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Interaction of Temperature and Solar Radiation Effect Sorghum Growth Under Drip Irrigated Saline Water

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Abstract: We investigated the impact of the interaction of temperature and solar radiation on the sorghum (*Sorghum bicolor* L.) growth during three years continuously 2004, 2005 and 2006. Sorghum was grown in dune sand in a plastic greenhouse. The saline irrigation water was 7.32 dS m^{-1} and control treatment was irrigated by good quality water (0.11 dS m^{-1}). The time series statistical parameters; mean, median, CV and the 80th percentile values (PC80), assessed to discriminate the temporal sensitivity of the temperature and solar radiation indicated that CV followed by PC80 are better than median and mean. Sorghum growth and grain yield depended on the interaction between temperature and solar radiation under saline condition rather than individual effect.

Key words: Drip irrigation, saline water, solar radiation, sorghum, temperature

INTRODUCTION

Fresh water resources in the arid and semi-arid regions are becoming increasingly scarce; therefore farmers are resorting to unconventional water sources, particularly those high in salinity. Irrigation saline water has been successfully practice (Roades *et al*., 1992; Broughton, 1995; Shani and Dudley, 2001). However, when irrigation saline water used due attention should be given into weather parameters.

The analytical procedures that have been used to characterise time series data include; statistical parameters (Rasiah *et al*., 2006; Van Dam, 2000) and multiple regression models (Rasiah *et al*., 2006; Hipel and McLeod, 1994). The statistical characterisation usually employs statistical parameters such as mean, median, 80th percentile values (PC80) and coefficient of variation, CV (Rasiah, *et al*., 2006; Van Dam, 2000). These parameters together with multiple regression models have been used to study the impact of system variables (spatial) on temporal dynamics (Rasiah *et al*., 2006; Bierkens *et al*., 2000). The physico-numerical analysis has been found to be appropriate for forecasting and for system viewpoint interpretation (Bierkens *et al*., 2000; Knotters and Bierkens, 2000). The selection of the procedure(s) selected to characterise time series data depends on the purpose and the information is required. Thus, when system viewpoint is of less concern then the statistical parameter approach seems to be more appropriate.

Although there have been numerous studies on the effect of salinity on the sorghum growth (Abichandai and Bhatt, 1965; Francois *et al*., 1984) and also about the interaction between salinity and temperature (Fowler, 1991; Esechie, 1994) none considered about the interaction of temperature and solar radiation. The purpose of this study was to investigate the effect of temperature × solar radiation interactions of sorghum growth under drip saline irrigation conditions.

MATERIALS AND METHODS

Experiment: The experiment was conducted at the Arid Land Research Center, Tottori University Tottori-Japan, for three years continuously, 2004, 2005 and 2006 in a greenhouse. 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-0.0055 and-1.6MPa, respectively). Sorghum was started on 1st April, 29th April and 23rd May in 2004, 2005 and 2006, respectively and was irrigated daily at rates equivalent to daily open-pan evaporation using a Drip Irrigation System (DIS). A randomized complete block design with three replicates was used in this study. The experimental plots received 180 kg N ha^{-1}, 45 kg P_2O_5 ha^{-1} and 80 kg K_2O ha^{-1} just before seeding. The experimental area was irrigated using DIS and each treatment plot (1.2×1.2 m) was fed by 3 laterals that branched off from the sub-main pipe. There were 4 emitters, spaced 30 cm apart, on each one of the 120 cm

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Table 1: Leaf area index and plant height during different irrigation season

Irrigation season	Treatments	20 days	50 days	85 days	100 days
Average of LAI					
Experiment 2004	Control	--	--	--	--
	Salinity	0.1a	1.3a	2.4a	2.0a
Experiment 2005	Control	0.2a	2.8d	6.0d	5.7d
	Salinity	0.1a	1.9c	3.0bc	2.9c
Experiment 2006	Control	0.2a	2.5d	5.4d	5.5d
	Salinity	0.1a	1.5ab	2.6b	2.7b
Plant height (cm)					
Experiment 2004	Control	--	--	--	--
	Salinity	12a	65a	87a	125a
Experiment 2005	Control	32b	88c	141d	148d
	Salinity	12a	81b	106c	132c
Experiment 2006	Control	35b	78bc	136d	155d
	Salinity	30ab	63bc	95b	137cb

Mean value with the different letter(s) are significant

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 two weeks after sowing and continued until harvesting. The salinity of the control water was 0.11 dS m^{-1}. The total irrigation input during the growing season was 765, 770 and 850 mm in 2004, 2005 and 2006, respectively. The characteristics of the soil are given in Table 1.

Weather condition: Solar, humidity and temperature were measured every 15 min using (HOBO H8 PRO SERIES LOGGER). The weather data also were used to compute daily crop Evapotranspiration (ETc).

The general details involved in the computation and the procedures used for the estimation of crop evapotranspiration from open-pan data are provided by Doorenbos and Pruit (1977). For details of the computation pertaining to this particular soil, crop and greenhouse conditions are given in Ould Ahmed *et al.* (2006b).

Leaf Area Index (LAI) and plant height was measured on the 20, 50, 85 and 100 day. After harvesting grain yield was measured, by oven drying at 70°C for 48 h.

Statistical analysis: The mean and stepwise multiple regressions analyze was conducted for the analysis of data using the SAS/Statg (1991) software package.

RESULTS AND DISCUSSION

Crop growth: The LAI and plant height temporal dynamic data (Table 1) indicated that the sorghum growth was different significant during irrigation season. During the first 20 days crop was not significant between control and salinity treatments. The higher LAI was observed during 2005 (0.29±0.02), followed by 2006 and 2004, respectively (0.26±0.01 and 0.24±0.03). Control treatment during 2005 and 2006 irrigation season was not significant differences (0.57±0.04 and 0.55±0.03, respectively). Thus, suggested that crop was subject to the impact of weather condition witch my have direct effect to the salt accumulation in the root zone.

Table 2: The sensitivity of the time series statistical parameters; mean, median, the percentile value (PC80) and Coefficient of Variation (CV), for temperature, solar radiation, irrigation input and ETc during three irrigation season

	Time series statistical parameters				
Irrigation seaon	Range	Mean	Median	PC80*	CV
Temperature (°C)					
Experiment 2004	11.49-33.62	23.85±4.14	24.50	26.58	17.34
Experiment 2005	18.26-36.50	27.94±4.35	27.70	32.46	20.56
Experiment 2006	20.31-40.85	29.48±5.34	28.24	34.64	18.12
Solar (MV $Kw^{-1}m^{-2}$)					
Experiment 2004	0.71-22.30	14.71±4.44	15.53	18.39	30.18
Experiment 2005	0.30-32.57	10.64±6.02	9.54	17.54	56.64
Experiment 2006	1.31-20.24	12.50±4.78	13.82	16.67	38.19
Irrigation input (mm day^{-1})					
Experiment 2004	2.68-11.59	7.29±2.31	7.29	9.49	30.73
Experiment 2005	2.91-11.87	7.86±2.30	7.86	9.92	31.00
Experiment 2006	3.60-13.87	8.21±2.63	8.31	10.59	31.97
Crop evapotranspiration (mm day^{-1})					
Experiment 2004	1.17-12.06	5.32±2.48	4.96	7.01	46.58
Experiment 2005	1.31-12.92	5.93±3.16	4.95	9.82	53.34
Experiment 2006	1.33-12.87	5.36±3.10	4.17	8.40	59.03

*80th Percentile value (20% of the times were greater than the value in the table); ±Values indicate the standard deviation

Plant height shows that the highest plant was observed during 2006 (137±0.12 cm) followed by 2005(132±0.08 cm) and 2004(125±0.10 cm), respectively. Unlike LAI the plant height was not significant between 2005 and 2006. In generally, that the control treatments during two irrigation season were almost same but among the salinity treatments they were significantly.

In our previous research we found that crop growth under saline water irrigation was directly impact by irrigation input (Ould Ahmed *et al.*, 2006a). The irrigation input was based on open-pan and this was directly impacted by temperature and solar radiation as well as the interaction between these two factors.

Table 2 show the time series analysis parameter for temperature, solar radiation, irrigation input and ETc for different irrigation season. The data analysis shows that the temperature was higher during 2006 irrigation season while solar radiation showed the highest during 2004 irrigation season. The solar radiation was fluctuated during irrigation season as impacted by weather in Tottori. Though there were differences in the ranges in temperature during different irrigation season, the mean±SD indicate no significant difference between 2004, 2005 and 2006 irrigation season and a similar trend was also observed for solar radiation (Table 2). In generally, temperature at the minimum they were differently, suggesting that the higher temperature was inducing the stress under water salinity. Irrigation input and ETc was not difference during irrigation season. However, the

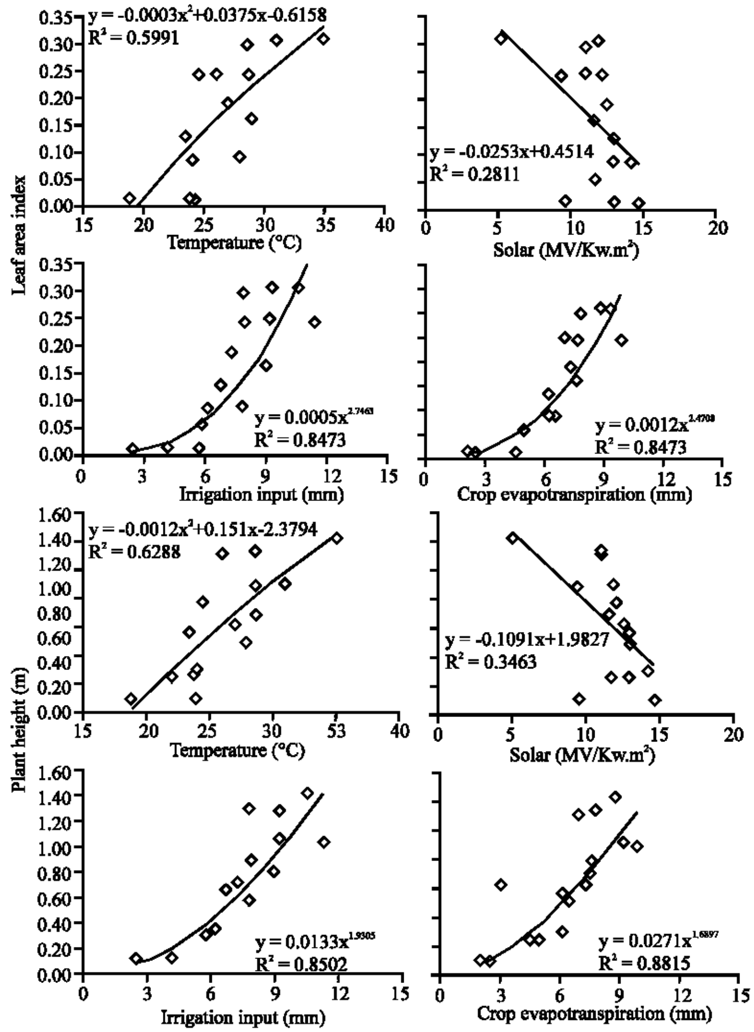

Fig. 1: Correlations between LAI, plant height and temperature, solar, irrigation input and crop evapotranspiration (ETc)

different between irrigation input and ETc suggested that irrigation input was able to be more than ETc.

This suggests the temporal changes in temperature and solar radiation, irrigation input and ETc as effected the crop growth can not be statistically discriminated by the mean parameter. On the other hand the temperature and solar radiation, in 2005 are characterized by larger CV than 2004 and 2006, suggesting the crop was subjected to larger variations in temperature and solar radiation during 2005 than in 2004 and 2006. An assessment of PC80 for 2005 vs. 2004 and 2006 indicated the temperature was discriminated by the medium (32 vs. 27 and 35°C, respectively) and a similar trend existed for solar radiation discrimination by (15 vs. 18 and 17, respectively). Data indicated that temperature was highest during 2006 and solar radiation was highest during 2004, suggesting that the interaction between these two factors was the main effect to crop growth rather than individual. It seems the time series statistical parameter CV best discriminated the temporal impact of temperature and solar radiation on the crop growth followed by PC80 and median in that order. The PC80 indicates that 20% of time the number is less than a given value and a larger CV value indicates lower risk associated with temperature or solar radiation. A comparison of the performance of time series statistical parameters (Rasiah *et al.*, 2006; Van Dam, 2000) mean, median, PC80 and CV for temperature, solar radiation, irrigation input and ETc in their discriminating ability of the growth response to saline irrigation water consistently outperformed the median and mean.

Figure 1 show the relationship between plant growth parameters (LAI and plant height) and temperature, solar radiation, irrigation input and ET. Data show strong relationship between temperature and LAI or plant height (R^2 = 0.60 and 0.62, respectively), while the relationship between solar radiation and plant parameters was negative correlation. The correlations between irrigation input and ETc with plant parameters were same and characterized by higher correlation.

The stepwise multiple regression analysis for LAI and plant height as a function interaction involving temperature and solar radiation (TEMP×SLAR) produced the following equation:

$$\text{HEIGHT} = -0.40-0.0002\ (\text{TEMP}\times\text{SLAR}) + 0.16\ \text{IRR} \quad (1)$$

$$R^2_{adj} = 0.70\ p<0.05$$

$$\text{LAI} = -0.16-0.0012\ (\text{TEMP}\times\text{SLAR}) + 0.04\ \text{IRR} \quad (2)$$

$$R^2_{adj} = 0.65\ p<0.03$$

The interaction indicated that increasing temperature or solar radiation would reduce crop growth at a given stage, while the increases in irrigation input would reduce the impact of salinity effect simultaneously on height and LAI.

Grain yield: The grain yield data are shown in (Fig. 2), the highest yield was observed under no saline water irrigation. However, the different between control treatments was not significant, while the different among salinity treatments during three irrigation season were different significantly. The highest was in 2005 (0.27±0.01) and the lowest in 2004 (0.23±0.01). Sorghum was grown in early April during 2004, end April in 2005 and end May in 2006, suggesting that crop was best when it sawing in end of April compared with binging April or end of May, which is characterized by low and higher temperature, respectively.

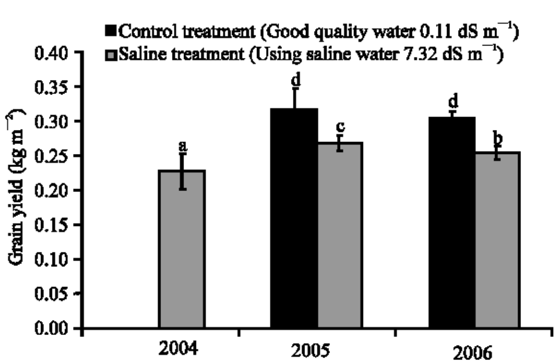

Fig. 2: Grain yield during three irrigation season

CONCLUSIONS

The grain yield of sorghum, grown on dune sand and irrigated with 7.32 dS m^{-1} saline water, indicated that crop was mainly affected by the interaction involving temperature and solar radiation rather than the individual affect. In general, the mean, of the data for each one of the temperature and solar radiation was not sensitive to discriminate the impact of the input variables. In this regard CV and PC80 were found to be most appropriate statistical time series parameters followed by the median values. Therefore, we recommend, use of CV and PC80 to characterize the temporal dynamics of the temperature and solar radiation effect to the crop growth under saline condition. Thus, we conclude the temporal sensitivity information in the interaction between temperature and solar radiation is useful to assess the temporal risk associated with saline water irrigation.

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