



Research Journal of
**Environmental
Sciences**

ISSN 1819-3412



Academic
Journals Inc.

www.academicjournals.com

The Effects of Different Water Qualities and Irrigation Methods on Soil Chemical Properties

¹M.A. Ebrahimizadeh, ²M.J. Amiri, ²S.S. Eslamian, ²J. Abedi-Koupai and ³M. Khozaei

¹Department of Desert Region Management,
School of Agriculture, Shiraz University, Shiraz, Iran

²Department of Water Engineering, School of Agriculture,
Isfahan University of Technology, Isfahan, Iran

³Department of Water Engineering, School of Agriculture, Shiraz University, Shiraz, Iran

Abstract: In this study, the effects of irrigation methods (surface drip and subsurface drip) and water qualities (municipal treated effluent and fresh water) with irrigation scheduling based on soil moisture and root depth monitoring were evaluated on the chemical properties of the soil. A split plot experiment with two main treatments (irrigation methods) and two sub-main treatments (irrigation water qualities) with four replications were designed and executed in Koshkak research centre (Southern Iran). Soil samples were collected from depths of 0-20, 20-40 and 40-60 cm and were analyzed for electrical conductivity (EC), soluble sodium (Na) and chloride (Cl) concentrations, total nitrogen (TN) and phosphorus (P). Results showed that the soil EC, Na and Cl of the second and third layers of soil were significantly greater with surface irrigation than with subsurface irrigation. The EC, Na and Cl of second and third soil layers irrigated with wastewater were higher as compared with groundwater. The soil EC, Na and Cl content increased with increasing the depth of the soil layer. The fluctuations in nitrogen concentration were opposite to the fluctuations in Cl concentration as the nitrogen content of the soil decreased with increasing the soil depth. The best water saving and water productivity was obtained with sub-surface drip irrigation.

Key words: Surface drip irrigation, sub-surface drip irrigation, reuse of wastewater, soil chemical properties

INTRODUCTION

Leaching of solutes from agricultural soils is a serious environmental problem. Nitrate (NO₃), phosphate (PO₄) and other solutes may leach and pollute both groundwater and surface water. Knowledge about the origin of solutes is required to define reasonable limits for groundwater and surface water qualities (De Vos *et al.*, 2002). With rapidly growing world population and increasing the pressure on limited fresh water resources, a tendency to reuse of municipal effluents for irrigation has been increased (George *et al.*, 2000). Wastewater is the only potential water source, which will increase as the population grows and the demand on freshwater increases (Heidarpour *et al.*, 2007).

As Iran is a country with limited water supplies and irrigated agriculture is the largest water consuming sector, it faces competing demands from other sectors. Using wastewater can be an effective remedy. However, the effects of replacing groundwater with wastewater are not completely well known and should be evaluated. The objectives of this study were to achieve higher water saving from different irrigation methods and then evaluate the effects of different water qualities and irrigation methods on the soil chemical properties.

Corresponding Author: Mohammad Javad Amiri, Department of Water Engineering, School of Agriculture, Isfahan University of Technology, Isfahan, Iran Tel: 0983113913432 Fax: 0983113913432

MATERIALS AND METHODS

The experimental site was located in Koshkak research centre north east of Shiraz, Southern of Iran (52° 34' N, 30° 7' E) with annual rainfall of 340 mm and annual evaporation of 2585 mm. In this study area, the mean annual area temperature is 17.8°C mean annual rainfall is 125 mm. The particle size separates at the experimental site is 45% clay, 25% silt and 30% sand. Two studies were carried out which corresponds to two growing seasons for maize: April 2006 to September 2006 and April 2007 to September 2007. The experimental design was a split plot with four treatments and four replications. The plot sizes were 42 m² and a total of 16 plots were established. The treatments were: SSDE (sub-surface drip with effluent), SSDF (sub-surface drip with freshwater), SDE (surface drip with effluent) and SDF (surface drip with freshwater). As the irrigation efficiency was not equal for the different methods of irrigation, the volume of required water within the root zone, for achieving the field capacity, was estimated by monitoring the soil moisture deficit within the root zone. This volume was divided by the efficiency of each method and the applied irrigation water was provided for each plot. Soil moisture was measured with a Neutron probe (Peralta and Stockle, 2001). For attaining crop water productivity (CWP), yield was divided by the used water. The maize crops were planted on 18 cm wide beds in rows spaced 75 cm apart at a depth of 3-5 cm. The growth period was 115 days (or about 4 months).

Generation of Samples

Two irrigation methods including: sub-surface drip (SSD) and surface drip (SD) with two water quality treatments (treated wastewater effluent and fresh water). Totally four treatments: SSDE (sub-surface drip with effluent), SSDF (sub-surface drip with freshwater), SDE (surface drip with effluent), SDF (surface drip with freshwater) were studied. Three filtration systems (screen, sand media and disc) were set up to filter the effluent before irrigation (Fig. 1).

There was 20 cm distance between the emitters in SSD and SD methods and the tubes were chosen from the tape type. In SSD treatment, the pipes were buried at 15-20 cm depth from the soil surface. Soil samples were collected at three points of a circle above and below the porous pipe for each treatment and sampling was done at three depths of 0-20, 20-40 and 40-60 cm. The samples of each depth were then blended and one sample was analyzed. The samples were air-dried and passed through a 2 mm sieve and chemical properties were determined.

Net depth of irrigation water was calculated using the equation below (the dominant soil texture was clay loam and the soil was classified as calcareous):

$$d_n = (\theta_f - \theta_w) A_s \times R$$

Where:

d_n = The net depth of irrigation water (mm)

θ_f = The soil moisture in field capacity (%)

θ_w = The soil moisture, in irrigation time (%)

A_s = The relative density

R = The root depth, in irrigation time (mm)

The test crop was maize (*Zea mays* L.) cv. Single Cross 704 was used for the experiment. What were the cultural methods used during cultivation such as weeding, insect control etc.

Analysis of Samples

A representative sample of the corn from each plot (4 rows of 5 m) was hand harvested in October of each year. The corn grains were dried in the oven (at 40°C temperature for 24 h) and their yield efficiency was measured for each plot (Woo and Seib, 2002). One kilogram grains were selected

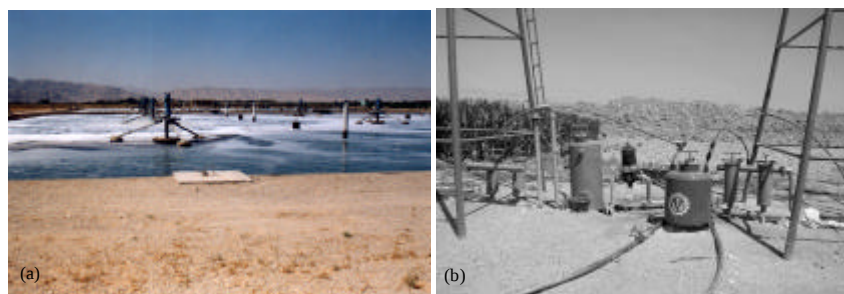


Fig. 1: The sewage treatment site (a) and the filtration systems (b)

from each plot randomly and ground in a Kenwood Portable Mill into flour to pass through a 1 mm sieve. The sampling was done from six treatments and four replications separately.

Soil pH was measured with a pH meter (McNeal, 1982). Electrical conductivity (EC) was determined by conductivity meter. Chloride was determined using a titrimetric method. Total N was determined using the Kjeldahl procedure (Bremner and Mulvaney, 1982). Na was measured using flame photometer (Richards, 1954).

Statistical Analysis

All data are the means of two experiments conducted in 2006 and 2007 and were analyzed using the analysis of variance (ANOVA) procedure of COSTAT and the comparison of means was performed using Duncan multiple range test DMRT, $p < 0.05$ (Heidarpour *et al.*, 2007).

RESULTS AND DISCUSSION

The SSD method with a mean water volume of $6100 \text{ m}^3 \text{ ha}^{-1}$ applied had higher water saving than that of SD ($6480 \text{ m}^3 \text{ ha}^{-1}$) (Table 1). However a significant increase has been observed in CWP (crop water productivity) for corn from SSD method (1.91 kg m^{-3}) (Table 2). The comparison of results from different irrigation methods on the maize yield showed that SSD increased the yield in compared to SD, but this increasing was not significant. According to Table 3, irrigation with effluent increased the grain yield and CWP as compared to the fresh water, but these differences were also not significant. The statistical analysis of CWP with respect to different irrigation methods showed that SSD increased the CWP comparing to SD method ($p < 0.05$). The chemical properties of the soil prior to the experiment are shown in Table 4.

Electrical conductivity (EC) indicates soluble salt concentration in the soil. Salt movement and distribution in soil is directly related to water movement (Nakayama and Bucks, 1986). The method of irrigation had a significant effect ($p < 0.05$) on soil EC in different layers of soil. In the first soil layer, mean EC values of SSD irrigation were greater as compared to SD irrigation, while surface irrigation had greater EC values in the second and third soil layers (Fig. 2). There was an increase in EC values in the first soil layer by subsurface irrigation over the study period.

In this research the EC value of wastewater was greater than freshwater (Fig. 2). Therefore, the application of wastewater would be expected to cause greater soil EC than freshwater in the second and third soil layers (Fig. 2). Mean EC values of wastewater irrigated soil were greater than those of groundwater irrigated soil for the first layer. This result is likely due to the effect of plant uptake on the soil solution. Because wastewater generated higher yield than groundwater, there was more water uptake and transpiration due to wastewater irrigation. These results are similar to those of other researchers such as Heidarpour *et al.* (2007), Choi and Suarez Rey (2004) and Assadian *et al.* (2005).

There were no significant effects on soil pH due to different water qualities. The pH values of all soil layers between 7.78 and 8.01, which is similar to results reported by Heidarpour *et al.* (2007) (Fig. 3).

Table 1: Chemical properties of effluent and fresh water. The data are the means of two experiments conducted in 2006 and 2007

Water quality	EC ($\mu\text{S m}^{-1}$)	SAR ($\text{meq L}^{-1/2}$)	pH	HCO_3^-	SO_4^{2-}	Cl^-	Ca^{+2}	Mg^{+2}	Na^+
Effluent	1.46	2.66	7.80	10.00	0.80	4.00	4.80	3.70	5.50
Fresh water	0.51	0.53	7.78	4.00	0.40	0.95	3.00	1.50	0.80

Table 2: Statistical analysis of CWP and yield for irrigation systems (Duncan, 5%)^a. The data are the means of two experiments conducted in 2006 and 2007

Irrigation method	SSD	SD
CWP (kg m^{-3})	1.91 ^a	1.75 ^b
Yield (t ha^{-1})	11.70 ^a	11.36 ^a

^aFor each factor, values with different following letters are significantly different ($p < 0.05$)

Table 3: Statistical analysis of CWP and yield for effluent and fresh water (Duncan, 5%)^a. The data are the means of two experiments conducted in 2006 and 2007

Water quality	Effluent	Fresh water
CWP (kg m^{-3})	1.70 ^a	1.70 ^a
Yield (t ha^{-1})	11.12 ^a	11.10 ^a

^aFor each factor, values with different following letters are significantly different ($p < 0.05$)

Table 4: Soil chemical properties prior to the cultivation. The data are the means of two experiments conducted in 2006 and 2007

Parameters	Soil depth (cm)		
	0-20	20-40	40-60
EC (dS m^{-1})	0.53	0.62	0.93
pH	8.19	8.26	8.29
OC (%)	1.62	0.44	0.83
Total N (%)	0.16	0.04	0.08
Available P (ppm)	18.80	16.70	14.60
Available K (ppm)	550.00	445.00	410.00
HCO_3^- (meq L^{-1})	1.50	1.20	2.50
Cl^- (meq L^{-1})	0.95	1.00	1.10
SO_4^{2-} (meq L^{-1})	2.00	4.00	5.30
Ca^{2+} (meq L^{-1})	2.30	2.30	3.80
Mg^{2+} (meq L^{-1})	0.20	2.50	2.20
Na^+ (meq L^{-1})	0.80	1.60	2.10
SAR ($\text{meq L}^{-1/2}$)	1.34	1.03	1.21

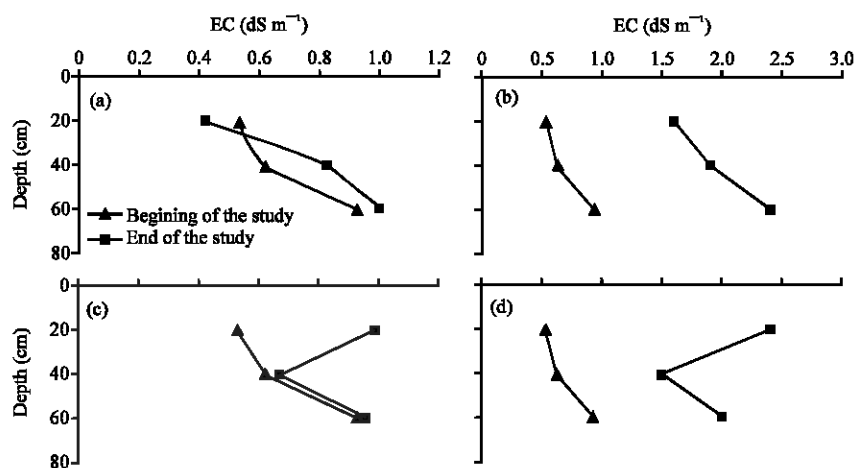


Fig. 2: EC of soil layers for different treatments: (a) SDF: surface drip with freshwater; (b) SDE: surface drip with effluent; (c) SSDF: sub-surface drip with freshwater and (d) SSDE: sub-surface drip with effluent

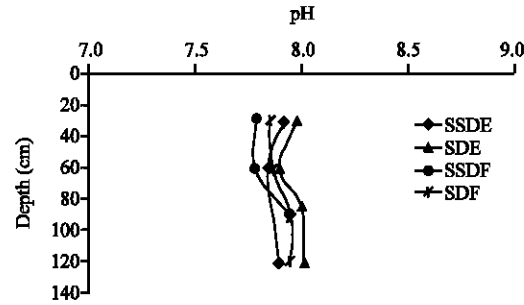


Fig. 3: pH of soil layers for different treatments: SDF: surface drip with freshwater; SDE: surface drip with effluent; SSDF: sub-surface drip with freshwater; SSDE: sub-surface drip with effluent

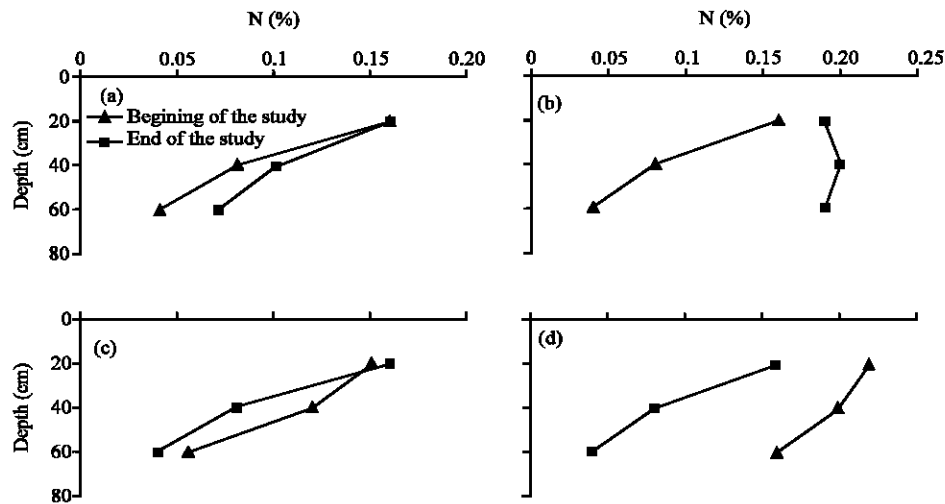


Fig. 4: TN concentration of soil layers for different treatments: (a) SDF: surface drip with freshwater; (b) SDE: surface drip with effluent; (c) SSDF: sub-surface drip with freshwater and (d) SSDE: sub-surface drip with effluent

With increasing in depth, nitrogen leaching decreased. This decreased was correlated with the transpiration rate of the plants. Transpiration continued to increase by growing the plants and drainage reduced during the experiment. The TN concentration of wastewater irrigated soils at the end of the study was greater than that of freshwater irrigated soil (Fig. 4). Irrigation with SSD method reduced TN concentrations of the second and third layer of the soil in comparison with SD method (Fig. 4), Which could be due to higher yield and lower water consumption of this method. These results are in agreement with Haberlandt *et al.* (2002) and Peralta *et al.* (2001).

The chloride (Cl) content in the 0-120 cm depth soil layer increased and most of the Cl was leached to the drains from the top of the soil profile (Fig. 5). The Cl concentration at greater depth remained high (Fig. 5). De Vos *et al.* (2002) showed that the impermeable layer starts at 120 cm depth and that the water flows occur only in the 0-120 cm depth soil layer. As the Cl concentration of effluent was higher than the fresh water, the Cl content of wastewater irrigated soils was higher in any soils layer ($p < 0.05$). The effect of method of irrigation on Cl concentration was significant. In the second and third layers of the soil, Cl concentration in SD method was higher than that of SSD, which

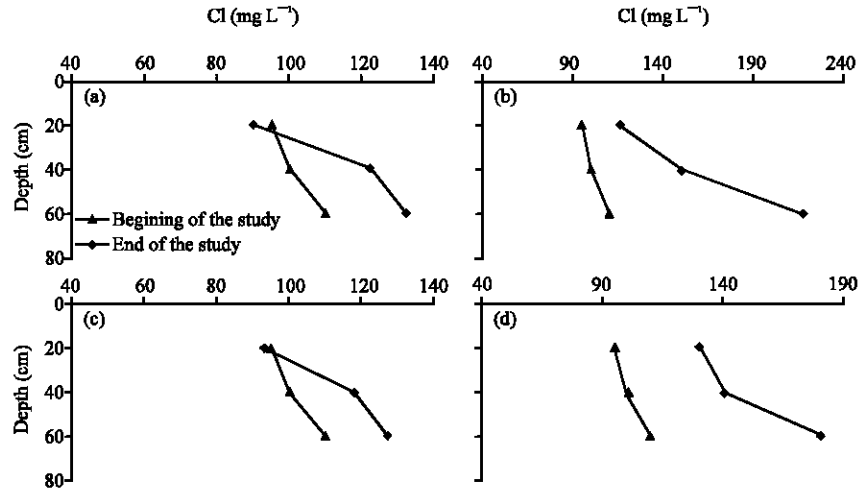


Fig. 5: Cl concentration of soil layers for different treatments: (a) SDF: surface drip with freshwater; (b) SDE: surface drip with effluent; (c) SSDF: sub-surface drip with freshwater and (d) SSDE: sub-surface drip with effluent

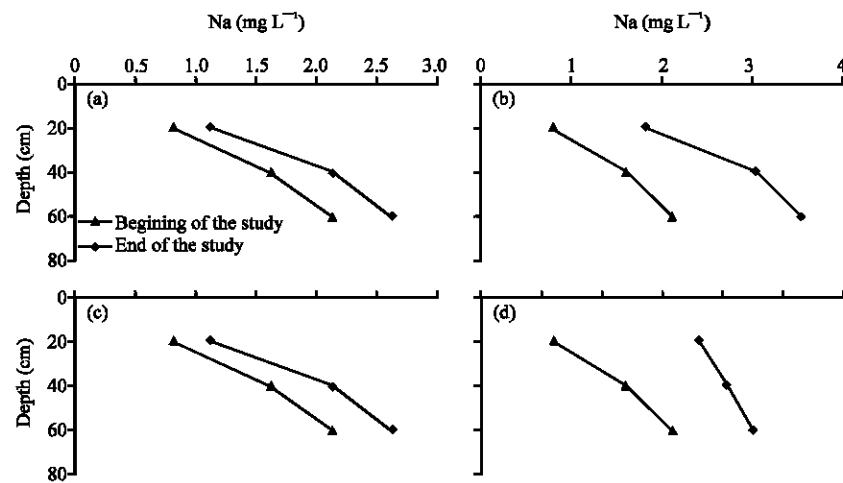


Fig. 6: Na concentration of soil layers for different treatments: (a) SDF: surface drip with freshwater; (b) SDE: surface drip with effluent; (c) SSDF: sub-surface drip with freshwater and (d) SSDE: sub-surface drip with effluent

referred to higher water consumption of this method. The fluctuations of nitrogen and Cl concentrations were opposite to each other (De Vos *et al.*, 2002). The lowest Cl concentration occurs in the 0-50 cm soil depth interval. For depths deeper than that the Cl concentration is high (De Vos *et al.*, 2002).

In the first soil layer, the Na concentration with SSD irrigation was significantly greater than with SD irrigation (Fig. 6), which refers to lower water consumption of SSD method. Soluble Na enters the first layer in SSD irrigation, while it is leached out from this layer by SD irrigation, because of higher water consumption of this method. Moreover, SSD irrigation elevated the initial Na concentration of

the first soil layer (Fig. 6). The Na concentration with wastewater irrigation was significantly greater than freshwater irrigation ($p < 0.05$) (Fig. 6).

CONCLUSION

The best water saving and water productivity was obtained with sub-surface drip irrigation. Water quality did not affect CWP and the corn yield, significantly. The concentration of chemical constituents in soil layers are influenced by water movement patterns, chemical concentrations in irrigation water and plant uptake. It seems that water quality and irrigation method have a significant effect on chemical properties of the soil. Although using wastewater seems an effective solution for the countries with limited water supplies, but we should be conscious about the long effect of that on chemical properties of soil.

REFERENCES

- Assadian, N.W., G.D. Di-Giovanni, J. Enciso, J. Iglesias and W. Lindemann, 2005. The transport of waterborne solutes and bacteriophage in soil subirrigated with a wastewater blend. *Agric. Ecosyst. Environ.*, 111: 279-291.
- Bremner, J.M. and C.S. Mulvaney, 1982. Nitrogen-Total. In: *Methods of Soil Analysis*, Klute, A. and A.L. Page (Eds.). American Society Agronomy, Madison, WI., ISBN: 0891180885, pp: 85-122.
- Choi, C.Y. and E.M. Suarez Rey, 2004. Subsurface drip irrigation for bermudagrass with reclaimed water. *Trans. ASAE*, 47: 1943-1951.
- De-Vos, J.A., P.A.C. Raats and R.A. Feddes, 2002. Chloride transport in a recently reclaimed Dutch Polder. *J. Hydrol.*, 257: 59-77.
- George, B.A., S.A. Shende and N.S. Raghuwanshi, 2000. Development and testing of an irrigation scheduling model. *Agric. Water Manage.*, 46: 121-136.
- Haberlandt, U., V. Krysanova and A. Bardossy, 2002. Assessment of nitrogen leaching from arable land in large river basins Part II: Regionalisation using fuzzy rule based modelling. *Ecol. Model.*, 150: 277-294.
- Heidarpour, M., B. Mostafazadeh-Fard, J.A. Koupai and R. Malekian, 2007. The effects of treated wastewater on soil chemical properties using subsurface and surface irrigation methods. *Agric. Water Manage.*, 90: 87-94.
- McLean, E.O., 1982. Soil pH and Lime Requirement. In: *Methods of Soil Analysis Part 2: Chemical and Microbiological Properties*, Page, A.L., R.H. Miller and D.R. Keeney (Eds.). ASA Inc., SSSA Inc., Publishers, New York, USA., ISBN: 0-8493-0022-3, pp: 199-224.
- Peralta, J.M. and C.O. Stockle, 2001. Dynamics of nitrate leaching under irrigated potato rotation in Washington State: A long-term simulation study. *J. Agric. Ecosyst. Environ.*, 88: 23-34.
- Richards, L.A., 1954. *Diagnosis and Improvement of Saline and Alkali Soils*. 1st Edn., United States Salinity Laboratory Staff. US Department of Agriculture, Washington, USA.
- Woo, K.S. and P.A. Seib, 2002. Cross-linked resistant starch: Preparation and properties. *Cereal Chem.*, 79: 819-825.