35	1,57	2.09	6.38	6.96	6.57

Table 3. Chemical properties of soil after cotton 2001-2002

Treatment	pH, at depth (cm)			ECc (dS m') at depth (cm)			SAR (mmol 1,-1)1 e. depth (cm)		
	0-15	15-30	30-60	0-15	15-30	30-60	0-15	15-30	30-60
'1'1	8.35	8,43	8.39	1,94	2.00	1.87bc	11,52	10,40ab	9.17
Te	8.39	8.51	8.30	3.09	3.06	2.73a	16.64	1205ab	9.59
T,	8.20	8.38	8.30	2.38	1.83	1,48c	12,49	12.05ab	903
Tt	8.29	8.31	8.26	3.71	3.07	2.04bc	13.53	13.63a	9.63
T,	8.06	8.11	8.11	3.28	3.66	3.02ab	10,42	9,41 b	8,48
LSD	0.39\5	0.38\5	0.38\S	2.19"5	2.20"s	1.14	6.21 \5	3.84	3.30"

Table 4. Physical properties of soil after wheat 2001-2002

Treatment	Bulk density (Mg m') at depth (cm)			Infi. Itration rate (cm h-1)	Crust strength at depth 0-5 mm (kPa)
	10-15	20-25	30-35		
T1	1,55 ab	1.59 a	1,49 b	1.00 b	1.99*
1.	1.61 a	1,61 a	1,57 a	0.60 c	207
'1',	1,54 be	1,58 ab	1,51 ab	0.70 c	2.04
T~	1,49c	1,48b	1,45b	1.20 ab	2.05
T,	1,48c	1.52 ab	1.50 ab	1.30 a	1,85
LSD	0.059	0.103	0.059	0.279	0.434"

* Measured at Field Capacity.

Table 5. Chemical properties of soil after wheat 2001-2002

lr.catmeni	pH, at depth (cm)			EC (dS m') at depth (cm)			SAR (rnrnol L)- at depth (cm I		
	0-15	15-30	30-60	0-15	15-30	30-60	0-15	15-30	30-60
11	8.28b	8.16	8.27ab	2.83b	3.77	2.73bc	21.58b	2153	16.79
I,	8.45ab	8.32	8.22a-e	4.67ab	4.17	3.83a-c	34.07a	26.00	22.13
I,	8.'i4a	8.28	8.41 a	3.22ab	3.97	2.17c	2'i.05b	:; 175	192'1
11	8.33b	8. 10	8.08be	4.93ab	1.40	4.67ab	37.48a	2'1.11	21.49
I,	8.08e	803	7.98e	5.53a	5.40	5.23a	2273b	19(J7	18.29
LSD	0.179	(U77"	0259	2.362	[illegible] 'S	2.271	7.550	6.009 "	7.964"

Table 6. Effect of treatments on growth characteristics of cotton and wheat crops

Ireatmen t	Cotton 200 I		Wheat 2001-02			
	No. 01' boils picked per plant	Seed cotton yield (kg ha l)	Tillers No. m		Yield (kg ha')	
			Productive	Non-productive	Straw	Grain
11	31	2015	493	45	9259	3803a
I,	J.	1982	414	70	8790	3284b
I,	30	2361	424	26	8753	3667a
11	32	2073	490	79	9037	3482ab
I,	26	2001	397	37	8839	3790a
ISD	1129"	2.306"	1704 "	55.6" S	766"	335

Table 7. Eeonomies of applied trcatmcnts for cotton and wheat crops

I rcauncnt	l:xpcnditurc (Rs. ha l)			Net Benefit (Rs . ha')			
				Cotton 200 I	Wheat 2001-2002		
	Cotton	Wheat	Total expenditure		Grain	Straw	Net Benefit
I1	-	-	-	40300	28523	7606	76429
I,	-	-	-	39640	24630	6568	70838
I,	-	-	-	47220	27503	7334	82057
11	1852	-	1852	41460	26115	6964	7261\7
I,	1667	1222	2889	40020	28425	7580	73136

Prices.: Cil'jJIIIII (/ R.I. J() I)L/" hag and FLIf a RI. 15fV!.()J tons;. Seed col/on yield .a Rs. I()()O-!() kg. Wheat gmin a RI 31111-lll k.\!;. llhca!I//'({)I'. a R.I. i!O-l1l kg

Cotton growth

lhc crop gr, ııı rh charactcrist., ics 01' cotton, i.c. number of boils picked per plant :uid seed cotton) icld were non-significantly al'/l.'cted b) the treatments (Table 6). This is because the values oITC,. pI I, and SAR arc still below the threshold levels (Ayers and West cot. 1(85). The seed cotton yield was in the order: '1', 11 1'll, I. while the order for number of boils picked per plant \la,: I, 1,"1'1 1'; 1',.

Wheat gnm th

lhc productive non productive tillers and straw) icld were non S1gIlIlic,lnth al!c'ctcd by the treatments. The height 01' plants \\as signilicanth .ufcctcd b) the treatments. maximum height being with 1'1 followed by 1',. '1',. 1', and 1') (Table 6). The treatments have significant effect on grain yield and was maximum with 1'1 followed by '1', .r, . 1'1 and '1'..• \ similar response of wheat crop to brackish water irrigation has als'l been reported by Ghafcor et al. (1998).

[valuation of economics of water management practices

Economical gains are the ultimate objective of any indusuv including agriculture. Economics of the present experiment has been calculated and additional expenditures for treatments (I) and '1',) are only considered. The e\pendjtures on uniform practices are not included. On the basis of income frum the first two crops, net benefit was the highest from 'I, followed by T1.

T", T_4 and T_5 (Table 7). Thus results (physical and chemical properties of soil + yield data) favor the use of gypsum for better crop production and soil health receiving brackish water for irrigation.

CONCLlISIONS

On the basis of data presented, it is concluded that tube well water. like the one used in this study. could be used for irrigation of crops by applying gypsum @ water GR with or without FYM @ 25 Mg ha'l without considerable loss to soil health and crop productivity provided the soil is well drained.

ACKNOWLEDGEMENTS

This research work was conducted under the project titled "Management or brackish water for cotton-wheat crop production". We are thankful to the University Grants Commission, Islamabad (Pakistan) for providing financial support under the Promotion of Research Fund and the Directorate of Water Management Research Centre. University of Agriculture. Faisalabad for facilitating the research work at their farm.

REFERENCES

Ansari, A. 1995. Snowfall and water crisis. The Dawn, Friday, 5th July. 1995.

Ayars, lE. and K.K. Tanji. 1999. Effects of drainage on water quality in arid and serniarid lands. In: Skaggs, R.W., van Schilfgaarde . J. (eds.). Agricultural Drainage. ASA-CSSA-SSSA, Madison, WI, USA,. pp.8] 1-867.

Ayers, R.S. and D.W. Westcot. . 1985. Water quality for agriculturc . I'AO Irrigation and Drainage Paper 29. FAO. Rome. Italv

Brady, N. C. ,'990. The nature and properties of soils (10th Ed.) . Macmillan Pub. Co., New York. pp. 91-122.

Ghafoor, A.. CJ. Murtaza and M. Qadir. . 200 I. Brackish water chemistry. treatment with amendments and economics of use for crops and/or amelioration of saline-sodic soils. Int. Proc. 2nd Nat. Sem. on Drainage in Pakistan. April 18-19, 200 I. Univ, Auric., Faisalabad, Pakistan.

Ghafoor. A. M. 071dir, G. Murtaza and H.R. Ahmad. 1998. Strategies to harvest sustainable rice and wheat yields using brackish water for irrigation. J. Arid Land Studies. 7S: 165-169.

Ghafoor, A. 1999. Historical perspectives of land use and land cover chances in Pakistan. Paper presented on Int. Workshop (~n Land-use. Land-cover Changes in South Asia. April 11-13. 1999, Pusa, New Delhi,lndia.

Ghafoor. , A.. M.R. Chaudhrv, . M. Qadir. . G. Murtaza and H.R. Ahmad. 1997. Use of drainage water for crops on normal and salt-affected soils without disturbing biosphere equilibrium. Int. Waterlogging and Salinity Res. Inst. (IWASRI). Publication No.176. IW ASRI. Lahore. Pakistan.

Malik, D.M., M.A. Khan and B. Ahmad. 1984. Gypsum and fertilizer use efficiency of crops under different irrigation system. Presented at seminar on "Optimizing Crop Production Through Management of Soil Resource". May 12-13,1984. Lahore.

Mohtadullah, K., e.A.U. Rehrnan and C.M. Munir. . 1993. Water for the 21 st century. Environ. and lJrban Affairs Div., Govt. . Pakistan. Islamabad. Pakistan.

Qadir, M., A. Ghafoor and G. Murtaza. 200 I. Use or saline-sodic waters through phytorernediation of calcareous saline-sodic soils. Agric. Water Manage. 1647 : 1-14.

Rafiq, M. 1990. Soil resources and soil related problems in Pakistan. P. 16-23. In: Ahmad, M., M. I. Akhtar and M.1. Nizami (eds.). Soil Physics application under stress environment. .. Proc. Symp. Applied soil physics in stress environment. .. lslamabad, Jan. 22-26. 1989. HARD Project. PARC,lslamabad.

Rhoades, J.D. 1983. Reusing saline drainage waters for irrigation: A strategy to reduce salt loading of rivers. Proc. Int. Symp. on State-of-the-Art Control or Salinity. USA. July 12-15, 1983. Salt Lake City. lJIl. . USA.

Rhoades. J. D. 1984. New strategy for using sal inc \\<lters ror irrigation. Proc. ASCE Irrigation and Drainage Spccialir, Co~f., Water Today and Tomorrow. July 24-26. 19X4. Flagstaff, Arizona, USA.. P.231-236.

Rhoades, J.D. 1993. Practices to control sal inity in irrigated soils. p. 379-387. In: H. Lieth and A. AI. Masoom (eds.) . Towards the Rational Use of High Salinity Tolerant Plants. Kluwer Academic Publishers. The Netherlands .

Rhoades, lD. 1998. Use of saline and brackish waters for irrigation: implication and role in increasing food production, conserving water, sustaining irrigation and controlling soil and water degradation. In: Ragab. R, Pearce. G. (eds.), Proc.. of the Int. Workshop on the Use or Saline and Brackish Water for Irrigation. 23-24 July 199X. Bali, Indonesia. pp. 261-304.

Shenu, M.V. and C. Xiuling. 1997. Using shallow saline groundwater for irrigation and regulating for soil salt-water regime. Irrig. Drainage Syst.. I I: 1-14.

Steel, R.G.D. and lH. Torrie. 1980. Principles and procedures of statistics (2nd Ed.). McGraw Hill Book Co . NY. USA.

US Salinity Lab. Staff 1954. Diagnosis and improvement of saline and alkali soils. USDA Handb.60. Washington. O.C., USA.