

ORIGINAL ARTICLES

The Effect of Irrigation Water Quantities and Tillage Treatments in Leaching Salts in Salt-affected Soils.

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ABSTRACT

This study was conducted during 2009 and 2010 summer seasons at the Faculty of Agricultural Technology and Fish Science Farm, University of Neelain (Jebel Awlia area) south of Khartoum to investigate the effect of different amounts of irrigation water and tillage treatments on salt leaching in the root zone. The water quantities used to leach the salts were crop water requirement (CWR) + 10% or 20% of the crop water requirement as a leaching fraction (L.F). Four tillage treatments namely, disc plow, chisel plow, disc harrow and zero tillage were used. The variables compared were pH, sodium adsorption ratio, electrical conductivity and calcium carbonate percentage. The results showed that CWR + 20% L.F. gave a higher leaching than CWR + 10% L.F. Whereas, chisel plow had the superiority in leaching of salts followed by disc plow then disc harrow and last zero tillage. The best leaching resulted when CWR + 20% L.F. was used in combination with chisel plowing. Also the results showed that salts were leached from the upper soil layer to the lower ones during the two seasons.

Key words: Crop water requirement, tillage, leaching fraction, electrical conductivity, sodium adsorption ratio.

Introduction

In the case of salty affected soils, to prevent excessive salt accumulation in the root zone, it is necessary to remove salts periodically by application of water in excess of the consumptive use of the crop. The excess water applied will remove salts from the root zone provided that the soil has adequate internal drainage. This concept (Richards, 1954) is quantified by the term 'leaching requirement' often referred to by the abbreviation, LR. By definition, leaching requirement (LR) is the fraction of total water applied that must drain below the root zone to restrict salinity to a specified level according to the level of tolerance of the crop (USSL Staff, 1954).

Salinity becomes a problem when enough salts accumulate in the root zone to negatively affect plant growth (Maziah *et al.*, 2009; Sadeghi 2009; Homayoun 2011; Mahmoodabad *et al.*, 2011; Rahimi and Biglarifard, 2011). Excess salts in the root zone hinder plant roots from withdrawing water from the surrounding soil. This lowers the amount of water available to the plant, regardless of the amount of water actually in the root zone (Akhtar, 2003).

Results from several laboratory experiments (Cardon *et al.*, 2000) and some field trials (Ahmed and Ahmed 2007) have shown that the quantity of salts removed per unit quantity of water leached can be increased appreciably by leaching at soil moisture contents of less than saturation, i.e. under unsaturated conditions. In the field unsaturated conditions during leaching were obtained by adopting intermittent ponding or by intermittent sprinkling at rates less than the infiltration rate of the soil. Leaching of salts from the root zone layer by excessive water percolating beneath the root zone remains the main practice to manage crop growth under salinity conditions (Schleiff, 2006).

Rhoades *et al* (1974) proposed the following relationship for determining the leaching requirement (LR) which is also known as leaching fraction (LF):

$$LF = \frac{ECi}{5ECe - ECi} \quad (1)$$

In which:

LF: leaching fraction

ECi : electrical conductivity of irrigation water

ECe: electrical conductivity of the saturated soil extract

Gobinathan *et al.*, (2009) reviewed the water extraction patterns with depth from several experiments and concluded that water is initially extracted from the regions nearest to the surface where the roots are more prolific with the zone of extraction progressing downward in the profile as the water becomes limiting in the upper zones. Application of excess water, above that needed for meeting the evapotranspiration needs, though useful for salinity control, puts a high demand on the water resources on one hand and increases the salt load of the drainage water on the other. Studies by Bernstein and Francois (1973) have shown that reducing the leaching fraction has only a small effect on the salinity of the upper root zone since this area is adequately leached during irrigation. As a result of these and other studies (Rhoades *et al.*, 1973), it is suggested that the leaching fraction can be reduced from the values suggested by earlier methods and adequate crop yields can still be obtained. There for the objectives of this study were to determine the optimum quantity of irrigation water with the appropriate tillage practice which leach soil salts and the rate of leaching of salts with successive seasons at different soil depths.

Methodology:

The experiment was conducted at Jebal Awlia area, Khartoum state - Sudan. Latitude 15°N, longitude 32°E during 2009 and 2010 Summer seasons. Average temperature was 29.9°C for the two seasons. The treatments were compared in complete randomized block design replicated three times. The quantities of water applied were crop water requirement +10% or 20% of the crop water requirement as leaching fractions. Soil samples were augured from each plot at three depths, 0 – 30, 30 – 60 and 60 -90cm before sowing and after harvesting. Samples were taken to the laboratory in a plastic tray for air-drying. 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⁺, Ca²⁺, and Mg²⁺ concentrations were commonly determined using atomic absorption spectrometry (AA). Percent calcium carbonate (CaCO₃%) was measured using acid neutralization method cited by Page *et al.*, (1982). The samples were treated with dilute acid and the residual acid (not consumed by carbonate) was titrated.

Results and discussion

Tables 1.a, 1.b and 1.c show the effect of soil depths, irrigation water quantities, tillage treatments and their interactions on soil pH during 2009 and 2010 seasons. Effect of soil depths and water quantities showed no significant difference during the two seasons. Whereas, tillage had a significant effect ($P \leq 0.01$) on soil pH during 2009 season. Zero tillage and disc plow gave higher significant values than chisel plow and disc harrow. But no significant difference was found between the four tillage treatments during 2010 season. Interaction between soil depths, water quantities and tillage treatments on pH level showed no significant difference during 2009 and 2010 seasons.

Tillage influences soil pH by affecting stratification of organic matter in the surface layers, leaching of cation to lower layers as mentioned by Unger (1991). Rasmussen *et al.*, (1972) stated that the success of deep plowing depends on the mixing of low-clay calcareous or gypsiferous subsoil material with high-clay, B-horizon material to provide a more favorable physical matrix for soil water movement.

Tables 2.a, 2.b and 2.c show the effect of soil depths, irrigation water quantities, tillage treatments and their interactions on soil sodium adsorption ratio (SAR) during 2009 and 2010 seasons. Soil depths showed no significant effect on soil SAR during 2009 season. Conversely a highly significant effect was found during 2010 season, in which depths 30 – 60 and 60 – 90cm gave higher SAR values than 0 – 30cm depth.

Table 1: Effect of soil depths, irrigation water quantities and tillage treatments on soil pH for 2009 and 2010 seasons. A – soil depths

Soil depths (cm)	pH season 2009	pH season 2010
0 - 30 (D1)	8.81a	9.32a
30 - 60 (D2)	8.88a	9.28a
60 - 90 (D3)	8.86a	9.24a
S.E ±	0.03	0.03

B – Irrigation Water Quantities.

Irrigation water amount	pH season 2009	pH season 2010
CWR + 10% L.F.	8.83	9.30
CWR + 20% L.F.	8.87	9.26
S.E ±	0.021	0.030

C – Tillage Treatments.

Tillage treatment	pH season 2009	pH season 2010
Zero tillage (T0)	8.90a	9.29a
Disc plow (T1)	8.90a	9.19a
Chisel plow (T2)	8.87b	9.32a
Harrow (T3)	8.74c	9.31a
S.E±	0.030	0.04

Means in the same column with similar letters are not significantly different at $P \leq 0.05$ according to DNMRT.

Table 2: Effect of soil depths, irrigation water quantities and tillage treatments on soil sodium adsorption ratio for 2009 and 2010 seasons. A - depths

Soil depths (cm)	SAR season 2009	SAR season 2010
0 - 30 (D1)	2.60a	2.12b
30 - 60 (D2)	3.31a	2.96a
60 - 90 (D3)	3.54a	2.96a
S.E ±	0.58	0.1

B – Irrigation Water Amount.

Irrigation water amount	SAR season 2009	SAR season 2010
CWR + 10% L.F.	2.48a	2.22
CWR + 20% L.F.	3.82a	3.14
S.E ±	0.47	0.08

C – Tillage Treatments.

Tillage treatment	SAR season 2009	SAR season 2010
Zero tillage (T0)	3.44a	3.97a
Disc plow (T1)	2.90a	3.97a
Chisel plow (T2)	3.14a	3.93a
Harrow (T3)	3.12a	3.98a
S.E±	0.670	0.11

Means in the same column with similar letters are not significantly different at $P \leq 0.05$ according to DNMRT.

Table 3: Effect of soil depths and tillage's on soil electrical conductivity during 2009 and 2010 seasons. A - Depths.

Soil depths	ECe season 2009	ECe season 2010
0 - 30 (D1)	0.88b	2.03a
30 - 60 (D2)	1.09ab	2.16a
60 - 90 (D3)	1.19a	2.26a
S.E ±	0.02	0.12

B – Irrigation Water Amount.

Irrigation water amount	ECe 2 season 009	ECe season 2010
CWR + 10% L.F.	1.04a	2.17a
CWR + 20% L.F.	1.06a	2.13a
S.E ±	0.066	0.090

C – Tillage Treatments.

Tillage treatments	ECe season 2009	ECe season 2010
Zero tillage (T0)	1.08a	2.114a
Disc plow (T1)	1.02a	2.264a
Chisel plow (T2)	1.05a	2.108a
Harrow (T3)	1.05a	2.109a
S.E±	0.093	0.13

Means in the same column with similar letters are not significantly different at $P \leq 0.05$ according to DNMRT.

This result indicated that irrigation water leached salts from the upper layer to the lower ones as mentioned by Gobinathan *et al.*, (2009) who reviewed the water extraction patterns with depth from several experiments and concluded that water is initially extracted from the regions nearest to the surface where the roots are more prolific with the zone of extraction progressing downward in the profile as the water becomes limiting in the upper zones.

Table 4: Effect of Soil Depths and Tillage's on Soil Calcium Carbonate Percentage During 2009 and 2010 Seasons. A – Soil depths

Soil depths	CaCO ₃ % season 2009	CaCO ₃ season 2010
0 - 30 (D1)	6.57a	4.84b
30 - 60 (D2)	6.65a	5.13a
60 - 90 (D3)	6.48a	5.29a
S.E ±	0.15	0.08

B – Irrigation Water Amount.

Irrigation water amount	CaCO ₃ % season 2009	CaCO ₃ % season 2010
CWR + 10% L.F.	6.80a	5.04a
CWR + 20% L.F.	6.34b	5.14a
S.E ±	0.12	0.07

C – Tillage Treatments.

Tillage treatments	Ca season 2009	ECe season 2010
Zero tillage (T0)	6.71a	6.87ab
Disc plow (T1)	6.60a	6.81b
Chisel plow (T2)	6.50a	7.12a
Harrow (T3)	6.48a	7.10a
S.E± 0.180	0.10	

Means in the same column with similar letters are not significantly different at $P \leq 0.05$ according to DNMRT.

Effect of irrigation water amount on soil SAR had no significant effect during 2009 season. While a significant effect ($P \leq 0.05$) was found during 2010 season in which crop water requirement+20% leaching fraction gave a higher SAR value than crop water requirement + 10% leaching fraction. This result agreed with the results obtained by Bernstein and Francois (1973) who showed that reducing the leaching fraction has only a small effect on the salinity of the upper root zone since this area is adequately leached during irrigation. As for the effect of tillage treatments on SAR level, analysis of variance showed no significant effect due to tillage treatments during both seasons of the study. Interaction between soil depths, water amounts and tillage treatments on SAR level gave a highly significant difference for interaction between water quantities and tillage treatments, water quantities and depths and tillage treatments and depths. Whereas, interaction between the three variables gave a significant difference ($P \leq 0.05$), in which, interaction between crop water requirement+20% leaching fraction, disc harrow and 30 – 60cm depth showed a higher SAR value over the others.

Tables 3.a, 3.b and 3.c show the effect of soil depths, irrigation water quantities, tillage treatments and their interactions on soil electrical conductivity (ECe) during 2009 and 2010 seasons. Effect of soil depths on soil ECe was significant ($P \leq 0.05$) during 2009 season in which, 60 – 90cm depth showed a higher significant value over 0 – 30cm depth but no significant difference between 60 – 90 and 30 – 60cm and between 30 – 60 and 0 – 30cm depths. No significant difference was found during 2010 season in ECe values between the three depths. This result indicated that salts were leached from the upper layer to the lower ones as mentioned by Ayers and Westcot (1994). They reported that the EC increased with depth and the EC increased at a given soil depth as the leaching fraction decreased.

Tables 4.a, 4.b and 4.c show the effect of soil depths, irrigation water quantities and tillage treatments on soil calcium carbonate during 2009 and 2010 seasons. Soil depths showed no significant effect on soil CaCO₃ during 2009 season. Highly significant effect ($P \leq 0.01$) was found during 2010 season in which depths 30 – 60 and 60 – 90cm gave higher values than 0 – 30cm depth.

Irrigation water quantities had a significant effect on CaCO₃ ($P \leq 0.05$) during 2009 season in which CWR +10% L.F gave higher values than CWR +20% L.F., but no significant effect was found due to applying different water quantities during 2010 season. This may be due to the fact that more water leaches more salt. Tillage treatments showed a significant effect on soil CaCO₃ during 2009 season. As for 2010 season there was a significant effect ($P \leq 0.05$), in which chisel plow and disc harrow gave higher significant values than disc plow. As for the effect of the interactions between soil depths, water quantities and tillage treatments, there was no significant difference in CaCO₃ levels during 2009 and 2010 seasons.

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