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Effect of RSC Water on Physico-chemical Properties of Typic Haplustalfs with Marigold (*Tagetes erecta*) and Chrysanthemum (*Chrysanthemum* spp.)

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Abstract: A lysimeter study was carried out in the Department of Agricultural Chemistry and Soil Science at Rajasthan College of Agriculture, Udaipur. The treatments comprized of two texturally different soils (sandy loam and clay loam), four RSC levels (0.0, 2.5, 5.0 and 7.5 m moles L^{-1}) in irrigation water and two flowering annuals (marigold and chrysanthemum) making 16 treatment combinations in factorial completely randomized design in triplicate. The ECe, organic carbon, water soluble Ca^{2+}, Mg^{2+}, K^+, Na^+, Cl^- and SO_4^- and exchangeable Ca^{2+}, Mg^{2+}, K^+ and SAR decreased, while the pH, water soluble CO_3^- and HCO_3^-, exchangeable Na^+ and ESP increased with rise in RSC level in irrigation water. A significantly low soluble Ca^{2+}, Mg^{2+} and HCO_3^- contents and higher values of soluble SO_4^- and exchangeable K^+ were observed in the soil with marigold. A higher accumulation of Mg^{2+}, K^+ and exchangeable K^+ was recorded in sandy loam soil, while higher values of exchangeable Ca^{2+}, Mg^{2+} and Na^+ were recorded in clay loam soil. Dry matter yield per lysimeter registered a decrease with an increase in RSC levels in irrigation water from 0.0 to 7.5 m moles L^{-1}. The reduction in dry matter yield was more pronounced in clay loam soil as compared to sandy loam soil. The content of N in flowering annuals increased with an increase in the RSC level in irrigation water, whereas the contents of P, K Cu, Fe, Mn and Zn showed a decrease with an increase in RSC levels in irrigation water from 0.0 to 7.5 m moles L^{-1}. Further, a higher content of N, P, Cu, Mn, and Zn was recorded for marigold.

Key words: Residual sodium carbonate, marigold, chrysanthemum, nutrient content.

In India 14.62 M ha of land, about 15% of cultivated area, is saline and/or sodic and more land is going out of cultivation every year due to continuous use of poor quality irrigation water or seepage from adjoining areas (Bhargawa and Kumar, 2004). In Rajasthan salt affected soils occupy about 1 M ha, of which nearly 70% area is in arid region (Mehta *et al.*, 1970). Soil salinity and alkalinity problems in Rajasthan are primarily due to continuous use of poor quality water and lack of sufficient rainfall. With the growing shortage of fresh water supplies, relatively poor quality water will have to be increasingly utilized for irrigation purpose. Amongst the various categories of poor quality water, alkali (sodic) waters have greater irrigation potential by virtue of their low salinity and amenability to reclamation, especially in semi-arid regions of north–west India, where their occurrence in ground waters is around 30-54% (Minhas and Bajwa, 2001). Such waters, with residual sodium carbonate (RSC) as high as 12 m moles L^{-1}, have been used successfully either for raising low water requiring crops on light textured soils or in conjunction with rain/canal water and application of amendments like gypsum (Bajwa *et al.*, 1986; Dhankar *et al.*, 1990). However, information on the impact of RSC water is limited especially when used on Typic Haplustalfs. Thus the present investigation was undertaken to study the effect of RSC water on physico-chemical properties of the Typic Haplustalfs.

Materials and Methods

The experiment was conducted in lysimeters (21 cm x 65 cm) at the green house of the Department of Agricultural Chemistry and Soil Science, Rajasthan College of Agriculture, Udaipur. The physico-chemical properties of the soils used in the study (Table 1) indicated that the light textured soil was sandy-loam and heavy textured soil was clay-loam in nature. Both the soils were non-saline, non-calcareous in nature and mild alkaline in reaction, medium in available phosphorus and potassium, while light textured soil was low and heavy textured soil was medium in available nitrogen. The DTPA extractable metallic cations status of both the soils was adequate for crop production.

The lysimeters, having coarse gravel of about 5 cm diameters at the bottom, were filled with soils

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Table 1. Physico-chemical properties of the soils used in the present study

Soil parameters	Coarse textured soil	Fine textured soil
Physical parameters		
Sand (%)	54.30	30.25
Silt (%)	25.12	40.27
Clay (%)	20.35	29.20
Textural class	Sandy loam	Clay loam
Chemical parameters		
pH (1:2, soil:water suspension)	8.20	8.50
EC (dS m^{-1} at 25°C)	1.20	1.10
Organic Carbon (g kg^{-1})	6.50	7.70
Available N (kg ha^{-1})	275.97	326.14
Available P (kg ha^{-1})	22.86	25.55
Available K (kg ha^{-1})	223.18	276.91
DTPA extractable Fe (mg kg^{-1})	6.96	8.25
DTPA extractable Cu (mg kg^{-1})	2.43	2.62
DTPA extractable Zn (mg kg^{-1})	1.73	1.85
DTPA extractable Mn (mg kg^{-1})	4.59	3.27
Soluble calcium (m moles L^{-1})	4.60	4.20
Soluble magnesium (m moles L^{-1})	2.20	2.00
Soluble potassium (m moles L^{-1})	0.50	0.60
Soluble sodium (m moles L^{-1})	6.90	6.50
Soluble carbonate (m moles L^{-1})	1.20	0.80
Soluble bicarbonate (m moles L^{-1})	4.00	4.20
Soluble chloride (m moles L^{-1})	5.10	5.30
Soluble sulphate (m moles L^{-1})	2.60	2.80

leaving about 10 cm space at the top. The lysimeters were arranged in factorial completely randomize design with two soil types (sandy loam and clay loam), two flowering annuals (chrysanthemum and marigold) and four levels of RSC in water (0.0, 2.5, 5.0 and 7.5 m moles L^{-1}) making in all 16 treatment combinations in triplicate. For irrigation waters of varying RSC levels (0.0, 2.5, 5.0 and 7.5 m moles L^{-1}) were prepared artificially by the addition of required amounts of NaCl, $CaCl_2$, $MgSO_4$ and $NaHCO_3$ to tap water and used for irrigation. The ingredients used to simulate different RSC waters are presented in Table 2.

The seeds of both the flowering annuals were sown by broadcasting on raised nursery beds. The seedlings attained a height of about 15 cm in four weeks and then they were transplanted in lysimeters, crop was irrigated with different levels of RSC water. Thirteen irrigations of 1 L each were given after transplanting of the saplings. The plants from individual treatment were harvested at full bloom and dry matter yield was recorded. The dry plant materials were digested in diacid using 4:1, nitric and perchloric acid (Richards, 1954). The extracts so obtained were subjected to chemical analysis using standard methods (Gupta, 2000). After harvesting of the crop soil samples from each lysimeter were drawn separately for analysis. Air dried soil samples were passed through 2 mm sieve and analyzed for physical and chemical characteristics following standard procedures (Black, 1965; Jackson, 1973). The soil reaction (pH of 1:2 soil water suspension) was determined by pH meter (Jackson, 1973). Electrical conductivity (ECe) of soil saturation extract, available potassium, soluble cations (Ca^{2+}, Mg^{2+}, K^+) and soluble anions (CO_3^{2-} and HCO_3^-) were determined using standard procedures (Richards, 1954). Soluble anions (Cl^- and SO_4^-) were determined in soil saturation extract following Jackson (1973). Organic carbon (OC), available nitrogen and phosphorus in the soil were estimated following Gupta (2000). The micronutrients were analyzed as per Lindsay and Norvell (1978). The data recorded for various attributes were analyzed statistically using analysis of variance suggested by Cochran and Cox (1950).

Table 2. Details of ingredients needed for the formulation of different RSC irrigation water

Level of RSC (m moles L^{-1})	EC (dS m^{-1})	m moles L^{-1} of various salts			
		NaCl	$CaCl_2$	$MgSO_4$	$NaHCO_3$
0.0	2.9	10.0	5.00	5.00	10.0
2.5	3.0	13.5	3.50	3.50	9.5
5.0	3.1	15.0	2.50	2.50	10.0
7.5	3.1	17.5	1.25	1.25	10.0

Results and Discussion

Effects on soil properties

An examination of the data (Table 3) revealed significant increase in pH of the soil with increasing levels of RSC in irrigation water, except the value recorded for the soil receiving water of 5.0 m moles L^{-1} over the soil receiving water with RSC level of 2.5 m moles L^{-1}. However, the pH values of two texturally different soils were statistically at par. The EC and OC content of the soil decreased with increase in the RSC levels of irrigation water. A significantly higher EC was recorded for sandy loam soil as compared to clay loam soil. However, in case of OC the trend was reverse. The differences in EC and OC content of the soil remained non-significant as a consequence of growing different flowering annuals. Increase in pH of the soil due to the use of higher RSC water for irrigation is attributed to an increased sodicity and decreased activity of calcium. Bajwa *et al*. (1992) also corroborate the findings of the present investigation. Higher OC

Table 3. Effect of different RSC levels in irrigation water, plant species and soil types on pH, EC and organic carbon of the soil

Treatments	Water soluble cations (m moles L^{-1})				Water soluble anions (m moles L^{-1})			
	Ca^{2+}	Mg^{2+}	K^+	Na^+	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-
RSC levels (me L^{-1})								
0.0	7.08	6.07	0.90	20.01	12.98	8.36	3.57	7.03
2.5	6.52	5.83	0.83	19.25	11.83	7.42	4.03	8.03
5.0	6.00	5.38	0.78	18.44	10.80	6.65	4.20	8.65
7.5	5.40	4.80	0.71	17.53	9.13	5.65	4.48	9.32
CD (5%)	0.25	0.19	0.03	0.39	0.29	0.28	0.16	0.28
Plant species								
Marigold	6.15	5.43	0.81	18.80	11.10	7.20	4.07	8.10
Chrysanthemum	6.35	5.62	0.80	18.82	11.28	6.84	4.07	8.41
CD (5%)	0.18	0.14	NS	NS	NS	0.20	NS	0.20
Soil types								
Sandy loam	6.30	5.64	0.82	18.88	11.10	7.12	4.05	8.29
Clay loam	6.20	5.40	0.79	18.74	11.27	6.93	4.08	8.23
CD (5%)	NS	0.14	0.02	NS	NS	NS	NS	NS

was observed in clay loam soil because these soils have higher fertility status as compared to sandy loam soil and thus might have led to greater root proliferation, leaving a greater crop residue in the soil. Further, a higher adsorption of calcium, magnesium and sodium on exchange complex in clay loam soil as compared to that of sandy loam soil can be explained on the basis of difference in organic matter and clay content of these two texturally different soils. Because of the dominance of clay minerals and fineness of the particles, the clay loam soil retained and adsorbed more cations than sandy loam soil (Singh and Narain, 1979). The physico-chemical properties of the soil due to different plant species of the flowering annuals in the present investigation did not vary much; however, certain variations recorded could be attributed to variation in utilization pattern of different ions from the growing medium

Increase in the RSC level from 0.0 to 7.5 m moles L^{-1} in irrigation water significantly decreased the content of water soluble calcium, magnesium, potassium, sodium, chloride and sulphate (Table 4). Contrary to this the water soluble carbonate and bicarbonate contents in soil saturation extracts significantly increased with increase in RSC level in irrigation water. The magnitude of decline of water soluble calcium, magnesium and sodium was more marked when the RSC of irrigation water was raised from 5.0 to 7.5 m moles L^{-1}. A significantly higher calcium, magnesium and sulphate and lower bicarbonate were recorded in the soil with chrysanthemum as compared to marigold.

Table 4. Effect of different RSC levels in irrigation water, plant species and soil types on water soluble cations and anions of the soil

Treatments	Exchangeable cations (m moles L^{-1})				SAR	ESP
	Ca^{2+}	Mg^{2+}	Na^+	K^+		
RSC levels (me L^{-1})						
0.0	6.72	7.34	4.86	0.55	7.80	24.96
2.5	6.27	6.70	5.74	0.49	7.75	29.90
5.0	5.62	6.54	6.75	0.43	7.73	34.90
7.5	4.53	5.93	7.62	0.39	7.76	41.26
CD (5%)	0.20	0.25	0.18	0.01	0.02	1.27
Plant species						
Marigold	5.81	6.61	6.28	0.47	7.81	32.76
Chrysanthemum	5.76	6.70	6.20	0.45	7.69	32.44
CD (5%)	NS	NS	NS	0.007	NS	NS
Soil types						
Sandy loam	5.57	6.36	6.03	0.47	7.73	32.76
Clay loam	6.00	6.89	6.46	0.45	7.78	32.63
CD (5%)	0.14	0.18	0.13	0.007	NS	NS

Table 5. Effect of different RSC levels in irrigation water, plant species and soil types on exchangeable cations retained by the soil, sodium absorption ratio (SAR) and exchangeable sodium percentage (ESP)

Treatments	pH	ECe (dS m^{-1})	OC (%)
RSC levels (me L^{-1})			
0.0	8.27	3.80	0.86
2.5	8.45	3.54	0.79
5.0	8.53	3.35	0.74
7.5	8.73	3.25	0.68
CD (5%)	0.139	0.084	0.014
Plant species			
Marigold	8.44	3.51	0.76
Chrysanthemum	8.54	3.46	0.77
CD (5%)	0.098	NS	NS
Soil types			
Sandy loam	8.46	3.55	0.75
Clay loam	8.53	3.43	0.78
CD (5%)	NS	0.059	.010

However, the values of potassium, sodium, chloride, carbonate and SAR remained non-significant as a consequence of growing different annuals. The sandy loam soil had significantly higher values of magnesium and potassium in the saturated extract, as compared to clay loam soil. However, the water soluble anions and SAR remained unaltered in the soil types. It is evident from the data on exchangeable cations retained by the soil (Table 5) that increasing RSC levels of irrigation water increased the exchangeable sodium. Increase in ESP was recorded with increase in RSC level of irrigation water. However, increase in ESP was non-signigicant due to plant species and soil type. Contrary to this, with increase in RSC level of irrigation water SAR also decreased significantly. The exchangeable Ca^{2+}, Mg^{2+} and K^{+} status, in general, showed a decrease with a rise in RSC level of irrigation water. However, the contents of exchangeable $Ca^{2+,}$ Mg^{2+} and Na^{+} did not differ as a consequence of plant species. The exchangeable K^{+} was significantly lower in the soil where chrysanthemum was grown as compared to the marigold. A significantly higher amount of exchangeable Ca^{2+}, Mg^{2+} and Na^{+} were retained by the clay loam soil, while, a significantly higher K^{+} was retained by the sandy loam soil. The decrease in water soluble calcium, magnesium and potassium with a rise in RSC level in irrigation water is attributed to their precipitation as carbonates and that of soluble sodium to its increased adsorption on the exchangeable complex, as is also evident by the increased exchangeable sodium status of the soil. The precipitation of calcium, magnesium and potassium and conversion of soluble sodium to adsorbed state in the soil in the present investigation have in turn decreased the electrolyte concentration in the soil solution and thereby EC of the soil saturation extract. Lal *et al.* (1980); Singh *et al.* (1994) and Whipker *et al.* (1996) have also reported similar findings.

Dry matter yield and nutrient content

Dry matter yield of flowering annuals (Table 6) significantly decreased with increasing RSC levels in irrigation water. The magnitude of decrease in dry matter yield was more marked when the RSC was raised from 5.0 to 7.5 m moles L^{-1}. A significantly higher dry matter yield was recorded for the chrysanthemum as compared to

Table 6. Effect of different RSC levels in irrigation water, plant species and soil types on dry matter yield and nutrient contents of plant

Treatments	Dry matter yield (g/lysimeter)	Macronutrient content (%)			Micronutrient content (mg kg^{-1})			
		N	P	K	Fe	Cu	Zn	Mn
RSC levels (me L^{-1})								
0.0	42.91	1.16	0.16	1.55	54.49	17.16	26.39	36.87
2.5	39.25	1.29	0.15	1.45	48.19	15.88	24.96	35.44
5.0	36.05	1.46	0.12	1.38	39.02	14.53	23.26	33.69
7.5	31.62	1.73	0.11	1.28	35.83	13.30	21.83	31.81
CD (5%)	1.74	0.03	0.004	0.03	1.75	0.39	0.35	0.69
Plant species								
Marigold	33.51	1.45	0.13	1.41	44.98	15.54	24.37	34.71
Chrysanthemum	43.16	1.38	0.12	1.41	44.24	14.90	23.84	34.19
CD (5%)	1.23	0.02	0.003	NS	NS	0.28	0.24	0.48
Soil types								
Sandy loam	37.46	1.42	0.13	1.42	46.04	14.83	23.71	33.76
Clay loam	39.21	1.41	0.13	1.41	43.18	15.61	24.49	35.15
CD (5%)	1.23	NS	NS	NS	1.24	0.28	.024	0.48

the marigold. Likewise, a significantly higher dry matter yield was recorded in plants raised in clay loam soil as compared to those raised in sandy loam soil. The reduction in dry matter yield of the flowering annuals with increase in RSC levels in irrigation water was due to deterioration of the soil physical conditions and imbalance in nutrients in the root zone due to increased exchangeable Na^+ and pH of the soil. The work of Verma *et al.* (1993); Singh and Pal (1994) and Singh and Totawat (1994) are in close conformity with the findings of the present investigation.

A critical examination of data revealed increase in the RSC level in irrigation water from 0.0 to 7.5 m moles L^{-1} significantly increased N in marigold as compared to the chrysanthemum (Table 6). The phosphorus and potassium contents in plants showed a significant decrease due to rise in the RSC levels in irrigation water from 0.0 to 7.5 m moles L^{-1} (Table 6). The magnitude of decrease in P content was more marked when the RSC of irrigation water was raised from 2.5 to 5.0 m moles L^{-1}. Further, a significantly higher P content in the plants was recorded for the marigold as compared to chrysanthemum. However, the N, P and K contents in plants grown in two texturally different soils remained statistically at par. The micronutrient (Fe, Cu, Zn and Mn) content in plant species (Table 6) significantly decreased with increase in RSC level. With a rise in RSC level from 2.5 to 5.0 m moles L^{-1} though Cu content decreased in plants, but the differences were not significant. However, the decrease in Fe content was distinctly higher when the RSC level of irrigation water was raised beyond 2.5 m moles L^{-1}. A significantly and distinctly lowest value of Mn and Zn content in plants was registered when the plants were irrigated with water of higher RSC level. Further, Cu, Zn and Mn contents were significantly higher in marigold as compared to chrysanthemum. The Fe content in both species was statistically at par. Likewise, a significantly higher Cu, Zn and Mn contents were recorded in plants grown in clay loam soil as compared to sandy loam soil. However, plant Fe content was significantly higher in annuals grown in sandy loam soil compared to clay loam soil.

The nitrogen in the plants increased with rise in RSC levels of irrigation water perhaps due to poor growth of plants which resulted in its increased concentration (Bains and Milton, 1964). A decrease in total phosphorus content in plants as a consequence of increase in RSC levels is an outcome of increased pH, which in turn increased the proportion of HPO_4^{2-}, and PO_3^- ions over $H_2PO_4^-$ ions at high pH (Somani,1990) limiting the absorption of phosphorus from the soil. Plants on the other hand have preferred to absorb H_2PO_4 ions. The OH^- ions, which increased with alkalinity is known to dictate the relative proportion of $H_2PO_4^-$ and HOP_4^{2-} ions in the soil solution (Lal *et al*, 1980). Moreover, the dominance of OH^- ions in the alkali medium also compete with $H_2PO_4^-$ ions for its absorption by the plant roots. Kanwar and Kanwar (1971) and Lal *et al.* (1980) also reported increase in pH of the soil due to irrigation with HCO_3^- rich waters decreased the absorption of phosphorus by plants. The decrease in K content as a consequence of increase in RSC levels seems to be outcome of partial substitution of K for Na (Singh *et al.*, 1994). Further, an increased proportion of Na in the soil solution due to precipitation of Ca and Mg as their carbonates increased the content of soluble Na in the growing medium, which in turn decreased the availability of K to the plants because it is competitor with K on adsorption sites (Effmert, 1960). Likewise, Fawzi and Abed (1975), Paliwal *et al.* (1978), Janzen and Clang (1987), Chauhan and Kumar (1993) have also reported that increasing levels of HCO_3^- ion concentration and RSC decreased the uptake of K by plants. The decreased micronutrients in the present investigation could be ascribed to more content of Ca^{2+}, Mg^{2+} and Na^+ at higher levels of RSC as a consequence of increased sodicity and pH which in turn reduced availability of micronutrients (Joshi, 1992).

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