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Water Relations of Kochia (*Kochia scoparia* (L.) Schrad) under Different Salinities of Irrigation Water

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ABSTRACT

In order to estimate kochia (*Kochia scoparia*) water use efficiency (WUE), an experiment was performed in Birjand, a dry and saline area in South Khorasan, Iran, by using irrigation water of three different salinity levels, i.e. 1.5, 8.6, and 28.2 dSm^{-1}. Several measurements were conducted during the growth season to determine radiation fraction passed through canopy and leaf area index, thereby ground cover percentage was calculated. Reference crop evapotranspiration calculated using Hargreave's method, corrected by FAO, and after drawing crop coefficient curves, crop evapotranspiration was determined. Ultimately, crop WUE in different salinity levels was calculated for forage and seed yields. Evaluation of crop coefficient curves showed that salinity caused a delay in initial season growth and forced plant maturity in late season. The mean crop evapotranspiration between salinity treatments was equal to 915 mm. WUE was affected by salinity, more than by evapotranspiration, showing biomass production is more sensitive to salinity than crop evapotranspiration. For forage yield, salinity enhancement from 1.5 to 8.6 dSm^{-1} caused WUE to be increased slightly from 11.5 to 11.9 kg ha^{-1} per each mm evapotranspiration, though at higher levels of salinity it decreased to 7.6 kg ha^{-1} per each mm evapotranspiration. WUE for seed yield in 1.5, 8.6, and 28.2 dSm^{-1} were 2.92, 2.42, and 2.44 kg ha^{-1} per each mm evapotranspiration, respectively. As forage use is the main purpose of kochia production, it seems that its biomass production have a high tolerance to water and soil salinity.

Keywords: crop coefficient, evapotranspiration, ground cover, halophyte, Hargreaves, radiation, water use efficiency

INTRODUCTION

Agricultural production is dependent on meeting the water requirements of crops. In most arid and semi-arid areas of Iran, more than 80% of exploited water is used to irrigate agricultural crops and the salinity of this water is increasing high due to excessive water harvesting and saline water influx from surface reservoirs (Jahani 1994). The predicted increased demand for irrigation in semiarid climates, as a result of the population increase and climate change, is likely to increase the extent of secondary salinization, with a consequent threat to food security of the population in these regions.

Salinity influences the water use efficiency (WUE) of plants in different ways, e.g. reducing soil water availability due its effects on the soil water potential (Richards 1992) or forcing stomata to close, cause WUE to increase due to water loss reduction. Salinity also reduces leaf area, leaf water potential, evapotranspiration, and, finally, crop yield (Richards 1992; Katerji *et al*. 2003). It is apparent that WUE of some species, especially halophytes, increases as salinity increases (McCree and Richardson 1987). Sustainable exploitation of saline water and soil resources requires the reassessment of environmental resources and non- or less-utilized plants.

There are many opportunities to improve WUE in agriculture through the manipulation of biological and environmental components of the system and/or by optimizing management decisions. Crop selection is the main factor determining water use. Cultivation of some palatable meso- or halophytic plants under drought or salinity stress, using existing water for irrigation, is a promising solution for the forage shortage problem in arid and semiarid regions. Kochia (*Kochia scoparia* L. Schrad) is a plant that establishes well in high saline soils (Sherrod 1971), and produces a protective short-lived plant cover. Therefore, kochia can be used as an alternate forage crop, especially in salt affected areas and in arid and semiarid regions with forage scarcity. The main objective of the present study was to take advantage of the halophytic nature of kochia and investigate its response to saline water irrigation, with respect to evapotranspiration and water use efficiency.

MATERIALS AND METHODS

The required data were collected from an experiment conducted during growth season of 2003 at the Experimental Station of the University of Birjand (13° 59′ N, 53° 32′ E), South Khorasan, Iran. The experimental design was done as a randomized complete block design (RCBD) with three replications, in which kochia plants were irrigated with different levels of salinity (1.5, 8.6 and 28.2 dSm^{-1}). The seeds were obtained from a land race of kochia, and due to its small seed size, they mixed with fine sands and then sown in 20 m^2 plots on 30 March, with flooding irrigation, which was performed weekly. Before planting, fertilizers including super phosphate (120 kg ha^{-1}) and nitrogen (150 kg ha^{-1}) were used (Zahran 1993).

Two levels of saline water (1.5 and 8.6 dSm^{-1}) were provided from two separate wells at the farm. The high level of saline water (28.2 dSm^{-1}) was supplied from a seasonal river, 3 Km from the farm. Three tanks (20 KL ach) were installed and water of each treatment stored in a separate tank. Saline water was applied weekly as flooding irrigation, using the pipes which already installed under soil surface between experimental plots and tanks. Water entrance volume was similar between all plots, controlled by a volumetric counter. To insure a good stand, all plots were irrigated with moderate saline water (5.5 dSm^{-1}) until thinning and after that (about 40 days after sowing), the salinity treatments were exerted.

To determine the soil coverage percentage and the fraction of

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Short Communication

radiation interception, about 12 measurements of incident radiation were made during the growth season, so that a proper distribution of measured radiation at different leaf area indices (LAI) was obtained. The measurements of incident radiation were made using a linear solarimeter (Sunscan, ΔT) from 1100 to 1300 h. These data were used to determine the fraction of radiation absorption by plant canopy during growth season using the method described by Goudriaan and van Laar (1993).

The reference crop evapotranspiration was calculated based on Hargreave's method (Allen *et al.* 1998; Villalobos *et al.* 2002). Hargreave's method was developed in 1985 for use when climatic data are not easily accessible. This method provides reasonable estimations of ET_O with a global validity between empirical models, and is also authorized by the Food and Agriculture Organization (FAO) (Allen *et al.* 1998) as:

$$ET_O\,(mm\,day^{-1}) = 9.388\times10^{-6}\,RA\,(T_{mean}+17.8)\,(T_{\max}-T_{\min})^{0.5} \qquad [1]$$

in which T_{max}, T_{min}, and T_{mean} are maximum, minimum, and mean daily temperatures, respectively, and RA is extraterrestrial radiation (MJ m^{-2} day^{-1}).

The initial crop coefficient ($K_{C\ ini}$) was calculated as a function of irrigation frequency and reference crop evapotranspiration (Villalobos *et al.* 2002):

$$K_{C\,ini} = 2(IL)^{-0.49}\exp[(-0.02-0.04\ln IL)\,ET_{O1}] \qquad [2]$$

where IL is the irrigation interval (day), and ET_{O1} is average reference crop evapotranspiration during the initial period. Calculating K_C for other growth stages was done based on the FAO recommended method (Allen *et al.* 1998). Considering these parameters, crop evapotranspiration (Etc) can be calculated by:

$$ET_C = ET_O\,.\,K_C \qquad [3]$$

All calculations and drawing figures were done using Genstat (9^{th} Edn) and Excel software.

RESULTS AND DISCUSSION

With increasing LAI, plant light absorption increased and at a LAI of 4.5-5, plants absorbed 95% of the incident radiation (**Fig. 1**).

Fig. 2 shows that as the season progresses and the temperature increases, reference crop evapotranspiration increases, and its cumulative value follows a sigmoidal trend. The maximum evaporative potential occurred during the warm summer months, which in the dry Birjand region are coincident with decreased air humidity.

To calculate the crop coefficient (Kc), the length of initial stage (Kc ini) was considered to be from planting to 20% radiation absorption (LAI = 0.53, **Fig. 1**). The onset of the mid-season stage (Kc mid), or time of maximum or near maximum plant development, was considered to be the time to reach effective full ground cover, in which 80% of incident radiation was absorbed by plant canopy (LAI = 2.9). The effective full cover for many crops occurs when LAI reaches three (Allen *et al.* 1998). Consistent with the observations of Bassil and Kaffka (2002) in safflower, it can be concluded from **Table 1** and **Fig. 3** that as salinity increased, the Kc reached a maximum value later at mid-season, and declined sooner at season's end, indicating that salinity delayed plant growth during the early season, and hastened plant maturity at the end of the season.

In general, an increase in salinity caused plant evapotranspiration to increase (**Fig. 4**); however, there was no significant difference between salinity levels, and plant evapotranspiration values in 1.5, 8.6, and 28.2 dSm^{-1} were 841.9, 831.5, and 812.3 mm at 147 DAP (forage harvesting), and 926.3, 918.2, and 899.3 mm at 172 DAP (seed harvesting), respectively.

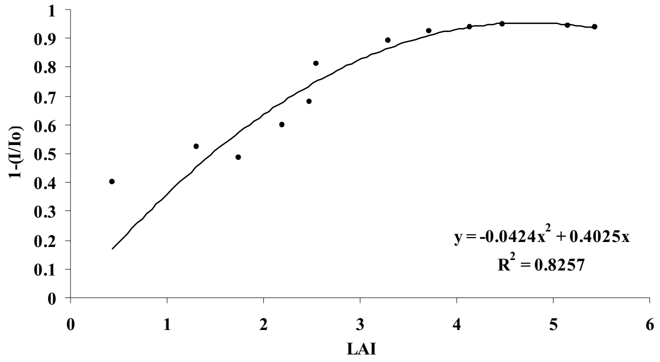

Fig. 1 Relation between fractions of absorbed radiation at solar noon with leaf area index.

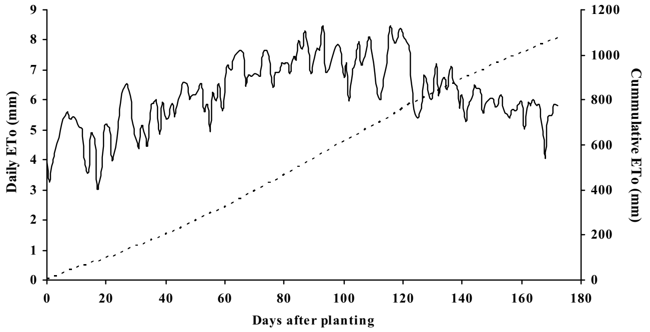

Fig. 2 The trend of daily and cumulative changes of reference evapotranspiration, estimated by Hargreave's equation.

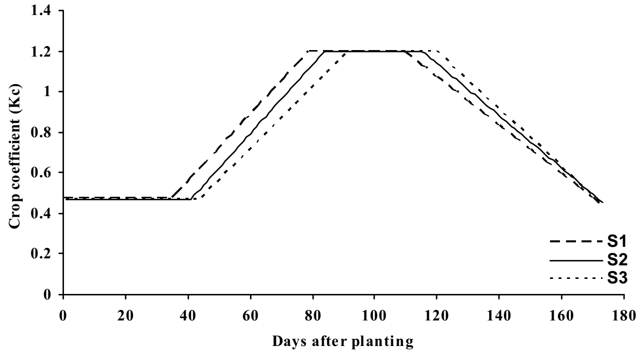

Fig. 3 Crop coefficient (K_C) curve, calculated at three salinity levels as 1.5 (S1), 8.6 (S2), and 28.2 (S3) dSm^{-1}.

Table 1 The length of each plant growth stage (day), estimated based on ground cover by plant canopy.

Salinity (dSm^{-1})	Initial stage	Development stage	Mid-season stage	End-season stage	Total
			day		
1.5	35	43	31	63	172
8.6	40	42	32	58	172
28.2	43	47	29	53	172

Generally, in this halophyte plant, a moderate salinity level not only reduced evapotranspiration but also stimulated dry matter accumulation. A similar finding was reported by McCree and Richardson (1987), who observed in their evaluated species that salinity decreased the initial rate of water loss by plants, leading to an increase in total carbon gain and a proportional increase in WUE.

In forage production, an increase in salinity up to 8.6 dSm^{-1} increased WUE slightly; however, a further rise in salinity caused WUE to decrease strongly (**Fig. 5**). To produce one tonne of dry forage, a total of 8.7 and 8.4 cm water were required at 1.5 and 8.6 dSm^{-1}, respectively (2.9 and 2.8 cm for fresh forage). Although a reduction in salinity from 28.2 to 8.6 dSm^{-1} caused a linear increase in the relationship between yield and evapotranspiration, plants at 1.5 dSm^{-1}, with more evapotranspiration, produced lower

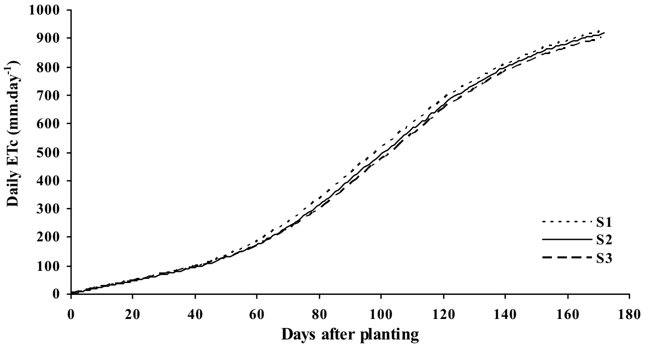

Fig. 4 Cumulative trend of crop evapotranspiration (Etc) at three salinity levels 1.5 (S1), 8.6 (S2), and 28.2 (S3) dSm^{-1}.

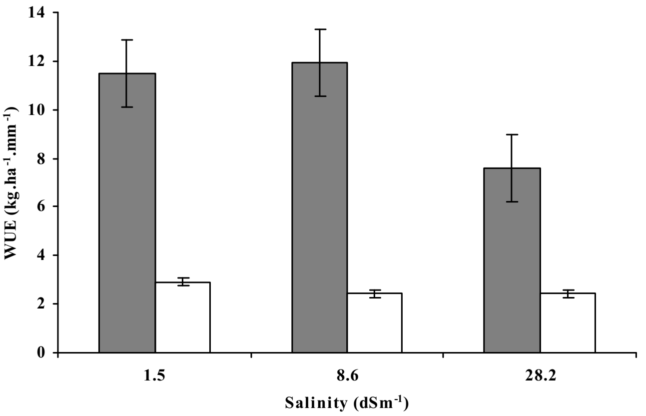

Fig. 5 Water use efficiency (kg.ha^{-1} per mm evapotranspired water) for forage and seed yields at different salinity levels. Vertical bars on each columns are presenting standard errors.

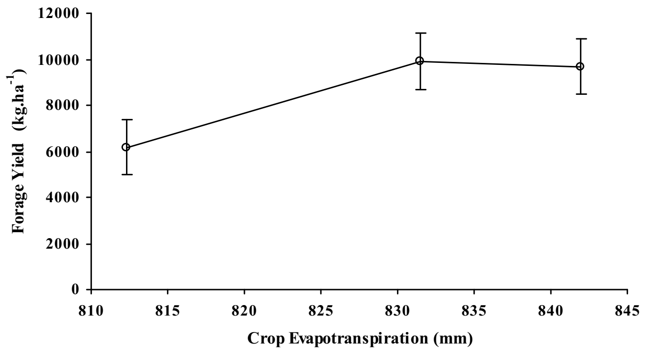

Fig. 6 The relation between total dry forage yield and estimated crop evapotranspiration. Vertical bars show standard errors.

yield than those of 8.6 dSm^{-1} (**Fig. 6**). Of course, the severe stress imposed on plants at the highest salinity should be considered, which caused a deviation in plant responses from the expected trends. A comparison of **Figs. 4** and **5** indicates that salinity influenced WUE more than evapotranspiration, confirming the general conclusion of Katerji *et al.* (2003) in a study of different crops, in which an increase in WUE in response to moderate salinities is a common physiological phenomenon. Richards (1992) stated that the possible reasons for this response are the reduction in stomata conductivity without a related loss in the assimilation capacity, and apparent increase of WUE due to salt accumulation in leaves. Thus it seems moderate salinity can stimulate growth and increase water use efficiency of kochia, leading more forage per applied water.

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