



CROP WATER USE OF COWPEA (*Vigna unguiculata*) UNDER DEFICIT IRRIGATION IN A CONTROLLED ENVIRONMENT

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Cowpea *Vigna unguiculata* was planted in a pot at a density of one per pot and placed in a greenhouse at the Department of Biological Sciences, University of Agriculture, Abeokuta. It was subjected to four water treatments. The treatments were as follows: No deficit irrigation, 25% deficit irrigation, 50% deficit irrigation and 75% deficit irrigation. The pots were weighed each day with a precision weighing scale of accuracy of 1g to determine the amount of water to be added to each treatment. Before the experiment, the physical characteristics of the soil, such as bulk density, were determined. Water was applied to the treatment weekly. The soil in the pots was at field capacity at the start of the experiment, and the amount of water to be applied to each treatment was based on the difference in weight at the end of the week and evaporated based on the above-mentioned water allocation. Some of the chemical characteristics of the irrigated water were also determined. The findings indicated that cowpea (*Vigna unguiculata*) plants were very sensitive to lack of soil water during the total growing season and the yield formation period. A minimal water use efficiency was observed with a 50% deficit irrigation method showing a more sensitive yield response factor K_y (0.269) than other treatments. This implies that 50% deficit irrigation treatment produces a better yield with minimal irrigation water.

1.0 Introduction

Accurate determination of plant water use is a prerequisite for a good irrigation water management strategy. Restricted water resources limit irrigation applications, and the available water supply is inadequate to produce the maximum yield on irrigable lands. The water available for irrigation is already regulated and requires deficit irrigation. Due to the problems associated with the annual supply of irrigation water, deficit irrigation management for different crops is necessary (Martin et al., 1989).

Deficit irrigation maximises water use efficiency for higher yields per unit of irrigation water applied. With a catalogue of irrigation research under study in Nigeria, efforts are being made to reduce agricultural water use on crops, and this study will continue even in the future. Even then, irrigated agriculture will occur under water scarcity (Oyelaja, 2008). Insufficient water supply for irrigation will be the norm rather than the exception, and irrigation management will shift from emphasising production per unit area to maximizing production per unit of water consumed. To cope with scarce supplies, deficit irrigation, defined as applying water below complete crop-water requirements (evaporation), is vital to reducing irrigation water use. Under conditions of scarce water supply, deficit irrigation can provide greater economic

returns than maximizing yields per unit of water. Kirda (2000) stated that properly practiced deficit irrigation may increase crop quality.

Cowpea, *Vigna unguiculata* L. Walp is a grain legume grown mainly in the savannah regions of the tropics and subtropics in Africa, Asia and South America. In Nigeria, full-scale cowpea production is primarily restricted to the northern part and the middle belt. In contrast, scanty production is limited to the southern part because of its climatic conditions. The value of cowpea lies in its high protein content and ability to tolerate drought; for that reason, cowpea can be cultivated under both irrigated and non-irrigated conditions. As a legume, cowpea also fixes atmospheric nitrogen, allowing it to grow on and improve poor soils. According to Doorenbos and Kassam (1979), about 7.56 million tonnes of cowpeas are produced worldwide annually on about 12.76 million hectares. This study is carried out to prove the response of cowpeas at different growth stages to water supply at different irrigation treatments.

Cowpea under deficit irrigation has lower evapotranspiration rates and yields. For optimum yield, it is necessary to prevent the crop from experiencing a water deficit, especially during the cowpea formation development stage. The crop appears less sensitive to water deficit during the vegetative and ripening periods (SOURCE). Excessive irrigation during the vegetative period can delay and reduce cowpea development (Doorenbos and Kassam, 1979).

Potential evapotranspiration is a measure of the ability of the atmosphere to remove water from the crop through evaporation and transpiration, assuming no control over the water supply. Actual evapotranspiration is the quantity of water removed from a surface due to evaporation and transpiration (Jensen 1974).

Scientists consider these two types of evapotranspiration for the practical purpose of Water Resources Management (WRM). Around the world, humans are involved in the production of a variety of plant crops. Many of these crops grow in environments that are naturally short of water. As a result, irrigation is used to supplement the crop's water needs. Managers of these crops can determine how much supplemental water is needed to achieve maximum productivity by estimating potential and actual evapotranspiration. Estimates of these values are then used in the following equation;

$$\text{Crop water need} = ET_p - ET_a \quad (1)$$

ET_a is actual crop evapotranspiration (mm/day)

The following factors are critical in estimating ET_p

ET_p (refer herein as potential evapotranspiration) requires energy for evaporation. The major source of this energy is the sun. The amount of energy received from the sun accounts for 80% of the variation in ET_p Kirda 2000.

Wind is the second most crucial factor influencing ET_p . Wind enables water molecules to be removed from the ground surface by a process known as eddy diffusion. The evapotranspiration rate is associated with the vapour gradient between the ground surface and the layer of the atmosphere receiving the evaporated water.

This study aimed to determine cowpea's water use characteristics under deficit irrigation at different growing stages and daily evapotranspiration, yield, yield response factor, and irrigation water use efficiency.

2.0 Materials and methods

A pot experiment on cowpea was conducted between 1st August and 30th November 2008 in the Department of Biological Science Research Greenhouse at the University of Agriculture, Abeokuta, Ogun State, Nigeria Campus. The pots were arranged in a completely randomized experimental design with four irrigation treatments replicated three times. Irrigation was

carried out manually. Cowpea seeds were planted at the density of one seed per pot, and an experiment was conducted on the planting date with the soil water content of all pots at field capacity (measured by pot's weight). The treatment is presented in Table 1.

Each treatment was replicated three times for soil water depletion (the difference in weight between the soil at field capacity and the soil before irrigation). In treatment I (pots 1, 5 and 9), irrigation water was supplied at 100% field capacity; treatment II (pots 2, 6 and 10), irrigation water was provided at 75% field capacity; treatment III (pots 3, 7 and 11), irrigation water was supplied at 50% field capacity; and treatment IV (pots 4, 8 and 12), irrigation water was provided at 25% field capacity respectively all at various stages of cowpea growth (vegetative, yield formation and ripening). Irrigation water was applied once a week. The pots were weighed daily. The water quantities were regulated by weight. In all treatments, the soil water content was at the soil field capacity in the establishment period. Each pot was 24cm in diameter and 22.5 cm deep and contained similar growth media (soil, sand, and manure in equal amounts).

Table 1: Treatments

S/N	Description	Deficit Irrigation	Code	Pots NO
1	Maintained field capacity	No deficit irrigation	Treatment 1	1, 5 & 9
2	Maintained at 0.75 of field capacity	25% deficit irrigation	Treatment 2	2, 6 & 10
3	Maintained at 0.50 of field capacity	50% deficit irrigation	Treatment 3	3, 7 & 11
4	Maintained at 0.25 of field capacity	75% deficit irrigation	Treatment 4	4, 8 & 12

The physical characteristics of the soil (such as bulk density g/cm^3) were measured, and the chemical characteristics of irrigation water were also determined. The chemical characteristics of the irrigated water, including the anions, cations, pH, and electrical conductivity, were analyzed and are given in Table 2. During the experiment, temperature, relative humidity, and light intensity of the environment were measured daily, and the average values for ten (10) days were calculated as shown in Table 3.

In the treatments, daily evapotranspiration was estimated as:

$$ET_{(0)1} = \frac{W_{i-1} - W_i}{\rho w * A} \quad i = 1, 2, 3, \quad (2)$$

where $ET_{(0)1}$ is the evapotranspiration (mm) W_{i-1} and W_i are the weights (kg) of the pot at day $i-1$ and i , respectively, ρw is the gravimetric water content (g/cm^3), and A is the surface area (m^2) of the pot. Water use efficiency (WUE) was estimated as

$$WUE = \frac{Y}{ET} \quad (3)$$

where WUE is the water use efficiency ($kg \text{ mm}^{-1} \text{ ha}^{-1}$), Y is the cowpea bulb yield ($Kg \text{ ha}^{-1}$), and ET is the seasonal evapotranspiration (mm) (Hilel and Guron, 1975).

Table 2: Chemical characteristics of irrigation water

		Cations, mg/l			Anions, mg/l					
pH	conductivity	Na+	K	CO ₃	HCO ₃	Cl	SO ₄	Ca ⁺⁺	Mg ⁺⁺	SAR
7.2	0.13	3.95	1.5	4.39	2.05	44.1	0.69	2.62	1.81	0.317

Source: Oyelaja, 2008

Observations determined the dates of the beginning and end of the plant growth periods. The relationship between cowpea yield and evapotranspiration (yield response factor, K_y) was determined according to the Steward model (Doorenbos and Kassam, 1979) with the following equation:

$$K_y = \frac{1 - Y_a / Y_m}{1 - E_{ta} / E_{Tm}} \quad (4)$$

where Y_a is the actual crop yield (kg ha^{-1}), Y_m is the maximum expected crop yield without water stress (kg ha^{-1}), E_a is actual crop evapotranspiration (mm/day), and ET_m is the maximum crop evapotranspiration without water stress (mm/day). Data were analyzed using a Microsoft Excel package to calculate the actual evapotranspiration rates of the cowpea plant per day.

Table 3: Average rainfall (outside greenhouse), temperature, relative humidity and sunshine in the greenhouse

First Trial		Rainfall, Mm	Max. Temp, °C	Min. Temp, °C	Rel. Humidity, %	Sunshine, hr
August, 2008	1st – 10th	4.61	27.9	22.5	78.9	0.22
	11th – 20th	3.07	27.3	20.3	61	0.17
	21st – 31st	2.68	29.3	20.2	60	0.23
September, 2008	1st – 10th	4.71	27.4	22.6	77.6	1.54
	11th – 20th	2.68	29.7	22.8	77.6	2.13
	21st – 30th	6.23	30	20.3	84.7	1.37
October, 2008	1st – 10th	4.61	31	21.2	85.1	1.5
Second Trial						
August, 2008	1st – 10th	5.4	30.9	22.1	69.9	1.41
	11th – 20th	4.38	32.3	23.4	64.5	1.16
	21st – 31st	3.7	33.3	23.9	63.3	1.26
September, 2008	1st – 10th	4.7	33.1	23.5	60.7	1.18
	11th – 20th	2.68	33.6	24.2	50.1	1.02
	21st – 30th	6.22	35.5	28.1	48.9	0.83
October, 2008	1st – 10th	4.62	34	27.2	49	1.23

3.0 Results and discussion

The amounts of water applied per treatment are shown in Table 4. Treatment I received the highest amount of water, followed by treatment 2. The 75% deficit irrigation treatment gets the lowest water in the two trials—the number of leaves per treatment six weeks after planting is shown in Table 5.

Table 4: Amount of water applied per treatment

S/N	Treatment	Treat code	Amount of water applied (mm)	
			First Trial	Second Trial
1	No deficit irrigation	Treatment I	75.32 ± 0.35	68.50 ± 0.31
2	25% deficit irrigation	Treatment II	71.75 ± 0.35	65.50 ± 0.31
3	50% deficit irrigation	Treatment III	69.69 ± 0.35	62.33 ± 0.31
4	75% deficit irrigation	Treatment IV	65.80 ± 0.35	59.70 ± 0.31

Table 5: Number of leaves per treatment at establishment and vegetative stage

S/N	Treatment	Treat code	Number of leaves	
			First Trial	Second Trial
1	No deficit irrigation	Treatment I	13	11
			15	11
			15	13
2	25% deficit irrigation	Treatment II	11	11
			13	9
			11	12
3	50% deficit irrigation	Treatment III	9	11
			9	9
			10	9
4	75% deficit irrigation	Treatment IV	9	9
			9	9
			9	9

It seemed, therefore, that the greater the amount of water received, the greater the number of leaves produced. Hence, it can be concluded that cowpeas respond favourably to the amount of water received for leaves produced.

The average actual or measured water use by the plant is presented in Table 6 for the trial. The relationship between water consumed by the plant and the function of days after planting for a vegetative period is expressed in figures 1a and 1b for the 1st and 2nd trials, respectively. The relationship is a polynomial function of the second degree. The R² values are very low, indicating a poor relationship because they cover mainly the vegetative aspect of the phenological stage of development. This trend is observed in all the treatments. The R² values vary between 0.0067 to 0.2032 for the first trial and 0.0055 to 0.2097 for the second trial. The values for all the phenological stages were considered in this case.

The average cumulative actual evapotranspiration values and relative evapotranspiration for all the treatments are presented in Table 8. The average cumulative values on the function of the days after planting are straight lines. The values vary from 23.77 mm to 33.39 mm for the combined trial. The magnitude of applied irrigation depth, as seen in Table 4, varies between 59mm and 75mm in the combined trial. The most extensive irrigation depth (75mm) was applied in the non-deficit treatment I (I₁, I₅, I₉). The measured daily evapotranspiration values in the treatments are shown in fig 1a and 1b, and calculated values for the individual growth periods and the total growing season are given in Table 6. The seasonal evapotranspiration was the highest (100.78mm) in the non-deficit treatment (I₁, I₅, I₉) and the lowest (62.38) in the 75% in the 75% deficit treatment (I₄, I₈, I₁₂). These values varied between 8.21 and 57.49mm in individual periods according to treatments and growth periods.

Evapotranspiration values for the individual growth periods, or the total growing season in non-deficit treatment I (I₁, I₅, I₉), were taken as the maximum evapotranspiration (ET_m) to determine the yield response factors and the actual evapotranspiration (ET_a) values were taken into consideration for the other treatments.

Table 6: Evapotranspiration values, mm

Growth period	Treatment I (No Deficit Irrigation)				Treatment II (25% Deficit)				Treatment III (50% Deficit)			Treatment IV (75% Deficit)				
	I ₁	I ₅	I ₉	av.	I ₂	I ₆	I ₁₀	av.	I ₃	I ₇	I ₁₁	av.	I ₄	I ₈	I ₁₂	av.
Establishment/Vegetative	33.39	27.93	24.11	28.48	30.69	27.53	24.42	27.55	27.08	24.46	28.51	26.68	23.77	25.24	24.59	24.53
Yield formation	57.49	53.11	54.65	55.08	50.12	49.56	48.01	49.23	39.42	40.96	38.40	39.59	30.15	29.45	27.56	29.05
Ripening stage	18.24	16.42	17.01	17.22	16.11	14.11	12.51	14.24	12.10	10.21	10.52	10.94	9.15	9.01	8.21	8.79
Total for the growing season	109.12	97.46	95.77		96.92	91.20	84.94		78.60	75.63	77.43		63.07	63.70	60.36	
Average total for the growing season		100.78				91.02				77.22				62.38		

Table 7: Average of Actual and Minimum Evapotranspiration (ET_a, ET_m), Yield (Y_a, Y_m) and Yield Response Factor K_y

Treatment	Deficit irrigation growth period	Y _m (t/ha)	ET _m (mm)	Y _a (t/ha)	ET _a (mm)	I – Y _a /Y _m	I – ET _a /ET _m	K _y	WUE
I ₁ , I ₅ , I ₉		0.64	100.78	0.64	100.78	-	-	-	-
I ₂ , I ₆ , I ₁₀	25%			0.54	91.02	0.156	0.097	1.61	5.93
I ₃ , I ₇ , I ₁₁	50%			0.60	77.22	0.063	0.234	0.269	7.77
I ₄ , I ₈ , I ₁₂	75%			0.39	62.38	0.391	0.381	1.03	6.25
Total									

Table 8: Average Cumulative Measured Evapotranspiration for the combined trial

	No deficit	25% deficit	50% deficit	75% deficit			
CUM 1	33.39	CUM 2	30.69	CUM 3	27.08	CUM 4	23.77
CUM 5	27.93	CUM 6	27.57	CUM 7	24.46	CUM 8	25.24
CUM 9	24.11	CUM 10	24.42	CUM 11	28.51	CUM 12	24.89
Average	28.48		27.56		26.68		24.63
STD	4.66		3.13		2.06		0.77

Relative evapotranspiration for the 1st trial

Etmax	no deficit	28.48	relET
	25% deficit	27.56	0.03
	50% deficit	26.68	0.06
	75% deficit	24.63	0.14

As shown in Table 7, the highest cowpea yield (0.64 t/ha) of about (6 g/plant) which translates to about 6 g per pot, was obtained in non-deficit treatment in which complete crop water requirements were met during the total growing period, and lowest yield was obtained in 75% deficit treatments. Soil water deficits during individual growth periods or the total growing season affected the cowpea yields significantly. The 75% deficit treatments or lack of soil water during the yield formation period was caused by a significant decrease in cowpea yield. As a result, irrigation is required to obtain yields, and the highest cowpea yield will be achieved if crop water is entirely provided during the growing season.

It was observed that the crop response factor K_y (0.269) of 50% deficit irrigation was the most sensitive to water requirements. There was no significant difference between the yields of non-deficit and 50% deficit irrigation (i.e. complete water application and 50% deficit irrigation).

4.0 Conclusion

According to these reports, we conclude that cowpeas under deficit irrigation of 50% have lower evapotranspiration rates and comparable yields to complete irrigation treatment. It also shows that irrigation is needed during the total growing season to obtain the maximum yield. We also recommend that to maximize the use of irrigation water, half of the total water requirement of cowpeas is here recommended.

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