

Sustainable use of highly saline water for irrigation of crops under arid and semi-arid conditions: new strategies. Corn yield response to saline irrigation water applied with a trickle system under Mediterranean climatic conditions

Yazar A., Hamdy A., Gençel B., Sezen M.S., Koç M.

in

Hamdy A. (ed.).

Regional Action Programme (RAP): Water resources management and water saving in irrigated agriculture (WASIA PROJECT)

Bari : CIHEAM

Options Méditerranéennes : Série B. Etudes et Recherches; n. 44

2003

pages 113-121

Article available on line / Article disponible en ligne à l'adresse :

<http://om.ciheam.org/article.php?IDPDF=3001799>

To cite this article / Pour citer cet article

Yazar A., Hamdy A., Gençel B., Sezen M.S., Koç M. **Sustainable use of highly saline water for irrigation of crops under arid and semi-arid conditions: new strategies. Corn yield response to saline irrigation water applied with a trickle system under Mediterranean climatic conditions.** In : Hamdy A. (ed.). *Regional Action Programme (RAP): Water resources management and water saving in irrigated agriculture (WASIA PROJECT)*. Bari : CIHEAM, 2003. p. 113-121 (Options Méditerranéennes : Série B. Etudes et Recherches; n. 44)



<http://www.ciheam.org/>
<http://om.ciheam.org/>

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

Corn yield response to saline irrigation water applied with a trickle system under Mediterranean climatic conditions

Attila Yazar¹, Atef Hamdy², Burçin Gençel¹, Metin S. Sezen¹

¹ Irrigation and Agricultural Structures Department, Çukurova University, 01330 Adana-Turkey
Phone: 90-322-3386516; Fax: 90-322-3386386; e-mail: yazarat@mail.cu.edu.tr

² Director of Research, CIHEAM/MAI Bari, Italy email: hamdy@iamb.it

ABSTRACT

A field experiment was carried out to evaluate the corn yield, yield loss, and water use efficiency in relation to the salt concentration level of irrigation water applied with a trickle system in the Mediterranean Region of Turkey. Saline irrigation water with electrical conductivities of 3.0, 6.0, 9.0, and 12.0 dS/m along with canal water of 0.5 dS/m was used. In addition, three treatments were included in the study by applying 10% leaching fraction to 0.5, 6.0, and 12.0 dS/m treatments after flowering. Results indicated no significant difference in corn grain yields among the treatments studied as indicated by the variance analysis. Highest yield averaging 8875 kg ha⁻¹ was obtained from the treatment plots irrigated with canal water. Generally, profile salt concentration increased with increasing salinity of irrigation water used. Higher salt concentration in the top layer was due to higher evaporation rate from the wetted surface. The general salt distribution profile under saline irrigation water treatments followed the typical water distribution pattern under trickle irrigation (bulb shape) with maximum EC_e occurring at the soil surface. Applying a leaching fraction of 10% after flowering did not affect the profile salt distribution significantly in treatments. There were no significant differences in dry matter production levels, water use efficiency (WUE), 1000-grain weight, and harvest index (HI) among the salinity treatments. This study concluded that saline irrigation water may be used for irrigating corn crop when applied with trickle system under the Mediterranean climatic conditions.

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

INTRODUCTION

The decreasing availability of fresh water for agriculture use, while the need for production of food and fuel from plants is increasing, has become a major concern 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 such as the saline water in the region. 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 region. 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 (Hamdy, 2002).

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 (Rhoades, 1977; Hamdy, 1997).

There is usually no single method 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).

In general, crops tolerate salinity up to a threshold level above which, the yields decrease approximately linearly as salt concentrations increase.⁵ Using proposed linear response model, the

maximum allowable salinity without yield decrease per unit increase in salinity beyond the threshold may be obtained. High crop productivity with salt-affected irrigation waters and soils can be attained if management practices are appropriate and environmental conditions are favorable. From around the world, numerous examples of successful results under saline conditions can be cited (Maas and Hoffman, 1977; Moore and Hefner, 1977).

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 (Tekinel et al., 1989).

Corn, cotton, and wheat are the major crops grown in the LSP. It should be noted that corn is classified as a moderately sensitive crop to soil salinity, which should be considered in the scheme of crop production.

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 drainage water can be used for irrigating wheat and cotton crops in the Lower Seyhan Project in Turkey without resulting in salinity build up in the soil profile as long as an efficient drainage system is provided.

The main objectives of this study are (1) to investigate new ways of using saline water for corn production under semi-arid conditions; (2) to characterize the plant growth parameters of investigated variety as a function of irrigation with saline water at different salt concentration levels; (3) to evaluate the yield production and yield loss in relation to the salt concentration levels of irrigation water; (4) to determine the WUE under saline water conditions, which is a key parameter in a water saving program.

Materials and Methods

The experiment was conducted at the Research Station of the Irrigation and Agricultural Structures Department of the Cukurova University in Adana, Turkey during 2001 corn growing season. The station has latitude of 36°59'N, a longitude of 35°18'E, and is at 375 m above mean sea level. The soil of the experimental site is classified as Mutlu soil series (*Palixerollic 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. Mean bulk density varies from 1.19 to 1.25 g/cm³. Average soil salinity (ECe=0.32 dS/m) at planting time is well below the salinity threshold level for reducing corn (ECe=1.7 dS/m) yield. Corn is classified as moderately sensitive to soil salinity (Maas, 1986). Typical Mediterranean climate prevails in the experimental site. Average annual rainfall is 630 mm, of which 65 % falls during the winter months.

Corn variety "Pioneer 3163" was planted on 19 April 2001 at a row spacing of 70 cm with a seeding density of 8 seeds per square meter. The experimental plot was fertilized with compound fertilizer of 15-15-15 at a rate of 105 kg/ha N, P₂O₅, and K₂O at planting. Prior to second irrigation, all plots received 115 kg N per hectare on June 5 in the form of urea. A pre-emergence herbicide was applied prior to sowing and weeds appearing later were controlled by hand-weeding and hoeing.

Irrigation was applied by drip system and scheduled at weekly intervals using cumulative evaporation during the irrigation interval from the Class A pan located at the experimental station. Drip irrigation systems were installed on the surface of the plots after the plant establishment. In the experiment, two drip irrigation systems were used simultaneously, one for the canal water and one for the saline water. Both systems were operated at 100 kPa throughout the study. The control unit of the drip irrigation system for saline water consisted of a pump, gravel filter, disk filter, flow meter, control valves and pressure gauges. Drip irrigation system for the fresh water including a disk filter, flow meter, and a pressure gauge was directly connected to a pressurized hydrant at the experimental site.

There were 8 different treatments in the study. Saline irrigation water with electrical conductivities (ECw) of 3.0, 6.0, 9.0, and 12.0 dS/m (prepared using various dilutions of sea water with salinity of 54 dS/m in the pool with irrigation canal water with salinity of 0.5 dS/m) along with canal water. In addition, three treatments were included in the study by applying a 10% leaching fraction (LF) to treatments of 0.5, 6.0, and 12.0 dS/m after flowering (silking). Thus, a total of 8 treatments were studied. Namely, 0.5, 3.0,

6.0, 9.0, and 12.0 dS/m; 0.5+10%, 6.0+10%, and 12.0+10% LF after flowering stage. The experiment was a randomized block design with three replications giving a total of 24 plots. The experimental plot dimensions were 10 m in length, and 2.8 m (four plant rows) in width.

There were two quadruple (four) drip laterals laid in the center of two adjacent crop rows in each treatment plot. When all four laterals were connected to the saline water manifold, the treatment received saline water of 12.0 dS/m; if all four laterals were connected to canal water line, the treatment irrigated with water of 0.5 dS/m was established. When three laterals were connected to saline line, and one lateral was connected to fresh line, then a salinity treatment of 9.0 dS/m was established. When two laterals were connected to saline line, and two laterals were connected to fresh water line, then a salinity level of 6.0 dS/m was created. For the 10% leaching fraction, additional laterals were connected to the manifolds. In this study, in-line drip emitters with a flow rate of 4.0 L/h and, spaced 75 cm apart were used on laterals of 16 mm in diameter.

The amount of water applied to each treatment plot was based on cumulative evaporation from Class A pan within the irrigation interval of 7 days. Both drip systems were operated simultaneously during each irrigation event. The amount of water applied to treatment plots were monitored with flow meters. Rainfall and the other meteorological parameters were recorded at the research station.

Measurements

Plant growth stages

The plant growth stages were observed weekly throughout the study. For this purpose, three plants in each replicate 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 were taken by cutting all plants in 1.0 m length of a row in each plot at two-week intervals. 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.

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 week prior to each irrigation. An access tube was installed in each treatment plot to a depth of 150 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 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 with an EC meter.

Crop water use (evapotranspiration)

Crop water consumption of the corn was calculated through use of water balance equation:

$$ET = I + P - S - D \quad (1)$$

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 was considered as deep percolation in this study.

Water use efficiency (WUE)

Water use efficiency was computed as the ratio of yield to water use. Irrigation water use efficiency

was determined as the ratio of wheat or corn grain yield for a particular treatment to the applied water for that treatment.

Harvest and harvest index (HI)

Corn plants were harvested by hand cutting all the plants in two rows each 6 m long at the ground level. Corn grain yield and biomass yield at harvest were determined for each treatment. Grain yield was adjusted to 15.5 % moisture content. In addition, 1000-seed weight was also evaluated.

RESULTS AND DISCUSSIONS

The seasonal amount of irrigation water applied, water use, biomass and grain yield, 1000-grain weight, water use efficiency and irrigation water use efficiency, and harvest index data are given in table 1. For good plant establishment, 35 mm of fresh water was applied equally to all treatment plots by means of a sprinkler system. The first treatment irrigation was applied on May 29, and soil water deficit was replenished to the field capacity. All irrigation treatments were terminated on July 31, thus, a total of 9 irrigation applications were made. The amount of water applied in each irrigation varied from 28 to 100 mm. All treatments received the same amount of irrigation water until the flowering stage. After flowering, 10 % leaching fractions was utilized in treatments of 0.5, 6.0, and 12.0 dS/m. Thus, the treatments without leaching received a total of 561.4 mm; treatments with 10% LF received 576.8 mm of irrigation water. Seasonal plant water use varied from 688.3 mm in treatment of 12 dS/m to 750.2 mm in the treatment plots irrigated with canal water. As the salinity of the irrigation water increased plant water uptake decreased slightly. Water use values were 746.4, 690.5, and 684.5 mm for treatments of 3.0 dS/m, 6.0 dS/m, and 9.0 dS/m, respectively. Cumulative evapotranspiration of corn crop under different treatments is shown in figure 1. As shown in figure 1, cumulative evapotranspiration of corn crop under different treatments were very similar. The effect of water salinity on plant water uptake with drip irrigation was slightly different. Water uptake was reduced approximately 8 percent in treatments with salinities higher than 6.0 dS/m as compared to plots irrigated with canal water.

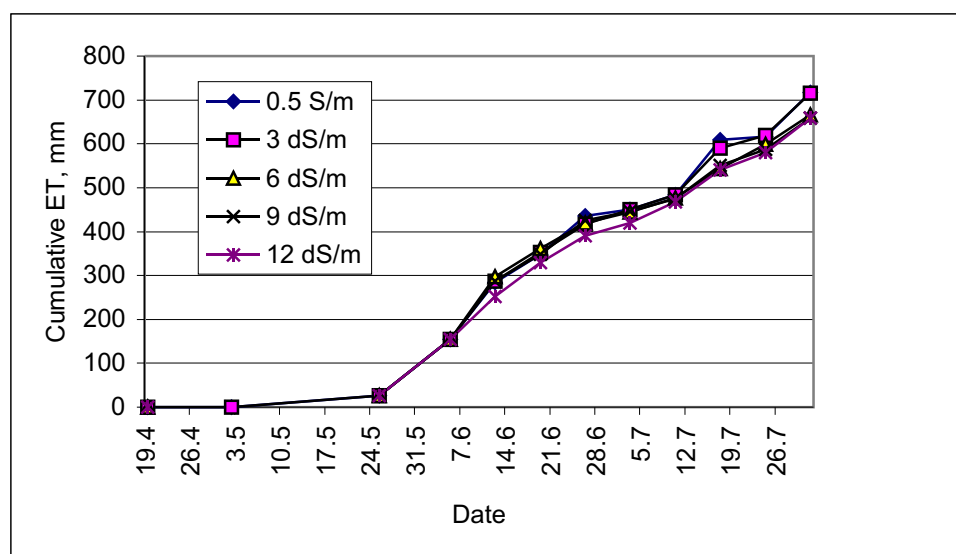


Fig 1. Cumulative evapotranspiration in the different treatments

Average corn grain yields obtained from different treatments are given in table 1, and variance analysis of the grain yield data is given in table 2. There was no significant difference in corn grain yields among the treatments studied as indicated by the variance analysis ($P < 0.2197$). Highest yield averaging 8875 kg/ha was obtained from the treatment plots irrigated with canal water. The effect of irrigation water salinities on corn grain yield was similar in all treatments. Increasing irrigation water salinity increased salt concentration and osmotic potential in the root zone. However, due to nature of trickle irrigation, frequent water applications maintained the soil water content in the root zone in the first 50% of the available water, thus reducing the effect of osmotic potential on water uptake.

Corn is moderately sensitive to soil salinity. The degree to which productivity (as measured by grain or silage yield) is affected by soil salinity termed corn's salt tolerance. For corn grown on either mineral or organic soils, no grain yield reduction is expected if electrical conductivity of soil water is less than 3.7 dS/m or 2400 ppm of total dissolved salts in the soil water (Willardson et al., 1985). Maas (1986) gives salt tolerance of corn as 1.7 dS/m.

Sometimes crops are exposed to conditions differing significantly from those for which salt tolerance data were obtained. Several factors, including soil, crop, and environmental conditions interact with salinity to cause a different yield response (Rhoades, 1984).

There were no significant differences in dry matter production levels between salinity treatments. Dry matter yields varied from 1.707 kg/m² in treatment 12 dS/m+10% to 2.270 kg/m² in treatment 3.0 dS/m.

There was a trend of decreasing dry matter production with increasing water salinity. The development of the aboveground portion of the crop was monitored for each treatment at two-week intervals until harvest, and the results are shown in Figure 2. Development of leaf area index for different treatments is shown in Figure 3. As shown in this figure, corn crop irrigated with canal water resulted in highest LAI. Saline irrigation water treatments resulted in similar LAIs but smaller than that of the fresh water.

As shown in table 1, there were no significant differences in WUE, IWUE, 1000-grain weight, and HI among the treatments studied. Highest WUE value was found in the treatment of 12.0 dS/m as 1.22 kg/m³. The lowest WUE value was observed in the treatment of 6.0 dS/m as 1.05 kg/m³. The highest IWUE value was estimated in the treatment of 0.5 dS/m as 1.58 kg/m³ and the lowest was found in the treatment of 12.0 dS/m+10% LF as 1.23 kg/m³. 1000-grain weight values ranged from 273.5 g to 293.5 g among the treatments. Generally, treatments resulted in similar values for the abovementioned parameters.

Table 1. Biomass, grain yields, 1000-grain weight, WUE, IWUE, HI in different treatments

Treatments	0.5 dS/m	3.0 dS/m	6.0 dS/m	9.0 dS/m	12.0 dS/m	0.5 dS/m +10% LF	6.0 dS/m +10%LF	12.0 dS/m +10% LF
Biomass, kg/m ²	2.059	2.27	2.027	2.103	1.798	2.164	1.905	1.707
Grain Yield, kg/ha	8875	8295	7267	7533	8164	7377	8222	7087
1000-Grain, g	282.6	290.6	293.5	273.5	277.6	282.2	287.2	273.6
ET, mm	750	746	690	684	668	750	690	668
I, mm	561	561	561	561	561	577	577	577
WUE, kg/m ³	1.18	1.11	1.05	1.10	1.22	0.98	1.19	1.06
IWUE, kg/m ³	1.58	1.48	1.29	1.34	1.45	1.28	1.43	1.23
HI	0.23	0.27	0.28	0.28	0.22	0.29	0.23	0.24

Table 2. Analysis of variance table for corn yield values from different treatments

	Degrees of	Sum of	Mean	F	
Source	Freedom	Squares	Square	Value	Prob
Replication	2	4828981.266	2414490.633	3.2654	0.0686
Factor A	7	8195179.298	1170739.900	1.5833	0.2197
Error	14	10351741.389	739410.099		
Total	23	23375901.953			

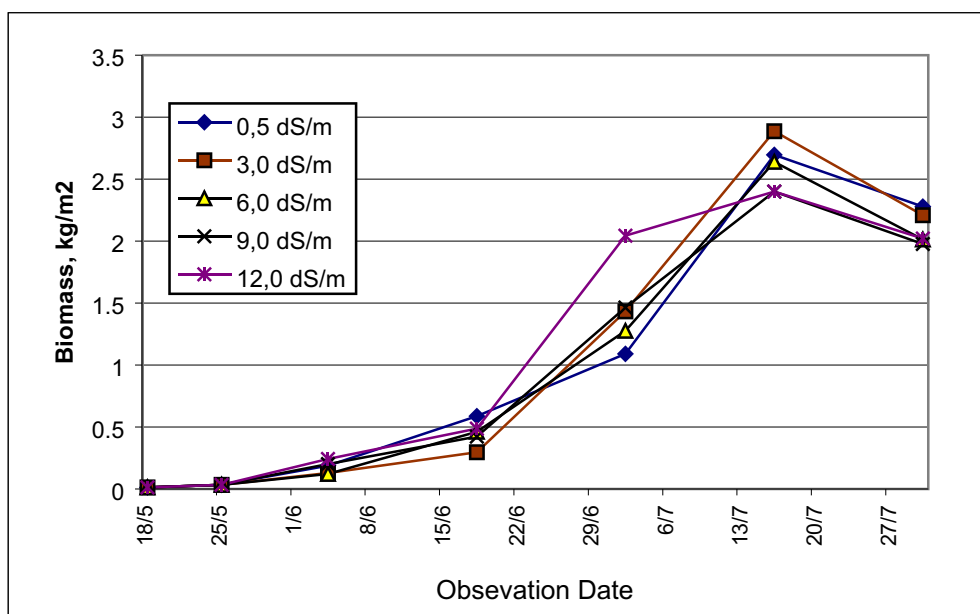


Fig. 2. Dry matter yield in the different treatments.

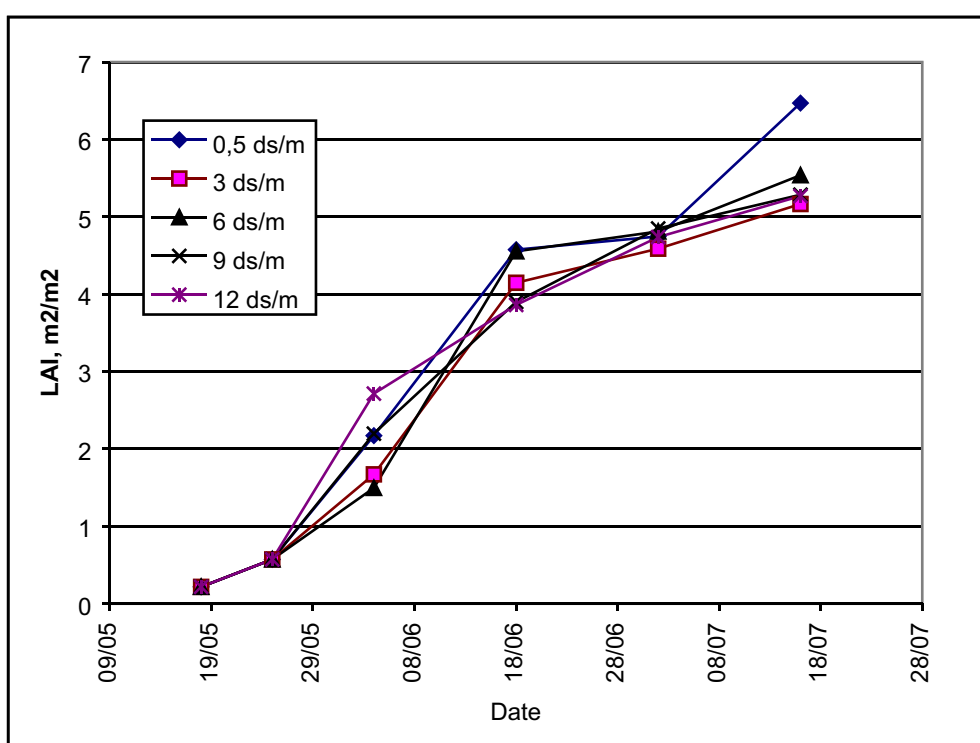


Fig. 3. Evolution of leaf area index (LAI) for different treatments.

Soil salinity

Soil salinity at planting varied from 0.295 dS/m at 100-120 cm soil layer to 0.310 dS/m at 10-20 cm soil layer. SAR values ranged from 0.27 to 0.55 at the time of planting. Before the salinity treatments were imposed, there were no significant differences in soil salinity or soil sodicity levels between the treatments. Soil salt distribution and concentration along the soil profile at planting, flowering, and harvest in different saline irrigation water treatments is shown in figures 4 and 5. The high salt concentration at the surface layer is due to high evaporation rate from the wetted areas and the nature of the soil water distribution associated with drip irrigation system.

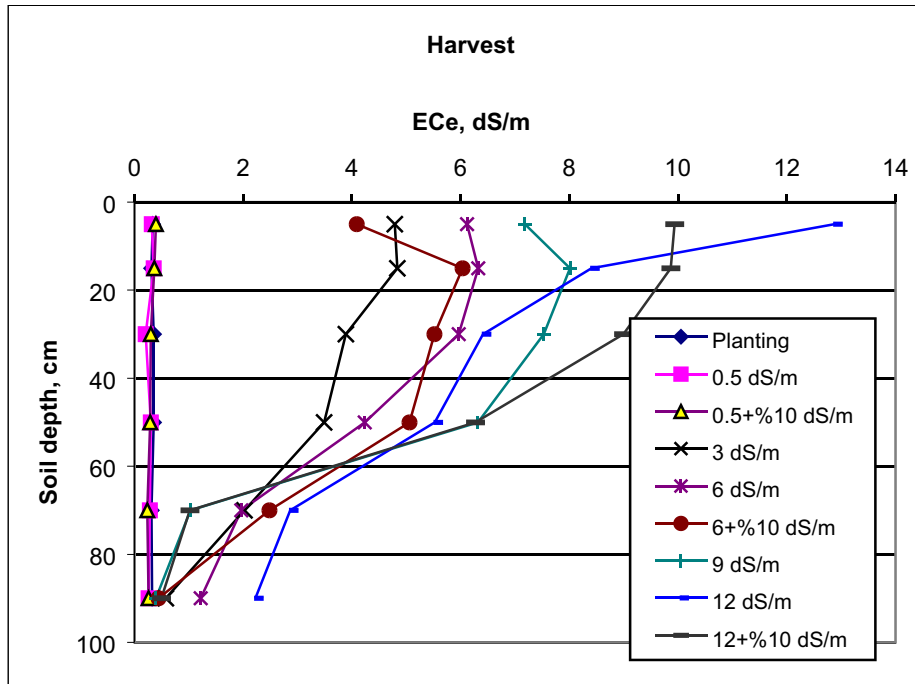


Fig. 4. Soil salinity profile at planting and at harvest in the different treatments

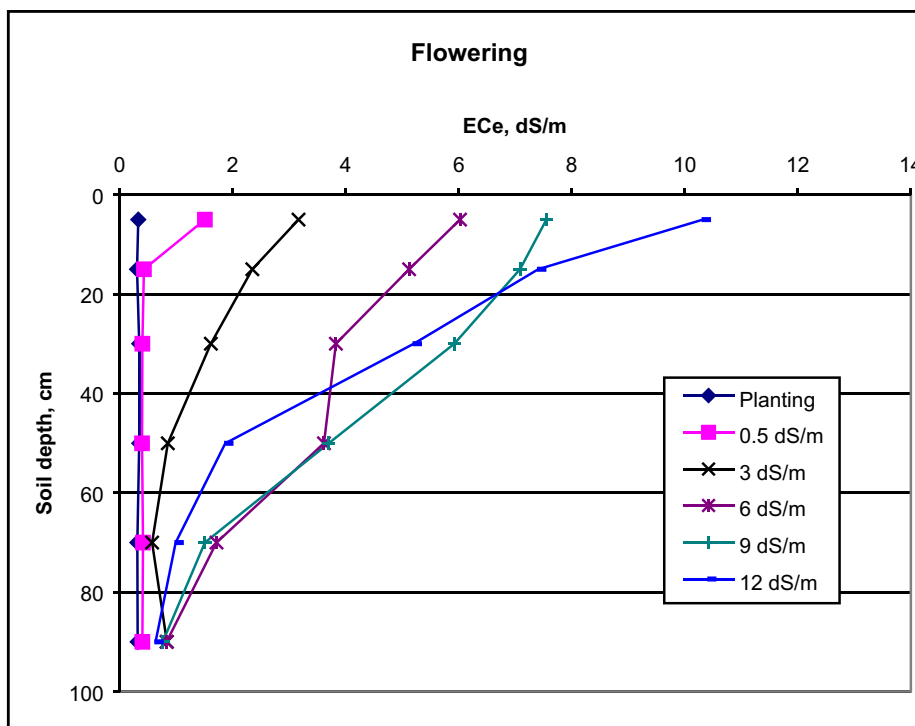


Fig. 5. Soil salinity profile at planting and at flowering in the different treatments

The general salt profile at saline irrigation water treatments followed the typical water distribution pattern under trickle irrigation (bulb shape) with maximum ECe occurring at the soil surface. In the control treatment (irrigation with canal water) maximum ECe was 1.5 dS/m at the surface layer at flowering stage. At harvest, profile salinity content decreased in all depths and salinity values were similar to those at planting time. A rainfall of 35 mm received before harvest leached the salts from the surface layer. Applying a leaching fraction of 10% after flowering did not affect the profile salt distribution significantly in treatment 0.5 dS/m+10% LF.

In treatment of 3.0 dS/m, ECe increased to a maximum of 3.0 dS/m at flowering and 5.0 dS/m at harvest in the 0-10 cm depth, and then gradually decreased with increasing depth following the wetting pattern of trickle irrigation. Soil salinity increased from planting to harvest period in all depths. In treatments of 6.0 dS/m and 6.0 dS/m+10% leaching, very similar salt distribution patterns to 3.0 dS/m treatment were observed. Maximum ECe occurred in the top 10 cm of the soil profile with a value of 6.4 dS/m at harvest. Profile salt content again increased towards the end of season as expected. Lowest salt content was measured in the soil layer of 80-100 cm. Applying a leaching fraction of 10% after flowering did not affect the profile salt distribution significantly in treatment 6.0 dS/m+10% LF as compared to 6.0 dS/m treatment except in the top soil layer in which salt content was 4.0 dS/m at harvest. In treatment of 9.0 dS/m, salt concentration distribution followed the same pattern as in the other treatments. Highest ECe of 8.0 dS/m was measured in the surface soil layer and then salt content decreased with increasing depth in the profile. Salt distribution at flowering and harvest had similar pattern. A rainfall of 35 mm received just prior to harvest reduced salt content in the top layer slightly. In treatments of 12.0 dS/m and 12.0 dS/m+10% leaching, resulted in the highest salt concentration throughout the soil profile as expected. The maximum ECe of 13 dS/m was measured in the surface soil layer in treatment plots irrigated with water of 12.0 dS/m. Salt content gradually decreased with increasing soil depth. Leaching reduced salt content throughout the profile in treatment 12.0 dS/m+10% as compared to 12.0 dS/m.

Generally, profile salt concentration increased with increasing salinity of irrigation water. Higher salt concentration in the top layer is due to high evaporation rate from the wetted surface.

When the concentration of sodium becomes excessive in proportion to calcium plus magnesium, the soil is said to be sodic (Maas and Hoffman, 1977). The sodium adsorption ratio (SAR) of irrigation water is a good indicator of the sodium status that will occur in the soil. Permissible value of SAR is a function of salinity. High salinity levels reduce swelling and aggregate breakdown (dispersion), promoting water penetration. SAR values were low at planting time ranging from 0.27 to 0.49 in different soil layers. SAR values increased drastically with the salinity content of irrigation water applied. In the treatment plots irrigated with canal water, SAR values remained low except SAR of the top layer. At harvest, SAR values were similar to those at planting. Maximum value of SAR was estimated in the treatment of 12.0 dS/m as 27.92. In other treatments, SAR values were in between values at planting and those in the 12 dS/m treatment plots.

Conclusions

There was no significant difference in corn grain yields among the treatments studied as indicated by the variance analysis. Highest yield averaging 8875 kg ha⁻¹ was obtained from the treatment plots irrigated with canal water. Increasing irrigation water salinity increased salt concentration and osmotic potential in the root zone. However, due to nature of trickle irrigation, frequent water applications maintained the soil water content in the root zone in the first 50% of the available water thus reduced the effect of osmotic potential on water uptake.

There were no significant differences in dry matter production levels between salinity treatments. Dry matter yields varied from 1.707 kg m⁻² in treatment of 12 dS/m+10% LF to 2.270 kg m⁻² in treatment 3.0 dS m⁻¹.

Generally, profile salt concentration increased with increasing salinity of irrigation water used. Higher salt concentration in the top layer is due to high evaporation rate from the wetted surface. Soil salinity reached and exceeded the threshold level of 1.7 dS/m in the saline water treatments. However, due to frequent watering high water content in the profile was maintained, thus in turn reduced the effect of osmotic potential on water uptake as well as plant growth.

The general salt profile at saline irrigation water treatments followed the typical water distribution pattern under trickle irrigation (bulb shape) with maximum ECe observed at the soil surface. In the control treatment (irrigation with canal water) maximum ECe was 1.5 dS m⁻¹ at the surface layer at flowering stage. At harvest, profile salinity content decreased in all depths and salinity values were similar to those at planting time. Rainfall of 35 mm received before harvest leached the salts from the surface layer. Applying a leaching fraction of 10% after flowering did not affect the profile salt distribution significantly in treatment 0.5 dS/m+10% LF.

SAR values increased drastically with the salinity content of irrigation water applied. In treatment plots irrigated with canal water, SAR values remained low except SAR of the top layer. At harvest, SAR values