# Effect of Regulated Deficit Irrigation on Nutrient Concentration in Leaves,Growth and Yield of Sorghum

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**Abstract**

The effects of regulated deficit irrigation technique on nutrient concentration in leaves, growth and yield of sorghum was examined in a greenhouse at the School of Science and Food Technology, Universiti 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 both experiments. 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 RDI 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.

**Keywords***: Regulated deficit irrigation, Nutrient Concentration, Growth, Yield, Sorghum, Water use efficiency.

## 1. 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.(FAO 2012).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 (Doggett, 1988 and 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. 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).

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).

Irrigated agriculture generates a major contribution to food security. The pressure on limited fresh water resources is on the increase.  Irrigated agriculture is the largest water consuming sector and it faces competing demand from other sectors such as the industrial and domestic sector (Graham and Vance 2003).  Irrigated agriculture uses more than 70% of the water withdrawn from the earth's rivers in developing countries the proportion excess 80% (FAO, 2002).  The possibility for further irrigation development to meet food requirement in the coming years is severely constraint by decreasing water resources.  The agricultural sector faces the challenge to produce more food with less water (FAO, 2003). 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.

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 emergence drought situations.

Currently, irrigated agriculture is caught between two perceptions that are contradictory; some perceive that agriculture is highly inefficient by growing water guzzling crops (Postel *et al,* 1996) while others emphasise 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).  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. The main objective of the study was to assess the effect of regulated deficit irrigation on nutrient concentration in leaves, growth and yield of sorghum cultivars.

## 2.  Materials and Methods

### 2.1 Experimental Site

The study was conducted in a greenhouse at School of Science and Food Technology, 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 plants were planted on Rengam soil series and Rhu Tapai soil series (Table 1). 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 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 dripper were attached with clipper for regulating the irrigation. Where connected to the pipe with stoppers attached at each joints of laterals connecting to main pipes. Emitters or drippers were attached according

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 | 7.14 |
| 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 | 6.5 | 23.5 |
| 1.0 bar | 4.0 | 30.5 |

to plant spacing of 75 by 50cm. The gross depths for the deficit irrigation methods used in this study were calculated as follows:

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

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). The method was adopted based on its simplicity, which requires measuring mean maximum and minimum air temperatures. The method is second to the FAO-56 Penman Monthieth method in terms of accuracy (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, 1977).

$$ET_c = K_c \text{ x } ET_c$$

Where;

$K_c$ = crop coefficient
$ET_o$ = reference crop evapotranspiration in mm/day

The sorghum cultivars SAMSORG 14-KSV8 developed by the Lake Chad Research Institute, Maiduguri, Borno State were used in this experiment.  The plant spacing recommended for sorghum is 75 x 50cm was adopted and four seeds for 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).

$$\text{Crop water use efficiency} = \frac{\text{Yield}}{\text{Evapotranspiration}}$$

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.

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

## 3.  Results and Discussion

*3.1 Effect of Regulated Deficit Irrigation 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 1). 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 1: Effect of Regulated Deficit Irrigation on Nutrient Concentration in Sorghum Leaves

| Treatments | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| | | | (%) | | |
| Irrigation | | | | | |
| $I_{100}$ | 2.57a | 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≤0.05 (DNMRT)

*3.2 Effects of Regulated Deficit Irrigation on Growth of Sorghum.*

Table 2 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 2 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 finding of Adamtey (2010). 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 0,05% 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 2 and also showed no significant different between Rhu Tapai and Rengam Soil Series.

Table 2 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 2.

The data in Tables 2 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*: (2001). However, they were statistically different at the jointed stage as shown in Table 2. 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 2 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 2. At the flowering stage as shown in table 4.3iii there was significant different among the applied regulated deficit irrigation, in Table 4.3iii 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 2 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 2)

Table 2: Effects of regulated deficit irrigation on growth 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 |

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

The result on root dry matter revealed that, root dry matter was influenced by regulated deficit irrigation treatments as shown in Table 3 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 3) further revealed that, treatment $I_{50}$ and $I_{25}$ recorded low root dry matter. The result is at tandem with the findings of Shape and Davies (1979). 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 3. $I_{100}$ produced thicker stem girth compared $I_{75}$ treatment. The result in Table 3 also revealed that, the $I_{50}$ and $I_{25}$ produced the smaller and smallest stem girths respectively. The data in Table 3 indicated interaction effect of irrigation and soils on stem girth. The Table 3 indicated that, there were interaction effects of regulated deficit irrigation and soils on tillers. The mean values as indicated in Table 3 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.

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

| Treatment | Root dry matter (g) | Girth (cm) | 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 $P \leq 0.05$ using DNMRT

The differences between the regulated deficit irrigation treatments $I_{100}$, $I_{75}$, $I_{50}$, and $I_{25}$ with respect to the grain yield were found significant as shown in Table 4. 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*., 2006b) and attribute to better stomatal control over plant water use (Dodd, 2005). Table 4 also showed that Rhu Tapai Soil Series and Rengam Soil Series are not significantly different.

Table 4 revealed that differences among the regulated deficit irrigation treatments applied with respect to panicle length were found to be significant. Means of the panicle lengths were 48.87cm, 47.0cm and 40.0cm at one hundred ($I_{100}$), seventy five percent ($I_{75}$) and fifty percent ($I_{50}$) irrigation treatments respectively. The panicle lengths were statistically the same at one hundred percent ($I_{100}$) and seventy five percent ($I_{75}$) irrigation treatments. However, they were found to be significant different from the panicle length at fifty percent ($I_{50}$) irrigation treatment (Table 4). The result also revealed that, there was no panicle length at twenty five percent ($I_{25}$) irrigation treatment, which was due to severe water deficit. Statistically no significant different at panicle length in terms of the two types of soil used.

Table 4: Effects of Regulated deficit irrigation on sorghum yield .

| Treatment | Yield (Kg/ha) | Panicle length (cm) | Panicle weight (g) | Harvest index (Kg/m$^3$) |
|---|---|---|---|---|
| Irrigation | | | | |
| $I_{100}$ | 7887.10[a] | 48.88[a] | 167.27[a] | 54.46[a] |
| $I_{75}$ | 7389. 40[a] | 47.00[a] | 152.04[a] | 53.44[a] |
| $I_{50}$ | 5563.30[b] | 40.00[b] | 124.81[b] | 41.46[b] |
| $I_{25}$ | 00.00[c] | 00.00[c] | 00.00[c] | 00.00[c] |
| Rhu Tapai Soil | 5216.90[a] | 34.75[a] | 112.46[a] | 40.86[a] |
| Rengam Soil | 5003.10[a] | 33.19[a] | 106.60[a] | 33.82[b] |

Means followed by the same letter within column are not significantly difference at P ≤ 0.05 using DNMRT

The differences among the regulated deficit irrigation treatments with respect to the panicle weight were found to be significant as shown in Table 4. The highest panicle weight value was obtained from one hundred percent ($I_{100}$) irrigation treatment, followed by seventy five percent ($I_{75}$) irrigation treatment and fifty percent ($I_{50}$) irrigation treatment. The lowest mean value was recorded at twenty five percent ($I_{25}$) irrigation treatments as shown in Table 4. The result revealed that, the one hundred percent ($I_{100}$) and seventy five percent ($I_{75}$) irrigation treatments were significant not different, but the fifty percent ($I_{50}$) irrigation treatment was significantly different as compared to the other two treatments. Table 4 indicates that statistically no different between the two types of soil. The effect of regulated deficit irrigation on harvest index (HI) showed significant difference among the treatments as shown in Table 4.The hundred percent regulated deficit irrigation($I_{100}$) and seventy five percent ($I_{75}$)regulated deficit irrigation treatments were found to have higher harvest index compared to the fifty percent($I_{50}$) regulated deficit irrigation and twenty five percent($I_{25}$) regulated deficit irrigation treatments that decreased markedly with increasing water deficit and this translates to higher sorghum efficiency in converting biomass into grain yield  under deficit irrigation situations. The result is supported by Liu *et al.* (2006) and Zhang *et al.* (2004). Results also indicated significant different between the soil types.

The results were in Table 5 shows that, the numbers of panicles were influenced by regulated deficit irrigation treatments. There was no difference in the means among $I_{100}$percent deficit irrigation treatment, $I_{75}$percent deficit irrigation treatment and $I_{50}$percent deficit irrigation treatment. However, the number of panicle of the twenty five percent ($I_{25}$) deficit irrigation treatment was significantly different from the other three regulated deficit irrigation treatments ($I_{100,}$ $I_{75}$, $I_{50}$) as shown in Table 5.

Table 5: Effects of Regulated deficit irrigation on sorghum yield and yield components.

| Treatment | Number of panicles | 1000 Grain weight (g) | Crop Water use efficiency (Kg/ha) |
|---|---|---|---|
| Irrigation | | | |
| $I_{100}$ | 5.00[a] | 38.31[a] | 1.50417[a] |
| $I_{75}$ | 5.00[a] | 38.31[a] | 1.29745[b] |
| $I_{50}$ | 3.00[b] | 28.61[b] | 1.04771[c] |
| $I_{25}$ | 0.00[c] | 00.00[c] | 0.00000[d] |
| Rhu Tapai Soil | 3.00[a] | 26.43[a] | 0.98246[a] |
| Rengam Soil | 3.00[a] | 25.97[a] | 0.94220[a] |

Means followed by the same letter within column are not significantly difference at P ≤ 0.05 using DNMRT

The weight of 1000grains represents the magnitude of grain development that relates to the final yield. The effect of regulated deficit irrigation on the one thousand grain weight of sorghum studied indicated that, there was a significant difference among the treatments as shown in Table 5. The 1000grain weight of regulated deficit irrigation indicated in Table 5 showed that, the one hundred percent ($I_{100}$) regulated deficit irrigation and seventy five percent ($I_{75}$) regulated deficit irrigation treatments  were not significantly  different. However, there was a significant difference between the fifty percent  ($I_{50}$) regulated deficit irrigation treatment and twenty five percent

regulated deficit irrigation treatment from the other two treatments ($I_{100}$ and I75)as showed in Table 5. No significant different between the Rhu Tapai Soil Series and Rengam Soil Series as perusal at the Table 5 have indicated.

Table 5 shows the result of crop water use efficiency for sorghum under regulated deficit irrigation treatments. The results revealed that, the crop water use efficiency of sorghum were statistically significant. However, perusal of the result (Table 5) shows that one hundred percent($I_{100}$) regulated deficit irrigation treatment had the highest crop water use efficiency value of 1.5kg/m$^3$ compared to 1.3Kg/m$^3$, 1.05Kg/m$^3$ and nil for seventy five percent($I_{75}$),fifty percent ($I_{50}$) and  twenty five percent ($I_{25}$) regulated deficit irrigation treatments respectively. The results are at tandem with the findings of the Tolk and Howell (2003) and Farre and Faci (2006). The result in Table 5 revealed that, the crop water use efficiency was significantly different among the treatments. There was no significant different between the two soil types as revealed by the result shown on Table 5.

## 4. Conclusion

The study evaluated the effects of deficit irrigation on growth and yield 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. The yield and yield components under the regulated deficit irrigation treatments as Indicated significant values in comparison within the treatments. In all the parameters the $I_{100}$ and $I_{75}$ percent regulated deficit irrigation treatments were numerically similar while there was no yield recorded at $I_{25}$ percent regulated deficit irrigation treatment.

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 grains grown on Rhu Tapai and Rengam Soil Series 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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