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Crop Water Use Efficiency and Yield of Cowpea under Varying Irrigation Schedule in a Derived Savannah

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Abstract - Efficient use of water resources can be made possible through the assessment of crop water requirements and proper scheduling of irrigation. This study determines the water use efficiency and yield of cowpea under varying irrigation schedule in a derived savannah region of Oyo State. The study was carried out in a screen house situated at Agricultural and Bio-Environmental Engineering Department of The Oke-Ogun Polytechnic, Saki (TOPS), Oyo State in South Western Nigeria. Surface soil samples from 0-15cm depth randomly collected for planting were taken to the laboratory for analysis to know the preliminary status of the soil before planting. Plant height, number of leaves and stem girth were measured as indicators for plant growth. The deviations between the average values of the growth parameters for the two irrigation frequencies were considered. One-way Analysis of Variance was also used to test for significant differences in the growth parameters for the two irrigation frequencies.

Generally, growth parameters were better for 4-days irrigation interval during the sprouting and seedling stages but better for the 2-day irrigation interval between 3-8 weeks after planting. This may be due to the water needs of the plants for metabolism. Also, the crop yield and dry matter yield of the 2-day irrigation frequency were found to be better.

Keywords - Cowpea, Growth, Yield, Irrigation Schedule, Water Use Efficiency.

I. INTRODUCTION

The production chain of cowpea (*Vigna unguiculata*) is an important source income and a means of food security for the people of south western Nigeria. Considering that Nigeria has two well-defined seasons: the first season being the rainy and the second being the dry season. The cultivation of this crop is thus limited to the first season of the year in the south western part of the country. The productivity of cowpea in the region could be increased with the adoption of irrigation systems in order to fully or partly supplement its water requirement during the driest period of the year.

Cowpeas thrive in poor dry conditions, growing well in soils up to 85% sand. This makes them a particularly important crop in arid, semi-desert regions where not many other crops will grow. As well as an important source of food for humans in poor arid regions the crop can also be used as feed for livestock. Its nitrogen fixing ability means that as well as functioning as a sole-crop, the cowpea can be effectively intercropped with sorghum, millet, maize, cassava or cotton (Blade et al., 1997) .

Most cowpeas are grown on the African continent, particularly in Nigeria and Niger which account for 66% of world cowpea production (FAO 2015). The Sahel region also contains other major producers such as Burkina Faso, Ghana, Senegal and Mali. Niger is the main exporter of cowpeas and Nigeria the main importer. Exact figures for cowpea production are hard to come up with as it is not a major export crop.

Cowpeas are grown mostly for their edible beans, although the leaves, green peas and green pea pods can also be consumed, meaning the cowpea can be used as a food source before the dried peas are harvested (Ehlers et al., 1997). Cowpeas seeds provide a rich source of proteins and calories, as well as minerals and vitamins (Goncalves et al., 2016). This complements the mainly cereal diet in countries that grow cowpeas as a major food crop (Phillips et al., 2003). A seed can consist of 25% protein and has very low fat content (Rangel et al., 2016). Cowpea starch is digested more slowly than the starch from cereals, which is more beneficial to human health (Goncalves et al., 2016). The grain is a rich source of folic acid, an important vitamin that helps prevent neural tube defects in unborn babies (Witthoft et al., 2016).

However, cowpea does contain some anti-nutritional elements, notable phytic acid and protease inhibitors, which reduces the nutritional value of the crop. Although little research has been conducted on the nutritional value of the leaves and immature pods, what is available suggests that the leaves have a similar nutrition value to black nightshade and sweet potato leaves, while the green pods have less anti-nutritional factors than the dried seeds (Goncalves et al., 2016).

Efficient use of water resources can be made possible through the assessment of crop water requirements and proper scheduling of irrigation. Temporal prediction of soil moisture and evapotranspiration (ET) plays a crucial role in irrigation water management (Abdelhadi et al., 2000; Ali et al., 2007) and drought monitoring (Narasimhan and Srinivasan, 2005). ET from the field is an actual unrecoverable water loss within the irrigation schemes (Bryla et al., 2003). It has been demonstrated that optimal irrigation scheduling requires accurate estimates of crop evapotranspiration (ETc) (Doorenbos and Pruitt, 1977; Kamel et al., 2012).

Allen et al. (1998) reported that factors, such as soil salinity, poor land fertility, limited application of fertilizers, presence of hard or impenetrable soil profiles, lack of proper control of diseases and pests and poor soil management may limit crop development and reduce ET. Other factors to be considered when assessing ET are ground cover, plant density and soil water content, however, ET is not an easy factor to measure.

Evapotranspiration is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through stomata in its leaves. Evapotranspiration is an important part of the water cycle. An element (such as a tree) that contributes to evapotranspiration can be called an evapotranspirator.

Evapotranspiration can be determined by direct and indirect methods. The lysimeter method is the oldest method, of which the weighing lysimeter is considered the most accurate; however, it is also the most expensive. The drainage lysimeters have advantages when compared to the water balance method in the field as the volume of vegetated soil is properly insulated and therefore, all inputs and outputs of water in this system are controlled (Santos et al., 2008). However, the isolation of plants can interfere with the water consumption, growth and development in comparison with field conditions.

It is important not to waste irrigation water because it is becoming increasingly scarce and expensive. To irrigate properly one needs to know how much water the plants are using. Determination of crop water requirement is one of the key parameters for precise irrigation scheduling. To improve irrigation planning and management, a modified soil water balance method must be used to determine the crop coefficients and water use for crop production. Also, in order to provide suitable irrigation management during the dry season, solid information regarding water demand by regional crops should be available.

This study determines the water use efficiency, growth parameters and yield of cowpea under varying irrigation schedules in a derived savannah area of south western Nigeria..

II. Materials and Methods

2.1 Description of the Study Area

This study was carried out in a screen house situated at Agricultural and Bio-Environmental Engineering Department of The Oke-Ogun Polytechnic, Saki, Oyo State in South Western Nigeria. The study area, Saki is located at latitude 8.6676197 and longitude 3.39393, in the northern hemisphere of Oyo State. The vegetation is a derived savannah with a mean annual rainfall of about 1289.2mm. Surface soil samples from 0-15cm depth randomly collected from the research and demonstration farm of the department in Saki, Oyo State was used for the experiment. Samples of the soil were taken to the laboratory for analysis before planting to know the preliminary status of the soil.

2.2 Experimental Procedures and Planting Operations

The study was conducted and carried out using experimental pots. Soil samples randomly taken from the research and demonstration farm of the department were bulked together into the experimental pots. The irrigation schedule was varied at two days and four days interval to give two treatments. Each irrigation interval was replicated thrice thus giving a total of six pots. The experimental pots used was 25 litres keg which was cut off at the top and with a circular rubber hose inserted into them at the bottom such that they align with the base of the experimental pots to form a kind of improvised lysimeters. The pots were then placed on wooden platforms to raise them above the ground. The experimental pots were tilted on the wooden platforms to aid drainage of excess water. Other end of the hose was put in a transparent plastic bottle for collecting drained water. Three seeds of cowpea (*Vigna Unguiculata*) were planted in each experimental pot at 2cm depth and later thinned to two after four weeks of planting. 1000cm3 of freshwater was used to irrigate each pot at the specified irrigation schedules of two days interval and four days interval.

2.3 Growth Indicators for Assessment

Plant Height: Plant height was measured from ground to the tip of terminal bud every two weeks after planting using measuring tape. The heights of plants in each replicates in an experimental pot were measured and their average values were determined.

Number of Leaves: The plant was selected from each experimental pot and numbers of leaves were counted for each experimental pot and the average number of leaves was determined for each experimental pot. This was done two weeks after planting and subsequently.

Stem Girth: The plant was selected for the determination of width of stem girth of plant in an experimental pot. The width of the stem girth of each experimental pot was measured at the average value for each for each experimental pot was determined.

2.4 Statistical Analysis of Results

The deviations between the average values of the growth parameters for the two irrigation schedule were considered. One-way Analysis of Variance was also used to test for significant differences in the growth parameters for the two irrigation frequencies using IBM SPSS Statistics, version 23.

III. Results and Discussions

3.1 Effects of varying irrigation frequency on the growth parameters

The results showing the effects of varying irrigation on the plant heights, stem girths and number of leaves at two weeks after planting (2 WAP), four weeks after planting (4 WAP), six weeks after planting (6 WAP) and eight weeks after planting (8 WAP) are presented in Figures 1, 2, 3 and 4 respectively. At 2 WAP, the numbers of leaf are the same for both treatments, while the plant heights and stem girths for the 4-day irrigation frequency are slightly higher than that o the 2-day irrigation frequency. At 4 WAP, the trend changed for both the plant heights and stem girths as the values for 2-day frequency were found slightly higher than that of 4-day irrigation frequency while the number of leaves remain the same for both treatments. At 6 WAP, there were higher disparities in the values o the treatments with 2-day irrigation frequency having higher values for the plant heights, stem girths and number of leaves than 4-day frequency. The trend for 8 WAP follows suit 6 WAP as the values for the plant heights, stem girths and number of leaves for 2-day irrigation frequency is higher than that of 4-day frequency.

For the growth parameters at 2 WAP, 4 WAP and 6 WAP, the alpha values of $F(1,4)$, $p > 0.05$, which revealed no significant difference in the three parameters for the two treatments. At 8 WAP, the alpha values of $F(1,4)$, $p > 0.05$ for both plant heights and number of leaves but $P<0.05$ for stem girth. Thus, there was no significant difference between the data for the plant heights and number of leaves for the two treatments but there was significant difference between the values of stem girths for the two treatments at 8 WAP.

3.2 Effects of varying Irrigation Frequency on the Yield of Cowpea

The yields from the two treatments of varying irrigation frequencies at twelve weeks after planting by weighing the harvested dried cowpeas pods from the three replicated pots for each treatment were found to be 15.2g for the 2-day irrigation interval and 9.2g for the 4-day frequency as presented in table 4.5. According to Kamara et al. (2016) report that in addition to planting improved cowpea varieties, farmers must immediately change from using the current 75 by 20 cm spacing with two seeds planted per stand (thus giving 133,333 plants / ha) to at least double rows on ridges to achieve corresponding densities of 266,666 plants / ha or triplpe rows on ridges to achieve corresponding densities of approximately 400,000 plants / ha. For double rows planting, the yield for the 2-day frequency at an average value of 5.1g gives 1.38 tons / ha and 2.04 tons / ha for tripple rows on ridges while the 4-day irrigation frequency gives 0.83 ton /ha for double rows planting and 1.24 tons /ha for tripple rows planting on ridges.

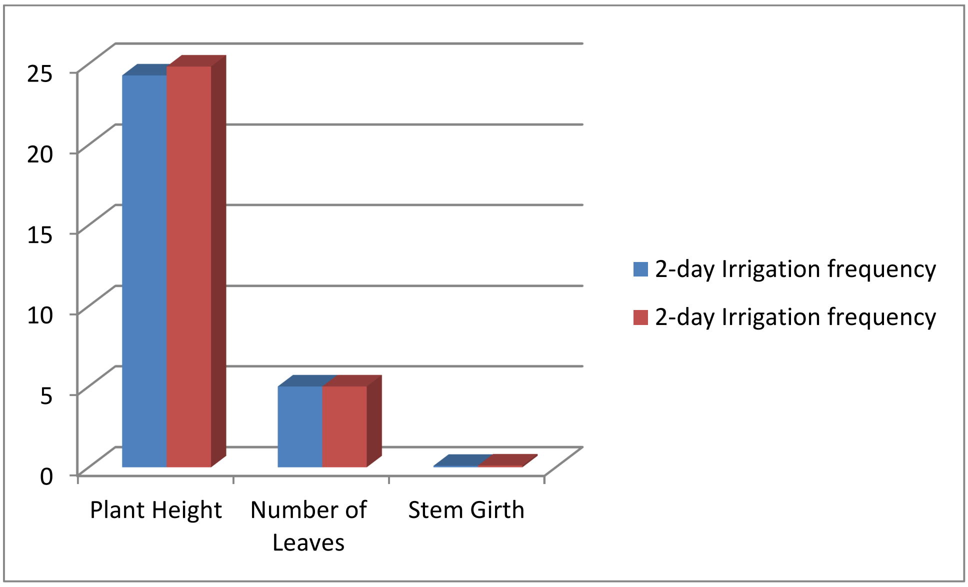

Figure 1 Average plant parameters for the two varying Irrigation Frequency at 2 WAP

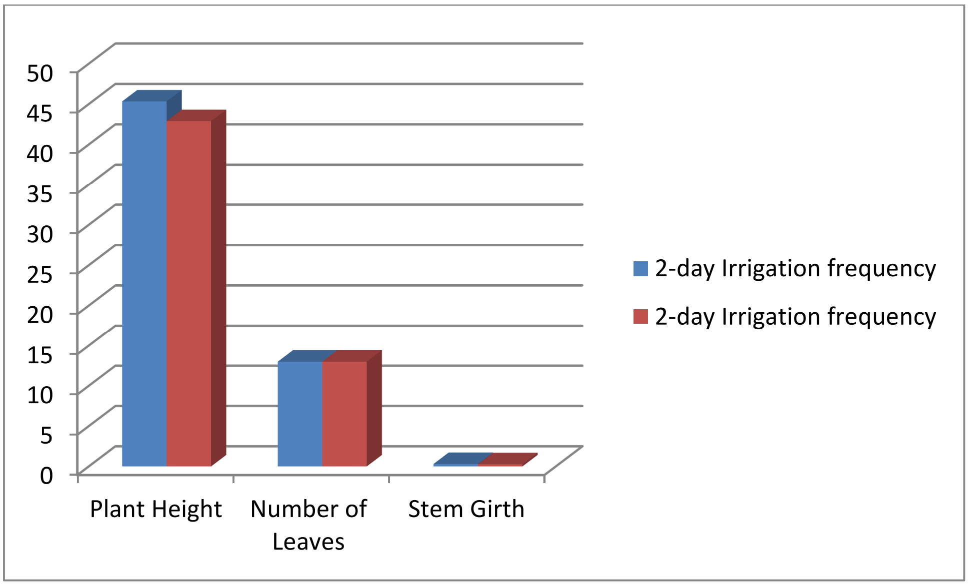

Figure 2 Average plant parameters for the two varying Irrigation Frequency at 4 WAP

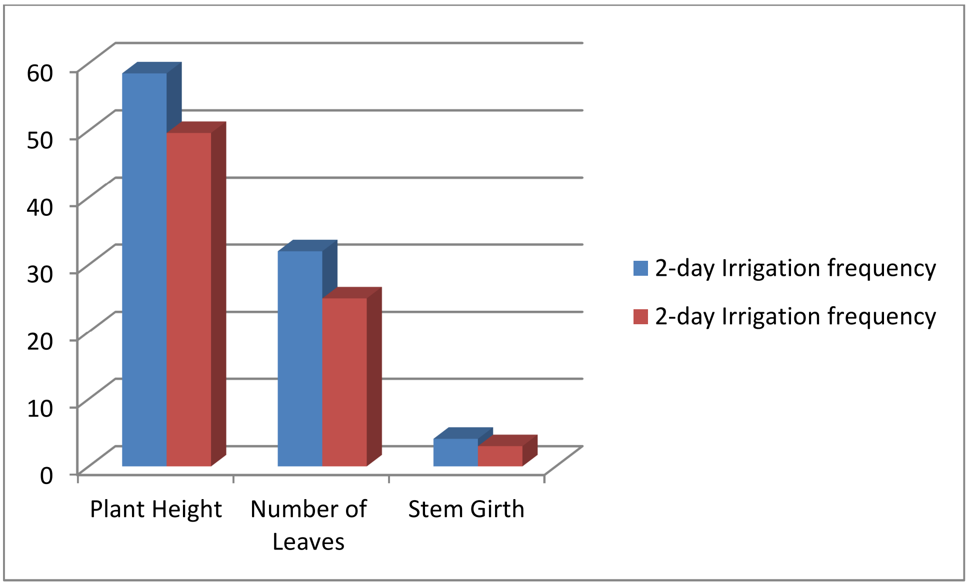

Figure 3 Average plant parameters for the two varying Irrigation Frequency at 6 WAP

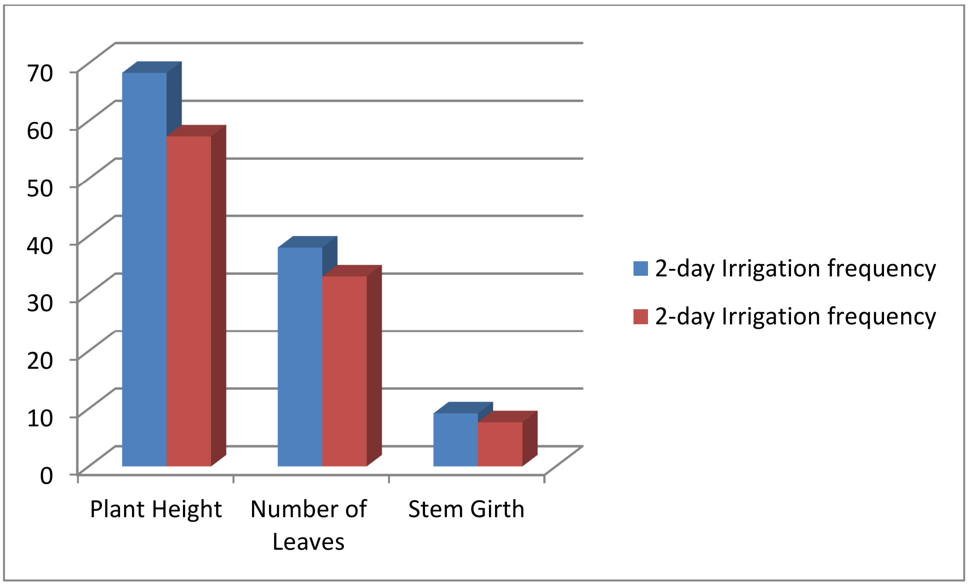

Figure 4 Average plant parameters for the two varying Irrigation Frequency at 8 WAP

3.3 Dry Matter Production

The data on Dry Matter Production (DMP) of the test crop are found to be 41.6g and 21.9g for the 2-day and 4-day irrigation frequency respectively. Using the analysis of Kamara et al., (2016), the DMP in tons per hectare using double rows planting are 3.70 tons /ha and 1.95 tons / ha for both the 2-day and 4-day irrigation frequency respectively. For tripple rows planting on ridges, the DMP are found to be 5.55 tons /ha and 2.92 tons / ha for both the 2-day and 4-day irrigation frequency respectively.

3.4 Crop Water Use Efficiency for cowpea at different growth stages

The data on crop water consumption (as ET values) of the crop at different growth stages are presented in Table 1. The amount of evapotranspiration (ET) was converted from kg to cm/cm by dividing the lysimeter measured evapotranspiration (WET) by the area of the lysimeter (cm^2) as follows:

$$ET = \frac{WET \quad (\text{Water Input} - \text{Drained Output})}{\text{Area of Lysimeter } (560cm^2)}$$

The peak value was found for the peak growth stage for the two treatments while the least for 2-day irrigation interval was during maturity stage but the least for 4-day interval was during seedling stage. Generally, the increasing trend from the seedling stage observed a diminishing return for the two treatments after reaching the peak values at the peak growth stages.

Table 1 Crop water consumption (as ET values) of the crop at different growth stages

Growth Stages	**ET (mm) for 2-day Frequency**	**ET (mm) for 4-day Frequency**
Seedling Stage (2 weeks)	16.63	11.33
Vegetative Stage (+ 4 weeks)	53.83	21.03
Peak Growth Stage (+ 2 weeks)	62.50	26.79
Maturity Stage (+ 2 weeks)	12.41	13.39

IV. CONCLUSIONS

Agriculture must meet future food security challenges by increasing production while conserving important natural resources. Freshwater is an increasingly limited resource that is often mismanaged. Efforts to improve water use management and efficiencies for crop growth need to be a high priority for farmers. Although water is one of the most abundant natural resources in the country, farmers face water scarcity and water-related hazards as they experience unpredictable rainfall patterns, long dry seasons, and increased frequency of extreme floods. This study assesses the water use efficiency of cowpea under varying irrigation schedule to determine the crop water productivity of the crop and eventually have indicators to plan irrigation schedule and improve water use management and efficiencies for cowpea cultivation.

On general assessment, growth parameters were better for 4-days irrigation interval during the sprouting and seedling stages but better for the 2-day irrigation interval between 3-8 WAP. This may be due to the water needs of the plants for metabolism at the different growth stages. Also, the crop yield and dry matter yield of the 2-day irrigation frequency were found to be better than 4 day interval.

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