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Effects of Regulated Deficit Irrigation on Growth of Sorghum Cultivar

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Abstract
The effects of regulated deficit irrigation technique on growth of sorghum was examined in a greenhouse at the Faculty of Agrotechnology and Food Science Research Farm, University Malaysia Terengganu. The experiments regulated deficit irrigation (RDI) consisted of a factorial combination of irrigation regimes and soil types laid in a randomised complete block design with eight treatments for each experiment which resulted into a total of sixteen treatments. Irrigation regimes were at four levels namely: I_{100}, I_{75}, I_{50} and I_{25} and the soil types were at two levels namely: Rhu Tapai and Rengam soil Series. The treatments were randomly assigned to experimental pots and replicated four times. A total of thirty two pots were used for the study. All agronomic practices starting from land preparation to harvesting were adhered to and growth parameters were recorded for the experiment. The result of the study shows that, sorghum performance improved under regulated deficit irrigation techniques. The results further revealed that, irrigation regimes I_{100} and I_{75} performed better in terms of growth parameters, crop water use efficiency, under Regulated deficit irrigation and compared to I_{50} and I_{25} irrigation regimes. The study also revealed that there were interaction effects of deficit irrigation and the two types of soil on some of the parameters used for the study. The study, therefore, recommended the use of I_{75}, for optimizing sorghum growth in this agro ecological zone.
Key words: Regulated deficit irrigation, Growth. Water use efficiency, Rhu Tapai soil series, Rengam soil series

Introduction

Sorghum (*sorghum bicolour* L. Moench) is the third important cereal crop grown in the United States and the fifth most important grain crop in the world after rice, maize and barley. In 2010, Nigeria was the world's largest producer of grain sorghum followed by the United States and India.(FAOSTAT, 2011).The world harvested 55.6 million tonnes of sorghum in 2010.The world average annual yield for the 2010 sorghum crop was 1.37 tonnes per hectare. It is one of the major sources of food for people in many developing countries (Rorhbach *et al.,* 2002). Sorghum is an important world crop used for food (as grain and in sorghum syrup or sorghum molasses), fodder, the production of alcoholic beverages, as well as biofuels (U.S.Grains Council). It was originated in the region of the North-East Africa comprising Ethiopia, Sudan and East Africa (Doggett, 1988). The crop is well adapted to the range of environmental condition in semi-arid region of Africa with high variability (Teshome *et al.* 1997; Rami *et al.* 1998). Generally constraints to the availability of water for irrigated agriculture are increasingly evident in many countries. Shortage may be seasonal, year round or progressively significant as demands from other users expand. Owing to the wide scale expansion of irrigation farming water has become increasingly a scarce resource. Scarcity is further complicated when water supplies are uncertain.

When water supplies are limiting, the farmer's aim should be to maximize net income per unit water used rather than per land unit. Infact recognition has been placed on the concept of water productivity (WP), defined either as the yield or net income per unit of water used in ET (Kijne *et al 2003)*. However, investigations in water-saving irrigation still are continued (Slryker *et al*., 2007). Nowadays, full irrigation is considered a luxury use of water that can be reduced with minor or no effect on profitable yield (Kang and Zhang, 2004). Water-saving irrigations are used to improve the water productivity (WP) in recent years. Regulated deficit irrigation is the water-saving irrigation method that cut down irrigation amounts of full irrigation to crops. The amounts of irrigation reduction is crop-dependent and generally accompanied by no or minor yield loss that increases the water productivity (Ahmadi et al., 2010b).

. Nevertheless, irrigated agriculture is still practiced in many areas in the world with complete disregard to basic principles of resources conservation and sustainability. Therefore irrigation water management in an era of water scarcity will have to be carried out most efficiently, aiming at saving water and at maximising the productivity. Deficit irrigation has widely been reported as a valuable strategy for dry regions (English, 1990; Pereira *et al.,* 2002; Fereres and Soriano, 2007) where water is the limiting factor in crop cultivation. The main objective of the study was to evaluate the effect of regulated deficit irrigation on the growth and water productivity of sorghum cultivars.

Materials and Methods

Experimental site and climatic data

The study was conducted in a greenhouse at Faculty of Agrotechnology and Food Science Universiti Malaysia Terengganu, with Latitude and Longitude; 5^{0}.20'N 103^{0} 5'E. The Altitude is about 32 m. The climate of the area is tropical rain-forest with a mean annual rainfall of 2911 mm (114.6 in).The average temperature in Terengganu is 26.7^{0}C (min 22^{0}C, max 32^{0}C),while the mean relative humidity for an average year is recorded as 71.7% and on a monthly basis it ranges from 68% in May and June to 79% in December. Sorghum (*Sorghum bicolor L. Moench*) cultivar Samsorg-KSV8 from Nigeria was used in this research. The physiochemical properties of the two types of soil are given in Table 1. The plants were planted on Rengam soil series and Rhu Tapai soil series. Various treatments comprising of different regimes of irrigation namely: (i) 100% RDI (ii) 75% RDI (iii) 50% RDI and (iv) 25% RDI, and one type of cultivar: SAMSORG14-KSV8 and two types of soil.. All treatments were layout by following a randomized complete block design factorial with four replications. A total of thirty two polythene bags were used. Plant spacing of 75 by 50cm

The gross depths for the deficit irrigation methods used in this study were calculated as follows:

$$\text{Gross irrigation depth for deficit irrigation} = \frac{\text{NWR}}{\text{Efficiency of the system}} \quad (1)$$

A total of irrigation events were calculated and carried out during the growing Period of the cultivars under study. An irrigation frequency were estimated and maintained during the irrigation throughout the growing period. The crop water use for the sorghum cultivars was determined by estimating the reference crop evapotranspiration from climatic data using the Hargreaves method (Hargreaves *et al.*2003, Lopez-Urea *et al.,* 2006).

The actual evaporation which is synonymous to crop water use was estimated by multiplying reference evapotranspiration with appropriate value of crop coefficient (Doorenbos and Prutt, 1975).

$$ET_c = K_c \text{ x } ET_c \quad (2)$$

Where;

K_c = crop coefficient

ET_o = reference crop evapotranspiration in mm/day

Four seeds per hole was planted and later thinned to two plants per stand two weeks after germination. Weeding was carried out manually throughout the growing period to reduce competition for space, water, light and nutrients between crops.

Data collection started after transplanting. Growth parameters were recorded during the crop growth and development.. The leaf area indexes of each randomly selected plant were computed using the formulae described by Duchemin *et al* (2006). Measurements were made at regular intervals of three weeks. The leaf density was calculated by multiplying plant density (no of plants) with numbers of leaves per plant. Hence the leaf area was calculated by multiplying leaf length with leaf width and the leaf shape correction factor. Where 0.75 is the leaf shape correction factor. However, leaf area index was finally determined by multiplying leaf density with leaf area. Harvest indexes were determined using the procedures described by Huhn (1990). The procedure used for the determination of the harvest indexes was by dividing grain yield with biological yield and multiplying the output by one hundred.

The crop water use efficiencies for the cultivar studied was determined using the methods described by Kumar (2004) and Michael (2008).

$$\text{Crop water use efficiency} = \frac{\text{Yield}}{\text{Evapotranspiration}} \quad (3)$$

All data collected were subjected to statistical analysis of variance using the Tukey-test with the aids of Statistical Analysis System (SAS 9.2) software.

Result and Discussion

Table 2a shows the result of the plant height as affected by regulated deficit irrigation treatments. Data on plant height were recorded on weekly basis after sowing. The result for the treatments indicates that, plant height increased with crop growth and reached a maximum stage at the grain filling stage. Based on the findings of this research, plant heights were affected by regulated deficit irrigation treatments significantly. The result also shows that one hundred percent full irrigation (I_{100}) produced taller plants compared to treatments seventy five percent regulated deficit irrigation (I_{75}), fifty percent regulated deficit irrigation (I_{50}) and twenty five percent regulated deficit irrigation (I_{25}) Table 2a. Treatment I_{100} and I_{75} are not significantly different from each other but they are significantly different from treatments I_{50} and I_{25}. Differences in plant height could be explained by decrease in formation of node on the main stem due to water deficit throughout the growth period. The result is in agreement the findings of Karam *et al* (2003), Adamtey *et al* 2010. Simsek and Comlekcioglo (2011). The result showed no significant difference between the soil types (Rhu Tapai and Rengam Soil Series) with respect to plant height. These could be due to the fact that the experiment was carried out in a climate-controlled greenhouse.

The effect of regulated deficit irrigation treatments were significant at $P<0.05$ on the number of leaves of sorghum as shown in Table 2. The data revealed that, in relation to soil types no significant difference was observed. Regulated deficit irrigation effect at one hundred percent (I_{100}) and seventy five percent (I_{75}) of the crop water requirement were found to have a significant effect on the number of leaves, at 5% level of significant. The data revealed that, in relation to soil types no significant difference was observed. The effect of regulated deficit irrigation on the number of leaves at one hundred percent (I_{100}) and seventy five percent (I_{75}) of crop water requirement were not significantly different. However, the fifty percent (I_{50}) and twenty five percent treatments (I_{25}) were significantly different from the other two treatments as shown in table 2a and also no significant different between Rhu Tapai and Rengam Soil Series.

Table 2a presents the interaction effects of regulated deficit irrigation treatments and soils on leaf area index at five leaf stage, that there was no significant difference among the treatments (P<.0.05) in terms of leaf area index at five leaves stage which revealed that in both soils, individual treatment within Rhu Tapai and Rengam Soil Series statistically similar. This could be attributed to smaller size and less number of leaves at those particular growth stages. Furthermore, in comparison between Rhu Tapai and Rengam Soil Series treatments were statistically not similar. The Rhu Tapai Soil Series had higher numerical values of regulated deficit irrigation treatments than Rengam Soil Series as showed in Table 2a.

The data in Tables 2a revealed that, for all treatments, the leaf area index (LAI) increased with crop development and attained a maximum value at dough stage. Leaf area index was essentially low for the all treatments at five leaves stage (FLS) and jointed stage (JS).This is in agreement with the findings of Howell *et al*: (2007). However, they were statistically different at the jointed stage as shown in table 2a.. The result indicated that, there was significant different at the Five Leaf and Jointed Stages in comparison between the Rhu Tapai and Rengam Soil Series, hence these could be due to early stages of the leaf development. The I_{100} and I_{75} treatments as indicated in Table 2a revealed that were statistically similar in both Rhu Tapai and Rengam Soil Series. These might be due to improvement in the colloidal activity and efficient application of irrigation. The I_{100} and I_{75} treatments were statistically not different, while the I_{50} and I_{25} treatments were statistically also not different but they were at par statistically compared with the other two treatments within the Rhu Tapai and Rengam Soil Series respectively at jointed stage as revealed in Table 2a. At the flowering stage as shown in table 2a there was significant different among the applied regulated deficit irrigation, in Table 2a as also indicated that the I_{100} and I_{75}
irrigation treatments were not significantly different at the flowering stage, I_{50} and I_{25} irrigation treatments were statistically different. Likewise, they were at par compared with the other two irrigation treatments (I_{100} and I_{50}).

The effect of regulated deficit irrigation on leaf area index as shown in Table 4.3iv revealed that there was significant difference at the dough stage. The result also showed applying one hundred percent (I_{100}) of the crop water requirement produced high ratio of leaf area index compared to seventy five percent (I_{75}), fifty percent (I_{50}) and twenty five percent (I_{25}) of the crop water requirement. Treatments I_{75} and I_{50} are not significantly different from each other but they are significantly different from I_{25} (Table 2a).

The result on root dry matter revealed that, root dry matter was influenced by regulated deficit irrigation treatments as shown in Table 2b which indicated significant difference among the treatments at 5% level of significance. Treatment I_{100} produced the highest root dry matter. This was followed closely by treatment I_{75}. The result (table 2b) further revealed that, treatment I_{50} and I_{25} recorded low root dry matter. The result is at tandem with the findings of Hsiao and Xu, 2000;.No significant difference was observed between the soil types

The result revealed interaction effects of regulated deficit irrigation treatments and soils on stem girth. Significant difference had occurred within the irrigation treatments of both Rhu Tapai and Rengam Soil Series respectively as shown in Table 2b. I_{100} produced thicker stem girth compared I_{75} treatment. The result in Table 2b also revealed that, the I_{50} and I_{25} produced the smaller and smallest stem girths respectively. The data in Table 2b indicated interaction effect of irrigation and soils on stem girth.

The Table 2b indicated that, there were interaction effects of regulated deficit irrigation and soils on tillers. The mean values as indicated in Table 2b also showed that, there was no significant difference among the I_{100} percent irrigation treatment, I_{75} irrigation treatment and I_{50} irrigation treatment in terms of tillering but they were found to be statistically different with I_{25} irrigation treatment. The result revealed that there was no statistical different within the both soil types in relation to the irrigation applied.

CONCLUSION

The study evaluated the effects of deficit irrigation on growth and water productivity of sorghum on two types of soil revealed the followings: The growth parameters plant height, number of leaves, leaf area index, root dry matter and tillers under regulated deficit irrigation treatments were significantly different while I_{100} and I_{75} percent regulated deficit irrigation treatments were similar. On the other hand, the stem girth showed significant difference in all treatments. In all the parameters the I_{100} and I_{75} percent regulated deficit irrigation treatments were numerically similar; the crop water use efficiency was significantly affected by the regulated deficit irrigation treatments. I_{100} percent regulated deficit irrigation treatment recorded the highest values of water efficiency (1.50417Kg/m^3) while the lowest was 1.04721Kg/m^3 at I_{50} percent regulated deficit irrigation treatment. .

Yield of sorghum's harvested biomass grown on Rhu Tapai and Rengam Soil Series as shown in Table 3a, 3b, have revealed that, there were significant different between the two types of soil used in relation to the irrigation water applied. The result indicated that, numerically Rhu Tapai and Rengam Soil Series recorded 5216.9 and 5003.1Kg/ha under the Regulated Deficit Irrigation respectively. These indicated that when Rhu Tapai Soil Series is correctly treated with sufficient organic matter and appropriate agronomic practices applied can produce competitive yield in comparison with Rengam Soil Series under sorghum production..

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Table 1: Physio-chemical properties of Rhu Tapai and Rengam Soil Series.

Soil properties	Rhu Tapai	Rengam
Particle size distribution		
Silt (%)	2.52	3.07
Sand (%)	67.35	30.28
Clay (%)	30.13	66.65
Texture	Sandy	Clay
Organic matter (%)	0.99	1.62
PH (1:1 suspension)	4.6	4.8
Bulk Density (g/cm^{-3})	1.27	1.31
CEC (cmol (+) Kg^{-1} soil	9.53	7.i4
Total nitrogen (%)	0.09	0.15
Exchangeable bases (cmol (+) kg^{-1} soil		
Ca (cmol (+) kg^{-1} soil	0.2	0.17
Mg (cmol (+) kg^{-1} soil)	0.02	0.10
K (cmol (+) kg^{-1} soil	0.01	0.10
% of water base on weight		
0.33 bar	6.5	23.5
1.0 bar	4.0	30.5
15 bar	3.02	17.2

Source; Field experiment.

Table 2a: Effects of regulated deficit irrigation on growth parameters of sorghum.

Treatment	Plant height (cm)	Number of leaves/plant	Leaf area index			
Irrigation			*Fls	*Js	*Fs	*Ds
I_{100}	222.41[a]	16.00[a]	0.12[a]	2.76[a]	6.10[a]	9.53[a]
I_{75}	207.94[a]	16.00[a]	0.14[a]	2.61[a]	5.22[a]	7.37[b]
I_{50}	178.05[b]	14.00[b]	0.15[a]	2.15[b]	4.27[b]	5.58[b]
I_{25}	152.03[b]	12.00[c]	0.12[a]	1.18[c]	2.20[c]	2.48[c]
Rhu Tapai Soil	194.47[a]	15.00[a]	0.20[a]	2.72[a]	4.50[a]	6.42[a]
Rengam Soil	185.75[a]	14.00[a]	0.06[b]	1.64[b]	3.90[a]	6.05[a]

Means followed by the same letter within column are not significantly difference at P $\leq$ 0.05 (DNMRT)
*Fls-Five leaf stage, *Js-Jointed stage,*Fs-Flowering stage,*Ds-Dough stage

`Table 2b: Effects of regulated deficit irrigation on growth parameters of sorghum.

Treatment	Root dry matter (g)	Girth (cm)	No. Tillers
Irrigation			
I_{100}	675.45[a]	4.78[a]	4.00[a]
I_{75}	659.71[a]	4.39[b]	4.00[a]
I_{50}	491.66[b]	3.78[c]	3.00[ab]
I_{25}	185.64[c]	3.36[d]	2.00[c]
Rhu Tapai Soil	540.01[a]	4.14[a]	4.00[a]
Rengam Soil	466.22[a]	4.01[b]	2.00[b]

Means followed by the same letter within column are not significantly difference at P $\leq$ 0.05 (DNMRT)

Table 3: Effects of regulated deficit irrigation on sorghum biomass.

Treatment	Crop Water use efficiency (Kg/m^3)	Herbage Dry Matter (Kg/m^3)
Irrigation		
I_{100}	1.50417[a]	929.99[a]
I_{75}	1.29745[b]	902.84[a]
I_{50}	1.04771[c]	643.14[c]
I_{25}	0.00000	437.53[d]
Rhu Tapai Soil	0.98246[a]	817.13[a]
Rengam Soil	0.94220[a]	614.62[b]

Means followed by the same letter within column are not significantly difference at P $\leq$ 0.05 (DNMRT)