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Original Article

Relationship Between Soil Exchangeable Sodium Percentage and Soil Sodium Adsorption Ratio in Marvdasht Plain, Iran

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ABSTRACT

Objective: Soil salinity is one of the major worldwide environmental constraints affecting agricultural production in arid and semiarid regions. Lack of proper management of water and soil resources lead to increase soil salinity and reduce soil fertility. On the other hand, it seems simple and cheap method of measuring soil salinity is necessary. The aim of this study was to determine the relationship between exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) in some salt-affected soils of Marvdasht plain, Fars, Iran. **Methods:** To this purpose, fifty soil samples were randomly taken from surface (0-10 cm) and subsurface (10-20) cm from different fields of experimental site. **Results:** The statistical results of the study indicated that to predict soil ESP based on soil SAR the linear regression model ESP=0.941+1.119SAR with R^2 =0.806 can be recommended.

1.INTRODUCTION

Salinity is one of the major abiotic stresses that limiting plant growth and productivity and approximately 800 million hectares of land are affected by high salt levels throughout the world (about 7% of the world's total lands area). The percentage of cultivated land affected by salt is even greater, comprises 19% of 2.8 billion hectares of arable land on the earth. Furthermore there is also a dangerous trend of a 10% per year increase in the saline area throughout the world (Munns, 2005; Kaya et al., 2002). Excess salt in the soil may adversely affect plant growth either through osmotic inhibition of water uptake by roots or specific ion effects. Specific ion effects may cause direct toxicity or, alternatively, the insolubility or competitive absorption of ions may affect plant nutritional balances and with NaCl being the most prevalent. Both osmotic and specific ionic stresses from salinity can cause stunted growth and a reduced plant yield (Akram et al., 2007; Kazi and Leon, 2002).

Two different criteria are currently recognized in the scientific literature as indices of salinity. These are the Sodium Adsorption Ratio (SAR) with a reported threshold of 12 $(cmol/kg)^{0.5}$ and the Exchangeable Sodium Percentage (ESP) with a reported threshold of 15%. These are defined as Eq. (1) and Eq. (2) (Quirk, 2001; Rengasamy and Churchman, 1999; Sumner, 1993):

$$(1)\quad SAR = Na^+/[(Ca^{2+}+Mg^{2+})/2]^{0.5}$$

Where: SAR = Sodium adsorption ratio, $(cmol/kg)^{0.5}$

Na^+, Ca^{2+}, Mg^{2+} = Measured exchangeable Na, Ca and Mg (cmol/kg), respectively.

$$(2)\quad ESP = (Na^+ / CEC)\times 100$$

Where:

ESP = Exchangeable sodium percentage (%)

Na^+ = Measured exchangeable Na (cmol/kg)

CEC = Cation exchange capacity (cmol/kg)

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Therefore, it is necessary to have soil cation exchange capacity (CEC) to determine soil ESR. But, as soil CEC are often determined using laborious and time consuming laboratory tests (Seilsepour and Rashidi, 2008), it may be more appropriate and economical to develop a method which determines soil ESP indirectly from a more simple soil salinity index.

Previously researches report a relationship between soil ESP and SAR (Kopittke et al., 2006, Bland et al., 1999, Richards, 1954). Rengasamy et al. (1984) established a linear relationship between SAR in soil-water extract (1:5) and ESP with R^2 about 0.82 for 138 samples of Australian soils. The linear relationship was ESP=1.95SAR+1.8. Seilsepour et al. (2009) indicated that linear regression model to predict soil ESP based on soil SAR was ESP=1.95+1.03SAR with R^2=0.92 for Varamin soils in Iran. Thus, soil SAR can be used to approximate or estimate soil ESP. For this reason, many attempts have been made to predict soil ESP from soil SAR. The specific objective of this study was to determine a linear regression model of soil exchangeable sodium percentage and soil sodium adsorption in some salt-affected soils of Marvdasht plain, Iran.

2. MATERIALS AND METHODS

Fifty Soil samples were randomly taken from surface (0-10 cm) and subsurface (10-20) cm from different fields of experimental site of Marvdasht, Fars, Iran in 2013. The site is located at latitude of 29°52′27″N 52°48′09″E and is 1620 m above mean sea level, in arid climate in the south of Iran (Fig. 1). Marvdasht has a cold weather in the hilly areas and moderate climate in other regions. Soils were selected from agricultural areas (ex. corn, wheat, alfalfa, barley, tomato,…etc) that had a wide range of salinity and textures. Soil initial conditions (pH, cation exchange capacity, calcium carbonate, gypsum and clay percentage) were measured by following soil analysis methods (Tan, 1995 and Page et al., 1982). The soil of the experimental site was a fine, mixed, thermic, typic haplocambids clay-loam soil. Each sample contained 10 g soil in a 50 mL centrifuge tube. The soil was waterlogged with water height of 2.5 cm above the soil surface with distilled water, in waterlogged treatments. Soil moisture content in non-waterlogged treatments was preserved at 24% (dry weight basis), corresponding to -20 kPa. At the end of each incubation period, the 0.5 N acetic acid extractable Na was determined. The extraction was performed on moist soil (-20 kPa and waterlogged) samples. For adjustment of extractant concentration, acetic acid was applied in concentrations of 1.34 and 0.55 N in waterlogged and non-waterlogged treatments, respectively. Sodium concentrations were measured by flame photometer (Model Jenway PFP7, Company Rhys Scientific, UK). Ca^{2+}, Mg^{2+} and soil adsorption ratio (SAR) were measured in saturated paste extract by using PYE UNICAM SP3 atomic absorption spectrophotometer (Tan, 1995 and Page et al., 1982).

Physical and chemical properties of the fifty soil samples used to determine the soil ESP-SAR model are shown in Table 1. Sand, silt and clay content (% by weight) and pH, EC, Na^+ , Ca^{2+}, Mg^{2+} , SAR and ESP of the soil samples were measured using laboratory tests as described by the Soil Survey Staff (1996).

Regression model

A typical linear regression model is shown in Equation 3:

(1) $Y = k_0 + k_1X$

k_0, k_1 = Regression coefficients.

Y = Dependent variable, for example ESP of soil.

X = Independent variable, for example SAR of soil.

A linear regression model as above was suggested to predict soil ESP from soil SAR.

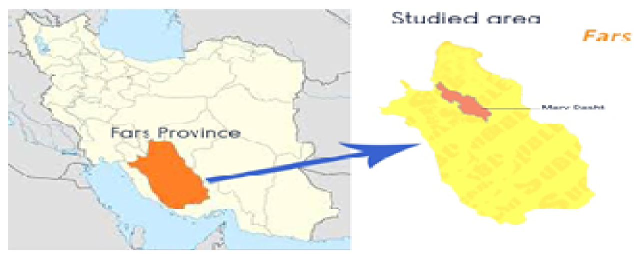

Figure 1. Location map of the study area

2.1. Statistical analysis

The paired samples T-test and the mean difference confidence interval approach were used to compare the soil ESP values predicted using the soil ESP-SAR model with the soil ESP values measured by laboratory tests. The Bland-Altman approach (1999) was also used to plot the agreement between the soil ESP values measured by laboratory tests with the soil ESP values predicted using the soil ESP-SAR model. The statistical analyses were performed using Minitab (1998) software. Microsoft Excel (Version 2007) software was used for charts adjustments as well.

3. RESULTS

The various statistics of linear models of predicting exchangeable sodium percentage (ESP) based on sodium adsorption ratio (SAR) under the studied soil texture was shown in Table 2. Based on the statistical result, the soil ESP-SAR model was judged acceptable due to statistical results. The R^2 value and C.V. of the model were 0.806 and 25.69%, respectively. The linear regression soil ESP-SAR model is given in Eq. (4).

(4) ESP=0.941+1.119 SAR

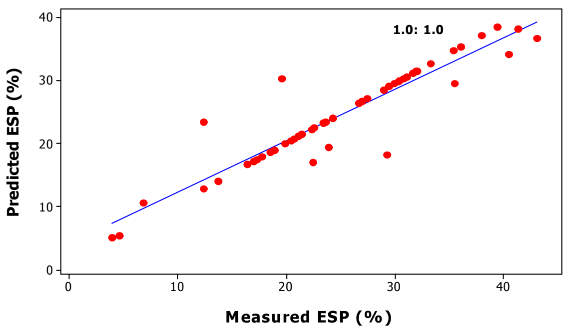

Figure 2. Measured ESP and predicted ESP using the soil ESP-SAR model with the line of equality (1.0: 1.0)

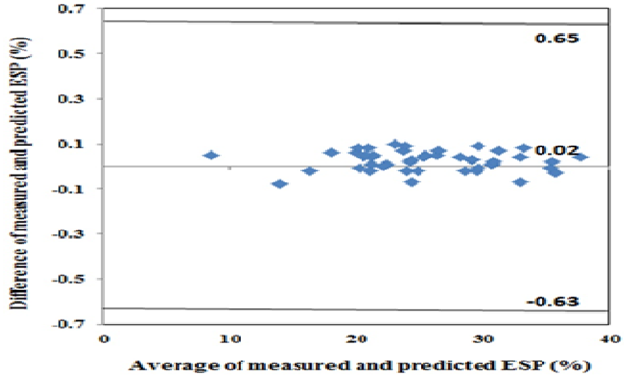

Figure 2. Bland-Altman plot for the comparison of measured ESP and predicted ESP using the soil ESP-SAR model; the outer lines indicate the 95% limits of agreement (-0.63, 0.65) and the center line shows the average difference (0.02)

Table 1.

The various statistics of physical and chemical properties of the fifty soil samples used to determine the soil ESP-SAR model

Parameters	Minimum	Maximum	Mean	S.D.	C.V. (%)
Sand (%)	10.74	47.04	25.40	8.25	33.55
Silt (%)	0.78	69.06	28.09	13.74	48.92
Clay (%)	8.94	79.26	46.51	15.54	33.40
pH	6.9	9.8	8.488	0.768	9.04
EC (dS/m)	4.2	18.3	13.356	3.487	26.11
Na^+ (cmol/kg)	14.10	263.60	101.27	61.54	60.77
Ca^{2+} (cmol/kg)	5.10	60.90	22.46	16.85	75.02
Mg^{2+} (cmol/kg)	2.30	110.40	22.38	22.94	94.08
SAR $(cmol/kg)^{0.5}$	4.1	32.8	21.63	5.77	26.69
ESP (%)	5.5	37.8	24.484	7.42	30.3

Table 2.

The various statistics of the soil ESP-SAR model

Model	Independent variable	p-value	R^2	C.V. (%)
$ESP = k_0+k_1SAR$	SAR	1.26E-9	0.806	25.69

Table 3.

Chemical properties of the fifty soil samples used to evaluate soil ESP-SAR model

Sample No.	SAR (cmol/kg)$^{0.5}$	ESP (%) Laboratory test	ESP (%) ESP-SAR model	Sample No.	SAR (cmol/kg)$^{0.5}$	ESP (%) Laboratory test	ESP (%) ESP-SAR model
1	15.30	18.0	18.06	26	20.42	23.7	23.79
2	13.80	16.4	16.38	27	19.80	23.0	23.10
3	18.00	21.0	21.08	28	17.70	20.7	20.75
4	17.00	19.9	19.96	29	22.90	26.5	26.57
5	20.90	24.4	24.33	30	6.80	8.5	8.55
6	20.50	23.9	23.88	31	17.20	20.2	20.19
7	26.60	30.7	30.71	32	18.00	21.1	21.08
8	20.40	23.7	23.77	33	4.10	7.8	5.53
9	21.80	25.3	25.34	34	11.60	14.0	13.92
10	20.90	24.3	24.33	35	25.10	29.0	29.03
11	18.20	21.3	21.31	36	24.40	28.2	28.24
12	21.90	25.4	25.45	37	21.80	25.3	25.34
13	28.50	32.9	32.83	38	25.60	29.5	29.59
14	21.90	25.4	25.45	39	26.60	30.7	30.71
15	19.19	22.4	22.41	40	25.50	29.5	29.48
16	22.80	26.4	26.45	41	25.60	29.6	29.59
17	18.14	21.2	21.24	42	27.10	31.2	31.27
18	19.00	22.2	22.20	43	31.04	35.7	35.67
19	28.60	32.9	32.94	44	28.90	33.2	33.28
20	21.30	24.8	24.78	45	24.70	28.6	28.58
21	17.60	20.6	20.64	46	30.70	35.3	35.29
22	20.80	24.2	24.22	47	30.90	35.5	35.52
23	18.24	21.3	21.35	48	25.10	29.0	29.03
24	17.10	20.0	20.08	49	32.80	37.6	37.64
25	21.80	25.3	25.34	50	26.70	30.8	30.82

Table 4.

Paired samples T-test analyses on comparing soil ESP determination methods

Determination methods	Average difference (%)	Standard deviation of difference (%)	p-value	95% confidence intervals for the difference in means (%)
ESP-SAR model and laboratory test	0.02	0.33	0.665	-0.07, 0.11

4. DISCUSSION

Various statistics were used to compare the soil exchangeable sodium percentage (ESP) values predicted using the soil ESP-SAR linear regression model with the soil ESP values measured by laboratory tests. The Bland-Altman approach (1999) was also used to plot the agreement between the soil ESP values measured by laboratory tests with the soil ESP values predicted using the soil ESP-SAR model.

The soil ESP values predicted by the soil ESP-SAR model were compared with the soil ESP values determined by laboratory tests were shown in Table 3. The comparison between measured and predicted data obtained from the mentioned model has been depicted that indicates good match (Fig. 2). The mean soil ESP difference between two methods was 0.02% (95% confidence interval:-0.07 and 0.11%; $P = 0.665$). The standard deviation of the soil ESP differences was 0.33%. The results of paired samples T-test indicated that the soil ESP values predicted with the soil ESP-SAR model were not significantly different than the soil ESP measured with laboratory tests (Table 4). The soil ESP differences between these two methods were normally distributed and 95% of the soil ESP differences were expected to lie between $\mu+1.96\sigma$ and $\mu-1.96\sigma$, known as 95% limits of agreement (Bland & Altman, 1999; Rashidi and Gholami, 2008; Seilsepour and Rashidi, 2008). The 95% limits of agreement for comparison of soil ESP determined with laboratory test and the soil ESP-SAR model were calculated at -0.63 and 0.65% (Fig. 3). Thus, soil ESP predicted by the soil ESP-SAR model may be 0.63% lower or 0.65% higher than soil ESP measured by laboratory test.

CONCLUSIONS

Linear regression model based on soil Sodium Adsorption Ratio (SAR) was used to predict soil Exchangeable Sodium Percentage (ESP). The soil ESP values predicted using the model was compared to the soil ESP values measured by laboratory tests. The paired samples T-test results indicated that the difference between the soil ESP values predicted by the model and measured by laboratory tests were not statistically significant ($P>0.05$). Therefore, the soil ESP-SAR model can provide an easy, economic and brief methodology to estimate soil ESP.

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