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Original Research Article

Effect of Irrigation on Growth of Cowpea at different Developmental Stages and Water Use Efficiency

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Determining soil moisture content is important in quantifying the impact of irrigation on the growth and yield of crops. For this purpose, a season field experiment was conducted during the dry season of 2014. The objectives were to determine the effect of soil moisture content on and growth of cowpea at different stages of growth and water use efficiency, under different irrigation regimes. Four irrigation regimes; 100%, 80%, 60% and 40% of net irrigation requirement (NIT) were adopted. Results showed that the crop growth parameters were not significantly ($P \leq 0.05$) affected at both and initial and vegetative stages, but were significantly ($P \leq 0.05$) affected at mid season and late season stages of growth. This is as a result of available moisture uptake that is significantly ($P \leq 0.05$) at soil depth of 10-20cm and 20-30cm. The optimum yield, Crop water use efficiency and field water use efficiency for effective water management were obtained at irrigation regime of 60% NIT which implies that about 40% of the irrigation would be saved.

Keywords: *Moisture content; Growth stages; Yield; Growth; Irrigation regimes*

INTRODUCTION

Cowpea (Vigna unguiculata (L.) walp) is one of the most widely adapted, versatile, and nutritious of all the cultivated grain legumes in West Africa. It is an important item in the diet of West Africans, as it is a rich source of plant protein. However, it is of major importance to the livelihood of millions of relatively poor people in less developed countries of the tropics (FAO, 2002). Islam et al. (2006) emphasized that all parts of the plant used as food are nutritious providing protein and vitamins, immature pods and peas are used as vegetables while several snacks and main dishes are prepared from the grains. It is eaten in various ways, either alone or mixed with maize, rice, fish or flour. The crop also has ability to maintain soil fertility through its excellent capacity to fix atmospheric nitrogen and thus does not require very fertile land for growth (Lobato et al., 2006; Peksen and Artik, 2004). Despite the nutritional and medicinal importance of the crop, its production especially in the humid and sub-humid regions of the tropical countries is largely limited to the rainy season of the year.

However, with the increasing need of this crop, it is necessary to accelerate and expand its production all year round. This implies transforming the existing largely traditional or subsistent agriculture into modern agriculture through intense use of modern irrigation facilities (Smith, 2000).Water plays an important role in the growth and production of crop. Water is becoming increasingly scarce resources in the West Africa sub-region (Fasimirin, 2007) and there is competition between municipal, industry users and agriculture for the finite amount of available water. The great challenge for coming decades in the dry season period will be focusing on increase food production by using less water (FAO, 2002b). The limited amount of water available for crops, especially during the dry season necessitates the need to practice deficit irrigation to save water and cost (English and Raja, 1996).

Several researchers have reported that irrigation regime impacts soil moisture available to crops which increases with applied irrigation amounts (Tolk et al., 1998 and Pandey et al, 2000). Recent years have witnessed a great intensification of the effect of irrigation regimes on the crop yield, growth and water use efficiency of crops grown under different soils and climatic condition. Kang et al., 2002 and Mermoud et al., 2005 reported that the responses of grain yields and water use efficiency to irrigation varied considerably due to differences in soil water content and irrigation schedule. Cowpea as a drought resistant crop can survive where there is limited supply

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of water (Dadson et al., 2005). Despite the inherent capacity of cowpea to survive levels of water stress that would render comparable crops unproductive (Ewansiha and Singh, 2006), significant differences exist among cowpea growth parameters and yield of different genotypes (Mai-Kodomi et al., 1999a; Agbogidi and Ofuoku, 2005) and cowpea grown under different water management (El-Noemani et al., 2010;). It has been reported that water stress leads to a decrease in plant water content, turgor reduction and consequently a decrease in cellular expansion and alteration of various essential physiological and biochemical processes that can affect growth and productivity(Pimentel, 2004; Costa et al., 2008; Lobato et al., 2008).

Despite the effect of varying water amounts that has been investigated on the growth and yield of cowpea by several researchers, little attempt has been made to quantify and investigate the effect of soil moisture availability on the growth of cowpea at different stages of development (growth) under different irrigation regimes in humid tropics. The objective of the present study was to study the effect of different irrigation regimes on the growth of cowpea at different stages of growth and determine the water use efficiency under sprinkler irrigation system.

MATERIALS AND METHODS

The Study Area

The field experiment was conducted during dry season 2014 (January - April) at Teaching and Research Farm of the Department of Agricultural Engineering, Federal University of Technology, Akure.

Field Experimentation

The field experiment was carried out between 28th January and 13th April, 2014. Cowpea variety "Ife Brown" was planted at the recommended spacing of 30cm on rows, 60cm apart. Thinning was done two weeks after planting to reduce the crop to two per stand. Weeds and insect pests were controlled as necessary using standard procedures. An experimental plot (13 x 13m2), ploughed and harrowed was divided into four irrigation regimes. The different irrigation regimes adopted were 100%, 80%, 60% and 40% NIT were adopted. Each irrigation regime was divided into four plots (2.7 x 2.7m2) to make a total of 16 plots and leaving 0.5m space between each plot. Two sprinklers (Rain Bird 30 TNT heads), with 1m risers each were arranged diagonally at the corner of each irrigation regime block to form a part circle irrigation water coverage pattern so as to apply water uniformly. A total of eight sprinklers heads were used to irrigate the crop field. The sprinklers were set to throw water at an angle of 900 in each irrigation regime block. The sprinklers produced a wetted radius of approximately 6m to irrigate cowpea in each of the irrigation level at an approximate operational pressure of 250 kPa and average discharge per sprinkler was 0.49m3/hr (Fig. 1).

Control valves were connected to the risers at each irrigation regime block to stop and regulate the flow of water application. Two uniform irrigations were applied to bring the soil to field capacity before planting to encourage seedling establishment. Irrigation depths applied at each irrigation regime was predetermined at each irrigation regime before sowing cowpea. The irrigation depths were measured using catch cans arranged in each irrigation regime. There were 20 catch cans per irrigation regime and the average was estimated over the total area of each irrigation regime block.

Measurement Procedures

Soil moisture content at depths of 0-10, 10-20 and 20-30cm were determined from all the irrigation regime blocks bi-weekly. The soil moisture contents were measured by using the gravimetric method (Lascano, 2000). The Soil bulk density (g/cm^3) was determined by the core method (Blake and Hartage, 1986) using a 10.0 cm long by 8.3 cm diameter cylindrical metal core. Samples were dried at 105^oC for 24h in a forced air oven. Crop actual evapotranspiration was determined from sowing to harvest using soil water balance equation (Hillel, 1998) as shown in equation (1).

$$ET_a = I + P \pm \Delta S \pm D \pm R \quad (1)$$

Where ET_a is the crop actual evapotranspiration (mm), I is applied irrigation (mm), P is the precipitation during the period of experiment (mm), ΔS is the change in soil moisture storage (mm), D are R are excess moisture drained from soil (mm) and run off from soil surface(mm) respectively. Drainage and run off were measured from a drainage lysimeter (Igbadun, 2012).
Weekly measurements of agronomic parameters; plant height, number of leaves and leaf area were measured starting from the first week of planting at 7 DAP to maturity stage in order to monitor the growth response to varying water applications and moisture availability. The leaf area index (LAI) was also measured weekly. Three plants were selected per plot for leaf area (LA) and leaf area index measurements. The greatest leaf width was measured with ruler and breadth of the leaf was multiplied by a correction factor of 0.75 (Agbogidi and Ofuoku, 2005) as given in equation (2).

$$\text{Leaf Area} = 0.75*L*W \quad (2)$$

Where L and W are the leaf length and maximum width of the leaf respectively. LAI is the leaf area per unit area of soil below (FAO, 1998). It was mathematically expressed and determined as given in equation (3);

$$LAI = \frac{0.75*L*W*NP*NL}{Land\ area\ covered} \quad (3)$$

Where NP and NL are the number of plants and the number of leaves respectively. An empirical model reported by Ritchie (1972) that relates leaf area index to crop cover fraction was used to estimate the crop cover fraction to confirm the period of attaining each phenological stage of the cowpea growth as given in equation (4);

$$LAI = -1.3\ln[(1-f_c)/(1+f_c)] \quad (4)$$

Where LAI is leaf area index and f_c is the crop cover fraction.
The equation was further solved, integrated and differentiated mathematically and take the form in equation (5);

$$Crop\ Cover\ Fraction\ (f_c) = \left(\frac{1-e^{-\frac{LAI}{1.3}}}{e^{-\frac{LAI}{1.3}}+1} \right) \quad (5)$$

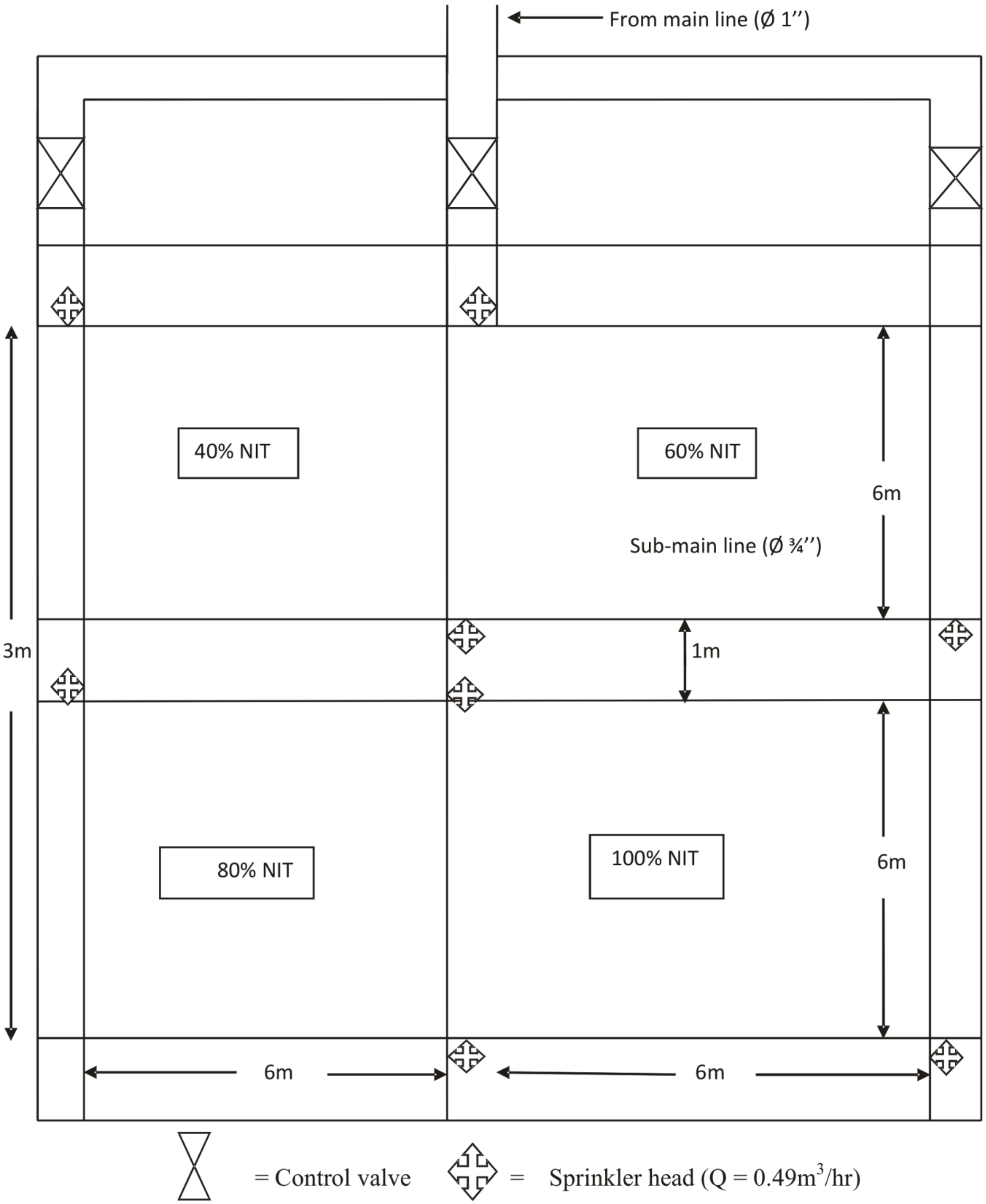

Fig. 1: Schematic diagram of the experimental sprinkler Irrigation System layout

The wetting pattern of each of the irrigation regime took the form in Figure 2

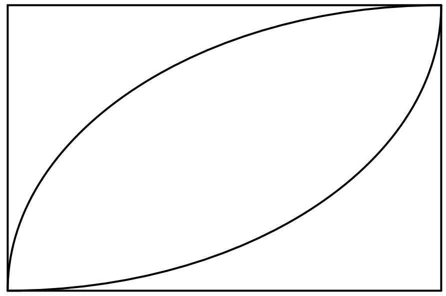

Fig. 2: Uniform wetting pattern in all the irrigation regime blocks

The growth session was divided into four stages as follows;

a) Initial stage;
b) Vegetative stage;
c) Mid season stage (flowering); and
d) Late season stage (maturity).

Cowpea peanut (grain) yield was determined at maturity. The yield was harvested in batches from the field. The yield of the cowpea was weighed using weighing balance.
The water use efficiencies (Crop Water Use Efficiency and Field Water Use Efficiency of the cowpea were determined from the following relationships as follows:

$$CWUE = \frac{Yield\ (t/ha)}{Water\,Use\ (mm)} \quad (6)$$

$$FWUE = \frac{Yield\ (t/ha)}{Water\ Applied\ (mm)} \quad (7)$$

Statistical analysis such as ANOVA was performed on soil moisture contents, cowpea growth parameters and yield base on different irrigation water managements imposed on the crop and using Statistical Package for the Social Sciences (SPSS, version 16.0). Mean comparison between treatments and their interactions were determined using Tukey's test.

Soil Properties at the Experimental Site

Table 1 and 2 show the physico-chemical properties of the soil at the experimental site. The site has a mean soil texture (USDA method) of sandy clay loam in the top soil which forms mainly the agricultural layer required for the cultivation of most shallow rooted crops. The soil is predominantly sandy (Table 1). This type of soil always allows downward movement of water, as a result of this, the crop to be cultivated on this soil would need to be regularly irrigated. The soil on the experimental site being dominantly sandy clay loam with a good aeration shows that crops grown on it would thrive well under sprinkler irrigation system.

Minimum and maximum organic carbon content of 0.63% and 0.78%, respectively were observed within the top 0.3 m depth of soil before planting. The top soil average carbon content falls within the range (0.6-1.2%) given by Young (1976) as desirable for tropical crop production. Table 1b shows that the soil pH varies from acidic to slight alkaline, 5.8-7.2. The pH of the soil falls within the slightly acidic range of 6.4. The pH average value is close to 6.5 which is considered ideal for better availability of plant nutrients in the mineral soils (Foth and Ellis, 1997). The bulk density of the experimental site ranges from 1.26–1.51g cm^{-3} within the first 0.3m depth of soil. The bulk densities of the soil at the experimental site at depths 0-10, 10-20, 20 -30cm are 1.29, 1.37 and 1.46g cm^{-3} respectively

RESULTS AND DISCUSSION

Water Applied

The irrigation water was applied to compensate the water deficiency of the root zone soil (0.20 m) in the first stage and the root zone soil (0.30 m) after, according to FAO (1998) for shallow rooted crops.The average amount of water received in treatments 100%, 80%, 60% and 40% NIT were 463.16, 433.90, 381.44 and 345.71mm. During the growing season, the total amount of rainfall recorded was 240.05mm in which 5 rainfall events were recorded during the late season of the growing season.

Rainfall and Irrigation Depth

Fig. 3 shows the varying depth of rainfall applied on cowpea during the growing season at the treatment blocks. A total of 13 rainfall events were recorded during the experiment. The rainfall depths measured during the experiment ranged from 1.13 to 42mm. The lowest rainfall was recorded at 16 DAP in February during the initial stage and highest rainfall of 42.04mm at 29 DAP in February. 76.51mm of rainfall (Table 3) was recorded as part of the seasonal water estimated during the late. But at this stage the crop does not need much water. The total amount of rainfall depth applied during the mid season was higher than other stages of growth. This is because this period has a longer day length than the periods of other stages of growth. During the late season, irrigation was not applied mainly because there was frequent application of water from rainfall.

Table 3 shows the total amount of irrigation and precipitation applied in the irrigation regime blocks. A total of 463.16, 433.90, 381.44 and 345.71mm of water were applied in irrigation regimes 100%, 80%, 60%, and 40% respectively.

Moisture Content Variation

The average soil moisture content measured under the different irrigation regimes; 100%, 80%, 60% and 40% NIT from 7–77 DAP and from the soil depth of 0 - 0.3m at interval of 10cm are illustrated in Table 4. The stored moisture in the soil profile was observed to increase down the soil profile. The peak soil moisture content of was recorded at 29DAP during development stage of growth as a result of two successive heavy rainfalls that preceded the soil moisture measurement.

Table 4 shows that there is no statistical difference between the soil moisture stored and measured at soil depth of 0-10cm. This may be due to moisture contents difference between the irrigation regimes that is so small. But there were significant differences between soil moisture means between irrigation regimes at soil depth of 10-20 and 20-30cm. This may be due to the amount of irrigation received by each irrigation regime block.

Growth Component of Cowpea

Plant Height

Table 5 shows the mean plant height measurement taken from all the irrigation regime blocks from 7 to 77 DAP. It was observed that there was rapid increase in the height of the crop during the initial and vegetative stage of the crop growth and until it got to the mid season stage. There was no significant ($P \leq 0.05$) difference between the means of the plant height at initial and vegetative stage among irrigation regimes. This may be due to adequate moisture available for the crop growth at these stages of growth. The plant height means were significantly ($P \leq 0.05$) different at the mid season and late season stages of cowpea growth between irrigation regimes. This may be due to the soil moisture available to the plant at these stages of growth. There were significant differences between the means of cowpea height due to Days after Planting (DAP) during the initial and vegetative stages of growth. But no significant differences ($P \leq 0.05$) were found due to Days after Planting (DAP) at both mid season and late season stages of growth. This is in agreement with the report by FAO (1998) with finding showing that cowpea experience little or no increase in height starting from mid season till the late season.

Responses with Respect to Number of Leaves

Table 6 shows the mean number of leaves measurement taken from all the irrigation regimes from 7- 77 DAP. From the table 6, irrigation regime 100% NIT, which received adequate water supply to meet evaporative demand has the highest number of leaves than the deficit irrigation regime plots. It was observed that there was rapid increase in number of leaves during the crop vegetative stage (14 – 35 DAP). There were no significant differences in the mean number of leaves observed among treatment plots at 5% level of significance at both initial and vegetative stages of growth. But there were significant differences in the mean soil moisture contents at the rooting depth of 10 – 20cm and 20-30cm therefore impacting the statistical difference in growth of cowpea at both mid season and late season.

There were significant differences between the means of cowpea number of leaves at 5% level of significance due to DAP during the initial and vegetative stages of growth. This may be due to the rapid growth of cowpea at this stage. There were no significant differences at both mid season and late season. The cowpea number of leaves were observed to be constant between 56 and 63 DAP, but started declining after 63 DAP till the time of harvest. This observation confirms the senescence stage of cowpea during the experiment.

Responses with Respect to Leaf Area

The results obtained for the measurement of the leaf area (LA) which were determined weekly during the growing season of the crop are presented in Table 7. From Table 7, it was observed that irrigation regime 100% NIT that received adequate water supply to meet evaporative demand has the highest leaf area than the deficit irrigation regimes. There was rapid increase in leaf area during the crop vegetative stage (14 – 35 DAP). Thus, at both initial and vegetative stage of growth, there were no significant differences in the means leaf area of cowpea between irrigation regimes. But significantly different due to DAP at 5% level of significance. During the mid season, there was significant difference between irrigation regimes and no significant difference due to DAP. This may be due primarily to the moisture available at the rooting zone at these stages of growth. Therefore, statistically, it has effect on the leaf area of cowpea. The leaf area was observed to be constant between 56 DAP and 63 DAP, but started declining after 63 DAP till the time of harvest. This observation confirmed the senescence stage of cowpea.

Responses with Respect to Leaf Area Index

Table 8 shows the mean leaf area index measurement taken from all the irrigation regimes from 7- 77 DAP. From Table 8, irrigation regime 100% NIT that received adequate water supply to meet atmospheric demand has the highest value of leaf area index (LAI) than the deficit treatments. It was observed that there was rapid increase in the leaf area index (LAI) during the crop vegetative stage. During the mid season, there was significant difference in the leaf area index as it was observed in all the irrigation regime plots. But there was no significant difference at 5% level of probability due to DAP. It was noticed that the plants clumped together when the LAI was between 3 and 4 (FAO, 1998).

This observation indicates the initiation of flowering of cowpea and it was noticed at 35 days after planting during the growing season. This observation is close to the report given by Adekalu and Okunade (2006). It was reported that 30 days after planting, cowpea (*ife brown* variety) would attain its flowering stage. There was reduction in leaf area index (LAI) as it was observed for 63 days after planting till the time of harvest, thereby indicating the beginning of cowpea senescence and it was observed when the leaves of cowpea began to dry out. The reduction in the LAI is as a result of the leaves drying out and some dropped on the soil surface of the experimental site. The 100% NIT had the greatest LAI throughout the growing season. The LAI of 100% NIT irrigation regime reached its peak value (3.97) at 63 DAP, than the other irrigation regimes which reached the peak LAI value approximately at the same period. LAI declined gradually towards the end of the growing season for all irrigation regimes. This is in agreement with the submission of Pandey *et al.* (2000) and Karam *et al.* (2003) due to the water deficit at different stages of growth.

Responses with Respect to Crop Cover Fraction (F_c)

Table 9 shows the change in the crop cover fraction with respect to DAP. The estimations obtained for the crop cover fraction following the empirical equation reported by Ritchie (1972) are given in Table 9. The empirical model gave the same results of crop cover fraction with the empirical of crop cover fraction reported by Hsiao *et al.,* 2009. Table 9 shows that crop cover fraction was increasing starting from the time after planting till 63 DAP in all the irrigation regime plots. Higher values of crop cover fraction were obtained throughout the growing season in the treatment that received highest amount of water and lower values were recorded in the deficit irrigation plots.

Table 1: Physical Properties of the Soil of the Experimental Field.

Soil depth	Sand (%)	Silt (%)	Clay (%)	Textural class	Bulk density	Organic Carbon (%)
0-10cm	70	21	9	Sandy clay-loam	1.36	0.78
10-20cm	68	19	13	Sandy clay-loam	1.48	0.68
20-30cm	65.6	20	14.4	Sandy clay-loam	1.51	0.62

Table 2: Physical and Chemical Properties of the Soil of the Experimental Field

Soil depth	Oganic matter (%)	Potassium (cmol/kg)	Magnessium (cmol/kg)	Nitrogen (%)	Magnessium (cmol/kg)	pH
0-10cm	1.35	0.24	1.2	0.44	1.2	5.8
10-20cm	1.17	0.26	0.9	0.52	0.9	6.8
20-30cm	1.07	0.29	0.8	0.61	0.8	6.2

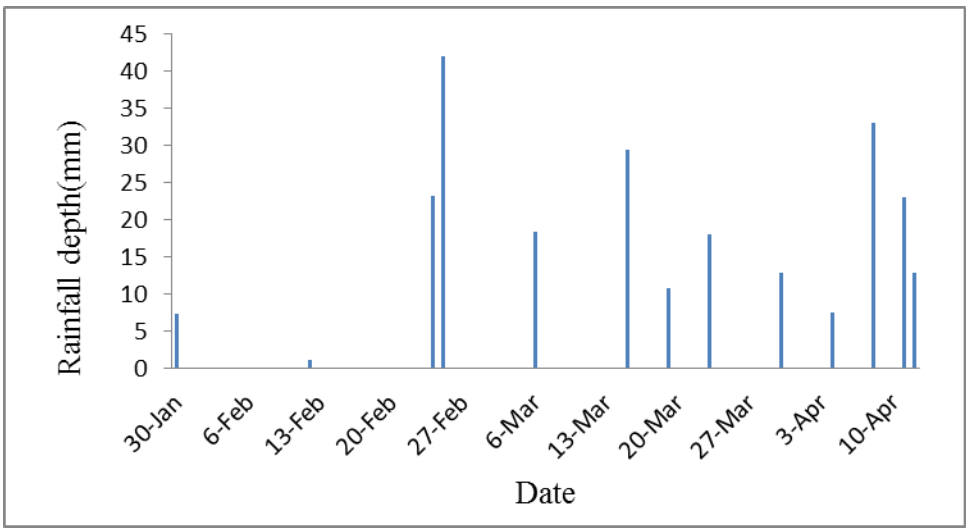

Fig. 3: Rainfall recorded at the Experimental Field during Cowpea Growing Season

There was rapid increase in crop cover fraction, that is, the ground cover fractions by the plant between 14 DAP and 35 DAP. This is because this period marks the vegetative stage or crop development stage of growth of the crop (cowpea) in all the irrigation regime plots.

The crop cover fraction was used to confirm the phonological stages of growth of the crop (cowpea) according to FAO (1998). In treatment 100%NIT, a value of 7.3% was observed at 14 days after planting, 20% at 21 days after planting, and 78% at 35 days after planting respectively. These values mark the initial stage, beginning of crop development and the end of crop development of the crop. These results obtained for each phonological stage of growth of the crop were in agreement with less than (<)10% and 70 – 80% reported by FAO (1998) for initial, interval between beginning of vegetative stage and mid season respectively for leguminous crops. It was discovered that after the crop had attained the beginning of senescence at 63 DAP, about 90% of the plants were no longer producing flower (beginning of pod fill to end of flowering). It was noticed that the crop cover fraction started decreasing at the end of mid season (63 DAP), and this was primarily due to some of the leaves that were drying out and finally dropping on the soil surface of the experimental plot.

The Effect of Irrigation on Cowpea Seed Yield and Water Use Efficiency

The results of cowpea grain yield in tons per hectare are given in Table 10. The mean of cowpea grain yield of the cowpea was highest in irrigation regime of 100% NIT and lowest in irrigation regime of 40% NIT. The cowpea grain yield harvested from all the treatments and its replicates ranged from 0.62 – 1.27t/ha. This compares favourably to the range of 0.7-1.88t/ha reported by Adekalu and Okunade (2006) for *ife brown* variety. In 2014 dry season, there was general increasing trend in cowpea yield with increasing irrigation amounts (Table 10). In general, the fully irrigated regime (100% NIT) had the greatest numerical yield than all other treatments. Its yields were same as yields for the 80% NIT and 60% NIT, but significantly higher than the yield for 40% NIT at (P=0.05) of significance. This is because of significant difference of available soil moisture among treatments which impacts the grain yield due to the varying irrigation amount.

Thus, about 40% of irrigation would be saved. This confirms the findings of (Dadson *et al*., 2005) that cowpea is a drought tolerant crop. Therefore, water stress in the deficit irrigation regimess can reduce crop yield by reducing CO2 assimilation area, leaf number, and total leaf area and yield components (Golombek and Al-Ramamneh, 2002). The CWUE and FWUE ranged from 0.0024-0.0027t/ha-mm and 0.0021–0.0023t/ha-mm in dry season of 2014 (Table 9). Adekalu and Okunade (2006) reported values of CWUE and FWUE ranging from 0.0029–0.0085t/ha-mm and 0.0025–0.0059 t/ha-mm among various irrigation regimes. The wide range difference in CWUE and FWUE could be caused by climate, irrigation amount, the length of the growing season, soil and crop management practices, and other factors (Abbas *et al*, 2005)

The field water use efficiency was greatest in irrigation regime (100% NIT) which received the highest amount of irrigation water. Field water use efficiency in general, was higher for irrigation water amounts of 100% NIT and 60% NIT during the season. These results confirm the findings of FAO (1995) which reported that, an irrigation regime that provides soil moisture for maximum crop growth and yield per unit area would be unlikely to produce maximum output per unit of water (FWUE). Although irrigation regimes of 100% and 80% NIT produced higher grain yield in the growing season, but 80% NIT could not translate this yield into higher field water use efficiency than 60% NIT as the relative difference in the grain yield was compensated for by the relative difference in the seasonal amount of irrigation water applied to the third irrigation regime of 60% NIT.

CONCLUSION

The study estimates the yield and growth components of cowpea under different irrigation regimes. Cowpea grain yield and growth components were not significantly affected by the irrigation regimes under sprinkler irrigation at initial and vegetative stages of growth, but were significantly affected at the mid season and late season stages of cowpea growth. Yield and the cowpea growth components were impacted by the irrigation regimes due to moisture available for the crop uptake. The yield and growth components measured increase with increasing water application. The optimum field water use efficiency and crop water use efficiency were obtained at irrigation amount of 60% NIT. The field and crop water use efficiency obtained at 60% NIT and 100%NIT were numerically the same. Therefore, showing that the treatment where the highest yield is obtained would not necessarily only produce the maximum field and water use efficiency.

Table 3: Irrigation and Precipitation amount applied at each Stage of Growth

	Irrigation(mm)				Precipitation(mm)
Growth stages	100% NIT	80% NIT	60% NIT	40% NIT	
Initial	49.58	43.14	31.42	23.48	7.45
Development	99.16	86.28	62.84	46.79	66.37
Mid season	74.37	64.43	47.13	35.39	89.72
Late season	0	0	0	0	76.51
Total(mm)	223.11	193.85	141.39	105.66	240.05

Mean followed by the same letter(s) in a row is not significantly different at P ≤ 0.05.

Table 4: Mean moisture content measured at soil depth of 0-0.3m throughout the growing season (mm)

	Soil depth		
Treatments	0-10	10-20	20-30
T-100	15.14a	18.61ab	20.68c
T-80	14.24a	17.59ab	19.72c
T-60	13.04a	16.09ab	18.12c
T-40	11.83a	14.39ac	16.67d

Mean followed by the same letter(s) in a coloumn is not significantly different at P ≤ 0.05.

Table 5: Mean Height of Cowpea Plant (cm) in all the irrigation regime blocks in 2014 Dry Season

Growth stages	DAP	100% NIT	80% NIT	60% NIT	40% NIT	Mean
	7	8.5	8.5	8.5	8.5	8.2d
Initial	14	17.17	16.3	16	15.48	15.79e
Means		12.84a	12.4a	12.25a	11.99a	
	21	23.48	23.39	23	21.46	22.83c
Vegetative	28	36	33.5	31.4	31	32.97cd
	35	47.5	46.75	45.39	44	45.91e
Means		35.66b	34.55b	33.26b	32.15b	
	42	50.4	49	48.2	46.5	48.53c
	49	55.2	52.5	50.6	48.3	51.65c
Mid season	56	57.6	53.4	51.7	49.1	52.95c
	63	58.6	54.1	52.1	50.03	53.71c
Means		55.45a	52.25a	50.65b	48.48c	
	70	58.6	54.4	52.1	50.03	53.78a
Late Sean	77	58.6	54.4	52.1	50.03	53.78a
Means		58.70a	54.45b	52.15d	50.13d	

Mean followed by the same letter(s) in a row or column are not significantly different at P ≤ 0.05.

Table 6: Mean Number of Leaves of Cowpea (cm) in all the irrigation regime blocks in 2014 Dry Season

Growth stages	DAP	T - 100	T - 80	T - 60	T – 40	Means
	7	4	4	4	4	4d
Initial	14	16	15	14	12	14.25e
Means		10a	9.5a	9a	8a	
	21	26	25	23	22	24c
Vegetative	28	44	39	37	34	38.5cd
	35	63	59	57	49	57e
Means		44.33b	41b	396b	35b	
	42	77	72	70	67	71.5dc
	49	79	73	72	69	73.25dc
Mid season	56	81	74	73	71	74.75dc
	63	81	74	73	71	74.75dc
Means		73.9a	68.28ab	66.78ab	64.26ab	
	70	79	71	70	69	72.25a
Late Sean	77	77	69	68	67	70.25a
Means		78a	70d	69d	68d	

Mean followed by the same letter(s) in a row or column are not significantly different at P ≤ 0.05.

Table 7: Mean Number of Leaf Area of Cowpea (cm^2) in all irrigation regime blocks in 2014 Dry Season

Growth stages	DAP	T - 100	T - 80	T - 60	T – 40	Means
	7	12.12	12.12	12.12	12.12	12.12d
Initial	14	20.78	20.35	16.64	13.31	17.77e
Means		16.45a	16.24a	14.38a	12.72a	
	21	35.14	33.39	28.99	26.11	30.91c
Vegetative	28	67.66	62.72	62	60.05	63.11cd
	35	79.92	76.96	71.11	70.59	74.65e
Means		60.91b	57.69b	54.03b	52.25b	
	42	83.5	78.2	74.04	73.04	77.20dc
	49	85.4	80.3	76.06	74.08	78.96dc
Mid season	56	86.12	82.3	77.34	75.15	80.23dc
	63	86.12	82.3	77.34	75.15	80.23dc
Means		85.29a	80.78a	76.20b	74.36c	
	70	86.12	82.3	77.34	75.15	72.25a
Late Sean	77	86.12	82.3	77.34	75.15	70.25a
Means		86.12a	82.3d	77.34d	75.15d	

Mean followed by the same letter(s) in a row or column are not significantly different at P ≤ 0.05.

Table 8: Mean of Leaf Area Index of Cowpea in all the irrigation regime blocks in 2014 Dry Season

`Growth stages	DAP	T - 100	T-80	T - 60	T – 40	Means
	7	0.03	0.03	0.03	0.03	0.03a
Initial	14	0.19	0.18	0.13	0.09	0.15d
Means		0.11c	0.105c	0.08c	0.06c	
	21	0.53	0.48	0.38	0.33	0.43dc
Vegetative	28	1.71	1.4	1.32	1.71	1.54de
	35	2.71	2.61	2.31	2	2.41fd
Means		1.65d	1.50d	1.33d	1.35d	
	42	3.69	3.21	2.95	2.65	3.13fg
	49	3.87	3.34	3.07	2.93	3.30fg
Mid season	56	3.97	3.38	3.09	2.96	3.35fg
	63	3.97	3.38	3.09	2.96	3.35fg
Means		3.88dc	3.33dc	3.05b	2.88a	
	70	3.87	3.27	3.06	2.93	3.28bc
Late Sean	77	3.77	3.18	2.85	2.79	83.5bc
Means		3.82fd	3.23fd	3.00dc	2.86de	

Mean followed by the same letter(s) in a row or column are not significantly different at P ≤ 0.05.

Table 9: Mean of Cowpea Cover Fraction in all the irrigation regime blocks in 2014 Dry Season

Growth stages	DAP	T - 100	T - 80	T - 60	T – 40	Means
	7	1.1	1.1	1.1	1.1	1.1a
Initial	14	7.3	6.7	5	3.4	5.6d
Means		4.2c	3.9c	3.1c	2.25c	
	21	20	18	15	13	16.5cd
Vegetative	28	58	49	47	42	49de
	35	78	76	71	65	72.5df
Means		52d	47.67d	44.33d	40d	
	42	89	84	81	77	82.75gf
	49	90	85	82	81	84.5gf
Mid season	56	91	86	83	82	85.5gf
	63	91	86	83	81	85.25gf
Means		90.25cd	85.25cd	82.25b	80.25c	
	70	90	85	83	81	84.75bc
Late Sean	77	89	84	82	79	83.5bc
Means		89.5df	84.5df	82.5b	80c	

Mean followed by the same letter(s) in a row or column are not significantly different at $P \leq 0.05$.

Table 10: Effect of the different irrigation regimes on cowpea yield and irrigation efficiencies in 2014 dry season

Treatments	Water Applied(mm)	Grain Yield (t/ha)	Water Storage (mm)	ETa	CWUE (t/ha-mm)	FWUE (t/ha-mm)
T-100	463.16	1.06a	364.43	397.52	0.0027	0.0023
T-80	433.9	0.95a	347.9	371.76	0.0026	0.0022
T-60	381.44	0.89a	307.86	335.38	0.0027	0.0023
T-40	345.71	0.71c	278.6	295.96	0.0024	0.0021

Mean followed by the same letter(s) in a column are not significantly different at $P \leq 0.05$

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Notations

The following symbols are used in this paper

Symbols	Unit	
DAP	day	Days after Planting
LA	cm^2	Leaf Area
LAI		Leaf Area Index
f_c	%	Crop cover fraction
NIT	mm	Net Irrigation Regime
CWUE	t/ha-mm	Crop Water Use Efficiency
FWUE	t/ha-mm	Field Water Use Efficiency

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