Print
Proceedings

Effect of Salinity, Sodicity and Soil Texture on Aggregate Stability of Semi-arid Soils

Mamedov[1] A.I., G.J. Levy[2], C. Huang[1], and L.D. Norton[1]
[1]USDA-ARS, National Soil Erosion Research Laboratory, West Lafayette, IN; [2]ARO, Volcani Center, Institute of Soil, Water and Environmental Sciences, Bet Dagan, Israel; E-mail: amrakh@purdue.edu, vwguy@volcani.agri.gov.il, chihua@purdue.edu, norton@purdue.edu

Resume

Soil texture, sodicity and salinity or water quality play a significant role in determining soil aggregate stability, hydraulic properties and the response of soil clays to dispersion and swelling. We studied aggregate stability from 60 samples of Israeli top soils, widely varying in clay content and sodicity using the high-energy-moisture-characteristics method. Dionized (DW) or saline water (SW) was used to simulate the effect of rain and effluent/saline irrigation water on aggregate stability. Susceptibility of soil aggregates to slaking decreased and therefore aggregate stability increased with the increase in clay content and the salinity of soil solution, and with the decrease in sodicity. The use of SW was more effective in sandy or loamy soils at a low sodicity, while in clay soil at high level of sodicity. This paper shows that salinity, sodicity and soil texture need to be consider together in preventing aggregate breakdown and surface sealing for semi-arid soils.

Introduction

Aggregate stability affects many aspects of a soil's physical function, such as hydraulic conductivity and infiltration. Breakdown of aggregates results in pore collapse which leads to runoff and erosion, and subsequently may cause soil degradation. Soil texture, sodicity (exchangeable sodium percentage, ESP) and salinity (or water quality) play a important role in determining soil aggregate stability, hydraulic properties and the response of soil clays to dispersion and swelling. This is particularly important in areas where the fresh water resources are short in supply and where effluent or saline-sodic or low quality water is used for irrigation. The stability of the soil aggregates is a function of the attractive and repulsive forces arising from intermolecular and electrostatic interaction between the soil solution and soil particles. Breakdown of aggregates by water may result from a variety of physical and physico-chemical mechanisms (slaking, differential swelling, machinery and physico-chemical dispersion), that differ in the type of energy involved in aggregate disruption, in the size distribution of disrupted products, and in type of soil properties affecting the mechanism. (Quirk and Schofield, 1955; Panabokke and Quirk, 1957; Shainberg and Letey, 1984). The effects of salinity and sodicity on soil structural behavior are interrelated and complicated due to variations in soil inherent properties and extrinsic factors (Levy and Mamedov, 2001). Our objective was therefore to evaluate the effects of sodicity and electrolyte concentration (EC) on aggregate slaking in soils exhibiting a wide range of clay content (8-70 %). In order to separate slaking from other processes taking place during aggregate breakdown, we used the high-energy-moisture-characteristics method (HEMC) where accurately controlled wetting of the aggregates (i.e., the driving force for slaking) was the only force exerted on the aggregates (Pierson and Mulla, 1989; Levy and Mamedov, 2002).

Materials and Methods

Soil samples from 0-25- cm depth from 60 cultivated fields in Israel were used in the current study. Some physical and chemical properties of the soils are presented in Table 1. The range of sodicity shown in Table 1 was due to differences in water quality used for irrigation (fresh water, treated effluent and saline-sodic water) or to soil leveling that was done in the 1960s.

Table 1. Selected chemical and physical properties of the soils studied.

Soil	Particle-size, %		CEC	$CaCO_3$	OM	ESP level				
	sand	clay	$cmol_c$/kg	%	%	2	5	10	20	30
Loamy sand	84	11	10	1	0.5	1	4	10	20	-
Loamy	59	22	17	16	1.0	2	6	9	20	28
Sandy clay	41	39	31	15	1.1	1	4	9	17	28
Clay	24	50	46	18	1.0	2	4	9	18	27
	17	62	56	12	1.9	1	4	9	20	29
	15	67	62	7	3.1	2	4	10	18	-

CEC=cation exchange capacity; ESP=exchangeable sodium percentage; OM=organic matter

To perform HEMC, fifteen g of 0.5-1.0 mm air-dried aggregates were placed in a 60 mm I.D. funnel with a fritted disc to form a bed of 5 mm thick. Aggregates in the funnel were subjected to either a fast (100 mm h^{-1}) or a slow (2 mm h^{-1}) wetting treatment using a peristaltic pump. Two levels of salinity, dionized water (DW, EC=0.4 $mmol_c$ L^{-1}) and saline water (SW, EC=20 $mmol_c$ L^{-1}) were used to simulate the effect of rain and effluent/saline irrigation water on aggregate stability. A moisture characteristic curve, at a matric potential range of 0 to -5.0 J kg^{-1} (up to 50 cm H_2O tension), was obtained using a hanging water column. An index of aggregate stability is obtained by quantifying differences in moisture content curves for fast and slow wetting (Fig. 1a). For a given wetting rate, a structural index is defined as the ratio of volume of drainable pores (VDP) to modal suction (Fig. 1b) derived from the modified van Genuchten model (Pierson and Mulla, 1989). Aggregate stability is concluded from the ratio of fast to slow structural indices, termed "stability ratio" (SR). As expected fast wetting in combination with high sodicity significantly affected slaking and thus the VDP and the modal suction (Fig. 1c).

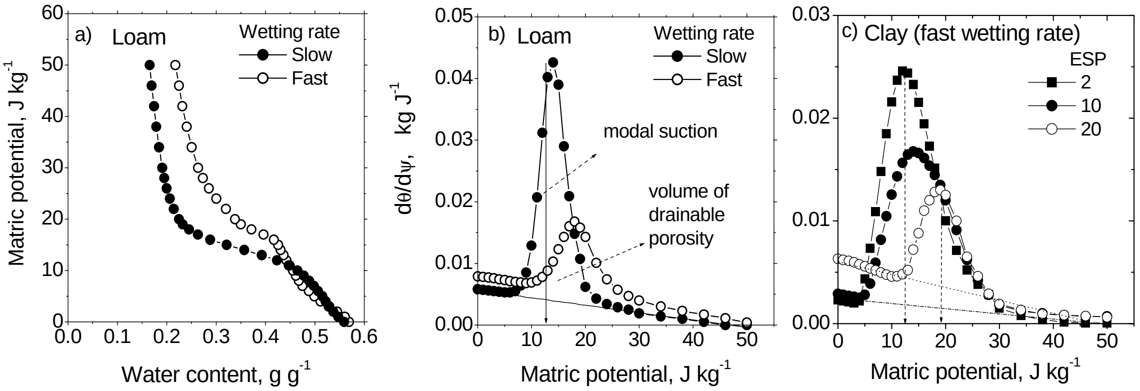

Fig.1.Moisture release (1a), specific water capacity curves of loam under fast and slow wetting(1b) and volume of dainable porosity and modal suction of clay soil as affected by sodicity (1c)

Results and discussion

Aggregates stability index (SR) derived from the DW and SW treatments are presented in Figure 2. The soils used demonstrated a wide range of SR (0.10-0.79), suggesting that aggregate susceptibility to slaking, strongly depended on the treatments. A multifactor analysis of variance showed that each main treatment, i.e., EC, ESP level and soil clay content, as well as their interaction, significantly (P<0.01) affected aggregate stability, showing a complex interaction. For low level of ESP (<5) aggregate resistance to slaking was found to increase with the increase in clay content (Figs. 2&3). The favorable effects of clay on building aggregates and increasing their resistance to breakdown and slaking by water, was related to the fact that clay acts as a cementing and binding agent in the soil. Aggregate stability decreased with the increase in ESP (Figs. 2&3). These observations indicated that aggregate slaking was affected by physico-chemical clay dispersion and swelling. Evidently, conditions favoring dispersive behavior of clay (high sodicity) adversely affected aggregate resistance to slaking.

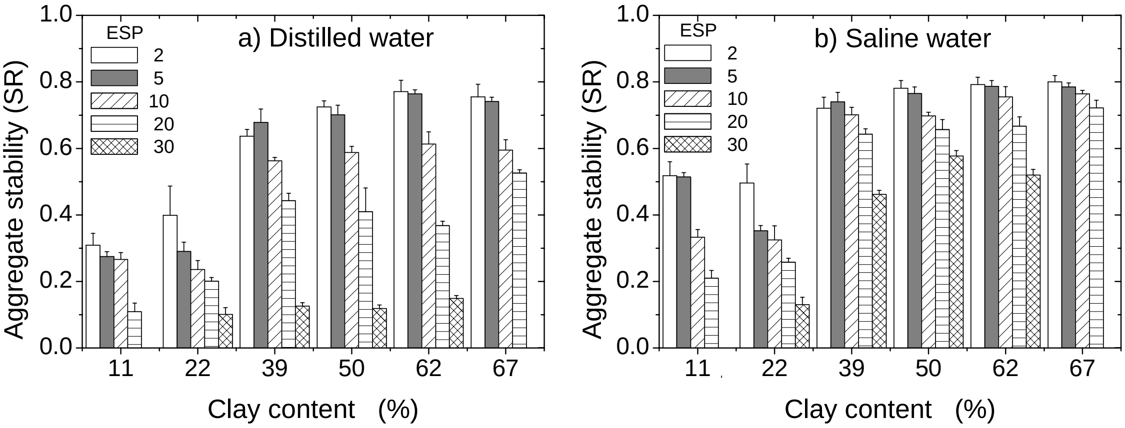

Fig.2. Aggregate stability as affected by sodicity (ESP) and water quality for the six soils (represented by their clay content). Bars indicate one standard deviation.

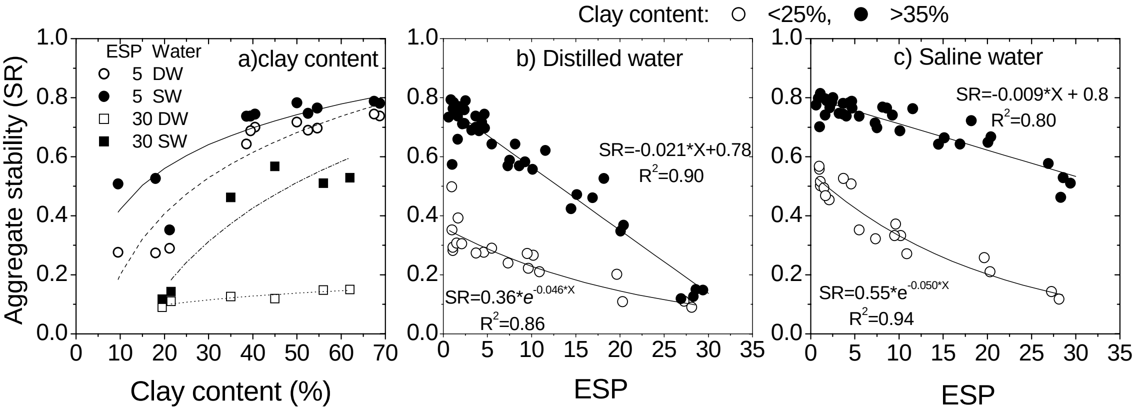

Figure 3. Aggregate stability (SR) as a function of clay content (3a) and sodicity (ESP) for distilled (3b) and saline (3c) water

Use of SW increased SR at all soil groups and ESP levels compared to the use of DW. However the effect of water quality on aggregate stabilizing depended on soil texture and increased with increase in clay content (Fig. 2b&3a). The data presented in Figure 3a further emphasizes that the dependence of aggregate stability on ESP, EC and clay content is enhanced at very low and very high ESP levels. At high clay content the aggregates were

Print

Proceedings

inherently stable and could benefit from the additional stabilizing effect of SW, albeit the high sodicity, in resisting slaking. Conversely, when the aggregates were unstable (low clay content), introducing electrolytes to the soil solution was not enough to decrease the aggregates tendency to slake. Thus the soils were divided in to two groups (Fig. 3 b & c) based on the aggregate stability (SR) data: course-textured soils (≤25% clay), and fine-textured soils (≥35% clay).

Results of a stepwise regression analysis (Table 2) clearly indicate the difference in the effects of water quality on aggregate stability. When DW was used the contribution of sodicity and that of clay content in determining SR was comparable; conversely, when SW was used the impact of clay content on aggregate stability was more than twice that of sodicity (Table 2).

Table 2. Stepwise regression analysis of effect of soil properties on aggregate stability

Treatment	Variability	P>F	R^2	
			partial	model
DW	ESP	0.0001	0.46	0.46
	Clay	0.0001	0.42	0.88
SW	Clay	0.0001	0.60	0.60
	ESP	0.0001	0.23	0.83
	OM	0.0001	0.03	0.86
	Silt	0.0041	0.01	0.87

Conclusions

Aggregates of semi-arid smectitic soils showed great sensitivity to ESP level and water quality Aggregate stability increased with increase in clay content and EC of water and with decrease in ESP. A significant triple interaction among ESP, EC and clay content ($p=0.05$) in their effect on aggregate slaking was noted, suggesting that the combined effects of these variables on slaking were complex. Based on the effects of ESP and water quality on aggregate stability, the soils were divided into two groups: unstable soils with medium-low clay content (≤25%) and stable soils with clay content > 35%. In the stable soils effects of water quality were more pronounced in high ESP level, whereas in the unstable soils effects of water quality were more pronounced at low ESP level. Consequently, our data suggest that use of aggregate stability for prediction of changes in structural stability of semi-arid soils require that effects of water quality, sodicty and soil texture on aggregate breakdown be considered simultaneously as these three parameters interact significantly. The data is usefull to understand the relative contribution of soil texture, sodicity and water quality on aggregate slaking and dispersion, as well as important management practices to reduce the impact of sodic condition on soil degradation, erosion and for the irrigation planning.

References

Levy G.J and A.I. Mamedov. 2001. Aggregate stability and seal formation. Soil Sc. Soc. Am. J. 66:1603-1609.

Panabokke, C.R. and J.P. Quirk. 1957. Effect of initial water content on stability of soil aggregates in water. Soil Sci. 83: 185-195.

Pierson, F.B., and D.J. Mulla. 1989. An improved method for measuring aggregate stability of a weakly aggregated loessial soil. Soil Sc. Soc. Am. J. 53: 1825-1831.

Quirk, J.P., and R.K. Schofield. 1955. The effect of electrolyte concentration on soil permeability. J. Soil Sci. 6 :163-178.

Shainberg, I., and J. Letey. 1984. Response of soils to sodic and saline conditions. Hilgardia 52:1-57.

Print

Proceedings