ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 4 (1): 5-9, 2005
ISSN 1812-5379

Effects of Various Leaching Fractions on Cotton Yield and Soil Salinity

[1]Berkant Odemis and [2]Riza Kanber
[1]Department of Irrigation and Drainage, Faculty of Agriculture, University of Mustafa Kemal, Hatay, Turkey
[2]Department of Irrigation and Drainage, Faculty of Agriculture, University of Çukurova, Adana, Turkey

Abstract: The objective of this study was to determine the effects of various leaching fractions on cotton yield and soil salinity. Leaching fractions were created by reduced water as moving away from the laterals and determined by depth percolation (LFt) using tensiometer and electrical conductivity ($LFec_{sw}$) using suctions probes (EC_{sw}), respectively. The highest coefficient of determination between the leaching fractions and yield was found for $LFec_{sw}$ values (R^2=0.61**). A quadratic relationship was found between the LFa and the amount of salt removed from the soil. Salt removed from the profile was at its minimum value and its maximum value when the leaching fractions were 0.05 and 0.56, respectively.

Key words: Salinity, drainage water, leaching fraction, cotton, leaching effectiveness

INTRODUCTION

The use of drainage water for irrigation in areas where good quality water resources are limited or expensive is highly important. Drainage water has been widely used in irrigation in Australia, India, Israel, Pakistan and USA. It was reported that more than 3.5 Mm^3 of irrigation water with a salinity of more than 4 dS m^{-1} has been used for irrigation in Egypt each year[1].

Use of drainage water depends on two factors: effective management and planning of the irrigated saline regions and improvement of soil quality by leaching[2]. It is well established that careless use of drainage water can destroy the hydraulic and structural properties of soil, thus resulting in reduced agricultural production[3]. Proper use of drainage water is considered to be a way that helps conserve irrigation water and protect from harmful effects of irrigation on the environment[4]. Leaching is the most important tool to maintain the salt balance in areas where salt is introduced into soil by irrigation. Through leaching, salt concentration in the root zone is controlled. During leaching, equilibrium between ions on the surface of the soil particles and those in soil solution are damaged. In order to reach a new equilibrium, the exchangeable are transferred to soil solution where they can be removed by leaching thereafter[5].

Studies investigating the effect of leaching fractions on yield and soil salinity when drainage water is used to prevent salt accumulation are limited[6-11]. The main objective of this study was therefore to determine the effects of different amount of drainage water with EC of 6.5 dS m^{-1} on the leaching of soil salt and cotton yield. For this purpose, the leaching fractions by different methods and leaching efficiency were determined. In this experiment cotton was chosen since it is a salt resistant crop, the largest revenue earning non-food crop in the study area and has a great potential for cultivation in saline areas[12]. It has already been used in numerous studies regarding saline water use or its growth in saline soil[13-15].

MATERIALS AND METHODS

The study was conducted on Mutlu series soil in Çukurova region. The mentioned soil series represent the characteristic of plain conditions[16]. Some of the physical and chemical characteristics of experimental soils are presented in Table 1. This region is located in Mediterranean climate with mean annual temperature 18.8°C and precipitation 646.5 mm. About 85% of the precipitation falls during winter months (November-March). In the study, Çukurova-1518 cotton cultivars were grown using drainage water with an average EC of 6.50 dS m^{-1}, pH of 7.58, SAR of 51.21.

For irrigation of cotton, the line-source sprinkler irrigation technique was used with four replications[17]. The system consisted of eight parallel laterals placed 12 m apart. Between the laterals, the plots were constructed in 2.8 m wide and 4 m long (Fig. 1). For these reasons, there were three-irrigation levels in the experiment.

Corresponding Author: Dr. Berkant Odemis, Department of Irrigation and Drainage, Faculty of Agriculture, University of Mustafa Kemal, 31040 Hatay, Turkey
Tel: +90 326 2455603 Fax: +90 326 2455832 E-mail: bodemis@mku.edu.tr

Table 1: Some physical and chemical soil characteristics of the experimental site

Depth (cm)	Textural class	SP	FC	Pwp	As	ESP	CEC	NaX	pH	ECe
0-30	C	64.6	34.4	17.5	1.19	1.72	66.58	0.78	7.58	0.29
30-60	C	67.3	36.7	18.2	1.16	0.80	68.44	0.55	7.20	0.31
60-90	C	69.3	38.4	19.2	1.15	0.83	66.24	0.55	7.15	0.32
90-120	C	66.5	37.8	19.4	1.25	1.03	68.77	0.71	7.30	0.40

SP: Saturation Point (%), FC: Field Capacity (%), Pwp: Permanent Wilting Point (%), As: Bulk Density (g cm^{-3}), ESP: Exchangeable Sodium Percentage, CEC: Cation Exchangeable Capacity (me 100 g^{-1}), NaX: Exchangeable Sodium (me 100 g^{-1}), ECe: Electrical conductivity of soil extract dS m^{-1}

Table 2: Irrigation treatments constructed in the experiment

	Irrigation treatments						
Growth period	A	B[a]	C	D	E	F	G
Germination	T[b]	T	T	T	T	T	T
Vegetative growth period	E	T	E	E	T	T	E
Flowering and boll formation	E	T	T	E	E	T	T
Opening of boll	E	T	T	T	E	E	E

[a] Control treatment, [b] T represents full irrigation; E represents the period when gradient irrigation was applied

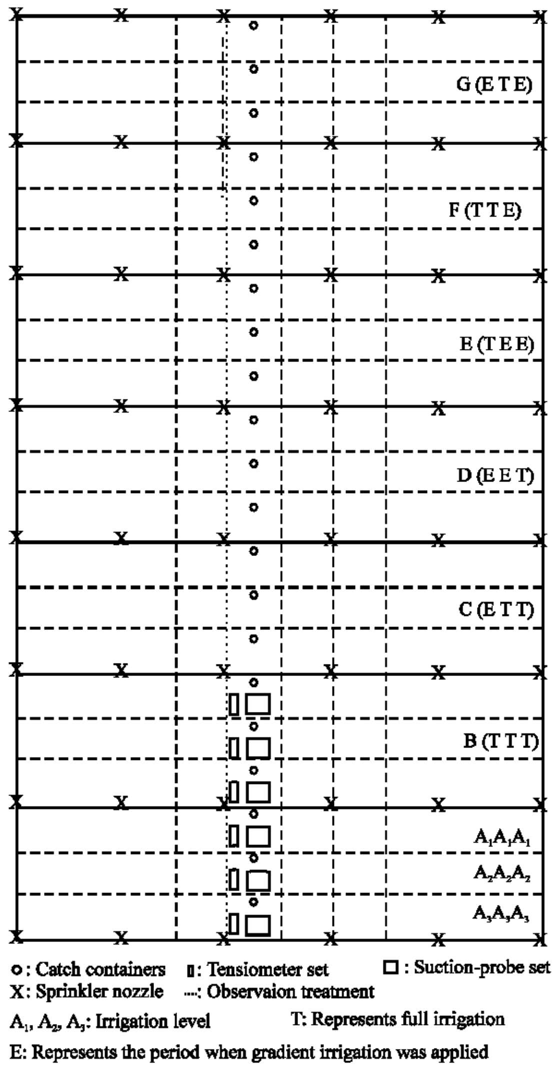

Fig. 1: Diagram of the experimental field

During irrigation, the water availability was reduced gradually as moved away from the laterals. As shown in Fig. 1, in the treatment A, gradient irrigation was applied in all the growth stages. The plots next to the lateral received the highest amount of irrigation water, while the furthest plots received the least. Water amounts in the sub-plots varied depending on operation duration of the laterals. There were 7 irrigation treatments at each of 3 growth stages (Vegetative growth period, Flowering and boll formation, Opening boll) (Table 2).

The first irrigation was applied when 60% of the available soil water in the 0-120 cm depth was consumed (12 cm). The amount of water to be applied was determined according to irrigation level A_2, which was taken as reference and was calculated as soil water deficit in the 60 cm depth. All irrigations were terminated when 10% more water than that in the treatment A_2 was applied. In this way, different leaching fractions were provided based on the mentioned treatment. To avoid undesired amount of irrigation in the treatments, the lateral test was performed. This test yielded the following simple linear regression equation ($R = 0.87^{**}$):

$$I = 190.96 - 5.146\,L \quad (1)$$

Where, I = amount of irrigation water in mm and L = distance from sprinkler in m. The runoff losses were avoided by making beds around the experimental plots raised to 40 cm high.

The actual leaching fraction (LFa) in the experiment was calculated by Eq. 2.

$$LFa = (Ik-Ig)/Ik \quad (2)$$

Where, Ik is the amount of water collected in the catch containers (mm), Ig is the net irrigation water requirements (mm). Ig values were determined by measuring soil water three times a week and calculating the water requirement of the cotton. One-neutron access tube was installed in each plot to monitor soil water content using a neutron probe. During irrigation, irrigation water exceeding the cotton water requirement was assigned as seepage which was calculated using measured tensiometer readings (60 and 75 cm depths) and the Darcy's equation[18] for treatments A and B. Saturated hydraulic conductivity values were measured at different soil depths (0-30, 30-60, 60-90, 90-120 cm). Soil water electrical conductivity (EC_{sw}) was determined from water collected by the suctions probes. In the treatments A and B, suctions probes were placed at the 60 and 75 cm depths (Fig. 1). Prior to each irrigation, 1.0 atmosphere vacuum was applied to the suctions probes and the amount of water in the probes was collected 24 h after irrigation. Using EC_{sw} measurements, leaching fractions, $LFec_{sw}$ (Eq. 3) and LFt (Eq. 4), were calculated[19]:

$$LFec_{SW} = ECw/ECsw \quad (3)$$

$$LFt = Dp/I \quad (4)$$

Where, ECw and ECsw are irrigation water and soil water electrical conductivity in dS m^{-1}, I is the amount of applied irrigation water in mm. $LFec_{sw}$ and LFt are the leaching fractions, depending upon electrical conductivity and tensiometer, respectively. Dp is seepage, mm.

In addition, to determine the amount of salt removed from the soil (ΔD), in other words effectiveness of leaching, a regression analysis between actual leaching fractions (LFa) and soil saturation extract (ECe) was carried out.

In addition, exchangeable sodium (NaX) and cation exchange capacity (CEC) values were determined from ammonium acetate extraction method. From these results, exchangeable sodium percentage (ESP) was determined from the cation exchange capacity[20].

RESULTS AND DISCUSSION

Relationships between leaching fractions and relative crop yields: The obtained results indicated a quadratic relationship among the leaching fractions and relative cotton yields (Yr) (Fig. 2 and 3). Amongst the methods used to measure the leaching fractions (LFa, LFt and to $LFec_{sw}$), the one determined by the $LFec_{sw}$ method yielded the highest correlation coefficient between leaching fraction and yield. Due to the quadratic relationship, minimum value of $LFec_{sw}$ (0.234) corresponded to the yield of 22.9 kg ha^{-1} while the maximum $LFec_{sw}$ values of (0.470) corresponded to the yield of 23.1 kg ha^{-1}.

When all treatments were taken into consideration, it was noted that the leached ones always had higher yields than those of the non-leached treatments. These results were thought to be resulted from two reasons: (I) changes in salt concentration in soil by leaching and (ii) increased plant water absorption by higher leaching fractions. Nonetheless, the increased leaching fractions increased the yield only to a certain point. Similar results for wheat and beet were reported, where the maximum yield was obtained from the leaching fractions of 0.60[6]. In geranium plant, the high leaching fractions increased the leaf area and shoot number[7]. It was also reported that the EC of the seepage water passing through the profile increased as leaching fraction decreased and this did not affect the yield[8]. In addition, several other studies reported the beneficial effects of leaching on yield and optimum growth of roots[9-12].

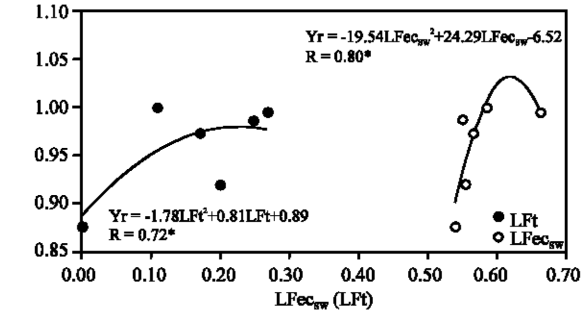

Fig. 2: The relationships between the values of relative cotton yield (Yr) and leaching fractions by tensiometer (LFt) or electrical conductivity of soil water ($LFec_{sw}$)

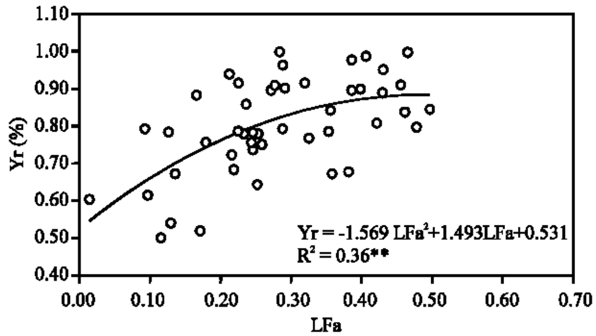

Fig. 3: The relationship between actual leaching fractions (LFa) and relative cotton yield (Yr)

Effects of leaching fractions on soil salinity: At the beginning of the experiment, the average salt concentration of the soil profile was measured as ECe=0.33 dS m^{-1}. However, the salt content of the soil profile varied depending on the leaching fractions and soil depth (Fig. 4). For example, in the first irrigation and at 0-30 cm depth, the ECe value of 0.60 dS m^{-1}, corresponding to LFa of 0.14, decreased to 0.32 dS m^{-1} when LF became 0.50. However, at 0-120 cm, the ECe value of 3.52 dS m^{-1}, corresponding to LF of 0.14, decreased more dramatically to 2.10 dS m^{-1} when LFa became 0.50. Thus, an increase of 0.36 in LFa caused a reduction of 0.60 dS m^{-1} at 0-30 cm and 1.42 dS m^{-1} at

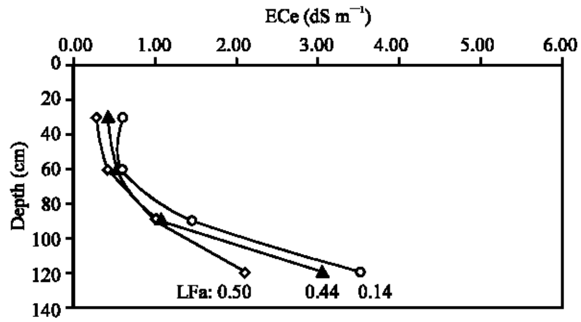

Fig. 4: The effect of actual leaching fractions (LFa) on salt concentration in the soil

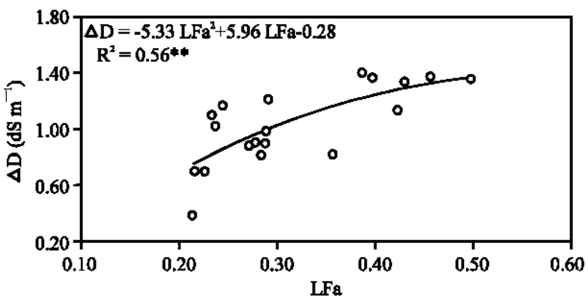

Fig. 5: The relationship between actual leaching fractions (LFa) and leaching salt amount from profile (ΔD)

0-120 cm, respectively. It is the fact that leaching was likely to carry the salt down to the lower profile of the soil, resulting in salt accumulation in the lower profile. Irrigation water with EC values of 0.2-2.4 dS m^{-1} were shown to result in a 2.05-fold increase in the salt content of the soil in the depth of 40-100 cm after three years of irrigation[21]. Van Der Moolen and Van Hoorn[22] determined that the salt concentration in the profile was significantly affected by the leaching fractions and that could be changed by leaching. Under any leaching conditions, profile salinity is affected by salinity of the irrigation water and the salt concentration in the lower profiles increased significantly[3, 23].

Effectiveness of leaching: When the salt concentration leached, ΔD, was plotted against the average seasonal leaching fractions, a quadratic relationship was obtained (Fig. 5). Within the limit of this study, ΔD increased gradually as the leaching fractions were increased. However, according to the equation presented in the Fig. 5, it is clear that the amount of salt leached from the profile will increase with the increased leaching fractions up to a certain point (LFa=0.56). When this point is exceeded, increasing the leaching fractions will not increase the ΔD value. The amount of salt removed from the profile reached its lowest level when the seasonal average leaching fractions were 0.05. Similar findings were reported by Al-Rawi *et al.*[24] showing a quadratic relationship between the leaching water and the salt leached from the profile.

Based on present findings, we have reached some conclusions and made some recommendations. Firstly, amongst the leaching fractions methods, $LFec_{sw}$ appeared to be the most sensitive method to reveal the relationship between leaching fractions and yield when compared to LFt and L,Fa and, its use is recommended. Secondly, a quadratic relationship was found between the leaching fractions and yield and between the leaching fractions and the amount of salt leached from soil profile, indicating that leaching fractions had a positive effect both on the yield and the amount of salt leached up to a certain point. In our case, for instance, the salt removed from profile was at its minimum value when the leaching fractions were 0.05 and at its maximum value when the leaching fractions were 0.56. However, these values are most likely to be different for soil with different properties and salt content of irrigation water, suggesting more studies. Thirdly, the salt accumulation in the soil varied depending on the soil profile depth and leaching fractions. Overall, it is recommended that water table level and the amount of salt accumulated in the profile should be measured after each irrigation to avoid from the problems arising from excess irrigation when drainage water is used and, that the amount of leaching fractions should be increased at the period when crop sensitivity to salt is high.

ACKNOWLEDGMENTS

We would like to thank Dr. Y. Kemal Avsar and Dr. F. Evrendilek for their invaluable comments on the previous version of the manuscript.

REFERENCES

1. Rhoades, J.D., A. Kandiah, A.M. Mashali, 1992. The use of saline waters for crop production. FAO No. 48: 1-133.
2. Ayers, R.S. and D.W. Westcot, 1989. Water quality for agriculture. FAO No. 29: 1-163.
3. Hoffman, G.J., 1990. Leaching Fraction and Root Zone Salinity Control. In: Tanji, K.K. (Ed.), Agricultural Salinity Assessment and Management. ASCE Manual, 71: 237-261.
4. Beltran, J.M., 1999. Irrigation with saline water: Benefits and environmental impact. Agric. Water Manage., 40: 183-194.
5. Oster, J.D., 1994. Irrigation with poor quality water. Agric. Water Manage., 25: 271-279.

6. Ku, C.S.M. and D.R. Hershey, 1992. Leachate electrical conductivity and growth of potted geranium with leaching fractions of 0 to 0.4. J. American Soc. Hortic. Sci, 117: 893-897.
7. Ku, C.S.M. and D.R. Hershey, 1991. Leachate electrical conductivity and growth of potted poinsettia with leaching fractions of 0 to 0.4. J. American Soc. Hortic. Sci., 116: 802-805.
8. Hoffman, G.J. and J.A. Jobes, 1983. Leaching Requirement for Salinity Control III. Barley, Cowpea and Celery. Agric. Water Manage., 6: 1-14.
9. Jobes, J.A., G.J. Hoffman and J.D. Wood, 1981. Leaching requirement for salinity control. II Oat, Tomato and Cauliflower. Agric. Water Manage., 4: 393-407.
10. Francois, L.E., 1981. Alfalfa management under saline conditions with zero leaching. Agron. J., 73: 1042-1046.
11. Khan, M.J. and E.P. Gleen, 1996. Yield and evapotranspiration of two barley varieties as affected by sodium chloride salinity and leaching fraction in lysimeter tanks. Communications in Soil Science and Plant Analysis, 27: 157-177.
12. Grattan, S.R., 1994. Irrigation with Saline Water. In: Tanji, K.K. and B. Yaron (Eds.). Advanced Series In Agricultural Sciences, 22: 179-195.
13. Maas, E.V. and G.J. Hoffman, 1977. Crop salt tolerance-current assessment. J. Irrigation and Drainage Division, ASCE., 103: 115-134.
14. Ayars, J.E., R.B. Hutmacher, R.A. Schoneman, S.S. Vail and D. Felleke, 1986. Drip Irrigation of Cotton with Saline Drainage Water. ASAE., 29: 1668-1673.
15. Bressler, M.B., 1979. The use of saline water for irrigation in the U.S.S.R. Joint Comiss. Sci. Tech. Coop., Water Resource Denver, pp: 1-20.
16. Dinc, C., M. Sari, S. Senol, S. Kapur, M. Sayin, M.R. Derici, V. Cavusgil, M. Gok, M. Aydin, H. Ekinci, N. Agca and E. Schlichting, 1990. Soils of Cukurova Region (in Turkish). Univ. Cukurova, Fac. Agric., No., 26: 1-172.
17. Hanks, R.J., J. Keller, V.P. Rasmussen and G.D. Wılson, 1976. Line source sprinkler for continous variable irrigation-crop production studies. Soil Sci. Soc. Am. J., 40: 426-429.
18. Wagenet, R.J., 1984. Salt and Water Movement in the Soil Profile. Soil Salinity Under Irrigation. In: Shaınberg, I., Shalhevet, J. (Eds.), pp: 100-115.
19. Rhoades, J.D. and S.D. Merrill, 1976. Assessing the suitability of water for irrigation: Theoretical and empirical approaches. In: Prognosis of Salinity and Alkalinity. Soils Bulletin. FAO No., 31: 69-109.
20. USSL., 1954. Diagnosis and Improvement of Saline and Alkali Soils U.S. Dept. Agric. Agricultural Handbook. No. 60. USA., pp: 1-160.
21. Tooth, T. and L. Blasko, 1998. Secondary Salinization Caused by Irrigation. The Soil as a Strategic Resource: Degradation Processes And Conservation Measures. In: Rodrıquez, R.A., C.C.J. Mendoza and M.L.T. Salguero, (Eds.), Geofarma Ediciones, Logrono, pp: 229-251.
22. Van Der Moolen, W.H. and J. Van Hoorn, 1978. The salty balance and leaching requirement irrigated soils. Intl. Ins. Land Rec. Imp. Wageningen, pp: 1-25.
23. Smets, S.M.P., M. Kuper, J.C. Van Dam and R.A. Feddes, 1997. Salinization and crop transpiration of irrigated fields in Pakistan's Punjab. Agric. Water Manage., 35: 43-60.
24. Al-Rawi, J., T.M. Husain, A.D. Al-Maithedi and L. Hamdi, 1989. Effect of Initial Moisture Content of Soil on Leaching Efficiency of Soluble Salts. J. Agric. Water Resources Res., 8: 15-24.