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Response of Crop Rotations to Sodic Waters and Amendments in Loamy Sands of Southern Haryana

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Abstract: A long term experiment was carried out to evaluate the effect of sodic waters (RSC 2.8, 12.0 and 16.0 me L^{-1}) and amendments (gypsum applied @ 100% neutralization of RSC above 2.8 me L^{-1} and FYM applied at @ 15 tonnes ha^{-1} $year^{-1}$) on the productivity of various cropping systems and physico-chemical characteristics of the loamy sand, typic Ustrocrept. The crop rotations were sorghum fodder-mustard, sorghum fodder-wheat, prickly sesbane-wheat and pearl millet-mustard, each rotation continued for three years. Progressive buildup of sodicity (ESP) and soil pH with low infiltration rate was observed with water of higher alkalinity (RSC 12 and 16 me L^{-1}). The gypsum maintained the ESP and pH of the soil and increased the infiltration rate. The FYM was more beneficial with irrigation water of RSC 2.8 me L^{-1}. Crop yields decreased significantly with increasing sodicity of the irrigation water. Sodic water of RSC 12 me L^{-1} with gypsum produced yields statistically equal to that of irrigation water of RSC 2.8 me L^{-1} in pearl millet, wheat, mustard, prickly sesbane and sorghum. Sodic water of RSC 16 me L^{-1} with both amendments was not found effective. FYM as an amendment increased the crop yields, but was inferior to gypsum under high sodic water condition (RSC 12 and 16 me L^{-1}). In general, sodic water of RSC 12 me L^{-1} along with gypsum can be successfully used in sorghum fodder-mustard, sorghum fodder-wheat, prickly sesbane-wheat and pearl millet-mustard crop rotations in light textured soils.

Key words: Brackish, sodic waters, crop rotation, RSC, amendment.

Irrigation strategies to use brackish water play a vital role in crop production in arid and semi-arid regions where scarcity of good quality water is a major problem. The underground waters of this region are mainly brackish and of which a sizable proportion is sodic in nature (Bajwa *et al.*, 1975). In Haryana on an average, 55% of ground waters are brackish in nature, out of which about 33% are exclusively sodic (Manchanda, 1976). A majority of these sodic water, exist in Southern zone of Haryana comprising districts of Rewari, Mohindergarh, Bhiwani and Gurgaon where more than 70% of the net irrigated area is covered by tube wells. Therefore, farmers of this zone have no other option except to utilize brackish water as irrigation source for earning their livelihood. However, continuous and indiscriminate use of sodic waters without suitable amendments causes deleterious effect on the physico-chemical properties of soil including sodification which ultimately renders the soil unfit for cultivation (Dhankhar *et al.,* 1990). Since soils of the zone are light in texture, possibilities have emerged that with suitable amendments, these sodic waters can be

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successfully used for crop production (Dhankhar *et al.,* 1986). Thus, potential for use of two types of naturally occurring sodic waters with amendments was evaluated in low and high water requirement cropping systems on a loamy sand soil.

Materials and Methods

The investigation was carried out at research farm of CCS HAU, Regional Research Station, Bawal (28.1°N latitude, 76.5°E longitude and 266 m above mean sea level), which is situated in the arid to semi-arid climate. The annual rainfall received at the site was 465.0, 399.0, 571.6, 264.5, 812.4 and 432.0 mm during 1999 to 2004. The physico-chemical characteristics of experimental soil (loamy sand, typic Ustrochrept) at start of experiment in 1983 are presented in Table 1. The three sodic waters with varying residual alkalinity of RSC 2.8, 12.0 and 16.0 me L^{-1} were evaluated in the field where irrigation water of RSC 12.0 me L^{-1} was used for growing wheat and barley before 1983. The chemical composition of these waters is given in Table 2. Under the present experiment in 1999, crop rotations namely sorghum fodder-mustard, sorghum fodder-wheat, pearl millet-mustard and prickly sesbane-wheat (i.e. less water requiring crops and high water requiring crops) were introduced. The amendment treatment included FYM @ 15 t ha^{-1} $year^{-1}$ and gypsum @ 100% neutralization of RSC in irrigation water above 2.8 me L^{-1}. Addition of FYM at 15 t ha^{-1} $year^{-1}$ added 183 kg Ca ha^{-1} $year^{-1}$ and 54 kg Mg ha^{-1} $year^{-1}$. The respective amount of gypsum applied for neutralizing the RSC 12 me L^{-1} was 4140, 1380, 3070, 2760 and 2070 kg ha^{-1} and for neutralizing the RSC 16 me L^{-1} was 5940, 1980, 2970, 3960 and 2970 kg ha^{-1} for wheat, pearl millet, mustard, sorghum and prickly sesbane, respectively. Gypsum and FYM as per treatment were applied in plots before pre-sowing irrigation.

Recommended package of practices were followed to raise the crops in various rotations. Depending upon the rainfall received during the growth of crops, number of irrigations (each of 7.5 cm depth) including pre-sowing irrigation were 6, 2, 3, 4 and 3 for wheat, pearl millet, mustard, sorghum and prickly sesbane, respectively. Soil samples were drawn after harvest of each crop at 0-15 cm depth. Air dried soil samples were ground to pass through 2 mm sieve and then analyzed for infiltration rate, pH_2 and ESP using standard procedures (Richard, 1954).

Results and Discussion

Effect on soil properties

Infiltration: The infiltration rate was adversely affected by increasing sodicity of irrigation water as given in Table 3. Application of gypsum improved the infiltration rate of soil significantly. Initially FYM decreased the infiltration rate with use of highly sodic waters of RSC 12 and 16 me L^{-1}, but its continuous application increased it. The effect of gypsum was more pronounced than that of FYM under highly sodic water of 12 and 16 me L^{-1}. However, the effect of FYM was more with irrigation water of RSC 2.8 me L^{-1}. In a long term study gypsum improved the infiltration rate even at 50% neutralization of RSC of irrigation water, but the application of FYM adversely affected infiltration rate (Manchanda *et al.*, 1985). This behavior of FYM was attributed

Table 1. Chemical composition of tubewell waters

Tube-well	EC (dS m^{-1})	RSC	$CO_3^{=}$	HCO_3^-	Cl^-	Ca^{++}	Mg^{++}	SAR (mmol $L^{-1})^{.5}$	pH
		me L^{-1}							
1	1.72	2.8	Nil	7.8	7.2	1.7	3.3	7.6	7.9
2	1.93	12.0	Nil	14.0	5.6	0.4	1.6	19.3	8.1
3	2.20	16.0	1.6	16.4	8.2	0.7	1.3	19.8	8.9

to dispersion of FYM in contact with sodic water and resultant clogging of microspores. However, Poonia and Pal (1979) reported that addition of FYM improved soil permeability and reduced the preference of soil colloids for sodium. The interaction of sodicity of irrigation water and amendment was significant in affecting the infiltration rate of soil.

Soil pH: Irrigation with sodic water of RSC 12 and 16 me L^{-1} for a period of six years in various crop rotations led to the development of maximum soil pH i.e., 9.45 and 9.76, followed by pH of FYM treatment i.e., 9.39 and 9.49 and least in gypsum treatment i.e., 9.11 and 9.24 during last week of harvesting i.e., April 2004 (Table 3). Neutralization of sodic water of 12 me L^{-1} with gypsum maintained the pH value of soil statistically at par with that of water of 2.8 me L^{-1} without gypsum. The beneficial effect of gypsum in lowering pH of the 'soil is due to the downward movement of Na owing to its replacement by Ca as a result of solubilization of gypsum. Prakash *et al.* (1994) and Yadav and Chhipa (2007) have also reported reduction in pH of post-harvest soil due to gypsum application. The FYM also decreases the pH of the soil by decreasing the precipitation of Ca and CO_3-- and increasing the removal of Na in drainage water (Sekhon and Bajwa, 1993; Yadav and Chhipa, 2007). However, Brij Mohan (1999) reported that FYM had no significant effect on pH of the soil.

ESP: The ESP buildup after the harvest of crops in March and April 2004 was maximum with water of RSC 12 and 16 me L^{-1}. The addition of gypsum to the soil on the basis of complete neutralization of RSC of irrigation water led to the least development of ESP of soil followed by FYM application (Table 3). The gypsum decreases the ESP of the soil by replacing sodium with Ca at the exchange site (Manchanda, 1985). Sekhon and Bajwa (1993) also reported that gypsum and incorporation of organic manure decreased the ESP of the soil. However, Manchanda *et al.* (1985) observed that FYM did not decrease the soil ESP which was supported by higher pH and lower infiltration rate in the FYM treatment.

Relatively higher ESP was buildup after sorghum fodder-wheat and prickly sesbane-wheat rotation than sorghum fodder-mustard and pearl millet-mustard, which could be

Table 2. Soil characteristics of experimental field at the start of experiment

Soil depth (cm)	Silt + clay (%)	Textural class	pH (1:2)	EC (1:2) (dS m^{-1})	$CaCO_3$ (%)	OC (%)	CEC (me/100 g)
0-15	17	LS	9.25	0.5	Traces	0.13	3.9
15-30	21	LS	9.30	0.7	Traces	0.06	4.0

Table 3. Soil properties (surface soil 0-15 cm) after rabi crops as affected by sodic waters, FYM and gypsum

Treatment		Crop rotation											
RSC me L^{-1}	Amendment	1999-2001						2001-2004					
		Sorghum-mustard			Sorghum-wheat			Pearl millet-mustard			Pricky sesbane-wheat		
		IR	pH	ESP	IR	pH	ESP	IR	pH	ESP	IR	pH	ESP
2.8		2.28	9.03	29.28	1.78	9.13	32.38	2.22	9.05	29.98	1.69	9.19	33.75
2.8	FYM	2.73	8.90	27.20	2.02	9.00	30.93	2.67	8.96	27.56	1.95	9.04	31.47
12.0	–	0.42	9.40	48.47	0.35	9.60	54.33	0.41	9.45	49.61	0.32	9.67	56.10
12.0	Gyp.	2.53	9.03	32.56	2.22	9.20	37.79	2.47	9.11	34.11	2.16	9.24	39.22
12.0	FYM	0.47	9.30	46.38	0.45	9.37	51.20	0.45	9.39	48.20	0.43	9.39	53.15
16.0	–	0.27	9.70	62.30	0.27	9.80	67.21	0.27	9.76	63.75	0.26	9.86	69.10
16.0	Gyp.	2.47	9.20	40.30	1.97	9.30	43.71	2.40	9.24	42.06	0.18	9.33	45.36
16.0	FYM	0.38	9.43	61.34	0.37	9.50	64.39	0.37	9.49	62.97	0.36	9.55	66.15
CD (P=0.05)													
RSC		0.08	0.07	1.51	0.06	0.07	1.51	0.06	0.08	1.64	0.05	0.08	1.62
Amendement		0.08	0.07	1.51	0.06	0.07	1.51	0.06	0.08	1.64	0.05	0.05	1.62
RSC x amendment		0.14	0.12	2.62	0.10	0.12	2.62	0.10	0.15	2.99	0.09	0.15	2.99

attributed to the difference in water requirement of crop rotation.

Effect on crop yield: The pooled data on yield of crops revealed that yield of all the crops tested decreased significantly and progressively when irrigated with water of RSC 12 and 16 me L^{-1} (Table 4). The per cent decrease in yield of wheat, pearl millet, mustard, sorghum and prickly sesbane was 35, 37-48, 50-52 and 37% with water of RSC 12 me L^{-1} and 55, 57, 52, 62-64 and 54 with water of RSC 16 me L^{-1}. Bajwa *et al.* (1992) reported significant yield reduction in wheat and cotton with use of RSC water of 10.0-11.1 me L^{-1}. Application of gypsum at the rate of 100% neutralization of RSC of water above 2.8 me L^{-1} significantly increased the yield of crops. The per cent increase was 53, 88, 56, 98-100, and 62 with water of RSC 12 me L^{-1} and 59, 66, 67, 71-126 and 89 with water of RSC 16 me L^{-1}, respectively. The higher yield with gypsum as observed in this experiment was due to improvement in physico-chemical environment of soil in the root zone and lowering of pH and ESP by gypsum application. Sharma and Manchanda (1989) reported that wheat, pearl millet and guar can be successfully grown with water of RSC 10 me L^{-1} provided gypsum is added at 100% GR of soil plus that required to neutralize RSC of irrigation water completely, on cumulative basis. Raghav (1991), Yadav (2002) and Yadav and Chippa (2007) also observed a similar response of gypsum on production of pearl millet, wheat and sorghum fodder. The application

Table 4. Effect of RSC levels, gypsum and FYM on yield of crops in various crop rotations

Treatment		Crop roration							
RSC (me L^{-1})	Amend-ment	1999-2001				2001-2004			
		Sorghum-mustard		Sorghum-wheat		Pearl millet-mustard		Pricky sesbane-wheat	
		t ha^{-1}	kg ha^{-1}	t ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	t ha^{-1}	kg ha^{-1}
2.8	–	38.89	2166	61.85	4371	2620	2005	17.20	3367
2.8	FYM	45.18	2352	69.26	4722	2900	2147	18.90	3552
12.0	–	19.26	1463	29.37	2852	1350	1263	10.80	2446
12.0	Gyp.	38.52	2185	58.18	4352	2540	1970	17.50	3402
12.0	FYM	29.40	1796	39.26	3403	1710	1515	14.10	3615
16.0	–	14.07	901	23.81	1981	1120	968	8.00	1531
16.0	Gyp.	31.86	1685	40.75	3145	1860	1620	15.10	2871
16.0	FYM	22.55	1159	30.15	2225	1420	1205	11.30	1698
CD (P=0.05)									
RSC		1.81	199	1.81	199	092	082	0.76	083
Amendement		1.81	199	1.81	199	092	082	0.76	083
RSC x amendment		3.13	346	3.13	346	160	117	1.32	144

of FYM increased the yield of all crops with water of RSC 2.8, 12.0 and 16.0 me L^{-1}. The increase was 8, 11, 7, 12-16 and 10% with water of RSC 2.8 me L^{-1} in comparison to per cent increase of 19, 27, 20, 34-52 and 31 with water of RSC 12 me L^{-1} and 38, 17, 41, 19, 42 and 47 with water of RSC 16 me L^{-1}, respectively. Sharma and Yadav (1986) and Yadav and Chippa (2007) reported that FYM increased the grain and straw yields of rice and wheat, respectively. However, Manchanda *et al.* (1985) did not observe any significant effect of FYM on grain yield of wheat. There was significant interaction between sodic water and amendments. The gypsum was more responsive in enhancing the yield of all crops in highly sodic waters of RSC 12 and 16 me L^{-1} while FYM was found more useful with water of RSC 2.8 me L^{-1} (Table 4).

Conclusion

It is concluded from above study that sodic water of RSC 12 and 16 me L^{-1} significantly reduced the yield of all the crops tested in above mentioned crop rotations. The application of gypsum @ 100% neutralization of RSC of water above 2.8 me L^{-1} significantly increased the yield of crops and maintained the pH and ESP of soil with improved infiltration rate in comparison to no gypsum in RSC water of 12 and 16 me L^{-1}. The sodic water of RSC of 12 me L^{-1} with gypsum produced yields statistically equal or more yield to RSC water of 2.8 me L^{-1} in wheat, pearl millet, mustard, sorghum and prickly sesbane. Sodic water of 16 me L^{-1} RSC even with gypsum as amendment was not found suitable for above crop rotations. FYM as amendment with RSC water of

12 and 16 me L^{-1} was found to be inferior than gypsum. Therefore, in light textured soils, the sodic water up to RSC of 12 me L^{-1} can successfully be used with gypsum for above crop rotations.

References

Bajwa, M.S., Chaudhary, A.P. and Josan, AS. 1992. Effect of continuous irrigation with sodic and saline sodic water on soil properties and crop yield under cotton wheat rotation. *Agriculture Water Management* 16: 53-61.

Bajwa, M.S., Singh, N.T., Randhawa, N.S. and Brar, S.P.S. 1975. Underground water quality map of the Punjab State. *Journal of Research, PAU* 12: 177.

Brij Mohan 1999. Effect of sodic water, FYM and gypsum on yield and quality of potato and physico-chemical properties of soil. *M.Sc. Thesis,* HAU, Hisar, India.

Dhankhar, O.P., Phogat, V.K., Sharma, D.R. and Sangwan, O.P. 1986. Field study on the effect of irrigation water quality on soil characteristics and crop yield. In *Proceedings of International Seminar on Water Management in Arid and Semi-arid Zone*, held at CCS HAU, Hisar, Nov. 27-29, 1986, Vol. II: 1.

Dhankhar, O.P., Yadav, B.D. and Yadav, A.P. 1990. Long term effect of sodic waters in soil deterioration and crop yield in a loamy sand soil of semi-arid region. *National Symposium on Water Resource Conservation, Recycling and Reuse* held at Nagpur, 3-5 Feb., 1990, pp. 57-59.

Manchanda, H.R. 1976. *Quality of Ground Waters in Haryana*. Haryana Agri. Univ. Hisar. p 160.

Manchanda, H.R., Garg, R.N., Sharma, S.K. and Singh, J.P. 1985. Effect of the continuous use of sodium and bicarbonate rich irrigation water with gypsum and farm yard manure on soil properties and yield of wheat in a fine loamy soil. *Journal of Soc. of Soil Science* 33: 876-883.

Poonia, S.R. and Paul, R. 1979. The effect of organic manuring and water quality on water transmission parameter and sodification of sandy loam soil. *Agril. Water Management* 2: 163-173.

Prakash, V., Sharma, N.L. and Singh, R. 1994. Effect of soil amendment on soil properties and yield of rice and barley in salt affected soils. *Current Agriculture* 18: 35-40.

Puntankar, S.S., Mehta, P.C. and Seth, S.P. 1972. Effect of gypsum and manure on the growth of wheat irrigated with bicarbonate rich water. *Journal of Indian Soc. Soil Science* 20(3): 281-288.

Raghav, R. 1991. Effect of long term use of sodic waters on water transmission and some chemical characteristics of a coarse loamy typic ustorthents. *M.Sc. Thesis*, Haryana Agriculture University, Hisar, India.

Richard, L.A. (Eds.) 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook No. 60. Oxford and IBH Publishing Co., New Delhi.

Sekhon, B.S. and Bajwa, M.S. 1993. Effect of organic matter and gypsum in controlling soil sodicity in rice-wheat maize system irrigated with sodic waters. *Agricultural Water Management* 24(1): 15-25.

Sharma, B.M. and Yadav, J.S.P. 1986. Iron, manganese and phosphorus uptake and yield of rice in sodic soil amended with gypsum and FYM. *Journal of Indian Soc. Soil Science* 34: 849-854.

Sharma, S.K. and Manchanda, H.R. 1989. Using sodic water with gypsum for some crops in relation to soil ESP. *Journal of the Indian Society of Soil Science* 37: 135-139.

Yadav, K.K. and Chhipa, B.R. 2007. Effect of FYM, gypsum and iron pyrites on fertility status of soil and yield of wheat irrigated with high RSC water. *Journal of ISSS* 3(55): 324-239.

Yadav, Promod Kumar 2002. Studies on the long term effect of sodic water, FYM and gypsum on the productivity of various cropping system and physico-chemical characteristics in light textured soils. *Ph.D. Thesis*, CCS HAU, Hisar, India.