Sensitivity of Stress Indicators for Sorghum Under Saline Water Drip Irrigation

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1. Introduction:

There is an increasing trend, particularly from developing countries in Asia and Africa, to use poor quality water, such as that high in salinity (saline water), for irrigation due to scarcity of quality water (Rhoades, et al., 1998). However, there also exists a need to increase the water use efficiency, particularly when groundwater is used for irrigation of small farms to avoid over-extraction and subsequent salinity. There are at least 3 interrelated issues that need attention in relation to saline water irrigation. They are water and salinity stresses, irrigation efficiency, and soil resource sustainability. The water and salinity stresses may change with time during crop growth and the effective stress will depend on the way in which crops respond to the integrated stress (Shalhevt, 1994). Richard et al., (1998) proposed the use of water (Kw) and salinity (Ks) stress coefficients to assess the impact, individually and collectively, of water and salinity stresses on crop yield. The crop response indicator to water stress in usually the LWP, but the water stress could either be due to insufficient water in soil profile (Katerji et al., 1991) and/or high salinity (Shalhevet, 1994). Therefore, an integrated approach involving the three-way interaction of LWP, Kw, and Ks may provide information on relative importance of the stresses and their association with yield. Thus, the objective of this study is to assess the impact of irrigation amount, frequency, and salinity level on the temporal sensitivity of the stress indicators Kw and Ks, and LWP and their association with sorghum grain yield.

2. Materials and methods:

Sorghum was cultivated during the 2004 growing season in a randomized complete block design experiment was conducted at the Arid Land Research Center, Tottori University. The treatments were (i) daily or once in every two day irrigation (ii) applied in amounts equivalent to 100% of open-pan evaporation (EP1.00) or at 50% (EP0.50), and (iii) three salinity levels 7.3, 9.4, and 12.5 dS m^{-1} with a control of 0.1 dS m^{-1}. Soil water content and soil solution electrical conductivity (EC_w) distribution in the soil profile at different depths were monitored daily using a TDR. The pressure-bomb apparatus was used for LWP determination.

3. Results and discussions:

The data for Kw, Ks, and LWP indicated they varied temporally (Fig. 1) and the temporal dynamics depended on the irrigation input, frequency, the time of measurement, and the salinity of the irrigated water. During the critical growth stage the crop was subjected to 35 days of stress in EP0.50 of 1day schedule compared with 7 days in the EP1.00 of 1 day schedule. The number of water stress days in the 2 day schedule increased from 7 days in the EP1.00 of 1 day schedule to 21 days. The data indicate the crop was subjected to less water stress under EP1.00 than EP0.50, regardless of the schedule. The Ks values indicated the crop was subjected to high degree of variable salinity stress under EP0.50 than in EP1.00 and in 2 day schedule than daily. During the critical growth stage the crop was subjected to 6 days of salinity stress under EP1.00 of 1day compared with 10 day in EP1.00 of 2 day schedule. Comparison of the number of water stress and salinity stress days indicate the least number of stress days

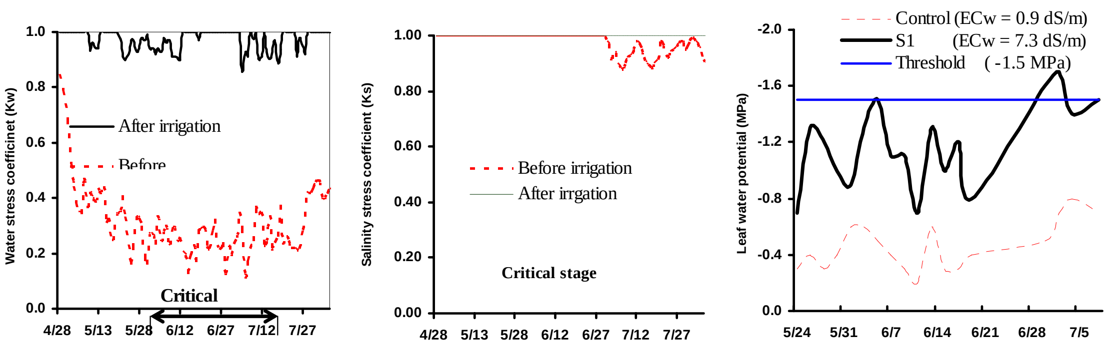

Figure 1. The temporal dynamics of water (Kw) and salinity (Ks) stress coefficients and the leaf water potential and under everyday irrigation at input equivalent to open-pan evaporation.

schedule, 6 days for salinity and 7 days for water, suggesting that EP1.00 of 1day schedule is the best irrigation management practice that provided the least stress with regard to water and salinity. It should be also noted the least number of water and salinity stress days overlapped each other, thus any impact on sorghum yield was integrative and additive, not simplistic.

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The LWP in the control during critical crop growth stage was always less than the threshold and higher than the threshold at salinity levels 1, 2, and 3 for 4, 16, and 19 days, respectively. Because LWP reflects water stress in plants, we suggest the stress increased with increasing salinity of the irrigation water.

The statistical analysis indicated the mean of Kw or Ks or LWP is not a sensitive indicator to discriminate the temporal dynamics of water or salinity stress levels. On the other hand, the CV seems to be a better indicator than mean to discriminate the temporal dynamics impact.

The stepwise multiple regression analysis for grain yield (Y t/ha) as a function of irrigation amount (EP), frequency (D), Kw, Ks, and interaction involving Kw and Ks (Kw x Ks) produced the following equation,

$$Y = 0.21 + 0.06\ EP - 0.05\ D + 0.02\ Kws.\ Kss \qquad (R^2_{adj} = 0.85, P < 0.005)$$

Equation [1] is consistent with the expectation that grain yield increased with increasing irrigation amount, more frequent irrigations, and less water and salinity stresses, i.e. larger values for Kws and Kss. The interaction involving Kw and Ks indicate that at a given soil salt load, the increases in soil water content will simultaneously reduce the impact of salinity and water stress on grain yield.

The stepwise multiple regression analysis procedure was used to characterize the impact of Kw, Ks, and Kw x Ks and LWP for grain yield (Y t/ha)

$$Y = -0.04 - 0.03\ LWP + 0.34\ Kws \times Kss \ (R^2_{adj} = 0.71, P < 0.03)$$

Equation [2] indicates that grain yield depended more on the interaction term Kws x Kss than on individual effects and on LWP. The interaction involving Kws and Kss confirms that at given soil salt load, the increases in soil water content will simultaneously reduce the impact of salinity and water stress on LWP and grain yield.

The ratio of $EC/EC_{Threshold}$ distributions at the end of the growing season indicates the saline water irrigated profiles were salinized up to 50 cm depth regardless of the salinity of irrigation water used. In general, the EC distributions indicate there was leaching of salt to depths > 45 cm. Though irrigation amount was designed to supply just sufficient quantity of water to meet sorghum's potential evapotranspiration need and to replenish the top 30 cm of the depleted profile, the salt distribution and accumulations at depths > 30 cm, indicate substantial leaching. This suggests that potential exists for the major proportion of the salt accumulated in the top 30 cm can be leached through off-season irrigation using saline water, thereby enabling a salt free root environment for the succeeding growing season.

4. Conclusions:

The stress indicators Kw, Ks, and LWP are temporally dynamic and the dynamics depended on the input variables irrigation amount, frequencies, and the salinity of the irrigated water. In general, the means of the temporal dynamic data for the stress indicators are not sensitive to discriminate the impact of the input variables and in this regard the CV has been shown to be more appropriate than the means. Thus, we recommend the use of CV to discriminate the impact of input variables to characterize the temporal dynamics of stress indicators. Salinity stress (Ks) increased with increasing water stress (Kw) and we show that daily irrigation equivalent to daily open-pan evaporation reduced the risk, to the minimum, of water and salt stress simultaneously. Though LWP increased (-ve) with increasing Kw or Ks, the interaction involving these two terms was much stronger than the individual terms in determining the impact on LWP or grain yield. We infer from the interaction dominance, that the impact of the accumulated salt on LWP and yield was reduced after irrigation through dilution. In this regard the daily irrigation seems to be the most appropriate schedule when saline water is used for irrigation; and our grain yield, irrigation amount and frequency data provide support to the aforementioned claim.

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