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Determination of Agronomic Performance and Consumptive Use of Irrigated Tiger Nut (*Cyperus esculentus*) Using Non-Weighing Lysimeter and Evaporation Pan

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Abstract
Makurdi is one of the areas that are considered could be viable for Tiger nut cultivation. This research was carried out to see if tiger nut can be produce in Makurdi. The experiments were laid in a randomized complete block design (RCBD) format with three replications, three varieties and the field (3×2×3) experimental design. Results showed that the consumptive use estimated with the lysimeter varied between stages of growth as 3.764, 4.679, 4.086 and 5.089 for initial, development, middle and end as well as 4.608, 7.272, 61.071 and 15.256 for season 1 and 2 respectively. Water use efficiency ranged from 52.05 – 77.33. TR2 recorded the highest value of 77.33.TR1 recorded the lowest value of 52.05 The three (3) model derived methods values were 6.960, 4.853, 7.711 and 11.250 for BMN 81.145, 134.770, 140.898 and 133.839 for Blaney Cridle and 1.315, 2.741, 2.539 and 2.508 for Hargreaves Samani respectively. Analysis of variance (ANOVA) was used to analyse the data at p=0.05% and mean separation done using DUCAN multiple range tests. Lysimeter derived K_C and ET_C were conformed to the Blaney-Morin-Nigeria and Hagreaves-Simoni models only. The three varieties were found to be suitable for Makurdi climate.

Keywords: *Tiger nut, non-weighing lysimeter, consumptive use, crop factor (Kc) evapotranspiration, evaporation pan, Makurdi climate, empericle models.*

1.0 INTRODUCTION

Tigernut (*Cyperus esculentus*) is a herbaceous perennial crop of the same genus as the papyrus, it belongs to the kingdom plantae, the Divis ion–Magnoliophyta, Class–Liliopsida, Order– cyperales and Family–*Cyperaceae* and the specie *Cyperus esculentus* It is among the oldest cultivated plants in Egypt, S(Des- Vries, 1991)Tiger nut, no doubt is an important food element in ancient Egypt during dynastic times, its cultivation in ancient times seems to have remained (totally or almost totally) an Egyptian specially. It is also grown in Ghana, Nigeria, Burkina Faso and Mali in west Africa (Rita, (2009), a tough erect fibrous-rooted perennial plant that grows up to 3 ft. high and reproduces by seeds and rhizomes, forms small tubers or nutlets at the tips of underground stems at maturity (Des-Vries, 1991). It is known by many other names like Zulu nut, yellow nut grass, ground almond, chufa, edible rush and rush nut. It is known in Nigeria as Aya in Hausa, Ofio in Yoruba and Akiausa in Igbo.

1.1. Tiger Nut (Cyperus Esculentus) Crop and Climate Factors.

Crops require a certain amount of water at some fixed time interval through its period or duration of growth on to its maturity level. Where the water requirement or consumption of a particular crop does not meet its required capacity, yield is definitely affected (Yuan *et al*, 2010). The agricultural lands in Makurdi climatic geopolitical zone is found to be favourable for the cultivation of many crops, it is characterized by high temperatures and low nitrogen levels proving by this study to increase tuber production. (De Abreu *et al.*, 2008), tiger nut grows best in moist sandy-loam soils but will also grow in the hardest clay, tolerates high soil moisture and is intolerant to shade. The plant produces small, oblong tubers in abundance, which are sweet and rich in fat (Des- Vries, 1991)

1.2. Varieties of Tiger Nut

According to Maduka *et al.* (2018), there are three main varieties of tiger nut tubers, based on color difference, the brown, yellow and the black variety. Two varieties are more commonly seen in Nigerian local markets among which are the yellow and brown varieties.

1.2.1 Cultivation of tiger nut (cyperus esculentus)

Cyperus esculentus is one of the cash crop that is very nutritious though yet to be harnessed Tiger nut yields more milk upon extraction that contain lower fat and more protein, it possesses less anti-nutritional factors especially polyphenols (Oladele et al, 2009)it is also reported to contain quality vegetable oils that contain large amounts of unsaturated fatty acids when mechanically extracted (Omale, 2023). Due to its numerous nutritious and health benefits, many researchers has carried out studies on tiger nut but none or less researched on tiger nut consumptive use, its crop factor (Kc) as well as its agronomic performers and Evapotranspiration (ETc) weather it can be cultivated or produce in Makurdi agro-climatic zone which happen to be one of the major tiger nut consuming zone, The dependence of agricultural production on rain fall is unsustainable due to the challenges of climate change and increased human population, to derive the maximum economic and nutritious value of tiger nut, its production in Makurdi, climatic zone must be sustained through proper planning , designed and installed irrigation system. The first step is to determine its water requirement which is the cardinal focus of this study Tiger nut requires irrigation almost every week until the tubers are due for harvesting (Oladele *et al.*, 2009)

2.0. MATERIALS AND METHODS,

2.1. STUDY AREA.

Joseph Sarwuan Tarka University Makurdi is located in the Northern part of Makurdi Local Government Area of Benue State, with a land mass of 8.048 hectares on (Latitude 7^0 48'N and Longitude 8^0 35.4'E). The vegetation is dominated by tall perennial grasses as woody species and the soil is sandy loam and loose in nature with much fertility.

2.1.1. Climate of the study area.

Makurdi is characterized as tropical savanna with distinct wet and dry seasons. Rain fall begins in April and ends in October with more than 1000 mm annually while dry season begins in November and ends in March with mean annual temperature of about 34^0C and 89-93% relative humidity (Isikwue *et al*., 2009). Average temperature in Makurdi is 30.4^0 C, the month of April records the hottest weather in the year while December records coldest period in the year, and Precipitation is lowest in December, with an average of 0 mm.

2.1.2. Site preparation

Field site was mapped out at the back of Agricultural and Environmental Engineering Laboratory with a land mass of approximately 6 square meters (Plate 5). Accommodating the nine (9) non-weighing lysimeters as presented in (Plate 5).

2.1.3. Soil properties of the study site.

The physical and chemical properties of the experimental soils were determined in accordance with the methods detailed in Haluschack (2006). Composite samples were taken from the experimental field at a depth of 0 – 30 cm and taken to the laboratory for analysis. The soil physical properties considered were; Porosity, bulk density, texture (sand, silt and clay), moisture content and pH. On the other hand soil organic carbon, organic matter, nitrogen, K, P, Ca, Mg, cation exchange capacity (CEC) and Base saturation (BS) were the chemical properties considered.

2.1.4. Field layout and design consideration.

The non–weighing lysimeter was designed and constructed using the readily available local materials (Plate 1-4), with due consideration of the crop density, the root depth of the crop (tiger nut (*Cyperus esculentus*), durability of the materials and the bulk density of the soil (sandy loan), ease of construction and installation, low maintenance of the non - weighing lysimeter.

2.1.5. Source of water and planting

The water source was an overhead reservoir of the college of engineering found at the engineering complex. The irrigation method was the manual sprinkler method (watering can) which was achieved by simulating rainfall, the rate of water evaporation was determined using a class A evaporation pan installed on the research site. The irrigation schedule was informed with the aid of the soil tensiometer principles (lack of water in the soil displays very high in cbars and much water in the soil displays low volumes of cbars).




Plate 1-4 form work. Plate 2 Plate 3 Plate 4.Casting


Plate 5.Experimental layout. Plate 6**:** Growth stage at week one

Planting: The three varieties of Tiger nut disignated as treatment TR1,TR2, TR3(Plate 6) were the brown, yellow and the black variety, planted in July 2021 and harvested in October for the first season while the second season was planted in November 2021 and harvested in February 2022. Tiger nut has a shot maturing period unlike other tuber crops, the brown variety matures within 50-53 days, and the yellow variety matures within 57-60 days while the black variety matures within 60-65 days respectively.


Plate 7: Three varieties of Tiger nut seeds Plate 8: Germination Test

2.2 Determination of water use Efficiency(WUE) The Water Use Efficiency for the different varieties at different growth stages of tiger nut (*Cyperus esculentus*) in the experimental lysimeters and field for two growing seasons were computed using equation 1.

$$Y_d = \frac{w+p}{a} \quad (1)$$

Where; Y_d is the yield (kg/ha), w is the weight of dry tubers (kg), p is the weight of dry biomass (kg) and a is the area of crop field in ha (0.0001ha).

$$WUE = \frac{y}{ET_a} \quad (2)$$

Where WUE is the water use efficiency (kg/ha/mm), y is the dry matter yield (kg/ha) and ET_a is the actual crop evapotranspiration of tiger nut (mm) obtained by multiplying the crop evapotranspiration (mm/day) by the growth period (days) for the particular stage. In this vein 5, 20, 16 and 11 days were used for the initial, development, mid and end stages of growth respectively.

The crop evapotranspiration values of lysimeter-grown tiger nut (*Cyperus esculentus*) varieties at different growth stages were computed by using equation 3 where all parameters for input in equation 2 were obtained by direct measurement of total applied water and total water losses as explained earlier (Itier *et al.*, 1997). The crop evapotranspiration values of tiger nut (*Cyperus esculentus*) varieties were estimated using the empirical methods of Blanney–Criddle, Blanney-Morin-Nigeria and Hergreaves-Simoni as given in equations 4, 5 and 6 respectively. The pan evaporation approach was also used to compute the crop evapotranspiration of tiger nut in accordance with the methods of pan evaporation from the reference evapotranspiration and crop factor values as given in equations 7 and 8 respectively. Values of lysimeter, pan evaporation and empirically determined crop evapotranspiration of tiger nut varieties at different growth stages for two seasons (1 and 2) were then compared as presented in table 10 and 11 respectively.

$$ET_C = I - D - R - \nabla S \quad (3)$$

Where; $ET_C =$ crop evapotranspiration (mm/day), I, D, R and ∇S are the irrigation water, drained water, runoff and change in storage respectively.

$$ET_o = P(0.46T_{mean} + 8.128 \quad (4)$$

Where:

ET_o = is the reference evapotranspiration (mm/day) or (mm/month)

T_{mean} = is the mean daily temperature (°C)

P= is the mean daily percentage of amount day/hour

$$ET_o = rf(0.45T_a - 8)(H - R^m) \quad (5)$$

Where: ET_o is the reference evapotranspiration (mm/day), rf is the ratio of monthly radiation to annual radiation for the different stages, T_a is the mean monthly temperature (°C), R is the relative humidity, H and m are constant of 520 and 1.31 respectively.

$$ET_o = 0.0023(T_{max} - T_{min})^{0.5}(T_{min} + 17.8)R_a \quad (6)$$

Where; ET_o is the reference evapotranspiration (mm/day), T_{max} and T_{min} are the maximum and minimum temperatures (°C) respectively, R_a is the radiation (W/m^2).

$$ET_o = E_{pan} \times K_{pan} \quad (7)$$

Where: E_{pan} *and* K_{pan} are the pan evaporation (mm/day) and pan coefficient respectively.

$$ET_C = ET_o \times K_c \quad (8)$$

Where; ET_C *and* K_c are the crop evapotranspiration (mm/day), and crop coefficient respectively.

Determining crop coefficient is a factor of crop water use and is directly related to evapotranspiration ET. The crop's water use can be determined by multiplying the reference ETo by a crop coefficient (Kc), that in turn adjust the calculated reference ETo to obtain the crop evapotranspiration ETc.

2.2.1. Determination of the Experimental and Agronomic Variables of Tiger nut.

Crop parameters for the three varieties (TR1, TR2 and TR3) of tiger nut (*Cyperus esculentus*) including plant height, plant girth and number of leaves, were determined at 5-day intervals from germination to maturity and mean values were computed following standard procedures in accordance with the methods of (Emuh, 2012). A graduated meter rule and vernier calipers were used to measure the plant heights and girth at 5- day intervals throughout the crop growth period and the average values were computed. The plant leaves were visually counted at the same intervals for the duration of plant growth up to its maturity. This was done for the tiger nut (*Cyperus esculentus*) grown lysimeters and those grown in the control field for two distinct growing seasons (season 1 and 2) for purposes of comparison.

. **Plate 9**: TR1 (brown variety) growth stage wk 1 – wk 3.

Plate 10 TR2 growth wk 1-wk 3.

Plate 11: TR 2 (yellow variety) at wk 5

Plate 12:TR3 (Black variety) stage at wk 5

Plate 13 matured tiger nut, harvesting and tubers harvested week at 8.

3.0. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Physical and Chemical Properties of Experimental Soils

Physical and chemical properties of the experimental site are presented in Table 1. The soil pH, percentage sand, clay and silt were 6.13, 69.80 %, 18.20 % and 12.0 % respectively which classify the soils as sandy-loam. The soil organic carbon, organic matter and nitrogen presented in table 1 along with macro element composition, cation exchange capacity and base saturation coupled with soil porosity, bulk density and moisture content shows that the soil is appropriate for numerous agricultural practice with or without fertilizer application.

3.1.2 Growth and Yield of Tiger Nut (*Cyperus esculentus*)

Table 2 showed the rate of water application. The agronomic performance of tiger nut during experiment was measured and presented in table 3 for the plant height, table 4 for the plant girth, table 5 for the number of leaves after five days interval respectively, the growth parameters of tiger nut from the germination state to the harvesting time is presented in table 6, while table 7 shows the yield of tiger nut as harvested showing both the total yield, the good and the bad tubers with the weight of the tiger nut respectively. Table 8 shows Mean values of Tiger nut Growth Parameters as Affected by Variety while table 9 shows the Mean Values of Tiger nut Growth Parameters as Affected by Growth Media.

Table 1: Soil Physical and Chemical Properties of Experimental Site

S/No	Soil Property	Value
1.	Soil Ph	6.13
2.	Sand (%)	69.80
3.	Clay (%)	18.20
4.	Silt (%)	12.0
5.	Organic Carbon (%)	0.67
6.	Organic Matter (%)	1.16
7.	Nitrogen (%)	0.09
8.	P (mg/L)	4.20
9.	Mg (Cmol/kg)	2.76
10.	Ca (Cmol/kg)	2.90
11.	K (Cmol/kg)	0.26
12.	Na (Cmol/kg)	0.22
13.	CEC (Cmol/kg)	7.24
14	Base Saturation (%)	84.80
15.	Porosity (%)	43.01
16.	Bulk Density (g/cm^3)	1.51
17.	Moisture Content (%)	21.25

Table 2: Rate of Water Application

Day	Irrigation (Ltr)																		
	TR 1			TR 2			TR 3			Control									Moisture Cont(Cbar)
										TR1			TR2			TR3			
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	
3	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	22.6
7	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	20.2
11	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	25
13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	25
19	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	26
21	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	26.2
26	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	30.2
30	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	25
32	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	32.5
37	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	40.2
39	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	45.2
41	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	40.2
44	-	-		13	13	13	13	13	13				13	13	13	13	13	13	35
47				13	13	13	13	13	13				13	13	13	13	13	13	30
52				13	13	13	13	13	13				13	13	13	13	13	13	40
55							13	13	13							13	13	13	37
TOTAL	**156**	**156**	**156**	**195**	**195**	**195**	**208**	**208**	**208**	**156**	**156**	**156**	**195**	**195**	**195**	**208**	**208**	**208**	**500.3**
AVG	**9.176**	**9.18**	**9.18**	**11.47**	**11.48**	**11.48**	**12.24**	**12.24**	**12.24**	**9.18**	**9.18**	**9.18**	**11.48**	**11.48**	**11.48**	**12.24**	**12.24**	**12.23**	**29.4**

Table 2: Plant Height after 5 days interval

Day	**Plant Height After 5 Days Interval (cm)**																	
	TR 1			**TR 2**			**TR 3**			**Control TR1**			**TR2**			**TR3**		
	R1	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**
6	8	9	6	7	6	6	5	5	4	9	25	26	6	6	6	4	4	4
12	27	28	27	24	23	22	23	24	23	26	38	37	23	22	23	22	21	22
16	38	40	37	36	35	40	37	36	38	39	52	53	36	35	36	35	34	35
21	59	60	57	57	54	56	49	52	50	53	67	68	55	54	55	47	46	46
26	67	72	66	63	60	60	61	65	59	68	68	68	60	60	59	66	66	65
31	67	73	67	65	60	63	62	66	60	68	68	68	62	63	61	67	67	66
37	69	73	69	67	63	63	64	68	62	68	68	68	63	63	62	67	67	67
43	69	73	69	67	63	63	64	68	62	68	68	68	63	63	63	67	67	67
49	67	70	66	65	66	67	61	66	60	66	68	68	60	60	62	65	65	66
55	-	-	-	63	58	57	60	64	58	-	-	-	58	58	59	63	63	63
Total	**471**	**498**	**464**	**514**	**488**	**497**	**486**	**514**	**476**	**465**	**522**	**524**	**486**	**484**	**486**	**503**	**500**	**501**
AVG	**27.706**	**29.294**	**27.2941**	**30.235**	**28.7059**	**29.24**	**28.58824**	**30.24**	**28**	**27.35**	**30.71**	**30.824**	**28.5882**	**28.5**	**28.588**	**29.58824**	**29.4118**	**29.471**

Table 3: Plant girth after 5 days interval

Day	Plant Girth After 5 Days Interval (cm)																	
	TR 1			TR 2			TR 3			Control TR1			TR2			TR3		
	R1	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**
6	0.2	0.2	0.2	0.3	0.2	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.3
12	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.3	0.5	0.4	0.3	0.4	0.5	0.5	0.4	0.4	0.4	0.3
16	0.4	0.4	0.4	0.7	0.5	0.5	0.8	0.7	0.8	0.4	0.4	0.4	0.7	0.6	0.6	0.8	0.7	0.8
21	0.6	0.5	0.6	0.8	0.7	0.8	0.9	0.8	0.8	0.5	0.4	0.5	0.8	0.8	0.7	0.8	0.8	0.8
26	0.6	0.5	0.6	0.9	0.8	0.8	0.9	1	1	0.6	0.5	0.6	0.7	0.8	0.6	1	0.9	0.8
31	0.7	0.6	0.6	0.9	1	0.9	1	1	1	0.6	0.6	0.6	0.8	0.7	0.6	1	0.9	0.8
37	0.7	0.6	0.6	0.9	1	0.9	1	1	1	0.6	0.6	0.6	0.8	0.8	0.8	1	0.9	0.9
43	0.7	0.6	0.6	0.9	1	0.9	1	1	1	0.6	0.5	0.5	0.8	0.8	0.8	1	0.9	0.9
49	0.6	0.6	0.5	0.8	0.9	0.8	0.9	0.9	0.9	0.5	0.5	0.5	0.7	0.7	0.7	0.9	0.8	0.8
55	-	-	-	0.7	0.8	0.7	0.8	0.8	0.8	-			0.6	0.6	0.6	0.8	0.7	0.7
TOTAL	**4.8**	**4.3**	**4.4**	**7.3**	**7.3**	**7**	**8.2**	**7.8**	**8.1**	**4.4**	**4**	**4.3**	**6.6**	**6.6**	**6**	**8**	**7.3**	**7.1**
AVG	**0.2824**	**0.2529**	**0.2588**	**0.4294**	**0.42941**	**0.41176**	**0.4824**	**0.459**	**0.4765**	**0.2588**	**0.2353**	**0.2529**	**0.3882**	**0.38824**	**0.3529**	**0.4706**	**0.4294**	**0.41765**

Table 4: Number of Leaves after 5 Days Interval

Day	Number of Leaves After 5 Days Interval (Cm)																	
	TR 1			TR 2			TR 3			Control TR1			TR2			TR3		
	R1	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**
6	5	4	4	4	4	4	4	5	4	4	4	4	3	3	3	3	3	3
12	7	7	7	6	7	6	8	7	6	6	6	5	7	7	6	7	7	8
16	9	9	9	9	8	9	11	9	9	8	7	8	9	8	8	9	9	8
21	11	11	11	11	10	10	12	12	11	10	9	10	9	9	9	12	12	9
26	12	13	12	14	11	12	15	14	13	12	11	12	13	12	13	14	13	13

31	12	13	13	14	13	13	15	14	14	13	12	12	13	13	13	14	13	13
37	12	13	14	14	13	13	15	14	14	13	13	12	13	13	13	14	14	14
43	12	13	14	14	13	13	15	14	14	13	13	13	13	13	13	14	14	14
49	12	13	14	14	13	13	15	14	14	13	13	13	13	13	13	14	14	14
55	12	13	14	14	13	13	15	14	14	13	13	13	13	13	13	14	14	14
Total	**104**	**109**	**112**	**114**	**105**	**106**	**125**	**117**	**113**	**105**	**101**	**102**	**106**	**104**	**104**	**115**	**113**	**110**
AVG	**6.118**	**6.412**	**6.588**	**6.70588**	**6.1765**	**6.235**	**7.3529**	**6.8824**	**6.6471**	**6.1765**	**5.941176**	**6**	**6.235**	**6.1176**	**6.1176**	**6.7647**	**6.6471**	**6.47059**

Table 5: Experimental and Agronomic Performance for Tiger nut

Crop- data measurement	**TR1**	**TR2**	**TR3**	**Mean**	**Control**			
					TR1	**TR2**	**TR3**	**Mean**
Emergence date (days)	4	5	7	11.3	4	5	7	11.3
Time to reach maximum Canopy cover(days)	14	15	17	15.3	14	15	16	15
Time to reach canopy Senescence(days)	21	23	28	24	21	22	28	23.6
Tuber initiation date (days)	27	28	32	29	26	28	31	28
Days to maturity (days)	49	52	55	52	49	52	55	52
Plant height(cm)	28.1	29.4	28.9	28.8	28.2	29.2	28.7	28.7
Plant Girth	0.26	0.42	0.47	0.38	0.26	0.41	0.46	0.37
Number of leaves	6.37	6.37	6.96	6.56	6.35	6.37	6.94	6.56

Table 7: Yield of Tiger nut/Weight measured

Number of Tubers

	R1	R2	R3	Total	Mean	CONTROL R1	R2	R3	Total	Mean
TR 1 (BV)	1382	1794	1376	4552	3.634	1268	1652	1289	4209	3.349
TR 2 (YV)	561	710	557	1828	1456	522	693	571	1786	1405
TR3 (BLK)	824	858	612	2294	1886	803	878	593	2.274	1878

Number of Good Tubers

	R1	R2	R3	Total	Mean	CONTROL R1	R2	R3	Total	Mean
TR 1 (BV)	1240	1606	1261	4107	3266	1168	1523	1231	3922	3.101
TR 2 (YV)	522	640	526	1688	1337	511	652	522	1685	1337
TR3 (BLK)	724	840	594	2158	1762	697	759	508	1964	1625

Number of bad Tubers

	R1	R2	R3	Total	Mean	CONTROL R1	R2	R3	Total	Mean
TR 1 (BV)	142	188	115	445	368	100	129	58	287	248
TR 2 (YV)	42	70	31	143	122	11	41	49	101	33
TR3 (BLK)	27	18	18	63	21	106	119	85	310	103

Weight of Tubers

	R1	R2	R3	Total	Mean	CONTROL R1	R2	R3	Total	Mean
TR 1 (BV)	0.332	0.513	0.347	1.192	0.397	0.364	0.493	0.336	1.193	0.397
TR 2 (YV)	0.479	0.629	0.627	1.731	0.577	0.434	0.529	0.532	1.495	0.498
TR3 (BLK)	1.132	1.193	1.001	3.326	2.658	1.425	1.183	1.532	4.140	1.380

Weight of Mass Wet Substrate (kg)

	R1	R2	R3	Total	Mean	CONTROL R1	R2	R3	Total	Mean
TR 1 (BV)	0.384	0.703	0.555	1.642	0.547	0.324	0.621	0.542	1.487	0.495
TR 2 (YV)	0.365	0.449	0.394	1.208	0.402	0.343	0.392	0.411	1.146	0.382
TR3 (BLK)	0.785	0.762	0.735	2.282	0.760	0.763	0.725	0.638	2.126	0.708

Weight of Mass Dry Substrate (kg)

	R1	R2	R3	Total	Mean	CONTROL R1	R2	R3	Total	Mean
TR 1 (BV)	0.20	0.313	0.225	0.73	0.24	0.192	0.29	0.219	0.701	0.233
TR 2 (YV)	0.266	0.188	0.267	0.714	0.238	0.121	0.23	0.235	0.586	0.195
TR3 (BLK)	0.591	0.533	0.570	1.694	0.564	0.547	0.496	0.631	1.674	0.558

TR1 MAJOR AND MINOR

	R1	R2	R3	Total	Mean	CONTROL R1	R2	R3	Total	Mean
MAJOR	0.9	1	1.1	3	1	0.9	0.9	1	2.8	0.9
MINOR	0.4	0.7	0.8	1.9	0.6	0.8	0.7	0.9	2.4	0.8

TR2 MAJOR AND MINOR

	R1	R2	R3	Total	Mean	CONTROL R1	R2	R3	Total	Mean
MAJOR	1.4	1.6	1.6	4.6	1.5	1.5	1.1	1.0	3.6	1.2
MINOR	0.9	1.2	1.3	3.4	1.1	1.2	1.0	1.4	3.8	1.2

TR2 MAJOR AND MINOR

	R1	R2	R3	Total	Mean	CONTROL R1	R2	R3	Total	Mean
MAJOR	1.8	2	2.1	5.9	1.9	2.2	2.1	2.0	6.3	2.1
MINOR	1.0	1.1	1.2	3.3	1.1	1.0	1.0	1.0	3	1

Table 8: Mean values of Tiger nut Growth Parameters as Affected by Variety

S/No	Parameter	Variety TR1	TR2	TR3
1.	Plant Height (cm)	$39.43^{a} \pm 0.327$	$43.42^{b} \pm 0.327$	$38.72^{a} \pm 0.327$
2.	Stem Girth (cm)	$0.37^{a} \pm 0.003$	$0.42^{c} \pm 0.003$	$0.40^{b} \pm 0.003$

3.	Number of Leaves	$5.83^{a} \pm 0.136$	$6.33^{b} \pm 0.136$	$5.50^{a} \pm 0.136$
4.	Dry Yield (kg/ha)	$2573.33^{a} \pm 423.781$	$3811.67^{a} \pm 423.781$	$3920.00^{a} \pm 423.781$

Values are means ± standard error of triplicate experiments. Means in the same row with same superscript are not significantly different at P ≤ 0.05.

Table 9: Mean Values of Tigernut Growth Parameters as Affected by Growth Media

S/No	Parameter	Growth Media	
		Lysimeter	Field (Control)
1.	Plant Height (cm)	$43.11^{b} \pm 0.267$	$37.93^{a} \pm 0.267$
	Stem Girth (cm)	$0.39^{a} \pm 0.003$	$0.39^{a} \pm 0.003$
2.			
3.	Number of Leaves	$6.22^{b} \pm 0.111$	$5.56^{a} \pm 0.111$
4.	Dry Yield (kg/ha)	$3262.22^{a} \pm 346.016$	$3607.78^{a} \pm 346.016$

Values are means ± standard error of triplicate experiments. Means in the same row with same superscript are not significantly different at P ≤ 0.05.

3.4. Experimental and Model-derived ET_C of Tiger Nut (*Cyperus esculentus*)

Results of the crop coefficient (K_C), reference evapotranspiration (ET_o) and crop evapotranspiration (ET_C) of tiger nut in Makurdi Agro-climatic zone was computed using the water balance method equation 3 as presented in (table 10 and 11) respectively. The crop coefficient (kc) according to the BCMAFF (2022), can be computed using equation 9.

$$K_C = {}^{w_p}/_{w_b} \quad (9)$$

Where; K_C = crop coefficient, w_p is the width of plant canopy and w_b is the bed spacing. The total area per plot in both the field and lysimeters were $1m^2$ (0.001ha) and a bed spacing of 8cm was adopted in this study with a plant population per plot of 50 stands, thus giving a canopy cover per plant/ plot of 0.02 per plant. The climatological data gotten from NIMET (Nigerian Metrological Agency, Headquaters Tactical Air Command Makurdi- Airport.) were used to compute ETo and ETc for the three Empirical models (Blaney criddle, Blaney morin Nigeria and Hargreaves Samoni). The pan evaporation method and the empirical models at different stages of growth in the first season are presented in Table10. Table 11 shows the same values as computed in the second season

Table 10: Consumptive Use of Tiger Nut in Makurdi Agro-climatic Zone

S/No	Method	Stage	K_C	ET_o(mm/day)	ET_C /irr. Req (mm/day)
1.	Lysimeter	Initial	0.025	0.094	3.769
		Development	0.748	3.499	4.679
		Middle	1.221	4.988	4.086
Sss		End	0.954	5.335	5.089
2.	#Epan	Initial	0.025	0.00073	0.003
		Development	0.748	0.775	1.037
		Middle	1.221	1.237	1.013
		End	0.954	1.143	1.197
3.	*BMN	Initial	0.025	0.218	8.727
		Development	0.748	3.815	5.103
		Middle	1.221	9.732	7.971
		End	0.954	11.391	11.940
4.	Blaney-Criddle	Initial	0.025	2.136	85.465

		Development	0.748	124.894	167.066
		Middle	1.221	238.571	195.390
		End	0.954	197.239	206.758
5.	Hargreaves-Samani	Initial	0.025	0.043	1.726
		Development	0.748	2.294	3.068
		Middle	1.221	4.177	3.421
		End	0.954	2.838	2.838

#mean Evaporation Pan, *means Blaney-Morin-Nigeria

Table 11: Consumptive Use of Tiger Nut in Makurdi Agro-climatic Zone in Second Season

S/No	Method	Stage	K_C	ET_o (mm/day)	ET_C / irr. Req. (mm/day)
1.	Lysimeter	Initial	0.416	1.917	4.608
		Development	0.964	7.009	7.272
		Middle	1.183	13.097	11.071
		End	0.8725	13.311	15.256
2.	#Epan	Initial	0.416	0.073	0.176
		Development	0.964	0.976	1.0125
		Middle	1.183	0.859	0.727
		End	0.8725	1.106	0.283
3.	*BMN	Initial	0.416	2.896	6.960
		Development	0.964	4.678	4.853
		Middle	1.183	9.122	7.711
		End	0.8725	9.816	11.250
4.	Blaney-Criddle	Initial	0.416	11.847	81.145
		Development	0.964	130.111	134.770
		Middle	1.183	166.682	140.898
		End	0.8725	116.677	133.839
5.	Hargreaves-Samani	Initial	0.416	0.547	1.315
		Development	0.964	2.643	2.741
		Middle	1.183	3.004	2.539
		End	0.8725	2.188	2.508

#mean Evaporation Pan, *means Blaney-Morin-Nigeria

Table 12: Stage-wise WUE as affected by Variety and Growth Media

S/No	Treatments	Water Use efficiency (kg/ha/mm)
	Initial Stage	
	Variety	
1	TRI	52.05[a] ± 8.341
2.	TR2	77.33[a] ± 8.341
3.	TR3	71.99[a] ± 8.341
	Growth Media	
1.	Lysimeter	63.88[a] ± 6.811
2.	Field (Control)	60.36[a] ± 6,811
	Development Stage	
	Variety	
1	TRI	9.02[a]± 1.483
2.	TR2	13.63[a]± 1.483
3.	TR3	12.67 ± 1.483
	Growth Media	
1.	Lysimeter	11.16[a]± 1.195
2.	Field (Control)	12.39[a]± 1.195
	Mid Stage	
	Variety	
1	TRI	14.65[a]± 2.467
2.	TR2	21.10[a]± 2.467
3.	TR3	20.26[a]± 2.467
	Growth Media	
1.	Lysimeter	17.54[a]± 2.014
2.	Field (Control)	19.81[a]± 2.014
	End Stage	
	Variety	
1	TRI	26.22[a]± 4.223
2.	TR2	38.80[a]± 4.223
3.	TR3	36.26[a]± 4.223
	Growth Media	
1.	Lysimeter	32.08[a]± 3.448
2.	Field (Control)	35.44[a]± 3.448

Values are means ± standard error of triplicate experiments. Means in the same column with same superscript are not significantly different at $P \leq 0.05$.

4.0. DISCUSSION

4.1. Physico-Chemical Properties of Soil in the Study Site

The physical and chemical properties of the experimental soils revealed the textural class was loamy sand, with composition of 69.80, 18.20 and 12.00 % of sand, clay and silt respectively (Table 1).

4.2. Growth and Yield of Tiger Nut as Affected by Experimental Variables.

Plant height from the 3 varieties(TR1, TR2 and TR3) of Tiger nut ranged from 38.72 –43.42 cm, Stem girth, 0.37 – 0.42cm, Number of leaves, 5.50 – 6.33 and yield from 2573.33 – 3920.00 kg/ha respectively (Table 11). The lowest values of all plant growth parameters and yield were found in TR1 (Brown variety) except for the plant height which was lowest in the Black Variety (TR3). The highest growths were observed with the Yellow variety (TR2), while the yield was highest in the black variety (TR3). For tiger nut (*Cyperus esculentus*) grown in the lysimeter and Control; the plant height, stem girth, number of leaves and yield were 37.93 and 4.11cm, 0.39cm, 5.56 and 6.22, 3607.78 and 3262.22 kg/ha respectively.The growth media had no significant effects on the yield and stem girth but was significant for plant height and number of leaves which was attributed to the functionality of the growth media as plants in the lysimeter were favoured with optimal water balance as compared to the field grown varieties (control).

4.2.1. Experimental and Model-derived ET_C of Tiger Nut (*Cyperus esculentus)*

The lysimeter-derived values of these parameters are also compared with the pan evaporation derived values and three model derived values at four (4) stages of tiger nut growth. The lysimeter-derived K_C and ET_C values (mm/day) of tiger nut were 0.025 and 3.759, 0.747 and 4.679, 1.221 and 4.086, 0.934 and 5.089 for the initial, development, mid and end growth stages respectively in season one and were 0.416 and 4.608, 0.964 and 7.272, 1.183 and 11.071, 0.873 and 15.256 for the initial, development, mid and end growth stages respectively in season two. The K_C and ET_C of tiger nut in the studied agro-climate as obtained from lysimeter experiments were comparable with the Blaney-Morin-Nigeria in the first season but were better compared with the Hagreaves-Simoni model in season two. However, the pan evaporation method which is also a diresct method was observed to fall short of the expected water requirement of tigernut. Blaney-Criddle model was observed to over-predict the ET_C of tiger nut of Makurdi agro-climatic zone. Wuese, (2019) found similar daily ET_C values as obtained in the lysimeter experiments in his study for okra in the same study location.

5.0. CONCLUSIONS AND RECOMMENDATIONS.

5.1. Conclusion.

The soil properties in the study area were found to be sandy loam which is suitable for the tiger nut production without the addition of fertilizers.Table 12 shows the water use efficiency measured in (kg/ha/mm) as it affect the growth media and tiger nut from the lysimeter-grown and Control as 63.88 and 60.36, 11.16 and 12.39, 17.54 and 19.81, 32.08 and 35.44 during the initial, development, mid and end stages of the crop growth period.The lysimeter-derived K_C and ET_C values (mm/day) of tiger nut were 0.025 and 3.759, 0.747 and 4.679, 1.221 and 4.086, 0.934 and 5.089 for the initial, development, mid and end growth stages respectively in season one and were 0.416 and 4.608, 0.964 and 7.272, 1.183 and 11.071, 0.873 and 15.256 for the initial, development, mid and end growth stages respectively in season two. Among the three varieties of Tiger nut (Borwn, Yellow and Black) used in the study, Black variety (TR3) grown in the lysimeters, recorded higher yield (3920 kg/ha), followed by the yellow variety (TR2) having 3811.67 and lastly the brown variety (TR1) with value of 2573.33 kg respectively.The lysimeter-derived K_C and ET_C were only comparable with the Blaney-Morin-Nigeria and Hagreaves-Simoni models.

5.2. RECOMMENDATIONS

The following recommendations are made from the present work:

The soils formed around the Joseph Sarwuan Tarka University Makurdi are suitable for growth of Tiger nut and should be explored further.

1. Tiger not should be grown in the field to cut down on the cost of lysimeter construction as the yield was not significantly different between the field-grown and the lysimeter-grown types.
2. All species of tiger nut a good for the Makurdi Agro-climate, however, the researcher recommends the black (TR3) variety for its improved yield and moderate water use efficiency

3. K_C and ET_C values of 0.025 and 3.759, 0.747 and 4.679, 1.221 and 4.086, 0.934 and 5.089 for the initial, development, mid and end growth stages respectively should be adopted for tiger nut cultivation in the study area, Design engineers in future works should incorporate the findings of this work in the design of sprinkler and drip irrigation systems towards tiger nut cultivation for economic gains.

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