Effect of Regulated Deficit Irrigation on Photosynthesis, Photosynthetic Active Radiation on Yield of Sorghum Cultivar

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Abstract
The effects of regulated deficit irrigation technique on photosynthesis, photosynthetic active radiation and yield of sorghum grown on Rhu Tapai and Rengam series soil were examined in a Control Environment House at the Faculty of Agrotechnology and Food Science, University Malaysia Terengganu. The experiments regulated deficit irrigation consisted of a factorial combination of irrigation regimes and soil types laid in a randomized complete block design with eight treatments for. 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 series soil. The treatments were randomly assigned to experimental pots and replicated four times. All agronomic practices starting from planting of sorghum to harvesting were adhered to and photosynthesis, photosynthetic active radiation and yield parameters were recorded for the experiment. The result of the study shows that sorghum performed better under regulated deficit irrigation technique. The results further revealed that, irrigation regimes I_{100} and I_{75} performed better in terms of photosynthesis, photosynthetic active radiation and yield parameters compared to I_{50} and I_{25} irrigation regimes. The study also revealed that there was no significant different between the two types of soil used for the study. The study, therefore, recommended the use of I_{75} percent regulated deficit irrigation for optimizing sorghum yield production in semi-arid regions.
Keywords: Regulated deficit Irrigation, photosynthesis, photosynthetic active radiation, yield, sorghum

1. Introduction

Sorghum (*sorghum bicolor* 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. 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 (Doggett, 1988; Teshome *et al*. 1997; Rami *et al*. 1998). In 2010, Sorghum is a key crop in the warm low-rainfall regions of the tropics. Hence, it is adapted to a wide scope of agro-ecological conditions ranging from the high rainfall highland of Rwanda to the arid zones of Libya, where it is produced under irrigation. Sorghum is normally grown during the rainy season, but on some soils, it may also be sown at the beginning of the dry season using the residual soil moisture as in the northern regions of Cameroun and Nigeria. It is also highly battle to drought and salinity and has a remarkable yield potential even in trivial environments (Cosentino, 1996.; Amaducci *et al*. 2004). The world harvested sorghum was estimated at 55.6 million tonnes in 2010. The world average annual yield for the 2010 sorghum crop was 1.37 tonnes per hectare. Sorghum is well adapted to temperate climates (Gnansounou *et al*. 2005; Kangama and Rumei, 2005).

To sustain the growing world population, agricultural production will need to increase (Howell, 2001), yet the portion of fresh water currently available for agriculture 72% is decreasing (Cai *et. al*. 2003). Hence, sustainable methods to increase crop water productivity are gaining in arid and semi-arid regions. Irrigated agriculture is the primary user of diverted water globally, reaching a proportion that exceeds 70-80% of the total in the arid and semi-arid zones. It is therefore not surprising that irrigated agriculture is perceived in those areas as the primary source of water especially in the surfacing drought situations. Currently, irrigated agriculture is wedged between two perceptions that are conflicting; some perceive that agriculture is highly inefficient by growing water guzzling crops" (Postel *et al,* 1996) while others emphasized that irrigation is essential for the production of sufficient food in the future, given the anticipated increases in food demand due to world population growth and changes in diets (Dyson, 1999). Globally, food production from irrigation represents >40% of the total and uses only about 17% of the land area devoted to food production (Fereres and Connor, 2004). 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; Fereres and Soriano, 2007) where water is the limiting factor in crop cultivation.

Water productivity (WP) is defined as crop yield per unit applied irrigation water that is the efficiency of applied irrigation water (Zhang, 2003). Partial stomatal closure and reduced leaf area occurred due to increased abscisic acid. These are the main physiological responses to decrease transpiration in plants under PRD and enhance WP (Davies *et al*., 2002 therefore, a higher WP (or WUE) is obtained (Morison *et al.,* 2008) Water productivity has been increased significantly by using partial rootzone drying on different crops (Davies *et al*., 2002, Sepaskhah and Khajehabdollahi, 2005, Fereres and Soriano, 2007, Costa *et al*., 2007, Geerts and Raes, 2009, Ahmadi *et al*., 2010b). Recently in a meta-analysis Sadras (2009) confirmed that use of partial rootzone drying improved water productivity by 82% compared to full irrigation with no noteworthy reduction in yields. However Liu *et al*. (2006b) indicated that partial rootzone drying was less efficient than deficit irrigation in enhancing water use efficiency and Wakrim *et al.* (2005) and Kirda *et al*., (2005) confirmed that partial rootzone drying resulted in lower water use efficiency than deficit irrigation in beans and maize respectively. Nevertheless, more optimistic effect on fruit quality was occurred in partial rootzone drying than in deficit irrigation (Kang and Zhang, 2004; Kirda *et al*., 2004; Leib *et al*., 2006). De la Hera *et al*. (2007) and Ahmadi *et al.* (2010b) indicated that to investigate the effectiveness of partial rootzone drying compared to deficit irrigation, it is necessary to investigate hormonal changes resulted by long-term partial rootzone drying on reproductive development whether the chemical signaling in partial rootzone drying is different from deficit irrigation, the differences in the pattern of soil water uptake, root growth, and how the water redistribution from roots can influence chemical signaling in dry roots and the duration and best timing for application of partial rootzone drying according to crop, soil, and site specifications. Sepaskhah and Ghasemi (2008) also reported findings from their study in partial rootzone drying conducted at Iran in semi-arid region resulted in an average of 28% reduction in sorghum grain yield with related reduction in applied water at customized 15 day irrigation intervals. Studied the effects of every-other furrow and every-furrow irrigations on grain sorghum yield and water productivity at various irrigation intervals of 10, 15 and 20 days. It was indicated that every-other furrow irrigation at 10 day intervals of every-other furrow abridged the applied water by 11% with no yield reduction compared every-furrow irrigation at 15 day intervals.

Important water saving coupled with the economic yield has been documented by Ahmadi (2009) and Dodd (2009) in a review of greenhouse and field studies on the application of partial rootzone drying on different species of trees and annual crops. Different experimental results in partial rootzone drying have shown that irrigation water may be reduced by approximately 30-50% in partial rootzone drying with no significant yield reduction. In some cases even better fruit quality was obtained in partial rootzone drying (Kang and Zhang, 2004, Kirda *et al.,* 2004, Leib *et al.,* 2006, Du *et al.,* 2010,, Guang-Cheng *et al*., 2008). The most investigations on partial root zone drying have initiated in the last decade and, however, practical progress of the technique still continues for agronomical and horticultural crops (Morison *et al.*, 2008; Guang-Cheng *et al.,* 2008; Ahmadi, 2009). The list of literature on experimental studies on partial rootzone drying is thorough; however, the following subsections include, but not limited to, a relatively complete and broad list of diverse crop species on which the partial rootzone drying has been applied in the last decade. The objective of the study was to assess the effect of deficit irrigation on the photosynthesis, photosynthetic active radiation and yield of sorghum cultivars.

2. Materials and Methods

Experiment was conducted in a Control Environment House at Faculty of Agrotechnology and Food Science Universiti Malaysia Terengganu, with Latitude and Longitude; 5^0.20'N 103^0 5'E (figure 1). 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 26.7^0C (min 22^0C, max 32^0C),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 experiments regulated deficit irrigation consisted of a factorial combination of irrigation regimes and soil types laid in a randomized complete block design with eight treatments for. 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 series soil (Sandy soil) and Rengam series soil Ultisol). The physio-chemical properties of Rhu Tapai and Rengam Soil Series are as shown in Table 1. The treatments were randomly assigned to experimental pots and replicated four times. All agronomic practices starting from planting of sorghum until harvesting were done.

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)	4.60	4.80
Bulk density (g/cm^{-3})	1.27	1.31
CEC (cmol (+) kg^{-1} soil	9.53	7.14
Total nitrogen (%)	0.09	0.15
Exchangeable bases (cmol (+) kg^{-1} soil		
Ca	0.20	0.17
Mg	0.02	0.10
K	0.01	0.10
% of water base on weight		
0.33 bar	6.50	23.5
1.0 bar	4.00	30.5

Data collection started after transplanting, physiological and yield parameters were recorded during the crop growth and development. Total yield per hectare were equally measured. Photosynthetic rate, photosynthesis also were measured.

All data collected were analyzed using SAS statistical program (SAS Inst 1999). Analysis of variance (ANOVA) test was conducted and significant differences among the treatments were determined using Duncan New Multiple Range Test (DNMRT) at $P \leq 0.05$.

3. Results and Discussion

3.1 Effect of Regulated Deficit Irrigation on Photosynthetic Parameters

As shown in Figure 1 showed that there was significant different among the deficit irrigation regimes applied. However, at the five leaf stage one hundred percent (I_{100}) treatment was significantly different compared to other three treatments, while, there were no significant different among three regimes. Figure.2 indicated that there no significant different between one hundred percent I_{100}) and seventy five percent (I_{75}) regulated deficit irrigation regimes at jointed stage and likewise in the other two regimes (I_{50} and I_{25}). The result also revealed that there was significant different between the two regimes (I_{100} and I_{75}) and the other two regimes (I_{50} and I_{25}) as affected photosynthesis. It presented a significant different at the flowering stage, where the one hundred percent (I_{100}) was significantly different compared with seventy five percent regulated deficit regime as showed in Figure 3 while there was no significant different in the other two regimes ($I_{50}$and I_{25}).

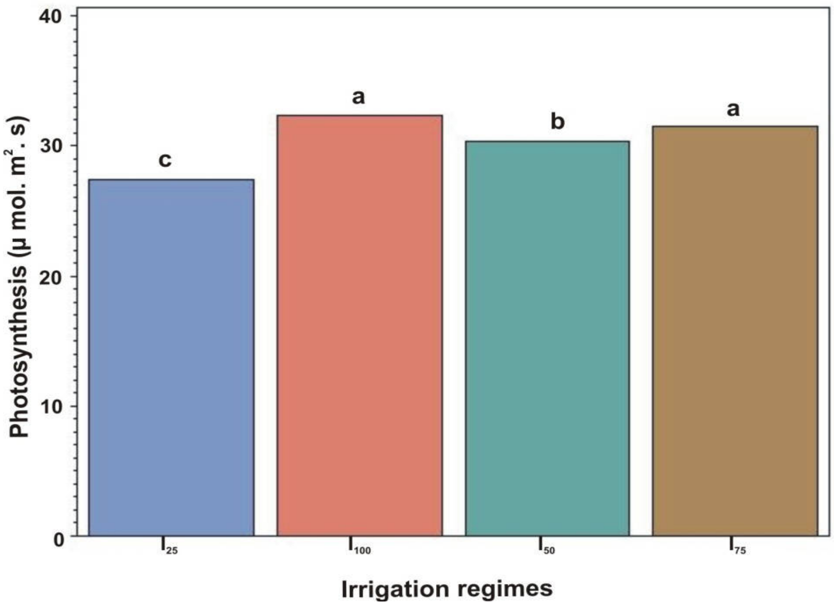

Figure 1: Effect of Regulated Deficit Irrigation on Photosynthesis at Five Leaf stage

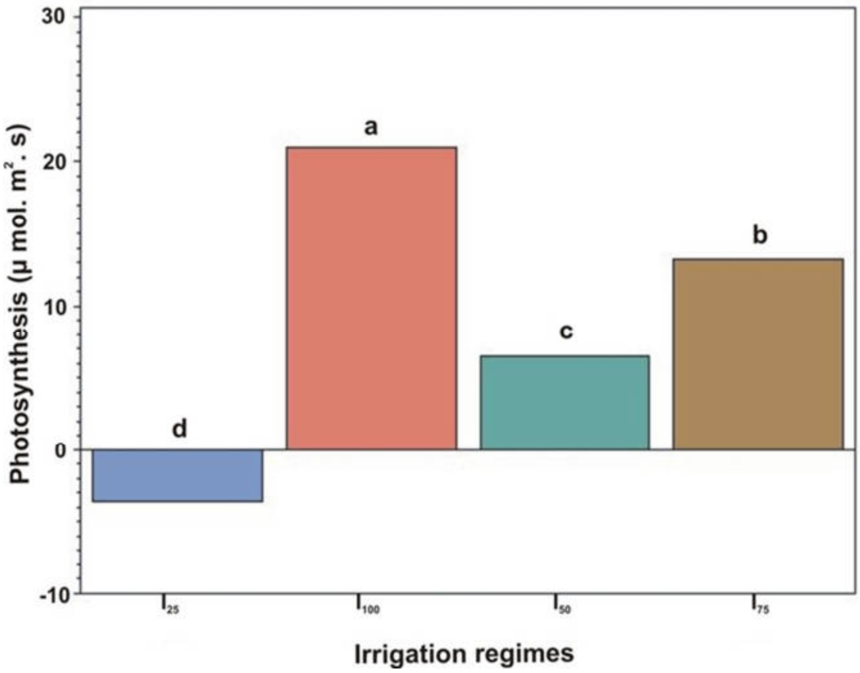

Figure 2**:** Effect of Regulated Deficit Irrigation on Photosynthesis at Jointed Stage

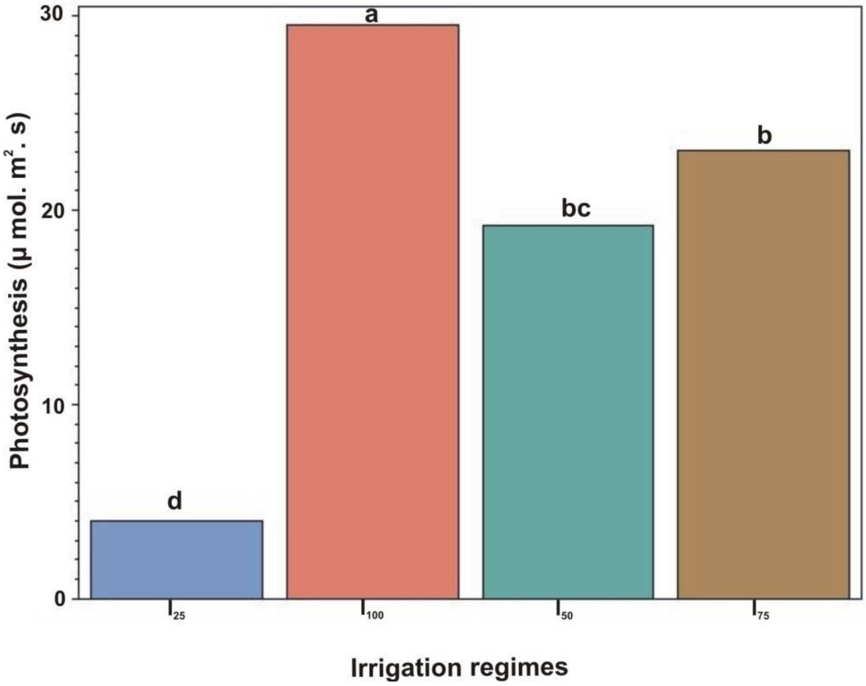

Figure.3: Effect of Regulated Deficit Irrigation on Photosynthesis at Flowering Stage.

The Figure 4 further revealed that at the dough stage, there was no significant different between I_{100} percent and the I_{75} percent regulated deficit irrigation regimes but there was significant different when compared with the I_{50} and i_{25}percent regulated deficit irrigation regimes. The process of photosynthesis is sensitive to changing environmental conditions, and the way in which plants adapt to their environment is related to photosynthesis. The variation of photosynthesis in most plants declines around mid-day which is induced by high radiation and serious water deficit (Tolk and Howell, 2003)

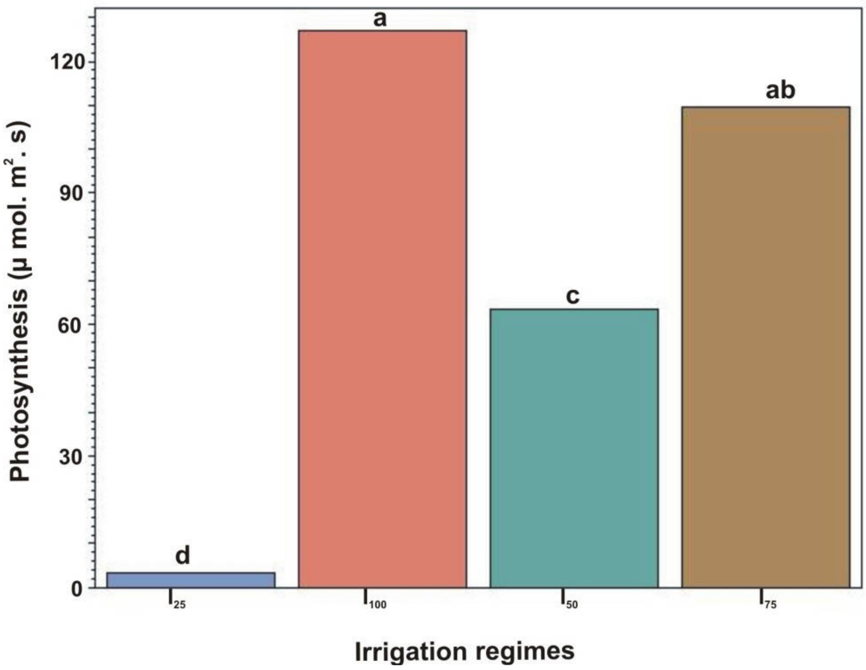

Figure 4: Effect of Regulated Deficit Irrigation on Photosynthesis at Dough Stage

3.2 Effect of Regulated Deficit Irrigation on Photosynthetically Active Radiation

There was no significant different at five leaf stage among three irrigation regimes, which includes I_{75},I_{50} and I_{25} percent regulated deficit irrigation regimes respectively. However, I_{100} percent regulated deficit irrigation regime was significantly different at the five leaf stage as revealed in Figure 5. The result as indicated in Figure 6, 7 and 8 showed that there was significant different among the irrigation regimes at the jointed, flowering and dough stages. The I_{100} and I_{75}percent irrigation regimes respectively as showed in all the growth stages indicated that there was no significant difference as compared statistically. Perusal of the result showed that I_{50} and I_{25} regulated deficit irrigation regimes were not statistically different throughout the growth stages as revealed in Figure.5, 6, 7 and 8.

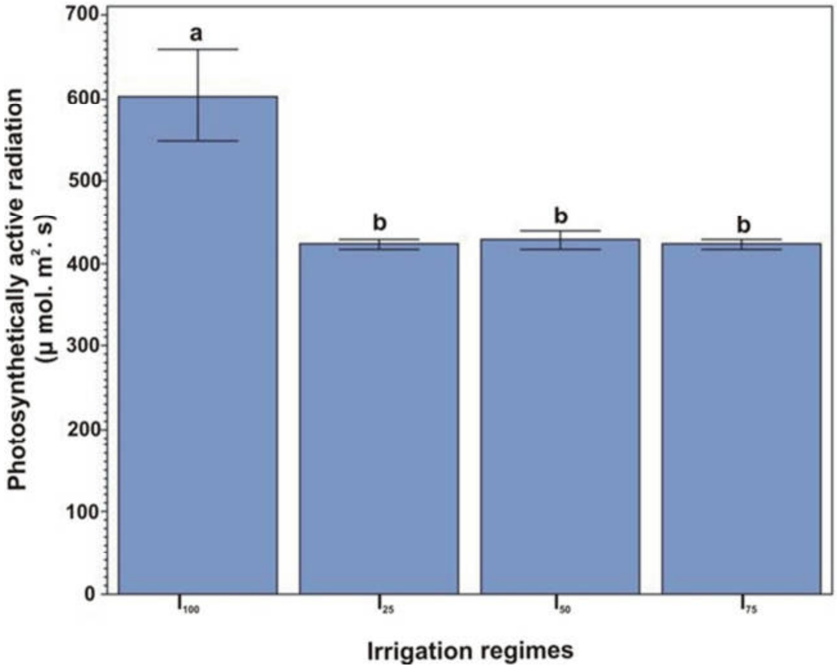

Figure 5**:** Effect Regulated Deficit Irrigation on Photosynthetically Active Radiation at Five Leaf Stage.

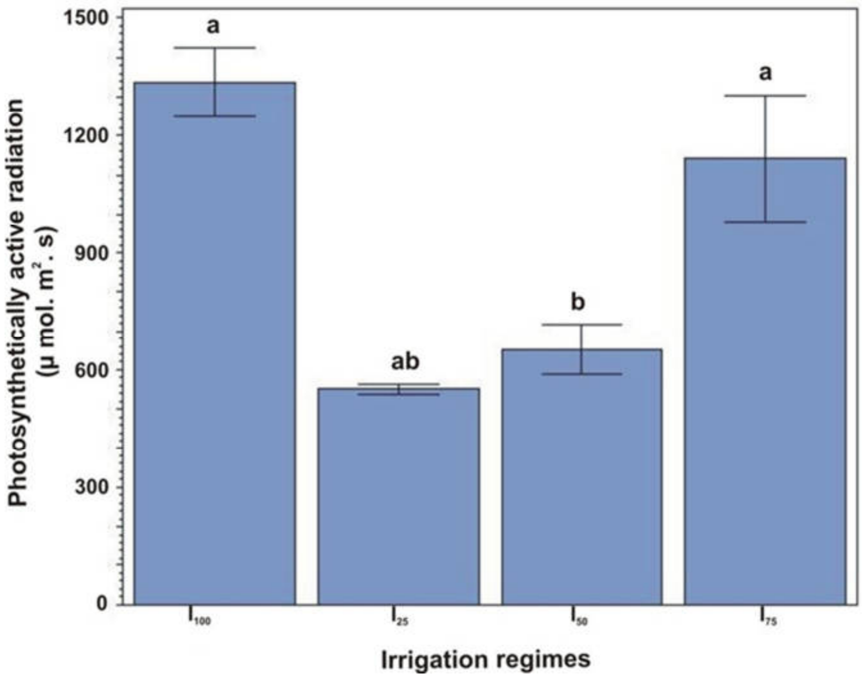

Figure 6**:** Effect Regulated Deficit Irrigation on Photosynthetically Active Radiation at Jointed Stage.

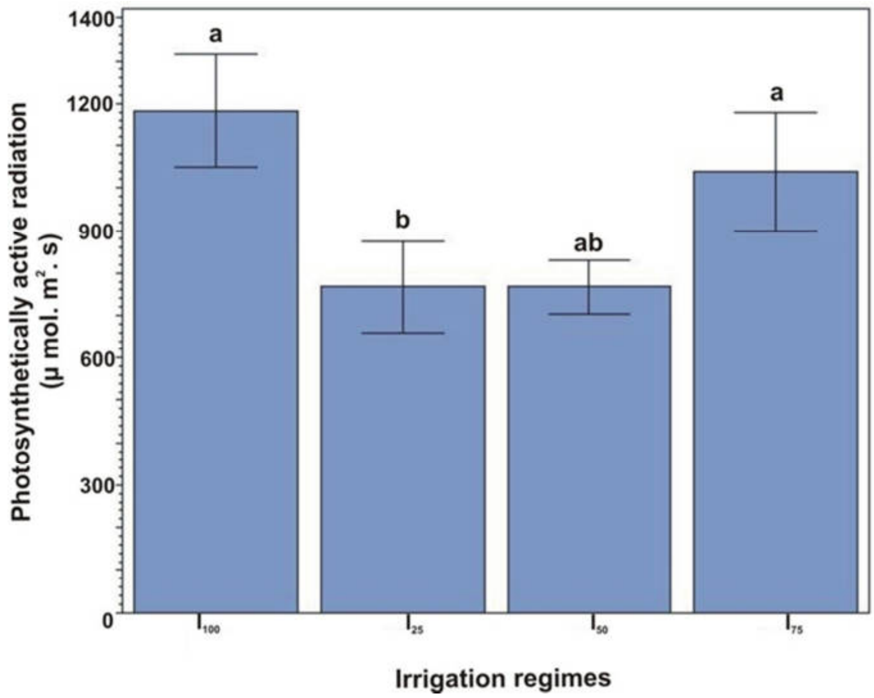

Figure 7: Effect of Regulated Deficit Irrigation on Photosynthetically Active Radiation at Flowering Stage

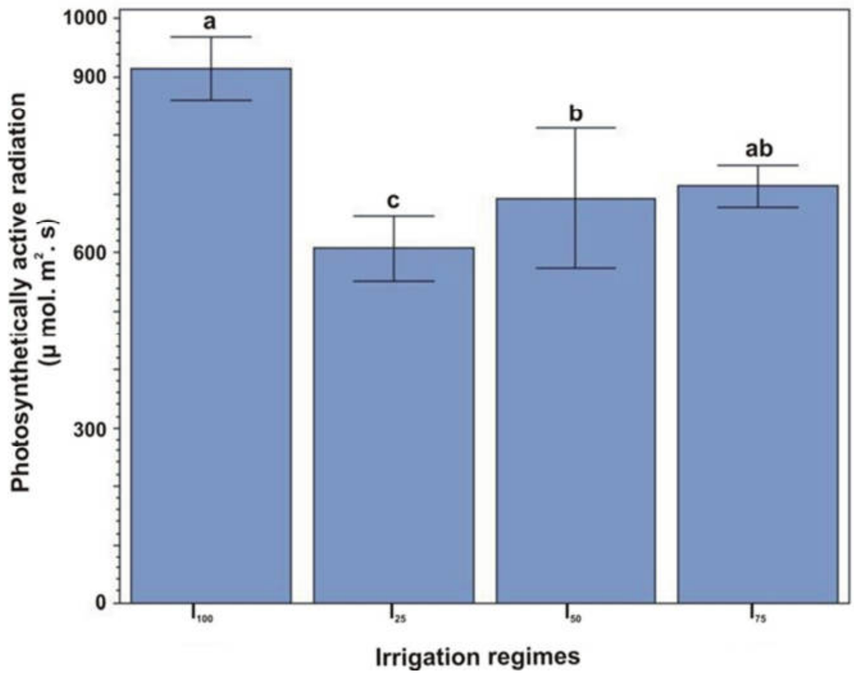

Figure 8: Effect of Regulated Deficit Irrigation on Photosynthetically Active Radiation at Dough Stage

3.3 Effect of Regulated Deficit Irrigation on Yield.

The differences between the regulated deficit irrigation (RDI) treatments I_{100}%, I_{75}%, I_{50}%, and I_{25}% with respect to the grain yield were found significant as shown in table 4.7. The highest grain yield was from the one hundred percent I_{100}% irrigation treatment followed by the fifty percent (I_{50}%) irrigation treatment. The yields were not significantly different between the one hundred (I_{100}%) and seventy five percent (I_{75}%) irrigation treatments. The lowest yield was obtained from I_{25}percent irrigation treatment. Nevertheless, apart from genetic influenced for enhancing plant's growth hormones production, deficit irrigation strategies also increases growth hormones levels in the plants (Dodd, 2009. Liu *et al.*, 2006). This has been agreed to attribute to better stomatal control over plant water use, (Dodd, 2009). Table 2 also showed that Rhu Tapai Soil Series and Rengam Soil Series are not significantly different.

Table 2: Effect Regulated Deficit Irrigation on Yield of Sorghum

Treatment	Yield (Kg/ha)
Irrigation	
I_{100}	7887.1^{a}
I_{75}	7389.4^{a}
I_{50}	5563.3^{c}
I_{25}	0.0^{d}
Rhu Tapai Soil Series	5216.9^{a}
Rengam Soil Series	5003.1^{a}

Means followed by the same letter are not significantly different at $p \leq 0.05$ (DNMRT)

4. Conclusion

The study shows that sorghum performed better under regulated deficit irrigation technique. Irrigation regimes I_{100} and I_{75} performed better in terms of photosynthesis, photosynthetic active radiation and yield parameters compared to I_{50} and I_{25} irrigation regimes. The study also revealed that there was no significant different between the two types of soil used for the study. It is therefore, recommended the use of I_{75} percent regulated deficit irrigation for optimizing sorghum yield production in semi-arid regions.

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