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Effect of Regulated Deficit Irrigation on Growth and Yield of Sorghum

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Abstract
The effects of regulated deficit irrigation technique on growth and yield 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 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, economic performance and profitable measures 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, 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 the growth and yield of sorghum cultivars.

2. Materials and Methods

2.1 Experimental Site

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 26.7^0C (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 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 to plant spacing of 75 by 50cm. The gross depths for the deficit irrigation methods used in this study were calculated as follows:

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

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).

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

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

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 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)

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.

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.

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.

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 4b 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.

3.1 Economic Performance and Profitability Measures.

Table 6 reports the average values of total revenue, total expenditures, and variable and fixed costs expenditures of sorghum production under regulated deficit irrigation (RDI) .The findings revealed that RDI is profitable under the different regulated deficit irrigation regimes. However, one hundred percent (I_{100}) regulated deficit irrigation have the highest net and gross profits while fifty percent (I_{50}) regulated deficit irrigation treatments has the lowest. This could be due to efficient water supply to I_{100}, which resulted to higher yield and subsequently high profit. The value of BCR, which measures the profit per unit dollar invested, shows a remarkable performance for all the different regulated deficit irrigation regimes. According to the findings of the study, sorghums farmers can generate \$2.1, \$1.8, and \$1.5 for every \$1 dollar invested in the I_{100}, I_{75} and I_{50} respectively.

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. The findings revealed that RDI is profitable under the different regulated deficit irrigation treatments. However, one hundred percent (I_{100}) regulated deficit irrigation have the highest net and gross profits while fifty percent (I_{50}) regulated deficit irrigation treatments has the lowest

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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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

Table 2: 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

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.

Table 3: Effects of regulated deficit irrigation on growth parameters 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

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

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 $P \leq 0.05$ using DNMRT,

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 $P \leq 0.05$ using DNMRT

Table 6: Costs and Benefits Analysis

	Items		
	I_{100}	I_{75}	I_{50}
Outputs			
Yields (Kg)	7779.1	6889.4	5563.3
Unit price(100kg)	0.31	0.31	0.31
Total revenue	2411.51	2135.71	1724.6
Variable inputs Costs			
Seed	0.75	0.75	0.75
Water used	7.55	7.55	7.55
Fertilizer	15.72	15.72	15.72
Land hiring/renting	22.1	22.1	22.1
Labor costs:			
Land preparation	3.14	3.14	3.14
Weeding	1.26	1.26	1.26
Fertilizer application	0.63	0.63	0.63
Water application	8.81	8.81	8.81
Harvesting	3.14	3.14	3.14
Total variable costs	63.1	63.1	63.1
Fixed inputs costs			
Depreciation costs	1100	1100	1100
Total fixed costs	1100	1100	1100
Total costs	1163.1	1163.1	1163.1
Net profit	1248.42	972.61	561.5
Gross profit	2348.42	2072.61	1661.5

Source; Field experiment.
RDI- Regulated deficit irrigation