Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 17 Issue 1 Version 1.0 Year 2017
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

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GJSFR-D Classification: *FOR Code: 820401*

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I. Introduction

The emerging threat to sustainability of irrigated agriculture in Nigeria requiresa paradigm shift in the way irrigation is practiced. The shift should embrace irrigation water management strategy that can facilitate the achievement of the goal of producing more crops per drop of water. Drip irrigation cum deficit irrigation scheduling seems a combination that may deliver on this goal. The drip irrigation system applies water tothe base of the plants as frequent as designed with a volume of water approaching the consumptive use of plants, thereby minimizing such conventional losses such as deep percolation, runoff and soil water evaporation (Mofoke *et al.*, 2006). Drip irrigation is accomplished by using small diameter plastic lateral lines with devices called emitters or drippers at selected spacing to deliver water to the soil surface near the base of the crops. The system applies water slowly to keep the soil moisture of the base of the plants within the desired range for plant growth (Ramalan *et al*., 2010; Angela 2012).

Deficit irrigation scheduling on the other hand is the practice of irrigating crops below the full water requirement. It can be described as rationing water applied to the cropped field. In economic terms, deficit irrigation increases irrigation efficiency, reduce cost of irrigation and opportunity cost of water, while in ecological terms it prevents rising water tables in areas where the water levels are near the surface and minimizes leaching of agrochemicals to ground water (Angela, 2012). The combination of drip irrigation system and deficit irrigation scheduling is therefore expected produce a remarkable improvement in terms of increased irrigation efficiency resulting from less water application, better water management irrigation improve.

The use of gravity fed drip irrigation systems is fast gaining popularity in Northern Nigeria. There are over a hundred units of drip kits scattered across Katsina, Zamfara and Kebbi States. Some are used with rainwater harvesting systems as the water source. The drip system uses gravity instead of a pump to provide the head (energy) for its operation. The water source (a tank or bucket) is usually place some meters above the ground to provide the pressure head to take water to the emitting points. In most cases, a drip irrigation system consists of raised water container, main-line, sub-main-line, drip laterals, filters, pressure gauges, flow meter and fittings (elbow, tee, nipple, socket, end cover, gate valve, ball valve, amongst others) (Mofoke *et al.*, 2006; Segal*etal.*,2000; Mofoke *et al*; 2006;Oyebode *et al*., 2011). Water is conducted under low pressure to a network of closely spaced outlets (emitters) which discharge water slowly at virtually zero pressure, with the purpose of supplying water to limited soil volume in which active root uptake can take place (Victor *et al.,* 2008; Ahmed, 2006).

Maize production in Nigeria is on the increase. The estimated average annual growth rate inmaize production over the last five years in Nigeria was 5.46% about twice the projected value of3.2% needed to meet demands. The FAO (2013) estimation of annual production of maize in Nigeria is 7.5milliontonnes. Maize production under irrigation is also on the increase, but the produce is largely harvested and sold as green maize, rather than dry grains. Irrigation water management is still a very major challenge for which drip irrigation system cum deficit irrigation scheduling can make significant impact. Yet knowledge gaps exist in terms of impact of deficit irrigation scheduling using drip irrigation kits on yield and water use efficiency of the maize crop. The objective of this study was to evaluate the effect of deficit irrigation scheduling, using the gravity drip kit, on yield and water use of a maize crop.

II. Materials and Methods

a) The Study Area

The field experiment was carried out at the Institute for Agricultural Research (I.A.R) Irrigation farm, Ahmadu Bello University, Zaria, Nigeria. Zaria lies on 11°11'N and 7°38'E, and at an altitude of 686 m above mean sea level, within the Northern Guinea Savannah ecological zone (Odunze, 1998). The weather data for the crop growing seasons are presented in Tables 1, while the characteristics of the soils of the study location are shown in Table 2.

Table 1: Weather data for crop growing season

Month	Humidity (%)	Max. temp(°C)	Min. temp(°C)	Sunshine (Hours)	Wind speed(km/d)	ETo[a] (mm/d)	Total Rainfall (mm)
January	19.37	32.48	17.74	8.01	142.66	6.82	-
February	13.52	35.50	18.79	7.49	131.44	8.56	-
March	26.37	39.29	22.77	7.63	118.24	9.14	-
April	38.85	37.47	24.77	7.09	143.03	7.89	58.76

Table 2: Physical properties of soils of the experimental site

Depth (cm)	FC (%Vol)	PWP (% Vol)	Bulk density (g/cm^3)	Hydraulic Conductivity (mm/hr)	Clay (%)	Silt (%)	Sand (%)	Textural Class[a]
0-15	24.8	13.6	1.58	70	22	28	50	Clay Loam
15-30	26.3	15.9	1.58	100	26	22	54	Clay Loam
30-45	27.4	17.1	1.57	100	28	18	54	Clay Loam
45-60	25.9	15.9	1.58	125	26	18	56	Sandy clay loam
60-80	29.5	18.2	1.55	125	30	22	48	Sandy clay loam

[a] *Based on USDA textural classification*

b) The Drip Irrigation System Setup

The drip system setup has a 2000-litre capacity Gee-Pee tank placed on a metal frame stand 3 m high which services as the water reservoir. (An 8 hp petrol pump (Robin Model) was used to lift water from a water sump to the Gee-Pee tank. The sump receives water supply from a lake located 65 m away from the experimental field). A low density polyethylene pipe (of length 2.5 m and diameter 0.25 m) connected at the bottom of the water tank takes the water to the ground level. A primary filter was installed at be base of the polyethylene pipe. Another pipe of 3.5 m long connected with an elbow joint to the polyethylene pipe takes the water to the main distribution line with a Tee connection. The entire field of 40 m by 20 m was divided into two wings (A and B). Each wing (20 m by 20 m) was use for a different experimental setup, which implies that two experiments were ongoing concurrently and each was being supplied water from the overhead tank. The work reported herein was the experiment in Wing A. The wing has three primary sub-mains which were connected to the main distribution line, and each sub-main has a control valve to regulate the flow. The primary sub-mains supply water to each experimental block. Over each experimental plot were laid three drip tapes (laterals) of 5 m long spaced 60 cm apart. The drip tapes were connected to some secondary sub-mains, and these secondary sub-mains were connected to the primary sub-mains with a valve to regulate the flow of water. With this arrangement, you can regulate the flow of water to each experimental plot. The drip tapes referred to laterals in this design has inline emitters (of 16 mm diameters) spaced 30 cm apart. In the layout for the wing whose experiment is reported herein, there were 72 laterals of obtained from three experimental blocks (which were the replicates of the experimental treatments), eight experimental treatments/ plots and each plots has three laterals. Plate 1 shows the picture of the entire field.

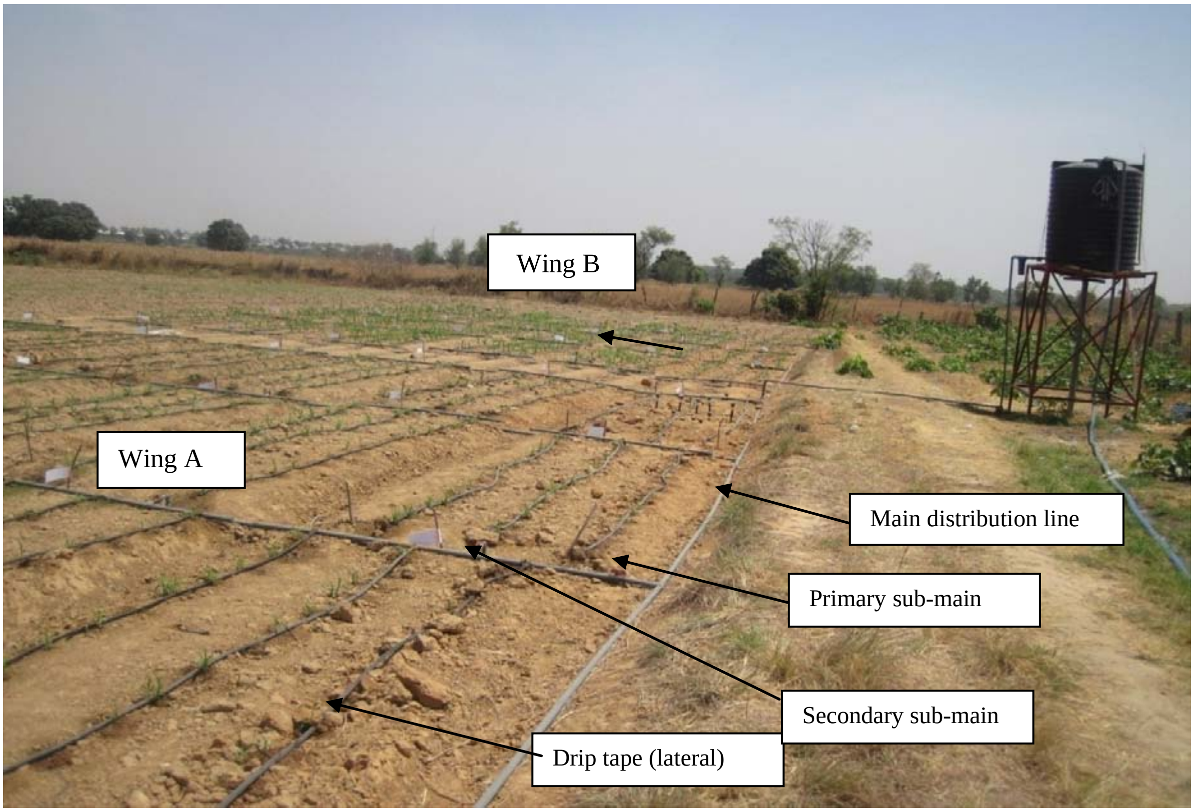

Plate 1: Experimental Layout of the field

The hydraulic performance of the drip system setup was evaluated using the Catch can test. Seventeen (17) drip points were randomly selected in the field; their distances from the water tank were noted and catch cans were used to collect water dripping from the drippers for one hour, and the following drip characteristics were determined: the emitter discharge (l/h) distribution uniformity (DU) (Merriam et al., 1980); emitter flow variation (Camp et al., 1997); emission uniformity (EU) (Michael, 1978), discharged coefficient of variation (Camp et al., 1997). coefficient of variation of uniformity, and water application efficiency (AE) (Vermeiren and Jobling, 1980).

c) *Experimental treatments, field practices and data collection*

The field experiment was carried out during the 2012/2013 irrigation season. The experiment consisted of eight (8) treatments replicated three times and laid in a randomized complete block design. The treatment description is as presented in Table 3. The $V_{100}F_{100}G_{100}$ treatments was full- irrigation (no deficit irrigation) while the $V_{50}F_{50}G_{50}$ treatment was full-deficit. In the other treatments, deficit water application took place in one growth stage which the other growth stages received full irrigation. The following growth-stages ranges were adopted: Vegetative (15-42 days after planting DAP); Flowering-tasseling to silking (43-57 DAP) and grain filling to physiological maturity stages (58-85 DAP).The variety of the maize crop planted was SAMMAZ 14 which is one of the releases of the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. Planted was done on the 7th February, 2013. Manual weeding with the use of hoe was carried out three times for both fields at three, six and nine weeks after planting. Compound fertilizer (NPK 15:15:15) was applied at the rate of 60 kgN/ha at three weeks after planting, applied as basal dose. Urea fertilizer was used for topdressing at 6 weeks after planting at a rate of 60 kgN/ha as recommended by the Institute for Agricultural Research, Samaru, Zaria; thus the total N applied was 120 kg/ha. The fertilizers were applied after weeding on each occasion.

Table 3: Description of Experimental Treatments

Treatment Label	Treatment Description
$V_{100} F_{100} G_{100}$	Water was applied at 100% of ETo in all the growth stages.
$V_{75} F_{100} G_{100}$	Water was applied at 75% of ETo at Vegetative (V) Stage and 100% of EToat Flowering(F) and Grain filling (G) Stages.
$V_{50} F_{100} G_{100}$	Water was applied at 50% of ETo at Vegetative (V) Stage and 100% of EToat Flowering(F) and Grain filling (G) Stages.
$V_{100} F_{75} G_{100}$	Water was applied at 75% of ETo at Flowering (F) Stage and 100% of ETo at Vegetative (V) and Grain filling (G) Stages
$V_{100} F_{50} G_{100}$	Water was applied at 50% of ETo at Flowering (F) Stage and 100% of ETo at Vegetative (V) and Grain filling (G) Stages
$V_{100} F_{100} G_{75}$	Water was applied at 75% of ETo at Grain filling (G) Stage 100% of ETo at Vegetative (V) and Stages Flowering (F)
$V_{100} F_{100} G_{50}$	Water was applied at 50% of ETo at Grain filling (G) Stage 100% of ETo at Vegetative (V) and Stages Flowering (F
$V_{50} F_{50} G_{50}$	Water was applied at 50% of ETo in all the growth stages

The irrigation interval was alternated between 3 and 4 days throughout the crop growing season. The amount of water applied in each irrigation event depends on the experimental treatment. The full-irrigation treatment was given the depth of water equivalent of the sum of daily reference evapotranspiration (ETo) for the irrigation interval. The other treatments were given the percentage of the ETo, depending on the treatment. The depth of water applied varied from 15 to 40 mm per irrigation while the seasonal water applied varied from 434 to 699 mm. The water application efficiency was taken as 90 % being a drip system. The daily ETo was computed based in Hargreaves equation (Allen et al., 1998).

Soil moisture contents of the experimental plots were monitored throughout the crop growing season using calibrated gypsum blocks. Four blocks were installed in each experimental plot to monitor soil moisture resistance at intervals at 0-15, 0-30, 30-60, 60-90 cm depths. Soil moisture resistances were measured using Delmhorst soil moisture tester KS-D1 4862 model a day after irrigation and just before the next irrigation. The resistances measured were converted to gravimetric soil moisture content using the Gypsum-gravimetric moisture content calibration curve developed for the sets of gypsum blocks. The expression was obtained as:

$$GMC = 44.75 * R^{-0.24} \quad (1)$$

Where: GMC is the gravimetric moisture content (% dry weight basis) and R, the electrical resistance in ohm (Ω). The coefficient of determination for the expression was 0.8770.

The actual crop evapotranspiration ETa was calculated from the measured soil moisture content data using the expression:

$$AET = \frac{\sum_{i=1}^{n} (MC_{1i} - MC_{2i}) * AZ_i \; D_i}{t} \quad (2)$$

Where AET is average daily actual evapotranspiration between successive soil moisture content sampling periods (mm/day); MC_{1i} is gravimetric soil moisture content at the time of first sampling in the i^{th} soil layer; MC_{2i} is gravimetric soil moisture content at the time of second sampling in the i^{th} layer; AZ_i is the bulk density of depth i^{th} layer, D_i is depth of i^{th} layer (mm); n is number of soil layers sampled in the root zone depth D, and 't' is number of days between successive soil moisture content sampling.

There was no incidence of pests or diseases during the cropping season. The crop attained physiological maturity at 85 days after planting; irrigation was withdrawn thereafter to allow the crop to dry. Accordingly, harvesting was done by cutting the above ground dry matter, and the grains were removed from the cob. Both dry matter and grains were weighed in the Laboratory. The grain and biomass yield, seasonal crop water use, biomass and grain yield irrigation water productivity were subjected to statistical analysis of variance and the significance among treatment means was evaluated with Duncan's Multiple Range Test (DMRT).

III. Results and Discussion

a) Hydraulic characteristics of the drip irrigation system setup

Table 4 shows the hydraulic parameters of the drip system setup which includes emitter discharge (ED), emission uniformity (EU), distribution uniformity (DU), emitter flow variation (Qvar); discharge coefficient of variation (CVq), coefficient of variation of uniformity (CvU) and application efficiency (AE).

Table 4: Dripper flow rate different plots as affected by Lateral Length

No of drippers	Distance from the tank (m)	ED (l/hr)	EU (%)	DU (%)	Qvar (%)	CVq (%)	CvU (%)	AE (%)
1	5.4	0.50	94.1	93.8	15.9	4.9	95.1	94.1
2	7.7	0.68	88.6	88.9	32.9	8.7	91.3	88.6
3	10	0.61	86.9	85.2	32.3	11.7	88.3	86.9
4	10.8	0.39	91.5	91.4	20.5	6.7	93.3	91.5
5	10.9	0.52	91.1	91.2	20	6.9	93.1	91.1
6	11.9	0.42	95.9	95.9	11.4	3.2	96.8	95.9
7	12.3	0.65	86.8	86.1	28.8	11	89	86.8
8	14.9	0.5	94.1	94.4	14.3	4.4	95.6	94.1
9	15	0.52	90.4	91	21.2	7.1	92.9	90.4
10	15.4	0.42	89.1	88.1	30.1	9.4	90.6	89.1
11	17.3	0.62	93.5	93.7	17.2	4.9	95.1	93.5
12	19.5	0.51	93.3	93.5	16.9	5.1	94.9	93.3
13	21.9	0.66	88.8	90.0	22.1	7.8	92.2	88.8
14	26.6	0.61	95.4	95.4	12.2	3.6	96.4	95.4
15	26.9	0.65	93.6	93.3	16.5	5.3	94.7	93.6
16	27.3	0.54	96	95.8	11.0	3.3	96.7	96.0
17	28.4	0.68	95.3	95.2	12.0	3.8	96.2	95.3
Average		*0.56*	*92.02*	*91.94*	*19.72*	*6.34*	*93.66*	*92.02*

The emitter discharges ranged from 0.489 to 0.612 l/h. The average emitter flow variation being 19.7% is satisfied Michael (1978) and Jensen (1983) who recommended that in drip irrigation setup the average variation of emitter flow rate in the entire field should not exceed 20%. The result obtained indicates that the arrangement of the drip lines were satisfactory in terms of uniformity of flow from individual emitters. The average emission uniformity was obtained as 92% while the distribution uniformity was 92%, which is an indication of even distribution of water in the system. The average discharge coefficient of variation was 6.34 % and the average coefficient of variation uniformity was calculated as 93.6%. These results were consistent with the recommendations of Keller et al. (2001) who stated that a drip irrigation system with uniformity parameters, emission uniformity and distribution of uniformity of 85% or more and discharge variation of the whole system less than 20% is considered to be satisfactory. The overall average water application efficiency of the system was 92.2% which implies that the hydraulic performance of the drip setup was satisfactory.

b) Grain and Biomass Yield

Table 5 shows the grain yield (GY), biomass yield (BY) and harvest index (HI) which is the ratio of grain yield to biomass yield. Table 5also shows the percentage decreases in grain (ΔGY)and biomass yield (ΔBY)with respect to the full-irrigation treatment for the different treatments. The grain yield varied from 1.56 to 3.39 t/ha while the biomass yield ranged from 5.6 to 11.1 t/ha. The statistical differences among the yields of the experimental treatments were highly significant. Grain yields reduction due to irrigating at 75 % and 50 % at vegetative growth stage 12.7 and 30.4 %, respectively. Biomass yields were found to also reduce by similar percentage for same deficit irrigation application. Interestingly, reducing water applied by 25 % of ETo (i.e. irrigating at 75 % of ETo) during flowering growth stages reduced both grain and biomass yields by less than 10 %; but at 50 % reduction of water application, grains and biomass yield reductions shot up to 26.8 % and 36.7 %, respectively. This shows how sensitive the flowering growth stage of the maize crop is to water deficit, irrespective of the irrigation method.

It may be noticed from Table 5 that the deficit irrigation schedule during the grain filling to maturity growth stage did not have significant effect on the crop yields. This result does not suggest that the growth stage is not sensitive to deficit irrigation. The result obtained was influenced by rainfall which occurred twice during this crop growing stage The total rainfall for that period was about 58.8 mm, which may have ameliorate the impact of the deficit treatment, making treatment not significant difference in yield from the control. Irrigating at half the water requirements throughout the crop growth stages (treatment: V_{50} F_{50} G_{50}) also led to about 50 % reduction in both grains and biomass yield.

Table 5: Grain yield, Biomass yield and Harvest index of the Maize crop

Treatments	GY(t/ha)	BY(t/ha)	HI (%)	ΔGY(%)	ΔBY(%)
$V_{100}F_{100}G_{100}$	3.39a*	11.12a	31	0.0	0.0
$V_{75}F_{100}G_{100}$	2.96 c	9.60c	30	12.7	13.7
$V_{50}F_{100}G_{100}$	2.36 d	7.65d	30	30.4	31.2
$V_{100}F_{75}G_{100}$	3.09c	10.07c	31	8.8	9.4
$V_{100}F_{50}G_{100}$	2.48d	7.04d	27	26.8	36.7
$V_{100}F_{100}G_{75}$	3.36a	10.90a	29	0.9	2.0
$V_{100}F_{100}G_{50}$	3.23b	10.46b	31	4.7	5.9
$V_{50}F_{50}G_{50}$	1.56e	5.63e	31	54.0	49.4

**Treatment means followed by the same letter(s) in any column are not significantly different at 5% level of significance.*

The range of grain yield obtained in this study were similar to those reported by Lyocks *et al.*(2013) being 2.05- 3.98 t/ha for Samaru, same study area as this experiment. Garba and Namo (2013) also reported grain yield of 3.88 and 3.49 t/ha for of Saminaka (lowland) and Vom (mountainous) in the same ecological belt as this study. However, maximum grain yield in this study was found to be far less compared to Sefer *et al*. (2011), who obtained grain yield ranging from 1.93- 10.4 t/ha under clay loam soil with the use of drip irrigation system in the Eastern Mediterranean climatic conditions of Turkey. It must however be understood that the magnitude of yield response to deficit irrigation is also dependent on the crop variety, extent of irrigation deficit, irrigation method, climate and other agronomic practices like weeding and fertilizer application.

c) Crop water use

Table 6 shows the seasonal evapotranspiration (SET), seasonal irrigation water applied (SIWA) and the total seasonal water applied (TSWA) which include the SIWA and the rainfall depth during the crop growing season. The seasonal irrigation water applied (SIWA) ranged from 375 to 640 mm. The highest SET value of 483 mm was obtained when 100% depth of water was applied throughout the crop growth stages, while the lowest crop water use value of 320 mm was obtained when 50% deficit was applied throughout the crop growth stages. This was expected since SET depends largely on moisture available for the crop uptake. The water applied in treatment $V_{50}F_{50}G_{50}$ was not within the range of 500-800mm given by Doorenbos and Kassam (1979) for a maize crop which further explains the differences in yield compared to the others treatments.

Table 6: Seasonal crop water use and water applied

Treatments	SET(mm)	SIWA(mm)	TSWA(mm)
$V_{100}F_{100}G_{100}$	483a*	640	699
$V_{75}F_{100}G_{100}$	441d	590	637
$V_{50}F_{100}G_{100}$	417e	540	574
$V_{100}F_{75}G_{100}$	453c	600	651
$V_{100}F_{50}G_{100}$	428e	520	599
$V_{100}F_{100}G_{75}$	470b	606	680
$V_{100}F_{100}G_{50}$	464bc	592	659
$V_{50}F_{50}G_{50}$	320f	432	434

**Treatment means followed by the same letter(s) in any column are not significantly different at 5% level of significance*

d) Water Use Efficiencies

Table 7 shows the seasonal water use efficiencies(WUE) of the maize crop expressed as yield over seasonal crop water use (SET). The WUE with respect to grain and biomass yields ranged from 0.41 to 0.63kg/m^3 and 1.76 to 1.98 kg/m^3, respectively. These values imply that about 0.41 to 0.63 kg of maize was produced from every cubic depth of water, while 1.76 to 1.98 kg of dry matter was produced from every cubic meter of irrigation water. Water use efficiencies of the treatments irrigated at 75 % of ETo at flowering and grain-filling to maturity stages were not statistically significantly different from the treatment which received full irrigation in all growth stages.

Table 7: Water Use Efficiencies of maize crop in the cropping season

Treatments	WUE(grain yield) kg/m	WUE(biomass yield) kg/m^3
$V_{100} F_{100} G_{100}$	0.63	1.98 a
$V_{75} F_{100} G_{100}$	0.51 b	1.75 c
$V_{50} F_{100} G_{100}$	0.51 b	1.82 b
$V_{100} F_{75} G_{100}$	0.56 ab	1.86 ab
$V_{100} F_{50} G_{100}$	0.50 c	1.74 c
$V_{100} F_{100} G_{75}$	0.58 ab	1.88 ab
$V_{100} F_{100} G_{50}$	0.54 b	1.81 b
$V_{50} F_{50} G_{50}$	0.41 c	1.76 c

**Treatment means followed by the same letter(s) in any column are not significantly different at 5% level of significance*

IV. Conclusion

The effects of deficit irrigation scheduling with gravity drip irrigation kit on water use efficiency a maize crop in Samaru, Nigeria was studied using field experiments conducted in 2012/2013 irrigation season in Zaria Nigeria. This study reveals that applying water with the drip kit at a quarter less than crop water requirement at flowering and grain filling to maturity after full dose application at vegetative growth stage does not significantly reduced crop yield and water use efficiency. If such magnitude of reduction takes place at vegetative growth stage, yield will be reduced by over 12 %. Moreover, applying water using the drip kit at half the crop water requirement at any single growth stage significantly reduces crop yields and water use efficiencies. The highest crop yield, seasonal water use and water use efficiency were obtained in the treatment that was fully irrigated, which implies that the deficit irrigation did not improve the crop response or water use efficiency. The results suggest that under high water application efficiency deficit irrigation practice may not necessarily lead to higher crop water use efficiency of the maize crop.

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