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# Effect of Partial Rootzone Drying Irrigation on Nutrient Concentration in Leaves, Photosynthesis, Photosynthesis Active Radiation and Yield of Sorghum Cultivar

*Adzemi Mat Arshad[1] and Ibrahim W[2]
[1]Soil Science Laboratory, Food Crop Science Unit, School of Food Science and Technology, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Malaysia
[2]School of Agricultural Technology and Food Science, Department of Agricultural Technology, Ramat Polytechnic Maiduguri, Borno State, Nigeria.
*adzemi@umt.edu.my

**Abstract**
The effects of partial rootzone drying irrigation technique on nutrient concentration in leaves, photosynthesis, photosynthetic active radiation and yield of sorghum grown on Rhu Tapai and Rengam series soil were examined at Control Environment House, Faculty of Agrotechnology and Food Science, University Malaysia Terengganu. The experiments partial rootzone drying irrigation consisted of a factorial combination of irrigation regimes and soil types laid in a randomized complete block design with eight 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 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 partial rootzone drying 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**:Partial rootzone drying irrigation, nutrient concentration, 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).

Water productivity (WP) is defined as crop yield per unit functional 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 diverse 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 enhanced 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. 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 on 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 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 15day intervals.

To protract the growing world population, agricultural production will need to increase (Howell, 2001) yet the fraction 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 stiff between two perceptions that are at variance, 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 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 priceless strategy for dry regions (English, 1990, 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 partial rootzone drying irrigation on the nutrient concentration in leaves, photosynthesis, photosynthetic active radiation and yield of sorghum cultivar.

## 2. Materials and Methods

Experiment was conducted at Control Environment House, Faculty of Agrotechnology and Food Science, Universiti Malaysia Terengganu with Latitude and Longitude $5^0$.20'N $103^0$ 5'E. The Altitude is 32m. The climate of the area is tropical rain-forest with a mean annual rainfall of 2911mm. (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 plants were planted on Rengam series soil (Ultisol) and Rhu Tapai series soil (Sandy soil) or Bris (Beach ridges interpersed with swales soil).

Various treatments comprising of different regimes of irrigation namely: (i) 100% RDI ($I_{100}$) (ii) 75% RDI ($I_{75}$) (iii) 50% RDI ($I_{50}$) and (iv) 25% RDI ($I_{25}$) and one type of cultivar: SAMSORG14-KSV8 and two types of soil: Rengam (Ultisol) and Rhu Tapai (Sandy soil) respectively. All treatments were laid out by following a randomized complete block design (RCBD) with four replications. A total of thirty two polythene bags were used. The total area of experimental field is 185.81m$^2$ and four lateral line pipes, each were connected to the pipe with stoppers attached at each joints of laterals connecting to main pipes. Emitters or drippers were attached according to plant spacing of 75 by 50cm. Regulated deficit irrigation treatments were arranged at the front while partial rootzone drying irrigation followed behind. On each drippers were attached with clippers for regulating the irrigate

Soil samples were taken from the experimental field. The samples were used to determine physical properties of the soil. The properties include soil texture, bulk density, field capacity, permanent wilting point and available water (Table 1).

The fertilizer nutrients recommended for sorghum are 64kg N, 30kg of $P_2O_5$ and 30kg $K_2O$ per hectare was applied. Single super-phosphate and muriate of potash were applied during polythene bags preparation and including poultry fertilizer. While urea as source of nitrogen was applied in split applications. 32kgN was applied three weeks after planting and the remaining half was applied six weeks after planting at 15cm from the plants. Weeding was carried out manually throughout the growing period to reduce competition for space, water, light and nutrients between crops. For determination of N, P and K in plant tissues of third blade below ear of sorghum leaves, wet ashing was employed by digesting tissue samples in concentrated $H_2SO_4$ and $H_2O_2$ (Thomas et. al., 1967). The concentration of N, P and K were determined by an auto-analyzer. Dry ashing was employed for determination of Ca and Mg (Chapman and Pratt, 1961) in third blade ear of sorghum leaves. The concentrations were determined using the atomic absorption spectrophoptometer.

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 | 23.50 |
| 1.0 bar | 4.00 | 30.05 |

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 the Duncan New Multiple Range Test (DNMRT) at $p \leq 0.05$

## 3. Results and Discussion

### *3.1 Effect of Partial Rootzone Drying on Nutrient Concentration in Leaves*

The result shows that there are no significant different in nutrient concentration of N, P, K, Ca and Mg in leaves of sorghum of different treatments. There is no interaction between the soils used in the experiment (Table 2). The N, P, K, Ca and Mg concentration in the leaves of sorghum are at adequate level for sorghum growth and yield production (Reuter and Robinson, 1986).

Table 2: Effect of Partial Rootzone Drying on Nutrient Concentration in Sorghum Leaves

| Treatments | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| | | | (%) | | |
| Irrigation | | | | | |
| $I_{100}$ | 2.56a | 0.44a | 3.10a | 0.35a | 0.23a |
| $I_{75}$ | 2.56a | 0.44a | 3.41a | 0.33a | 0.21a |
| $I_{50}$ | 2.52a | 0.56a | 2.99a | 0.34a | 0.19a |
| $I_{25}$ | 2.46a | 0.47a | 3.06a | 0.33a | 0.20a |
| Rhu Tapai Soil Series | 2.55a | 0.45a | 3.10a | 0.35a | 0.21a |
| Rengam Soil Series | 2.55a | 0.46a | 3.11a | 0.35a | 0.22a |

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

 

*3.2 Effect of Partial Rootzone Drying on Photosynthesis*

The result in Figure 1 revealed that at five leaves stage there was significant different In the partial rootzone drying irrigation regimes applied. The $I_{100}$% irrigation regime recorded highest numerical values when compared to the three other irrigation regimes ($I_{75}$%, $I_{50}$% and $I_{25}$%). The result also indicated that $I_{100}$% and $I_{75}$% partial rootzone drying irrigation regimes were not significantly different in all the growth stages except at five leaf stage as showed in Figure 2, 3 and 4 respectively.

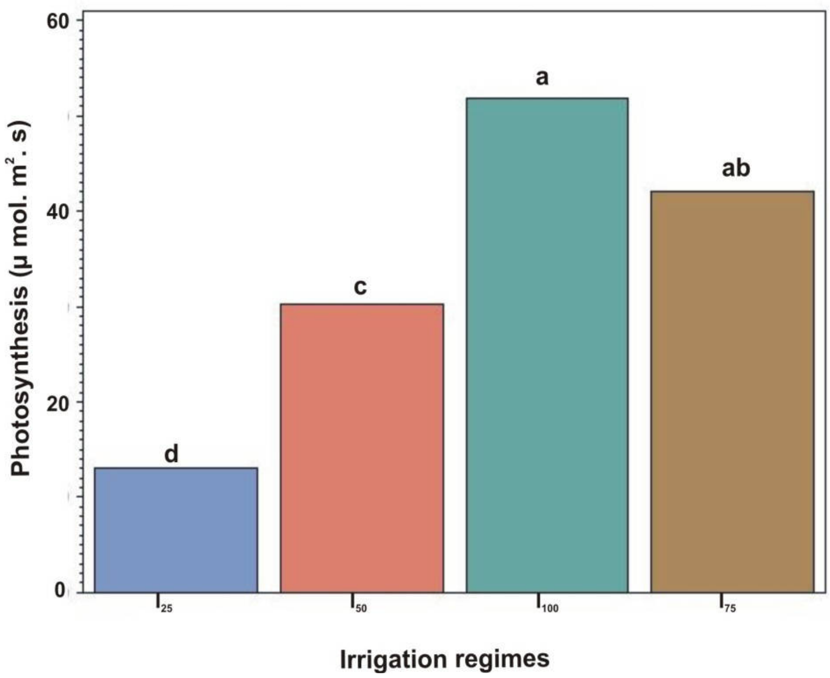


Figure 1: Effect of Partial Rootzone Drying on Photosynthesis at Five Leaf Stage

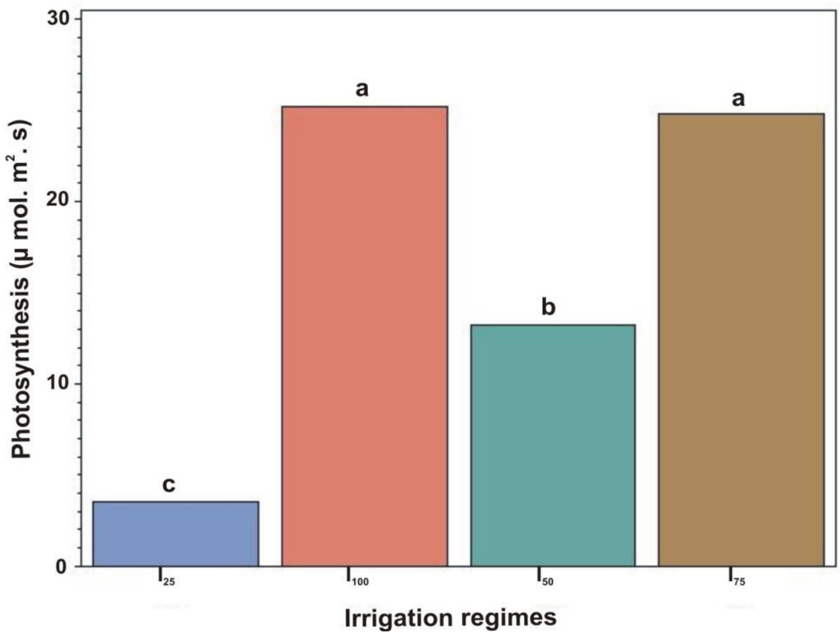


Figure 2: Effect of Partial Rootzone Drying on Photosynthesis at Jointed Stage

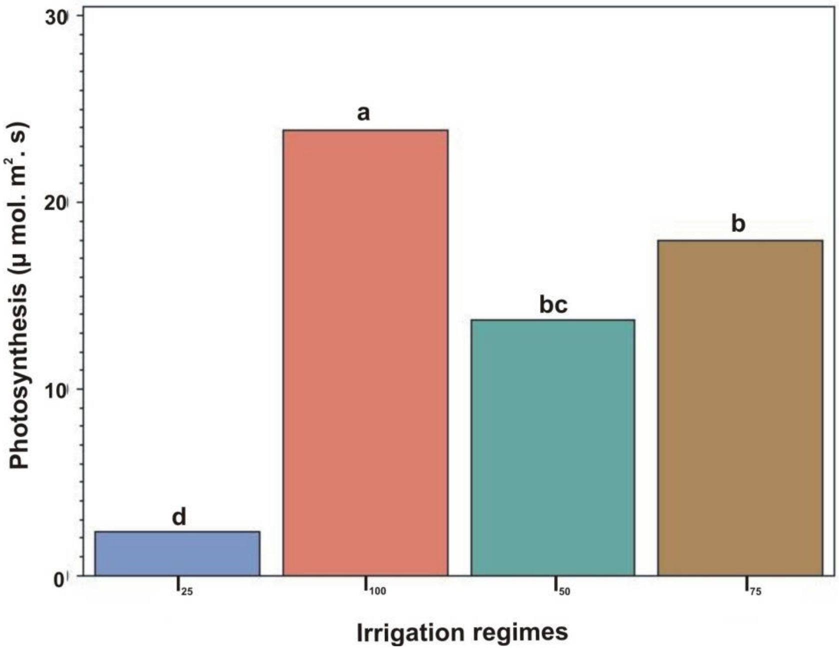


Figure 3: Effect of Partial Rootzone Drying on Photosynthesis at Flowering Stage.

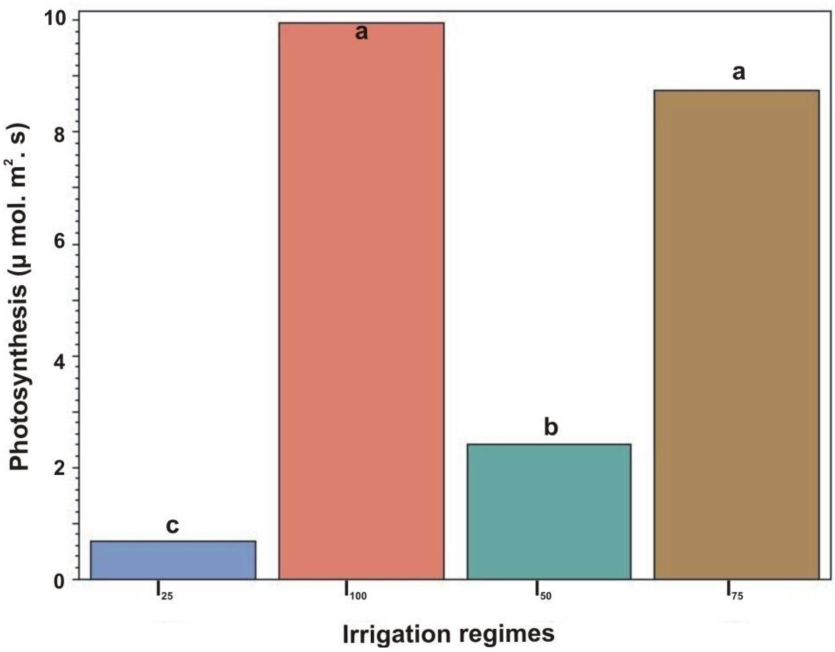


Figure 4: Effect of Partial Rootzone Drying on Photosynthesis at Dough Stage

*3.3 Effect of Partial Rootzone Drying on Photosynthetic Active Radiation*

All the effect of partial rootzone drying irrigation regimes on photosynthetically active radiation at various growth stages resulted in significant differences. The $I_{100}$% partial rootzone drying irrigation regime was significantly at par when compared to the other three regimes ($I_{75}$%, $I_{50}$% and $I_{25}$%). However, the other three partial rootzone drying irrigation regimes were not significantly different as indicated in Figure 5 and furthermore Figure 6, 7 and 8 as showed that the lowest photosynthetically active radiation values were recorded under the $I_{25}$% partial rootzone drying irrigation regime.

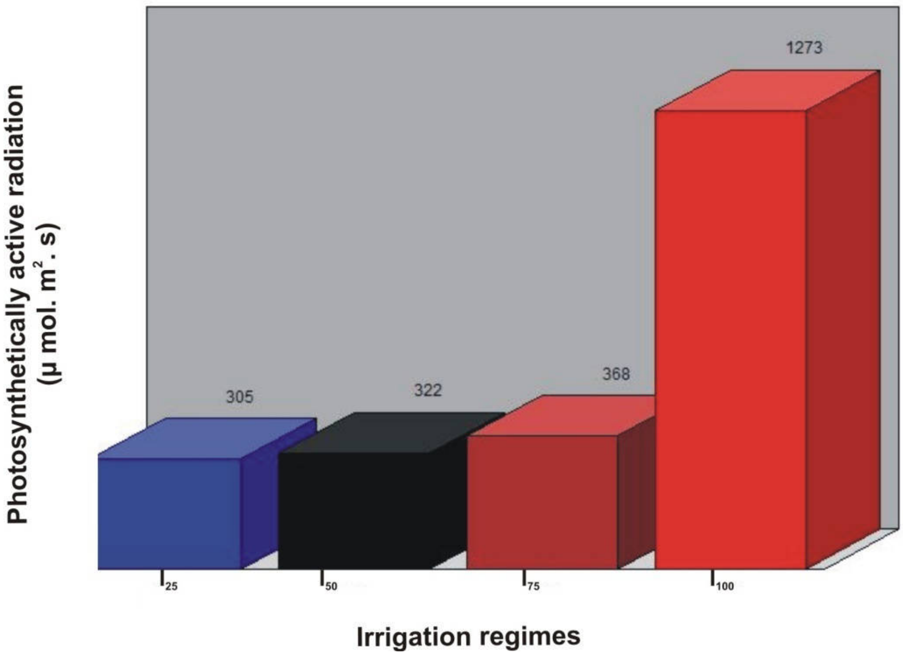


Figure 5: Effect of Partial Rootzone Drying on Photosynthetic Active Radiation at Five Leaf Stage.

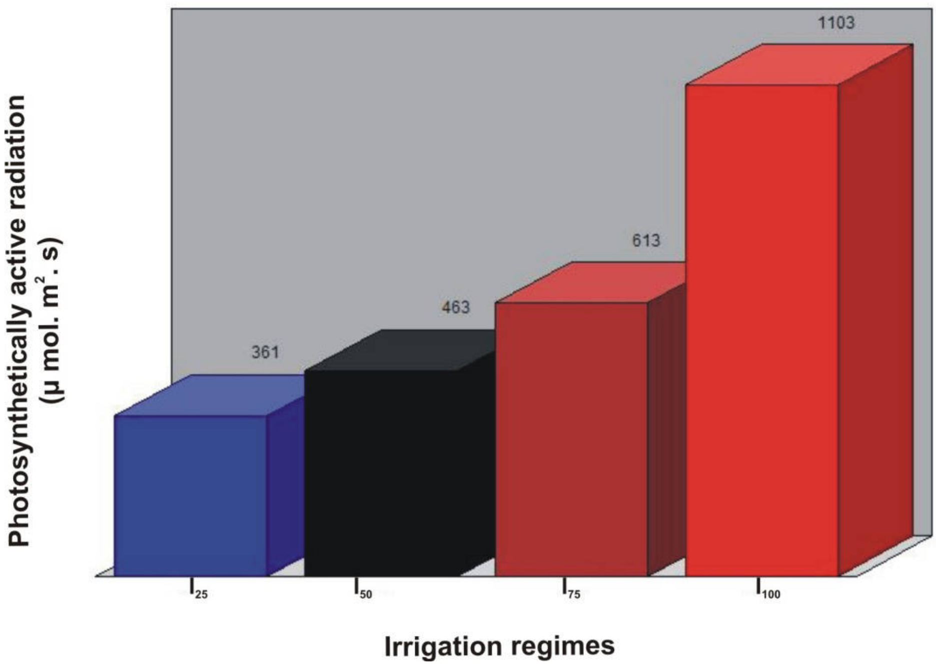


Figure 6: Effect of Partial Rootzone Drying on Photosynthetic Active Radiation at Jointed Stage

 

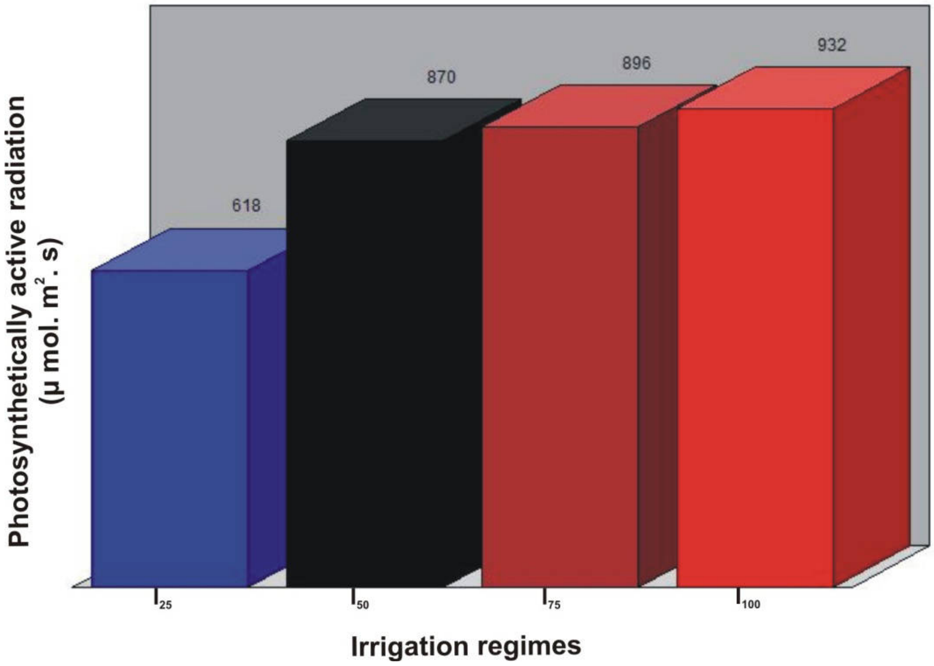


Figure **7:** Effect of Partial Rootzone Drying on Photosynthetic Active Radiation at Flowering Stage.

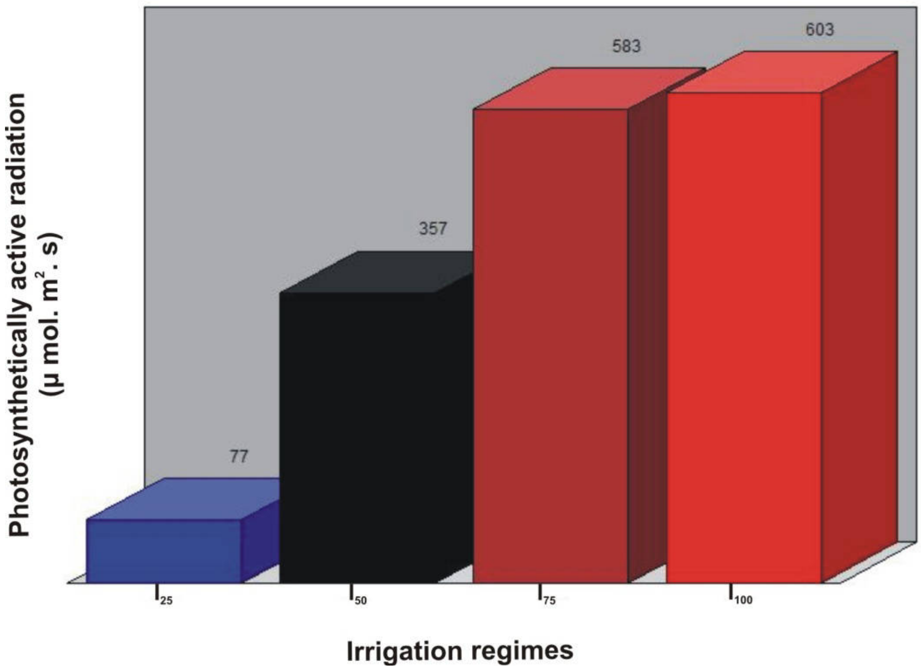


Figure 8**:** Effect of Partial Rootzone Drying on Photosynthetic ally Active Radiation at Dough Stage.

*3.4 Effect of Partial Rootzone Drying on Yield of Sorghum*

Table 3 revealed that grain yield were higher in one hundred percent irrigation regime ($I_{100}$%). The result further revealed that seventy five percent irrigation regime ($I_{75}$%) was numerically higher than the other two irrigation regimes as shown in Table 3. However, partial rootzone drying irrigation resulting in also high yield in seventy five percent irrigation regime ($I_{75}$%) and fifty percent irrigation regime ($I_{50}$%). This result is benefit for sorghum. These results support the reputed drought tolerance of sorghum (Krieg and Lascano, 1990). This result is in conformity with findings of the followings, the different experiment results in partial rootzone drying have shown that irrigation water may be reduced by approximately 30% to 50% in partial rootzone drying with no significant yield reduction (Kang and Zhang, 2004; Leib *et al*, 2006; Guang-cheng, *et al,* 2008; Ahmadi, 2009).

Table 3: Effect of Partial Rootzone Drying on Yield of Sorghum

| Treatment | Yield (Kg/ha) |
|---|---|
| Irrigation | |
| $I_{100}$ | 8037.1[a] |
| $I_{75}$ | 6939.4[b] |
| $I_{50}$ | 5613.3[c] |
| $I_{25}$ | 0.0[d] |
| Rhu Tapai Soil Series | 5254.4[a] |
| Rengam Soil Series | 5040.3[a] |

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

**Conclusion**

The result of the study shows that sorghum performed better under partial rootzone drying 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. The study, therefore, recommended the use of $I_{75}$ percent regulated deficit irrigation for optimizing sorghum yield production in semi-arid regions.

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