

Effects of Electrical Conductivity and Sodium Adsorption Ratio of Water on Aggregate Stability in Soils With Different Organic Matter Content

F. Tajik¹, H. Rahimi² and E. Pazira³

ABSTRACT

The properties of soils affected by salinity and the processes involving degradation of soil structure are relatively well-known. However, the effects of saline and sodic conditions on the physical and mechanical properties of soils have been studied to a lesser extent. In this research, the effects of electrical conductivity (EC) and sodium adsorption ratio (SAR) of solutions were assessed on soils containing various amounts of organic matter under laboratory conditions. The soils used were collected from the Dasht-e-Naz of Sari region in the north of Iran and contained the same clay type, predominantly Illite. The major difference between the soils was their organic matter content. The treatments consisted of applying solutions with definite EC and SAR (two levels of EC: 0.5 and 4 dS/m and three levels of SAR: 0, 5 and 15). With an increase of SAR, the wet aggregate stability (WAS) decreased and the amount of dispersible clay (DC) increased. At a similar SAR, higher EC values were associated with lower DC. The order of average aggregate stability of soils were: virgin soils > soils under continuous cultivation of *Festuca* > soils under intensive cultivation with regular crop rotation > soils under continuous cultivation of *Agropyron*. The analysis of variance showed significant differences (at 1%) between soil types, soil sampling depths, EC and SAR.

Keywords: Dispersible Clay (DC), Organic carbon, Salt-affected Soils, Wet aggregate stability (WAS).

INTRODUCTION

The physical and mechanical properties of soils are mainly dependent on the quantity, size and strength of soil aggregates and their stability in water. Hence, studies of the nature of soil aggregates are considered as a means for evaluating soil physical and mechanical properties. If soil aggregates do not disintegrate in wet conditions or by the action of agricultural machinery and equipment, it is expected that irrigation, drainage, rainfall, and farming operations would not have an adverse effect on soil structure, and soil possesses relatively acceptable stability (Bybordi, 1989). Understanding the process

of soil structure degradation under saline and sodic conditions in arid and semi-arid regions could improve crop management. The dispersion of soil particles and slaking of soil aggregates resulting in soil crusting and hardening of soil surfaces, lead to negative effects on air and water transport, germination of seeds and root growth, and also intensify soil erosion (Bybordi, 1993).

The role of organic matter in soil structure stabilization is not yet completely understood. The mechanism of stabilization depends not only on the chemical nature of the organic matter, but also on its arrangement with respect to the mineral constituents (Aringhieri and Sequi, 1979). Various equations

¹ Iranian Agricultural Engineering Research Institute (IAERI), PO Box 31585-845, Karaj, Islamic Republic of Iran. E-mail: del13taj@yahoo.com

² Faculty of Agriculture, University of Tehran, Karaj, Islamic Republic of Iran.

³ Agricultural Research, Education and Extension Organization, Tehran, Islamic Republic of Iran.

have been developed for explaining the relationship between organic matter and soil aggregate stability. These are sometimes quite different from one another. The reasons for these differences were discussed by Tisdall and Oades (1982).

Many studies have emphasized the dispersion of dry soil aggregates because of organic bond effects. However, if stress is applied (e.g. tillage in wet conditions) the organic matter sticks to the clay particles. This increases the repellent forces between the particles and intensifies the colloidal state in soil (Emerson, 1984). Reid and Goss (1981) investigated the influence of root growth and activities on soil aggregate stability using five crop species and two soils. They showed that the root growth of perennial ryegrass and lucerne was generally associated with increases in aggregate stability. These beneficial effects were associated with periodate sensitive materials (probably polysaccharides) produced in the rhizosphere. However, growth of maize, tomato and wheat roots decreased the wet aggregate stability. This suggests that the growth and activities of living roots may be a major factor controlling the overall direction and magnitude of changes in aggregate stability under arable or ley crops (Reid and Goss, 1981).

Studies have been conducted for relating the cropping history to soil structure. Baldock and Kay (1987) observed that during 15 years continuous cultivation of corn, the size and amount of stable soil aggregates decreased in comparison with the continuous cultivation of brome grass. The severity of soil structural degradation was greater in soils under continuous cultivation of corn (Baldock and Kay, 1987).

Emerson (1984) compared a grassland with an adjacent cultivated soil. Both contained Illite and a small amount of carbonate, but their organic matter contents were 5.0 and 0.7 percent, respectively. The aggregates of grassland soil preserved their stability when washed with 0.5 M NaCl solution but those of the cultivated soil were completely dispersed when washed with 0.02 M

NaCl (Emerson, 1984). Barzegar *et al.* (1994) found that increasing the SAR up to 30 decreased aggregate stability. For a given SAR, aggregate stability increased with increasing organic carbon content. Their results showed that sodicity decreased the amount of aggregates > 250 μm and consequently increased proportions of aggregates < 250 μm . Soils with a high organic carbon (>2%) had less dispersible clay than others at a given sodicity and salinity. They concluded that by improving the organic matter status of a soil, the effects caused by sodicity on aggregate stability can be modified (Barzegar *et al.*, 1994).

The objective of this study was to investigate the effects of EC and SAR, as indices of saline-sodic conditions, and soil organic matter content on soil aggregate stability under laboratory conditions. It may aid future studies at regional and national levels in Iran.

MATERIALS AND METHODS

Soil Sampling Methods and Locations

Soil sampling sites were situated between the cities of Sari and Neka, approximately 20 km from the Caspian Sea. The soils contained appreciable amounts of organic matter and possessed a good structure. They are classified as Brown forest soils (typic xerochrepts) (Soil Institute of Iran, 1956) and typic calcixerolls (Iranian Soil and Water Research Institute (ISWRI), 1980). The EC of the soils is less than 1.0 dS/m. However, in the east and west of the sampling sites, soils are saline (ISWRI, 1995). Before 1966, the soils were covered with natural forest. Later, most of the forest was cleared and the land was cultivated.

The soil sampling sites were:

- The wild life park of Dasht-e-Naz (code P) that has been a virgin land for the past hundred years. Since 1966, it has been a protected area for the grazing of yellow deer.

- The cultivated farms (code W), where an intensive agriculture is practiced under sys-

tematic crop rotation. At the time of sampling, the plot was under wheat cultivation, and the crop rotation was wheat-corn-soybeans-corn-wheat-soybeans- corn/ bre-seem clover.

-The Dolemarz Station that has been established for seed propagation of forage during the past 10 years. From two sampling plots, one (code F) was under rain-fed tall fescue (*Festuca arundinaceae*), and another (code E) was under rain-fed tall wheat grass (*Agropyron elengatum*). Prior to this experiment these plots had not been cultivated during the past 10 years.

Soil samples were collected from at least ten locations in each site from depths of 0-10 and 10-20 cm. At the site of the virgin soil, samples were taken from depths of 0-5 and 5-10 cm. Soil samples were transferred to the laboratory at the Iranian Agricultural Engineering Research Institute (IAERI) and were air-dried. The 2-4 mm aggregates were separated and preserved for treatment preparation. Particles smaller than 2 mm were used for physical and chemical analyses. Soil sampling was done in July 1996, after the harvest and before new cultivation.

Determination of Soil Physical and Chemical Properties

The soil properties determined for the particles of less than 2 mm were: EC, pH, and SAR in saturation extract; calcium carbonate; sand, silt and clay percentage. Clay type was identified by X-ray and organic carbon content by the Walkley and Black method

(Nelson *et al.*, 1982). Table 1 shows the measured physical and chemical properties of the soils.

Treatments

The 2-4 mm aggregates were treated on the sintered glass funnels with solutions having definite EC and SAR. The solutions (with EC levels of 0.5 and 4 dS/m and SAR levels of 0, 5, and 15) were prepared on a calculated basis using pure reagents of sodium, calcium, and magnesium chlorides.

Each treatment consisted of five wetting and drying cycles with 48 hour intervals. In each cycle, the samples were wetted by submerging in solutions for seven hours and then subjected to 30 cm (3 kPa) suction for 17 hours. Afterwards, the samples were drained and allowed to stand for another 24 hours. After five wetting/drying cycles, the EC and SAR of the drained solutions in each funnel were determined. Finally, the samples were air dried and retained for further analysis.

Determination of Wet Aggregate Stability (WAS) and Dispersible Clay (DC)

The wet aggregate stability (WAS) and dispersible clay (DC) were determined on the basis of a procedure used by Pojasok and Kay (1990) as follows. First, 20 g of the treated 2-4 mm soil aggregates were dried at 110°C for 24 hours and then poured into 100-ml tube and 40 ml of distilled water

Table 1. Physical and chemical characteristics of the soils studied.

Soil	Depth (cm)	pH	EC (dS/m)	SAR	O.C. (%)	CaCO ₃ (%)	Clay (%)	Silt (%)	Sand (%)
W.1	0-10	8.04	0.47	1.4	2.18	18.94	34	29	37
W.2	10-20	8.06	0.47	1.7	2.17	17.38	33	29	38
E.1	0-10	7.75	0.54	0.7	2.38	26.38	23	38.6	38.4
E.2	0-20	7.80	0.43	0.6	2.13	30.13	20	40	40
F.1	0-10	7.43	0.84	0.6	3.42	24.25	27	36	37
F.2	10-20	7.55	0.63	0.5	2.89	27.63	32	31	37
P.1	0-5	7.27	0.97	0.3	10.3	3.63	28	30	42
P.2	5-10	7.55	0.60	0.5	7.19	7.38	33	29	38

added. The tube was then shaken horizontally for 15 minutes at 100 rpm and the solution poured through a 0.25 mm sieve and washed using two additional 40 ml aliquots of distilled water. Materials left on the sieve were oven-dried and weighed. The filtrate passing through the sieve was transferred to another vessel. After three hours, a sample was taken from the top of the suspension. The amount of dispersed clay was then determined. The wet aggregate stability was calculated using the equation:

$$\% \text{ WAS} = \left(\frac{\text{Dry weight of aggregates remaining on 0.25 mm sieve}}{\text{Total weight of oven dried soil}} \times 100 \right) \quad (1)$$

The amount of sand (particles greater than 0.25 mm) remaining on the sieve was not measured.

To determine the amount of dispersible clay (DC), the absorbance of each sample was measured using a spectrophotometer at 620 nm (Pojasok and Kay, 1990). The spectrophotometer was calibrated to zero absorption using distilled water. These quantities were recorded in terms of dispersible clay per 100 g of total soil. The calibration curves of each soil were prepared using a 20-g sample of soil aggregates. To this sample, 100 ml of distilled water was added and the mixture was vigorously shaken. After three hours, 3 ml of supernatant liquid was taken

as a sample. Samples from each treatment were oven-dried and the amount of clay was determined in mg/ml of water. Serial dilutions were made to include the range of concentrations required for drawing the standard curve. The amount of DC was expressed as a percentage of the total oven-dry soil sample weight.

The quantities of WAS and DC for each treatment are shown in Table 2.

RESULTS

Figures 1 and 2 show the wet aggregate stability and dispersible clay of soils in the order of their organic carbon content (Table 1) and in relation to the treatments employed. In most soils the WAS increased with increasing organic carbon and was dependent on the particular treatment of each soil (Figure 1). The WAS decreased proportionally with the increase of the SAR.

In most cases and in each treatment, the amount of DC decreased with increase of organic carbon (Figure 2). In any particular soil, DC changed with the treatment used and increased out higher SAR values. In similar SAR, soils with a higher EC had a lower DC. In Figures 1 and 2, the significance of these differences will be explained by analysis of variance.

Table 2. The WAS (%) and DC (g clay /100 g soil) of soils and treatments^a.

Soils	P.1	P.2	F.1	F.2	E.1	W.1	W.2	E.2	
Treatments									
EC=0.5 dS/m, SAR = 0	94.55	91.57	89.12	82.37	70.82	76.31	76.02	66.05	WAS
	0.49	0.58	0.64	0.70	0.88	0.74	0.85	0.84	DC
EC=0.5 dS/m, SAR=5	93.00	87.41	88.72	80.49	64.03	74.58	72.92	53.24	WAS
	1.11	1.10	1.16	1.23	1.50	1.30	1.20	1.49	DC
EC=0.5dS/m,SAR= 15	89.21	86.89	86.27	74.49	50.49	71.55	68.77	47.22	WAS
	1.10	1.00	1.62	1.90	3.45	2.11	2.27	3.20	DC
EC= 4 dS/m, SAR = 0	90.25	90.2	87.91	77.86	51.32	73.51	73.99	47.89	WAS
	0.19	0.22	0.29	0.21	0.42	0.29	0.30	0.32	DC
EC= 4 dS/m, SAR = 5	84.26	86.00	84.13	74.18	48.11	70.52	64.77	36.02	WAS
	0.50	0.56	0.95	0.68	1.50	1.00	0.98	1.61	DC
EC= 4dS/m, SAR = 15	81.80	80.91	77.65	70.05	47.18	70.12	58.30	46.80	WAS
	1.25	1.40	1.93	2.15	2.73	2.21	2.34	2.68	DC

^a The organic carbon of soils were decreased from P.1 to E.2

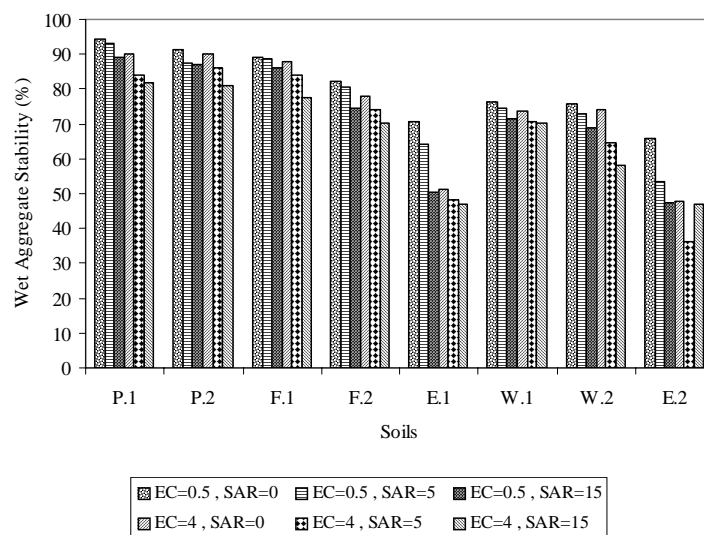


Figure 1. Wet Aggregate Stability of soils in order to their organic carbon and treatments (the organic carbon of soils was decreased from P.1 to E.2).

Figure 3 and 4 also show the apparent effects of the treatments.

The analysis of variance in a factorial experiment (with four levels of soil factor, two levels of soil sampling depth, two levels of EC, and three levels of SAR) was imple-

mented in a completely randomized block design. The significance of the differences was determined by Duncan method (at 1%). Table 3 gives a summary of these results.

The Duncan test for the WAS showed significant difference for the soil factor (or-

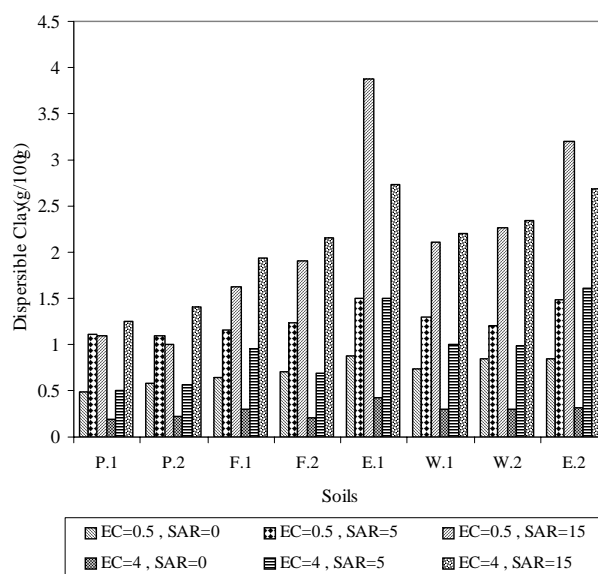


Figure 2. Dispersible Clay of soils in order to their organic carbon and treatments (the organic carbon of soils was decreased from P.1 to E.2).

Table 3. Summary of variance analysis of data^a

Variables	WAS	DC
Soil	**	**
Depth	**	ns
Soil × depth	**	**
EC	**	**
Soil × EC	**	**
Depth × EC	ns	ns
Soil × depth × EC	**	ns
SAR	**	**
Soil × SAR	**	**
Depth × SAR	**	*
Soil × depth × SAR	**	*
SAR × EC	*	**
Soil × SAR × EC	**	**
Depth × SAR × EC	ns	ns
Soil × depth × SAR × EC	*	ns

^a* significant at 5%; ** significant at 1%; ns not significant

ganic carbon). The order of WAS averages was:

E.2 < W.2 < W.1 < E.1 < F.2 < F.1 < P.2 < P.1

The SAR factor was also significant and the order of WAS averages was:

SAR=15 < SAR=5 < SAR=0

The Duncan test showed a reverse trend for the DC variable.

DISCUSSION

The amount and type of organic matter, at various stages of decomposition, are considered important factors in stabilizing soil structure. The complex soil system makes it very difficult to explain the mechanisms involved in the soil structure stability. The dual role of organic matter (Emerson, 1984) can be explained in terms of two processes:

1. Increase of repelling forces between particles due to the increase in negative charges of pure clay that intensifies the colloidal condition of soil particles and results in increased dispersion.

2. The formation of bonds with adsorbed cations that increase the physical resistance

of soil aggregates to dispersion and, therefore increase the aggregate stability.

Crop rotation and land management, due to their effects on the amount and type of organic matter, affects the stability of soil aggregates. This effect is caused by the physical and chemical influence of plant roots. Organic matter can also improve the negative effect of sodic conditions in soils. The stability is also influenced by the presence of cations such as calcium, magnesium and aluminum in the soil solution. The negative effect of sodic conditions decreases with an increase in the salt concentration, which was in agreement with our data. Interaction between EC and SAR was significant at 5% for the WAS.

In this study, higher aggregate stability and lower dispersible clay were obtained with an increase in the organic matter of soils. An increase in the SAR also had a negative relation with wet aggregate stability and a positive relation with dispersible clay. At a similar SAR, treatments with higher EC had less dispersion. This shows the adjusting effect of EC on soil sodic conditions. Visual evaluation of aggregates during the treatment preparation also confirms the negative relation of aggregate stability with SAR.

The analysis of variance of data showed significant difference between soils, depth of sampling, and levels of EC and SAR. The differences between soils in view of the amount of organic matter and its management were expected. However, one interesting result was that samples E and F, planted under rain-fed pasture in one location showed significant differences in their WAS and DC. This could be attributed to the difference in the amount of clay, calcium carbonate, and organic carbon in soils (Table 1). Soil E had a lower content of organic carbon and clay and higher content of calcium carbonate. Furthermore, Festuca (in soil F) compared to Agropyron (in soil E) has deeper and denser roots (Shaidaie and Nemati, 1978), and therefore had higher aggregate stability and lower dispersible clay.

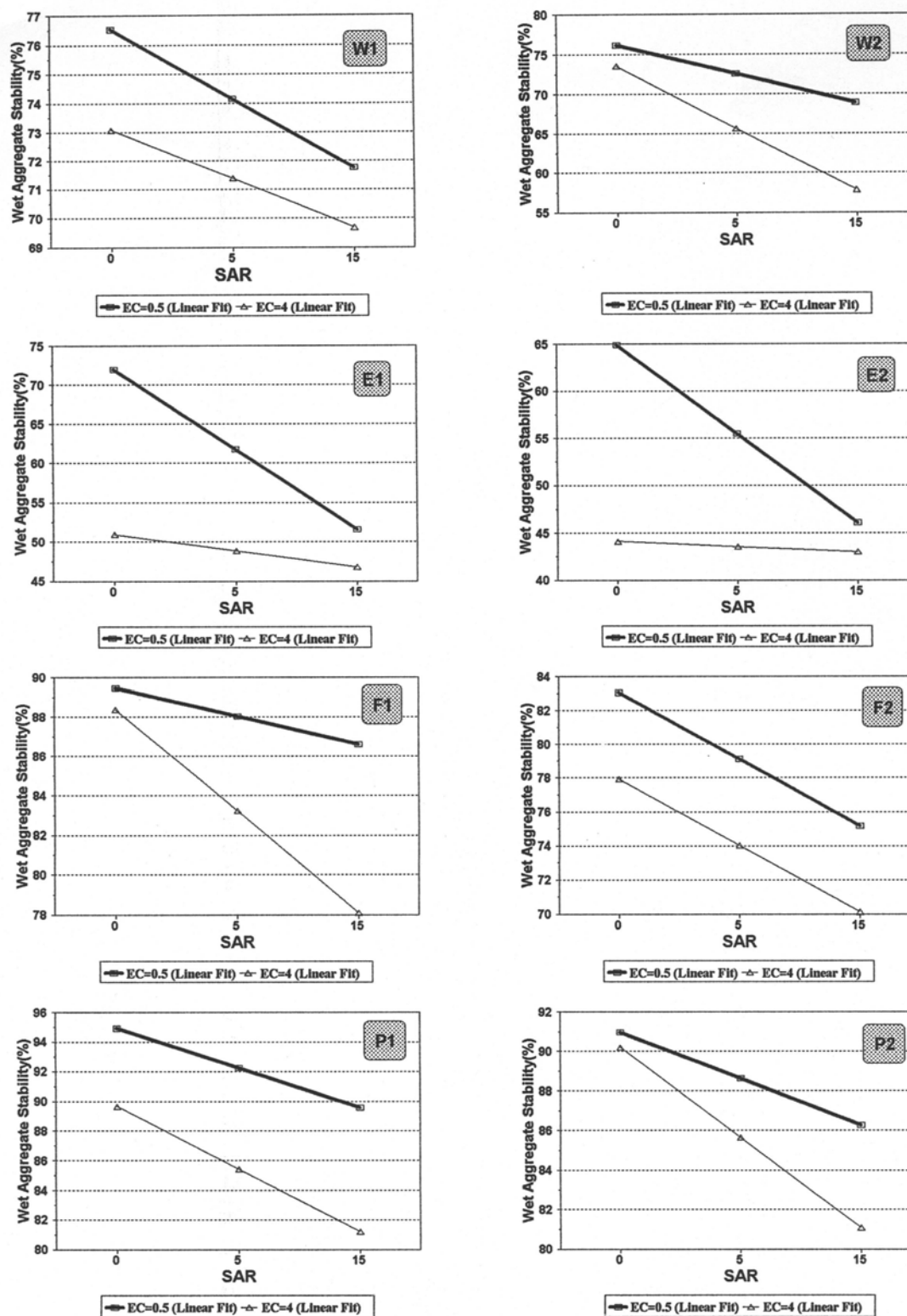


Figure 3. The effect of EC and SAR treatments on wet aggregate stability.

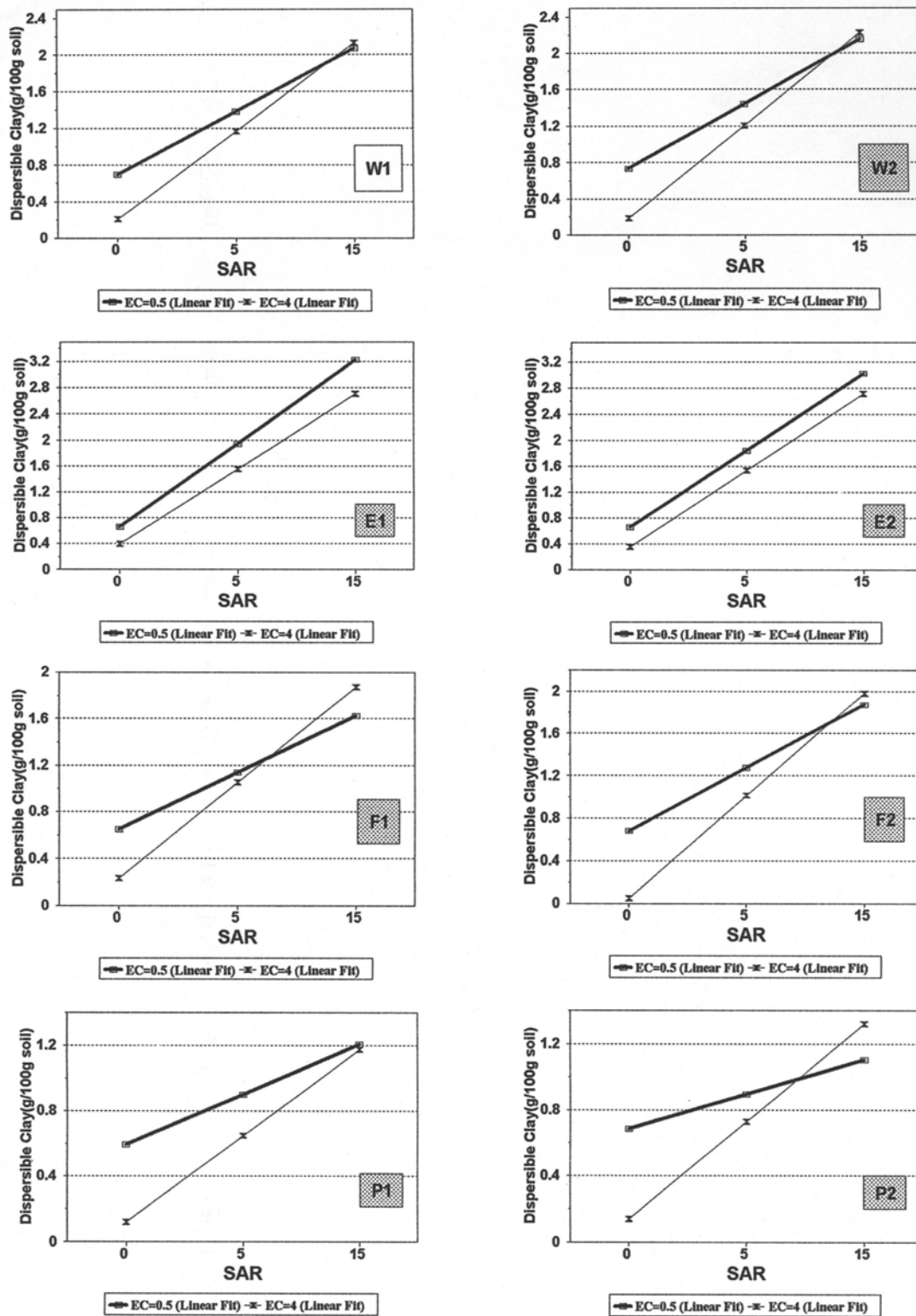


Figure 4. The effect of EC and SAR treatments on dispersible clay.

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REFERENCES

1. Aringhieri, R. and Sequi, P. 1979. The Arrangement of Organic Matter in a Soil Crumb. In: " *Modification of Soil Structure*". (Eds.): W. W. Emerson *et al.* John Wiley & Sons, Chichester. pp. 145-150.
2. Baldock, J. A. and Kay, B. D. 1987. Influence of Cropping History and Chemical Treatments on the Water-stable Aggregation of a Silt Loam Soil. *Can. J. Soil Sci.*, **67**: 501-511.
3. Barzegar, A. R., Oades, J. M., Rengasamy, P. and Giles, L. 1994. Effect of Sodicity and Salinity on Disaggregation and Tensile Strength of an Alfisol under Different Cropping Systems. *Soil & Till. Res.*, **32**: 329-345.
4. Bybordi, M. 1989. *Principal of Drainage Engineering and Improvement of Soil*. University of Tehran, Tehran (In Persian).
5. Bybordi, M. 1993. *Soil Physics*. University of Tehran, Tehran (In Persian).
6. Emerson, W. W. 1984. Soil Structure in Saline and Sodic Soils. In: " *Soil salinity under Irrigation*" (Eds.): Shainberg, I. and Shalhevet, J. Springer-Verlag, Berlin. PP. 65- 76.
7. Iranian Soil and Water Research Institute (ISWRI) .1980. *Detailed Soil Survey Report of Makran Research Station (Sari)*. Technical publication No. 585, ISWRI, Tehran (In Persian).
8. Iranian Soil and Water Research Institute (ISWRI) .1995. *Land Resource Evaluation and Suitability Map of Mazandaran Province*, ISWRI, Tehran (In Persian).
9. Nelson, D. W. and Sommers, L. E. 1982 . Total Carbon, Organic Carbon, and Organic Matter. In: " *Methods of Soil Analysis- Part 2 Chemical and Microbiological Properties*", ASA - SSSA, Madison. PP. 539- 579.
10. Pojasok, T. and Kay, B. D. 1990. Assessment of a Combination of Wet Sieving and Turbidimetry to Characterize the Structural Stability of Moist Aggregates. *Can. J. Soil Sci.*, **70**: 33- 42.
11. Reid, J. B. and Goss, M. J. 1981. Effect of Living Roots of Different Plant Species on the Aggregate Stability of two Arable Soils. *J. Soil Sci.*, **32**: 521-541.
12. Shaidaie, G. and Nemati, N. 1978. *New Method of Forage and Fodder Production in Iran*. Forest and Rangelands Organization of Iran, Tehran (In Persian).
13. Soil Institute of Iran. 1956. *Semi-detailed Soil Survey and Classification of Mazandaran Province* (Neka-Siahroud region). Publication No. 492, Tehran (In Persian).
14. Tisdal, J. M. and Oades, J. M. 1982. Organic Matter and Water-stable Aggregates in Soils. *J. Soil Sci.*, **33**: 141 - 163.

اثر هدایت الکتریکی و نسبت جذب سدیم آب بر پایداری خاکدانه‌ها در خاکهای حاوی مقادیر مختلف مواد آلی

ف. تاجیک، ح. رحیمی و ا. پذیرا

چکیده

ویژگیهای خاک‌های تحت اثر املاح و فرآیند تخریب ساختمان خاک تا حدی شناخته شده اما اثر شرایط شور و سدیمی بر ویژگی‌های مکانیکی و فیزیکی خاکها، کمتر مورد مطالعه قرار گرفته است. در این پژوهش، اثر هدایت الکتریکی (EC) و نسبت جذب سدیم (SAR) بر خاکهایی که مقدار مواد آلی متفاوت دارند، در شرایط آزمایشگاهی بررسی گردیده است. خاک‌های مورد مطالعه از منطقه دشت ناز ساری تهیه شده و دارای نوع رس یکسان (با کانی غالب ایلات) می‌باشند. تفاوت عمده خاکها در مقدار مواد آلی آنهاست. محلولهایی با هدایت الکتریکی $0.5/4$ دسی زیمنس بر متر و SAR در سه سطح (صفر، ۵ و ۱۵) تیمارهای آزمایش را تشکیل می‌دهند که مقدار پایداری خاکدانه‌های تر (WAS) و پراکنش رس (DC) تابعی از آنهاست با افزایش SAR، پایداری خاکدانه‌ها (WAS) و مقدار پراکنش رس (DC) افزایش یافته است. در SAR مشابه، تیمارهایی با EC بالاتر، DC کمتری داشته است. ترتیب میانگین پایداری خاکدانه‌ها چنین بوده است: خاک بکر < خاک تحت کشت علوفه فسکیو < خاک تحت کشت متراکم با تناوب منظم < خاک تحت کشت علوفه آگروپایرون. آنالیز واریانس داده‌ها تفاوت معنی‌داری (در سطح ۱٪) میان نوع خاکها، عمق نمونه‌برداری و مقادیر EC و SAR نشان داده است.