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Effect of levels of polymaleic acid on the structural stability of saline soils

P.R.C. LOPES¹; J.M. GISBERT²; L.D. SOUZA³;
L.D. GOMEZ² & O.A. ALMEIDA³

¹Embrapa Semi-Arid researcher. Caixa Postal 23. 56300-000, Petrolina. PE. Brazil.
Tel.: 81 8621551. Fax: 81 9621744. E-mail: proberto@cpatsa.embrapa.br

²Universidad Politécnica de Valencia. Depto. de Producción Vegetal. Unidad Docente
de Suelos. Camino de Vera s/n. 46010 Valencia. Spain.

³Embrapa Tropical Fruit researcher. Caixa Postal 02.
44380-000 Cruz das Almas. BA. Brazil.

ABSTRACT

The effect of levels of polymaleic acid was studied on the structural stability of two saline soils exposed to intensive cultivation. Soil samples with undisturbed structure were collected and placed in containers where levels of polymaleic acid (0, 10, 20 and 30L/ha) were applied diluted in distilled water, in order to raise the moisture up to field capacity. One week later, controlled drip irrigation was applied using a volume corresponding to the pluviometric precipitation of the areas where the samples were collected. The washed soil samples were taken from the containers with the objective of lowering the moisture and separating the aggregates, considering those which passed through a 4 mm sieve and were retained in a 2 mm sieve. From each soil type, four bags of aggregates weighting 1 kg were taken, received a second application of the same levels of the polymer diluted in the irrigation water, adjusting the moisture of the samples of aggregates to 80% of the field capacity. The plastic bags with the humid samples were weighted and closed to keep the moisture uniform. Three subsamples from each bag were taken every 30 days to determine the weighed mean diameter (WMD) of the aggregates up to 150 days. After washing the soil with distilled water, WMD of the aggregates was reduced in the two soil types, in different proportions. The highest levels caused a lower reduction on the stability grade, showing the role of the polymer on protection of the

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aggregates against disintegration. After 30 days of the second application of the polymer on washed aggregates, WMD started to increase differently for all the treatments, showing its effect on increasing structural stability of the soils.

Key Words: salinity, soil conditioner, aggregate, dispersed clay

INTRODUCTION

The high contents of salts and exchangeable sodium influence the physical and chemical soil characteristics, difficulting normal crop development. The soil colloid swelling mechanism, caused by sodium ions, affects its structure due to the thickness increase of the water layer bounded to the particles, making them disaggregate and causing clay dispersion. This process is the main responsible for soil structural stability decrease, which influences the decrease of infiltration rates and hydraulic conductivity.

The clay dispersion in the soil can happen through mechanical and chemical processes. The first one is caused by the direct impact of the rain drops over the nude soil surface, which destroy the aggregates and disperse the clay particles, obstructing the pores, inducing a superficial crust formation. The factors that influence the chemical processes include the soil solution electrolitic concentration and its composition (Rengasamy et al., 1984; Shainberg & Letey, 1984.), the pH (Suarez et al., 1984), the clay structure and mineralogy (Oster & Rhoades, 1984), the exchangeable sodium concentration and the organic matter content (Schainberg & Letey, 1984).

The organic matter shows an important effect improving the physical soil characteristics affected by salts, especially sodium. The humic acids show the capacity of increasing the aggregation level of the thin soil superficial layer, increasing its stability.

To rehabilitate soils affected by salts and interchangeable sodium, special attention must be given to their physical characteristics, using practices able to improve soil structural stability and, consequently, the infiltration rate and hydraulic conductivity (Richards, 1973). A very common practice is the use of synthetic polymers as soil conditioners, with the aim of improving the physical and chemical soil characteristics affected by salts and sodium interchangeable excess. The polymer application in the soil decreases the clay dispersion (Helalia & Letey, 1989) and the superficial crust and increases the stability (Allison, 1956; Ben-Hur & Karen, 1997) the infiltration rate and, consequently, hydraulic conductivity (El Morsy et al., 1991). The way that the soil conditioners work is frequently described for their capacity to promote dispersed clay flocculation and to increase aggregate structure stability. Mitchel (1986) applied polyacrilamide (32 kg/ha) and reduced clay dispersion, superficial crust resistance and formation, and increased the aggregate stability in 45.2%, while the increase in the control was only 9.0%.

Moen & Richardson (1984), studying the dispersion resistance of soil types (clayey and lime), concluded that the application of polyvinil alcohol polymer and glyoxal T403 decreased the clay dispersion and increased the aggregate stability in 50%, compared with the control.

The objective of this work was to study the effect of a soil conditioner (polymaleic acid) on the aggregates stability and on the percentage of dispersed clay in two saline soils, with distilled water simulating rainfall.

MATERIALS AND METHODS

This work was carried at the soil laboratory of the Universidad Politécnica de Valencia, Spain, using two types of soils with high salinity levels, one with franc clay texture, here named R, collected in Orihuela, Alicante. The other, here named PL, shows franc lime texture, collected in Pulpi, Almeria. Their physical and chemical characteristics are shown on Table 1.

Soil samples were collected in the field with undisturbed structure using plastic boxes- 20 x 12 x 20 cm, open in the upper and in the lower parts, which were put in the soil at 20 cm depth, then digged with a hoe around the boxes deeper than their heights, in order to take them without breaking the soil structure. Then, the boxes were closed in the lower parts with a perforated lid to allow water leave. Aggregate soil samples were collected at the same places where the soil samples in boxes were taken, to determine the weighed mean diameter (WMD) of the water dispersed clay, and gravimetric moisture percentage, before soil washing.

In the laboratory, rates of 0, 5, 10 and 15L/ha of soil conditioner (polymaleic acid) were applied over the samples surface with unaltered structure, diluted in the first irrigation water, with enough volume to increase soil moisture to field capacity. The soil conditioner used is composed by polymaleic acid 33%, its polyanionic, with 47 to 53% of solid contents, pH ranging from 1.0 to 2.0, viscosity between 10 and 35 mm², the molecular weight of 500-1000 K daltons. It is water and methanol soluble. In order to rehabilitate soils affected by salts and interchangeable sodium, special attention has to be given to their physical characteristics, using hand work able to improve the structural stability and, consequently, the infiltration rate and hydraulic conductivity of the soil (Richards, 1973).

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

Soils	Texture %			pH	CE dS/m	SAR (meq/L) ^{0.5}	
	Sand	Silt	Clay				
R	27	46	27	8.45	7.21	10.62	
PL	13	64	23	8.15	5.10	2.08	
	Cations mmol _c kg ⁻¹				Anions		
	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	Cl ⁻	SO ₄ ⁼	HCO ₃ ⁻
R	27	20	51.5	2.0	50.8	44.9	3.0
PL	30	21	10.5	2.2	15.5	42.5	4.2

Two weeks after polymer application rates, enough time for it to work in the soil, controlled irrigations were applied with distilled water, simulating a rainfall, with drip irrigation, applying for each type of soil a water layer corresponding to the pluviometric precipitation of the area where samples were collected.

After washing the soil samples they were taken out from the plastic boxes to reduce moisture, in order to separate the natural aggregates in their cleavage planes utilizing those that had passed through a 4.00 mm sieve and were retained in a 2.00 mm one.

The aggregates separated from each box, with their respective polymer rates, were air dried and put in plastic bags. After this, gravimetric moisture, aggregates weighed mean diameter (WMD) and the water dispersed clay percentage were calculated. From each type of soil, four bags with aggregates were separated, corresponding to each polymer rate, weighting 1.0 kg, where the same rates applied before were applied in the 30th day, diluted in irrigation water with 1.10 dS/m of electric conductivity, adjusting the aggregates moisture to 80% of field capacity. The plastic bags with humid aggregates were weighted and closed to keep the moisture uniform. Every 30 days, aggregate subsamples were taken from each bag to find the gravimetric moisture, WMD and the water dispersed clay, until 150 days after the evaluation. After removing the samples from the bags, they were weighted and the aggregate moisture corrected to be uniform during all experimental time.

The stable aggregate distribution in water and their weighed mean diameter (WMD) were determined with the technique described by Kemper & Chepel (1965), and the water dispersed clay percentage by the pipett method (Embrapa, 1979). It was used a split-plot design with four treatments (levels) and three replications for each determination, at the pre-established times.

The obtained results were analyzed by Duncan test at the level of 95% with the statistical package Statgraphics.

RESULTS AND DISCUSSION

The variation of aggregates weighed mean diameter (WMD) in soil R, after washed, related to the polymer and time, is shown in Figure 1. There is a great WMD reduction for all the treatments after the soil washing with distilled water simulating the rainfall (at 30 days) and a great increase of water dispersed clay percentage (Figure 2). The treatments with the highest levels showed the smallest reduction in structural stability, evidencing the polymer capacity to protect the soil aggregates against disintegration.

From the 30th day one, when the second polymer level was applied on the washed aggregates, the WMD began to increase and the water dispersed clay began to decrease in a different way in all treatments studied (Figures 1 and 2), showing its effect on structural stability increase. WMD and water dispersed clay values obtained in soil R were statistically analysed and are shown in Table 2.

The washed aggregate WMD in soil PL and the variation of water dispersed clay percentage, related to the polymer levels applied, are shown in Figures 3 and 4, respective-

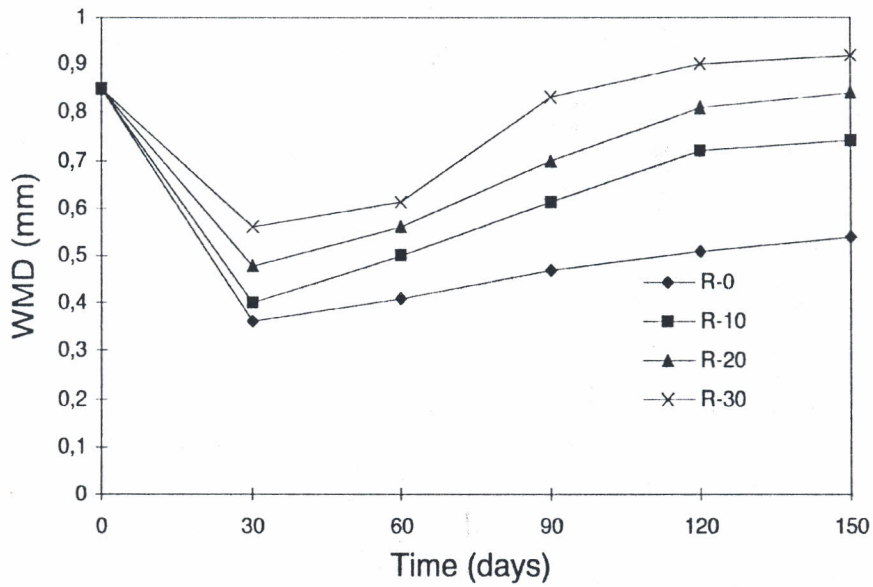


Fig. 1. WMD variation in soil R washed related to the polymer levels and time

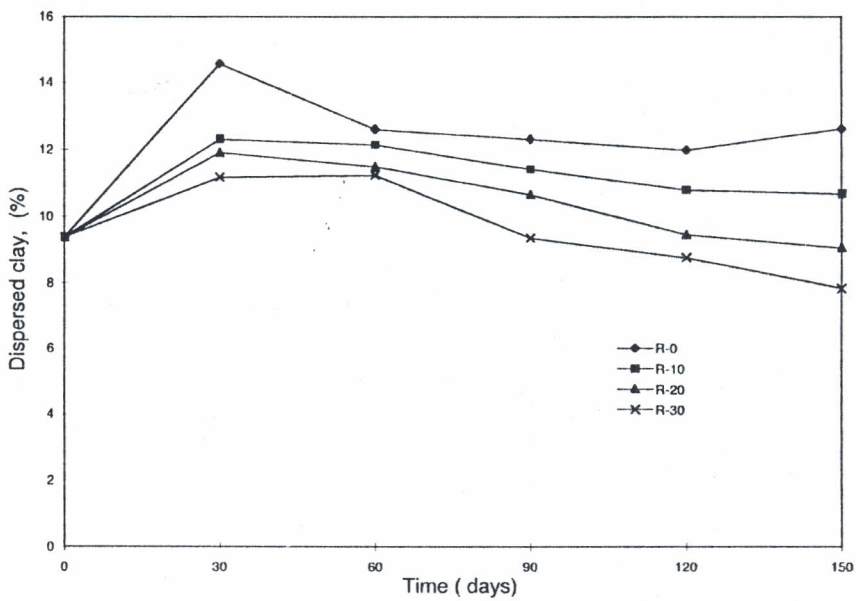


Fig. 2. Dispersed clay variation in soil R washed related to the polymer levels and time

ly. After washing the soil, a WMD reduction was observed, mainly in the control. Both treatments with the highest levels showed a lesser reduction in the aggregation level and in the water dispersed clay percentage. The average values for WMD and for water dispersed clay obtained in soil PL were statistically analysed and are shown in Table 2.

Table 2. Weighed mean diameter average of the aggregates and percentage of the water dispersed clay, related to the evaluated polymaleic levels

Levels ($L \cdot ha^{-1}$)	Soil R		Soil PL	
	WMD (mm)	Dispersed clay (%)	WMD (mm)	Dispersed clay (%)
0	0.46a	12.63 a	0.29a	9.61a
10	0.58 b	11.64 b	0.32 b	8.13 ab
20	0.68 bc	10.84 bc	0.33 b	7.86 b
30	0.76 c	9.63 c	0.36 c	7.09 c

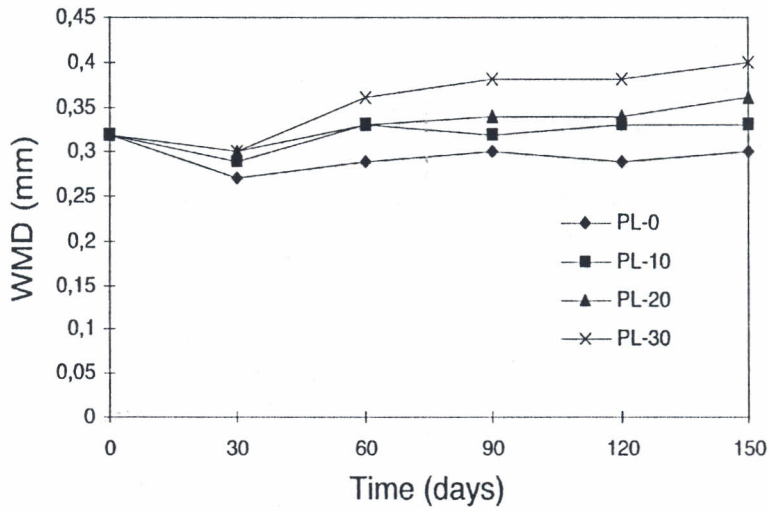


Fig. 3. WMD variation in soil PL washed related to the polymer levels and time

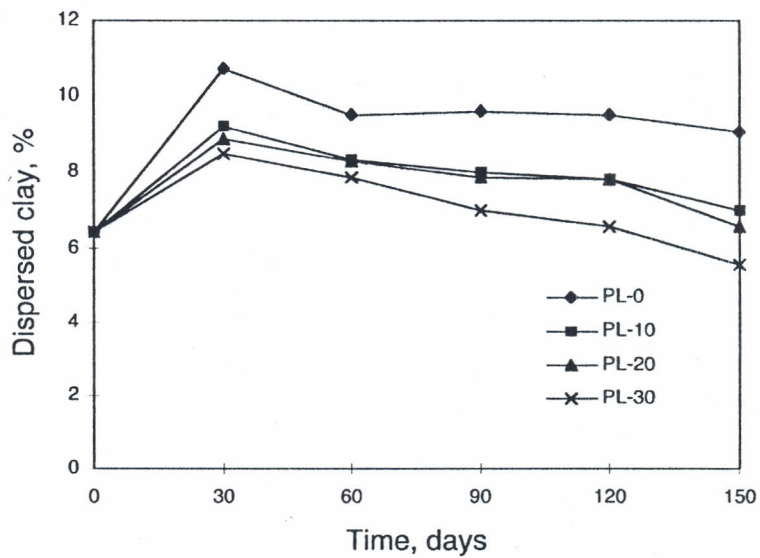


Fig. 4. Dispersed clay variation in soil PL washed related to the polymer levels and time

After the application of the second polymer level on soil washed aggregates in soil PL, the WMD began to increase and the water dispersed clay began to decrease in all the treatments (at 60 days). The highest levels showed the greatest WMD increase during all the observation times, while the treatments with the two intermediary levels overcame the initial WMD. The two lowest levels showed lesser effect than the first ones.

The WMD reduction and the increase in water dispersed clay observed after washing the two soil types may happen due to the decrease of the soil electrolytic concentration under the typical values, which caused the clay dispersion and aggregate resistance decrease. The most saline and sodic soils are very sensible to solutions with low electrolytic concentrations.

Shainberg et al. (1981) found that saline soil washing process with good water quality causes a decrease in the electrolytic concentration that stays under the soil flocculation value, causing clay dispersion and, as a consequence, decreases the aggregate stability.

McNeal et al. (1966) found that saline soils with high clay contents are more susceptible to dispersion than those with low contents. Comparing the results obtained in both soils studied, it was observed that soil R showed the highest reduction in the aggregate stability with all evaluated levels after the aggregate washing with distilled water, due to higher clay contents in its granulometrical composition, that might have caused a greater dispersion (Figure 2). For soil PL, the decrease in the aggregate stability was smaller than for soil R, due to its initial low WMD. Shainberg et al. (1981) found that the structure development degree depends on the type of particles that composes the soil and interacts, with high or low intensity, with the cementing agent, increasing the structural stability.

After the application of the second polymer level diluted in irrigation water, applied on the washed aggregates (at the 30th day), their stability began to increase in both soils. The mixture of the diluted polymer with water with an electrical conductivity of 1.10 dS/m increased the electrolytic concentration in the soil solution, probably by compressing the double diffuse layer due to the monovalent ions exchanged by the divalent ones, inducing the disperse clay flocculation by the soil washing with distilled water. Following clay dispersion, the flocculation process, the soil organic matter decomposition and the solution polymer conditioner effect have, probably, influenced the particles aggregation during the time, increasing the aggregate stabilization degree. Shainberg et al. (1992) found that aggregates become stable in long term with the incorporation of binding substances, which give them better resistance to clay dispersion. The presence of particles with superficial electrical charges allows to explain the existence of forces responsible for the interactions between the mineral particles, the soil and water components, the organic matter, and the polymer functional groups. The flocculation conditions are essential to form the aggregates, but it does not mean that they are stable. In a practical view, we have to consider the factors involved in the aggregate formation, and those that give them stability after their formation. The flocculation drying, humidification and root mechanics work on aggregate formation, while the organic matter, the polymers and the clay, when combined with the appropriate cations, work as cementing agents, increasing the aggregate stability (Ben-Hur & Karen, 1997).

The increased WMD in the control in both soil types, after washing, probably happened due to the presence of soil organic matter, which, when decomposed, formed humic substances, increasing the aggregation. The good moisture and temperature conditions could have induced the increase in soil organic matter decomposition in the first days, improving the aggregation stability.

The microbial activity, polysaccharides and polyuronides have the characteristic of forming small dimension chains, so the formed structures have short life.

According to organic molecular size, the organo-mineral complex will show different mobilities in the soil. With biological action and high bases content, the polymerization is built with big size molecules, forming insoluble and stable complexes, with important porous space between them (Dzhanpeisov et al., 1984).

As it is shown in Figures 1 and 3, we can see that the polymer made a great effect increasing the aggregate stability, showing high or low intensity according to soil type and the amount applied. Shainberg & Levy (1994) reported that polymers with high molecular weight can flocculate the dispersed clay and increase the aggregate stability in water. Even if the clay shows the same polymer charge (negative), the reactions between them and the anionic polymer include reactions between polyvalent cations, clay and polymer. The existing organic matter also shows a positive effect on the response of the polymers on the soil. Allison & Moore (1956) reported that the synthetic conditioners can improve the aggregated stability in sodic soils. Carr & Greenland (1975) reported that clay dispersion decreases as molecular weight of the polymer increases. The polymer chains dissolved in water penetrate inside the aggregate, giving them a better disintegration resistance. The slow movement of the high molecular weight polymer makes it be more adsorbed and, therefore, it is more efficient in reducing the clay dispersion. They also reported that the polymer is more efficient when applied in fractional levels, indicating that its working time influences the soil stabilization. Differently, Letey (1994) reported that the polymer penetrates little inside the aggregates and its main action is on the cementation, forming an external protective pellicle that increases its stability in water.

Hendrick & Mowry (1952) evaluated the effect of vinyl maleic acetate (CD-186) on the aggregate stability and concluded that there was an increase of 20% in nontreated soils, while in the ones treated with 0.02 and 0.1% solutions, the aggregate stability was 37 and 66.0%, respectively. They attributed the aggregate stability increase in the control to the organic matter in the soil. Nath & Nagar (1960) reported that krylium and maleic acid increased significantly the percentage of stable aggregate in water in three types of soils: a clayey (48% clay), lateritic (28% clay) and alluvial (18% clay), in this increasing efficiency order. The best solution levels were those between 0.05 and 0.1%, sprayed on soil surface.

The polymaleic acid action on soil conditions happens in humid conditions, where the polymer chains in presence of water break the maleic acid in individual molecules, which interact with calcium and magnesium salts, increasing their solubility. Furthermore, the polymer which shows a low pH, slightly acidifies the reactions, increasing the carbonates solubility (Allison, 1956). The polymer efficiency in improving the soil physical conditions can be evaluated in various ways, being the aggregates stability in water the most used index. The structural stability reflects the soil particle conformation, the

porous geometry between the aggregates, which, then, influences other properties like infiltration rate, hydraulic conductivity and soil erodibility.

CONCLUSIONS

Saline soils washed by rainfall reduce the stability of aggregates and increase the water dispersed clay percentage. For both soils studied, the highest polymer levels showed better efficiency in increasing the stability of aggregates and reduced the water dispersed clay. Finally, the polymaleic acid showed high efficiency in saline soils stabilization during the washing process.

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