Determination of the Effect of Gypsum and Irrigation Water in Reclamation of Sodic Soils in South Khartoum

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Abstract— The research was conducted during 2012 season at Jebal Awlia locality south of Khartoum to determine the effect of gypsum and irrigation water in reclamation of sodic soils. The variables compared were pH, sodium adsorption ratio and electrical conductivity. The results indicated that the pH of the soil decreases from the range (8.00 – 8.34) to the range (7.81 – 7.94), electrical conductivity (EC) decreases from the range (3.81 – 4.53) to the range (1.44 – 1.96) and sodium adsorption ratio decreases from the range (1.34 – 17.80) to the range (1.08 – 7.36) after the addition of gypsum and the process of washing by irrigation water.
The objective of this study was to evaluate the efficiency of gypsum applied in the irrigation water for the reclamation and improvement of saline-sodic and sodic soils in south Khartoum.

Keywords— gypsum, reclamation, sodium adsorption ratio, electrical conductivity.

I. Introduction

IRRIGATION is the most important practice to stabilize crop production in arid and semi-arid regions. However, the high evapotranspiration rates and low precipitation can increase salt concentration, resulting in soil salinization and alkalization, reducing soil productivity and threatening the sustainability of the agricultural system (Silveira *et al*., 2008).

Salinization is the increase of the total soluble salt in the root zone of a soil profile whereas; sodication or alkalization is the increase of exchangeable sodium percentage in the root zone of a soil profile. Both processes occur naturally but they may be accelerated by adverse human activities. Furthermore, the two processes may operate simultaneously and form saline sodic soils. The three types of soils occur in all continents and under almost all climatic conditions. However, their distribution is relatively more extensive in the arid and semi-arid regions (Mustafa, 2007).

Sodic and saline-sodic soil exhibit structural problems such as slaking, swelling, dispersion of clay and surface crusting, Such problems may impede water and air movement, decrease plant –available water, reduce nutrient availability, root penetration and seedling emergence and increase runoff and erosion potential (Suarez, 2001; Qadir and Schubert, 2002). Accumulation of salts in such agricultural soils alters its physic-chemical properties, including pH, exchangeable sodium, electrical conductivity, sodium adsorption ratio, hydraulic conductivity and soil available water (Al-Busaidi and kooksen, 2003).This problem manifests itself especially in arid and semiarid regions with poorly drained soils because of continual addition of salts with irrigation practices (Ayars and Tanji 1999).

Ameliorating saline sodic soils is of a great importance to render these degraded soils suitable for agriculture. The sodium hazard of soil usually is expressed as the sodium adsorption ration (SAR). This is the proportion of water soluble Na to Ca plus Mg in the soil. The formula used to calculate SAR is shown in Figure 1.

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Fig.1 Formula for calculate SAR (sodium adsorption ration).

The SAR is determined from a water extract of a saturated soil paste. SAR value below 13 is desirable. If the SAR is above 13, sodium can cause soil structure deterioration and water infiltration problems (Davis *et al*., 2003).

Leaching has been shown to be the most effective method for removal of soluble salts from the Rhizosphere (Abrol *et al.* 1988). The high quality fresh water is intensely irrigated onto the soil surface and allowed to flush the soluble salts down as it infiltrates, and is usually incorporated with an effective drainage system. On the other hand, removal of exchangeable sodium necessitates application of chemical amendments to remove the sodium from the soil's cation exchange sites (Sahin *et al.* 2003).

Gypsum is the most common material used to splay calcium for sodic soil reclamation because it is calcium-rich, dissolves at high pH, and does not contain elements or compounds that might interfere with reclamation and the sulfate in gypsum is not likely to be a problem for crops (Horneck *et al*, 2007).

Gypsum provides a source of calcium (Ca^{2+}) to replace excessive Na^+ from the cation exchange sites. The replaced Na^+ is either leached from the root zone by excess irrigation, and/or taken up by crops (Qadir and Oster, 2002).

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Gypsum can help break up compacted soil, especially when combined with deep tillage to break up the compaction. Also, gypsum increases water-use efficiency of crops by improve water infiltration rates, improve hydraulic conductivity of soil, better water storage in the soil all lead to deeper rooting and better water-use efficiency (Shainberg *et al.*, 1989).

Some studies have shown that the use of gypsum on saline-sodic and sodic soils improves most of the properties including the infiltration rate and helps in leaching the salts into the lower layer. Addition of gypsum at different rates to salinity sodic soils then leaching by irrigation water lead to increase sodium, chloride, zinc and manganese concentration in leached water and decrease in soil salinity, soil pH, dissolved and exchangeable sodium and dissolved chloride with increase in gypsum rate (Sahin *et al*., 2003; Makoi and Ndakidemi, 2007).

II. MATERIALS AND METHOD

The experiment was conducted at Jebal Awlia locality, south Khartoum, latitude 15°N and longitude 32°E, during 2012 season. Average temperature was 29.9C°. Soil samples were taken before and after addition of gypsum and leaching by irrigation water to the laboratory in a plastic tray for air-drying, then crushed and sieved in 2mm sieve.

The pH of the soil was potentiometrically measured in the supernatant of a 1:2.5 soil: liquid mixture. The apparatus used was pH meter with glass-calomel electrode with buffer solutions, pH 4.00, 7.00 and 9.00.

Electrical conductivity was measured in the saturation extract using a conductivity bridge Model 4460 mentioned by Hach (1962).

Sodium adsorption ratio (SAR) was determined by first extracting the ions from the soil into solution then analyzed to determine concentrations of the selected ions. Na^+, Ca^{2+}, and Mg^{2+} concentrations were commonly determined using atomic absorption spectrometry (AA).

III. Results And Discussion

Table (1) shows that soil pH before and after addition of gypsum and leaching by irrigation water. A significantly affected ($P \leq 0.01$) was found in which, pH values were significantly higher before addition of gypsum and leaching by irrigation water than after addition of gypsum and leaching by irrigation water. This result agreed with Sahin *et al*., 2003; Makoi and Ndakidemi, (2007) who mention that, addition of gypsum at different rates to salinity sodic soils then leaching by irrigation water lead to increase sodium, chloride, zinc and manganese concentration in leached water and decrease in soil salinity, soil pH, dissolved and exchangeable sodium and dissolved chloride with increase in gypsum rate.

Table (2) shows that the soil (EC) before and after addition of gypsum and leaching by irrigation water. A significant affected ($P \leq 0.01$) was found in which, (EC) values were significantly higher before addition of gypsum and leaching by irrigation water than after addition of gypsum and leaching by irrigation water. This reduction in (EC) may be due to leaching of salts by water down the soil profile as the leaching fraction decreased as mention above by Ayers and Tanji (1999). He continues that, there are no amendments that can directly control soil salinity; some amendments can improve soil drainage, and indirectly help control soil salinity by improving conditions for leaching salts. Maintaining soil drainage and providing good irrigation management are the factors under the grower's control that can help control soil salinity.

Table (3) shows that the soil Ca, Mg, Na and SAR before and after addition of gypsum and leaching by irrigation water. As for Ca, a significant affected ($P \leq 0.01$) was found in which, Ca values were significantly increased after addition of gypsum and leaching by irrigation water. This increase in Ca may be due to the effect of gypsum in splay calcium for sodic soil reclamation as mentioned by Horneck *et al.*, (2007). While for Mg, no significant difference was found in values before and after addition of gypsum and leaching by irrigation water. Na showed a significant affected ($P \leq 0.01$) in which a reduction in Na values were found after the addition of gypsum and leaching by irrigation water, this reduction is the result of substitute of Na by Ca after the addition of gypsum and this result also agreed with Horneck *et al*., (2007) mention above.

TABLE I
COMPARISON BETWEEN PH BEFORE AND AFTER ADDITION OF GYPSUM AND LEACHING BY WATER

Sample	pH	
	Before	After
1	8.01	7.86
2	8.00	7.94
3	8.02	7.91
4	8.02	7.92
5	8.05	7.83
6	8.07	7.83
7	8.17	7.82
8	8.20	7.81
9	8.23	7.88
10	8.30	7.85
11	8.32	7.83
12	8.34	7.85
Average	8.14	7.86

TABLE II.
COMPARISON BETWEEN SOIL (EC) ***(DS/M)*** BEFORE AND AFTER ADDITION OF GYPSUM AND LEACHING BY WATER

Sample	EC	
	Before	
1	3.81	1
2	**3.84**	2
3	**3.87**	3
4	4.45	4
5	4.47	5
6	**4.49**	6
7	**4.49**	7
8	4.50	8
9	4.51	9
10	4.43	10
11	4.48	11
12	**4.53**	12
Average	4.32	Average

TABLE III
COMPARISON BETWEEN SOIL CA, MG, NA AND SAR BEFORE AND AFTER ADDITION OF GYPSUM AND LEACHING BY IRRIGATION WATER

Sam	Ca		Mg		Na		SAR	
	Bef	Aft	Bef	Aft	Bef	Aft	Bef	Aft
1	2.8	3.0	1.2	0.8	2.40	3.50	1.70	2.53
2	1.7	2.9	1.3	1.9	7.60	6.30	6.21	4.07
3	1.5	4.8	1.5	2.9	10.90	8.37	8.90	4.27
4	2.7	6.7	1.3	2.5	1.90	2.40	1.34	1.12
5	5.0	5.3	3.0	2.3	25.70	3.70	12.83	1.91
6	6.5	5.0	3.5	1.5	39.80	13.30	17.80	7.36
7	3.1	3.9	1.9	1.7	3.40	1.80	2.15	1.08
8	2.2	3.0	1.8	1.8	5.60	3.20	3.96	2.07
9	2.0	3.7	2.0	2.1	4.20	4.80	2.97	2.83
10	2.4	2.5	1.6	0.6	6.20	2.00	3.92	1.61
11	2.9	3.1	2.1	1.3	3.80	3.60	2.19	2.42
12	3.2	3.4	2.8	1.0	3.90	5.43	2.26	3.66
Av	3.0	3.9	2.0	1.7	9.62	4.87	5.52	2.91

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