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Effects of Irrigation Water Salinity and Leaching on Soil Chemical Properties in an Arid Region

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ABSTRACT

An experiment was conducted to determine the effects of irrigation water salinity and different levels of leaching on some soil chemical properties such as salinity, acidity, sodium adsorption ratio and soil water holding capacity using silty clay, loam soil and a typical soils with three irrigation water salinities (4, 9 and 12 dS m^{-1}) and four leaching levels (0, 17, 29 and 37%). The results showed that as the irrigation water salinity increased the soil salinity and soil sodium adsorption ratio increased and the effects were greater for the top as compared to the lower layer soil. The increase in irrigation water salinity had no effect on the soil acidity, but it decreased the water holding capacity. With increase in leaching level, the damages due to increased irrigation water salinity decreased significantly but the soil acidity increased. The increase in irrigation water salinity decreased the leaching efficiency of soils.

Key Words: Irrigation water salinity; Leaching; Soil salinity; Arid region

INTRODUCTION

Soil salinity is a major environmental factor limiting the productivity of agricultural lands. Soil salinity causes land degradation and affects food production (Sharma & Rao, 1998). This problem is not only reducing the agricultural productivity, but is also putting far reaching impacts on the livelihood strategies of small farmers (Tanwir *et al.*, 2003). During the last 3 - 4 decades due to increased demand for food, the use of irrigation has increased by about 300%. Due to scarcity of surface water resources especially in arid and semi-arid region for supplying irrigation water for agricultural lands, the excessive discharge of the ground water with low quality has occurred, which has imposed a further increase in soil salinization (Poustini & Siosemardeh, 2004).

It is estimated that up to 20% of irrigated lands in the world are affected somehow by different levels of salinity and sodium content. In Iran about 15% of lands, that is about 25 million ha, are suffering from this problem, including 0.32 million hectare of lands in Isfahan province (Feizi, 1993). Overcoming soil salinity and sodicity in arid and semi-arid regions can be achieved by managing water resources, cultivating salt tolerant plants and using leaching with appropriate drainage system. The quality and quantity of water needed to leach soluble salts is an important factor governing reclamation of saline soils. Several researchers believe that appropriate leaching level is related to salinity of drainage water (Hoffman *et al.*, 1979). Researchers found that the best estimation for leaching level for soil desalinization can be made based on soil depth and if the ratio of leaching to soil depth becomes 1, eventually 87% of salts will be discharged from the soil and this occurs when the water used for leaching has a low salinity (Khosla *et al.*, 1979). Several studies report that the first leaching is most effective to soil desalinization as compared to the other leaching and using the same level of leaching for long period; soil salinity will continue to rise (Feizi, 1993; El-Sayed *et al.*, 2001).

The Roudasht region is located in southeast of Isfahan city, central part of Iran, with about 50000 ha of salt affected soils. Because of high evapotranspiration demand, low annual rainfall, limitation of fresh river water and use of saline underground and drainage water for irrigation, the soils have lost their productivity due to salinity problems.in Roudasht region. Considering the fact that leaching is the most effective and practical method for improvement of saline sodic soils, this study was undertaken to: a) determine the effect of different irrigation water salinities and leaching levels on some soil chemical properties and b) compare the changes in soil chemical properties at the end and beginning of a growing season in order to have better strategies for irrigating arid region soils.

MATERIALS AND METHODS

To achieve the objectives of the study, a typical soil of Roudasht region, silty clay loam texture, was used to conduct the experiment in a greenhouse. The physico-chemical properties of soil under study are given in Table I. Eighty four plastic pots each with depth of 0.4 m and diameter of 0.3 m having a hole at the bottom for drainage were used. Bottom of each pot was covered with 5 cm course gravel to act as filter. The soil bulk density in each pot was 1.34 g cm^{-3}, which was similar to the bulk density of soil of Roudasht area. The spring wheat (*Triticum aestivum* L.) was planted in each pot. Three irrigation water salinity of 4, 9 and 12 dS m^{-1} as the main treatments and four leaching of 0, 17, 29 and 37% as secondary treatments were used in a factorial statistical design with 7 replications for each treatment. The irrigation was based on the reduction in pot weight. All pots were weighted at field capacity and moisture content of soil. Irrigations were started at soil moisture deficit of 50% (Alizadeh, 2001). Ten irrigations were applied during the cropping season. Soil samples from each pot were collected at different stages of crop growth, from two soil depths of 0 - 15 and 15 - 30 cm. Soil samples were analyzed to determine the saturated soil paste pH (pH_s), saturation paste extract EC (EC_e), Ca^{2+} + Mg^{2+}, CO_3^{2-}, HCO_3^-, Cl^- and Na^+ using standard methods. The SAR and ESP of the samples were also calculated. The above parameters were determined at the beginning, middle and end of the growing season. The data were statistically analyzed and means were compared using LSD test.

RESULT AND DISCUSSION

Effects on soil saturation paste extract. Table II and III present the effects of different irrigation water salinities and leaching levels on some chemical properties of soil. As the irrigation water salinity increased or leaching levels decreased the salinity of saturation paste extract increased. Irrigation water salinity of 12 dS m^{-1} had caused greatest soil salinity at the end of season and irrigation water salinities of 9 and 4 dS m^{-1} decreased soil salinity 34 and 68%, respectively (Table II). As leaching level increased, more salt leached from soil. At the end of growing season the highest salt accumulation in the soil profile belonged to 0% leaching. Leaching levels of 17, 29 and 37% decreased soil salinities 38, 55 and 65%, respectively as compared with the 0% leaching (Table III). Leaching for salt removal can be useful up to a certain leaching level and after that the increase of leaching level does not affect the soil salinity or salt removal from soil (Hoffman et al., 1979). Salinity in soil profile indicated that in all treatments, the salinity of top layer soil (0 - 15 cm) was greater than the salinity of lower layer soil (15 - 30 cm) (Fig. 1 & 2). Effects of irrigation water salinity and leaching level were significantly higher for top layer soil as compared to the lower layer soil. The highest difference between salinity of top layer soil and lower layer soil occurred at irrigation water salinity of 12 dS m^{-1} and leaching level of 0%. The comparison of soil salinities at the beginning, middle and end of season indicate that a single leaching level is not

Table I. Physical and chemical characteristics of soil

(A) Physical characteristics

Sand (%)	Silt (%)	Clay (%)	Gepsum (mgr/100 gr soil)	Lime (%)	Bulk density (gr/cm^3)
7	52.9	40.1	10	38	1.34

(B) Chemical characteristics

EC dS/m	PH	Na meq/lit	Ca+Mg meq/lit	Cl meq/lit	CEC	EXCH Na	HCO_3 meq/lit	SAR	ESP
13.2	7.22	96	72	100	18.5	4	2.2	11.31	13.4

Table II. Comparison of soil characteristics influenced by irrigation water salinity

	Middle of season			End of season		
Salinity (dS/m)	4	9	12	4	9	12
EC (0-15)	11.25 c	20.4 b	25.58 a	10.47 c	21.39 b	32.5 a
EC (15-30)	7.3 c	9.92 b	11.93 a	6.46 c	9.81 b	11.95 a
PH (0-15)	7.24 b	7.36 a	7.41a	7.47 a	7.4 a	7.46 a
PH (15-30)	7.4 b	7.46 a	7.48 a	7.53 a	7.48 a	7.52 a
SAR (0-15)	10.77 c	17.61 b	23.7 a	10.84 a	18.68 b	28.09 a
SAR (15-30)	9 c	10.16 b	11.7 a	8.06 c	11.21 b	13.5 a

Table III. Comparison of soil characteristics influenced by leaching fraction

	Middle of season				End of season			
Leaching (%) Soil parameters	0	17	29	37	0	17	29	37
EC (0-15)	29.46 a	20.05 b	14.68 c	11.92 d	35.73 a	21.8 b	15.76 c	12.54 d
EC (15-30)	11.47 a	9.81 b	9.25 c	8.31 d	11.93 a	9.93 b	8.66 c	7.11 d
PH (0-15)	7.22 b	7.34 a	7.35 a	7.43 a	7.31 c	7.43 b	7.49 ab	7.54 a
PH (15-30)	7.35 b	7.43 a	7.48 a	7.5 a	7.42 b	7.5 ab	7.5 ab	7.59 a
SAR (0-15)	22.44 a	18.32 b	15.85 c	12.83 d	25.33a	19.97 b	16.41 c	15.12 c
SAR (15-30)	9.96 b	10.24 ab	10.43 a	10.52 a	12.05 a	11.35 ab	10.7 b	9.59 c

Fig. 1. Effect of irrigation water salinity on soil salinity

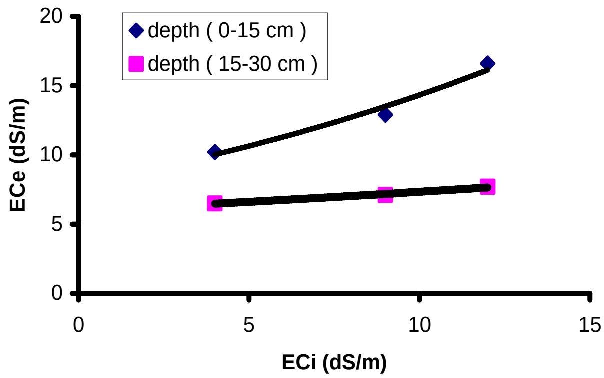


Fig. 2. Effect of leaching on soil salinity

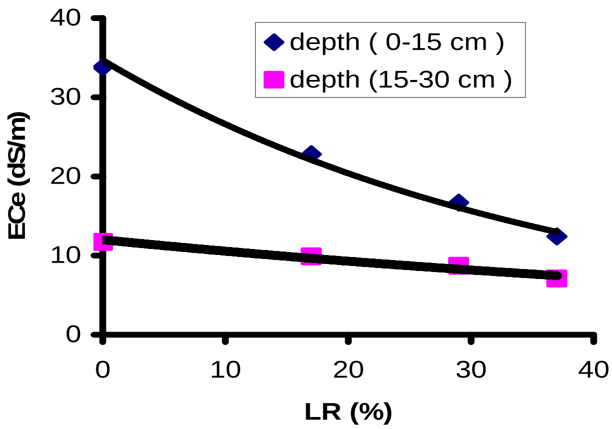
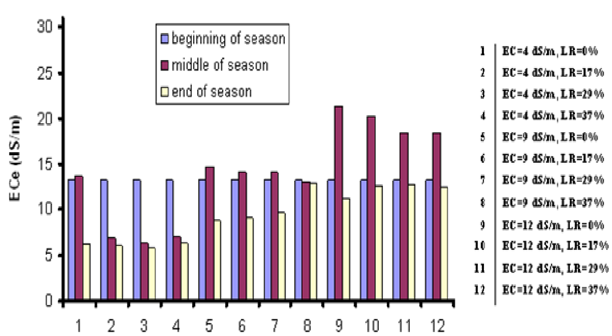


Fig. 3. Effect of irrigation water salinity on soil salinity for beginning, middle and end of season



sufficient for desalinization of a saline soil and the quality of leaching has an important role in salt removal from soil. Comparison of different treatments indicated that leaching with irrigation water salinity of 4 dS m^{-1} was able to decrease soil salinity at the end of season as compared to the beginning of the growing season (Fig. 3). Leaching level of 37% and irrigation water salinity of 4 dS m^{-1}, reducing initial soil salinity up to 56%, was the best treatment. Leaching level of 0% and irrigation water salinity of 12 dS m^{-1} was the worst treatment. Irrigation with salinity of 9 dS m^{-1} and leaching level of 37% caused no salt accumulation and, therefore, can be used as an option for irrigation.

Effects on soil acidity. Water salinity had no significant effect on soil acidity (Table II). The increase in leaching level increases soil acidity at both soil depths of 0 - 15 and 15 - 30 cm and this effect was more significant on soil depth of 0 - 15 cm at the end of season (Table III). Results for the end of growing season indicated that leaching level of 37% for soil depth of 15 - 30 cm caused the greatest soil acidity. Soil acidity increased in the soil profile, but the difference between soil acidity of two soil layers was not significant.

Effects on sodium adsorption ratio (SAR). As the irrigation water salinity increased, the SAR increased significantly (Table II). The use of irrigation water salinities of 9 and 12 dS m^{-1} increased the SAR to 56 and 67%, respectively. The leaching reduces the SAR for both soil layers. Leaching levels of 17, 29 and 37% decreased the SAR to 20, 35 and 40%, respectively as compared with no leaching (Table III). In all treatments, the SAR values in top layer soil were higher than the lower layer soil (Fig. 4a & 4b). The leaching level increased the SAR decreased, while the water salinity also increased SAR (Fig. 5a & b).

Effects of on soil water holding capacity (I_n). At the beginning of the season, all pots had the same soil water holding capacities, but treatments with different qualities and quantities changed the soil water holding capacity. In saline soils the strength that is required to extract soil water must be greater than the soil osmotic pressure and the evapotranspiration is mainly affected by soil salinity

Fig. 4. Effect of irrigation water salinity (4-a) and leaching (4-b) on sodium adsorption ratio

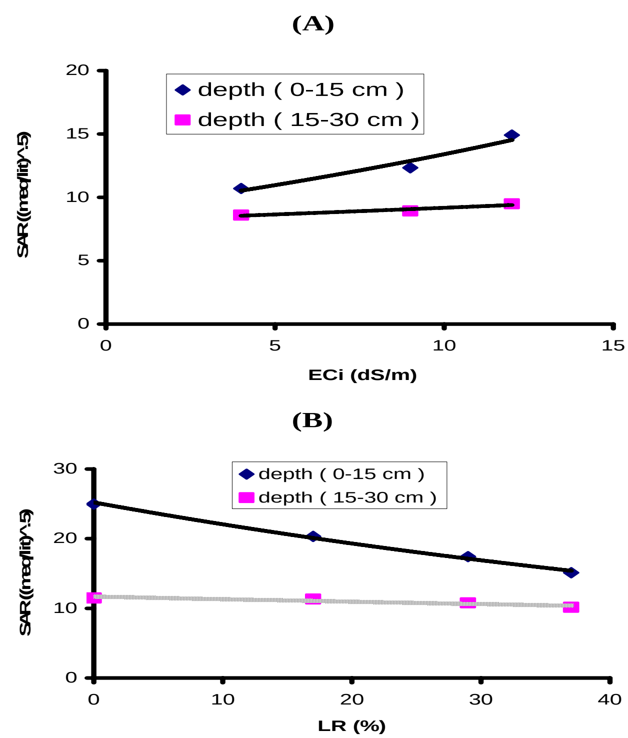
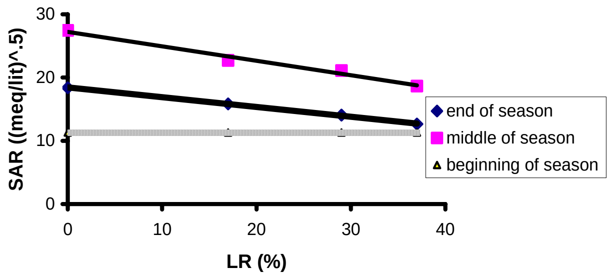


Fig. 5. Effect of leaching (5-a) and irrigation water salinity (5-b) on soil sodium adsorption ratio

(A)



(B)

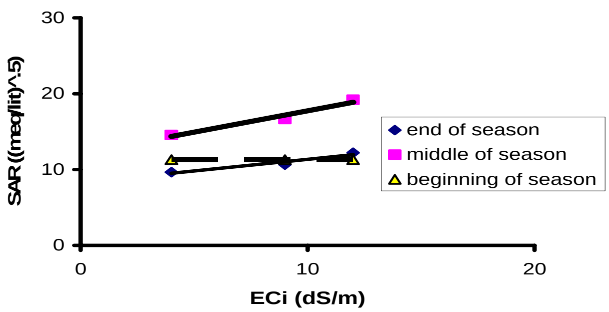
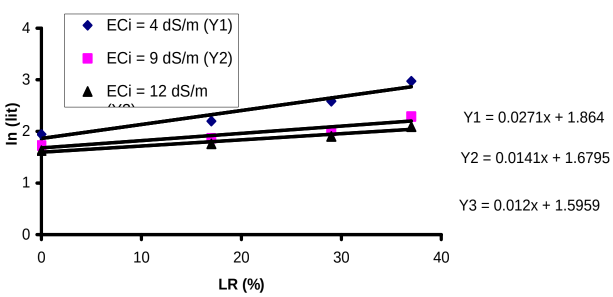


Fig. 6. Effect of leaching on soil water holding capacity for different irrigation water salinities



(Katerji *et al*., 2004). Maximum soil water holding capacity was accrued at irrigation water salinity of 4 dS m^{-1} and leaching level of 37% (Fig. 6). This indicated that the quality of irrigation water and leaching level had a crucial role on soil water holding capacities and leaching efficiency.

CONCLUSION

Leaching can decrease soil salinity effectively by improving the quality of irrigation water. Increased leaching levels can be useful to certain limits. Effects of these factors were significantly higher for upper than lower layer soil. Leaching efficiency was reduced by increasing irrigation water salinity in these soils without accumulation of salt in soil profile. Appropriate leaching fraction in connection with suitable irrigation water salinity can be used as an effective tool to manage soils of arid region.

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