

Effect of Sodium to Calcium Activity Ratio and Residual Sodium Carbonate in Irrigation Water on Physico-chemical Properties of the Haplustalfs and Performance of Wheat (*Triticum aestivum* L.)

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Abstract Two texturally different, fine loamy (clay loam) and coarse loamy (sandy loam) mixed hyperthermic Haplustalfs were irrigated with waters of varying quality, prepared artificially using different levels of SCAR (Sodium to calcium activity ratio) and RSC (Residual sodium carbonate) to raise the wheat crop. The magnitude of change in physico-chemical properties is not identical at equivalent level of RSC in irrigation water. Increasing levels of SCAR from 7 to 10 and RSC from 0 to 10 me L⁻¹ in irrigation water decreased the electrical conductivity, hydraulic conductivity, water holding capacity and contents of organic carbon, soluble cations and anions and increased the pH and ESP of the soil. The effect on morphological characters, dry matter yield and uptake of nutrient varied with Mg:Ca ratio in irrigation water and clay content of the soil. The reduction in plant growth, dry matter yield and nutrient uptake was more pronounced at SCAR value of 10 in irrigation water and in soil finer in texture, indicating SCAR to be a better index for judging the suitability of irrigation water than that of SAR.

Key words Mg:Ca ratio, Residual sodium carbonate (RSC), Sodium to calcium activity ratio (SCAR), *Triticum aestivum* L.

In arid and semi-arid regions, groundwater is either quite saline or contains high residual sodium carbonate (RSC). Bicarbonate ions form a major portion in waters of low salinity (Paliwal 1973). Besides, leaving effect on the ionic composition of soil solution HCO₃ by virtue of precipitation and hydrolysis process influences the ionic equilibria of the solid phase leading to enhance the sodicity hazard. It has often been suspected that a high Mg:Ca ratio in the irrigation water causes more deterioration of soil structure in arid and semi-arid regions leading to development of a Mg-solnetz (Ell's & Coldwell 1935). Present investigation was therefore undertaken to assess the effect of SCAR and RSC levels in irrigation water on soil physico-chemical properties of two texturally different soils and performance of wheat taking Lok-1 variety as a test crop.

Materials and Methods

Two texturally different, fine loamy (clay loam) and coarse loamy (sandy loam) mixed hyperther-

mic Haplustalfs were collected (0.15 cm) from two different locations, viz, Agronomy farm, RCA, Udaipur (S₁) and Farmer's field, Lalmadari, Tehsil Nathdwara, District Rajsamand (S₂). These soils were subjected to irrigation with ten different

Table 1 Physico-chemical characteristics of soils prior to experimentation

Characteristics	Soil	
	S ₁	S ₂
Textural class	Clay loam	Sandy loam
Hydraulic conductivity (cm ha ⁻¹)	1.15	1.50
Water holding capacity (%)	42.3	38.9
ECe (dSm ⁻¹)	0.98	0.95
pH	8.4	8.3
CaCO ₃ (%)	2.1	1.6
Organic carbon (%)	0.79	0.69
Available nutrients (kg ha ⁻¹)		
N	170.0	161.6
P	17.4	16.6
K	172.6	171.6

Table 2 Effect of SCAR and RSC levels in irrigation water on physico-chemical properties of soils

Treatments	HC (cm hr ⁻¹)	WHC (%)	EC (dSm ⁻¹)	pH	OC (%)	Soluble cations (me L ⁻¹)			Soluble anions (me L ⁻¹)			ESP	
						Na ⁺	Ca ⁺⁺	Mg ⁺⁺	K ⁺	HCO ₃ ⁻	Cl ⁻		SO ₄ ⁼
SCAR													
7	1.34	39.7	2.96	8.1	0.72	18.2	9.1	4.6	0.22	12.0	11.9	6.9	15.3
10	0.95	28.9	2.52	8.9	0.67	15.0	4.7	2.6	0.17	9.2	9.8	4.7	16.0
SEm±	0.10	4.3	0.15	0.3	0.01	0.10	0.06	0.13	0.03	0.05	0.04	0.03	0.10
CD 5%	0.25	10.2	0.36	0.7	0.02	0.18	0.10	0.22	0.05	0.09	0.07	0.05	0.18
RSC (me L⁻¹)													
0.0	1.28	38.5	2.90	8.3	0.78	17.2	7.3	4.2	0.30	10.0	12.0	7.0	12.4
2.5	1.22	36.2	2.81	8.4	0.75	16.9	7.0	3.9	0.25	10.2	11.5	6.4	14.0
5.0	1.16	34.8	2.75	8.5	0.70	16.6	6.9	3.7	0.23	10.6	10.8	5.9	15.1
7.5	1.11	32.4	2.65	8.8	0.65	16.3	6.7	3.4	0.13	11.0	10.3	5.2	17.5
10.0	0.96	29.6	2.54	8.9	0.61	16.0	6.6	3.2	0.10	11.2	9.9	4.7	19.1
SEm±	0.07	3.0	0.11	0.2	0.02	0.16	0.09	0.11	0.04	0.08	0.06	0.04	0.17
CD 5%	0.18	7.2	0.26	0.5	0.04	0.28	0.16	0.21	0.08	0.15	0.11	0.08	0.29
Soil													
Clay loam	1.05	28.9	2.99	8.9	0.63	15.3	5.3	2.6	0.18	11.3	11.6	7.0	16.4
Sandy loam	1.24	39.7	2.48	8.2	0.76	17.9	8.5	4.4	0.22	9.9	10.2	4.6	14.8
SEm±	0.10	4.3	0.15	0.3	0.01	0.10	0.06	0.13	0.03	0.05	0.04	0.03	0.10
CD 5%	NS	10.2	0.36	0.7	0.02	0.17	0.10	0.22	0.05	0.09	0.07	0.05	0.18

quality waters computed from two levels of SCAR (7 and 10) and five levels of RSC (0, 2.5, 5.0, 7.5 and 10) having a constant value of electrolyte concentration ($EC\ 3.0\ dSm^{-1}$). The soil S_1 was normal in reaction, non-saline, calcareous, medium in N, high in available P and K and fairly drained, whereas soil S_2 was normal in reaction, non-saline, non-calcareous, medium in N, high in available P and K and well drained (Table 1). Wheat (*Triticum aestivum* L.) variety Lok-1 was grown as a test crop for 60 days of crop growth in plastic wares of 7 kg capacity ($23 \times 18 \times 13\ cm$) using $60\ kg\ N\ ha^{-1}$ and $17.5\ kg\ P\ ha^{-1}$ as a basal dose. In all six irrigations with different quality waters, so prepared artificially were given at 50% of field capacity moisture depletion using 500 mL of water in each irrigation. After the harvest of wheat crop soil from each pot was analysed for the physico-chemical properties using standard methods of analysis (Richards 1954).

The morphological characters of the plants (number of tillers $plant^{-1}$, height and leaf area of flag leaf), dry matter weight of top and root, CEC (Crooke 1964) and content of plant nutrients, N (Lindner 1944), P (Dickman & Bray 1940), K, Na, Ca and Mg (Richards 1954) were determined to assess the treatment effects.

Results and Discussion

Soils physical properties : An increase in SCAR from 7 to 10 and RSC value beyond $7.5\ me\ L^{-1}$ in irrigation water resulted in a significant decrease in the hydraulic conductivity and water holding capacity of the soil (Table 2), compared with the values recorded from the treatment receiving water of minimum values. Deterioration in soil physical conditions with an increase in RSC and SCAR value in irrigation water is attributable to an increased sodium on the exchange complex leading to dispersion of soil aggregates and in turn decreased permeability (Somani *et al.* 1988). Further, a drastic reduction in the water holding capacity of the soil finer in texture has occurred when subject to such an irrigation, because dispersion of finer fraction of clay loam soil changes the pore geometry, increasing the proportion of small sized pores and decreasing the total soil porosity (Dargan *et al.* 1980).

Soil chemical properties : A marked decrease in Ec, organic carbon, soluble cations (calcium, magnesium, potassium and sodium) and anions (bicarbonate, chloride, and sulphate) and increase in pH

and exchangeable sodium percentage (ESP) of the soil (Table 2) was recorded with a rise of RSC and SCAR levels in irrigation water except bicarbonate ion concentration which recorded an increase with rise in RSC values. The decrease in soluble calcium and magnesium can be attributed to their precipitation as carbonate and that of soluble sodium to an increased adsorption on the exchange complex as is evident by the increased ESP of the soil. With the preprecipitation of Ca^{2+} and Mg^{2+} and conversion of soluble sodium to absorbed state, resulted in lowering down of the electrolyte concentration in the soil solution and thereby EC of the soil extract under the present investigation (Somani *et al.* 1988). Increase in pH of the soil at high value of SCAR and RSC in irrigation water is an outcome of increased sodicity and decreased activity of calcium (Pal *et al.* 1987). Further, at the equivalent level of RSC, a higher value of ESP was recorded for the soil which was clay loam in texture (Table 3) because higher the clay content more they are conducive for deterioration in physical conditions (Dargan *et al.* 1982), thereby decreasing the permeability of the soil and increasing the absorption of sodium on exchange complex (Lal & Lal 1977).

Plant growth and nutrient uptake : The morphological characters, dry matter yield, root weight, root CEC and uptake of nutrient elements except sodium by the wheat plants (Table 4) recorded a decrease with an increase in the SCAR from 7 to 10 and RSC value beyond $5.0\ me\ L^{-1}$ in the irrigation water. The reduction in plant growth and uptake of nutrient elements under these treatments is attributable to the deterioration in soil physical conditions and nutrient imbalance created in the root zone making the soil environment uncondusive for the proper growth (Fine *et al.* 1959). Further, the decreasing effect on these parameters was more pronounced in the plants raised on clay loam soil

Table 3 Interaction between RSC in irrigation water and soil types on ESP of the soil

Levels of RSC ($me\ L^{-1}$)	Soils	
	Clay loam	Sandy loam
0.0	12.87	12.08
2.5	14.62	13.47
5.0	15.86	14.39
7.5	18.15	16.91
10.1	20.75	17.55
SEm \pm	0.246	
CD 5%	0.410	

Table 4 Effect of SCAR and RSC levels in irrigation water on morphological characters, dry matter yield, and uptake of nutrient by wheat (*Triticum aestivum* L.)

Treatments	Height (cm)	No. of tillers plant ⁻¹	Flag leaf area (cm ²)	Dry matter (g pot ⁻¹)	Root weight (g pot ⁻¹)	Nutrient uptake (mg pot ⁻¹)					Root CEC me 100g ⁻¹	
						N	P	K	Na	Ca		Mg
SCAR												
7	38.4	1.6	5.79	7.33	1.88	72.2	3.0	123	29.7	59.2	7.9	9.18
10	36.8	1.6	5.00	6.57	1.74	70.2	2.9	93	36.7	42.9	11.3	8.91
SEM ±	0.4	0.07	0.04	0.23	0.03	0.8	0.2	12	3.9	5.7	1.9	0.09
CD 5%	1.1	NS	0.09	0.55	0.07	NS	0.5	28	5.5	13.5	2.6	0.21
RSC (me L⁻¹)												
0.0	38.9	1.8	5.51	7.43	2.20	74.2	3.3	123	28.5	56.9	11.7	9.56
2.5	38.0	1.7	5.45	7.31	2.10	74.1	3.2	117	31.7	54.6	11.0	9.43
5.0	37.9	1.6	5.40	7.24	1.75	73.4	3.1	114	34.3	53.0	10.5	8.93
7.5	37.3	1.6	5.37	6.80	1.57	70.1	2.9	103	35.3	47.4	9.3	8.75
10.0	35.9	1.3	5.25	6.11	1.42	64.2	2.4	86	35.9	30.9	5.4	8.56
SEM ±	0.7	0.11	0.06	0.37	0.05	0.60	0.1	8	2.7	4.0	1.3	0.14
Soil												
Clay loam	37.0	1.5	5.09	6.67	1.73	70.5	2.8	93	37.8	41.6	7.4	8.91
Sandy loam	38.2	1.6	5.70	7.29	1.89	72.0	3.2	124	28.5	59.2	11.8	9.18
SEM ±	0.4	0.07	0.04	0.23	0.03	0.8	0.2	12	3.9	5.7	1.9	0.09
CD 5%	1.1	NS	0.09	0.55	0.07	NS	0.5	28	5.5	13.5	2.6	0.21

than on sandy loam soil. The differential response on two soil types used under study is an outcome of the degree of their deterioration in soil physical and chemical properties (Dargan *et al.* 1982).

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