Current Trends in Natural Sciences
Vol. 11, Issue 22, pp. 19-28, 2022
https://doi.org/10.47068/ctns.2022.v11i22.002
Current Trends in Natural Sciences (on-line)
ISSN: 2284-953X
ISSN-L: 2284-9521
Current Trends in Natural Sciences (CD-Rom)
ISSN: 2284-9521
ISSN-L: 2284-9521

THE EFFECT OF EXCESSIVE SODIUM-CONTAINING IRRIGATION WATERS ON SOIL INFILTRATION RATE

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Abstract
Due to increasing demand for limited water resources, the pressure on irrigation water used in agricultural production is also increasing. One of the alternative solutions to meet the irrigation water needed in agricultural production is to use low-quality water resources. However, use of these waters can cause serious problems for the environment, especially for soil and plants, in the short, medium and long term. The sodium concentration of the irrigation water affects the structure of the soil, infiltration rate and hydraulic conductivity properties, as well as negatively affects the nutrient uptake of the plants. In this study, the effect of irrigation water with excess sodium content on the infiltration rate, which is one of the important parameters for the design and operation of irrigation systems and sustainable agricultural production, was researched. The infiltration rate was measured by the double-ring infiltrometer method. In this study, irrigation water with four different Electrical Conductivity (ECi = 0.6 [control], 5, 10 and 15 dS m^{-1}) and Sodium Adsorption Ratio (SAR) (1, 20, 40 and 50) were used. Cumulative infiltration values varied between 360-446 mm, and a 9-19% reduction was determined as compared to the control treatments, depending on the increasing ECi and SAR ratios. The steady-state infiltration rate of the treatments varied between 24.5-36.5 mm h^{-1} and decreased by 24-34%. In response to increased EC and SAR in irrigation water, the infiltration rates and cumulative infiltration values of soils decreased.

Keywords: Irrigation water quality, EC, SAR

1. INTRODUCTION

For sustainable agricultural production, water quality and plant root zone salinity should be evaluated together. In recent years, water resources have been exposed to great pressures due to the negative effects of climate irregularity and increasing demands. On the other hand, water resources are deteriorated day by day both in terms of quality and quantity. Such deteriorations are more evident, especially in arid and semi-arid regions. Dissolved salts are transmitted into the soil with irrigation. Depending on the nature of the water resource, salinity and alkalinity problems are encountered in irrigated areas over time and such problems can reach to high levels that will limit or even eliminate agricultural production if no precautions are taken.

Infiltration rate is of great importance in determining the maximum amount of water to be applied in irrigation, possible water and soil losses, in selection of places where small and large water storage structures will be built, in the selection and operation of irrigation methods. At the same time, the change in infiltration rate and infiltration time are effective factors in determining the part of the precipitation that passes into the runoff. Therefore, infiltration rate of the soil is one of the

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important criteria for many study areas such as hydrological, drainage, soil improvement, soil and water erosion studies as well as irrigation.

The rate of infiltration depends on physical properties of the soil such as the structure, texture, density of the soil, the initial moisture content of the soil, the distribution of moisture along the soil profile, the degree of compaction of the soil, the colloid and organic substances of the soil, the trapped air in the soil, the size of the pores, and other chemical and biological characteristics of the soil. In addition, the degree of slope of the soil surface, topography, vegetation, soil cultivation, grazing, soil temperature, temperature of the applied water, water application time and intensity of precipitation are also effective factors on the infiltration rate (Ertuğrul and Apan, 1979). Evaporative losses and, accordingly, irrigation efficiency is reduced because the irrigation water is ponded on the soil surface for a long time or infiltrated very slowly. One of the factors affecting infiltration in terms of water quality is the ratio of the total salt content of the water and the ratio of sodium ion concentration to the sum of calcium and magnesium ion concentrations.

The quality of irrigation water is evaluated not only by the total amount of salt it contains, but also by the type of salts. The quality of the water or its suitability for use is evaluated based on the potential problems that may arise with the long-term use of the water. The problems commonly encountered in irrigated agriculture depending on water quality can be grouped under four main headings: salinity of the root zone, water infiltration rate, special ion toxicity and other problems. The water quality is primarily affected by the physical properties of the soil such as the types of clay minerals and the soil texture, as well as the chemical properties such as exchangeable cations. The infiltration rate generally decreases with salinity or increases with decreasing salinity or increasing calcium/magnesium ratios and decreases with increasing sodium content. Therefore, salinity and sodium absorption ratio (SAR) values are the most important elements to consider in the evaluation of infiltration (Ayers and Westcot, 1994).

Saline water is used to irrigate farmlands of arid and semi-arid climate zones that account for about 41% of land area worldwide. These regions are poor in water and water quality (UNDP 1997). Annual precipitations are also insufficient (<400 mm) for salt leaching through soil profile, resulting in the accumulation of salt in the soil and affecting soil characteristics. Sodium, magnesium and calcium ion concentrations significantly influence soil properties, especially clay dispersion, hydraulic conductivity and water holding capacity of the soil (Shainberg and Letey, 1983), aggregate stability and soil crust formation (Varallyay, 1977a, b; Tedeschi and Dell's Aquila, 2005; Huang et al., 2011). Dispersed particles can clog soil pores, then reduce porosity, permeability and hydraulic conductivity (Felhendler et al., 1974; Frenkel et al., 1978; Pupisky and Shainberg, 1979; Shainberg et al., 1981a, b; Shainberg and Levy, 1992; Ame'zketa, 1999; Huang et al., 2011). In addition, poor control of soil salinity accumulation, inappropriate agricultural and management practices can exacerbate salinity. As a result, salinity increases in most irrigated salinity-degraded soils (Ghassemi et al., 1995; Huang et al., 2011).

Saline waters generally are not used in irrigations, but saline waters still constitute the main source of irrigation water of arid climate zones in developing countries with deficit freshwater resources and rapidly growing populations and increasing water demands. In order to maintain the existing arable land and ensure farmer livelihoods, local farmers have to use saltine groundwater to irrigate their arable lands. High evaporation rates can lead to accumulation of salt in the soil. Soil salinization leads to vegetation and land degradation and various environmental problems (Wang and Cui, 2004). Adverse effects of brackish water used for irrigation could be diminished through the implementation of proper brackish water and soil management, requiring well-comprehension

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of the impacts of brackish water on irrigation systems, soil properties and arable lands (Huang et.al., 2011).

In irrigated areas, water users both waste scarce freshwater and cause salinity and drainage problems with insufficient information and wrong practices. Unsuitable irrigation practices, especially in arid and semi-arid areas, cause ponding of irrigation water on the soil surface, while at the same time large amounts of evaporation occur due to climate. This causes an increase in soil salinity. In this study, irrigation waters with high ECi and SAR values were prepared and used in infiltration tests with double-ring infiltrometer method. The changes in the infiltration rates and cumulative infiltration values of waters with high EC and SAR were examined.

2. MATERIALS AND METHODS

2.1. Research Area and Soil Properties

Infiltration tests were carried out on the Kısas series soils located in the irrigation area of Kısas Irrigation Association of Harran plain. Soil samples were taken from 0-120 cm soil profile at 30 cm intervals and basic parameters were analyzed in the laboratory. Soil analysis results are provided in Table 1. Experimental soils were clay in texture and had a high lime content. Depending on the lime content, soil pH was higher than 8. The electrical conductivity values increased from the soil surface to the lower layers.

Table 1. Some Physical and Chemical Properties of Experimental Soils

Depth (cm)	FC (Pw)	WP (Pw)	As (g/cm^3)	pH	EC (dS m^{-1})	$CaCO_3$ (%)	Texture Class
0-30	33.23	22.12	1.30	8.1	0.565	29	C
30-60	34.79	22.71	1.33	8.2	0.732	30	C
60-90	34.96	22.78	1.34	8.2	0.919	30	C
90-120	35.03	23.14	1.35	8.2	1.012	31	C

FC: Field Capacity; WP: Wilting Point; As: Volume Weight:

2.2. Properties of Water Used in Infiltration Tests

Salt concentrations were calculated for different EC (control treatment [0.60], 5, 10 and 15 dS m^{-1}) and SAR (1, 20, 40 and 50) values using sodium chloride (NaCl) salt for use in the test. Sampling was made from the prepared solution for control purposes and analyzed in the laboratory, and the results are provided in Table 2. Based on the cations, first the SAR values and then using this value, the exchangeable sodium percentage (ESP) values for the possible sodium content of the soil were calculated. To convert the SAR of a soil solution or irrigation water into the expected soil ESP, following equation was used (Richards, 1954):

$$ESP = (100(-0.0126+0.01475*SAR))/(1+(-0.0126 + 0.01475*SAR))$$

This experimental condition fulfills the hypothetical limit condition for high SAR and ESP values. In any case, the first information utilized in the inference of this relationship were SAR < 65 and ESP < 50. The opposite relapsed relationship (USSL, 1954) was applied for ESP > 50 (Anonymous, 2011).

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Table 2. Chemical properties of the water used in the test

Parameter	Unit	EC_1	EC_2	EC_3	EC_4
EC	(dS/m)	0.6	5	10	15
SAR		1	20	40	50
ESP*		0.29	22.12	36.64	42.13
Na	(me/l)	1.58	41.68	90.02	135.92
K		0.09	0.12	0.13	0.19
Ca		3.30	5.98	7.02	8.78
Mg		1.20	2.61	3.08	5.87
HCO_3		3.57	3.87	3.57	4.57
Cl		2.14	45.42	95.98	144.63
SO_4		0.45	0.86	0.91	1.12

* Calculated using the equation given in Richards (1954) and expresses the probable value of the soil.

2.3. Performance of Infiltration Tests

Infiltration tests were conducted with the use of a double-ring infiltrometer set (Brouwer et al., 1985). Infiltrometers were placed in accordance with the standards and the readings were made accordingly. The water surface height was measured with a steel ruler and recorded. The test was performed in 3 replications.

3. RESULTS AND DISCUSSIONS

3.1. Change in Infiltration Rates and Cumulative Infiltration Values

The values calculated by using the measurements obtained as a result of the test are presented in Table 3 and the infiltration graphs and equations created by using these values are presented in Figures 1, 2, 3 and 4. The infiltration values decreased due to the increase in the SAR value of the waters used in the test. The infiltration rate, which was initially determined as 288 mm/h for control, initially showed a slight increase in the treatments of increasing SAR value, but then decreased rapidly. At the end of the net infiltration period of 480 minutes for the control, the stable infiltration rate was 36.5 mm/h and the cumulative infiltration value was 446 mm. These values were measured as 28 mm/h and 404 mm for treatment with a SAR value of 20, 25 mm/h and 376 mm for a treatment with a SAR value of 40, and 24.5 mm/h and 360 mm for a treatment with a SAR value of 50. Parallel to increasing irrigation water SAR values as compared to the control treatment, both infiltration rates (24-34%) and cumulative infiltration values (9-19%) decreased.
Compounds in water get into physical and chemical reactions with organic and inorganic complexes in the soil. As a result, some desired or undesired soil properties emerge. For example, the presence of calcium in the water increases the air and water permeability of the soil; the presence of sodium creates the opposite situation. Substances dissolved in water change the physical properties and chemical composition of soils, such as infiltration rate, air and water permeability, structure, porosity and looseness. In addition, the total porosity and aggregate stability index may decrease due to increasing irrigation water salinity. The high salt content of the irrigation water increases the infiltration initially, while the low calcium and magnesium contents, presence of high sodium content reduce the infiltration rate. In addition, the high pH value of the soil also results in increase in infiltration rates.

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Table 3. Infiltration rate and cumulative infiltration values measured in experimental treatments

	ECi = 0.6 dS m^{-1} and SAR = 1		ECi = 5 dS m^{-1} and SAR = 20		ECi = 10 dS m^{-1} and SAR = 40		ECi = 15 dS m^{-1} and SAR = 50	
Time	Infiltration Rate (mm/h)	Infiltration Depth (mm)	Infiltration Rate (mm/h)	Infiltration Depth (mm)	Infiltration Rate (mm/h)	Infiltration Depth (mm)	Infiltration Rate (mm/h)	Infiltration Depth (mm)
5	288.0	24	300.0	25	288.0	24	276.0	23
10	216.0	42	252.0	46	228.0	43	216.0	41
20	150.0	67	168.0	74	150.0	68	144.0	65
30	126.0	88	132.0	96	120.0	88	120.0	85
45	104.0	114	104.0	122	100.0	113	96.0	109
60	88.0	136	84.0	143	80.0	133	76.0	128
90	70.0	171	68.0	177	64.0	165	60.0	158
120	62.0	202	58.0	206	54.0	192	50.0	183
180	51.0	253	44.0	250	42.0	234	40.0	223
300	45.0	298	38.0	288	36.0	270	34.0	257
420	37.5	373	30.0	348	28.0	326	27.0	311
480	36.5	446	28.0	404	25.0	376	24.5	360
Rates of reduction by control treatment (%)			24	9	32	16	34	19

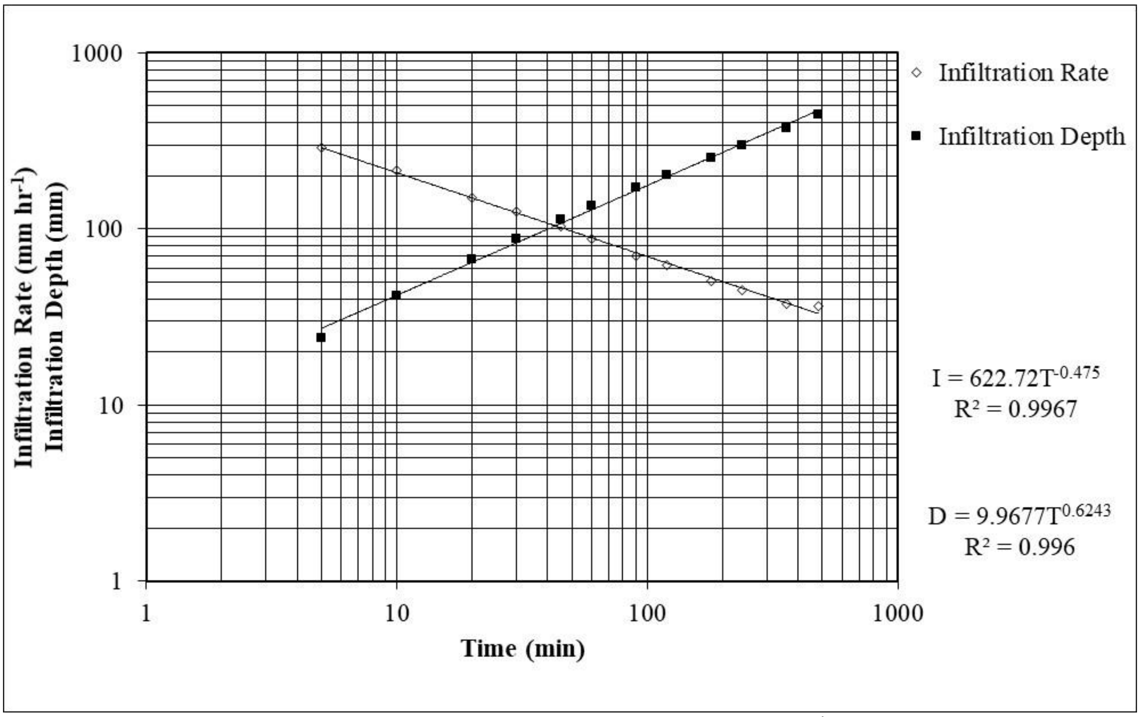

Figure 1. Infiltration graphs of water with EC = 0.65 dS m^{-1} and SAR = 1

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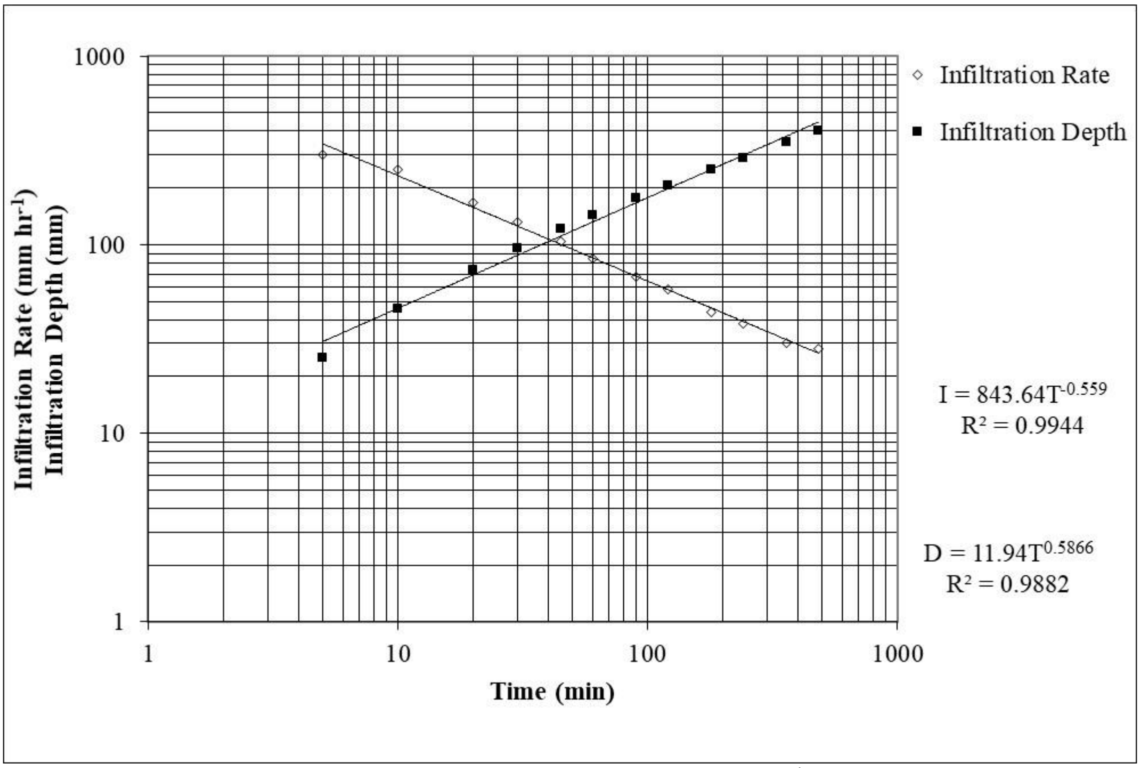

Figure 2. Infiltration graphs of water with EC = 5 dS m^{-1} and SAR = 20

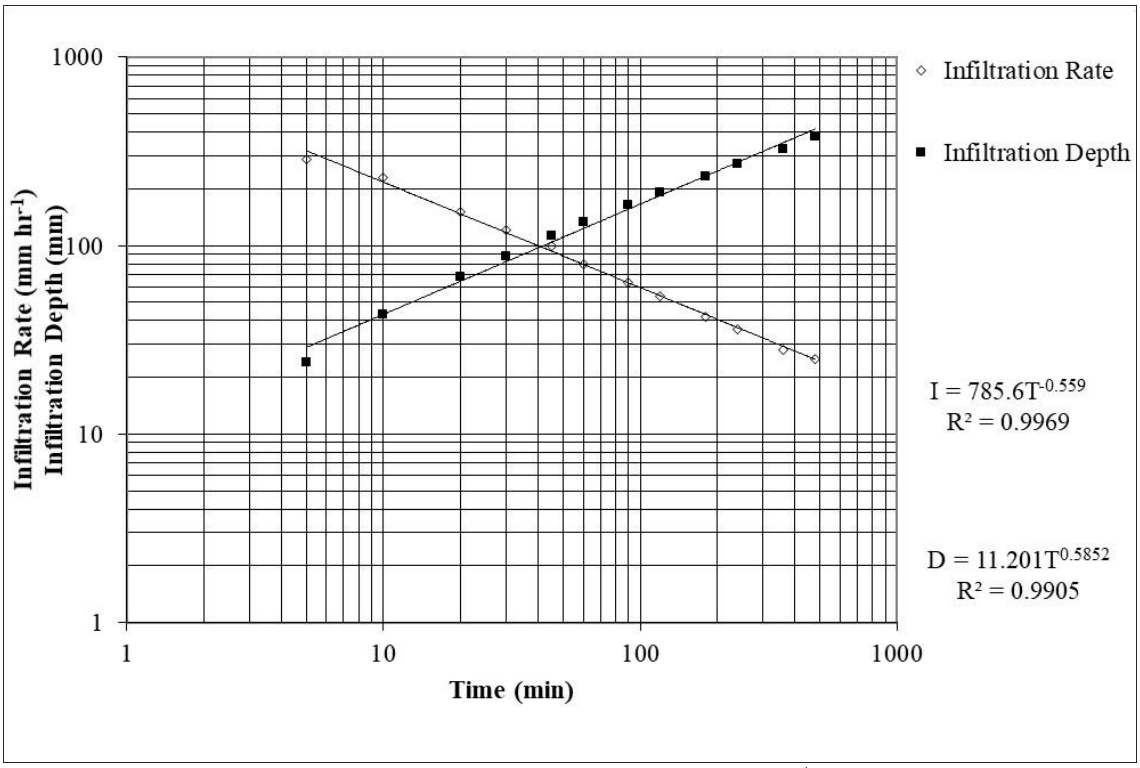

Figure 3. Infiltration graphs of water with EC = 10 dS m^{-1} and SAR = 40

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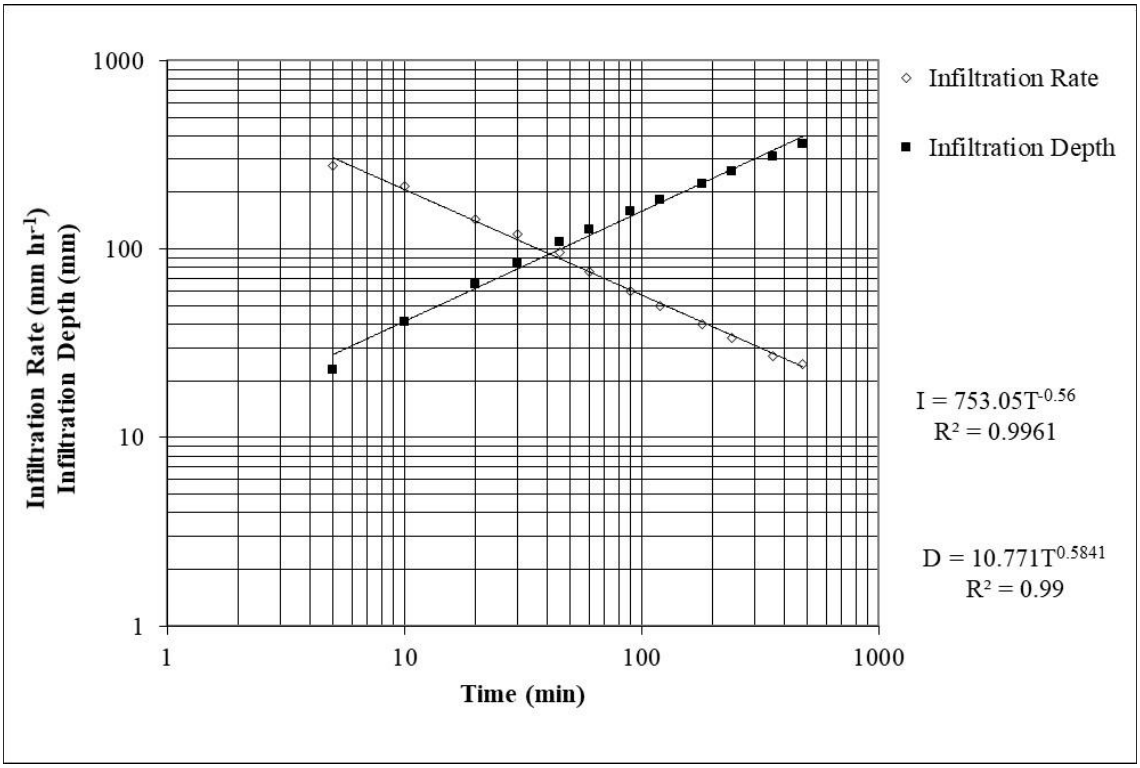

Figure 4. Infiltration graphs of water with EC = 15 dS m^{-1} and SAR = 50

The exchangeable sodium level in the soil can cause decomposition of the soil, decreasing water permeability and developmental disorders in plants, starting from 10% level (Kanber and Ünlü, 2010). While the salt concentration in the soil increases, if sodium prevails in the environment, the clay particles will be dispersed. In this case, as they adsorb excess sodium ions on the surfaces of the clay particles, a lot of water is collected around them. Excess water pushes the clay particles apart, increasing the zeta potential. As the zeta potential increases, the clays act as single grains. This situation is called dispersion. The dispersed clay particles are washed into the lower layers as fine particles, forming an impermeable layer there. Depending on the type of clay, swelling begins to appear more as a result of wetting. Air and water permeability is significantly reduced. Crusting occurs on the soil surface. The soil becomes sticky when wet and hard when it dries. Thus, a situation that is not suitable for tillage and plant cultivation begins to be seen and soil pollution emerges (Kanber et al., 1990).

Salinity and alkalinity are discrete phenomenon largely influenced by soluble salts in soil and water. Salinity induces complete convergence of salts in soils and waters. Soil alkalinity addresses the overall greater part of replaceable sodium contrasted with the other interchangeable cations, predominantly Ca, Mg, K, H and Al. Complicated relationships are utilized to portray possible impacts of Na. Sodium absorption ratio (SAR) is a proportion of general vast majority of broken down Na in water contrasted with measures of disintegrated Ca and Mg. Numerical type of this action follows from a hypothetically determined and habitually noticed relations with the share of Na held in replaceable structure in soil. Exchangeable sodium percentage (ESP) is a relative quantity of Na ion present on the soil surface and it is expressed in percentage of Cation Exchange Capacity (CEC) (Van de Graaff and Patterson, 2001).

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A few research investigated in detail the effects of salt accumulation on decay and deflocculation of soil clods through annihilation of soil structure and stopping up full-scale pores, joined by troublesome results on soil hydrological characteristics (Shainberg and Levy, 2004; Rengasamy et al., 1996; Shainberg and Letey, 1983; Minhas and Sharma, 1986; Huang et.al., 2011).
Ahmed et al. (1969) and Quirk and Schofield (1955) indicated that water holding capacity (WHC) was connected with interchangeable cations in accompanying request Ca = Mg > K > Na. In any case, a few scientists reported bigger totals of more noteworthy strength in K-immersed soils than in soils soaked with divalent cations (Cecconi et al., 1963; Ravina, 1973). Peculiarity and Schofield (1955) additionally recommended enlargement of soil particles to bring about aggregate blockage of directing pores. Clay particles expand with increasing level of monovalent interchangeable cations. Clogged soil pores then result in deflocculation, scattering and mud development especially in clay soils (Quirk and Schofield, 1955). Significance of scattering was perceived by a few agents (Frenkel et al., 1978; Pupisky and Shainberg, 1979; Shainberg et al., 1981).
Quirk (1986) and Quirk and Schofield (1955) indicated that salt-induced soil flocculation may reduce soil porosity. Elevated salinity levels, consequently, actuate substitution of pores of bigger aggregates with pores of more modest widths. Rising salinity levels increase overall porosity and total strength and increasing ECe levels with rising salinity of the water system reduce water holding capacity of the surface soil (Huang et al., 2011).

4. CONCLUSIONS

Many factors affect the infiltration rate of the soil. Sustainable irrigated farming can only be possible by evaluating irrigation water quality together with water, soil and plant components. Despite the increase in the demand for clean water resources in recent years, inadequate nutrition due to climate irregularities causes deterioration of water resources, while at the same time, it makes it necessary to use water that is considered marginal in agricultural production as irrigation water. In regions where such necessities exist, an adequate and effective drainage system must be established. In addition, a sufficient amount of leaching water should be added to each unit of irrigation water and applied accordingly.
Soil infiltration problems usually occur in the first few centimeters of the soil surface. When irrigation water containing high sodium ions is applied to the root zone of the plant, the soil structure in the upper soil layer has deteriorated. Aggregates decompose and soil pores are clogged. This situation can also be observed due to the low calcium content of the layer in question. On the other hand, low salinity irrigation waters can cause similar effects. This is due to the corrosive nature of low salinity water. Low salinity irrigation waters wash away many other soluble salts, including calcium from the surface soil, into the lower layers.
The dominance of exchangeable cations, including sodium, in soils containing large amounts of clay but with low salt concentration, causes deterioration of the soil structure. When the sodium (SAR value) adsorbed in the soil exceeds 10%, the clay complexes become dispersed, permeability decreases, tillage becomes difficult and germination weakens. This situation continues until the flocculation starts with the increase of the concentration. As can be understood from this evaluation, as a result of the use of water with a high salt concentration in irrigation, the infiltration rate decreases over time, while the cumulative infiltration value decreases in parallel. This may lead to reductions in yield and quality in plant production or even to a complete stop. This situation can also cause many undesirable environmental problems. In addition to the widespread excessive irrigation in the Harran plain, when it is combined with incorrect/incomplete agricultural practices,

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the danger of saline groundwater arises (Tas and Zaimoglu, 2001). Particular attention should be paid to the high SAR hazard in areas irrigated with drainage water. Otherwise, it is possible to encounter very difficult problems to compensate.

5. REFERENCES

Ahmed, S., Swindale, L.D., El-Swaify, S.A. (1969). Effect of adsorbed cations on physical properties of tropical black earth. 1. Plastic limit, percentage stable aggregate and hydraulic conductivity. *J. Soil Sci. 21*, 255–268.

Ame´zketa, E. (1999). Soil aggregate stability: a review. *J Sust Agric 14*, 83–151

Anonymous. (2011). Salinity management handbook. Second edition. National Library of Australia Cataloguing in Publication data. Department of Environment and Resource Management. GPO Box 2454. Brisbane Qld 4001.

Ayers, R.S., Westcot D.W. (1994). Water quality for agriculture. FAO Irrig. And Drain. Paper No.29. Rome.

Brouwer C., Goffeau A., Heibloem M. (1985). Irrigation Water Management: Training Manual No. 1 - Introduction to Irrigation. Food and Agriculture Organization of The United Nations, Roma.

Ertuğrul, H., Apan, M. (1979). Sulama Sistemlerinin Projelenmesi [Irrigation System Design]. Atatürk Univ. Press, No: 252, Erzurum, Turkey.

Felhendler, R., Shainberg, I., Frenkel, H. (1974). Dispersion and hydraulic conductivity of soils in mixed solution'. In: Transac- tions of the 10th international congress of soil science (Moscow). Nauka Pub. House, Moscow, 103–112.

Frenkel, H., Goertzen, J.O., Rhoades, J.D. (1978). Effects of clay type and content exchangeable sodium percentage, and electrolyte concentration on clay dispersion and soil hydraulic conductivity. *Soil Sci Soc Am 42*, 32–39.

Ghassemi, F., Jakeman, A.J., Nix, H.A. (1995). Salinization of land and water resources: human causes, extent, management and case studies. Cab International, 526.

Huang, C.H., Xue, X., Wang, T., De Mascellis, R., Mele, G., You, Q.G., Peng, F., Tedeschi, A. (2011). Effects of saline water irrigation on soil properties in northwest China. *Environmental Earth Sciences 63(4)*, 701-708.

Kanber, R., Unlu M. (2010). Tarımda su ve toprak tuzluluğu [Water and Soil Salinity in agriculture]. Cukurova Univ. Press, Adana, Turkey.

Kanber, R., Kırda, C., Tekinel, O. (1990). Sulama suyu niteliği ve sulamada tuzluluk sorunları [Irrigatino water quality and salinity problems]. Cukurova Univ. Press, Adana, Turkey.

Keller, J., Bliesner, R.D. (1990). Sprinkle and Tricle Irrigation. Van Nostrand Reinhold, New York.

Minhas, P.S., Sharma, D.R. (1986). Hydraulic conductivity and clay dispersion as affected by application sequence of saline and simulated rainwater. *Irrig Sci 7(3)*, 159–167.

Pupisky, H., Shainberg, I. (1979). Salt effects on the hydraulic conductivity of a sandy soil. *Soil Sci Soc Am J 43*, 429–433.

Quirk, P.J. (1986). Soil permeability in relation to sodicity and salinity. *Phil Trans R Soc Lond A 316*, 297–317.

Quirk, P.J., Schofield, R.K. (1955). The effects of electrolyte concentration on soil permeability. *Eur J Soil Sci 6*, 163–178.

Ravina, I. (1973). The mechanical and physical behavior of Ca clay soil and K clay soil. *Bertin Ecol. Stud. 4*, 131-140.

Rengasamy, P., McLeod, A.J., Ragusa, S.R. (1996). Effects of dispersible soil clay and algae on seepage prevention from small dams. *Agric Water Manage 29(2)*, 117–127.

Richards, L.A. (1954). Diagnosis and improvement of saline alkali soils. Agriculture, 160, Handbook 60. US Department of Agriculture, Washington DC.

Shainberg, I., Letey, J. (1983). Response of soils to sodic and saline conditions. *Hilgardia 52(2)*, 1–57.

Shainberg, I., Levy, G.J. (1992). Physical-chemical effects of salts upon infiltration and water movement in soils. In: Wagenet, R.J., Baveye, P., Stewart, B.A. (Eds). Interacting processes in soil science, 38–93.

Shainberg, I., Levy, G.J. (2004). Flocculation and dispersion. Encyclopedia of Soils in the Environment, 27–34.

Shainberg, I., Rhoades, J.D., Prather, R.J. (1981a). Effect of low electrolyte concentration on clay dispersion and hydraulic conductivity of a sodic soil. *Soil Soc Sci Am J 45*, 273–277.

Shainberg, I., Rhoades, J.D., Prather, R.J. (1981b). Effect of mineral weathering on clay dispersion and hydraulic conductivity of sodic soils. *Soil Soc Sci Am J 45*, 287–291.

Tas, I., Zaimoglu, Z. (2001). Yüksek tuz konsantrasyonuna sahip suların sulamada kullanımının toprak infiltrasyonu üzerine etkisi [Effects of irrigation waters with high salt concentrations on soil infiltration]. 1. Türkiye Su Kongresi. 8-10 Ocak 2001. İstanbul.

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Tedeschi, A., Dell' Aquila, R. (2005). Effects of irrigation with saline waters, at different concentrations on soil physical and chemical characteristics. *Agric Water Manage 77*, 308–322.
UNDP (1997). Aridity zones and dryland populations. An assessment of population levels in the world's drylands. UNSO/UNDP, New York
Van de Graaff, R., Patterson, R.A. (2001). Explaining the Mysteries of Salinity, Sodicity, SAR and ESP in On-site Practice in Proceedings of On-site '01 Conference: Advancing On-site Wastewater Systems by R.A. Patterson & M.J. Jones (Eds). Published by Lanfax Laboratories, Armidale, 361 – 368.
Varallyay, G. (1977a). Moisture states and flow phenomena in salt- affected soils. In: Proceedings of the Indo-Hung seminar on management of salt affected soils. Pergamon Press, Oxford, 85–102.
Varallyay, G. (1977b). Soil water problems related to salinity and alkalinity in irrigated lands. In: Arid land irrigation in developing countries. Pergamon Press, Oxford, 251-264.
Wang, B., Cui, X.H. (2004). Researches on laws of water balance at transitional zone between oasis and desert in Minqin. *Acta Acol Sin 24(2)*, 235–240.

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