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Note

Effect of some amendments on leachate properties of a calcareous saline-sodic soil

N. Yazdanpanah[1]*, *E. Pazira*[2], *A. Neshat*[3], *H. Naghavi*[4], *A.A. Moezi*[5], *and M. Mahmoodabadi*[6]

[1] Department of Soil Science, Science and Research Branch, Islamic Azad University, Khuzestan, Iran
[2] Department of Soil Science, Science and Research Branch, Islamic Azad University, Tehran, Iran
[3] Department of Water Engineering, Islamic Azad University, Kerman Branch, Kerman, Iran
[4] Kerman Agriculture and Natural Resources Research Centre, Kerman, Iran
[5] Department of Soil Science, Sahid Chamran University, Ahvaz, Iran
[6] Department of Soil Science, Shahid Bahonar University of Kerman, Kerman, Iran

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A b s t r a c t. The effect of some amendments for ameliorating a calcareous saline sodic soil was investigated using experimental columns. The amendment treatments were: control, manure, pistachio residue, gypsum, manure+gypsum and pistachio residue+ gypsum, applied once at the beginning of the experiment. After soil columns preparation, an intermittent irrigation method was employed. The results indicated that for the first leaching experiment, the salinity and sodicity values of leachate were high, while for subsequent irrigation steps they decreased, significantly. When gypsum was added in conjunction with organic amendments, greater amounts of Na were leached. The results of this study reveal that organic amendments have more ability in depleting deleterious salts from the soil than the mineral amendments. However, combination of organic and mineral amendments can improve their efficiency.

K e y w o r d s: soil, salinity, sodicity, leachate, organic amendment, gypsum

INTRODUCTION

Soil salinity and sodicity are escalating problems worldwide. Accumulation of dispersive cations such as Na^+ in soil solution and exchange phases affects the soil properties. The depressive influence that salinity and sodicity inflict on soil physical (Balashov *et al*., 2010), chemical (Adesodun and Odejimi, 2010), biological (Clark *et al*., 2007) properties and plant growth (Hamza and Anderson, 2003) has been reported. Reclamation of sodic soils involves replacement of exchangeable Na with Ca. The replaced Na is removed either below the root zone or out of the profile by leaching water. The typical source of Ca is an amendment that either contains soluble Ca or dissolves Ca upon reaction in the soil.

Gypsum (Amezketa *et al*., 2005) and organic matter (Wong *et al*., 2009) are some of the amendments which have been used. Gypsum is the most commonly used amendment for sodic soil reclamation and for reducing the harmful effects of high-sodium irrigation waters in agricultural areas because of its solubility, low cost, availability and ease of handling (Amezketa *et al*., 2005). Studies on the effect of gypsum application on saline-sodic soil reclamation have shown that the soil receiving gypsum at higher rate removes the greatest amount of Na^+ from the soil columns and causes a substantial decrease in soil electrical conductivity (EC) and sodium adsorption ratio (SAR) (Hamza and Anderson, 2003). It has been proved that some organic sources can be applied to reclaim salt and sodic affected soils. The addition of organic matter in conjunction with gypsum has been successful in reducing adverse soil properties associated with sodic soils. Addition of organic matter and gypsum to the surface soil will decrease spontaneous dispersion and EC down to the subsoil, compared to the addition of gypsum alone (Vance *et al*., 1998).

In Iran, focus has centred on dryland salinity and sodicity because 90% of the country is located in arid and semi-arid areas (Qureshi *et al*., 2007). However, little attention has been paid to the reclamation of saline-sodic soils using soil column under laboratory conditions. Also, few studies have assessed the combined effects of different amendments during the remediation process on leachate properties.

The aim of this study was to investigate the effect of different amendments for ameliorating a saline-sodic soil.

*Corresponding author's e-mail: najmeyazdanpanah@yahoo.com

MATERIALS AND METHODS

Soil used in the laboratory experiments was collected from the 0-30 cm layer of a calcareous saline-sodic soil, country-side of Kerman city, south-central Iran (56° 59' E and 30° 19' N). The soil sample was air-dried and then crushed to pass through a 2 mm sieve. Some physical and chemical properties of the soil were measured (Pansu and Gautheyrou, 2006), which are shown in Table 1. A laboratory experiment using soil column was conducted to evaluate the effect of different amendments on leachate properties. PVC cylinders with a 10 cm inner diameter were used to contain a 30 cm long soil column. Prior to filling the columns, a 5 cm layer of scrubbed gravel and sand as a filter was placed at the bottom of each column to facilitate leaching. Six treatments were prepared, consisting of control (*C*= untreated), cattle manure (*M*), pistachio residue (*P*), gypsum (*G* = equivalent of gypsum requirement), *M*+*G* and *P*+*G*, with three replications. Cattle manure and pistachio residue were chosen to represent animal and plant residues as organic amendment, both at 30 g kg^{-1}. In addition, gypsum as an inorganic material was used since it is available in the region. Some chemical properties of the organic amendments used in the study are listed in Table 2.

The soil samples were mixed thoroughly with the amendments and poured into the cylinders in 2 cm increments and stirred to prevent layering and to obtain a uniform soil column. The soils were maintained in a constant temperature environment at 25°C for the duration of the incubation. To reflect the natural conditions, an intermittent irrigation method was employed. That is, a 500 ml influent of the water treatment (EC =0.536 dS m^{-1}, SAR = 1.3 [meq $l^{-1}]^{0.5}$) was slowly added to the top of the column every 30 days. The experiment was conducted for a period of 120 days, thus totally four irrigation treatments were applied on each column. Following each irrigation application, the leachate samples were collected every day at the bottom of the soil columns and analyzed.

RESULTS AND DISCUSSION

Figure 1 shows the leachate EC for all applied treatments during four-month leaching experiments. For the first irrigation stage, the salinity of outflow appeared to be the highest, with the range of 47- 92 dS m^{-1}, while it decreased to the range of 4-20 dS m^{-1} for the fourth leaching experiment. It would be expected that probably, because of the leaching process of salts following irrigation, the EC has been decreased. According to Fig. 1, the control and gypsum treated soils exhibited the lowest salinity of the leachate. The lowest values of EC due to gypsum application are contrary to the observations of Clark *et al*. (2007) that an addition of gypsum with no irrigation water application resulted in high soil EC compared to control. In the present study, probably due to the considerable amount of $CaCO_3$ in the initial soil (Table 1), it would be expected that the solubility of gypsum has been limited which can be attributed to the common ion effect of Ca^{+2}.

It is also apparent from the results that *M*+*G* (manure+ gypsum) and *M* (manure) treatments nearly led to the most leaching of salts. It would be expected that following the application of cattle manure with considerable EC (Table 2) some salts have been added to the soil. Although, for the first leaching experiment pistachio residue resulted in the highest EC, since its salinity is slightly greater than the cattle manure. The increases in salinity with organic amendments application compared to the control are consistent with those reported by Hao and Chang (2003) using cattle manure.

T a b l e 1. Chemical properties of the initial soil used in the study prior to amendments application

EC_e (dS m^{-1})	pH_s	Cations (meq l^{-1})				SAR	Equivalent $CaCO_3$ (%)	SOC (%)
		Na^+	K^+	Ca^{+2}	Mg^{+2}			
19.8	7.8	264.5	4.2	37	98	32.2	20.7	0.49

SOC – soil organic carbon content.

T a b l e 2. Some chemical properties of organic amendments used in the study

Organic amendment	EC* (dS m^{-1})	pH*	Cations (total %)			
			Na	K	Ca	Mg
Cattle manure	8.62	7.69	1.22	2.45	2.40	0.92
Pistachio residue	10.85	8.05	0.19	6.70	2.87	0.58

*1 g in 10 ml water shaken for 1 h.

Furthermore, since salts are very mobile, the EC of soil and consequent leachate would be affected not only by amendment type, but also by the movement of water in the soil column (Hao and Chang, 2003). Because of downward leaching with irrigation, some of the salts apparently have been transported to the deeper sections or removed from the soil column. It appears that EC increased with the incorporation of organic materials in soils amended with gypsum. These increases in the leachate EC are most likely due to an increase of ions in solution, which may have resulted from mineral dissolution caused by the increase in PCO_2 (Flavel and Murphy, 2006) or the formation of organic acids (Wong *et al*., 2009). The H^+ ion of the organic acids displaces the cations from the exchange sites, reduces the cation exchange capacity, and increases the concentrations of these cations in the soil solution. Figure 2 shows changes of SAR in the leachate during the four-month experiments. Similar to EC, the sodicity of outflow for the first leaching experiment appeared to be the highest. Since the initial soil was saline sodic, high amounts of soluble Na^+ would be supplied for leaching in the first irrigation. Sodicity will decline if there is a ready source of favourable cations, particularly Ca^{+2}, to reduce the concentration of Na^+. Because of organic acids formation (Wong *et al*., 2009) due to organic amendments application, a higher amount of Ca^{+2} was supplied from the soil $CaCO_3$ source to the solution phase. Similar observations were found in sodicity reduction of alkaline subsoil with 20 t ha^{-1} of green shoots of common vetch (Harris and Rengasamy, 2004).

It is apparent from this study that the application of gypsum led to the lowest SAR values in the leachate. As described above, due to the common ion effect of Ca^{+2}, in the presence of $CaCO_3$ the solubility of gypsum would be limited. In contrast, when gypsum was added in conjunction

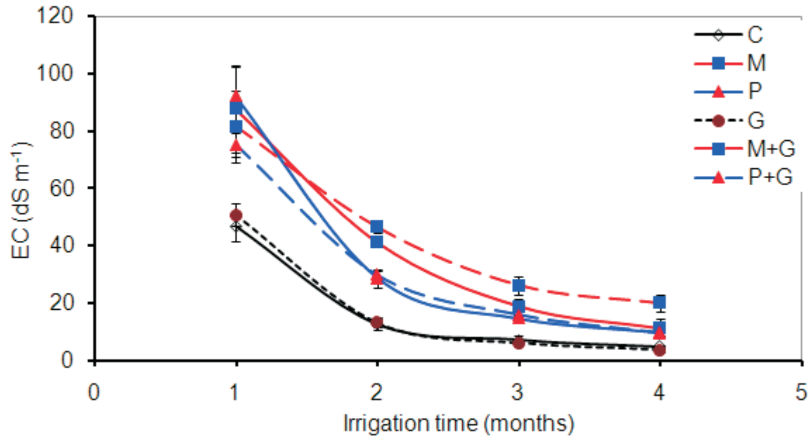

Fig. 1. Changes in the leachate EC during four-month leaching experiments for applied treatments.

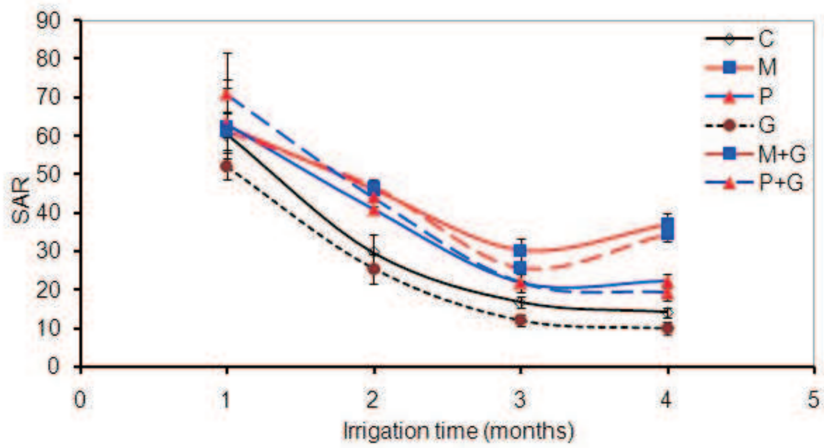

Fig. 2. Changes in the leachate SAR during four-month leaching experiments for applied treatments.

with organic amendments, higher amounts of SAR were displayed. This may be attributed to the relatively important role of organic matters which can improve soil properties. However, leachate characteristics depend on the properties of original soil and chemical composition of amendment. The findings of this study reveal that organic amendments have more capability in depleting salts from saline sodic soils than the mineral amendments. However, this may be accelerated by combination of both organic and mineral amendments.

CONCLUSIONS

1. For the first leaching experiment, the electrical conductivity and sodium adsorption ratio values of leachate were high while for the next irrigation steps they decreased significantly.

2. Due to the common ion effect of Ca^{+2}, in the presence of $CaCO_3$ the solubility of gypsum was limited. In contrast, when gypsum was added to the organic amendments, greater amounts of Na were leached.

3. Organic amendments have greater ability of depleting deleterious salts from a saline sodic soil than the mineral amendments. However, combination of organic and mineral amendments can improve their efficiency. Due to organic amendments application, a higher amount of Ca^{+2} was supplied from the soil $CaCO_3$ source to the solution phase.

4. Leachate characteristics depend not only on the properties of the original soil but also on the chemical composition of the applied amendment. Therefore, the chemical properties of the amendment must be considered.

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