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EFFECT OF SUPPLEMENTARY SALINE IRRIGATION ON YIELD AND STOMATAL CONDUCTANCE OF WHEAT UNDER THE MEDITERRANEAN CLIMATIC CONDITIONS

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SUMMARY- 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 (canal 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. The effect of salinity levels of irrigation water used in the study on grain yields was not significantly different (P<0.4057). Average dry-matter yields varied from 1506 to 1691 g/m^2 from the different treatments at harvest time. However, treatments resulted in similar biomass yields (P<0.3664). Water use efficiency (WUE) values from the treatments ranged from 1.29 to 1.44 kg/m^3. As the salinity level of irrigation water increased WUE values also increased slightly. Harvest index (HI) values from the different treatments varied from 0.38 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. There was no well-defined relationship between stomatal conductances of wheat leaves and irrigation water salinities under the study conditions. Thus, the results obtained provide a promising option for the use of poor quality water can be used for irrigation of wheat crop in the Mediterranean region without undue yield reduction and soil degradation since 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 yield, dry matter yield, water management, water use efficiency, stomatal conductance

RESUME*- La réponse et la conductance stomatale du blé (Triticum aestivum L.) aux différents niveaux de salinité de l'aux d'irrigation dans les conditions climatiques méditerranéennes a fait l'onjet d'une étude menée à la expérimentale de l'Université de Cukurova à Adana, Turquie pendant la saison 2001-2002. Des eaux salées ayant des valeurs de conductivité électrique de 0.5 (eau douce), 3.0, 6.0, 9.0, et 12.0 dS/m ont été utilisée pour l'irrigation de blé. Les rendements moyens en graines variaient de 5940 à 6484 kg/ha dans les différents traitements. L'analyse de la variance des données des rendements en graines a montré que l'effet des niveaux de salinité de l'eau d'irrigation utilisée dans l'étude sue les rendements en graines n'était pas significantivement différent.Les rendements moyens en matiére séeche variaient de 1154 à 1394 g/m2 dans les différents traitements à l'époque de la récolte. Toutefois, les traitements montraient presque les mêmes valuers des rendements en biomasse. Puisque le blé n'a été irrigué que deux fois pendant le cycle cultural et vu les pluies assez importantes reçues pendant le cycle, les sels apporté au sol avec l'eau d'irrigation sont restés à des niveaux acceptables et n'ont pas affecté le rendement en biomasses du blé. En général, la salinité du sol a augmenté avec la teneur en sel de l'eau d'irrigation utilisée dans l'étude. Donc, l'eau d'irrigation salée peut être utilisée pour l'irrigation de la culture de blé dans le région méditerranéennes du fait des pluies efficaces hivernales qui lessivent les sels de la zone racinaire, tant que l'on prévoit un système de drainage efficace.*

***Mots clés:** blé, salinité, l'eau salée, conductance stomatale*

INTRODUCTION

Supplies of good quality irrigation water are expected to decrease in the future because the development of new water supplies will not keep pace with the increasing water needs of industries and municipalities. Thus, irrigated agriculture faces the challange of using less water, in may cases of poorer quality, to provide food and fiber for an expanding population. Some of the these future water needs can be met by using available water supplies more efficiently, bu in may cases it will prove necessary to make increased use municipal waste waters and irrigation drainage waters. Limited supplies of fresh water are increasingly in demand for competing uses and create the need to use marginal quality water in agriculture. 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 (Oster, 1994; Beltran, 1999; Hamdy, 2002). When the availability of freshwater is limited, agriculture is likely to be forced to make increasing use of nonconventional waters, either brackish water or sewage effluents (Hamdy, 1999; Dinar *et al*., 1986).

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 (Shalhavet, 1994; Rhoades *et al*, 1992; Pereira, 1994).

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; Rhoades, 1999; Oster and Grattan, 2002; Bradford and Letey, 1993).

Salinity of irrigated agricultural soils can be managed satisfactorily for salt-tolerant and moderately salt tolerant crops when using saline water for irrigation (Ayers and Westcot, 1985; Hamdy, 2002). 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 (Shannon *et al*., 1994).

A careful selection of the crop and the variety most suited to a given environment is of paramount importance for obtaining high efficient production. In general, crops can tolerate salinity up to threshold level above which, the yields decrease approximately linearly as salt concentrations increase (Maas, 1986; Letey *et al*, 1985).

Wheat (*Triticum aestivum*) is one of the most important cereal crops of the world to nourish the mankind. It is grown in wide range of climatic zone and mostly in irrigated conditions. In the arid and semi-arid areas, saline ground water is a common feature. Irrigation with saline water throughout the growth period of crops resulted in deterimental effect on growth and yield potential of the crops. Therefore, it will be of vital interest for scientist to try to overcome the salinity menace to predict the wheat crop growth development and yield potential with varying salinity of irrigation water on the basis of long term experimentation (Chauhan and Singh, 1993).

Chauhan and Singh (1993) conducted a seven-year consecutive saline irrigation experiment in India and conclude that in light textured soils and semi arid climatic conditions, wheat can be grown upto EC_{iw}-8 dS/m comparable to control (canal water). The saline irrigation at EC_{iw}-12 and 16 dS/m reduced wheat yield by 21 and 37 per cent over control with negative significant correlation (r = -0.42). The reduction in yield mainly caused by poor germination and tillering, stunted growth and to some extent by low 1000 grain weight.

Datta *et al*. (1998) carried out an experiment in Karnal (India) using five levels of saline irrigation treatments (ECiw = 0.5, 6, 9, 12, 18 and 27 dS/m) along with recommended agronomic and cultural practices. 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; 18 dS/m gave 4.51 t/ha. As the salinity level of irrigation water increased yield level decreased accordingly.

A research aimed at investigating the possibility of applying supplemental irrigation to wheat and barley during their sensitive phenophases of flowering and seed formation using brackish water with salinity levels generally considered too high for its use (EC of 3–9 dS/m) was conducted in a greenhouse at the Mediterranean Agronomic Institute in Bari, Italy. Results showed the possibility of securing high yields, with mean reductions of only 21% in barley and 25% in wheat compared to the fully, fresh-water irrigated control, through the application of limited amounts of brackish water. The sustainability of the practice is presumably high, due to the limited amounts of added salts, which can be easily leached out even by a modest precipitation (Hamdy *et al.,* 2005).

In the Mediterranean climate, rainfed cereal crops are planted in autumn and harvested in late spring, relying on the rains during this period for the conclusion of their cycle; the vagaries of rains, however, often put at risk the final harvest. Thus, supplemantal irrigation of wheat is widely practiced in the region to avoid water shortages. Reuse of drainage water for crop production is a common practice in downstream section of the Lower Seyhan Irrigation Project (LSP) area in the Mediterranean region of Turkey. Therefore, effective salinity control measures must be implemented for sustainable irrigated agriculture, which requires safe use of saline, low quality irrigation and drainage waters for crop production. Reuse of agricultural drainage water is either being practiced to save fresh water for other uses or as in the case of LSP, insufficient fresh water availability for the downstream users due to over use of canal water in the upstream section. Thus, farmers in the downstream section have no other choice but to use drainage water for irrigating their crops (Tekinel *et al.,* 1989).

Yazar and Yarpuzlu (1997) conducted a five-year study in the Lower Seyhan Irrigation Scheme in Turkey from 1991 to 1995 in order to evaluate the response of cotton and wheat grown in rotation on a clay soil to drainage water applications with four different leaching fractions (varying from 0.15 to 0.60) as well as salinity build-up in the soil profile. Effect of winter rainfall on salt balance of the soil profile was also investigated in this study. The results revealed that using drainage water with salinities varying from 1.26 to 6.26 dS/m for irrigation of wheat did not result in the salinity built up in the soil profile in the Lower Seyhan Project in Turkey.

The main objectives of this study are to evaluate the yield production and yield loss in relation to the various salt concentration levels of irrigation water; to investigate the salinity build up in the soil profile under different irrigation programs; to determine the water use efficiency (WUE) under saline water conditions, which is a key parameter in water saving program. In addition, to study the effect of saline supplementary irrigation on leaf stomatal conductance of wheat in the esatern Mediterranean region of Turkey.

MATERIALS AND METHODS

Experimental site

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). Descriptions of some physical and chemical characteristics of the experimental soil are given in *Tables 1* and *2*, respectively.

As shown in *Table 1*, 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 2* 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).

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

Soil Depth cm	Particle Size Distribution (%)			Soil Texture	Field Capacity (cm^3/cm^3)	Wilting Point (cm^3/cm^3)	Saturation (cm^3/cm^3)	Bulk Density (g/cm^3)
	Sand	Silt	Clay					
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

Table 2. Description of the some chemical properties of the experimental soil

					Cations (me/l)				Anions (me/l)		
Depth (cm)	ECe (dS/m)	pH	$CaCO_3$ (%)	O.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

*OM:Organic matter

Treatments and experimental desing

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 was determined by harvesting all plants in an area of 8 m^2 in each plot.

Fertilizer applications were based on soil analysis recommendations. All treatment plots received the same amount of total fertilizer. A compound fertilizer of 20-20-0 was applied at arate of 75 kg N and 75 kg P2O5 as pure matter per ha at planting. The rest of N fertilizer was applied on February 23, 2002 in the form of ammonium nitrate (26% N) during tillering at a rate of 75 kg N per ha.

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. Five salinity levels of irrigation water with ECiw 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 (control) with salinity of 0.5 dS/m were tried in a completely randomised block design with three replications. 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. Each experimental plot was 5 m long and 2.5 m wide.

Irrigation, soil water and salinity monitoring

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 applied to each treatment plot was based on replenishing the soil water deficit within the 100 cm soil profile during the irrigation interval of 14 days to field capacity (Sezen and Yazar, 1996).

Soil water in each experimental plot was measured with a neutron probe (CP Model 503DR Hydroprobe) as well as by gravimetric sampling at 0.20 m depth increments down to 1.00 m, every two-week and prior to each irrigation application. A calibration equation developed for the experimental site was used to calculate the soil water in the profile prior to irrigation. At planting, and at flowering stage all treatment plots were soil sampled at depth intervals of 0-10 cm, 10-20 cm, 20-40 cm, 40-60, 60-80, 80-100 cm using an auger. The electrical conductivity of the soil samples was measured on saturation extracts (ECe) with an EC meter.

Water use (ET) of the wheat crop was calculated through the use of water balance equation:

$$ET = I + P \pm \Delta S - D \tag{1}$$

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

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. Harvest index (HI) was obtained as the ratio of grain yield (kg/m^2) to aboveground biomass yield (kg/m^2).

Dry-matter, leaf area

The phenological growth stages were observed weekly throughout the study. For this purpose, plants in 1.0 m long row section 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.

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. Leaf area of the samples was measured with an optical leaf area meter.

Wheat plants were hand harvested in all treatment plots by cutting all plants in 8 m^2 section of each plot on June 6, 2002. Then, using a tresher grains were separated from the strarw, and grain yields were determined.

Stomatal conductance measurements

Stomatal conductance measurements were carried out on five main treatments during the vegetative growth stage before and after irrigation. Diffusion porometry is based on measurement of the rate of water vapor loss from a leaf or portion of a leaf enclosed in a porometer chamber and the resistance is measured. Stomatal conductance is calculated as the inverse of the resistance measured (Beadle et al., 1986). The measurement is done with an automatic porometer (Li-Cor, Lincoln, NE, USA, 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. The obtained values were calculated twice to reflect abaxial and adaxial leaf surfaces.

MSTATC program (Michigan State University) was used to carry out statistical analysis. Treatment means were compared using Duncan's Multiple Range Test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Rainfall and irrigation

A total of 742 mm of rainfall received during the 2001-2002 wheat growing season was significantly higher than the long-term average annual rainfall of 630 mm. *Table 3* 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. Except the rainfall, other climatic prameters during the growing season were typical those prevail in the Mediterranean region. Because of the above normal rainfall in December 2001 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 fraction (LF) 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% LF 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, which received 198 mm of irrigation water.

Dry matter and grain yields

The data pertaining to effect of varying saline irrigation on wheat crop growth and grain yields, dry matter yields, water use, water use efficiency, harvest index and 1000-grain weight values obtained from treatments irrigated with water with different salinity levels are presented in *Table 4*. As indicated in *Table 4*, the average grain yields ranged from 5940 to 6484 kg /ha in the different treatments.

Table 3. Historical monthly mean and growing season climatic data of the experimental area

Climatic Parameters	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Long-term average (1929-2000)								
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, Class A Pan (mm)	66.3	47.0	47.3	56.1	84.9	11 8.6	19 5.6	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, Class A Pan (mm)	73.4	36.1	58.9	64.0	88.9	72.5	155.2	215.5
Solar Radiation (MJ $m^{-2}d^{-1}$)	273.3	166.9	289.8	359.1	465.1	511.8	657.7	706.5

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 received in the study area. Bernstein (1964), Bhumbla *et al,* (1964), Kanwar and Kanwar (1969) and Tripathi and Pal (1980) have reported the reduction in yield of wheat with high saline irrigations. Besides, grain yield, crop growth and yield attributes are found to vary with sensitivity for salinity. Chauhan and Singh (1993) reported a remarkable reduction in grain yield started above EC_{iw} 8 dS/m in India. With EC_{iw} 12 and 16 dS/m the grain yield lowered by 21 and 37% respectively. Reduction in grain yield per unit EC of water from 8 to 16 dS/m was about 4%.

Table 4. Grain and dry matter yield, water use and water use efficiency (WUE) data for the treatments

Salinity of Irrigation Water (dS/m)	Dry Matter Yield (kg/ha)	Grain Yield (kg/ha)	Harvest Index (HI)	Seasonal Irrigation (mm)	Water Use (mm)	WUE (kg/m^3)	1000 Grain Weight (g)
0.5 (FW)	15063	6176	0.41	180	480	1.286	45.2
3.0	15230	5940	0.39	180	461	1.288	46.1
6.0	16210	6484	0.40	180	496	1.307	46.4
9.0	16341	6373	0.39	180	462	1.379	45.1
12.0	15216	6391	0.42	180	452	1.414	46.2
12.0+(10%)	16915	6427	0.38	198	445	1.444	46.8

Average dry-matter yields varied from 1506 to 1691 g/m^2 from the different treatments at harvest time. However, six different saline irrigation 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. Chauhan and Singh, (1993) reposted that drymatter yield declined only at EC_{iw}12 and 16 dS/m by 18 and 33% respectively, as compared to canal water.

Seasonal water use of wheat in the different treatments ranged from 445 to 496 mm. 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 1.29 to 1.44 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. Zwart and Bastiaansen (2004) viewed the water use efficiency values for major crops and reported the range of WUE for wheat, varying between 0.6–1.7 kg/m^3 throughout the world.

Dry-matter yields obtained from the different treatments varied from 15063 kg/ha in treatment irrigated with fresh water (0.5 dS/m), to 16915 kg/ha in treatment of 12.0 + (10%) dS/m. However, there was no significant difference in the dry-matter yield among the treatments.

The evolution of leaf arae index (LAI) under different treatments with time is presented in Fig. 1. As shown in Figure 1, irrigation water salinity resulted in gradual reduction of LAI. The negative impacts of salinity on the LAI development started to appear after the flowering stage. The reduction in LAI ranged from 10.8 to 12.0% lower than the fresh water treatment. However, the differences in LAI values were not significant among the treatments.

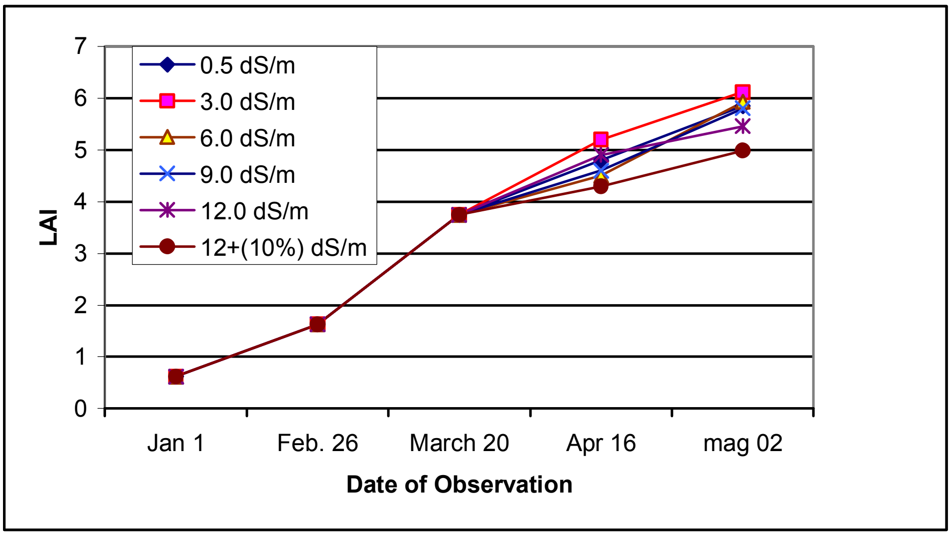

Fig. 1. Evolution of leaf area index (LAI) in different treatments

Harvest index (HI), defined as the ratio of grain yield to dry matter yield, values from the different treatments are given in *Table 4*. It shows that the harvest index values from the different treatments varied from 0.38 to 0.42. However, there was no significant difference among the treatments.

Average 1000-grain weight values from the different salinity treatments ranged between 45.1 and 46.8 g. However, 1000-grain weight values obtained from the treatments were not significantly different. However, Chauhan and Singh (1993) stated that 1000 grain weight was started to decline from EC_{iw} 2 dS/m onwards progressively but with very low degree.

Soil salinity

Soil salinity profiles resulting from the different salinity treatments are shown in Fig. 2. Soil salinity profiles were established at planting, at flowering, and at harvest for each treatment studied. As shown in the Fig. 2, 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 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. 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 in soil salinities between 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).

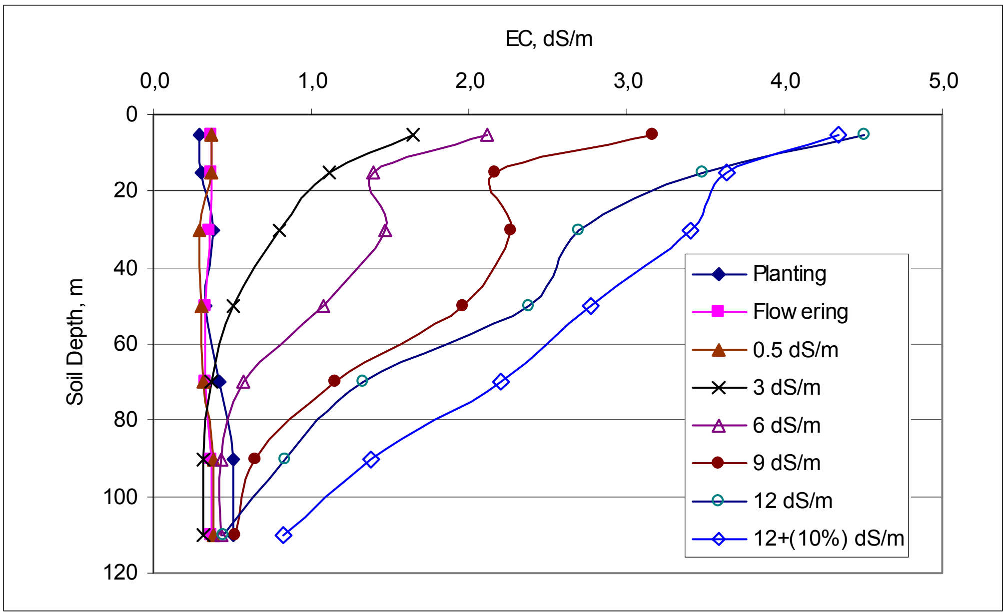

Fig. 2. Soil salinity profiles at planting, flowering and harvest for the treatments

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 prior to the flowering growth stage was very similar in all treatments and were lower than 0.5 dS/m throughout the profile as indicated in Fig. 2. 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. From the research findings, it can be conclude that saline irrigation water can be used for irrigation of wheat crop in the Mediterranean region since effective winter rainfalls leach the salts out of the root zone as long as an efficient drainage system is provided.

Average pH values of the saturation extracts under different treatments at harvest 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 was not affected considerably by the saline irrigation water applications.

Highest average sodium absoprtion ratio (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, g_s

Stomata play a pivotal role in controling the balance between the water loss and carbon gain i.e. biomass production. Measurements of the size of the stomatal opening or of the resistance to CO_2 and water vapor (H_2O) transfer between the atmosphere and the internal tissue of the leaf imposed by the stomata are important in studies of biomass production. This is particularly the case in cropping situations where it is important to maximize water use efficiency (Beadle et al., 1986).

Average stomatal conductances of wheat leaves measured in different dates under the different treatments are given in Figure 4. As indicated in Figure 4, 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 mmol $m^{-2}s^{-1}$. 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^2s. Stomatal conductance values decreased in all treatments on April 15. The highest stomatal conductance was measured in the 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 except in the treatment of 3.0 dS/m. Highest stomatal conductance was measured in treatment irrigated with fresh water followed by 12dS/m+10% LF, 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. Zang et al. (1998) evaluated the diurnal variation of stomatal conductance in China with 600 mm annual rainfall, and stated that midday depression of g_s were also evident in field grown wheat. Xue et al. (2004) explained the gs movement of field grown wheat in the United States as a feedforward response, which means that stomata sensed the air vapor pressure directly. Increased water loss through the stomata caused a water potential decline of the guard cell. In conclusion, there was no well-defined relationship between stomatal conductances and irrigation water salinities under the study conditions.

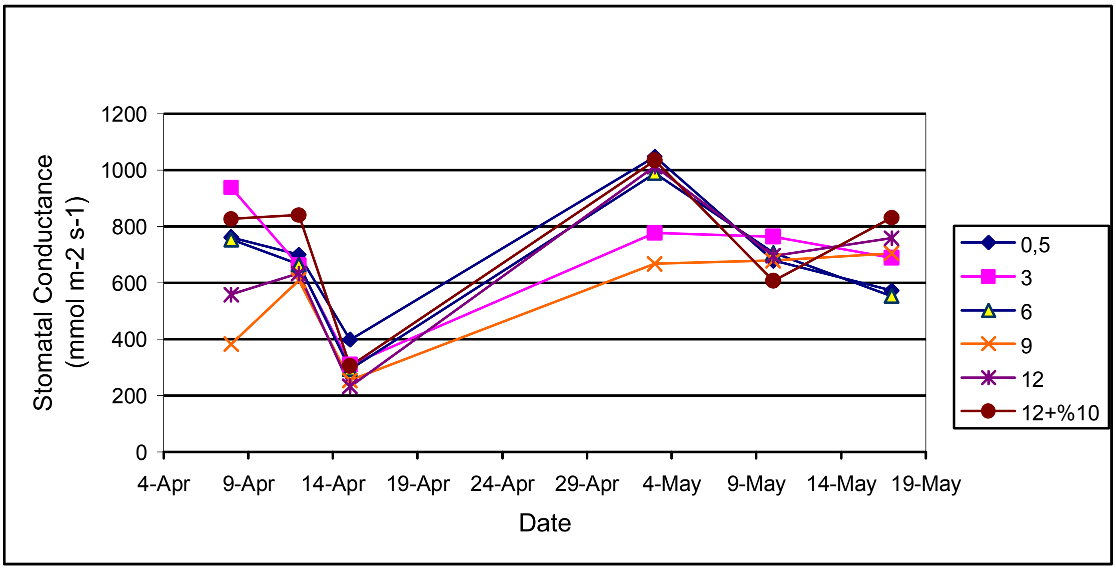

Fig. 3. Variation of average stomatal conductance values of wheat leaves under the different treatments

CONCLUSIONS

In the Mediterranean climate, rainfed cereal crops are planted in autumn and harvested in late spring, relying on the rains during this period for the conclusion of their cycle; the vagaries of rains, however, often put at risk the final harvest. 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 research results revealed that the effects of salinity levels of irrigation water used in the study on grain yields as well as dry-matter yields were not significantly different. 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 a level that did not affect the biomass yield of wheat.

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.

Water use efficiency (WUE) values from the treatments ranged from 1.29 to 1.44 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.

There was no well-defined relationship between stomatal conductances of wheat leaves and irrigation water salinities under the study conditions.

Thus, saline irrigation water under the semi arid climatic conditions in the Mediterranean region can be used for irrigation of wheat crop up to EC_w-12 dS/m comparable to control (canal water) because of effective winter rainfalls leach the salts out of the root zone as long as an efficient drainage system is provided. The sustainability of this practice is presumably high, due to the limited amounts of added salts, which can be easily leached out even by a modest precipitation.

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