EFFECT OF MULCH AND DEFICIT IRRIGATION ON YIELD AND WATER USE EFFICIENCY OF COWPEA (*Vigna unguiculata* (L.) WALP) UNDER GRAVITY DRIP IRRIGATION SYSTEM

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Abstract: A field experiment was conducted in 2016 dry season at the Department of Agricultural and Bio-resources Engineering irrigation experimental field, Samaru to determine the yield and water use efficiency of cowpea under deficit irrigation and mulching. The treatment consisted of three levels of irrigation water application depth of 50, 75 and 100% replacement of soil moisture deficit and three types of mulch materials ((Black polythene mulch (BPM), Rice straw mulch (RSM) and no-mulch (NM)) combined in Randomized Complete Block Design and replicated three times, irrigation water was applied to each plot using drip laterals. The soil moisture was monitor throughout the season with a theta probes. Results obtained from the research showed that highest seed yield of 1499.8 kg/ha was obtained when the cowpea crop was irrigated at 75% soil moisture deficit with black polyethylene mulch (I_{75}BPM). The lowest yield of 800.4 kg/ha was obtained when irrigation was done at 50% SMD and no mulch (I_{50}NM). The highest seasonal water use was obtained at I_{100}NM with 242 mm and the least is at I_{50}BPM with 120 mm. The highest irrigation water applied is at I_{100}NM with 283.15 mm and the least is at I_{50}BPM with 133 mm. The highest crop water use efficiency and irrigation water use efficiency is at I_{75}BPM with 10.37 and 9.28 kg/ha-mm, respectively. It can be concluded from the results of the present study that for achieving maximum grain yield and optimum water productivity, cowpea crop can be drip irrigated at 75% SMD with black polythene mulch.

Keywords: Drip irrigation, mulch, soil moisture deficit, water use efficiency

Introduction

Agriculture accounts for about 69 – 70% use of available water in the world (FAO, 2016 AQUASTAT). However, dwindling water availability has made it necessary to improve on the way water is used in Agriculture. Competition for water supplies is a world-wide phenomenon, and climate change is the most serious threat facing the world today. Impact of this climate change occurs on ecosystems, food security, health, water resources, settlements and infrastructure. It is argued that the impact on water resources is central to all other impact. The International Panel on Climate Change IPCC (2019) takes water impacts to be crucial for all sectors and regions; and the United Nations (2012) has considered water as the primary medium through which climate change influences the earth's ecosystem and thus the livelihood of human and other living organisms.

According to United Nations (2012), by 2050, the world's population will reach 9.1 billion, 34 percent higher than today. Nearly all of this population increase will occur in developing countries. In order to match food production with this population increase, annual cereal production will need to rise to about 3 billion tonnes from 2.l billion today. However, rain fed agriculture is still the main traditional way of producing crops in some parts of the world. In many other parts, rainfall amount are decreasing. Irrigation is the only alternative option for growing crops all year round. In such regions, the success of farming depends entirely on the ability of farmers to manage these scarce resources (water) for agriculture.

In Nigeria, agricultural production is both rain fed and irrigation. According to Federal Ministry of Water Resources (FMWR, 2014) and World Bank (2014), Nigeria has a very large irrigable land of about 3.14 million hectares. In view of differences in production potentials in agro-ecological zones, irrigation will continue to be justified particularly in the northern part of the country for local production of cereal and legume crops.

Deficit irrigation is a strategy which allows a crop to sustain some degrees of water deficit in order to reduce irrigation costs and potentially increase revenue. English and Raja (1996) described three deficit irrigation case studies in which the reduction in irrigation water cost was greater than the reduction in revenue cost due to reduced yield. The potential of deficit irrigation practices in conserving scarce water resources and increasing farm productivity has been recognized (Kirdra, 2000). The increase in productivity of cowpea will assist to fulfill the increasing demand of protein food. Careful and positive attention to cowpea would support 850 million people in the world with high incidence of undernourishment as documented by FAO (2006). The aim and objectives of the study is to evaluate the effect of mulch and deficit irrigation on yield and water use response of cowpea under gravity drip irrigation system, to also evaluate the hydraulic performance of the gravity drip irrigation system and to determine water use efficiency of cowpea under deficit drip irrigation and mulch.

Materials and Methods

Study area

Field experiment was conducted during 2016 dry season at the Department of Agricultural and Bio-resources Engineering Irrigation Experimental Field, Ahmadu Bello University, Zaria. It lies on latitude 11° 11 'N, longitude 7°38'E, and altitude 686 m above mean sea level in the northern guinea savannah ecological zone of Nigeria with a semi-arid climate.

Description of the selected field

For the purpose of textural classification of the root zone profile of the experimental site, soil particle analysis was carried out prior to planting on soil samples at some incremental depths of 0 -15 cm, 15 -30 cm and 30 -45 cm, 45-60cm and 60-75cm to determine the moisture content at field capacity and at wilting point conditions. The bulk density at the different depth was also determined.

Treatments and experimental design

The experiment consisted of two factors namely: Irrigation at three (3) level {(50, 75 and 100% of Soil Moisture Deficit (SMD)} and three types of mulching materials (No mulch, rice straw and black polythene mulch) treatments laid in Randomized Complete Block Design (RCBD) with three replications

The variety used for the trial (SAMPEA 8) was obtained from seed processing Unit of Institute for Agricultural Research, Samaru, Zaria. It has a semi-erect growth habit, early maturing (60-65 days), medium white seeds with yield potential of 1200 kg ha^{-1} . It has some level of resistance to insects and diseases Ichi *et al.* (2013)

Land preparation

The experimental field was cleared, harrowed and made into ridges to create a favourable condition for seed establishment with a distance of 0.75 m between ridges and 1m between blocks. The field was marked into three (3) plots and nine (9) laterals per replication, with a total of 27 laterals.

Planting

The seeds were sown manually at three seeds per hole, with an inter-row and intra-row spacing of 75 and 30 cm respectively at the rate 25 kg/ha (reason for change in conventional spacing is due to the emitter design spacing). After germination, seedlings were thinned to two plants per stand at 10 days after emergence. Fertilizer was applied using 100 kg of compound fertilizer (NPK 15-15-15) per hectare and 30 kg SSP (Dugje *et al.,* 2009). Pre-emergence herbicide (Gramazon) was applied at planting. Thereafter weeding in the plots was done manually with hoe which was carried out two times, at 2 and 4 weeks after planting.

Mulching placement

The mulch materials were placed two weeks after planting. The polyethylene material (black) was cut to size and placed over the ridge. Holes were created in accordance with the plant spacing and the cowpea seedlings were passed through the holes carefully. The thickness of the polyethylene measured with a micrometer screw gauge was about 2 mm. About 1 kg m^{-2} of rice straw mulch was applied uniformly on each plot according to treatment description.

Crop protection

Infestation by *Aphis craccivora* at 4 weeks after planting was checked with the application of "sharp shooter*"(projenofos 40% + cypermethrin 4% E.C)* at 0.81itre/ha using 40 ml in 15 liters' knapsack sprayer as recommended by Avav and Ayuba (2006). Other insect pests were controlled at 2 weeks after sowing, pre-flowering, flowering and podding with Lara Force, with an active ingredient Lambda-cyhalothrin 25%EC. (100 ml/ 16 l of water) while fungal diseases were controlled using Benomyl as benated (50WP). Rabbit is another pest that affected the crop at the pod formation stage; this was properly managed traditionally by use of local traps**.**

Harvesting and threshing

The harvesting of the dried pods started 5 weeks after sowing. Picking was carried out three times at an interval of two weeks, this was carried out by hand –picking when the pods were fully matured and dried. All the net plots were harvested separately. Harvested pods were sun dried before threshing and the threshed seeds were further dried in the sun before weighing. The grain weight per each net plot was weighed and converted to grain yield in kilogram per hectare (kg/ha).

Soil moisture determination

Soil moisture content was monitored throughout the crop growing seasons with ML3 Theta Probe (Delta –T devices, London). The Theta Probe measures moisture content in-situ and expresses the volumetric soil moisture regime. Soil moisture measurement through the soil profile was done a day after an irrigation and before next irrigation at incremental depth of 0-15, 15-30, 45-60, 60-75 cm. Five Pieces of 7.2 cm diameter PVC pipes were installed to the depths mentioned above in each plot. The pipe provides access for inserting the theta probe into the soil. Soil moisture measurement was made by inserting the sensing head of the theta probe into the soil through the access pipes to the various depths required below the soil surface.

Soil water use in the experiment was obtained principally from routine measurements of the soil moisture content by the gravimetric method and use of theta probe meter. For the soil depth of 0-15 cm, soil samples were collected with soil auger just before irrigation and one day after irrigation to compute soil water contents as;

$$Sw = ov.Z = OM.Bd.Z = \frac{FW-DW}{DW}.Bd.DZ \qquad (1)$$

Where: Sw = soil water content in the soil layer (0-15 cm).cm; ov, om, = volumetric and gravimetric moisture contents in the depth in cm^3/cm^3 and g/cm^3; and Fw.Dw =wet and dried weights of soil sample.

For soil layer below 15 cm depth, Theta probe meter with forty eight access tubes made of 5 cm diameter, 150 cm long aluminimum pipes were used to obtained soil water content at different depths .The total available water is the water held in the root zone depth at moisture contents defined as field capacity (upper limit) and permanent wilting point (lower limit).In the experiment, upper limit of soil moisture contents were fixed at 0, 50, 75 and 100% of TAW. Water use by the cowpea was therefore calculated based on the moisture depleted from storage to satisfy actual crop evapotranspiration minus any rainfall in the interval plus leaching fraction (leaching was not considered in the study as the soil was non-saline) effective rainfall was not accounted taking into account application efficiency of the system.

Prior to planting, soil moisture content at depths up to 20 mm were determined using the gravimetric method and one irrigation applied to raise the moisture content of the soil. The uniform application of water was done to ensure the crop is properly established before imposing the treatments.

Water source

Surface runoff harvested from departmental drainage channels and stored in a 50 m^3 capacity underground sump, 6m deep, was the main source of the irrigation water. The sump water was recharged daily from the university water supply. A 2 -horse power electric pump was used to lift water from the underground tank to the elevated tanks, 2 m above ground which was placed on a concrete stand. When water has been pumped to full capacity in tank A, the valve at the junction of pipe that supply water to tank A was turned off. Valve at the junction that supply water to tank B was then opened until tank B is filled to capacity. Tank B supplies water to plots 2 and 3. Water from the elevated tank was released into a supply line 20 mm diameter, 5 m long made from Low Density Polyethylene Pipe (LDPEP). A ball valve and a primary filter were fixed on the mainline of the same material. Four sub- mainlines each 180cm long, and 20 mm in diameter were connected to the mainline. There were 27 laterals altogether installed. The hydraulic characteristics of the system installed that were evaluated included: emitter flow rate, emitter flow rate variation, uniformity coefficient and emission uniformity and application efficiency.

Emitter flow rate was computed as;

$$q_e = \frac{v}{t} \qquad (2)$$

Where: q_e=emitter discharge(l/hr); V =Volume of water (1); t=time (hr.);

The emitter follow variation**(Q_{var})** was simply computed as;

$$Q_{var} (\%) = 100 \left(\frac{q_{max}-q_{min}}{q_{max}}\right) \qquad (3)$$

Where: Q_{var} =emitter flow variation; q_{max} = maximum emitter flow along the lateral line (1/hr.); q_{mm} = minimum emitter flow along the lateral line (1/hr.)

Emission uniformity (EU) was computed as;

$$EU = 100\left(\frac{q_{iq}}{q}q\right) \qquad (4)$$

Where: $q_{iq}q$= Average rate at low quarter (25%) of emitter discharge observations (1/hr.); q = Average discharge rate of all observations (1/hr.).

Application efficiency. The overall application efficiency of the drip irrigation system was estimated from the relationship given as;

$$Ea(\%) = Ks.EU \quad (5)$$

Where: Ea is application efficiency,%; Ks is average water stored in the root zone over average depth of water applied and is a coefficient which expresses the storage efficiency of the soil taking into account the pressure variation in the drip system (Ks = 1 for loam soil) and Eu = Emission uniformity as given in eq.(4)

Uniformity coefficient was computed as;

$$UC=1-\frac{\sum_{i=1}^{n}[q-qn)}{Nqn}x100$$

Where: q indicated the outflow rates of drip emitter number tested (l/h),qn was the average emitter outflow of emitters tested in each treatment (l/h), and N was the total number of experimental emitters in each treatment.

Crop water use efficiency (CWUE)

Water use efficiency was computed using Burman *et al.*, (1980) equation given as

$$CWUE=\frac{Y}{CWU} \quad (6)$$

Where: Y=Crop yield (kg/ha); CWU=Crop water use (mm); CWUE = Crop water use efficiency (kg/ha-mm)

Irrigation water use efficiency (IWUE)

$$IWUE = \frac{Y}{IWU}, \quad (7)$$

Where: IWUE = Irrigation water use efficiency (kg/ha-mm); **IWU =** Irrigation water use (mm)

Statistical analysis

The data collected were subjected to analysis of variance using SAS (9.0). Treatment mean were compare using LSD at 5% level of probability.

Results and Discussion

Emission uniformity (EU)

The EU obtained in this research varied from 69 to 95% with average of 82.3% as shown in Table 1. The result agrees with Bralts *et al.* (1987) who stated that uniformity coefficient of drip emitter is best when the EU is not less than 90% but it can be greater than 95%. However, result obtained is below 95%, this may be due to ageing of the drip lines which affects emitter discharge and emission uniformity. The result obtained also confirmed the findings of Ramalan *et al.* (2010).

Table 1: Emitter discharge, coefficient and emission uniformly at different operating pressures

Junction	Emitter discharge (1/h)	Operating pressure (kPa)	Coefficient of variation (%)	Emission uniformity (%)	Emitter flow variation
J1	0.552	8.63	16.3	95	18.3
J2	0.526	7.49	13.2	92	12.5
J3	0.398	6.45	14.0	89	21.8
J4	0.381	5.14	13.3	84	19.7
J5	0.463	4.43	12.4	83	22
J6	0.543	3.44	13.2	80	21
J7	0.440	1.67	13.7	76	26.8
J8	0.384	1.50	13.8	73	26.7
J9	0.381	1.43	14.3	69	27.1

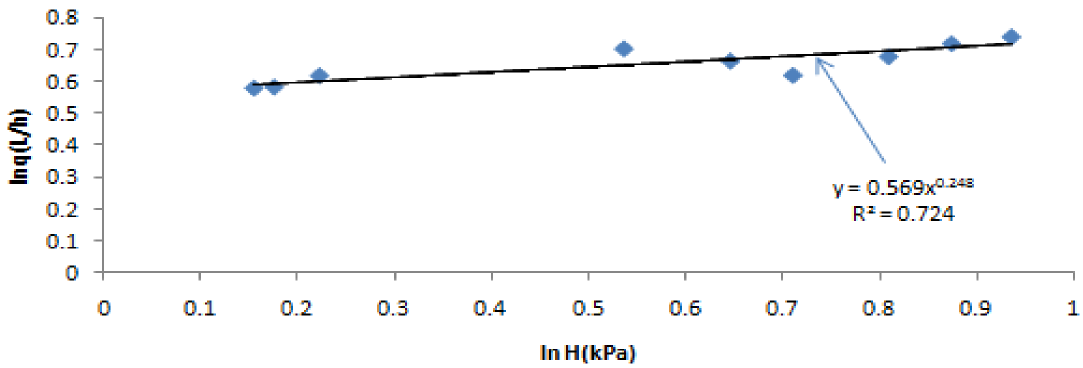

Fig. 1: Linear relationship between discharge and different operating pressures

Coefficient of variation (CV) and emitter flow variation (Qvar)

The average CVq is 13.8% and the average qvar is 21.7.% against the standard 13 and 20% respectively. The increase in q_{var} and CVq is an indication of greater magnitude of the difference between the maximum and minimum emission rates. Jensen (1983) stated that in drip irrigation, the average variation should not exceed 20%. Also according to the International Organization for Standardization (ISO) the drip system is classified as medium which is considered good.

However, the relationship between the operating pressure and the emitter discharge is expressed as:

$$\mathbf{Q = 0.596xH^{0.248}} \quad (8)$$

Where: Q is emitter flow rate (L/h) and H is operating pressure

The r^2 which is the coefficient of determination of the relationship was obtained as 0.717, and was adjudged good, which shows that the expression is an appropriate model to describe relationship between the discharge and the pressure of the emitters. From the above relation, it shows that the emitter discharge coefficient (Ke) of the drip system evaluated equal to 0.596 and the emitter discharge exponent ‘x’ equals 0.248 (Fig. 1). The flow regime of the emitter can be regarded as laminar based on (Braud and Soon, 1980) classification which considered emitter discharge exponent less than 0.5 as laminar flow. It observed that the discharge increased linearly with operating pressure for all the tested emitters.

Irrigation water applied and seasonal water use

Table 2 shows the variation of water application depth along the growing season for the tested rates of water deficits. The Table indicates that water application depth for all treatments took the same trend along the growing season, but with lower values according to the percent of water deficit. The **Figure** also shows that, water application depth for each treatment no matter the types of mulch material used had significantly affected availability of moisture to the crop. Irrigating at 100% of soil moisture depletion (SMD) with black polythene mulch (BPM) gives lower moisture depletion from the soil.

Table 2: Irrigation water applied (mm) for cowpea during 2016 dry season

Treatment	I_{100} RSM	I_{100} BPM	I_{100} NM	I_{75} RSM	I_{75} BPM	I_{75} NM	I_{50} RSM	I_{50} BPM	I_{50} NM
17/2/2016	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
21/2/2016	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
25/2/2016	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
29/2/2016	9.7	6.8	16.0	5.2	5.0	6.2	3.2	4.5	10.0
03/3/2016	9.8	7.0	16.1	5.9	6.3	6.9	3.4	4.6	10.9
07/3/2016	10.9	9.2	17.3	5.2	9.0	10.2	3.6	3.8	5.2
11/3/2016	10.9	9.8	17.3	6.0	8.9	9.0	4.2	3.4	5.4
16/3/2016	14.6	9.0	21.0	4.2	8.0	11.1	6.2	5.1	6.7
28/3/2016	14.9	9.3	22.5	4.5	8.2	11.2	6.8	6.0	6.8
31/3/2016	16.1	12.0	18.0	9.1	9.0	12.4	7.5	7.2	7.1
04/4/2016	16.3	13.9	18.2	10.0	6.3	12.3	7.0	7.6	6.4
08/4/2016	15.2	14.1	17.1	10.2	7.2	10.5	8.1	5.3	10.0
12/4/2016	9.5	15.0	17.2	9.7	5.2	11.0	7.0	5.4	9.0
16/4/2016	9.2	9.0	17.2	5.7	4.7	10.9	3.8	4.8	6.8
20/4/2016	7.2	9.9	17.6	5.2	4.5	10.9	3.6	4.9	7.2
24/4/2016	7.0	5.1	14.0	5.3	4.6	6.0	3.4	3.2	9.9
28/4/2016	6.5	6.1	14.5	7.7	4.3	6.3	3.2	3.4	6.1
02/5/2016	5.0	5.1	6.2	4.3	2.9	3.9	2.6	2.8	3.1
Total	**223.95**	**202.3**	**311.15**	**159.2**	**155.1**	**199.8**	**134.6**	**133**	**168.6**

I_{100}NM = Application of depth of 100% soil moisture deficit no mulch; I_{75}NM = Application of depth of 75% soil moisture deficit no mulch; I_{50}NM = Application of depth of 50% soil moisture deficit no mulch; I_{100}BPM = Application of depth of 100% soil moisture deficit black polythene mulch; I_{75}BPM = Application of depth of 75% soil moisture deficit black polythene mulch; I_{50} BPM = Application of depth of 100% soil moisture deficit black polythene mulch; I_{100}RSM = Application of depth of 100% soil moisture deficit rice straw mulch; I_{75}RSM = Application of depth of 100% soil moisture deficit rice straw mulch; I_{50}RSM = Application of depth of 100% soil moisture deficit rice straw mulch

Table 3: Crop water use for cowpea during 2016 dry season

Treatment	I_{100} RSM	I_{100} BPM	I_{100} NM	I_{75} RSM	I_{75} BPM	I_{75} NM	I_{50} RSM	I_{50} BPM	I_{50} NM
21/2/2016	5.0	6.0	9.0	6.0	5.0	5.0	5.0	5.0	6.0
25/2/2016	6.0	7.0	8.0	5.0	7.0	7.0	6.0	4.0	7.0
29/2/2016	6.0	8.0	16.0	6.0	8.0	7.0	7.0	5.0	6.0
03/3/2016	9.0	8.0	16.0	6.0	12.0	6.0	6.0	7.0	7.0
07/3/2016	10.0	9.0	17.0	6.0	12.0	7.0	7.0	6.0	7.0
11/3/2016	11.0	9.0	18.0	7.0	11.0	9.0	8.0	6.0	10.0
16/3/2016	11.0	13.0	20.0	8.0	12.0	10.0	13.0	11.0	10.0
28/3/2016	11.5	14.0	22.0	8.0	11.0	13.0	19.0	15.0	17.0
31/3/2016	11.8	14.0	20.0	7.0	12.0	14.0	15.0	15.0	15.0
04/4/2016	16.0	15.0	14.0	19.0	8.0	15.0	7.0	14.0	20.0
08/4/2016	16.2	10.0	20.0	10.0	9.0	15.0	8.0	14.0	16.0
12/4/2016	15.0	9.0	19.0	14.0	7.0	16.0	7.0	13.0	16.0
16/4/2016	15.0	5.0	9.0	15.0	8.0	17.0	6.0	8.0	15.0
20/4/2016	10.0	6.0	9.0	7.0	6.0	19.0	4.0	7.0	12.0
24/4/2016	9.0	6.0	7.0	5.0	6.0	10.0	5.0	5.0	11.0
28/4/2016	7.0	5.0	6.0	7.0	6.0	8.0	4.0	4.0	10.0
02/5/2016	5.0	5.0	5.0	5.0	4.5	8.0	5.0	5.0	5.0
Total	**179.5**	**155**	**242**	**148**	**149.5**	**152**	**117**	**120**	**135**

Tables 2 and 3 show that the irrigation water applied and the seasonal water use decreased with increase in deficit irrigation. The pattern of decrease in water use as a result of deficit irrigation was expected since deficit irrigation reduces the amount of water available in the soil for the plant to use. The highest irrigation water applied under irrigation treatment was at 100%SMD with 311.15 mm followed by 75% SMD with 199.8 mm then 50% SMD with 168.6 mm. However, the seasonal water use was significantly higher at 100% soil moisture depletion with 242 mm compared to the seasonal water use at 75% SMD and 50% SMD. In general, irrigation water applied and seasonal water use were found to decrease with decrease in % of soil moisture depletion from 100 to 50%. However, with the use of different mulch materials, both the irrigation water applied and the seasonal water use recorded have high value at NM with 311.15 mm and 242.55 mm, while RSM and BPM were found to be similar. Mulching with rice straw and black polyethylene recorded significantly lower values of irrigation water applied and seasonal water use for cowpea compared to the no mulch treatment. This is expected as mulching helps to conserve moisture for crop use.

The effect of irrigation deficit on cowpea yield and water use efficiency

Table 4 shows the result of yield of cowpea in kg per hectare .The mean yield of the cowpea was highest in I_{75}BPM plot and lowest in I_{50}NM. The cowpea grain yield harvested from all the treatments and its replicates ranged from 0.800 –1.522 t ha. This compares favourably with the range of 0.58t/ha -1.88 t/ha reported by Adekalu and Okunade (2006) for Ife brown variety.

In general, the fully irrigated regime (100% SMD) would have had the highest numerical yield than all other treatments. However, its yield was almost similar to yields for the 75% SMD, but significantly higher than the yield for 50% SMD at 5% level of significance. This is because of significant difference of available soil moisture among treatments which impacts the grain yield due to the varying irrigation levels. Thus, about 25% 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 regime can reduce crop yield by reducing CO_2 assimilation area, leaf number, and total leaf area and yield components (Golombek and Al-Ramamneh, 2002). The IWUE and CWUE ranged from 4.345552 – 9.66989 kg/ha-mm and 5.726667 – 10.023 kg/ha - mm in the dry season of 2016 (Table 4). Adekalu and Okunade (2006) reported values of CWUE and IWUE ranging from 2.9 - 8.5 and 2.5 - 5.9 kg/ha- mm among various irrigation regimes. The wide range of differences in CWUE and IWUE 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% SMD) which received the highest amount of irrigation water. Crop water use efficiency in general, was higher for irrigation level at 75% SMD and 50% SMD 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 (IWUE). Although irrigation regime of 100% SMD produced higher grain yield in the growing season, but (100% SMD) could not translate this yield into higher field water use efficiency than 50% SMD 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 50% SMD.

Table 4: Cowpea yield, irrigation water use, crop water use, IWUE and CWUE as affected by deficit and mulch covers

Treatment	Water applied(mm)	Water Used(mm)	Yield (kg/ha)	IWUE (kg/ha-mm)	CWUE (kg/ha-mm)
I_{100}NM	311.20	242	1425.5bc	4.9	5.9g
I_{100}RSM	223.9	179.5	1428.6b	6.4	9.2d
I_{100}BPM	202.3	155	1520.6a	7.5	8.5 f
I_{75}NM	199.8	152	1362.0e	6.8	8.9e
I_{75}RSM	159.2	148	1397.8d	8.8	9.4b
I_{75}BPM	155.1	149.5	1499.8a	9.7	10.03a
I_{50}NM	168.6	135	800.1h	4.3	5.73g
I_{50}RSM	134.6	117	978.4g	7.3	8.4f
I_{50}BPM	133.0	120	1103.3f	8.3	9.20 d

Mean followed by the same letter(s), in a column of any treatment group are not significantly different at 5% level; ** = highly significant difference; Where I_{100}, I_{75}, I_{50} are 100, 75, and 25% replacement of soil moisture depleted, respectively. RSM =rice straw mulch, BPM = black polythene mulch, NM = no mulch; IWUE = Irrigation water use efficiency, CWUE = Crop water use efficiency

The black polythene mulch recorded higher total yield with 1520 kg/ha (Table 4), which is preceded by rice straw mulch with 1428.6 kg /ha which was similar to the RSM and then no mulch (NM) with 1425.5 kg/ha when irrigation was given at 100% SMD. However, irrigation at 75 and 50% SMD, and black polyethylene mulch recorded higher yield of 1499.8 and 1381 kg/ha followed by rice straw mulch with 1397.8 and 978.4 kg/ha compared to the no mulch with 1362.8 and 800.1 kg/ha. At 50% soil moisture depletion (SMD), the no mulch had the least value with 800.1 kg/ha followed by the rice straw mulch with 978.4 kg/ha and the highest was the black polythene mulch with 1381.4 kg/ha.

It was observed that irrigation at either 100 or 75% soil moisture depletion and black polythene mulch resulted to higher seed yield followed by 50% soil moisture depletion with 1425.5 kg/ha. However, with black polyethylene mulch, irrigation at 75% replacement of moisture depletion recorded significantly higher total yield with 1520.6 kg/ha followed by 1_{100} with 1499.09 kg/ha then I_{50} with 1381.4 kg/ha. Similarly, under no mulch condition, the highest yield was recorded at I_{100} with 1425.5.35kg/ha followed by I_{75} with 1362.8.78 kg/ha and then 1_{50} with 800.1 kg/ha I_{75}. However, when irrigation was at $I_{50,}$ the BPM recorded the highest yield with 1381.48 kg/ha followed by RSM with 978.4.21 kg/ha and the least was NM with 800.1 kg/ha. Based on different mulch materials, mulching with RSM resulted to higher yield at either irrigating at I_{100} or I_{50} followed by I_{75} with 1425.5 Kg/ha. When BPM was adopted, the highest yield value was at I_{100} with 1520.6 kg/ha followed by I_{75} with 1499.6 kg/ha then I_{50} with 1381.4. With NM, the highest yield value was at I_{100} with 1425.5 kg/ha followed by I_{75} with 1362.8 kg/ha then 1_{50} with 800.1 kg/ha. The study showed that different irrigation levels and mulch type had effect on the total cowpea yield. However, the minimum irrigation level at which there is no significant difference is 75% SMD.

Conclusion

The study establishes that crop water use efficiency (CWUE) of 10.03 kg/ha-mm can be achieved under deficit irrigation of 75% soil moisture deficit with black polythene mulch. This implies that 1mm of water gives economic yield of 10.03 kg/ha. The yield of cowpea was found to decrease with increase in the level of water deficit. This means that relative reduction in yield per relative reduction in water deficit was found to be 0.76 for BPM which was the best performance for the mulch materials used.

Conflict of Interest

Authors have declared that there is no conflict of interest reported in this work.

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