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The impact of saline water irrigation management options in a dune sand on available soil water and its salinity

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ABSTRACT

In this study the effect of two levels of irrigation input, each at two frequencies, were assessed on sorghum (*Sorghum bicolor* (L.) Moench) grain yield as impacted by available soil water after irrigation and the electrical conductivity of soil water (EC_{sw}) in a dune sand, in a greenhouse experiment. Saline water (7.32 dS m^{-1}) at input amounts equivalent to 50% or 100% of pan evaporation was applied daily or every second day. Using time domain reflectometry technique, soil water content and EC_{sw} were monitored simultaneously just before and 1–2 h after irrigation. The cumulative recharge by irrigation in the top 25 cm of the profile ranged from 309 to 662 mm and it depended on irrigation input amounts, which ranged from 382 to 765 mm, and frequency. The potential cumulative evapotranspiration (ET_c) was 578 mm. The daily recharge matched against the corresponding ET_c indicated that grain yield might have been impacted by water stress in the 50% irrigation input, regardless of the frequency, but not in the 100% input treatment. The daily EC_{sw} in the root-zone matched against the FAO threshold (13.6 dS m^{-1}) indicated the possibility of salinity stress during the late maturity stage in the 50% input treatment, regardless of the irrigation frequency, but no stress in the 100% input treatment. Though there was no water or salinity stress in the every second day irrigated 100% input treatment, the significant relative yield reduction, compared with the daily 100% input, is attributed to inherent limited available soil water capacity and rapid percolation losses between irrigations in this sand. The results indicate daily irrigation at 100% input is the most appropriate saline water irrigation management option for this dune sand.

1. Introduction

Dwindling supplies of quality water for irrigation and increasing demand from other users are forcing farmers to use saline irrigation waters (Rhoades, 1987; Rhoades et al., 1992; Shani and Dudley, 2001). Several workers (Shani and Dudley, 2001; Gideon et al., 2002; Katerji et al., 2003) have indicated that when saline waters are used for irrigation due attention should be given to minimize root-zone salinity. Others have indicated the need for selection and use of appropriate irrigation systems and practices that will supply just sufficient quantity of water to the root-zone to meet the evaporative demand and minimize salt accumulation in the root-zone (Fisher, 1980; Munns, 2002). The third approach is to select crops/varieties that can tolerate water and salinity stress to a given degree (DeMalach and Pasternak, 1993; Mastrorilli et al., 1995; Claudivan et al., 2005).

In the Mauritanian semi-arid regions, irrigated rice production, even using quality water (0.10–0.25 dS m^{-1}), has led to rising groundwater levels and increases in soil water

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salinity (2.20 dS m^{-1}) in the root-zone (Josserand and Silva, 2002; van Asten et al., 2003). In this country sorghum, which occupies 60% of the total area under grain production, is a dryland crop grown mostly in the arid to semi-arid regions. Sorghum is widely used for human consumption and as feed and fodder (Ministère du développement rural, 1998). Josserand and Silva (2002) reported that sorghum in Mauritania accounts for 25% of the total grain production. Farmers frequently face crop failure due to drought, but supplementary or full irrigation for this crop has never been tried out. This may be partially due to insufficient water resources other than groundwater, which is primarily used for human and livestock consumption. The wells are usually 5–20 m deep and the dry-out during consecutive dry years. The groundwater tends to become saline after years of water extraction. Under such circumstances, people abandon saline wells and move to new wells. This suggests that even if supplementary irrigation is introduced for sorghum, the potential for irrigation induced salinity risk is high and the sustainability of the already fragile soil resources may be at risk.

Data from vegetable producing semi-arid regions of Mauritania indicate that salinity is already an issue in the groundwater irrigated projects (SONADER, 1998; Josserand and Silva, 2002). Irrigation is usually gravity fed and the water application efficiency is very low. The needs for introduction of new irrigation systems and improvements in existing practices, at least in the intensive vegetable producing regions, have been identified. The drip irrigation is the most efficient system in delivering just the required amount of water directly in the crop root-zone (Shalhevet, 1991). The use of such system is particularly important where limited water resources, including saline groundwater, are used for irrigation. However, the coast of installation and maintenance and the technical skills required for its operation are high for a country like Mauritania. Nevertheless, for future planning purposes at least some limited background information about appropriate management practices is required for saline water irrigation in drip systems (Ayers and Westcot, 1985; Pasternak and DeMalach, 1987; Gideon et al., 1995) to sustain productivity and soil resource utilization in this country. Thus, a greenhouse experiment was conducted, mimicking Mauritanian conditions, to assess the effect of two water input amounts, each at two frequencies, on sorghum grain yield as impacted by available soil water and its EC_{sw} in a dune using saline irrigation water in drip irrigation system (DIS).

2. Materials and methods

2.1. *Experiment*

The experiment was conducted in a greenhouse located at the Arid Land Research Center, Tottori University in Tottori, Japan. The textural composition of the soil is 95% sand, 1.3% silt, and 3.7% clay and is usually referred to as dune sand. The water holding capacity of this soil sand is 0.05 $cm^3\,cm^{-3}$ (0.027 $cm^3\,cm^{-3}$ is wilting point and 0.08 $cm^3\,cm^{-3}$ is field capacity, and these correspond to matric potentials of -1.6 and -0.0055 MPa), respectively.

A randomized complete block design with three replicates was used in this study. The treatments consisted of two irrigation input amounts, 50% (EP0.5) and 100% (EP1.0) of open-pan evaporation, which was measured in the greenhouse. These amounts were applied at two frequencies (daily and every second day). In the every second irrigated treatment, the input on a particular day is equal to the amount applied on the previous day plus the amount due on that particular day of the daily irrigated treatment. This implies the total irrigation input during the growing season in the daily and every second day irrigated treatment are approximately equal for a given input treatment. Sorghum was sown, along lateral lines just by the emitters, on 1 April 2004 at 12 plants per block and harvested on 15 July 2004. Fertilizer was applied, at 180 kg h^{-1} N, 45 kg h^{-1} P, 80 kg h^{-1} K, just before seeding and incorporated into the soil.

The experimental area was irrigated using DIS and each treatment plot (1.2 m $\times$ 1.2 m) was fed by three laterals that branched off from the sub-main pipe. There were 4 emitters, spaced 30 cm apart, on each one of the 120 cm long laterals. The discharge rate from the emitters was 2 L h^{-1}, which was maintained by an operating pressure of 0.1 MPa. Saline water (EC = 7.32 dS m^{-1}) irrigation commenced 2 weeks after sowing and continued until 15 July 2004. However, crop establishment was achieved using 65 mm of quality water (EC = 0.11 dS m^{-1}), i.e. during the first 2 weeks. The total saline water irrigation input in the EP1.0 was around 765 mm for daily and every second day frequency and that for EP0.5 it was around 380 mm. A water-tank was used to prepare saline water, covered to minimize evaporation and cleaned once in every 5 days. The salinity of the irrigation water used in this study was based on invoking two assumptions. First, the average salinity of groundwater in Mauritania is 8.0 dS m^{-1} and secondly the FAO has determined that when saline waters of 6.8 dS m^{-1} were used for irrigating sorghum this could lead to 50% yield reduction. Therefore we decided to use an average between 8.0 and 6.8 dS m^{-1}. At harvest the grain yield was measured after oven drying at 70 °C for 48 h.

A control using quality irrigation water and the associated irrigation option treatments were not included in this experiment due to inadequate greenhouse space. However, during the subsequent year a control using quality irrigation water (EC = 0.11 dS m^{-1}) at EP1.0 on daily basis was included in an experiment in the same greenhouse and the grain yield from this control is included as the background in this paper.

2.2. *Weather condition*

Humidity and temperature were measured every 15 min using (HOBO H8 PRO SERIES LOGGER). The air temperature (maximum, minimum and daily mean) during the growing season increased from April until July and decreased thereafter. The mean monthly temperatures were 20 °C for April, 24 °C for May, 25 °C for June, and 30.1 °C for July. During the growing season the lowest daily mean temperature was 11 °C in April and the highest was 48 °C in July. The mean monthly humidity ranged from 56% to 69%. The lowest diurnal variation in humidity was 33% in June and the highest was 97% in April. The weather data were used to compute daily crop evapotranspiration (ET_c).