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INTERACTING INFLUENCE OF SAR AND ELECTROLYTE CONCENTRATION ON THE HYDRAULIC CONDUCTIVITY AND DISPERSION OF SOILS

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ABSTRACT

Ladoratory studies on the interacting influence of Sodium Adsorption Ratio (SAR) and electrolye concentration on soil hydraulic conductivity (HC) and dispersion on two black and one red soils of Karnataka indicated that the hydraulic conductivity of soils decreased with increasing ESP and decreating electrolyte concentration. At dear eguivalest ESP and electrolyte concentontion, the greater reductions in hydraulic conductivity were observed in red soil as compared to black soils. The critical ESP value at which a sudden drop in HC occured varied from soil to soil. Red soil required higher threshold salt concentration (THC) than black soils at lower ESP values and vice-versa was observed at higher ESP values. Dispersion Index (DT) of all soils increased with increase in ESP. The greater the dispersion index of soils, the greater was the reduction in hydraulic conductivity.

A major concern in irrigation agriculture is the maintenance of sufficiently high soil permeability for salinity control. It is well known that the concentration and composition of the percolating solution have a great influence on the stability of soil structure and hydraulic conductivity of the soil. A decrease in soil hydraulic conductivity with decreasing electrolyte concentration and increasing SAR of the percolating solution was reported (McNeal and Coleman, 1966; Hamid and Mustafa, 1975 Pupisky and Shainberg, 1979). MuNeal and Coleman (1966) also reported that the *in situ* swelling and dispersion were the main reasons for reduction in hydraulic conductivity of 2:1 type of soils and disperion long was responsible in 1:1 type of soils. It was also observed that the threshold salt concentration increased as the ESP increased. A satisfactory permeability could be maintained even at higher levels of ESP provided the concentration of electrolyte is maintained progressively at higher levels.

MATERIALS AND METHODS

The experiment was conducted on two black soils, one from Malaprabha command area (Belvatagi) and the other from Tungabhadra command area (Siruguppa) and one red soil from Malaprabha command area (Manoli). The surface soil (0.15 cm) samples collected from different locations were air dried and processed to pass through

Table 1. Physico-chemical properties of soils

Soil properties	Belvatagi	Siruguppa	Manoli
pH (1:2 soil-water suspension)	8.10	8.20	7.90
EC (ds/m) (1:2 soil-water extract)	0.20	0.30	2.00
$CaCO_3$ (%)	10.50	8.50	8.15
Organic carbon (%)	0.60	0.80	0.65
Particle size analysis (%)			
Coarse sand	9.60	8.90	32.90
Fine sand	14.10	15.20	18.00
Silt	18.30	22.20	13.70
Clay	58.00	52.70	35.00
CEC (C mol K^{-1})	66.30	56.80	25.40

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Table 2. Effect of ESP and electrolyte concentration on the hydraulic conductivity (cm/hr) of different soils

ESP	Electrolyte concentration (me/l)					800
	800	200	50	12.5	3.13	
			BELVATAGI SOIL			
9.80	0.78 (1.00	0.78 (1.00)	0.76 (0.97)	0.75 (0.96)	0.68 (0.87)	0.73 (0.99)
13.10	0.77 (1.00)	0.75 0.97)	0.74 (0.96)	0.72 (0.94)	0.59 (0.77)	0.69 (0.89)
16.60	0.77 (1.00)	0.73 (0.95)	0.69 (0.89)	0.60 (0.77)	0.31 (0.40)	0.62 (0.81)
19.80	0.74 (1.00)	0.70 (0.99)	0.55 (0.74)	0.31 (0.42)	0.19 (0.25)	0.46 (0.63)
21.40	0.73 (1.00)	0.65 (0.89)	0.46 (0.63)	0.17 (0.23)	0.00 (0.00)	0.29 (0.39)
28.50	0.71 (1.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.17 (0.23)
			SIRUGUPPA SOIL			
13.60	0.62 (1.00)	0.63 (1.02)	0.62 (1.00)	0.60 (0.96)	0.56 (0.90)	0.58 (0.93)
22.30	0.59 (1.00)	0.60 (1.01)	0.54 (0.91)	0.44 (0.75)	0.40 (0.67)	0.52 (0.88)
28.20	0.59 (1.00)	0.58 (0.98)	0.52 (0.88)	0.36 (0.61)	0.28 (0.47)	0.41 (0.69)
35.40	0.57 (1.00)	0.52 (0.91)	0.33 (0.58)	0.21 (0.37)	0.04 (0.07)	0.1 (0.36)
38.00	0.55 (1.00)	0.21 (0.38)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.10 (0.18)
42.00	0.52 (1.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.07 (0.13)
			MANOLI SOIL			
7.10	3.46 (1.00)	3.36 (0.97)	3.08 (0.89)	2.90 (0.84)	2.77 (0.80)	2.49 (0.72)
11.20	3.29 (1.00)	3.16 (0.96)	2.86 (0.87)	2.60 (0.79)	2.37 (0.77)	2.24 (0.68)
17.60	3.20 (1.00)	3.01 (0.94)	2.60 (0.81)	2.24 (0.70)	2.05 (0.64)	2.12 (0.66)
22.10	2.92 (1.00)	2.69 (0.92)	2.31 (0.79)	1.96 (0.67)	1.52 (0.52)	1.82 (0.62)
26.90	2.85 (1.00)	2.50 (0.88)	2.19 (0.77)	1.85 (0.65)	0.78 (0.27)	1.12 (0.39)
42.00	2.10 (1.00)	1.77 (0.84)	1.37 (0.65)	0.86 (0.41)	0.36 (0.17)	0.46 (0.22)

Note : Values in parenthesis indicate RHC values.

a 2 mm sieve. The physico-chemical properties of soils are given in Table 1.

The soils were equilibrated with different SAR solutions (10, 20, 30, 40, 50 and 100 me/1) to have graded ESP value soils. Hydraulic conductivity and soil dispersion were studied on the equilibrated samples. Hydraulic condutivity measurements were made using plaxi- glass permeameters similar to those described by McNeal and Reeve (1964). The procedure for measuring the dispersion index was similar to that of Hamid and Mustafa (1975). Exchangeable sodium

Table 3. **Dispersion Index (%) as affected by ESP of different soils in distilled water**

Belvatagi		Siruguppa		Manoli	
ESP	DI	ESP	DI	ESP	DI
9.80	8.10	13.60	5.20	7.10	12.66
13.10	9.50	22.30	6.30	11.20	15.32
16.60	18.70	28.20	12.10	17.60	18.45
19.80	26.30	35.40	41.60	22.10	26.00
21.40	31.10	28.00	42.30	26.30	46.50
28.50	44.40	42.00	48.10	42.00	68.00

ESP = Exchangeable sodium percentage
DI = Dispersion index

percentage (ESP) of equilibrated samples was determined. The total time required for a sequence of determinations on a given sample ranged from a few days to several months. To suppress microbial activity, 40 ppm of $HgCl_2$ was added to all solutions.

RESULTS AND DISCUSSION

i) HYDRAULIC CONDUCTIVITY

The HC of all soils decreased with increasing ESP and decreasing electrolyte concentration. (Table 2) At the lowest ESP, decreasing the salt concentration from 800 to 3.13 me/1 did not cause drastic reductions in HC. At the highest electrolyte concentration (800 me/1), the reduction in HC with increasing ESP was found to be almost negligible suggesting that higher concentration electrolye could effectively counteract the adverse effects of exchangeable sodium. These results are in conformity with the findings of McNeal and Coleman (1966), Hamid and Mustafe (1975) and Pupisky and Shainberg (1979). The most rapid changes in Hc occured at salt concentration below 50 me/1. However, the concentration at which the HC became essentially equal to zero varied from soil to soil. The corresponding critical electrolyte concentration was 12.5, 12.5 and 50 me/1 for Belvatagi, Siruguppa and Manoli soils, respectively.

Similarly, the maximum ESP value at which HC reduced to minimum varied from soil to soil. The HC of Belvatagi and Siruguappa soil was reduced to almost nil a an ESP of 21.4 and 38.0 respectively. This reduction in HC of black soils might be attributed to swelling and subsequent dispersion of soil in the permeameter cup. In Belvatagi soil, the maximum swelling was at an electrolyte concentration of 3.13 me/1 and at an ESP of 21.4 whereas for Siruguppa soil, it was 50 me/1 at an ESP of 38.0. This indicates that at such a high level of ESP and low electrolyte concentration the breakdown of aggregates might have occured with the consequent release of humic acids which are responsible for binding and this must have resulted in the dispersion of clay particles. Even at relatively lower ESP values, the red soil was readily affected by the changes in electrolyte concentration. The HC of red soil was reduced to minimum, i.e., 0.36 cm/hr at an ESP of 42.0. Which could be attributed to the increased dispersion of soil. The increased dispersion was probably due to its higher content of coarse sand (32.9%) as the yield of water dispersible clay has been found to increase with the increase in coase sand content (Ashford *et al*, 1972).

Siruguppa soil was quite stable even at relatively higher ESP values as compared to Belvatagi soil. This was probably due to differences in their minerological make-up. The Siruguppa soil having mixed type of caly (Kenchana Gowda, 1977, Bhargava *et al.*, 1976) did not exhibit drastic changes in HC at higher ESP values. The excess exchangeable

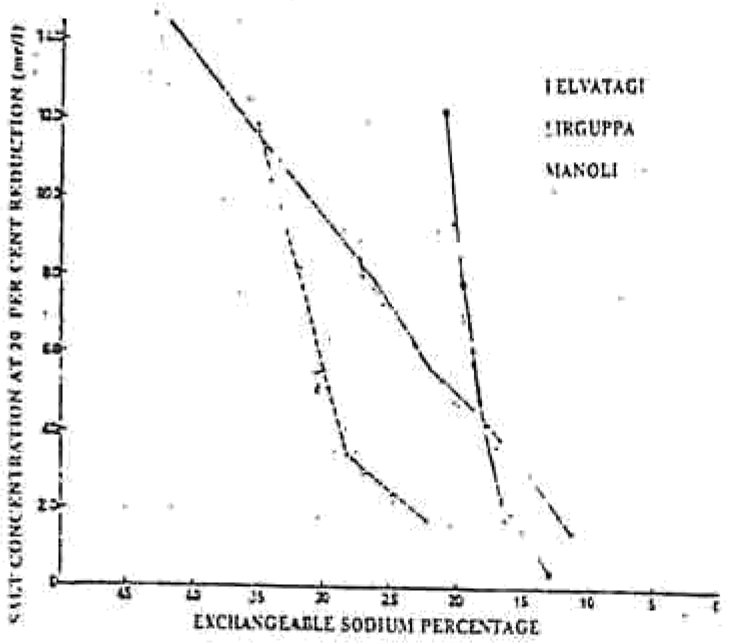

FIG.1 Combinations of Salt Concentration and Exchangeable Sodium percentage at which 20 per cent reduction

sodium adsorbed by the mixed type of clay minerals especially by mica was essentially in active in reducing soil permeability which is in conformity with the findings of Thomas and Yaron, (1968).

At lower ESP values, Siruguppa black soil showed a slight increase in HC over the initial HC when a solution of higher electrolyte concentration (800 me/1) was replaced by a solution of lower electrolyte concentration (200 me/1). This was due to decrease in the viscosity of the leaching solution. The viscosity effect, however, becomes insignificant at the highest ESP values as the soil structure will be lost due to dispersion and/or swelling. Thus, permiability of soils decrease rapidaly (Waldron and Constantim, 1970).

The inital high electrolyte concentraton (800 me/1) which re- inctroducted at the end resulted in the recovery of HC to varying degrees in all types of soils. The recovery was more or less equal to the initial HC at lowever ESP values and decreased with increasing ESP in the case of black soils. But in red soil the recovery was very poor. The above results suggest that the swelling in montenorillomite could be reversed whereas dispersion of clay in red soil could not be aggreagated with high salt solutions (McNeal and Coleman. 1966)

A slight improvement in HC was observed in all soils even then soil HC was tended to zero. This clearly indicates that higher salt concentrations bring flocculation of soil and helps in maintaining the higher HC.

ii) RELATIVE HYDRAULIC CONDUCTIVITY

The RHC values were calculated by expressing the HC for a given solution as a fraction of initial HC value obtained for the highest salt solution (800 me/1) at a given ESP. The RHC diminished with increase in ESP and decreasing salt concentration from 800 to 3.13 me/1 in all soils. The pattern of RHC changes in both red and black soils were identical.

The combinations of ESP and the corresponding threshold concentration (THC) which is required to maintain 80 per cent of the initial RHC in both black and red soils are depicted in Fig.1. From the figure, it is obvious that THC increases as the ESP increases. The critical ESP at which a sudden drop in RHC occured varied from soil to soil. This critical ESP and corresponding THC reguired to maintain 80 per cest of the Initital RHC was 13.1 and 4.0 me/1 for Belvatagi soil. 22.3 and 18.0 me/1 for Siruguppa soil, 11.2 and 15.0 me/1 for Manoli red soil, respectively.

iii) DISPERSION INDEX

The results on the dispersion behavious of soils in distilled water presented in Table 3 indicated that DI increased with increase in ESP. The Manoli red soil was more dispersed than black soils at near equivalent ESP. Even at lower ESP value, the red soil disperesed more than black soils. The abrasive action of sand during agitation associated with water dispersion resulting in breakdown of aggregates containing clay was the main reason for the increased dispersion of red soils (Ashford *et al*, 1972). Another reason for increased dispersion might be attributed to the presence of little quantity or absence of sesqui-oxides which otherwise would have brought structural stability of red soils (El-Swaify *et al*, 1970). On the other hand, the stability of black soils to dispersion might be due to presence of high free $CaCo_3$. The least dispersion in Siruguppa soil could also be attributed to its mixed mineralogy. Similar results were reported by Velasco-Molina *et al*. (1971).

From the results on HC and dispersion it is clear that greater reductions in HC coincided with higher dispersion indices and the adverse effects of sodium became significant only when a particular ESP was reached which is said to be the 'critical ESP' and this critical ESP varied from soil to soil. The red soil had lower critical ESP which indicates that red soils are more vulnerable to adverse effects of sodium than bleak soils. The Belvatagi soil had lower critical ESP than Siruguppa soil due to its higher clay content. The finer the texture, the lesser the value of critical ESP because of smaller grain pressure as reported by Lagerwerff *et al* (1969). The critical ESP of Siruguppa soil could be attributed to its mixed type of mineralogy. Thus, the critical ESP 15 which had been arbitrarily fixed to differentiate sodic and non- sodic soils assumes no significance for all the soils.

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