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Effect of sodium adsorption ratio and total electrolytic concentration on chemical properties of salt affected soils in Purna valley of Maharashtra

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Abstract
The present investigation was carried out in the Purna valley of Vidarbha region of Maharashtra to study the effect of sodium adsorption ratio with total electrolyte concentration and on chemical properties of salt affected soils in Purna valley of Maharashtra. The sampling was done in the month of October, 2013. The soil samples were taken from two sites; at the depth of 0-20 cm (surface soil) and 20- 40 cm (sub-surface soil) respectively. For equilibration of soil samples the synthetic waters were prepared with 4 levels of total electrolyte concentrations (TEC) i.e.10, 20,40,80 meL^{-1} with three levels of SAR viz., 5, 10 and 15 mmol$^{1/2}$L$^{-1/2}$. At low electrolyte concentration, high SAR values were not attained in the equilibrating solution. The positive interaction of total electrolyte concentration.

Keywords: Total electrolyte concentration, Sodium adsorption ratio, Exchangeable sodium percentage

Introduction

Soil salinity and sodicity is the major threat to the agriculture, which not only seriously harm the agricultural productivity but also cause soil degradation.

Salt affected soils consists of saline, saline-sodic and sodic soils. Millions of hectares (955 M.ha) of land throughout the world are affected by salinity and sodicity and this area is increasing year after year because of salt accumulation (Lal *et al.* 1993) [9]. In India these soils occupy an area about 12 M.ha (Sharma and Gupta, 1986). In Maharashtra about 0.54 M.ha of swell-shrink soils are initially reported to be salt affected (Abhange *et al.* 1986) [1] which has been increased to 1.06 M.ha (3.4%) of the total geographical area (Gaikwad and Challa 1996) [5]. The Purna valley of Vidharbha region is an East – West elongated basin with slight curving to south, occupying part of Amravati (1738 sq.km), Akola (1939 sq.km) and Buldhana (1015sq.km) district of Vidharbha and extends from 20^045' to 21^051' N latitude and 75^025' to 77^045' E longitude with east west length 100-150 km (Balpande *et al.*1993) [2].

The tract spreads both sides of Purna River influencing about 894 villages, covering area about 4692 sq.km. The land form is nearly plain. The soils are fine textured with imperfect poor drainage and high water holding capacity. The clay content ranges from 52-70%, the pH, ECe and ESP ranges from 7.7 to 9.4, 0.90 to 5.20 dSm^{-1} and 2.57 to 33.78 respectively. The soils are mostly normal at surface horizons and problem of salinity / sodicity increase with depth (Padole *et al.* 1998) [10].

Materials and Methods

The present laboratory investigation entitled "Effect of Sodium Adsorption Ratio with Total Electrolyte Concentration and on Chemical Properties of Salt Affected Soils in Purna Valley of Maharashtra " was carried out during 2013-14 in Purna valley of Vidarbha region of Maharashtra state. The materials and methods are discussed in this chapter.

Site Description and Collection of Soil

The study area comprises parts of Purna valley of Vidarbha region of Maharashtra state. Soil samples were collected from Ramagar village under Daryapurtashil of Amravati district (latitude: 20° 55' 19.452 " N, longitude: 77° 19' 36.40 " E). The sampling was done in the month of October, 2013. The soil samples were taken from two sites, the samples were collected up to the depth of 0-20 cm (surface soil) and 20- 40 cm (sub-surface soil) respectively.

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Preparation of different qualities of synthetic water
For equilibration of soil samples, the synthetic waters were prepared with 4 levels of total electrolyte concentrations (TEC) i.e.10, 20, 40, 80 meL^{-1} with three levels of SAR viz., 5, 10 and 15 mmol$^{1/2}$ L$^{-1/2}$. The Ca: Mg ratio were kept at 1: 1.5 in these solutions. Pure AR grade chloride salts of calcium magnesium and sodium were used to prepare different quality waters.

Each quality of waters is prepared as below. As per definition

$$SAR = \frac{Na^+}{\sqrt{\dfrac{Ca^{2+} + Mg^{2+}}{2}}}$$

Physicochemical Properties
The physicochemical properties of experimental soil samples were determined by using the standard methods. The Soil pH was determined by a glass electrode pH meter in 1:2 soil: water suspension as given by Jackson, 1973 [6]. The Electrical conductivity (1:2) measured by measured by ELICO conductivity bridge meter (Jackson, 1973) [6]. The organic carbon was determined by Walkely and Black (1934) [17] rapid titration procedure. Soil samples were oxidized by Potassium dichromate (1N) and the concentrated H_2SO_4 was used to generate the heat of dilution. The amount of unutilized dichromate was determined by back titration with Standerd ferrous ammonium sulphate solution (0.5N). The free calcium carbonate was determined by rapid titration method (Pipper, 1966). The soil was treated with a known volume of 0.5 N HCl to neutralize all the carbonates. The unutilized HCl was back titrated with Standard NaOH of 0.25N using phenolphthalein as an indicator. The exchangeable Ca^{2+} and Mg^{2+} were determined by leaching the soils in 1N KCl TEA, buffer solution (pH 8.2) and titrating the leachate with standard EDTA solution using mureoxide and EBT as an indicator (Jackson.1973) [6]. Exchangeable sodium and potassium were determined by leaching the soil with 1N ammonium acetate (pH7) solution, Na^+ and K^+ from the leachate were estimated by using Flame photometer given by Page *et al.* (1982) [11]. For the determination of cation exchange capacity (CEC) soil was saturated with 1N NaOAC (sodium acetate pH 8.2), after removal of excess, sodium acetate by washing with alcohol, the adsorbed sodium was extracted by washing with 1N NH_4OAC (ammonium acetate

pH7) and the leachate was made up to known volume. Na^+ present in the leachate was determined with flame emission spectrophotometer (Jackson, 1973) [6] and Percent Base saturation, Exchangeable sodium percentage (ESP) was derived by using following equations:

$$PBS = \frac{\text{Exchangeable base}}{CEC} \times 100$$

$$ESP = \frac{\text{Exchangeable sodium}}{CEC} \times 100$$

Where, Exchangeable cations and CEC of soils were expressed in c mol (p+) kg^{-1}

Exchangeable sodium ratio (ESR)
The exchangeable sodium ratio determined by

From extract ESR = (-0.0126 + 0.01475 SAR) developed by U.S. Salinity Laboratory Staff (1954) [16].

$$\text{From soil ESR} = \frac{Ex\ Na}{CEC - Ex\ Na} \times 100, \text{developed by Jurinak et al. (1984).}$$

Exchangeable Sodium Percentage (ESP)
The exchangeable sodium percentage from the paste extract was determined by

$$ESP = \frac{100(-0.0126 + 0.01475\ SAR)}{1 + (0.0126 + 0.01475\ SAR)}$$

The above equation was developed by U.S. Salinity Laboratory Staff (1954) [16].

Saturation extracts analysis
The saturated paste was prepared and the extract was obtained. The method described by Richards (1954) [14] was followed for the saturation extract preparation. The saturation extracts of the soil samples were analyzed for pHs, electrical conductivity (ECe) and cations and anions as per the methods outlined by Richards (1954) [14]. Saturation percentage was determined from a volume of water required to prepare the paste of known weight of the soil.

Chemical composition of different quality of synthetic solutions

SAR mmol1/2 L-1/2	TEC 10 meL^{-1}					TEC 20 meL^{-1}					TEC 40 meL^{-1}					TEC 80 meL^{-1}				
	Na$^+$	Ca^{2+}	Mg^{2+}	Cl$^-$	Total	Na$^+$	Ca^{2+}	Mg^{2+}	Cl$^-$	Total	Na$^+$	Ca^{2+}	Mg^{2+}	Cl$^-$	Total	Na$^+$	Ca^{2+}	Mg^{2+}	Cl$^-$	Total
5	6.4	1.8	1.8	10	10	11	3.5	5.7	20	20	17	8.9	14	40	40	27	22	31	80	80
10	8.7	0.5	0.9	10	10	15	1.8	2.7	20	20	26	6	8.1	40	40	43	15	22	80	80
15	9	0.5	0.5	10	10	18	1.1	1.1	20	20	31	3.4	5	40	40	54	10	16	80	80

Equilibration of soil samples
Soil samples passed through 2 mm sieve were kept on the Buchner funnels and allowed to leach with the equilibrating solution. About 300 g soils were taken in the Buchner funnel. After addition of the solution the leaching were facilitated by the application of suction to Buchner funnel using a vacuum pump. The leaching process was continued till effluent attains nearly the constant composition. For certain estimations such

as organic carbon, samples were further ground and passed through a 0.2 mm (80 mesh) sievs, as suggested by Jackson, (1973) [6]. The soil samples thus prepared were air dried and after appropriate grinding, sieved the samples were used for the determination of different properties viz. swelling, degree of dispersion, hydraulic conductivity and aggregate stability and as well as coefficient of linear extensibility.

Statistical analysis:
Statistical analysis was carried out by analysis of variance technique for two way classification as suggested by Panse and Sukhatme (1985) [12] and multiple linear regression as suggested by Darlington *et al.* (1973) [3].

$$Y = a + b_1 X_1 + b_2 X_2.$$

Where,
X_1 = TEC
X_2 = SAR
Y = Ca^{+2}, Na^+, SAR (eq.), ESP.

Results and Discussions
The data presented in Table 1 revealed that the pH (1:2) was recorded 8.53 (surface soil) to 8.6 (sub-surface soil) for first site and for second site it was 8.31(surface soil) and 8.37(sub-surface soil) which was increased with depth. This may be due to the alkaline hydrolysis of bicarbonates which is predominant in these soils. The electrical conductivity ranged from 0.17 dSm^{-1} (surface soil) and 0.23 dSm^{-1}(sub-surface soil) for the first site, and for second site it was 0.16 dSm^{-1} (surface soil) and 0.25 dSm^{-1}(sub-surface soil). The electrical conductivity in subsoil was observed more. The calcium carbonate was 9.4% (surface soil) and 11.6% (sub-surface soil) for the first site, and for second site it was 8.37% (surface soil) and 10.2 per cent (sub-surface soil). Calcium carbonate concentration is increased in sub soil layers. The organic carbon was recorded 4.0 g kg^{-1}(surface soil) and 2.7 g kg^{-1}(sub-surface soil) in first site, and for second site it was 4.3 g kg^{-1}(surface soil) and 2.5 gkg^{-1}(sub-surface soil). In general, the organic carbon observed low in the sub soil which is due to dispersion of organic matter caused by exchangeable Na^+.

Table 1: Initial chemical properties of soil

Depth	pH (1:2)	EC (1:2) dSm-1	CaCO₃ (%)	Organic Carbon (g kg-1)
Site I (0-20 cm)	8.53	0.17	9.4	4
Site I (0-20 cm)	8.6	0.23	11.6	2.7
Site II (0-20 cm)	8.31	0.16	8.37	4.3
Site II (20-40 cm)	8.37	0.25	10.2	2.5

Ion exchange analysis
The exchange complex of studied soil was dominated by calcium, magnesium and sodium. The calcium ion (Ca^{2+}) and magnesium ion (Mg^{+2}) in general showed decreasing trend with depth in soil where sodium (Na^+) showed increasing trend. The base saturation percentage was 96.77 per cent (surface soil) and 87.44 per cent (sub-surface soil) in the first site and 94.61 per cent (surface soil) and 85.16 per cent (sub-surface soil) in the second site, which was highly base saturated (Table 2)

Table 2: Ion exchange analysis data of initial soil

Site/ Depth	Extractable basesc mol (P+) Kg-1				Total Cations	CEC Cmol (p+) kg-1	Base saturation (%)	ESP (%)	ESR
	Ca²⁺	Mg²⁺	Na⁺	K⁺					
Site I (0-20 cm)	33.4	12.6	4.2	1.3	51.58	53.3	96.77	7.87	0.08
Site I (20-40 cm)	30.4	11.8	5.1	0.97	48.27	55.2	87.44	9.23	0.1
Site II (0-20 cm)	33	12.4	4.6	1.28	51.28	54.2	94.61	8.48	0.09
Site II (20-40 cm)	31.4	10.8	5.7	0.9	48.8	57.3	85.16	9.94	0.11

Soluble cations
The cations viz. Ca^{+2}, Mg^{+2}, Na^+ in two sites are presented in Table 3 and 4. The Ca^{+2} content in the equilibrated soil solution was increased at 10 to 80 meL^{-1} total electrolyte concentration level and with SAR level from 5 to 15 mmol$^{1/2}$L$^{1/2}$ calcium concentration decreased. Similar result was found in case of magnesium. Sodium concentration was increased at 5 to 15 SAR level and with 10 to 80 meL^{-1} total electrolyte concentration level sodium concentration was increased.

SAR of equilibrated soil
The data presented in Table 3 and 4 showed that SAR increased with increasing SAR levels and also with increasing total electrolyte concentration. With increasing depth there was a sharp increase in the SAR values of the equilibrated soils. It indicated that sodification started in deeper layer and it is continuing upward. At low total electrolyte concentration, high SAR values were not attained in the equilibrating solution may be because of addition of calcium and magnesium from the mineral dissolution as well as exchange phase.

Exchangeable sodium percent (ESP)
The data reading ESP at different total electrolyte concentration and SAR level presented in Table 3 and 4. The ESP values increased with depth. The increase in ESP values with depth might be due to high sodimized clay content which increased with depth.

Exchangeable sodium ratio
Exchangeable sodium ratio was increased along with increasing total electrolyte concentration level and with increasing SAR. ESR was increased along with soil depth in two different sites.

Table 3: Saturation paste extract analysis data of equilibrated soil in site I

Depth	SAR (mmol$^{1/2}$L$^{-1/2}$)	Soluble cations (meL^{-1})			SAR (mmol$^{1/2}$L$^{-1/2}$)	ESP	ESR
		Ca^{+2}	Mg^{+2}	Na$^+$			
0-20 cm	TEC 10 (meL^{-1})						
	5	2.6	6	6.49	3.13	3.19	0.03
	10	2.2	5.4	8.62	4.28	4.71	0.05
	15	2	5.6	9.12	4.7	5.25	0.05
	TEC 20 (meL^{-1})						
	5	3.3	6.8	6.81	3.04	3.06	0.03
	10	3.2	6.6	11.3	5.11	5.8	0.06
	15	3.1	6.5	12.32	5.62	6.44	0.07
	TEC 40 (meL^{-1})						
	5	4.4	7	10.22	4.29	4.72	0.05
	10	4.1	6.9	32.31	13.8	15.77	0.19
	15	4	6.7	34.11	14.76	16.67	0.2
	TEC 80 (meL^{-1})						
	5	5.5	8	28.98	11.18	13.01	0.15
	10	5.4	7.8	30.23	11.8	14.73	0.16
	15	5.2	7.4	59.19	23.67	24.74	0.33
20-40 cm	TEC 10 (meL^{-1})						
	5	3.5	6.7	6.69	2.97	2.97	0.03
	10	3.3	6.5	8.85	4	4.33	0.04
	15	3.1	6	9.13	4.28	4.71	0.05
	TEC 20 (meL^{-1})						
	5	4.4	6.9	14.69	6.19	7.15	0.07
	10	4.1	6.7	15	6.46	7.5	0.08
	15	4	6.5	18.7	8.16	9.53	0.1
	TEC 40 (meL^{-1})						
	5	5.5	7	17	6.8	7.9	0.08
	10	5.3	6.9	34.2	13.9	15.9	0.19
	15	5	6.6	37.2	15.5	17.41	0.21
	TEC 80 (meL^{-1})						
	5	7.4	8.4	30.82	10.96	12.73	0.14
	10	7.2	8.3	50.11	18.02	19.92	0.25
	15	7.1	8.1	67.78	24.64	25.6	0.35

Table 4: Saturation paste extract analysis data of equilibrated soil in site II

Depth	SAR (mmol$^{1/2}$L$^{-1/2}$)	Soluble cations (meL^{-1})			SAR (mmol$^{1/2}$L$^{-1/2}$)	ESP	ESR
		Ca^{+2}	Mg^{+2}	Na$^+$			
0-20 cm	TEC 10 (meL^{-1})						
	5	2.4	5.8	7.2	3.56	3.76	0.03
	10	2.2	5.7	8.6	4.34	4.8	0.05
	15	2.1	5.6	9.1	4.64	5.16	0.06
	TEC 20 (meL^{-1})						
	5	3.7	6.8	6.99	3.05	3.07	0.03
	10	3.4	6.6	11.11	4.98	5.62	0.06
	15	3.2	6.3	13.69	6.3	7.3	0.08
	TEC 40 (meL^{-1})						
	5	4.4	6.9	11.29	4.76	5.33	0.05
	10	4.3	6.8	30.52	12.98	14.9	0.17
	15	4.2	6.7	32.07	13.76	15.72	0.19
	TEC 80 (meL^{-1})						
	5	5.3	7.9	31.25	12.2	14.05	0.16
	10	5.2	7.8	33.98	13.37	15.38	0.18
	15	5.1	7.6	60.82	24.23	25.72	0.34
20-40 cm	TEC 10 (meL^{-1})						
	5	3.3	6.6	7.78	3.5	3.67	0.03
	10	3.2	6.5	8.16	3.7	3.95	0.04
	15	3.1	6.3	9.54	4.41	4.89	0.05
	TEC 20 (meL^{-1})						
	5	4.5	6.8	15.64	6.59	7.69	0.08
	10	4.3	6.7	16.89	7.21	8.49	0.09
	15	4.2	6.5	19.97	8.64	11.16	0.11
	TEC 40 (meL^{-1})						
	5	5.7	6.9	18.12	7.24	8.47	0.09
	10	5.5	6.8	33.89	13.72	15.67	0.18

15	5.4	6.7	35.25	14.38	16.35	0.19
TEC 80 (meL^{-1})						
5	7.3	8.3	31.82	11.4	14.23	0.15
10	7.2	8.1	52.31	18.95	20.68	0.26
15	7	8	70.03	22.82	24.17	0.32

Calcium concentration of the equilibrated soil

The results with respect to calcium concentration of the equilibrated samples treated with different total electrolyte concentration and SAR are presented in Table 9 for first and second site of soil respectively.

Effect of total electrolyte concentration on the Calcium concentration

The results presented in Table 5 showed that calcium concentration of site I (surface soil) was 2.27, 3.20, 4.17 and 5.37 meL^{-1} at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels. The calcium concentration was found to increased by 136.56% with increase in different total electrolyte concentration levels of equilibrating solution.

Similarly in site I of sub-surface soil, the calcium concentration was 3.30, 4.17, 5.27 and 7.23 meL^{-1} at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels. The calcium concentration was found to decrease by 119.09% with increase in different total electrolyte concentration levels of equilibrating solution.

Table 5: Effect of total electrolyte concentration and SAR on Calcium concentration

Depth (cm)	SAR (mmol$^{1/2}$L$^{-1/2}$)	Ca^{+2} (meL^{-1})				Mean
		Total electrolyte concentration (meL^{-1})				
		10	20	40	80	
Site I (0-20)	5	2.60	3.30	4.40	5.50	3.95
	10	2.20	3.20	4.10	5.40	3.73
	15	2.00	3.10	4.00	5.20	3.58
	Mean	2.27	3.20	4.17	5.37	
	TEC: SE (m) = 0.05 CD at 5% = 0.19			SAR: SE (m) = 0.04 CD at 5% = 0.16		
Site I (20-40)	5	3.50	4.40	5.50	7.40	5.20
	10	3.30	4.10	5.30	7.20	4.98
	15	3.10	4.00	5.00	7.10	4.80
	Mean	3.30	4.17	5.27	7.23	
	TEC: SE (m) = 0.03 CD at 5% = 0.11			SAR: SE (m) = 0.02 CD at 5% = 0.09		
Site II (0-20)	5	2.40	3.70	4.40	5.30	3.95
	10	2.20	3.40	4.30	5.20	3.78
	15	2.10	3.20	4.20	5.10	3.65
	Mean	2.23	3.43	4.30	5.20	
	TEC: SE (m) = 0.04 CD at 5% = 0.14			SAR: SE (m) = 0.03 CD at 5% = 0.12		
Site II (20-40)	5	3.30	4.50	5.70	7.30	5.20
	10	3.20	4.30	5.50	7.20	5.05
	15	3.10	4.20	5.40	7.00	4.93
	Mean	3.20	4.33	5.53	7.17	
	TEC: SE (m) = 0.02 CD at 5% = 0.07			SAR: SE (m) = 0.01 CD at 5% = 0.06		

As per the results showed in Table 5 with the increase in the total electrolyte concentration from 10, 20, 40 and 80 meL^{-1} in the second site (Surface soil) calcium concentration was 2.23, 3.43, 4.3 and 5.2 meL^{-1} respectively, irrespective of SAR levels and in site II of sub-surface soil, the calcium concentration was 3.20, 4.33, 5.53 and 7.17 meL^{-1} at 10, 20, 40 and 80 meL^{-1} TEC of equilibrating solution.

At the same SAR level, the calcium concentration was found to increase by 133.18% and 124.06% respectively with increase in total electrolyte concentrations level of the equilibrating solution (Fig. 1).

Effect of SAR on the calcium concentration

The results in Table 5 showed that the calcium concentration of site I (surface soil) was 3.95, 3.73 and 3.58 meL^{-1} at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different total electrolyte concentrations level.

In sub-surface soilof site I the calcium concentration was 5.20, 4.98 and 4.80 meL^{-1} at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte levels.

At the same total electrolyte concentration levels, the calcium concentration was found to decrease by 10.33% and 8.33% respectively with increase in SAR level 5 to 15 of the equilibrating solution.

In site II (surface soil) the calcium concentration was 3.95, 3.78 and 3.65 meL^{-1} respectively, whereas, in sub-surface soil, the calcium concentration of equilibrated samples were 5.20, 5.05 and 4.93 meL^{-1} at 5, 10 and 15 SAR levels respectively, irrespective of different electrolyte levels.

At the same level of concentration, the calcium concentration was found to decrease about 8.21% and 5.47% respectively with increase in SAR levels from 5 to 15 of the equilibrating solution.
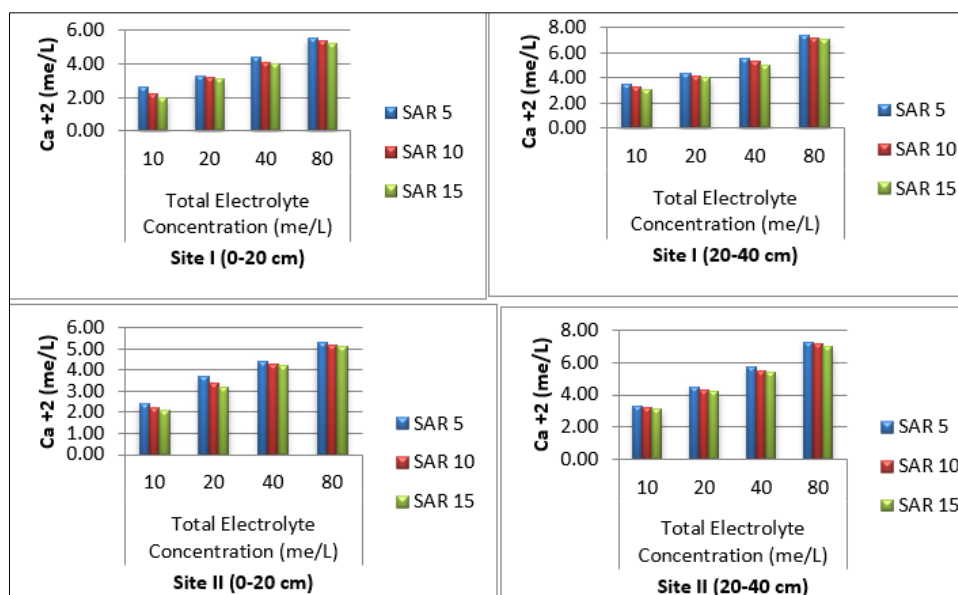
Fig 1: Relationship between total electrolytes concentration and sodium adsorption ratio with calcium concentration in different site

Relationship between total electrolytes concentration and sodium adsorption ratio with calcium concentration in different sites

The data presented in Table 5 revealed that with increase in TEC level from 10 to 80 meL^{-1} calcium concentrations increased. There is a significant relationship between total electrolyte concentration and calcium concentration at 5% level of significance.

The results showed that with increase in SAR, calcium concentration of the equilibrated soil was increased. So, there is a significant relation between SAR and calcium concentration of the equilibrated soil at 5% level of significance. With increasing TEC, calcium concentration was increased, because addition of calcium and magnesium mineral and their dissolution.

The results with respect to total electrolytes concentration and sodium adsorption ratio with calcium concentration of equilibrated samples for multiple regressions are presented in Table 6.

Table 6: Multiple linear regression of TEC and SAR with calcium concentration in different sites

Independent variable	Site I (0-20 cm)	Site I (20-40 cm)	Site II (0-20 cm)	Site II (20-40 cm)
a (Constant)	2.55	3.34	2.65	3.31
b_1 (TEC)	0.04**	0.05**	0.03**	0.05**
b_2 (SAR)	-0.03*	-0.04**	-0.03	-0.02
R^2	0.94**	0.99**	0.88**	0.96**

**Significant at 0.01% level of significance
*Significant at 0.05% level of significance

In the site I surface soil the total electrolytes concentration positively significant at 0.05% level of significance and sodium adsorption ratio negatively significant at 0.01% level of significance. It showed that the coefficient of determination was significant at 0.01% level of significance. Similarly in the site I sub-surface soil the total electrolyte concentration positively significant and sodium adsorption ratio negatively significant at 0.01% level of significance. It showed that the coefficient of determination was significant at 0.01% level of significance.

In the site II surface soil the total electrolyte concentration positively significant at 0.01% level of significance and sodium adsorption ratio was negatively related. It showed that the coefficient of determination was significant at 0.01% level of significance. Similarly in the site II sub-surface soil the total electrolytes concentration positively significant at 0.01% level of significance and sodium adsorption ratio was negatively related. It showed that the coefficient of determination was significant at 0.01% level of significance.

Sodium concentration of the equilibrated soil

The results with respect to sodium concentration of the equilibrated samples with different TEC and SAR are presented in Table 7 for first and second site of soil respectively.

Effect of total electrolyte concentration on the sodium concentration

The results presented on Table 7 showed that, sodium concentration of site I (surface soil) was 8.08, 10.14, 25.55 and 39.47 meL^{-1} at 10, 20, 40 and 80 meL^{-1} at total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels.

Similarly in site I of sub-surface soil, the sodium concentration was 8.22, 16.13, 29.47 and 49.57 meL^{-1} at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels. At the same SAR level the sodium concentration was found to increase by 388.49% and 503.04% respectively with increase in different electrolyte concentration levels of equilibrating solution.

As per the results presented in Table 7, with the increase in the total electrolyte concentration from 10, 20, 40 and 80 meL^{-1} in the first depth of the second site (surface soil) sodium concentration was 8.30, 10.60, 24.63 and 42.02 meL^{-1} respectively, irrespective of SAR levels and in site II of sub-surface soil the sodium concentration was 8.49, 17.50, 29.09

and 51.39 meL^{-1} at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution.

At the same SAR level, the sodium concentration was found to increase by 406.26% and 505.30% respectively with increase in total electrolyte concentration level of the equilibrating solution (Fig. 2).

Table 7: Effect of total electrolyte concentration and SAR on sodium concentration

| Depth (cm)	SAR (mmol$^{1/2}$L$^{-1/2}$)	Na$^+$ (meL^{-1}) Total electrolyte concentration (meL^{-1})				Mean
		10	20	40	80	
Site I(0-20)	5	6.49	6.81	10.22	28.98	13.13
	10	8.62	11.30	32.31	30.23	20.62
	15	9.12	12.32	34.11	59.19	28.69
	Mean	8.08	10.14	25.55	39.47	
	TEC: SE (m) =5.13 CD at 5% = 17.77			SAR: SE (m) =4.44 CD at 5% = NS			
Site I (20-40)	5	6.69	14.69	17.00	30.82	17.30
	10	8.85	15.00	34.20	50.11	27.04
	15	9.13	18.70	37.20	67.78	33.20
	Mean	8.22	16.13	29.47	49.57	
	TEC: SE (m) =4.83 CD at 5% = 16.72			SAR: SE (m) = 4.18 CD at 5% = NS			
Site II(0-20)	5	7.20	6.99	11.29	31.25	14.18
	10	8.60	11.11	30.52	33.98	21.05
	15	9.10	13.69	32.07	60.82	28.92
	Mean	8.30	10.60	24.63	42.02	
	TEC: SE (m) =4.66 CD at 5% = 16.14			SAR: SE (m) = 4.04 CD at 5% = NS			
Site II(20-40)	5	7.78	15.64	18.12	31.82	18.34
	10	8.16	16.89	33.89	52.31	27.81
	15	9.54	19.97	35.25	70.03	33.70
	Mean	8.49	17.50	29.09	51.39	
	TEC: SE (m) = 5.01 CD at 5% = 17.34			SAR: SE (m) = 4.33 CD at 5% = NS			
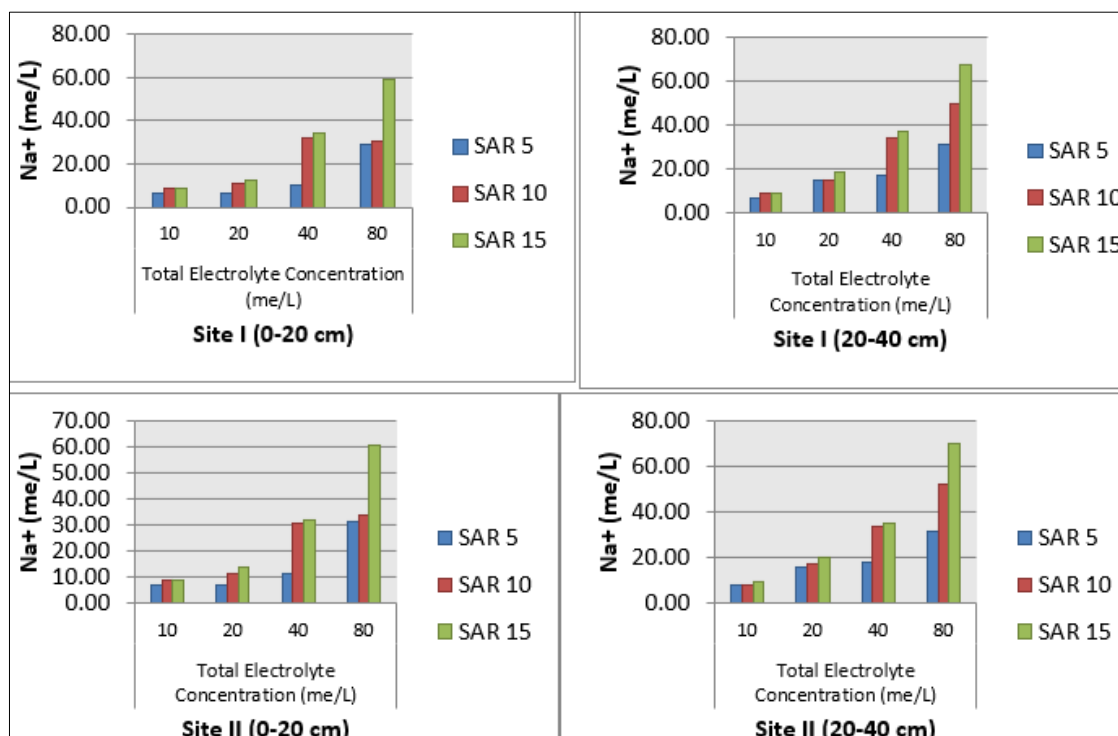
Fig 2: Relationship between total electrolytes concentration and sodium adsorption ratio with sodium concentration in different site

Effect of SAR on the sodium concentration
The results (Table 7) presented that, the sodium concentration of site I (surface soil) was 13.13, 20.62 and 28.69 meL^{-1} at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different total electrolyte concentration levels.
In site I of sub-surface soil, the sodium concentration was

17.30, 27.04 and 33.20 meL^{-1} at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte levels.
At the same total electrolyte concentration levels the sodium concentration was found to increase by 118.50% and 91.90% respectively with increase in SAR levels 5 to 15 of the

equilibrating solution (Fig. 2).

In site II (surface soil) the sodium concentration was 14.18, 21.05 and 28.92 meL^{-1} respectively, whereas, in site II of sub-surface soil the sodium concentration of equilibrated samples was 18.34, 27.81 and 33.70 meL^{-1} at 5, 10 and 15 SAR level respectively, irrespective of different electrolyte levels.

At the same level of concentration, the sodium concentration was found to increase about 103.94% and 83.75% respectively with increase in SAR levels from 5 to 15 of the equilibrating solution.

Relationship between total electrolytes concentration and

sodium adsorption ratio with sodium concentration in different sites

The results obtained in Table 7 showed that, with increase in total electrolyte concentration level from 10 to 80 meL^{-1} sodium concentration increased. There is a significant relationship between total electrolyte concentration and sodium concentration at 5% level of significance.

The results with respect to total electrolytes concentration and sodium adsorption ratio with sodium concentration of equilibrated samples for multiple regressions are presented in Table 8.

Table 8: Multiple linear regression of TEC and SAR with sodium concentration in different sites

Independent variable	Site I (0-20 cm)	Site I (20-40 cm)	Site II (0-20 cm)	Site II (20-40 cm)
a (Constant)	-12.25	-11.86	-12.05	-11.13
b_1 (TEC)	0.46**	0.58**	0.49**	0.59**
b_2 (SAR)	1.56**	1.59**	1.47**	1.53**
R^2	0.81**	0.88**	0.86**	0.88**

**Significant at 0.01% level of significance
*Significant at 0.05% level of significance

It was revealed from the Table 8 that the site I surface soil, the total electrolytes concentration and sodium adsorption ratio are positively significant at 0.01% level of significance. It showed that the coefficient of determination was (0.81) significant at 0.01% level of significance. Similarly in the site I sub-surface soil, the total electrolytes concentration and sodium adsorption ratio are positively significant at 0.01% level of significance. It showed that the coefficient of determination was (0.88) significant at 0.01% level of significance.

In the site II surface soil, the total electrolyte concentration and sodium adsorption ratio are positively significant at 0.01% level of significance. It showed that the coefficient of determination was (0.86) significant at 0.01% level of significance. Similarly in the site II sub-surface soil, the total electrolytes concentration and sodium adsorption ratio are positively significant at 0.01% level of significance. It showed that the coefficient of determination was (0.88) significant at 0.01% level of significance.

The high sodium content might be due to formation of these soils from basalt, which contained sufficient amount of alkali

feldspar to give alkali and alkaline earth base. These results are supported with the findings of Dubey and Sharma (1990) [6].

Sodium adsorption ratio of the equilibrated soil

The results with respect to sodium adsorption ratio of the equilibrated samples treated with different TEC and SAR are presented in Table 9 for first and second site of soil respectively.

Effect of total electrolyte concentration on the sodium adsorption ratio

The results presented on Table 9 revealed that sodium adsorption ratio of site I (surface soil) was 4.04, 4.59, 10.95 and 15.55 mmol$^{1/2}$ L$^{-1/2}$ at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels. The sodium adsorption ratio was found to increase by 281.12% with increase in different total electrolyte concentration levels of equilibrating solution.

Table 9: Effect of total electrolyte concentration and SAR on sodium adsorption ratio

Depth (cm)	SAR (mmol$^{1/2}$L$^{-1/2}$)	SAR (eq.) (mmol$^{1/2}$L$^{-1/2}$) Total electrolyte concentration (meL^{-1})				Mean
		10	20	40	80	
Site I(0-20)	5	3.13	3.04	4.29	11.18	5.41
	10	4.28	5.11	13.80	11.80	8.75
	15	4.70	5.62	14.76	23.67	12.19
	Mean	4.04	4.59	10.95	15.55	
	TEC: SE (m) =2.09 CD at 5% = 7.26			SAR: SE (m) =1.81 CD at 5% = NS		
Site I(20-40)	5	2.97	6.19	6.80	10.96	6.73
	10	4.00	6.46	13.90	18.02	10.60
	15	4.28	8.16	15.50	24.64	13.15
	Mean	3.75	6.94	12.07	17.87	
	TEC: SE (m) = 1.76 CD at 5% = 6.11			SAR: SE (m) = 1.53 CD at 5% = NS		
Site II(0-20)	5	3.56	3.05	4.76	12.20	5.89
	10	4.34	4.98	12.98	13.37	8.92
	15	4.64	6.30	13.76	24.23	12.23
	Mean	4.18	4.78	10.50	16.60	
	TEC: SE (m) = 1.87 CD at 5% = 6.48			SAR: SE (m) = 1.62 CD at 5% = NS		
Site II (20-40)	5	3.50	6.59	7.24	11.40	7.18

	10	3.70	7.21	13.72	18.95	10.90
	15	4.41	8.64	14.38	22.82	12.56
	Mean	3.87	7.48	11.78	17.72	
	TEC: SE (m) = 1.50 CD at 5% = 5.19			SAR: SE (m) = 1.30 CD at 5% = NS		

Similarly in sub-surface soil of site I the sodium adsorption ratio was 3.75, 6.94, 12.07 and 17.87 $mmol^{1/2}L^{-1/2}$ at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels. The sodium adsorption ratio was found to increase by 376.53% with increase in different total electrolyte concentration levels of equilibrating solution (Fig. 3).

As per the results presented in Table 9, with the increase in the total electrolyte concentration from 10, 20, 40 and 80 meL^{-1} in the surface soil of the second site sodium adsorption ratio was 4.18, 4.78, 10.50 and 16.60 $mmol^{1/2}L^{-1/2}$ respectively, irrespective of SAR levels and in sub-surface soil, the sodium adsorption ratio was 3.87, 7.48, 11.78 and 17.72 at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution

At the same SAR level, the sodium adsorption ratio was found to increase by 297.12% and 357.88% respectively with increase in total electrolyte concentration levels of the equilibrating solution.

Effect of SAR on the sodium adsorption ratio of equilibrated soil

The results presented Table 9revealed that the sodium adsorption ratio of site I (surface soil) was 5.41, 8.77 and 12.12 at 5, 10, 15 SAR levels of equilibrating solution respectively, irrespective of different TEC levels.

In site I (sub-surface soil) the sodium adsorption ratio was 6.73, 10.60 and 13.15 at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte level.

At the same total electrolyte concentration levels the sodium adsorption ratio was found to increase by 124.02% and 95.39% respectively with increase in SAR level 5 to 15 of the equilibrating solution.

In the results showed that in site II (surface soil) the sodium adsorption ratio was 5.89, 8.92 and 12.23 $mmol^{1/2}L^{-1/2}$ respectively, whereas, in site II of sub-surface soil, the sodium adsorption ratio of equilibrated samples were 7.18, 10.90 and 12.56 at 5, 10 and 15 SAR level respectively, irrespective of different electrolyte level (Fig.3). At the same level of concentration the sodium adsorption ratio was found to increase about 109.41% and 74.93% respectively with

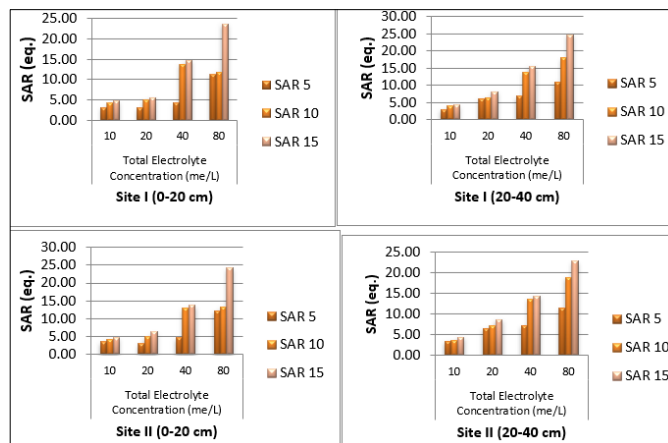increase in SAR levels from 5 to 15 of the equilibrating solution.

Fig 3: Relationship between total electrolytes concentration and sodium adsorption ratio with equilibrated SAR in different site

Relationship between total electrolytes concentration and sodium adsorption ratio with equilibrated SAR in different sites

The results showed that with increase in total electrolyte concentration levels from 10 to 80 meL^{-1} sodium adsorption ratio was also increased. There is a significant relationship between TEC and sodium adsorption ratio at 5% level of significance.

The SAR values increased with depth. It indicated that sodification started deeper layer and it is continuing upward. Sagare *et al*. (1991) [15] recorded the similar trend. At low total electrolyte concentration, high SAR values were not attained in the equilibrium solution may be because of addition of calcium and magnesium from the mineral dissolution as well as exchange phase.

The results with respect to total electrolytes concentration and sodium adsorption ratio with sodium adsorption ratio of equilibrated samples for multiple regressions are presented in Table 10.

Table 10: Multiple linear regression of TEC and SAR with equilibrated SAR in different sites

Independent variable	Site I (0-20 cm)	Site I (20-40 cm)	Site II (0-20 cm)	Site II (20-40 cm)
a (Constant)	-4.47	-3.63	-4.28	-2.28
b_1 (TEC)	+0.17**	+0.19**	+0.18**	+0.18**
b_2 (SAR)	+0.67**	+0.64**	+0.63**	+0.53**
R^2	0.78**	0.88**	0.84**	0.87**

**Significant at 0.01% level of significance
*Significant at 0.05% level of significance

It was revealed from Table 10 that in the site I the total electrolytes concentration and sodium adsorption ratio are positively significant at 0.01% level of significance in surface soil. It showed that the coefficient of determination was (0.78) significant at 0.01% level of significance. Similarly in the site I sub-surface soil, the total electrolytes concentration and

sodium adsorption ratio are positively significant at 0.01% level of significance. It showed that the coefficient of determination was (0.88) significant at 0.01% level of significance.

In the site II surface soil the total electrolyte concentration and sodium adsorption ratio are positively significant at

0.01% level of significance. It showed that the coefficient of determination was (0.84) significant at 0.01% level of significance. Similarly in the site II sub-surface soil, the total electrolyte concentration and sodium adsorption ratio are positively significant at 0.01% level of significance. It showed that the coefficient of determination was (0.87) significant at 0.01% level of significance.

Exchangeable sodium percentage of the equilibrated soil
The results with respect to exchangeable sodium percentage of the equilibrated samples treated with different total electrolyte concentration and SAR are presented in Table 11 for first and second site of soil respectively.

Effect of total electrolyte concentration on the exchangeable sodium percentage
The results presented in Table 11 that exchangeable sodium percentage of site I (surface soil) was 4.38, 5.10, 12.39 and 17.49 at 10, 20, 40 and 80 meL^{-1} total electrolyte

concentration of equilibrating solution respectively, irrespective of SAR levels.
Similarly in site I (sub-surface soil) the exchangeable sodium percentage was 4.0, 8.06, 13.74 and 19.42 at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution respectively, irrespective of SAR levels.
At the same SAR level the exchangeable sodium percentage was found to increase by 299.31% and 385.5% respectively with increase in different total electrolyte concentration levels of equilibrating solution (Fig.4).
As per the results presented in Table 11 with the increase in the total electrolyte concentration from 10, 20, 40 and 80 meL^{-1} in the first depth of the second site (surface soil) exchangeable sodium percentage was 4.57, 5.33, 11.98 and 18.38 respectively, irrespective of SAR levels and in site II of sub-surface soil, the exchangeable sodium percentage was 4.17, 9.11, 13.50 and 19.69 at 10, 20, 40 and 80 meL^{-1} total electrolyte concentration of equilibrating solution.

Table 11: Effect of total electrolyte concentration and SAR on exchangeable sodium percentage

Depth (cm)	SAR (mmol$^{1/2}$L$^{-1/2}$)	ESP (%)				Mean
		Total electrolyte concentration (meL^{-1})				
		10	20	40	80	
Site I (0-20)	5.00	3.19	3.06	4.72	13.01	6.00
	10.00	4.71	5.80	15.77	14.73	10.25
	15.00	5.25	6.44	16.67	24.74	13.27
	Mean	4.38	5.10	12.39	17.49	
	TEC: SE (m) = 1.97 CD at 5% =6.85			SAR: SE (m) = 1.71 CD at 5% = NS		
Site I (20-40)	5.00	2.97	7.15	7.90	12.73	7.69
	10.00	4.33	7.50	15.90	19.92	11.91
	15.00	4.71	9.53	17.41	25.60	14.31
	Mean	4.00	8.06	13.74	19.42	
	TEC: SE (m) =1.67 CD at 5% = 5.79			SAR: SE (m) =1.44 CD at 5% = 5.01		
Site II (0-20)	5.00	3.76	3.07	5.33	14.05	6.55
	10.00	4.80	5.62	14.90	15.38	10.18
	15.00	5.16	7.30	15.72	25.72	13.48
	Mean	4.57	5.33	11.98	18.38	
	TEC: SE (m) = 1.86 CD at 5% = 6.45			SAR: SE (m) = 1.61 CD at 5% = NS		
Site II (20-40)	5.00	3.67	7.69	8.47	14.23	8.52
	10.00	3.95	8.49	15.67	20.68	12.20
	15.00	4.89	11.16	16.35	24.17	14.14
	Mean	4.17	9.11	13.50	19.69	
	TEC: SE (m) = 1.31 CD at 5% =4.54			SAR: SE (m) =1.13 CD at 5% = 3.93		

At the same SAR levels, the exchangeable sodium percentage was found be to increase by 302.18% and 372.18% respectively, with increase in total electrolyte concentration level of the equilibrating solution.

Effect of SAR on the exchangeable sodium percentage
The results presented in Table 11 showed that the exchangeable sodium percentage of site I (surface soil) was 6.00, 10.25 and 13.27 at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different total electrolyte concentration level.
In site I (sub-surface soil) the exchangeable sodium percentage was 7.69, 11.91 and 14.31 at 5, 10, 15 SAR of equilibrating solution respectively, irrespective of different electrolyte level.

At the same total electrolyte concentration levels the exchangeable sodium percentage was found to increase by 121.16% and 86.08% respectively with increase in SAR level 5 to 15 of the equilibrating solution.
Whereas, in site II (surface soil) the percent exchangeable sodium percentage was 6.55, 10.18 and 13.48 respectively, whereas, in site II of sub-surface soil, the exchangeable sodium percentage of equilibrated samples were 8.52, 12.20 and 14.14 at 5, 10 and 15 SAR level respectively, irrespective of different electrolyte levels.
At the same level of concentration the exchangeable sodium percentage was found to increase about 105.80% and 65.96% respectively with increase in SAR levels from 5 to 15 of the equilibrating solution (Fig.4).
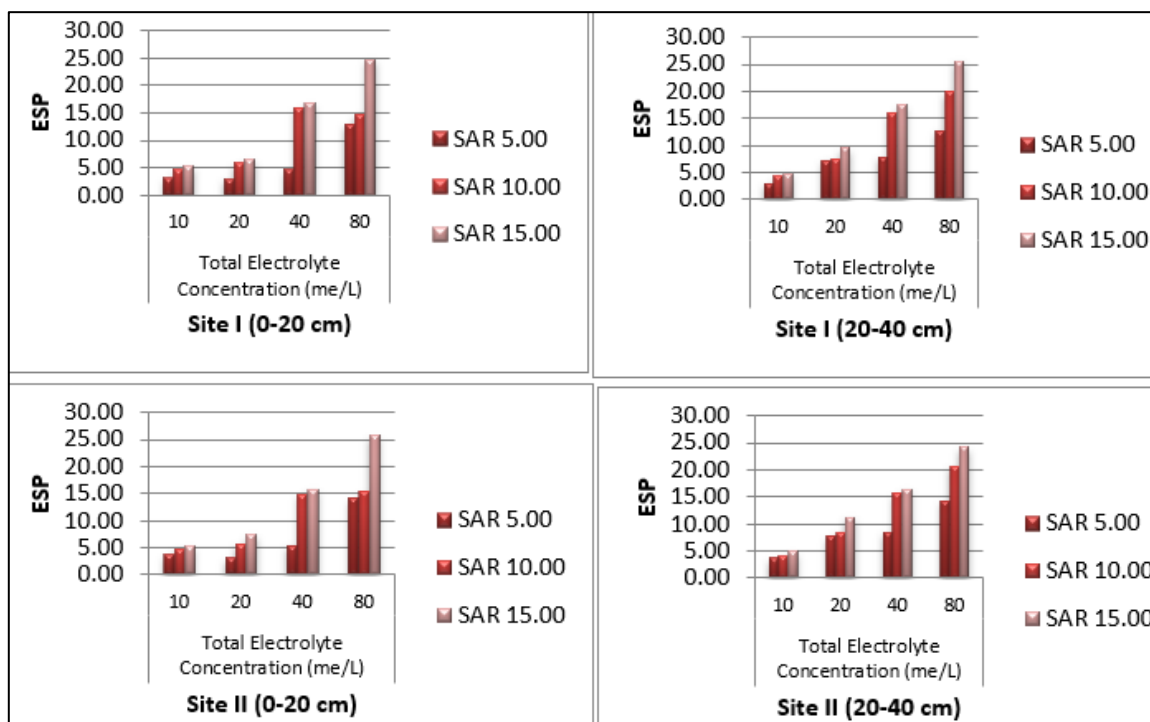
Fig 4: Relationship between total electrolyte concentration and SAR with ESP in different site

Relationship between total electrolyte concentration and SAR with ESP in different sites

The results presented in Table 11 showed that with increase in total electrolyte concentration levels from 10 to 80 meL^{-1} exchangeable sodium percentages increased. There is a significant relationship between total electrolyte concentration and exchangeable sodium percentage at 5% level of significance. The ESP values increased with depth in both two sites. The increase in ESP values with depth might be due to high sodimized clay content with strong total electrolyte concentration and low TEC. Rakhunde (1980) [13] have also reported that similar results in saline sodic soils.

The results showed in site I and site II (sub-surface soil) there is significant relationship between ESP and SAR at 5% level of significance.

The results with respect to electrolyte concentration and sodium adsorption ratio with exchangeable sodium percentage of equilibrated samples for multiple regressions are presented in Table 12.

Table 12: Multiple linear regression of TEC and SAR with ESP in different sites

Independent variable	Site I (0-20 cm)	Site I (20-40 cm)	Site II (0-20 cm)	Site II (20-40 cm)
a (Constant)	-4.80	-3.25	-4.57	-1.79
b_1 (TEC)	0.73**	0.66**	0.69**	0.56**
b_2 (SAR)	0.20**	0.21**	0.20**	0.20**
R^2	0.83**	0.87**	0.86**	0.89**

**Significant at 0.01% level of significance
*Significant at 0.05% level of significance

It was revealed from Table 12 that the in the site I (surface soil) the electrolyte concentration and sodium adsorption ratio are positively significant at 0.01% level of significance. It showed that the coefficient of determination was (0.83) significant at 0.01% level of significance. Similarly, in the site I (sub-surface soil) the electrolyte concentration and sodium adsorption ratio are positively significant at 0.01% level of significance. It showed that the coefficient of determination was (0.87) significant at 0.01% level of significance.

In the site II (surface soil) the electrolyte concentration and sodium adsorption ratio are positively significant at 0.01% level of significance. It showed that the coefficient of determination was (0.86) significant at 0.01% level of significance. Similarly in the site I (sub-surface soil) the electrolyte concentration and sodium adsorption ratio are positively significant at 0.01% level of significance. It showed that the coefficient of determination was (0.89) significant at 0.01% level of significance.

The presented data revealed that the ESP increased with increasing SAR and TEC of equilibrated solution. The positive interaction of TEC and SAR influence ESP built up. The ESP values increased with the soil depth. This might be due to high sodimized clay content and strong alkaline condition at lower depth (Jadhao 2003) [7].

Conclusion

Calcium concentration in the equilibrated soil solution was increased with increasing electrolyte concentration and with increasing SAR level calcium concentration decreased. With increasing depth there was a sharp increase in the SAR values of the equilibrated soils. Sodification started in deeper layer and it is continuing upward. The increase in ESP values with depth might be due to high sodimized clay content which increased with depth.

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