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SUSTAINABLE USE OF HIGHLY SALINE WATER FOR IRRIGATION OF CROPS UNDER ARID AND SEMI-ARID CONDITIONS: NEW STRATEGIES

Wheat Yield Response to Irrigation With Saline Water Under the Mediterranean Climatic Conditions in Turkey

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Abstract

The response of wheat (*Triticum aestivum* L.) to different salinity levels of irrigation water under the Mediterranean climatic conditions was investigated in a field study at the experimental station of Cukurova University in Adana, Turkey during the 2001-2002 growing season. Saline waters with electrical conductivity values of 0.5 (fresh water), 3.0, 6.0, 9.0, and 12.0 dS/m were used for irrigation of wheat. The average grain yields ranged from 5940 to 6484 kg /ha in different treatments. Variance analysis of the grain yield data showed that the effect of salinity levels of irrigation water used in the study on grain yields was not significantly different. Average dry-matter yields varied from 1154 to 1349 g/m^2 from the different treatments at harvest time. However, treatments resulted in similar biomass yields. Since wheat was irrigated only twice during the growing season, and significant amount of rainfall received during the wheat growing period, salts added to soil with irrigation remained at insignificant level and did not affect the biomass yield of wheat. Harvest index values from the different treatments varied from 0.36 to 0.42. However, there was no significant difference among the treatments. Generally soil salinity increased with salinity content of irrigation water used in the study. Soil salinity decreased almost linearly with increasing depth in the profile. SAR values increased with increasing salinity of irrigation water. However, SAR values observed in all treatments did not constitute a serious threat to wheat growth under the study conditions. Thus, saline irrigation water can safely be used for irrigation of wheat crop in the Mediterranean region because of effective winter rainfalls leach the salts out of the root zone as long as an efficient drainage system is provided.

Key words: Saline water, wheat, trickle irrigation, water management

INTRODUCTION

The world is facing water scarcity in both quantity and quality. Limited supplies of fresh water are increasingly in demand for competing uses and create the need to use marginal quality water in agriculture (Hamdy, 1995). From the viewpoint of irrigation, the use of marginal quality waters require careful planning, more complex management practices and stringent monitoring procedures, than when good quality water is used (FAO, 1999; Beltran, 1999).

The decreasing availability of fresh water for agriculture use, while the need for production of food and fuel from plants is increasing, which is nowadays a problem common to many countries in the region. Under such condition of fresh water scarcity, agriculture is forced to use more and more waters of poorer quality or saline ones. Fortunately, there are abundant sources of those water sources that could be used successfully in irrigation, but they are still marginally used in the arid and semi arid countries of the Mediterranean. Water availability for irrigation in the region could be enhanced through proper use and management of saline water and the recycling of treated sewage water.

Saline water is a potential source for irrigation. Recent research developments on plant breeding and selection, soil crop and water management, irrigation and drainage technologies enhanced and facilitated the use of saline water for irrigating crops with minimum adverse effects on the soil productivity and environment. From the point of irrigation, the use of marginal quality waters will require careful planning, more complex management practices and stringent monitoring procedures than when good quality water is used (Hamdy, 1993; and Hamdy, 1996).

There is usually no single way to achieve safe use of saline water in irrigation. Many different approaches and practices can be combined into satisfactory saline water irrigation systems; the appropriate combination depends upon economic, climatic, social, as well as edaphic and hydrogeologic situations (Rhoades et al., 1992).

Salinity of irrigated agricultural soils can be managed satisfactorily for salt-tolerant and moderately salt tolerant crops when using saline water for irrigation (Ayars et al, 1992). Irrigation with saline water usually causes a progressive soil salinization, which is more or less severe according to salt supply, soil properties (whether clay or sandy), leaching caused by rainfall and applied irrigation technique. As the soil salinity rises, the osmotic potential soil water decreases resulting in reduced water availability and physiological diseases (Para and Cruz Romeo, 1980).

A careful selection of the crop and the variety most suited to a given environment is of paramount importance for obtaining high efficient production (Doorenbos et al, 1979). In general, Crops tolerate salinity up to threshold level above which, the yields decrease approximately linearly as salt concentrations increase (Mass and Hoffman, 1977). Using proposed linear response model (Mass and Hoffman, 1977), the maximum allowable salinity without yield decrease per unit increase in salinity beyond the threshold.

Deviation from the linear decrease occurs at yields considerably less than 50% of potential, at which level yields are unacceptable. Exceeding the threshold and knowing the threshold and slope obtained from the model, relative yield (Yr) for any given soil salinity exceeding the threshold could be calculated according to the following equation:

$$Yr = 100 - B\,(ECe - A')$$

Where:

- Yr: Relative crop yield expressed in percentage (%)
- A': The salinity threshold just beginning to decline expressed in dS/m.
- B: The slope expressed in (%) per dS/m (yield losses per unit increase in salinity).
- Ece: The mean electrical conductivity of the saturated soil extract of root-zone.

In a field experiment in 1983-86 at Kholapur, Maharashtra, wheat cv. HD2189 was grown after irrigated cotton cv. AHH 468 (crowbar method or furrow irrigation with saline water) or rainfed sorghum cv. CHS 9. Wheat was irrigated with saline water (2.4 dS/m) every 12 d (8 irrigations), at 6 growth stages (crown-root initiation, late-tillering, late-jointing, flowering, milk stage and dough stages) at 4 growth stages [not given] or at late jointing + milk stage. Wheat grain yields were decreased by 36 and 33% from 4 and 2 irrigations, respectively. Soil salinity levels increased with decrease in irrigation frequency, but this salt build up was leached out by the monsoon rains before the next winter season. The highest net returns were obtained from cotton with furrow irrigation-wheat cropping sequence (Deshmukh *et al*., 1992).

Data *et al*. (1998) estimated the production function of wheat crop under saline conditions for determining the optimal mix of saline drainage water and good quality canal water at Sampla experimental station of the Central Soil Salinity Research Institute, Karnal (India). The electrical conductivity of soil (ECe) ranged from 25 to 80 dS/m in 0-15 cm layer to about 20 dS/m at depth 100 cm. The experiment was conducted under a fix wheat-fallow rotation, a common practice generally followed in the region where good quality irrigation water is not available in adequate quantities. The experiment consisted of five level of saline irrigation treatments (ECiw = 0.5, 6, 9, 12, 18 and 27 dS/m) along with recommended agronomic and cultural practices. They obtained quadratic form of the production function, which gave the best results. Optimum yield was obtained from the treatment irrigated with canal water as 5.9 t/ha, followed by 6 dS/m as 5.69 t/ha, and 9 dS/m as 5.39 t/ha. The treatment irrigated with saline water of 12 dS/m resulted in yield of 5 t/ha; 15dS/m gave 4.51 t/ha. As the salinity level of irrigation water increased yield level decreased accordingly.

The response of wheat to varying depths of irrigation, quantity of water applied and to the drainage conditions was studied in lysimeters filled with a sandy loam soil in India. Saline water with an electricial conductivity of 8.6 dS/m was used for irrigation. (Khosla and Gupta, 1997). They concluded that the reduction in growth as well as grain yield of wheat during saline water irrigation in the undrained lysimeters was mainly associated with larger depth increments and due to the sharp rise in water table depth. The occurrence of saline water table at rather shallow depths limited the proliferation of roots to lower depths and the soil water uptake was adevesely affected.

The main objectives of this study are (1) to investigate new ways of using saline water for wheat production under arid, and semi-arid conditions; (2) to obtain the characterizing the plant growing parameters of investigated varies as a function of irrigation with saline water of different salt concentration levels; (3) to evaluate the yield production and yield loss in relation to the salt concentration level of irrigation water; (4) to asses the salt balance under different irrigation programs; (5) to classify the investigated wheat crop with respect to its salt tolerance degree; and (6) to obtain the suitable leaching fractions for obtaining high yield from investigated wheat crop irrigated with saline water; (7) to determine the WUE under saline water conditions, which is a key parameter in water saving program.

MATERIALS AND METHODS

The field experiment was conducted at the Research Station of the Irrigation and Agricultural Structures Department of the Cukurova University in Adana, Turkey during 2001/2002 wheat growing season (November-June, 2002). Description of some physical and chemical characteristics the experimental soil is given in Table 1a and 1b.

Table 1a. Description of the some physical characteristics of the experimental soil

Soil Depth	Particle Size Distribution (%)			Soil Texture	Field Capacity	Wilting Point	Saturation Water Content	Bulk Density
cm	Sand	Silt	Clay		cm^3/cm^3	cm^3/cm^3	cm^3/cm^3	g/cm^3
0-5	28	21	51	C	42	23.8	51	1.19
5-15	28	21	51	C	42	23.8	51	1.19
15-30	28	21	51	C	42	23.8	51	1.19
30-60	28	19	53	C	45	23.2	54	1.16
60-90	28	18	54	C	44	21.8	55	1.15
90-120	27	19	54	C	42	18.8	50	1.25

As shown in Table 2a, the soil of the experimental site is classified as Mutlu soil series (*Palexerollic Chromoxeret*) with clay texture throughout the soil profile. Available water holding capacity of the soil is 256.2 mm in the 120 cm soil profile.

Table 1b. Description of the some chemical characteristics of the experimental soil

Soil Depth	Soil Salinity	pH	$CaCO_3$	O.M.	Cations (me/l)				Anions (me/l)		
(cm)	(dS/m)		(%)	(%)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{-2}	Cl^{-}
0-10	0.335	6.95	5.92	1.28	1.48	1.10	0.40	0.10	2.06	0.10	0.92
10-20	0.310	6.63	5.92	1.28	1.66	1.10	0.32	0.08	2.14	0.26	0.77
20-40	0.353	6.81	6.11	1.14	1.94	1.17	0.35	0.07	2.24	0.40	0.89
40-60	0.354	6.93	6.38	0.98	1.48	0.80	0.43	0.05	1.84	0.10	0.83
60-80	0.314	7.15	6.65	-	1.45	1.31	0.44	0.05	2.04	0.34	0.88
80-100	0.324	6.99	7.40	-	1.52	1.09	0.56	0.05	2.14	0.21	0.87
100-120	0.295	6.95	7.45		1.16	0.97	0.57	0.05	1.90	0.12	0.74

Table 1b indicates that soil salinity at planting time is well below the salinity threshold level for reducing wheat yields of ECe=6.0 dS/m. Wheat is classified as medium tolerant to soil salinity (Maas, 1986).

Crop Variety

Balatilla, a bread variety of wheat (*Triticum aestivum* L.) was planted on 24 November 2001 at a row spacing of 12.5 cm, and after plant establishment dikes were constructed around each plot since border irrigation was used due to close growing nature of wheat crop. Wheat grain yield will be determined by harvesting all plants in an area of 8 m^2 in each plot.

All plots received the same fertilizer treatment. At planting, 40 kg/ha urea (46% N) was applied. Ammonium nitrate (26% N) was applied at a rate of 400 kg/ha on February 23, 2002; Plots also received 160 and 200 kg/ha urea on March 12, and April 15, 2002, repectively.

Saline Irrigation Water

The saline water was prepared by mixing fresh water (0.5 dS/m) with sea water (54 dS/m) in order to obtain an average salinity level of 12 dS/m in a concerete pool with dimensions of 10m x 10 m x 2.5 m at the experimental site. Sea water was transported by a tanker from the Mediterranean Sea 65 km away from the experimental field. Saline irrigation water with electrical conductivities (ECw) of 3.0, 6.0, 9.0, and 12.0 dS/m (being various dilutions of stock solution in the pool with irrigation canal water) along with 0.5 dS/m canal water was applied commencing on March 29, 2002.

Treatments and Experimental Design

There were 6 different treatments in the study. Saline irrigation water with ECw of 3.0, 6.0, 9.0, and 12.0 dS/m (being various dilutions of stock solution in the pool with irrigation canal water) along with canal water with salinity of 0.5 dS/m. In addition, a treatment was included in the study by applying a 10% leaching fraction to 12.0 dS/m treatments after flowering. Thus, a total of 6 treatments were studied. Namely, 0.5, 3.0, 6.0, 9.0, and 12.0 dS/m; and 12.0+10% leaching after flowering stage were condidered. A completely randomised block design with three replications was utilized for the wheat experiment. Each plot will be 5 m long and 2.15 m wide. There will be a total of 18 plots in the study.

Saline irrigation water was prepared by mixing sea water with fresh water and stock saline water with electrical conductivity of 12.0 dS/m will be attained. Gated pipes were used for applying water to plots. For mixing saline water and fresh water at specified salinity level, tanks were utilized at the head of each plot. Flow meters were utilized to determine the volume of water applied to each plot. The amount of water to be applied to each treatment plot will be based on soil water deficit within the 120 cm soil profile during the irrigation interval of 14 days (Sezen *et a*l., 2001).

Measurements

Phenological growth stages

The phonological growth stages were observed weekly throughout the study. For this purpose, plants in each replicate for each treatment were randomly selected representing all the characteristics of its treatment. Occurrences of different growth stages were monitored on these plants. Plant height measurements were also carried out on these selected plants and average plant height was calculated for each treatment.

Dry matter and leaf area index

The development of the above-ground portion of the crop was monitored by destructive sampling during the season. Plant samples consisted of all plants within 0.5 m of a row were taken at two- week intervals. The plants were bagged and taken to the laboratory for determination biomass yield and leaf area index. Leaf area of the samples was measured with an optical plant area meter. After leaf area measurements, all leaves and stems were dried in the oven at 68°C until constant weight was achieved.

Stomatal conductance

Stomatal conductance measurements were carried out on five main treatments (0.5, 3.0, 6.0, 9.0, and 12.0 dS/m) during the vegetative growth stage before and after irrigation. The measurement is done with an automatic porometer (LICOR, inc, Model LI-1600), that diffuses water vapor. From each treatment fully developed upper two leaves were taken for measurement. Measurements were carried out during noon time.

Soil water

Soil water in each experimental plot was monitored with a neutron probe as well as by gravimetric sampling at 0-20, 20-40, 40-60, 60-80, 80-100 cm depths every two-week prior to each irrigation application. An access tube was installed in each treatment plot to a depth of 120 cm. A calibration equation developed for the experimental site was used to calculate the soil water in the profile prior to irrigation.

Soil salinity

At planting, and at flowering stage all treatment plots were soil sampled at depth intervals of 0-10 10-20 cm, 20-40 cm, 40-60, 60-80, 80-100 cm using an auger. Soil samples were air-dried and thencrushed to pass through a 2 mm sieve. The electrical conductivity of the soil samples was measured on saturation extracts (Ece).

Crop water use (evapotranspiration)

Water consumption of the wheat was calculated through use of water balance equation described by Garrity et al. [1].

$$ET \quad I \quad P \quad S \quad D \qquad (1)$$

where ET is evapotranspiration (mm), I irrigation (mm), P precipitation (mm), D deep percolation (i.e., drainage, mm) and S is change of soil water storage in a given time period t (days) within plant rooting zone. The amount of water above the field capacity is considered as deep percolation in yhis study.

Water use efficiency (WUE)

Water use efficiency (kg/m^3) was computed as the ratio of grain yield (kg/m^2) to water use (m). Irrigation water use efficiency was determined as the ratio of grain yield for a particular treatment to the applied water for that treatment (Howell et al., 1994).

$$WUE= Y/ET \qquad (2)$$

Where WUE is water use efficiency (kg/m^3); Y is grain yield (kg/m^2); and ET is water use (m).

Harvest Index (HI)

Harvest index (HI) is defined as the ratio of grain yield (kg/m^2) to aboveground biomass yield and calculated as:

$$HI=Y/DM \qquad (3)$$

Where HI is harvest index, Y is grain yield (kg/m^2), and DM is dry matter yield (kg/m^2).

RESULTS AND DISCUSSION

The 2001-2002 wheat growing season in the experimental area had significantly higher than the long-term average annual rainfall of 630 mm during the season as 742 mm (Figure 1). Table 2 summarizes the average monthly climate data compared to the long-term mean climatic data for the Lower Seyhan Plain, where the experiment was carried out. Because of the above normal rainfall during the wheat growing season in the experimental area, wheat was irrigated twice. The first irrigation application was made on March 22, 2002 and 100 mm of water was applied to treatments with different salinity levels. Treatment of 12.0 dS/m+ 10% leaching received 110 mm. The second irrigation was applied on May 7, 2002 and 80 mm of irrigation water with different salinity contents were applied to the treatment plots. Treatment of 12.0 dS/m+ 10% leaching received 88 mm of irrigation water. Thus, a total of 180 mm of irrigation water with different salinity levels were applied to treatments except treatment 12dS/m+10% LF received 198 mm of irrigation water. Wheat in the Lower Seyhan Plain is not irrigated in general due to the sufficient winter rainfalls received during the growing season. However, the distribution of rainfall sometimes results in water shortages during the growing season and then supplemantary irrigation is required in the Mediterranean region of Turkey.

Table 2. Histori cal mean monthly and growing season climatic data of the experimental area

Climatic Parameters	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Long-term average								
Average Temperature (C)	15.1	11.1	9.9	10.4	13.1	15.2	21.4	28.0
Rainfall (mm)	67.2	118.1	111.7	92.8	67.9	25.4	25.6	4.8
Relative Humidity (%)	63	66	66	66	66	69	67	66
Wind Speed (m/s)	1.6	1.9	2.2	2.2	2.3	1.6	1.9	2.5
Evaporation, CAP (mm)	66.3	47.0	47.3	56.1	84.9	118.6	195.6	320.5
2001-2002 Growing Season								
Average Temperature (C)	13.9	10.7	7.9	12.3	14.7	16.5	21.4	26.6
Rainfall (mm)	88.1	320.9	109.2	68.1	40.3	88.8	22.0	0.8
Relative Humidity (%)	67.4	78.2	66.1	64.7	67.4	76.0	68.4	62.9
Wind Speed (m/s)	1.6	1.8	2.1	2.3	2.3	1.7	2.0	2.4
Evaporation, CAP (mm)	73.4	36.1	58.9	64.0	88.9	72.5	155.2	215.5
Solar Radiation (cal/cm^2)	6527	3987	6923	8578	11108	12223	15710	16875

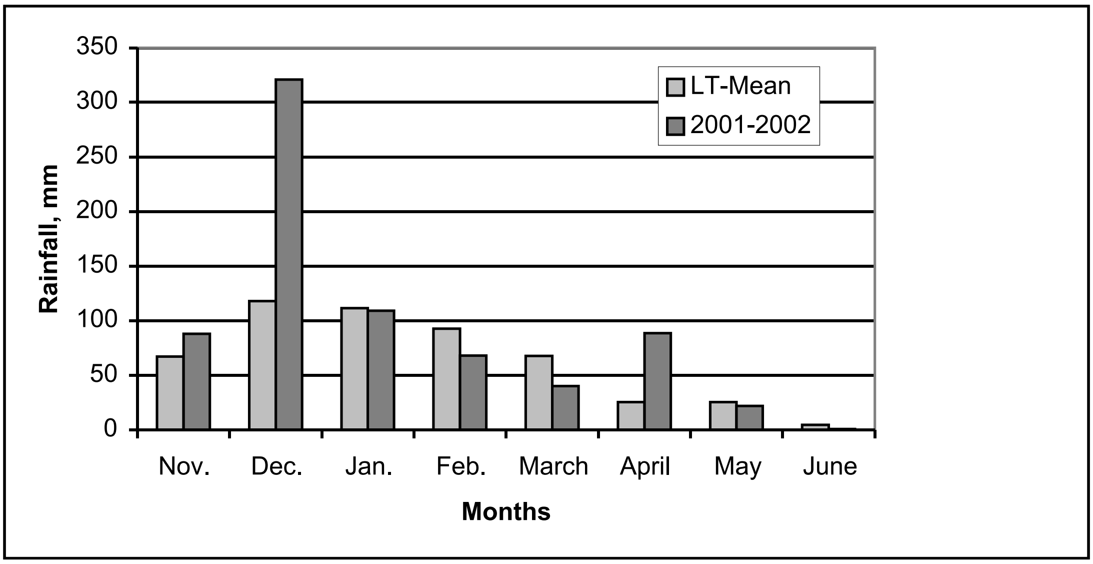

Fig. 1. Long-term and 2001-2002 wheat growing season monthly rainfalls, mm

Wheat grain yields, dry matter yields, waster use, water use efficiency, harvest index and 1000-grain weight values obtained from treatments irrigated with water with different salinity levels are shown in table 3. As indicated in table 3, the average grain yields ranged from 5940 to 6484 kg /ha in different treatments. Variance analysis of the grain yield data showed that the effect of salinity levels of irrigation water used in the study on grain yields was not significantly different (Table 4). Therefore, treatments resulted in similar wheat grain yields in this experiment. This result is expected because wheat was irrigated twice during the growing season due to significant amount of rainfall receivedin the study area in year 2002.

Table 3. Grain and dry matter yield, water use and water use efficiency data for the treatments

Salinity Of Irrigation Water (dS/m)	Dry Matter Yield (kg/ha)	Grain Yield (kg/ha)	HI	Seasonal Irrigation (mm)	Water Use (mm)	WUE (kg/m^3)	1000 Grain Weight (g)
0.5 (FW)	11500	6176	0.41	180	480	1.286	45,2
3.0	12000	5940	0.40	180	461	1.288	46,1
6.0	12620	6484	0.40	180	496	1.307	46,4
9.0	12850	6373	0.36	180	462	1.379	45,1
12.0	11650	6391	0.42	180	452	1.414	46,2
12.0+10%	11530	6427	0.38	198	445	1.444	46,8

Table 4. Analysis of variance for grain yield data

Variation Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Replication	2	1572352.111	786176.056	7.0769	0.0122
Treatments	5	626553.778	125310.756	1.1280	0.4057
Error	10	1110906.556	111090.656		
Total	17	3309812.444			

Coefficient of Variation: 5.29%

Average dry-matter yields varied from 1154 to 1349 g/m^2 from the different treatments at harvest time. However, treatments resulted in similar biomass yields. Since wheat was irrigated only twice during the growing season, and significant amount of rainfall received during the wheat growing period, salts added to soil with irrigation remained at insignificant level and did not affect the biomass yield of wheat.

As indicated by the table 3, a total of 180 mm of irrigation water with different salinity concentration were applied to treatments without any leaching. The treatment with 10 % leaching received a total of 198 mm of irrigation water. Seasonal water use of wheat in different treatments ranged from 452 to 596 mm.

Since significant amount of rainfall received during the growing season, approximately 40 % of the total rainfall was considered as effective rainfall. Thus, the amount of rainfall greater than soil water deficit in the soil profile was considered as deep percolation. Thus, considerable amount of deep percolation occurred in this particular year, and leached out significant amount of salts from the profile. Water use efficiency (WUE) values from the treatments ranged from 1.286 to 1.444 kg/m^3. As the salinity level of irrigation water increased WUE values also increased slightly. However, the WUE values were not significantly different among the treatments studied.

Harvest index (HI), defined as the ratio of grain yield to dry matter yield, values from the different treatments are given in table 3. As shown in table 3, harvest index values from the different treatments varied from 0.36 to 0.42. However, there was no significant difference among the treatments as indicated by the variance analysis table.

Average 1000-grain weight values from the different salinity treatments ranged between 43.78 and 47.32 g. The variance analysis of the 1000-grain weight data is given in table. As indicated in the table, 1000-grain weight values obtained from the treatments were not significantly different. Thus, salinity of irrigation water did not have any effect on grain weight of wheat under the Mediterranean climatic conditions.

Soil Salinity (Ece)

Soil salinity profiles resulting from the different salinity treatments are shown in figures 2 through 7 Soil salinity profiles were established at planting, at flowering, and at harvest for each treatment studied. As shown in the figures, soil salinity at planting varied from 0.27 dS/m in surface soil layers to 0.50 dS/m in deeper layers. However, soil salinity throughout the soil profile was very low in the experimental soil. Soil salinity increased slightly in the surface layer (ECe=0.35 dS/m) in the treatment irrigated with fresh water.

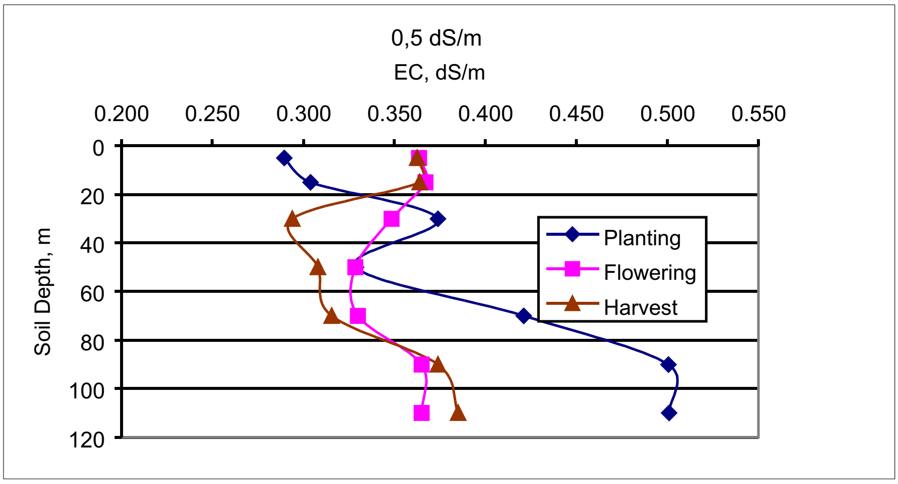

Fig. 2. Soil salinity profiles at planting, flowering and harvest for 0.5 dS/m treatment

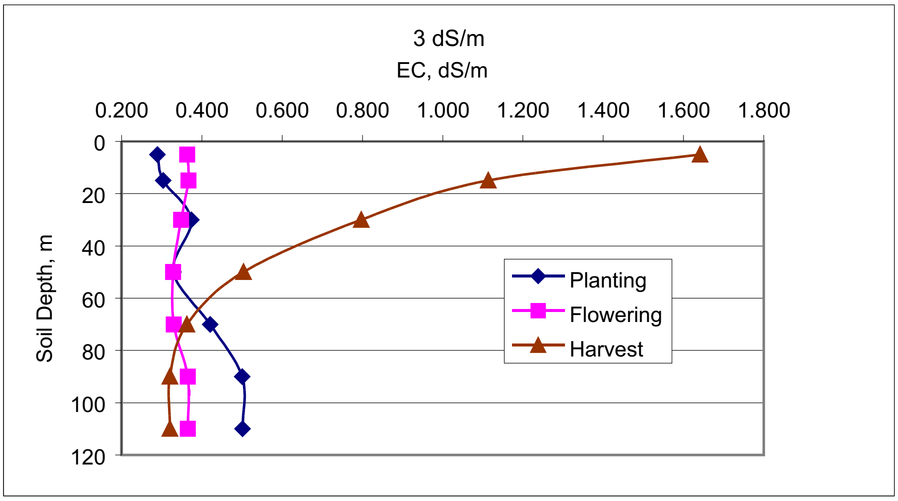

Fig. 3. Soil salinity profiles at planting, flowering and harvest for 3.0 dS/m treatment

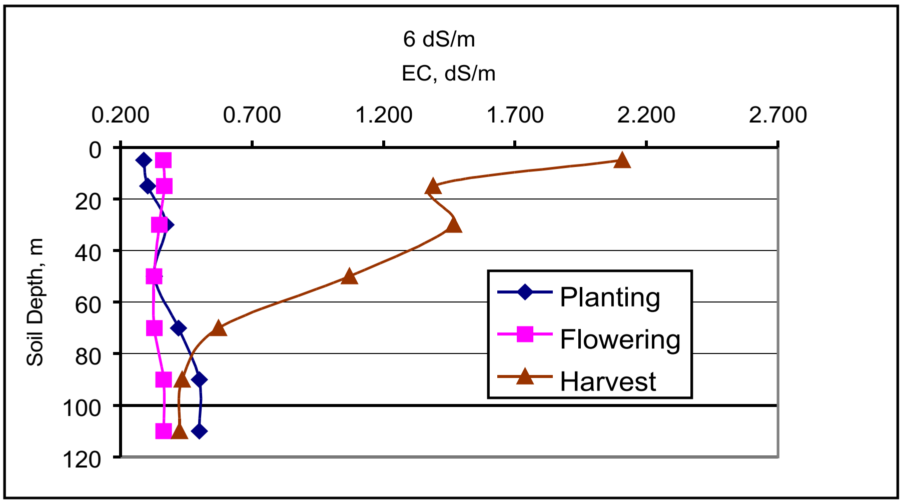

Fig. 4. Soil salinity profiles at planting, flowering and harvest for 6.0 dS/m treatment

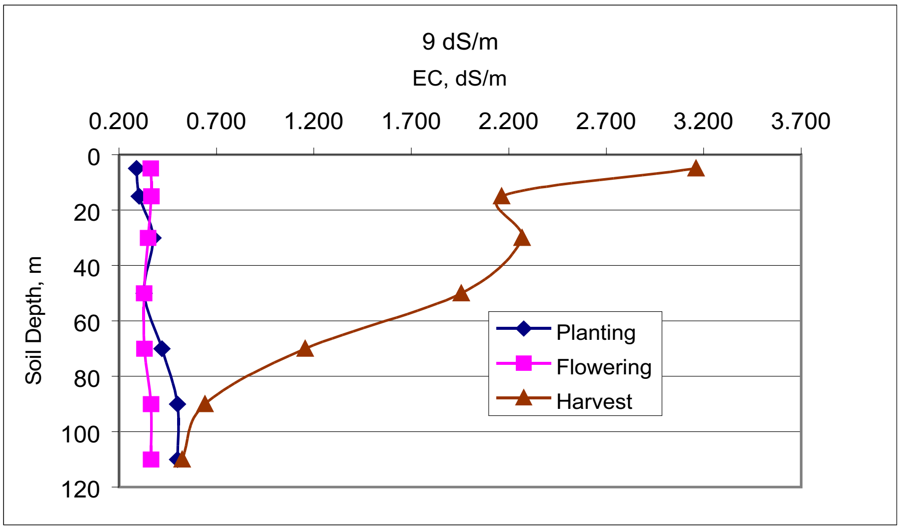

Fig. 5. Soil salinity profiles at planting, flowering and harvest for 9.0 dS/m treatment

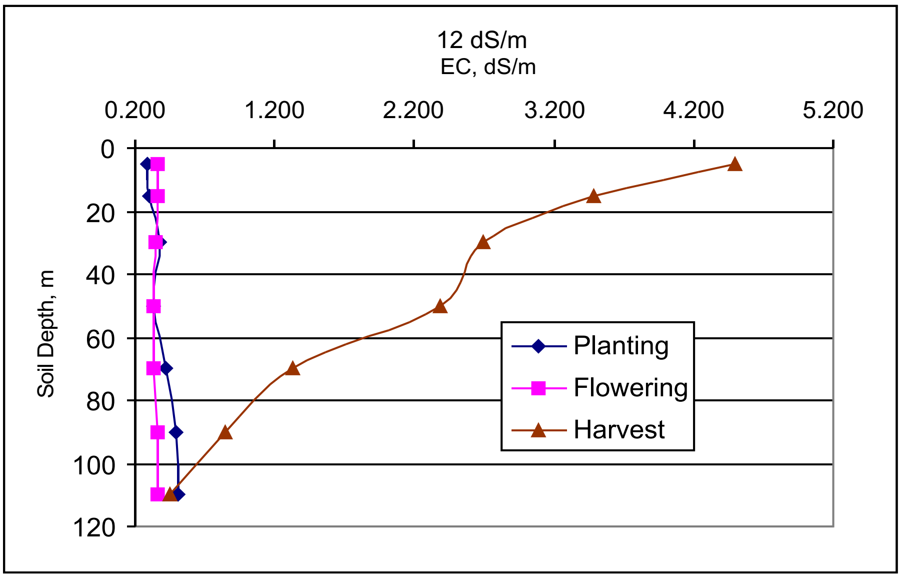

Fig. 6. Soil salinity profiles at planting, flowering and harvest for 12 dS/m treatment

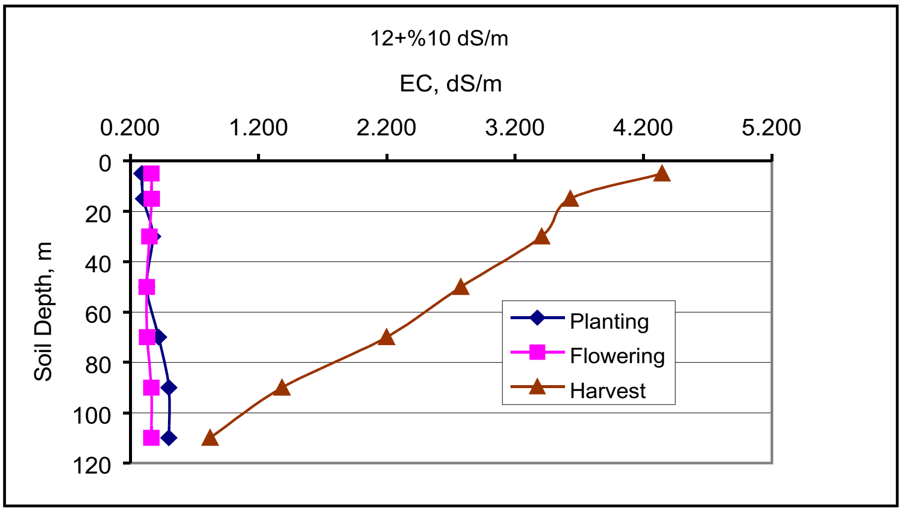

Fig. 7. Soil salinity profiles at planting, flowering and harvest for 12+10% dS/m treatment

Generally soil salinity increased with salinity content of irrigation water used in the study. Highest soil salinity was observed in the 0-10 cm soil layer in treatments irrigated with ECw of 12 dS/m and 12 dS/m+10% leaching as ECe=4.3 dS/m. Then soil salinity decreased almost linearly with increasing depth in the profile. Soil salinity in the 100-120 cm soil layer was 0.8 dS/m in these two most saline treatment plots. There was no significant difference is soil salinities in these two treatments. Soil salinity during the wheat growing period did not reach the threshold salinity level of 6.0 dS/m (Ayers and Westcot, 1985).

The treatment irrigated with saline irrigation water of 9.0 dS/m resulted in soil salinity of 3.2 dS/m in the top layer (0-10 cm) and 2.2 dS/m in the 10-20 cm layer. Then soil salinity decreased with increasing depth. The lowest salinity in the soil profile was observed in the 100-120 cm soil layer with 0.6 dS/m. Soil salinity during the flowering growth stage was very similar in all treatments and had salinities lower than 0.5 dS/m throughout the profile.

The treatment irrigated with saline irrigation water of 6.0 dS/m resulted in soil salinity of 2.1 dS/m in the top layer (0-10 cm) and 1.4 dS/m in the 10-20 cm layer. Then soil salinity decreased with increasing depth. The lowest salinity in the soil profile was observed in the 100-120 cm soil layer with 0.5 dS/m.

The treatment irrigated with saline irrigation water of 3.0 dS/m resulted in soil salinity of 1.65 dS/m in the top layer (0-10 cm) and 1.1 dS/m in the 10-20 cm layer. Then soil salinity decreased with increasing depth. The lowest salinity in the soil profile was observed in the 100-120 cm soil layer with 0.4 dS/m.

Rainfalls received during the growing season especially prior to flowering stage leached out the salts from the profile in all treatments studied. Irrigation application after the flowering stage resulted in increased soil salinities in saline irrigation water treatments since the rainfall received after flowering stage was not sufficient to leach out salts from the profile. Thus, saline irrigation water can safely be used for irrigation of wheat crop in the Mediterranean region because of effective winter rainfalls leach the salts out of the root zone as long as an efficient drainage system is provided.

Variation of pH of the saturation extracts under different treatments at harvest is given in Table 3.11. As indicated by the table, average pH values remained between 7.0 and 8.0 in all plots. There were no significant difference among the treatments with respect to pH values of the saturation extracts. Thus, pH is not affected by the saline irrigation water applications.

Average Na and Ca+Mg contents at different depths under different salinity treatments are given in table 3.12 and 3.13 , respectively. As shown in table, average Na contents generally increased with increasing salinity of irrigation water. Highest Na content was measured in the treatment irrigated with 12 dS/m +10% leaching as 26.88 meq/L in the top layer (0-10 cm), followed by 12.0 dS/m treatment as 25.50 meq/L. Na concentration decreased with increasing depth in the soil profile. Lowest Na concentration in general was determined in the 100-120 cm soil layer.

Highest average Ca+Mg contents were also measured in the surface layer of 0-10 cm under the treatment irrigated with 12 dS/m +10% leaching as 15.50 meq/L, and followed by 12.0 dS/m treatment with 13.50 meq/L in the 0-10 cm layer. In treatment irrigated with fresh canal water, highest Ca+Mg content was measured in 80-100 cm soil layer.

Highest average SAR value was determined in the top layer of soil as 9.74 in the treatment irrigated with water of 9.0 dS/m, followed by 12.0 dS/m treatment as 7.53 and 7.11 in the treatment irrigated with 12 dS/m +10% leaching. In general, SAR values increased with increasing salinity of irrigation water. However, SAR values observed in all treatments did not constitute a serious threat to wheat growth under the study conditions.

Stomatal Conductance (mmol/m^2 s)

Average stomatal conductances of wheat leaves measured in different dates under different treatments are given in table 5, and in figures 8 and 9.

Table 5. Stomatal conductance variation with salinity content of irrigation water

Salinity Treatments	Observation Dates					
	April 8	April 12	April 15	May.03	May.10	May.17
0,5 dS/m	760,7	698,7	398	1046	678	571,7
3.0 dS/m	936,7	661,3	309,7	776	763,7	688,7
6.0 dS/m	752,7	664,3	293	989	705,3	552,3
9.0 dS/m	382	608,7	253,3	666	678	704
12.0 dS/m	559	632,7	232,3	1012	695,3	758
12.0 + 10% dS/m	826	839	305,3	1034	607,3	830,7

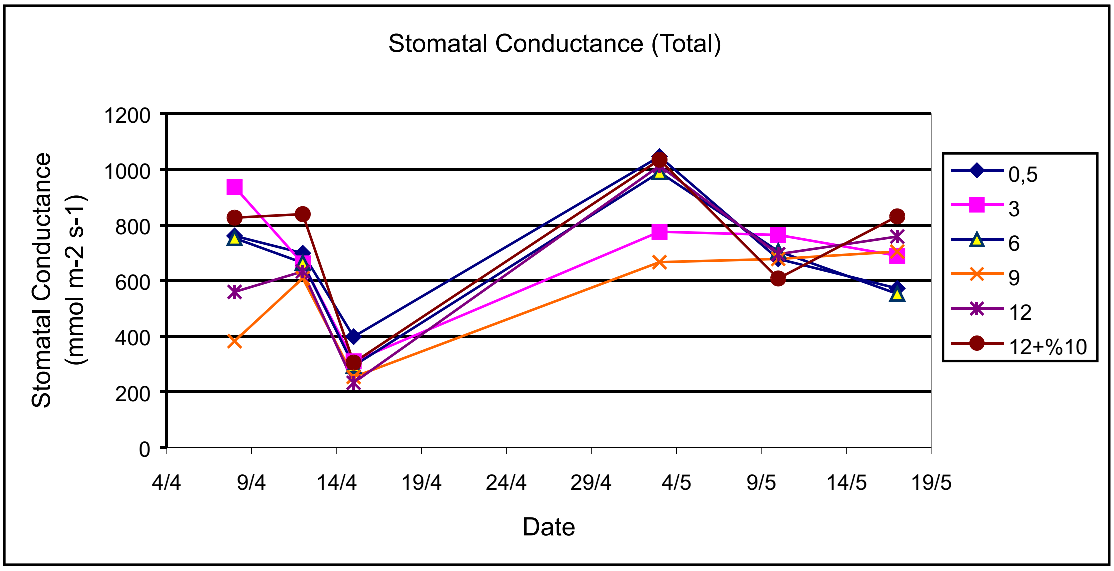

Fig. 8. Variation of stomatal conductance values of wheat leaves under different treatments

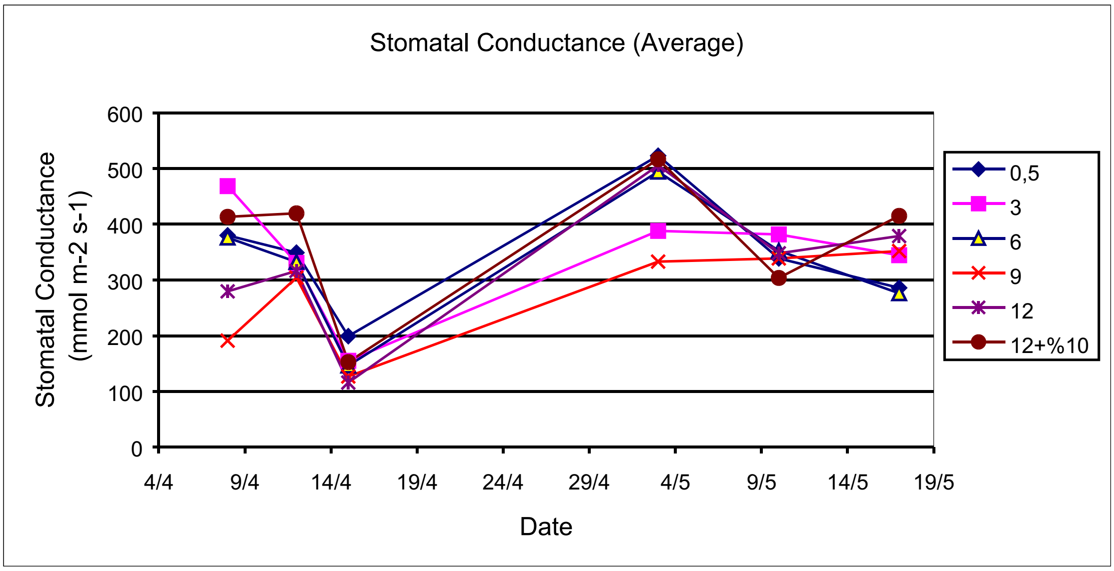

Fig. 9. Variation of stomatal conductance values of wheat leaves under different treatments

As indicated in the table, stomatal conductance measurements were started on April 8 and continued until May 17, 2002. Stomatal conductance (upper+lower epidermis) values on April 8, was highest in 3.0 dS/m treatment followed by 12 dS/m+10% leaching treatment. The lowest average stomatal conductance was observed in treatment of 9.0 dS/m as 382 mmhol/m^{2}s. A total of 5 mm of rainfall recieved prior to measurements on the same day. On April 12, stomatal conductances were very similar in all treatments except in 12 dS/m+10% leaching, in which highest value was measured as 839 mmol/m^{2}s. Stomatal conductance values decreased in all treatments on April 15. The highest stomatal conductance was measured in treatment irrigated with fresh water, and the lowest was observed in treatment of 12.0 dS/m. On May 3 a total of 2 mm of rainfall was received before the measurements, stomatal conductances reached their highest values in most treatments excep in treatment of 3.0 dS/m. Highest stomatal conductance was measured in treatment irrigated with fresh water followed by 12dS/m+10, and 12 dS/m treatments. On May 7, 80 mm of irrigation water of different salinity content was applied to treatment plots. Average stomatal conductance values slightly decreased on May 10 as compared to May 3 values. A total of 2 mm of rainfall was received on May 16. On May 17, slightly decreased on low salinity treatments, and slightly increased on higher salinity treatments.

CONCLUSIONS

The response of wheat (*Triticum aestivum* L.) to different salinity levels of irrigation water under the Mediterranean climatic conditions was investigated in a field study at the experimental station of Cukurova University in Adana, Turkey during the 2001-2002 growing season. Saline waters with electrical conductivity values of 0.5 (fresh water), 3.0, 6.0, 9.0, and 12.0 dS/m were used for irrigation of wheat.

The average grain yields ranged from 5940 to 6484 kg /ha in different treatments. Variance analysis of the grain yield data showed that the effect of salinity levels of irrigation water used in the study on grain yields was not significantly different.

Average dry-matter yields varied from 1154 to 1349 g/m^2 from the different treatments at harvest time. However, treatments resulted in similar biomass yields. Since wheat was irrigated only twice during the growing season, and significant amount of rainfall received during the wheat growing period, salts added to soil with irrigation remained at insignificant level and did not affect the biomass yield of wheat.

Harvest index values from the different treatments varied from 0.36 to 0.42. However, there was no significant difference among the treatments.

Generally soil salinity increased with salinity content of irrigation water used in the study. Highest soil salinity was observed in the 0-10 cm soil layer in treatments irrigated with ECw of 12 dS/m and 12 dS/m+10% leaching as ECe=4.3 dS/m. Then soil salinity decreased almost linearly with increasing depth in the profile.

Highest average SAR value was determined in the top layer of soil as 9.74 in the treatment irrigated with water of 9.0 dS/m, followed by 12.0 dS/m treatment as 7.53 and 7.11 dS/m in the treatment irrigated with 12 dS/m +10% leaching. In general, SAR values increased with increasing salinity of irrigation water. However, SAR values observed in all treatments did not constitute a serious threat to wheat growth under the study conditions.

Rainfalls received during the growing season especially prior to flowering stage leached out the salts from the profile in all treatments studied. Irrigation application after the flowering stage resulted in increased soil salinities in saline irrigation water treatments since the rainfall received after flowering stage was not sufficient to leach out salts from the profile. Thus, saline irrigation water can safely be used for irrigation of wheat crop in the Mediterranean region because of effective winter rainfalls leach the salts out of the root zone as long as an efficient drainage system is provided.

Water use efficiency (WUE) values from the treatments ranged from 1.286 to 1.444 kg/m^3. As the salinity level of irrigation water increased WUE values also increased slightly. However, the WUE values were not significantly different among the treatments studied.

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