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Soil Available Water as Affected by Some Soil Physio-chemical Properties in Salt Affected Soils

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Abstract: The limiting factor for growing plant in salt affected soil is available water (AW). The present work was carried out to portioning the correlation between some soil physical and chemical properties in some selected salt affected soil differed in texture and estimate the percentage of contribution in soil AW directly and/ or indirectly effect by using path analysis. Results show that r values of coarse particles was increased with decreasing the coarse particles in soil (change the soil texture from course to fine is associated with decrease in coarse particles and increase in fine one). Direct effect of fine particles on AW found to be higher than that of the other studied soil properties. Also, fine particles has higher indirect effect through the studied soil parameters which means that fine particles (silt + clay) play an important role than whole soil properties under investigation. According to OM effect on soil AW under the studied soils, significant correlations were found under the coarse textured soils (sand and loamy sand), while highly significant correlations were attained under clay loam and clay soils. According to the indirect effect of CEC on soil AW, the maximum values were 11.4 % (coarse particles), 12.4 % (OM), 15.5 % ($CaCO_3$) and 23.4 % (fine particles) under sand, loamy sand, clay loam and clay soils, respectively. While the lowest value of the indirect effect on AW through CEC were 6.5 % (EC), 4.9 % (coarse particles), 4.2% (coarse particles), 4.2% (coarse particles) and 6.8 % (coarse particles) under sand, loamy sand, clay loam and clay soils. Data points that SAR and ESP contribute on soil ability to retain water through direct effect was increased with increasing fine particles but values of SAR is more than those of ESP by 2.7, 2.6, 1.7 and 1.5 times for sand, loamy sand, clay loam and clay soils. Whereas, the maximum and minimum values of direct SAR and ESP on available water were 23.5, 15.8 % and 12.8, 4.7 % under sand and clay soil, respectively.

Key words: Available water, salt affected soils, texture, physio-chemical properties, path analysis.

INTRODUCTION

Reclamation of salt affected soil depending mainly on improving their hydrophysical characteristics which affect direct and/or indirectly on the soil available water (AW). Gupta and Larson (1979) stated that soil water retention especially available water is a basic soil properties which is influenced by many of physico-chemical properties which is related to soil moisture constant, fluids movement in soils, irrigation scheduling and drainage requirement. While, Tetsu *et al.* (2003) mentioned that water retention relations were obtained for a wide range of energy, with respect to water retained in intra-granular pores and along particles surfaces. They added that water films on external surfaces are volumetrically insignificant at matric particles less than about-2 kPa. They mentioned also that residual water in coarse textured soils occurs in intra-granular pores, represent about 10 % of the total soil porosity, and is effectively hydraulically immobile, while the opposite was true in case of fine textures soils.

In most soils, optimum growth of grown plants occurs when the water retained in soils is kept near the field capacity (to be more easily taken up by plant) or at least did not approach the wilting point (plant suffer from drought), in other words, increasing AW is a preferable goal.

Partioning the simple correlations between AW and independent ones which represents by physical and chemical soil properties into direct and indirect effects was permitted by using path analysis (Basta *et al.*, 1993). They added that direct and indirect effects are derived from linear regression of soil properties on soil water constant and simple correlation values among soil properties.

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Moreover, soil moisture constants are based on an equilibrium established with those forces exerting degrees of tension on the water, they have utility for many agronomic purposes and for measuring relative differences in AW within and among soil aggregates (Bauer and Black, 1992).

Rawls *et al.* (1992) studied the relationships between field capacity, wilting point and available water from side and some soil properties from the other one. They found that these constant could be determined by means of developed regression models. Any increase in organic matter by a unit cause a relatively large increase in the percentage of water retained in soil at the field capacity than at wilting point in coarse textured soils and the opposite was true in case of fine textured ones where showed increased in both EC and wilting point with increasing organic matter by a unit (Bauer and Black, 1992).

The increments in OM% in soils tend to exhibit very poor physical properties, if the clay content is fairly high (Bolt and Bruggenwert, 1978). Klute and Dirksen (1986) mentioned that increasing soil ability to supply plant by its water requirement would follow increasing soil organic matter by available water. Bauer and Black (1992) stated that increasing organic matter decrease bulk density and consequently increase soil total porosity. They added that soil organic matter influences on water movement in soil because of its hydrophilic character and its effect on soil structure and bulk density. However soil properties seldom, if ever, directly constituent's formative elements of methods. Commonly available models are mathematical descriptions of water retention characteristics and hydraulic property curves with unknown parameters (Vereeken *et al.*, 1995). They added that much of the appears attributed to basic soil properties.

Path analysis is used to investigate the relationships among soil properties, so a good view of relations among the studied characters, as quantitative evaluation is possible by using this method (Meck *et al.*, 2002 and Abdel Hady, 2005).

The objective of the present study is to estimate the relationships between some soil physical and chemical properties from side and soil available water from the other one under salt affected soils differed in texture.

MATERIALS AND METHODS

Surface soil samples (0-20 cm) were taken from different locations (six sites with three replicates) to represent salt affected soil and also were differed in texture. Some soil physical and chemical characteristics, such as particle size distribution (%), EC (dSm^{-1}), organic matter % (OM), $CaCO_3$ (%), cation exchangeable capacity (CEC, meq/100 g soil), exchangeable sodium percent (ESP), soluble cations and anions in soil paste extract (meq/l) were determined after Rebecca (2004). Sodium adsorption ratio (SAR) was calculated from the following equation:

$$SAR = Na^+ / ((Ca^{++} + Mg^{++})/2)^{0.5}$$

Where: Na^+, Ca^{++} and Mg^{++} in meq/l

Soil water content (on weight basis) at field capacity and wilting point (%) determined in undisturbed samples saturated for 24 hours and equilibrated for 24 hours at 0.3 and 15.0 bars on a tension table and

Table 1: Descriptive analysis of soil physical and chemical properties.

Soil parameter		Mean	Minimum	Maximum	Standard Deviation
Coarse particles	%	61.8	17.3	89.3	13.2
Fine particles		58.7	12.2	80.2	10.5
OM		1.1	0.2	1.4	14.2
CaCO3		10.4	0.8	17.9	19.8
pH		8.02	7.85	8.11	6.9
EC	dSm^{-1}	7.3	4.6	11.3	13.7
CEC	meq/100 g soil	19.8	7.5	37.3	17.2
Ca^{++}		25.0	12.0	32.5	9.1
Mg^{++}		9.9	3.5	13.5	4.4
Na^+		23.2	9.1	37.8	12.1
K^+		1.3	0.3	3.4	1.5
CO_3^-	meq/liter	0.0	0.0	0.0	0.0
HCO_3^-		2.1	1.6	2.8	0.5
Cl^-		30.3	5.0	72.8	29.4
$SO_4^=$		27.0	7.3	42.9	17.7
SAR		5.8	2.1	9.6	12.5
ESP	%	37.1	33.7	45.3	4.7
Field capacity		24.3	12.5	38.7	10.5
Wilting point		15.9	3.7	21.9	16.3
Available water		19.8	9.6	27.4	15.2

CEC: Cation Exchangeable Capacity, SAR: Sodium Adsorption Ratio, ESP: Exchangeable sodium percent pressure-plate apparatus, respectively (Klute, 1986). Available water (AW) was calculated as percentage by find the differences between moisture % at field capacity and wilting point.

Data were statistically analyzed for correlations coefficient using the SAS (1988) program. Path analysis was carried out according to Williams *et al.* (1990). Available water was selected as dependant variable to determine statistical relationships among studied soil properties mentioned above and with AW under different salt affected soil differed in texture. Both direct and indirect effects of the studied soil properties on AW as percentage were derived using path analysis.

RESULTS AND DISCUSSIONS

Simple correlation (r) values between coarse, fine particles, OM, $CaCO_3$, EC, CEC, SAR and ESP from side and soil available water from the other one are given in Table 2 under the studied soil texture. Significant negative correlations between coarse particles and AW under all the studied soils texture were observed. The highest and the lowest correlations coefficient of coarse particles versus soil available water (AW) were found under sand and clay loam soil with r values -0.783** and -0.424*, respectively.

One can notice that r values of coarse particles decreased with decreasing the coarse particles in soil (changed the soil texture from course to fine associated with decrease in coarse particles and increase in fine one). Direct effect of fine particles on AW found to be higher than that of the other studied soil properties. Also, fine particles has higher indirect effect through the studied soil parameters which means that fine particles (silt + clay) play an important role than whole soil properties under investigation, consequently its role in aggregate formation and established stable pore size distribution (Abdel Hady, 2005).

The higher indirect effect of soil properties through coarse particles were observed with soil EC followed by fine particles with values 16.5, 15.6; 18.2, 16.8; 16.7, 15.8 % under sand, sand loam and clay loam soil, respectively. But ESP and EC show highly indirect effect on soil AW through coarse particles with values 13.3 and 12.2 %, respectively.

In case of fine particles, there were close relations between fine particles and soil AW where highly significant positive correlations were observed. Results indicated that r values was associated with increasing soil texture from sand (0.454**) to clay soil (0.734**). The highest indirect effect values were attained with EC (15.9%) followed by SAR (13.2%) (16.8-12.6 %) and (16.5-12.1 %) in sand and loamy sand soils, respectively. Whereas, in clay loam and clay soils EC (16.5%), ESP (12.3%); SAR (12.1%) and EC (15.4%), ESP 15.3%; SAR (13.5 %); CEC (13.3%), respectively. The lowest indirect effect value of soil properties on AW through fine particles were OM (3.8%,4.1%), under sand, loamy sand and coarse particles (3.8%, 6.2%) under clay loam and clay soils, respectively. These means that OM dose not involve with coarse particles to affect on AW through aggregate formation due to its large particles, which affect on the water flow under saturated and unsaturated condition (Tayel and Abdel Hady, 2005).

According to OM effect on soil AW under the studied soils, data in Table (2) show that no significant correlations were found under the coarse textured soils (sand and loamy sand), while highly significant correlations were attained under clay loam and clay soils. This means that these are poor in OM content in first condition and to role of OM its self in water absorption. Results also indicated that the lowest direct effect of OM on soil AW was found under sand soil (2.3%) and loamy sand (3.7%), while the highest values were obtained in clay loam (8.4%) and clay soil (12.2%).

According to the indirect effect of some studied soil characters on AW through OM, data indicates that fine particles has the highest indirect effect with values 21.3, 19.8, 20.3, and 17.2 % under sand, loamy sand, clay loam and clay soils. The same trend was observed in case of the lowest indirect effect through OM. These values ranged from 2.3 % (sand) to 3.3 % (clay loam) after coarse particles. This result agrees with that obtained by Ebtisam (2007) who mentioned that OM play an important role in decrease soil salinity to extent improved barley grains germination.

Table (2) illustrate that there were significant correlation between $CaCO_3$ content on AW under the studied soils except sand soil. According, the direct effect of $CaCO_3$ on AW in the studied soils, the highest (16.9%) and the lowest (1.8 %) values were recorded under clay loam and sand soil, respectively. This may be due to its lower content of $CaCO_3$ content where the highest and lowest values of $CaCO_3$ content were 17.86 and 1.50 % in clay loam and sand soils. However, the coarse texture soils have the lowest content of $CaCO_3$, the maximum indirect effect through $CaCO_3$ was observed with fine particles such as sand (14.3%) and Loamy sand (16.8%), while coarse particles show the lowest values of indirect effect through $CaCO_3$ on soil AW 5.6 and 5.4 %, respectively. This finding agrees with those obtained by Viator *et al.* (2002).

Table 2: Path analysis results of available water and their relationships with some soil properties under salt affects soil differed in texture.

				Indirect effect %								
Soil	Soil proporties	r	Direct effect %	particles Coarse	Fine	OM	CaCO3	EC	CEC	SAR	ESP	Residual%
Sand	Coarse	-0.783**	6.5	0.0	15.6	3.2	2.9	16.5	6.8	13.9	8.8	25.8
	Fine	0.434**	21.2	4.5	0.0	3.8	4.2	12.9	7.1	8.3	10.1	21.9
	OM	0.242	2.3	2.3	21.3	0.0	6.5	12.3	9.1	11.3	12.4	22.5
	CaCO3	0.224	1.8	5.6	14.3	6.5	0.0	13.2	11.3	12.6	11.7	23.0
	EC	-0.645**	14.6	1.3	13.5	4.6	9.5	0.0	13.6	10.8	15.2	16.9
	CEC	0.245	6.4	4.4	19.2	9.2	8.6	6.5	0.0	7.7	8.1	22.9
	SAR	-0.452**	12.8	1.2	15.4	2.3	9.8	10.2	13.2	0.0	12.2	22.9
	ESP	-0.342*	4.7	2.2	16.7	2.9	12.4	12.3	10.8	11.4	0.0	26.6
Loamy S	Coarse	-0.548**	7.1	0.0	16.8	3.3	3.8	18.2	7.2	14.6	9.7	19.3
	Fine	0.513**	24.3	4.6	0.0	4.1	5.7	16.8	8.3	12.6	9.7	3.9
	OM	0.298	3.7	2.8	19.8	0.0	8.9	13.7	10.4	12.2	10.9	17.6
	CaCO3	-0.471*	6.7	5.4	16.8	7.5	0.0	14.8	12.7	10.9	11.3	13.9
	EC	0.315*	16.2	2.3	12.6	6.7	9.1	0.0	14.3	12.4	16.1	10.3
	CEC	-0.373*	11.3	4.9	8.3	17.5	10.9	13.2	0.0	10.8	10.2	12.9
	SAR	-0.473**	14.3	2.2	17.7	3.5	15.2	.	12.8	0.0	18.1	16.2
	ESP	-0.455**	5.6	3.6	18.4	8.2	13.7	15.6	10.1	12.7	0.0	12.1
Clay L	Coarse	-0.424**	5.3	0.0	15.8	14.7	8.3	16.7	6.8	15.8	10.2	6.4
	Fine	0.532**	33.8	3.8	0.0	5.3	6.8	12.5	9.3	9.2	12.3	7.0
	OM	0.429**	8.4	3.3	20.3	0.0	12.3	14.2	12.6	11.8	14.6	2.5
	CaCO3	0.565**	16.9	6.2	16.0	6.8	0.0	14.2	16.4	9.9	11.4	2.2
	EC	-0.472**	10.3	3.7	14.5	6.6	12.2	0.0	17.8	13.1	16.7	5.1
	CEC	0.523**	17.4	4.2	14.6	13.8	18.3	9.3	0.0	9.5	11.2	1.7
	SAR	-0.489**	14.6	5.2	19.7	4.2	18.1	11.6	12.3	0.0	12.7	1.6
	ESP	-0.513**	8.5	4.5	18.3	5.8	19.4	10.3	14.3	11.8	0.0	7.1
Clay	Coarse	-0.446**	5.2	0.0	14.6	16.0	9.2	13.8	6.5	16.8	11.2	6.7
	Fine	0.534**	35.3	6.2	0.0	6.8	6.5	12.2	11.3	5.8	13.3	2.6
	OM	0.415*	12.2	3.1	17.2	0.0	11.1	15.3	12.5	11.4	14.2	3.0
	CaCO3	-0.391*	2.6	6.8	14.3	7.6	0.0	16.9	15.8	14.6	14.8	6.6
	EC	0.411*	7.8	5.4	16.5	8.9	11.8	0.0	16.2	15.2	15.7	2.5
	CEC	0.540**	21.3	6.8	19.2	13.4	5.4	9.4	0.0	8.5	12.8	3.2
	SAR	-0.567**	23.5	6.5	14.3	6.1	8.9	11.5	12.7	0.0	14.2	2.3
	ESP	-0.544**	15.8	5.8	20.3	8.4	7.4	16.9	13.3	10.8	0.0	1.3

CEC: Cation Exchangeable capacity, SAR: Sodium Adsorption Ratio, ESP: Exchangeable sodium percent, Loamy S: Loamy Send, Clay L: Clay Loam

In fine texture soils, clay loam and clay soils, the maximum indirect effect through $CaCO_3$ on AW were observed in CEC (16.4%) and fine particles (16.0 %) under clay loam and CEC (15.8 %) and ESP (15.8%) under clay soil. This means that CaCO3 in clay loam soil was in fine fraction and is responsible on increasing its CEC and salt content.

Table (2) illustrates the correlations coefficients, direct effect and indirect effect of soil EC on AW. There were negative significant correlations between soil EC and AW in the studied soils. The highest and lowest r values of EC were -0.645** and -0.315* under sand and loamy sand soils. The highest and lowest direct effects of EC on AW were recorded with CEC and coarse particles under loamy sand and clay soil with values 16.2 and 7.8 %, respectively. While the highest and the lowest indirect effects were 17.8 and 1.3 % under clay loam and sand, respectively. This result could be explain on the basis of clay soil ability to retain cations without being reflected on soil EC and / or the exist of gypsum in amount that affect on EC measure. But in clay loam soil the coarse particles is a dominant fraction and its surface area is low and consequently it has low CEC (9.6 meq/100 g soil). Resulted negative correlations between soil EC and AW means that any increase in salt concentration in soil is associated with reduction in soil AW.

Data on hand reveal that soil CEC does not appear any significant affect on soil EC. The highest significant effect correlated negatively with coarse particles and positively with fine one (0.802** and 0.805**). This result might be responsible and appeared in highly significant positive correlation under the studied soils except under sandy one, and increasing fine particles are involved increasing r values.

The highest direct effect of CEC on AW was obtained under clay soil followed by loamy clay, loamy sand and sand soil in descending order. According to the indirect effect of CEC on soil AW, the maximum values were 11.4 % (coarse particles), 17.5 % (OM), 18.3 % ($CaCO_3$) and 23.4 % (fine particles) under sand, loamy sand, clay loam and clay soils, respectively. While the lowest value of the indirect effect on AW through CEC were 4.4 % (coarse particles), 4.9 % (coarse particles), 4.2 % (coarse particles) and 6.8 % (coarse particles) under sand, loamy sand, clay loam and clay soils.

Sodium adsorption ratio (SAR) reflect the ratio between Na^{+} and Ca^{2+} + Mg^{2+} in the soil solution, so it describe precisely soil quality (relative to salinity). Also, exchangeable sodium percent (ESP) represent the amount of Na+ adsorbed on the soil complexes. Both of SAR and ESP in the present study show the same trend. Highly significant negative correlation at 1% level between SAR and ESP and soil AW except ESP under sand soil condition. This result may be attributed to its low content of fine particles and consequently decreasing the Na+ absorb ion was expected (FAO, 1992).

Also, data indicate that SAR and ESP contribute on soil ability to retain water through direct effect increased with increasing fine particles but values of SAR is more than those of ESP by 2.7, 2.6, 1.7 and 1.5 times for sand, loamy sand, clay loam and clay soils. Whereas, the maximum and minimum values of direct SAR and ESP on available water were 23.5, 15.8 % and 12.8, 4.7 % under sand and clay soil, respectively.

Data in Table 2. reveal that the highest indirect effect of SAR and ESP on AW were found through fine particles with value 15.4, 16.7% and 17.7, 18.4 % under sand and and loamy sand soils, respectively. The same trend was observed in case of lowest values of indirect effect of SAR and ESP through coarse particles in the same sequence. Regarding the fine textured soils, there were many soil properties can affect soil AW through SAR and ESP. In clay loam soil, fine particles followed by $CaCO_3$ were 19.7, 20.1% and 22.5, 19.4% were the highest indirect effect on AW through SAR and ESP, respectively. While they are sharing in the lowest values of indirect effect with course particles through SAR and ESP, respectively. The situation was changed in case of clay soil where the highest values of indirect effect were observed in SAR through fine particles (14.3 %), ESP (20.3%) and ESP (14.2%). While in ESP, fine particles (20.3%), EC (16.9%) and CEC (13.3%) are the main soil properties affects. Coarse particles were the lowest indirect value that affects on AW through SAR and ESP with values 6.5 and 5.8 %, respectively.

Results indicated that the residual effect increased strongly in sand followed by loamy sand soil while these values dramatically decreased in clay followed by clay loam. This result could be described on base of the selected soil parameters used in this investigation was precise in fine texture soils, while the opposite was true in coarse ones. Also there were other parameters in coarse texture soils might be taken in consideration when studying the factors that affect on AW in these soils.

Finally, it is clear that fine particles play an important role by its character and through its effect on other soil properties such as OM, CEC, $CaCO_3$ content and aggregate formation and consequently on pore size distribution and intragranular surface area (Atinut *et al*.. 2004). Also, biological technique and use of organic matter has long been known to facilitate the reclamation of saline soils. The beneficial effect of organic materials incorporation followed by leaching is preferred to the decomposition of organic matter resulting in the evolution of carbon dioxide and organic acids, lowering soil pH and release of Ca by solubilization of $CaCO_3$ and other soil minerals, thereby increasing the electrical conductivity and replacement of exchangeable sodium by actions like calcium and magnesium and thus lowering the ESP (Alam and Khan, 2006).

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