Journal of Agroforestry and Environment
Volume 18, Issue 1, 2025
Journal DOI: https://doi.org/10.55706/jae
Journal homepage: www.jagroforenviron.com

Performance of Tiger Nut (*Cyperus esculentus L.*) as Influenced by Row Spacing and Fertilizer Application in a Nigerian Rain Forest

Ehizogie Joyce FALODUN[1] and Osayamon Anthonia BAKARE[2]

[1]Department of Crop Science, Faculty of Agriculture, University of Benin, Nigeria
[2]Department of Soil and Land Management, Faculty of Agriculture, University of Benin, Nigeria

[*]Correspondence: ehizogie.falodun@uniben.edu; Phone: +2348080641984

Received: 11/02 /2025
Accepted: 08/05/2025
Available online: 18/05/2025

Abstract: Tiger-nut (*Cyperus esculentus L*) serves as a source of income and nutrition for billions of people globally. Despite the economic importance of this crop, cultivation is not common in Edo rain forest of Nigeria and efforts to cultivate it require fertile soils and appropriate plant spacing. Field and laboratory trials were conducted to investigate the effect of row spacing and fertilizer application on the growth, yield and quality of Tiger-nut (*Cyperus esculentus L*) in the University of Benin, Nigeria. The experimental design was a 3 x 4 factorial arrangement fitted into a randomised complete block design (RCBD), replicated three times. The treatments consisted of three plant spacing (S1= 15 cm x 20 cm, S2= 15 cm x 25 cm and S3= 15 cm x 30 cm) and four fertilizer application rates: F0: Control, F1: 400 kg ha $^{-1}$ NPK 15:15:15, F2: 20 t ha $^{-1}$ poultry manure F3: 10 t ha $^{-1}$ poultry manure + 200 kg ha $^{-1}$ NPK 15:15:15. The effect of plant spacing was not significant on the vegetative characters of tiger nuts but significant on the nut yield. N concentration and uptake increased at S_2F_3 (15 cm x 25 cm spacing at 10 t ha $^{-1}$ poultry manure + 200 kg ha $^{-1}$ NPK 15:15:15) and the protein at S_2F_2 (15 cm x 25 cm spacing at 20 t ha $^{-1}$ poultry manure) and carbohydrate content was highest at S_3F_3 (15 cm x 30 cm spacing with 10 t ha $^{-1}$ poultry manure + 200 kg ha $^{-1}$ NPK 15:15:15). The application of 20 t ha $^{-1}$ poultry manure increased most of the yield components and produced significantly ($p \leq 0.05$) more number of nuts (31.61), fresh weight of nuts (22.87g) per plant and the nut tuber yield by 12.38% above the unfertilized plots at S1 (15 cm x 20 cm). Fertilizer application rate of 20 t ha $^{-1}$ poultry manure at a spacing of either, 15 cm x 20 cm or 15 cm x 25 cm should be adopted for higher nut yield and quality of *C. esculentus*.

Keywords: Tiger nut; Protein; Yield; Spacing; Fertilizer.

INTRODUCTION

Tiger nut *Cyperus esculentus* L. is a fast-growing underutilized tuber crop of the family Cyperaceae, which produces spherical rhizomes from the base of the tuber and often confused with weeds in some areas. According to Abaejoh *et al*. (2006) tiger nut is widely grown and consumed in Nigeria, other parts of West Africa, East Africa, parts of Europe particularly Spain as well as in the Arabian Peninsula. In Nigeria, tiger nut is well grown in the middle belt and northern region (Oladele *et al*. 2009), where it is sold locally and consumed uncooked. Nutritionally, the tubers are the economic or most important part of the plant because they consist of some amount of digestible carbohydrates, protein, fiber and oil (Zhang & Parsons 1996). The tubers are rich in fiber and minerals such as phosphorus, potassium, calcium, magnesium, iron and its alleged to have an aphrodisiac effect when consumed by men. Maduka & Ire, (2018) stated that the crop contains vitamins E and C and a good quantity of vitamin B1 which helps in stabilizing the central nervous system and defends the internal mechanism of the body against stress. Despite the health and nutritional benefits of this crop and its potentials as feeds for both humans and animals in alleviating hunger and malnutrition in developing countries, the yield is still low due to cultivation in small farm holdings confined to the northern part of Nigeria where the crop is labelled as a mere weed. The demand for tiger nut for local consumption is quite high, and as a result it is quite expensive. The cultivation of this crop has attracted very little scientific and technological attention in recent times especially in the rainforest zone of Nigeria and this awareness will help to increase tiger nut production for a worthwhile economic return in the developing countries of the world. Plant spacing and nutrient availability is crucial for optimizing its cultivation, wider spacing shows insufficient vegetative cover which can lead to reduction in crop yield per hectare. Appropriate plant spacing can increase tiger nut productivity by reducing competition for sunlight, water, nutrients as well as prevents the sprea d of pests and diseases from one plant to another and allows plant to develop their full potential above and underneath the ground. Xu *et al*. (2018), reported that local tiger nut planters space their crops at 30 cm – 50 cm row spacing and stressed that crop spaced greater than 50 cm decreases productivity. In addition, tiger nuts can grow well in soils with low to moderate fertility, since they are not heavy feeders. However, proper fertilization is required for increased productivity and quality. The use of inorganic fertilizer to enhance yield of crop has been found to be effective only within few years, demanding consistent use on long-term basis. The hazardous environmental consequences and high cost of inorganic fertilizers make them not only undesirable but also uneconomical and out of reach of resource poor farmers who still dominate the Nigerian Agricultural sector and this has led to increased use of organic manure, which is environmentally friendly and a readily available alternative.

The complementary application of organic and inorganic fertilizers has been found to meet the immediate soil nutrient deficits, improve the soil physical properties and enhance yield stability. Combined application of poultry manure and NPK fertilizer may also result in synergistic effects, as organic matter from poultry manure can improve the soil's ability to retain and release nutrients from the NPK fertilizer (Ojeniyi *et al*. 2017). Falodun *et al.*, (2013) stated that combine application of organic and inorganic fertilizer gave better results than their sole application in onion production, they emphasized that high and sustainable crop yield can be obtained with judicious use of combine application. The objective of this work was to determine the response and quality of tiger nut to different spacing and fertilizer application.

MATERIALS AND METHODS

Experimental site

The study was conducted in (latitude 06^{o} 20 'N and latitude, 5^{o} 36 'E) in the southern rain forest of Nigeria (Fig 1). The average annual rainfall for the period of cultivation was 2074 mm and average temperature was 27^{o}C characterized by sandy loam with a low nutrient content and soil order ultisol.

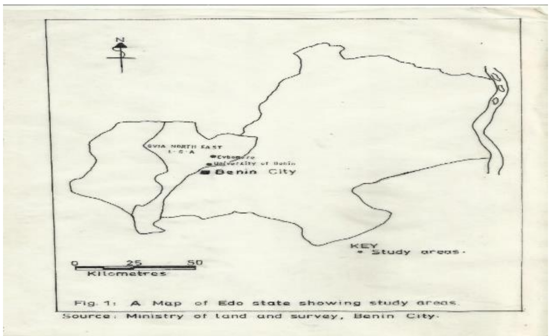

Figure 1. Study area

Prior to planting, soil samples were randomly collected from a depth of 0 – 15 cm using a metal soil auger. Composite soil samples and poultry manure were analyzed for pH, organic carbon and total nitrogen. Soil pH was determined using a soil-water medium at ratio 1:2 with a digital electronic pH meter. Soil organic carbon (OC) was determined by the procedure of Walkley and Black using the dichromate wet oxidation method. Total N was determined by the micro-Kjeldahl digestion method. The available phosphorous was determined by (Bray & Kurtz, 1945) and Murphy & Riley (1962), blue colour method was used to estimate phosphorus. Flame photometer was used to estimate the exchangeable sodium and potassium while Atomic Absorption Spectrophotometer (AAS) was used to determine the calcium and magnesium content of the soil. The physical and chemical properties of the soil at a depth of 0-15 cm on the experimental field and the chemical properties of the poultry manure is shown in (Table 1 and 2).

Source of planting materials

The tiger nuts tubers were purchased from a reliable source in Benin City. The inorganic fertilizer (NPK 15:15:15) used for the experiment was obtained from a fertilizer store and the poultry manure was procured from University of Benin Farm Project.

Experimental design

The experiment was laid as a 3 x 4 factorial arranged in a randomize complete block design (RCBD) in three replications. The treatments were made up of three plant spacing (S1= 15 cm x 20 cm, S2= 15 cm x 25 cm and S3= 15 cm x 30 cm) and four fertilizer application rates: F0: Control, F1: 400 kg ha $^{-1}$ NPK 15:15:15, F2: 20 t ha $^{-1}$ poultry manure F3: 10 t ha $^{-1}$ poultry manure + 200 kg ha $^{-1}$ NPK 15:15:15.

Land Preparation and planting

The soil was cleared, tilled manually and then divided into plots of 1 m^{2}, cured poultry manure was applied immediately into experimental plots depending on the treatments. To facilitate sprouting, seeds were hydro primed before sowing and kept for approximately 24h under ambient temperature. Primed seeds of uniform size were manually sown directly into prepared soil beds to a depth of about 5cm. Two seeds were sowed per hole and later thinned to one plants per stand on sprouting. The beds were mulched,

DOI: https://doi.org/10.55706/jae1804

insects were controlled when necessary and the plots were weeded at 2, 4 and 6 weeks after planting (WAP).

Data collection

Data collection started at 4 WAP on four randomly selected plants. The parameters measured were; plant height (cm) stem diameter(cm), no of leaves, leave area (cm^2) no of nut, fresh weight of nut (g), nut diameter (cm) fresh weight of herbage (g), nut yield (t ha^{-1}), herbage yield (t ha^{-1}), total yield (t ha^{-1}) and harvest index (%).

Vegetative characters

Plant height (cm): The height was taken using measuring tape, from the ground level to the tip of the apical shoot of the four randomly selected plants per plot and average recorded

Stem diameter (cm): The diameter of the stem was measure using vernier caliper placed on the stem of each plant. and average recorded.

No of leaves: The numbers of leaves were counted manually and average recorded

Leave area (cm^2): These was done by measuring the length and breadth of the leaves with the use of a measuring tape

Yield and yield characters

Harvesting was done at 12 WAP when the tubers were matured, tubers were excavated at maturity. Four plants were randomly excavated for data collection purposes, after which the rest were harvested using a hand fork and hoe and the tubers, handpicked from the soil.

Number of nuts per m^2: The number of nuts harvested from each plot was counted and recorded.

Nut weight (g) per plant: This was taken as the weight of nuts harvested per plot divided by the number of plants per plot.

Nut length (cm): At harvest, four nuts were randomly selected among the nuts within a plot. A vernier caliper was placed on the vertical section of each nut and length measured. The mean nut length was computed and recorded

Nut diameter (cm): This was obtained at harvest by measuring the transverse section of four randomly selected nuts from each plot with a vernier caliper. The mean nut diameter was calculated and recorded.

Nut weight (g) per m^2: The weight of nuts per m^2 was estimated by taking the weight on four randomly selected nuts with a digital scale (Furi spec) and the mean weight multiplied by the number of nuts harvested per plot.

Total fresh weight/ plant: This was measured by determining the fresh weight of four randomly selected whole plant (leaves and nuts) with a sensitive scale and the mean of the four samples taken as average total fresh weight per plant.

Herbage weight (g) per m^2: At harvest, the shoots of tagged plants were separated from the nuts and cleaned of soil particles and weighed with a sensitive balance scale and the mean weight multiplied by the number of plants harvested per plot and recorded.

Nut yield (t ha^{-1}): The nut yield was obtained from the weight of all the nuts harvested from each sub-plots and calculated as follows and then estimated to t ha^{-1}

$$\text{Nut yield kg ha}^{-1} = \frac{nut\ yield\ per\ plot\ (kg) \times 10{,}000\ m^2}{Plot\ size\ (m^2)}$$

Herbage yield (t ha^{-1}): The herbage yield was obtained from the weight of all the shoots after separating the nuts from the harvested plants and calculated as follows and then estimated to t ha^{-1}

$$\text{Herbage yield (t ha}^{-1}) = \frac{herbage\ yield\ per\ plot\ (kg) \times 10{,}000\ m^2}{Plot\ size\ (m^2)}$$

Total yield (t ha^{-1}): The total yield (t/ha) was influenced by nut yield and herbage yield.

(%) Harvest index (HI) was determined based on the formula below

$$\text{HI (\%)} = \frac{\text{Nut yield}}{\text{Total yield}} \times 100$$

Proximate Analysis

This was carried out to determine the quantities of moisture, ash, crude fat, crude fibre, and crude protein present in tiger nut tubers.

Moisture Content

Moisture content was determined by oven-drying method which is based on weight loss of water due to evaporation. Two gram (g) of each sample was weighed into dry pre-weighed crucibles and transferred to an oven maintained at $105^{O}C$ and dried until constant weight (AOAC,1990). The loss in weight during drying represented percentage moisture content based on the formula below:

$$\%\ Moisture = \frac{Loss\ of\ weight\ due\ to\ drying}{weight\ of\ sample\ taken} X \frac{100}{1}$$

Ash (%)

One gram (g) each of finely ground sample was placed in a dry crucible and weighed (W_I). The organic matter was burnt off using Bunsen flame until samples became charred. The crucibles were then transferred to the muffle furnace set at $550^{O}C$. Ashing continued until a light grey or white ash was obtained. The crucibles were then cooled in a dessicator before weighing (W_2) (AOAC, 1990). The percent ash content was calculated with the formula below.

$$\%\ Ash = \frac{W_2 - W_1}{weight\ of\ sample} X \frac{100}{1}$$

Crude fat (%)

DOI: https://doi.org/10.55706/jae1804

One and half grams (g) of each sample was placed into a thimble and weighed (W_2). The thimble was weighed before sample addition as (W_1). The thimble with the sample (W_2) was inserted into a soxhlet apparatus. Extraction under reflux was carried out with petroleum ether at 40-60^{O}C boiling range for 5 hours. At the end of extraction, the thimble was dried in an oven for about 30 minutes at 100 ^{O}C to evaporate the solvent. The thimble was then allowed to cool in a dessicator and later weighed (W_3). The fat extracted was deduced from the formula below:

$$fat\ (\%) \quad = \quad \frac{weight\ loss\ of\ sample\ (extracted\ fat)}{weight\ of\ sample}\ X\ \frac{100}{1}$$

Crude Fibre (%)

One and half grams (g) of the sample (W_1) was weighed into a 1 litre conical flask followed by the addition of 200ml of boiling 1.25% H_2S0_4. The solution boiled for 30 minutes before it was filtered through a muslin cloth stretched over a 9cm Buchner funnel. The residue was scrapped back into the original flask with a spatula and 200ml of boiling 1.25 NaOH was added. The solution was allowed to boil gently for 30 minutes. Again it was washed thoroughly with hot distilled water, and rinsed once with 10% methylated spirit. The residue was rinse three times with petroleum ether of 40-60^{O}C boiling range then transferred into a weighed crucible(W_2) and dried at 105 ^{O}C in the oven to constant weight before weighing again (W_3). Next the sample in the crucible was ashed at 550^{0}C for 90 minutes in a muffle furnace. After ashing the crucible and ash were cooled in a dessicator before the ash was weighed (W_4). The percent crude fibre was calculated with the formula

$$\%\ \text{Crude fiber} = \frac{(W_3 - W_2) - (W_4 - W_2)}{W_1} \times 100$$

Crude protein (%)

This was estimated as the product of nitrogen concentration (%) and a correction factor of 6.25 (Osborne & Voogt, 1978).

Data analysis

The data collected was subjected to analysis of variance using SAS statistical package and the significant difference between the treatment means were separated using least significant difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Physical and chemical properties of experimental soils

The physical and chemical properties of 0 - 15 cm soil depth at different points on the experimental field before planting shows that the textural class of the soil is sandy loam. The percentage of clay, silt and sand in the soil sample analyzed were 5.5 %, 6.3 % and 88.2 % respectively (Table 1). The analysis showed that the soil sample had a higher percentage of sand particles, followed by silt and then clay which is suitable for tiger nut cultivation. The soil is slightly acidic pH (5.06), slightly rich in organic matter (18.03 %) but low in some major essential plant nutrients, total nitrogen (TN) (0.06 g kg $^{-1}$), potassium (0.20 cmol kg $^{-1}$), calcium (0.77 cmol kg $^{-1}$), magnesium (0.18 cmol kg $^{-1}$) except phosphorus (0.21 mg kg $^{-1}$) which is above the critical concentration level of available plant nutrients (Table 1). The poultry manure analysis showed that the poultry manure (PM) has 2.21 % N which implies that the PM has high nitrogen content (Table 2).

Table 1. Chemical and physical properties of experimental soil

Soil Depth	Soil properties										Soil particle size distribution (%)			Textural class
		(%)	(%)	(g/kg)		(cmol/kg)								
0-15	pH (H_2O)	Organic matter	Total N	P	K	Ca	Mg	Na	H^{+1}	Al^{+3}	Sand	silt	clay	Sandy loam
	5.06	18.03	0.06	21.40	0.20	0.75	0.80	0.10	0.21	0.12	88.20	5.50	6.30	

Table 2. Chemical properties of poultry manure

Properties							
	(%)	(%)	(g/kg)		(cmol/kg)		
pH (H_2O)	Organic matter	Total N	P	K	Ca	Mg	Na
6.25	28.28	2.21	1.64	1.25	0.72	0.13	0.35

DOI: https://doi.org/10.55706/jae1804

Effect of plant spacing and fertilizer application on some vegetative characters of *C. esculentus*

The effect of spacing was not significant on most of the vegetative characters measured except in 2023, cropping season where plant height increased from 83.76 cm to 88.74 cm (Table 3). The narrower spacing of S1 (15 cm x 20 cm) produced the highest (88.74 cm) plant height which was not significantly different from (87.43 cm) produced at S2 (15 cm x 25 cm) while significantly, lowest plant height (83.76 cm) was produced at the wider spacing of S3 (15 cm x 30 cm) The increase in plant height with the narrower spacing supports Baloch *et al.* (2012); Abu & Odo, (2017) who reported similar results on eggplants. This increase in plant height with narrower spacing could be attributed to higher plant population which reduced light penetration and led to increase in endogenous auxins formation which probably enhanced taller plants. The analysis of variance showed significant differences at P<0.05 in most of the vegetative characters for the different fertilizer rates in both cropping seasons (Table 3). Fertilizer application enhanced most of the vegetative parameters measured above the control indicating that fertilizers adequately supported plant growth. According to Tan *et al.* (2023) fertilization increases above ground biomass, tiller formation, crop growth rate, and dry matter accumulation, which, in turn, produces greater number of tubers within the crop population. In both years, plants that received no fertilizer significantly produced lower values for plant height (80.26 cm and 80.23 cm), number of leaves (12.57 and 12.21), stem diameter (0.33 cm and 0.35 cm) and leaf area (63.41 cm and 66.39 cm) Table 3.

Table 3. Effect of row spacing and fertilizer application on some vegetative characters of Tiger nut (*Cyperus esculentus*)

	2022 Cropping season				2023 Cropping season			
Treatments	Plant height (cm)	Number of leaves	Stem diameter (cm)	Leaf area (cm^2)	Plant height (cm)	Number of leaves	Stem diameter (cm)	Leaf area (cm^2)
Row Spacing (cm)								
S1 (15x20)	86.58[a]	12.86[a]	0.35[a]	72.34[a]	88.74[a]	13.45[a]	0.39[a]	75.50[a]
S2 (15x25)	85.35[a]	13.41[a]	0.35[a]	71.32[a]	87.43[a]	13.94[a]	0.36[a]	75.44[a]
S3 (15x30)	84.54[a]	13.07[a]	0.34[a]	70.03[a]	83.76[b]	13.38[a]	0.36[a]	72.12[a]
LSD (0.05)	2.20	0.71	0.04	4.09	2.81	0.71	0.05	5.42
Significance	N.S	N.S	N.S	N.S	*	N.S	N.S	N.S
Fertilizer Application								
F0 (control)	80.26[b]	12.57[b]	0.33[b]	63.41[b]	80.23[b]	12.21[b]	0.35[b]	66.39[b]
F1 (400 kg/ha NPK 15:15:15)	85.33[ab]	13.61[a]	0.37[ab]	72.61[a]	86.33[a]	13.57[a]	0.39[ab]	74.22[a]
F2 (20t/ha Poultry Manure)	88.65[a]	13.11[ab]	0.41[a]	75.34[a]	89.87[a]	13.26[a]	0.43[a]	78.32[a]
F3 (200kg/ha NPK 15:15:15 + 10t/ha Poultry manure)	88.06[ab]	13.18[ab]	0.38[ab]	73.68[a]	89.06[a]	13.23[a]	0.40[ab]	75.69[a]
LSD (0.05)	5. 78	0.82	0.06	5.26	3.21	0.60	0.07	6.34
Significance	*	*	*	*	*	*	*	*

Means with the same letters along the same column are not significantly different at 5% level of probability.
Ns = Not significant; *= significant at 0.05 probability

This results corroborate the findings of Tan *et al*., (2023), who reported that N application can substantially improve the functional attributes of tiger nut leaves in nutrient deficient soils, thus increasing tuber yield. Previous research has established a significant positive correlation between nut tuber yield, dry matter accumulation, leaf function, and photosynthetic capacity which indicates that these characters are the major components for yield (Simkin *et al*. (2020); Tan *et al*. (2017). In both years, the leaf area followed the same pattern and application rate of 20 t ha^{-1} poultry manure notably increased the leaf area from (63.41 cm to 75.34 cm) and from (66.39 cm to 78.32 cm) in 2022 and 2023 cropping seasons respectively (Table 3). This observation could be linked to the fact that organic manure improves the soil structure and activates many species of living organisms which release phytohormones that help to stimulate plant growth and absorption of nutrients. Numerous research findings have shown that poultry manure has the potential to increase crop growth and also reduce environmental pollution attributable to inorganic fertilizers in the soil (Vilarrasa-Nogué, *et al*., (2019); Tan, *et al*., (2017). Additionally, poultry manure holds up nutrients and releases them slowly over an extended period, this property demonstrates distinct advantage over the inorganic fertilizer which is a fast releaser of nutrients within a very short time.

DOI: https://doi.org/10.55706/jae1804

Effect of plant spacing and fertilizer application on yield and yield components of *C. esculentus*

Table 4, shows that the number of nuts, nut diameter, nut fresh weight plant^{-1} and herbage fresh weight plant^{-1} were not significantly influenced by spacing. However, the effect of fertilizer application was significant on some of these parameters. In both years, number of nuts increased from F0 (18.80 and 15.12), control plots to (31.61 and 29.57) when the fertilizer application rate of F2 (20 t ha^{-1} poultry manure) was applied. Nut fresh weight plant^{-1} followed the same trend and increased from (14.22 g and 14.48 g) under the control to (20.08 g and 22.87 g) when F2 (20 t ha^{-1} poultry manure) was applied (Table 4). The positive response of these parameters to poultry manure could probably be due to the additional nutrients N, P, K, Zn, Fe, Mn supplied through the poultry manure. In 2023, cropping season, the control plots significantly produced lower herbage fresh weight per plant (6.06 g) compared with (10.21g) produced from plots that received fertilizer 400 kg ha^{-1} NPK 15:15:15 which was not significantly $P < 0.05$ different from (10.02 g) produced from, F2 (20 t ha^{-1} poultry manure) and (9.31 g) from F3 (200 kg ha^{-1} NPK 15:15:15 + 10 t ha^{-1} poultry manure) (Table 4). These results reveal the possibility of reducing chemical fertilizer by using eco-friendly poultry manure which is readily available and could reduce environmental pollution.

Table 4. Effect of row spacing and fertilizer application on yield components of Tiger nut (*Cyperus esculentus*)

	2022 Cropping season				**2023 Cropping season**			
Treatments	Number of nut/plant	Nut diameter (cm)	Fresh nut wt./plant	Herbage fresh wt./plant	Number of nut/plant	Nut diameter (cm)	Fresh nut wt./plant	Herbage fresh wt./plant
Row Spacing (cm)								
S1 (15x20)	25.10^{a}	0.95^{a}	20.12^{a}	11.72^{a}	20.21^{a}	0.90^{a}	18.40^{a}	10.52^{a}
S2 (15x25)	26.87^{a}	1.02^{a}	20.22^{a}	9.67^{a}	25.22^{a}	1.02^{a}	20.55^{a}	8.84^{a}
S3 (15x30)	26.18^{a}	1.00^{a}	16.80^{a}	9.42^{a}	24.47^{a}	1.02^{a}	21.14^{a}	9.35^{a}
LSD (0.05)	7.45	0.08	5.24	3.53	6.13	0.08	4.22	3.82
Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Fertilizer Application								
F0 (control)	18.80^{b}	1.00^{a}	14.22^{b}	9.45^{a}	15.12^{b}	1.00^{a}	14.48^{b}	6.06^{b}
F1 (400 kg ha^{-1} NPK 15:15:15)	24.88^{ab}	1.04^{a}	22.15^{a}	11.50^{a}	23.18^{a}	1.01^{a}	19.98^{ab}	10.12^{a}
F2 (20 t ha^{-1} Poultry Manure)	31.61^{a}	1.06^{a}	22.87^{a}	10.15^{a}	29.57^{a}	1.05^{a}	22.08^{a}	10.02^{a}
F3 (200 kg ha^{-1} NPK 15:15:15 + 10t/ha Poultry manure)	27.58^{a}	1.00^{a}	21.59^{a}	9.97^{a}	26.44^{a}	1.02^{a}	18.39^{ab}	9.31^{a}
LSD (0.05)	8.60	0.09	6.57	4.07	7.94	0.09	6.05	3.04
Significance	*	Ns	*	Ns	*	Ns	*	*

Means with the same letters along the same column are not significantly different at 5% level of probability.
N.S= Not significant; *= significant at 0.05 probability

In contrast to some growth parameters and some other yield components per plant, spacing had a significant effect on the fresh nut yield, fresh herbage yield and total fresh yield of *C. esculentus*, lowest fresh nut yields (3.63 t ha^{-1} and 3.02 t ha^{-1}) were produced at the wider spacing of S3 (15 cm x 30 cm) while the narrower spacing of S1(15 cm x 20 cm) and S2 (15 cm x 25 cm) significantly produced higher fresh nut yield (6.26 t ha^{-1} and 5.20 t ha^{-1}); (5.92 t ha^{-1} and 5.18 t ha^{-1}), higher fresh herbage yield (3.86 t ha^{-1} and 2.49 t ha^{-1}); (2.44 t ha^{-1} and 2.46 t ha^{-1}) and higher total yield (10.17 t ha^{-1} and 7.77 t ha^{-1}); (8.40 t ha^{-1} and 7.62 t ha^{-1}) for 2022 and 2023 cropping season respectively (Table 5). Xu *et al.*, (2018), reported that wider spacing decreases productivity, shows insufficient vegetative cover which can lead to reduction in crop yield per hectare. The increase in the total yield as a result of the narrower spacing suggests that the spacing was fully utilized and that the plants in that environment had adequate ground cover thereby preventing excessive loss of moisture from the soil as well as suppressing weed growth. The increase in the number of plants per hectare could probably be an added advantage to the increase in tuber yield of tiger nut. Although the harvest index was not significantly influenced by spacing and fertilizer application (Table 5), all the plants that received fertilizer performed better compared with the control unfertilized plant, this may probably be due to the fact that the plants under the control plots had to rely on the intrinsic soil nutrients for growth and development. In

DOI: https://doi.org/10.55706/jae1804

2022 cropping season, fertilizer application increased the fresh nut yield in this other, F0 (3.68 t ha $^{-1}$) < F1 ((5.30 t ha $^{-1}$) F3 < (5.43 t ha $^{-1}$) and F2 (6.28 t ha $^{-1}$) and this trend was similar in 2023, cropping season where F0 significantly produced the lowest fresh nut yield (3.05 t ha $^{-1}$) Table 5. This result asserts the report of Tan *et al.* (2023) who reported that fertilizer regime especially N can increase dry matter accumulation, tuber yield and tuber producing stolons.

Table 5. Effect of row spacing and fertilizer application on yield and yield components of Tiger nut (*Cyperus esculentus*)

	2022 Cropping season				**2023 Cropping season**			
Treatments	Fresh nut yield (t ha $^{-1}$)	Fresh herbage yield (t ha $^{-1}$)	Total fresh yield (t ha $^{-1}$)	Harvest index (%)	Fresh nut yield (t ha $^{-1}$)	Fresh herbage yield (t ha $^{-1}$)	Total fresh yield (t ha $^{-1}$)	Harvest index (%)
Row Spacing (cm)								
S1 (15x20)	6.26^{a}	3.86^{a}	10.17^{a}	64.58^{a}	5.92^{a}	2.46^{a}	8.40^{a}	62.52^{a}
S2 (15x25)	5.20^{a}	2.49^{a}	7.77^{a}	66.91^{a}	5.18^{a}	2.44^{a}	7.62^{a}	62.84^{a}
S3 (15x30)	3.63^{b}	2.07^{b}	5.64^{b}	64.58^{a}	3.02^{b}	2.12^{b}	5.14^{b}	63.35^{a}
LSD (0.05)	1.62	1.22	2.46	8.79	1.56	1.18	2.23	8.79
Significance	*	*	*	Ns	*	*	*	Ns
Fertilizer Application								
F0 (control)	3.68^{b}	2 48^{a}	6.42^{a}	60.33^{a}	3.05^{b}	2.43^{a}	5.48^{b}	60.21^{a}
F1 (400 kg ha^{-1} NPK 15:15:15)	5.30^{ab}	3.14^{a}	8.39^{a}	68.00^{a}	5.09^{a}	3.08^{a}	8.17^{a}	65.27^{a}
F2 (20 t ha^{-1} Poultry Manure)	6.28^{a}	2.81^{a}	8.79^{a}	68.77^{a}	5.94^{a}	2.25^{a}	8.19^{a}	65.82^{a}
F3 (200 kg ha^{-1} NPK 15:15:15 + 10t/ha Poultry manure)	5.43^{ab}	2 80^{a}	7.84^{a}	67.33^{a}	5.24^{a}	2.32^{a}	7.56^{a}	64.31^{a}
LSD (0.05)	1.87	1.41	2.61	10.15	1.48	1.22	2.52	10.04
Significance	*	Ns	Ns	Ns	*	Ns	Ns	Ns

Means with the same letters along the same column are not significantly different at 5% level of probability.
N.S= Not significant; *= significant at 0.05 probability

Effect of plant spacing and fertilizer application on nutrient concentration and uptake of tiger nut *C esculentus*

The effect of spacing and fertilizer application on nutrient concentration and uptake was significant. N concentration and uptake increased (0.07 % and 0.08 %) from the narrower spacing of 15 cm x 20 cm with no fertilizer application (S1F0) to (0.12 % and 0.28%) when spacing was increased to, 15cm x 25cm with 20 t ha^{-1} poultry manure application (Table 6).

Table 6. Effect of row spacing and fertilizer application on nutrient concentration of Tiger nut (*Cyperus esculentus*)

	Nutrient concentration				**Nutrient uptake**			
Treatments	N (%)	P (mg g^{-1})	K (%)	Fe (mg g^{-1})	N (%)	P (mg g^{-1})	K (%)	Fe (mg g^{-1})
S_1f_0	0.07^{e}	11.18^{j}	0.14^{j}	6.25^{l}	0.08^{g}	12.53^{h}	0.43^{f}	7.78^{k}
S_1f_1	0.09^{d}	15.12^{f}	0.43^{d}	8.68^{e}	0.10^{f}	17.08^{e}	0.49^{d}	9.80^{e}
S_1f_2	0.10^{c}	17.37^{d}	0.38^{e}	7.27^{i}	0.11^{e}	19.03^{d}	0.44^{e}	8.50^{i}
S_1f_3	0.09^{d}	17.54^{b}	0.97^{c}	10.98^{b}	0.08^{g}	19.83^{b}	1.10^{c}	12.40^{b}
S_2f_0	0.07^{e}	10.50^{l}	0.17^{i}	10.88^{c}	0.11^{e}	17.78^{j}	0.17^{k}	11.40^{c}
S_2f_1	0.10^{c}	10.53^{e}	0.24^{h}	10.91^{c}	0.19^{b}	11.89^{i}	0.27^{j}	12.30^{b}
S_2f_2	0.12^{a}	12.27^{g}	2.00^{a}	12.88^{a}	0.28^{a}	13.87^{f}	2.21^{a}	15.80^{a}
S_2f_3	0.09^{d}	11.58^{i}	0.37^{f}	7.01^{j}	0.20^{c}	12.89^{g}	0.41^{h}	7.80^{j}
S_3f_0	0.07^{e}	11.00^{h}	0.38^{e}	8. 09^{g}	0.13^{c}	12.89^{g}	0.42^{g}	8.90^{g}
S_3f_1	0.12^{a}	17.78^{a}	1.96^{b}	6.95^{k}	0.20^{c}	19.93^{a}	2.10^{b}	6.70^{l}

DOI: https://doi.org/10.55706/jae1804

S_3f_2	0.07^e	17.18^e	0.25^h	9.22^d	0.20^c	19.21^c	2.19^b	10.30^d
S_3f_3	0.11^b	17.51^c	0.26^g	8.49^f	0.12^d	19.21^c	0.28^i	9.30^f
Significance	*	*	*	*	*	*	*	*

Means with the same letters along the same column are not sig nificantly different at 5% level of probability.*= significant at 0.05 probability

This observation may be due to the fact that the plants under S2F2 were adequate, received nutrients and faced less competition for growth factors compared to S1F0 which were more closely spaced and had to compete for the intrinsic soil nutrients.

The higher significant nutrient concentration and uptake values for P (17.78 mg g $^{-1}$ and 19.93 mg g $^{-1}$), K (2.00 % and 2.21 %) and Fe (12.88 mg g $^{-1}$ and 15.80 mg g $^{-1}$) were recorded in (S3F1) 15cm x 30cm with 400kg/ha NPK 15:15:15, (S2F2) 15 cm x 25 cm with 20 t ha^{-1} poultry manure, and (S2F2) 15cm x 25cm with 20 t ha^{-1} poultry manure respectively (Table 6). The increase in N concentration, uptake, yield and better quality of plants that received fertilizers supports the work of Ayyub *et al*., (2019) who showed that N uptake and N fertilizer use efficiency has a direct relationship with tuber yield and quality in tuberous crops grown in sandy soil. Optimum fertilizer application plays an important role in harmonizing the source sink dynamics, improving the assimilation of leaf-derived photosynthetic products and root N uptake, aiding in the translocation and reallocation of carbon and N compounds to nut tubers (Da Silva, *et al*., 2023 ; Fontes, 2010).

Effect of plant spacing and fertilizer application on proximate composition of tiger nut *C esculentus*

The proximate composition of *C. esculentus* in Table 7, showed that tiger nut has so many food and medicinal potentials. Generally, irrespective of the spacing, the ether extract ranged from 20.65% (S3F0) to 32.71% (S3F1), which is similar to the report of S´anchez-Zapata *et al.*, (2012). This result shows that Tiger nuts are unique in their ability to accumulate large amounts of oil in their tubers and possess high nutritional value. Zang & Sun, (2023); Liu, *et al*., (2020); Gasparre & Rosell (2019); Carvalho Barros, *et al.*, (2020) in their work reported that the oil extracted from tiger nuts is a naturally high oleic edible oil, which can reduce the levels of total and saturated fats while increasing unsaturated fatty acids, making it widely accepted and comparable with the olive oils (Arafat *et al*., 2009). The starch in tiger nut is beneficial to human health, as it is absorbed slowly in the human body promoting postprandial blood sugar stability which made the drink a functional beverage with antidiabetic potential (Badejo, *et al*., (2020); Liu, *et al*. (2020); Gasparre and Rosell (2019). In Table 7, the percentage moisture content of tubers increased in this order (12.87 > 12.21 > 11.72 > 11.55 > 11.46 > 10.87 > 10.57 > 10.53 > 9.79 > 8.84 > 7.65) for S1FI, S2F3, S1F2, S1F3, S2F1, S3F1, S3F2, S2F2, S3F3, S3F0, S1F0 and S2F0 respectively and were higher in tubers harvested from the fertilized plots compared with the unfertilized plots.

Table 7. Effect of row spacing and fertilizer application on proximate composition of Tiger nut (*Cyperus esculentus*)

Treatments	Ether extract (%)	Ash (%)	Protein (%)	Moisture content (%)	Fibre (%)	CHO (%)
S_1f_0	26.15^g	1.92^d	5.05^i	8.84^f	3.37^i	48.72^g
S_1f_1	27.23^d	0.93^h	6.25^f	12.87^a	7.27^a	46.82^f
S_1f_2	25.00^j	0.92^i	6.73^d	11.72^c	5.83^c	48.65^g
S_1f_3	26.02^h	1.90^e	6.04^g	11.55^d	4.85^e	49.64^e
S_2f_0	26.98^e	1.90^e	4.95^j	7.65^i	6.93^b	47.59^h
S_2f_1	26.42^f	4.72^a	6.90^c	11.46^e	4.37^e	46.13^i
S_2f_2	21.88^k	0.92^i	8.48^a	10.53^h	4.39^h	55.80^b
S_2f_3	29.59^c	2.37^b	7.93^h	12.21^b	5.39^d	44.52^j
S_3f_0	20.65^l	1.93^c	5.41^h	9.26^i	3.90^k	43.85^k
S_3f_1	32.71^a	1.49^g	8.41^a	10.87^h	4.27^j	58.25^a
S_3f_2	30.05^b	1.86^f	6.95^j	10.57^g	4.43^f	51.14^d
S_3f_3	25.38^i	0.47^j	7.81^b	9.79^i	4.41^g	52.09^c
Significance	*	*	*	*	*	*

Means with the same letters along the same column are not significantly different at 5% level of probability. *= significant at 0.05 probability

This could be due to the fact that application of nitrogenous fertilizer increased the moisture content of tuber crop by influencing the water uptake and retention capabilities. This is in agreement with Kareem *et al*., (2020) who reported that the moisture content of sweet potato could be increased through the application of NPK fertilizers. The higher protein content (8.48%), from S2F2 compared with S1F0

DOI: https://doi.org/10.55706/jae1804

(5.05%), S2F0 (4.95%) and S3F0 (5.41%), could be attributed to the fact that N in the S2F2 soil increased significantly as a result of the fertilizer treatment relative to the control, N is known to be an integral component in plants including amino acids that are building blocks of protein and enzymes that are involved in catalyzing most biochemical processes. The ash content (4.72), fiber content (7.27%) and carbohydrate content (58.25 %) were higher at S2F1, S1F1 and S3F1 respectively. The high biomass yield and proximate composition of tiger nuts make them a promising resource for food, oil, and feed, addressing hunger, starvation and malnutrition amongst growing and diverse global needs. According to Maduka & Ire (2018); Arafat, *et al*., (2009), tiger nut could be explored to contribute to Agricultural gross domestic product (GDP) through its local and international trade as well as providing dietary diversification for the alleviation of hunger and micronutrient deficiencies among the poor and children.

CONCLUSION

The empirical data derived from this study suggests that tiger nut can sustainably be grown in southern Nigeria with appropriate fertilizer rates and spacing in addition to other agronomic practices. Fertilizer application rate of 20 t ha $^{-1}$ poultry manure improved the quality and increased the fresh nut yield by 12.38% above the control. Narrower plant spacing of (15 cm x 20 cm) and (15 cm x 25 cm) gave the highest significant values for all yield parameters and either of these spacing with 20 t ha $^{-1}$ poultry manure should be recommended for sustainable tiger nut *Cyperus esculentus* production in this locality.

Author's contributions

Authors contributed to the conception and design of the study. The first draft of the manuscript was written by EJF and OAB proof read the manuscript. All authors commented on previous versions of the manuscript. Authors read and approved the final manuscript.

Conflict of Interest

There is no conflict of interest to declare.

REFERENCES

Abaejoh, R., Djomdi, I., & Ndojouenkeu, R. (2006). Characteristics of Tiger Nut (*Cyprus esculentus*) tubers and their performance in the production of a milky drink. *Journal of Food Processing and Preservation*, 30, 145-163.

Abu, N.E., & Odo, C.V. (2017). The effect of plant density on growth and yield of Nsukka yellow aromatic pepper (*Capsicum annum* L.) *African Journal of Agricultural Resources*, 12 (15): 1269-1277.

Arafat, S.M., Gaafar, A.M., Basuny, A.M., & Nassef, S.L. (2009). Chufa tubers (*Cyperus esculentus* L.): As a new source of food. *World Applied Journal of Sciences*, 7, 151–156.

Association of Official Analytical Chemist. (1990) Official Methods of Analysis. 17th Edition Association of Official Analytical Chemist. Washington D. C. USA.

Ayyub, C., Wasim Haidar, M., Zulfiqar, F., Abideen, Z., & Wright, S.R. (2019). Potato tuber yield and quality in response to different nitrogen fertilizer application rates under two split doses in an irrigated sandy loam soil. *Journal of Plant Nutrition*, (42): 1850– 1860.

Badejo, A.A., Falarunu, A.J., Duyilemi, T.I., & Fasuhanmi, O.S. (2020). Antioxidative and anti-diabetic potentials of tigernut (*Cyperus esculentus*) sedge beverages fortified with *Vernonia amygdalina* and *Momordica charantia. Journal of Food Measurement and characterization* 14, 2790–2799.

Baloch, Q.B., Dero, B., & Memon, N. (2012). Influence of sowing patterns on the growth and productivity of brinjal (Solanum melongena). *Journal of Agriculture and Technology*, 8 (6) : 2043 2051.

Bray, R.H., & Kurtz, L.T. (1945). Determination of total organic and available forms of P in soils. *Soil Science*, 59: 39 – 45.

Carvalho Barros, J., Munekata, P.E., de Carvalho, F.A.L., Pateiro, M., Barba, F.J., Domínguez, R., & Lorenzo, J.M. (2020). Use of tiger nut (*Cyperus esculentus* L.) oil emulsion as animal fat replacement in beef burgers. *Foods* 9, 44.

Da Silva, A.L.B.R., Zotarelli, L., Dukes, M.D., Van Santen, E., & Asseng, S. (2023). Nitrogen fertilizer rate and timing of application for potato under different irrigation methods. *Agriculture and Water Manag*ement (283): 108312.

Falodun, E.J., Ehigiator, J.O. & Egharevba, R.K.A. (2013). Growth and yield of onion as influenced by organic and inorganic fertilizer in Edo Rainforest of Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension*, 12 (3): 15 – 24.

Fontes, P.C., Braun, H., Busato, C., & Cecon, P.R. (2010). Economic optimum nitrogen fertilization rates and nitrogen fertilization rate effects on tuber characteristics of potato cultivars. *Potato Resources*. (53) 167–179.

Gasparre, N., & Rosell, C.M. (2019). Role of hydrocolloids in gluten free noodles made with tiger nut flour as non-conventional powder. *Food Hydrocoll*. 2019, 97, 105194.

Kareem, I., Akinrinde, E. A., Oladosu, Y,. Efifediyi, E. K., Abdulmaliq, S.Y., Alasinrin, S.Y., Kareem, S.A., & Adekola, O. F. (2020): The influence of organic, inorganic and organo-mineral fertilizer on yield and quality of sweet potato (*Ipomoea batatas*). doi:https://dx.doi.org/10.4314/*JASEM*, 24, 1-16

Liu, D., Ji, H., & Yang, Z. (2020). Functional characterization of three novel genes encoding diacylglycerol acyltransferase (DGAT) from oil-rich tubers of *Cyperus esculentus. Plant Cell Physiology*. 61, 118–129.

Maduka, N., & Ire, F.S. (2018). A Review, Tiger nut (*Cyperus esculentus*) plant and useful application of

DOI: https://doi.org/10.55706/jae1804

Tiger nut tubers. *Current Journal of Applied Science and Technology*, 29 (3): 1-23.

Murphy, J. and Riley, J.P (1962). Modified Single solution methods for determination of phosphorus in natural water. *Analytical Chemistry Acta* 27:31 –36.

Ojeniyi, S. O., Adebiyi, F. M., Olubode, O. S., & Adebayo, G. S. (2017). Soil Fertility Improvement and Yield Response of Maize (*Zea mays* L.) to Organic and Inorganic Fertilizers in a Tropical Rainforest Ultisol. *International Journal of Agronomy*, pp. 1-9.

Oladele, A. K., Ibanga, U. I., & Adebesin, O. L. (2009). Effect of Substituting Maize with Tiger Nut on the Quality and Acceptability of Dakuwa. In: Proceedings of the 33rd Annual Conference and General Meeting of Nigerian Institute of Food Science and Technology.

Osborne, D. R., & Voogt, P. (1978). Calculation of Caloric Value. In: "Analysis of Nutrients in Foods". Academic Press, New York, PP. 23-34.

S´anchez-Zapata, E., Fern´andez-L´opez, J., & Angel P´erez Alvarez, J. (2012). Tiger nut (*Cyperus esculentus*) commercialization: health aspects, composition, properties, and food applications. *Comprehensive Reviews in Food Science and Food Safety*, 11, (4) pp. 366–377.

Simkin, A.J., Faralli, M., Ramamoorthy, S., & Lawson, T. (2020). Photosynthesis in non-foliar tissues: Implications for yield. *Plant Journal*, (101): 1001–1015.

Tan, Y., Xu, C., Liu, D., Wu, W., Lal, R., & Meng, F. (2017). Effects of optimized N fertilization on greenhouse gas emission and crop production in the North China Plain. *Field Crops Resources.* (205): 135–146.

Tan, J., Wu, X., He, Y., Li, Y., Li, X., Yu, X., & Shi, J. (2023). Mutual feedback mechanisms between functional traits and soil nutrients drive adaptive potential of tiger nuts (*Cyperus esculentus* L.) in marginal land. *Plant Soil*, 495, 177–194.

Vilarrasa-Nogué, M., Teira-Esmatges, M.R., Villar, J., Rufat, J. (2019). Effect of N dose on soil GHG emissions from a drip-fertigated olive (Olea europaea L.) orchard. *Science of the Total Environment.* (677): 350–361.

Walkley, J., & Black, J.P. (1962). A critical examination of a rapid method for determining organic carbon in soils. Effects of variation in digestion conditions and of organic carbon constituents. *Soil Sci*. 63:251 – 263.

Xu, Z., Li, M-H., & Zimmermann, N.E., (2018). Plant functional diversity modulates global environmental change effects on grassland productivity. *Journal of Ecology*, 106: 1941–1951.

Zhang, Y. E., & Parsons, C. M., (1996). Effects of over processing on the nutritional quality of peanut meal. *Poultry Science*., 75 (4): 514-518

Zhang, Y., & Sun, S., (2023). Tiger nut (*Cyperus esculentus* L.) oil: A review of bioactive compounds, extraction technologies, potential hazards and applications. *Food Chemistry* 19, 100868.

DOI: https://doi.org/10.55706/jae1804