Journal of Agriculture and Environment
Vol. 22 No. 1, 2026: 141-157

Influence of plant population, NPK fertilizer rates and types on growth, chlorophyl content and tuber weight of Kpamyo Yam minitubers in Abuja, Nigeria

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ABSTRACT

Low soil fertility and inappropriate fertilizer management remain major constraints to seed yam production in the Nigerian savanna. This study evaluated the influence of NPK fertilizer types and rates on growth attributes, chlorophyll content, and tuber yield of Kpamyo yam (*Dioscorea rotundata* L.) minitubers. Field experiments were conducted during the 2023 and 2024 cropping seasons at the IITA research farm, Kubwa, Abuja, using a split–split plot design with three replications. Treatments consisted of three planting populations (266,000, 133,000 and 88,000 plant ha^{-1}), three fertilizer types (NPK 15:15:15, 20:10:10, and 27:13:13), and four fertilizer rates (0, 200, 400, and 600 $kgha^{-1}$). Growth parameters, chlorophyll content (SPAD), and yield attributes were measured and subjected to analysis of variance. Results showed that fertilizer types and rates significantly ($p<0.05$) affected plant height, leaf area index, chlorophyll content, tuber yield, sett multiplication ratio and harvest index. NPK 27:13:13 promoted the most vigorous vegetative growth but produced comparatively lower tuber yield and harvest index, in contrast, NPK 15:15:15 consistently resulted in higher chlorophyll content and superior yield performance. Tuber yield increased with fertilizer rate up to 400 kg ha^{-1} but declined at 600 kg ha^{-1}. Plant population density significantly influenced tuber size, with higher densities reducing mean tuber weight due to increased competition. The application of NPK 15:15:15 at 400 kg ha^{-1} provides the optimum nutrient combination for maximizing physiological efficiency and tuber yield of Kpamyo yam minitubers under Southern Guinea Savanna conditions, offering a practical strategy for improving seed yam production in Nigeria.

Keywords: Chlorophyll; *Dioscorea rotundata*; physiology; tuber weight

https://www.ajol.info/index.php/jagrenv
ISSN: 1595-465X (Print) 2695-236X (Online)
correspondence: tapgun.caroline@gmail.com
https://dx.doi.org/10.4314/jagrenv.v22i1.12

INTRODUCTION

Yam (*Dioscorea* spp.) is one of the most important tuber crops in the tropics, serving as a major source of food, income, and cultural identity for millions of households. Globally, about 74.8–74.9 million tonnes of yam are produced annually, with Africa contributing approximately 97.8% of total output (Aighewi *et al*., 2023). West African countries particularly Nigeria, Ghana, Benin, and Côte d'Ivoire account for over 92% of global production, while Nigeria alone produces about 66.9% of the world's yam supply, equivalent to more than 50 million tonnes per year (Wumbei *et al*., 2022; Aighewi *et al*., 2023).

Beyond its economic relevance, yam provides up to 200 kcal/person/day for nearly 300 million people in the tropics and is valued for its high carbohydrate content, including starch, fibre, and sugars, making it a strategic crop for food security and rural livelihoods (Masaudi, 2022).

Despite its importance, yam production is constrained by declining soil fertility, high demand for planting materials, and inefficient nutrient management practices. Traditionally, yam is cultivated as the first crop after land clearing because of its high nutrient requirement. Continuous cropping, shortening fallow periods, and increased pressure on arable land have resulted in severe nutrient depletion and, in some cases, deterioration of soil physical properties, leading to reduced yield potential (Owusu *et al*., 2022)

To sustain production under these conditions, the application of inorganic fertilizers has become increasingly necessary. Studies and field observations show that yam responds favorably to fertilization when nutrients are applied in appropriate formulations and rates, with commonly used blends including NPK 15:15:15, NPK 20:10:10, and NPK 27:13:13, with the recommended rates of 200-300 kg/ha NPK, depending on the soil test result (Tapgun, 2025).

Another major bottleneck in yam production is the low multiplication ratio of planting materials. Conventional propagation relies on planting large tuber setts, often weighing up to 500 g, which also serve as food. This system produces a multiplication ratio of approximately 1:3, resulting in chronic shortages and high costs of seed yam at planting time. To address this challenge, the minituber technology was introduced (Aighewi *et al*., 2021). Minitubers, typically weighing less than 10 g and derived from microtubers or in-vitro plantlets, can be planted directly in the field or screen houses to produce seed yams or ware yams. This innovation enhances multiplication rates, improves uniformity of seed size, and reduces the scarcity and cost of planting materials to farmers (Adejumobi *et al*., 2023; Tapgun, 2025).

However, the successful field establishment and productivity of yam minitubers depend strongly on soil nutrient availability and fertilizer management. Fertilizer type and application rate influence vegetative growth, canopy development, chlorophyll synthesis, and ultimately tuber bulking and yield. Chlorophyll content, commonly measured using SPAD meters, is a reliable indicator of leaf nitrogen status and photosynthetic capacity. Fertilizer application rate significantly affects chlorophyll content, with higher rates (up to 600 kg ha^{-1}) producing higher SPAD values, reflecting increased nitrogen availability and enhanced photosynthetic pigment formation (Tapgun, 2025).

This is agronomically important because improved photosynthetic efficiency increases assimilate production and translocation to developing tubers, thereby strengthening the source–sink relationship that determines final yield.

Source–sink dynamics play a critical role in tuber crops such as yam. Leaves act as the primary source of assimilates, while developing tubers function as the main sink.

Fertilizer application, particularly nitrogen, has been shown to increase leaf nitrogen concentration, chlorophyll content, and photosynthetic capacity, thereby enhancing assimilate supply to sink organs during critical growth stages (Cornet *et al.,* 2022; Tapgun, 2025).

When nutrient supply is excessive or unbalanced, however, vegetative growth may be promoted at the expense of tuber formation, reducing harvestable yield. This phenomenon has been observed with high-nitrogen formulations such as NPK 27:13:13, which tend to stimulate luxuriant vine and leaf development while suppressing efficient tuber bulking.

Although these findings highlight the importance of fertilizer management, detailed understanding of how different NPK formulations and application rates regulate growth physiology and chlorophyll dynamics in yam minitubers remains limited, especially under field production systems in the Nigerian savannah. Such knowledge is essential for developing fertilizer recommendations that optimize photosynthetic efficiency, improve assimilate partitioning to tubers, and enhance seed yam productivity while minimizing unnecessary fertilizer use and environmental risks.

Therefore, this study focuses on evaluating the influence of NPK fertilizer types and application rates on growth, chlorophyll content, and tuber yield of Kpamyo yam minitubers.

MATERIALS AND METHODS

Study Area

The field experiments were conducted during the 2023 and 2024 cropping seasons at the research farm of the International Institute of Tropical Agriculture (IITA), Kubwa, located in Bwari Area Council of the Federal Capital Territory (FCT), Nigeria. The site lies within the Nigerian "yam belt" between latitudes 9.164694°N and 9.164672° N and longitudes 7.345136° E and 7.345158°, with an elevation of approximately 424 m above mean sea level.

The area is characterized by a tropical climate with distinct wet and dry seasons. Mean annual temperature is about 26.4 °C, with March being the hottest month (≈30.1 °C) and August the coolest (≈23.2 °C). Annual rainfall averaged 1,643 mm, peaking in August (≈347 mm) and declining sharply in December (≈1 mm). Relative humidity ranges from about 20% during the dry season to 50% in the wet season.

These climatic conditions are typical of the Southern Guinea Savanna agro-ecological zone and are suitable for yam cultivation and fertilizer response studies.

Land Preparation and Experimental Layout

The experimental field was mechanically cleared using a tractor, followed by ploughing, and harrowing to achieve a fine tilth. Ridges were constructed mechanically at 0.75 m inter row spacing between ridges. The total experimental area measured 54 m × 12 m. Each gross plot measured 3 m × 2 m (6 m²), with four ridges per plot, out of which the two central ridges constituted the net plot.

Plots were separated by 0.75 m alleys, while replications were separated by 2 m wide paths to minimize inter-plot interference and facilitate field operations.

Experimental Materials

The planting material used was an improved minituber (<10 g) of Kpamyo yam variety (TDr 95/19177), sourced from IITA. Three compound inorganic fertilizers were evaluated:
NPK 15:15:15
NPK 20:10:10
NPK 27:13:13

Experimental Treatments

The experiment comprised three factors:

Planting population
266,000 plants ha^{-1} with intra and inter row spacing of 0.05 by 0.75 m (P1)
133,000 plants ha^{-1} with intra and inter row spacing of 0.1 by 0.75 m (P2)
88,000 plants ha^{-1} with intra and inter row spacing of 0.15 by 0.75 m (P3)
Fertilizer type
NPK 15:15:15
NPK 20:10:10
NPK 27:13:13
Fertilizer application rate
0 kg ha^{-1} (L0)
200 kg ha^{-1} (L1)
400 kg ha^{-1} (L2)
600 kg ha^{-1} (L3)
The combination of these factors resulted in 36 treatment combinations (3 × 3 × 4) applied to minitubers sown under the different population densities.

Experimental Design

The treatments were arranged in a split–split plot design fitted into a randomized complete block design (RCBD) with three replications. Plant population constituted the main plot factor, fertilizer type the subplot factor, and fertilizer application rate the sub-subplot factor.

A total of 108 experimental plots were used. Each plot measured 3 m × 2 m, and the total plant population across the experiment was 2,628 stands.

Planting and Pre-planting Operations

Healthy, uniform minitubers were selected and planted manually on the ridges at spacings corresponding to the designated plant population densities. Planting was carried out at the onset of the rainy season in both cropping years, on the 13th and 16th of June in 2023 and 2024, respectively to ensure adequate soil moisture for establishment.

No chemical seed treatment was reported prior to planting, but field sanitation and proper land preparation were ensured to minimize early pest and disease incidence.

Field Maintenance and Fertilizer Application

Weed control was achieved through the application of pre-emergence herbicides. Premextra® (290 g l^{-1} S-metolachlor + 370 g l^{-1} atrazine) was applied at 3.2 kg a.i. ha^{-1}, and Gramoxone® (200 g l^{-1} paraquat) at 1.1 kg a.i. ha^{-1}, two weeks after planting (WAP). Subsequent weed control was carried out manually using hoes, which also served to earth-up the ridges and maintain their shape.

Plants were staked at six WAP using a trellis system, in which ropes were tied between bamboo poles positioned at both ends of each ridge to support vine growth.

The NPK fertilizers were applied in two equal split doses at 6 and 10 WAP, using the band placement method on both sides of the ridges to enhance nutrient use efficiency and minimize volatilization and runoff losses.

Soil Sampling and Laboratory Analysis

Composite soil samples were collected from the experimental field prior to planting at depths of 0–30 cm using a soil auger. Sampling followed a grid method, with four subsamples collected per grid and a total of twelve composite samples obtained across the field.

The samples were air-dried, gently crushed, and passed through a 2-mm sieve before laboratory analysis. Physical and chemical properties analyzed included soil pH (H_20 and KCl), organic carbon, total nitrogen, available phosphorus (Mehlich method), exchangeable bases (Ca, Mg, K, Na), effective cation exchange capacity (ECEC), micronutrients (Fe and Mn), and particle size distribution (textural class) were subjected to routine soil analysis according to the standard procedure described in IITA (1989).

Data Collection

Growth and yield parameters were recorded as follows:

Percent field establishment (%): determined at 6 WAP and at harvest by counting the number of emerged plants per plot divided by the total number planted ×100.

Plant height (cm): measured at 8 and 12 WAP from soil level to the tip of the vine on ten randomly selected and tagged plants per plot, using tape calibrated in cm and average computed.

Leaf area index (LAI): measured at 12 WAP using a CI-110 Plant Canopy Imager, based on gap fraction and photosynthetically active radiation (PAR) analysis.

Chlorophyll content (SPAD units): recorded at 12 WAP using a TYS-4N chlorophyll meter by clamping the meter head on selected leaves for three seconds and reading the displayed value.

Mean tuber weight (g): calculated by dividing total tuber weight by the number of tubers harvested per plot.

Sett multiplication ratio (SMR): computed as the ratio of the weight of tubers harvested to the weight of minitubers planted.

Harvest index (HI): Calculated as shown in the formular below;

$$HI = \frac{Tuber\ yield}{Total\ Biomas\ yield} \times 100$$

These procedures followed the standardized protocols described.

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) appropriate for a split–split plot design using the agricolae package in R statistical software (version 4.2.2).

Where significant differences exist, treatment means were separated using the least significant difference (LSD) test at 0.05 probability level. Where significant interactions occurred, Duncan Multiple Range Test (DMRT) and standard error (SE) values were computed to further compare means.

RESULTS

Initial Soil Properties of the Experimental Site

The soil of the experimental field was sandy loam in texture, moderately acidic, and low in organic carbon and total nitrogen. Exchangeable bases and available phosphorus were moderate, while micronutrients (Fe and Mn) were adequate for yam production.

Table 1: Selected physical and chemical properties of soil (0–30 cm depth) before planting

Parameter	Value
Sand (%)	69.2
Silt (%)	15.4
Clay (%)	15.4
Textural class	Sandy loam
pH (H_2O)	5.6
Organic carbon (g kg^{-1})	7.4
Total N (g kg^{-1})	0.62
Available P (mg kg^{-1})	9.8
Exchangeable K (cmol kg^{-1})	0.21
Exchangeable Ca (cmol kg^{-1})	2.31
Exchangeable Mg (cmol kg^{-1})	0.84
ECEC (cmol kg^{-1})	4.02

Field Establishment

The percent plant establishment as influenced by different regimes of inorganic fertilizer is shows that there was a significant difference in the field establishment from 266,000, 133,000, and 88,000 plants per hectare in 2023, where the highest percent of 95.6% was recorded from 266,000, though not significantly different from 95.1% from 133,000. The lowest percentage was 92.7% from 88,000.

In 2024, the highest percentage of 95.6% was recorded from 266,000, though not significantly different from 94.8% from 133,000. The lowest rate was 92.2% from 88,000. Similarly, the combined year shows a significant difference in the field establishment from 266,000, 133,000, and 88,000 where 95.6% was recorded as the highest field establishment from 266,000, though not significantly different from 95.0% from 133,000. The lowest percentage of 92.5% was recorded from 88,000.

Irrespective of various fertilizer types there was no significant difference in their effect on the field establishment in 2023, 2024, and combined. Fertilizer levels, however, show no significant difference in their effect on the plants in 2023, 2024, and combined.

Table 1: Percent plant establishment as influenced by different regimes of inorganic fertilizer application

Treatments	2023	2024	Combined
Plant population			
266,000 plants/ha	95.6a	95.6a	95.6a
133,000 plants/ha	95.1a	94.8a	95.0a
88,000 plants/ha	92.7b	92.2b	92.5b
LSD	0.79	1.71	1.12
Fertilizer types			
NPK 15:15:15	94.9	94.3	94.6
NPK 20:10:10	93.7	93.1	93.4
NPK 27:13:13	94.9	95.1	95.1
LSD	2.52	2.33	2.15
Fertilizer levels			
0 kg/ha	94.2	94.1	94.1
200 kg/ha	94.6	94.2	94.4
400 kg/ha	95.4	94.9	95.1
600 kg/ha	93.8	93.6	93.7
LSD	2.08	2.76	2.5

Means followed by the same letter(s) in a column of any set of treatments are not significantly different at $p \leq 0.05$ using LSD. WAP = weeks after planting. * = Significant at $p \leq 0.05$, NS = Not significant at $p \leq 0.05$.

Plant Height

Plant height (cm) as influenced by different regimes of inorganic fertilizer application is shown in Table 3. There was no significant difference in the height of plants from 8 WAP in 266,000, 133,000, and 88,000 in 2023. In 2024, there was a statistical difference in the height of the plant population from 8 WAP, where the highest height of 93.6cm was recorded from 133,000 plants, though not significantly different from 266,000 plants with 93.3cm. The lowest plant height was 87.9cm from 88,000 plants.

Similarly, the combined years show a significant difference in the plant's height from 266,000, 133,000, and 88,000 where 90.8cm was recorded as the highest plant height from 133,000, though not significantly different from 90.1cm from 266,000. The lowest plant height was from 88,000 with 85.8cm. In 2023, there was a significant difference in the height of the plant population from 12 WAP, where the highest height of 197.5cm was recorded from 266,000 plants. The lowest plant height was 183.9cm from 88,000 plants.

In 2024, there was a significant difference in the height of the plant population from 12 WAP, where the highest height of 208.0cm was recorded from 266,000 plants. The lowest plant height was 195.4cm from 88,000 plants.

Similarly, the combined show a significant difference in the height of the plant population from 12 WAP, where the highest height of 202.8cm was recorded from 266,000 plants. The lowest plant height was 189.6cm from 88,000 plants.

Fertilizer types show no significant difference in their effect on the plant's height in 2023, 2024, and combined for plants of 8 WAP. In 2023, there was a statistical difference in the height of the plant population when different types of fertilizer were applied from 12 WAP, where the highest height of 197.4cm was recorded when NPK 27:13:13 was used, though not significantly different from 188.2cm applied with NPK 15:15:15. The lowest plants height was 184.4cm from plants applied with NPK 15:15:15.

Table 2: Plant height (cm) as influenced by different regimes of inorganic fertilizer application

Treatments	2023	2024	Combined	2023	2024	Combined
	8 WAP			12 WAP		
Plant population						
266,000 Plants/Ha	86.9	93.3a	90.1a	197.5a	208.0a	202.8a
133,000 Plants/Ha	88.1	93.6a	90.8a	188.6b	199.2b	193.9b
88,000 Plants/Ha	83.6	87.9b	85.8b	183.9b	195.4b	189.6b
LSD	5.75	4.19	4.91	8.25	4.78	5.83
Fertilizer types						
NPK 15:15:15	86.9	91.9	89.4	188.2b	197.9b	193.0b
NPK 20:10:10	84.1	90.2	87.2	184.4b	196.4b	190.4b
NPK 27:13:13	87.6	92.6	90.1	197.4a	208.3a	202.9a
LSD	8.1	9.77	9.34	9.8	10.67	9.64
Fertilizer levels						
0 kg/ha	74.2b	79.8b	77.0b	133.9d	143.0d	138.5d
200 kg/ha	90.5a	96.1a	93.3a	165.8c	177.3c	171.5c
400 kg/ha	91.5a	98.0a	94.7a	212.4b	224.7b	218.6b
600 kg/ha	88.6a	92.5a	90.5a	247.8a	258.5a	253.2a
LSD	9.25	8.6	8.16	9.34	10.66	9.96
Interactions						
Population x Fertilizer types	ns	ns	ns	*	*	*
Population x Fertilizer Levels	*	*	*	*	*	*
Fertilizer types x Fertilizer Levels	*	*	*	*	*	*
Population x Fertilizer types x Fertilizer Levels	ns	ns	ns	ns	ns	ns

Means followed by the same letter(s) in a column of any set of treatments are not significantly different at $p \leq 0.05$ using LSD. WAP = weeks after planting. * = Significant at $p \leq 0.05$, NS = Not significant at $p \leq 0.05$.

In 2024, there was a significant difference in the height of plant population from 12 WAP, where the highest height of 208.3cm was recorded when NPK 27:13:13 was applied, though not significantly different from 197.9cm applied with NPK15:15:15. The lowest plants height was 196.4cm when NPK 20:10:10 was applied.

Similarly, the combined shows a significant difference in the height of the plant population when different types of fertilizer were applied from 12 WAP, where the highest height of 202.9cm was recorded when NPK 27:13:13 was applied. The lowest plant height was 190.4cm when NPK 20:10:10 was applied.

In 2023, 8 WAP, there was a significant difference after applying different fertilizer levels on the plants. The highest height of 91.5 cm was recorded when 400 kg/ha was used, though not significantly different from others except 74.2cm applied with 0 kg/ha. The lowest plant height was 74.2 cm when 0 kg/ha was applied.

In 2024, 8 WAP, there was a significant difference after applying different fertilizer levels to the plants. The highest height of 98.0 cm was recorded when 400 kg/ha was used, though not significantly different from others except 76.8 cm applied with 0 kg/ha. The lowest plant height was 76.8 cm when 0 kg/ha was applied.

Leaf Area Index (LAI)

Leaf Area Index was significantly affected by fertilizer type and rate but not consistently by population density.

The highest LAI values were recorded under NPK 27:13:13 at 600 kg ha^{-1}, reflecting excessive canopy development. NPK 15:15:15 at 400 kg ha^{-1} produced a moderate but more efficient canopy structure. NPK 27:13:13 produced the highest LAI at all fertilizer levels, particularly at 600 kg ha^{-1}.

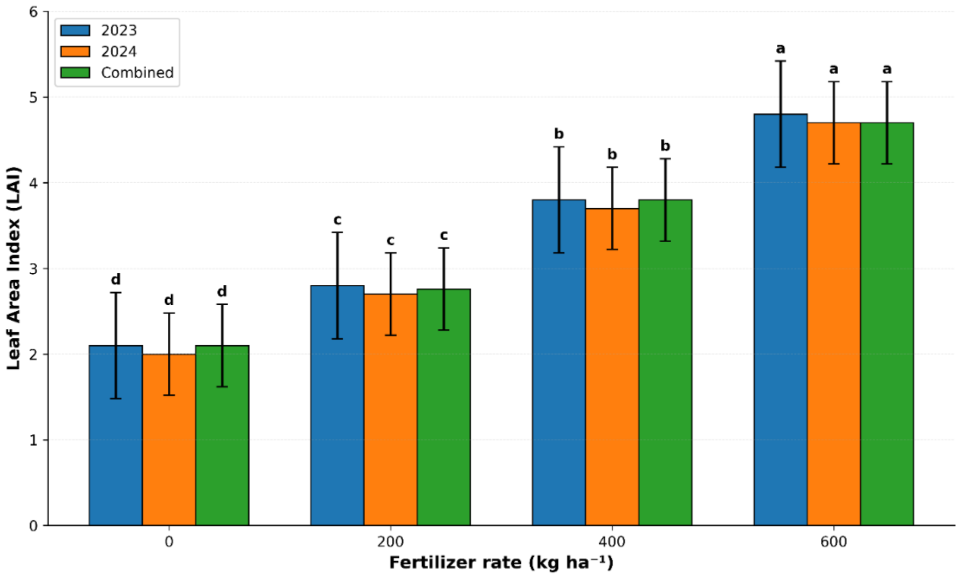

Figure 1: Bar chart showing LAI response to fertilizer types and application rates in Kpamyo yam minitubers.

Chlorophyll Content (SPAD Units)

Table 4 shows the chlorophyll content as influenced by different regimes of inorganic fertilizer application, there was a significant difference in the chlorophyll content of plants from 266,000 plants/ha, 133,000 plants/ha, and 88,000 plants/ha in 2023, the highest chlorophyll content was 27.1 from 266,000 plants/ha, though not significantly different from 133,000 plants/ha plants with 25.5. The lowest chlorophyll content was 24.1 from 88,000 plants/ha plants. In 2024, there was a significant difference in the chlorophyll content of plants from 266,000 plants/ha, 133,000 plants/ha, and 88,000 plants/ha in 2023, the highest chlorophyll content was 26.1 from 88,000 plants/ha plants. The lowest chlorophyll content was 25.2 from 266,000 plants/ha and 88,000 plants/ha.

The combined year shows no significant difference in the chlorophyll content of plants from 266,000 plants/ha, 133,000 plants/ha, and 88,000 plants/ha.

In 2023, there was a significant difference in the chlorophyll content of plants when different fertilizer types were applied, where the highest chlorophyll content was 27.5 when NPK 27:13:13 was applied. The lowest chlorophyll content was 24.4 when NPK 15:15:15 was applied. In 2024, there was a significant difference in the chlorophyll content of plants when different fertilizer types were applied, where the highest chlorophyll content was 26.9 when NPK 27:13:13 was applied. The lowest chlorophyll content was 24.4 when NPK 20:10:10 was applied.

Chlorophyll content increased significantly with fertilizer application rate. Values ranged from approximately 17 SPAD units in the control plots to over 32 SPAD units at 600 kg ha^{-1}. Among fertilizer types, NPK 15:15:15 consistently recorded higher chlorophyll content than the other formulations at comparable rates, indicating better nitrogen uptake efficiency and balanced nutrient supply.

Table 4: Chlorophyll content as influenced by different regimes of inorganic fertilizer application

Treatments	2023	2024	Combined
Plant Population			
266,000 plants/ha	27.1a	25.2b	26.1a
133,000 plants/ha	25.5ab	25.2b	25.3a
88,000 plants/ha	24.1b	26.1a	25.1a
LSD	2.91	0.78	1.43
Fertilizer types			
NPK 15:15:15	24.4b	25.2b	24.8b
NPK 20:10:10	24.8b	24.4c	24.6b
NPK 27:13:13	27.5a	26.9a	27.2a
LSD	1.12	0.54	0.65
Fertilizer levels			
0 kg/ha	17.5d	17.1d	17.3d
200 kg/ha	22.4c	23.4c	22.9c
400 kg/ha	29.8b	28.9b	29.4b
600 kg/ha	32.5a	32.6a	32.5a
LSD	1.04	0.98	0.81
Interactions			
Population x Fertilizer types	ns	Ns	ns
Population x Fertilizer Levels	*	*	*
Fertilizer types x Fertilizer Levels	*	*	*
Population x Fertilizer types x Fertilizer Levels	ns	Ns	ns

Means followed by the same letter(s) in a column of any set of treatments are not significantly different at $p \leq 0.05$ using WAP = weeks after planting. * = Significant at $p \leq 0.05$, NS = Not significant at $p \leq 0.05$.

Mean Tuber Weight (g)

Table 5 shows the mean tuber weight (g) as influenced by different regimes of inorganic fertilizer application, there was a significant difference in mean tuber weight (g) of plants from 266,000 plants/ha, 133,000 plants/ha, and 88,000 plants/ha in 2023, the highest mean tuber weight (g) was 396.4g from 88,000 plants/ha plants. The lowest mean tuber weight (g) was 163.8g from 266,000 plants/ha plants while in 2024, there was a significant difference in the mean tuber weight (g) of plants from 266,000 plants/ha, 133,000 plants/ha, and 88,000 plants/ha, the highest mean tuber weight (g) was 400.7g from 88,000 plants/ha plants, the lowest mean tuber weight (g) was 163.2g from 266,000 plants/ha plants, where the combined year shows a significant difference in the mean tuber weight (g) of plants from 266,000 plants/ha, 133,000 plants/ha, and 88,000 plants/ha, the highest mean tuber weight (g) was 398.6 from 88,000 plants/ha plants, while the lowest mean tuber weight (g) was 163.5 from 266,000 plants/ha plants.

Table 5: Mean tuber weight (g) as influenced by different regimes of inorganic fertilizer application

Treatments	2023	2024	Combined
Plant population			
266,000 plants/ha	163.8c	163.2c	163.5c
133,000 plants/ha	336.6b	335.3b	335.0b
88,000 plants/ha	396.4a	400.7a	398.6a
LSD	42.01	24.2	32.7
Fertilizer types			
NPK 15:15:15	324.0a	325.6a	324.8a
NPK 20:10:10	301.2ab	296.1ab	298.6ab
NPK 27:13:13	271.6b	277.5b	274.6b
LSD	44.76	39.69	40.88
Fertilizer levels			
0 kg/ha	159.4d	154.3d	156.8d
200 kg/ha	254.0c	259.7c	256.8c
400 kg/ha	447.2a	443.5a	445.4a
600 kg/ha	335.2b	341.2b	338.4b
LSD	42.53	44.6	43.7
Interactions			
Population x Fertilizer types	*	*	*
Population x Fertilizer Levels	*	*	*
Fertilizer types x Fertilizer Levels	*	*	*
Population x Fertilizer types x Fertilizer Levels	*	*	*

Means followed by the same letter(s) in a column of any set of treatments are not significantly different at $p \leq 0.05$ using LSD. WAP = weeks after planting. * = Significant at $p \leq 0.01$, NS = Not significant at $p \leq 0.05$.

In 2023, there was a significant difference in the mean tuber weight (g) of plants, as different fertilizer types were applied, where the highest mean tuber weight (g) was 324.0g when NPK 15:15:15 was used, though not statistically different from 301.2g when NPK 20:10:10 was applied. The lowest mean tuber weight (g) was 271.6g when NPK 27:13:13 was applied highest mean tuber weight (g) was 324.8g when NPK 15:15:15 was used, though not statistically different from 298.6g when NPK 20:10:10 was applied. The lowest mean tuber weight (g) was 274.6g when NPK 27:13:13 was applied. Where in 2024, there was a significant difference in the mean tuber weight (g) of plants, as different fertilizer types were applied, where the highest mean tuber weight (g) was 325.6g when NPK 15:15:15 was used, though not statistically different from 296.1g when NPK 20:10:10 was applied. The lowest mean tuber weight (g) was 277.5g when NPK 27:13:13 was applied. The combined year also shows that there was a significant difference in the mean tuber weight (g) of plants, as different fertilizer types were applied, where the

While in 2023, there was a significant difference in the mean tuber weight (g) of plants, as different fertilizer levels were applied, the highest mean tuber weight (g) was 447.2g when 400 kg/ha was applied, while the lowest mean tuber weight (g) was 159.4g when 0 kg/ha was applied. A similar trend was observed both in 2024 and combine, where 400 kg/ha had the highest mean tuber weight and 0 kg/ha had the least.

Mean tuber weigh was significantly affected ($p < 0.05$) by fertilizer type, fertilizer rate, and their interaction with plant population density. The highest yields were consistently obtained from NPK 15:15:15 at 400 kg ha^{-1}, across all population densities. Yield declined slightly at 600 kg ha^{-1}, suggesting nutrient imbalance or excessive vegetative growth. NPK 27:13:13 produced the lowest tuber yield despite vigorous vine growth.

Sett Multiplication Ratio (SMR)

Sett multiplication ratio as influenced by different regimes of inorganic fertilizer application (Table 6), shows significant difference in the sett multiplication ratio of plants from 266,000 plants/ha, 133,000 plants/ha, and 88,000 plants/ha in 2023, the highest sett multiplication ratio was 89.7 from 88,000 plants/ha. The lowest sett multiplication ratio was 38.2 from 266,000 plants/ha. In 2024, there was a significant difference in the sett multiplication ratio of plants from 266,000 plants/ha, 133,000 plants/ha, and 88,000 plants/ha, the highest sett multiplication ratio was 92.8 from 88,000 plants/ha. The lowest sett multiplication ratio was 38.5 from 266,000 plants/ha.

The combined year shows a significant difference in the sett multiplication ratio of plants from 266,000 plants/ha, 133,000 plants/ha, and 88,000 plants/ha the highest sett multiplication ratio was 91.2 from 88,000 plants/ha. The lowest sett multiplication ratio was 38.4 from 266,000 plants/ha. In 2023, 2024, and combined years there was no significant difference in the sett multiplication ratio of plants, as different fertilizer types were applied.

In 2023. There was a significant difference in the sett multiplication ratio of plants, as different fertilizer levels were applied, the highest sett multiplication ratio was 103.3 when 400 kg/ha was applied. The lowest sett multiplication ratio was 35.3 when 0 kg/ha was applied. In 2024. There was a significant difference in the sett multiplication ratio of plants, as different fertilizer levels were applied, the highest sett multiplication ratio was 103.2 when 400 kg/ha was applied. The lowest sett multiplication ratio was 35.3 when 0 kg/ha was applied. Combined, there was a significant difference in the sett multiplication ratio of plants, as different fertilizer levels were applied, the highest sett multiplication ratio was 103.2 when 400 kg/ha was applied. The lowest sett multiplication ratio was 35.3 when 0 kg/ha was applied.

SMR increased with fertilizer application up to 400 kg ha^{-1} and declined slightly thereafter, NPK 15:15:15 produced the highest SMR, confirming its suitability for seed yam production.

Table 6: Sett multiplication ratio as influenced by different regimes of inorganic fertilizer application

Treatments	2023	2024	Combined
Plant population			
266,000 plants/ha	38.2c	38.5c	38.4c
133,000 plants/ha	78.1b	78.7b	78.4b
88,000 plants/ha	89.7a	92.8a	91.2a
LSD	10.93	7.38	8.72
Fertilizer types			
NPK 15:15:15	74.3a	74.4a	74.4a
NPK 20:10:10	67.7a	69.1a	68.4a
NPK 27:13:13	64.0a	66.5a	65.2a
LSD	9.38	10.91	10.71
Fertilizer levels			
0 kg/ha	35.3d	35.3d	35.3d
200 kg/ha	59.1c	62.2c	60.6c
400 kg/ha	103.3a	103.2a	103.2a
600 kg/ha	77.0b	79.3b	78.1b
LSD	10.89	9.39	9.02
Interactions			
Population x Fertilizer types	NS	NS	NS
Population x Fertilizer Levels	*	*	*
Fertilizer types x Fertilizer Levels	NS	NS	NS
Population x Fertilizer types x Fertilizer Levels	NS	NS	NS

Means followed by the same letter(s) in a column of any set of treatments are not significantly different at $p \leq 0.05$ using LSD. WAP = weeks after planting. * = Significant at $p \leq 0.05$, NS = Not significant at $p \leq 0.05$.

Harvest Index

Figure 2 shows the harvest index as influenced by different regimes of inorganic fertilizer application, there was no significant difference in the harvest index of plants from 266,000 plants/ha, 133,000 plants/ha, and 88,000 plants/ha in 2023, 2024, and the combined years. In 2023, 2024, and the combined years. There was no significant difference in the harvest index of plants, as different fertilizer types were applied. In 2023. There was no significant difference in the harvest index of plants, as different fertilizer levels were used.

In 2024, there was a significant difference in the harvest index of plants, as different fertilizer levels were used, the highest harvest index was 75.0 when 0 kg/ha was applied. The lowest harvest index was 71.4 when 600 kg/ha was used. The combined years, there was a significant difference in the harvest index of plants, as different fertilizer levels were applied, the highest harvest index was 72.3 when 0 kg/ha was used, though not significantly different from 71.3 when 200 kg/ha was used. The lowest harvest index was 70.5 when 400 kg/ha, and 600 kg/ha were used.

Harvest index was highest under NPK 15:15:15 at 400 kg ha^{-1} and lowest under NPK 27:13:13, reflecting inefficient assimilate partitioning to tubers in the latter.

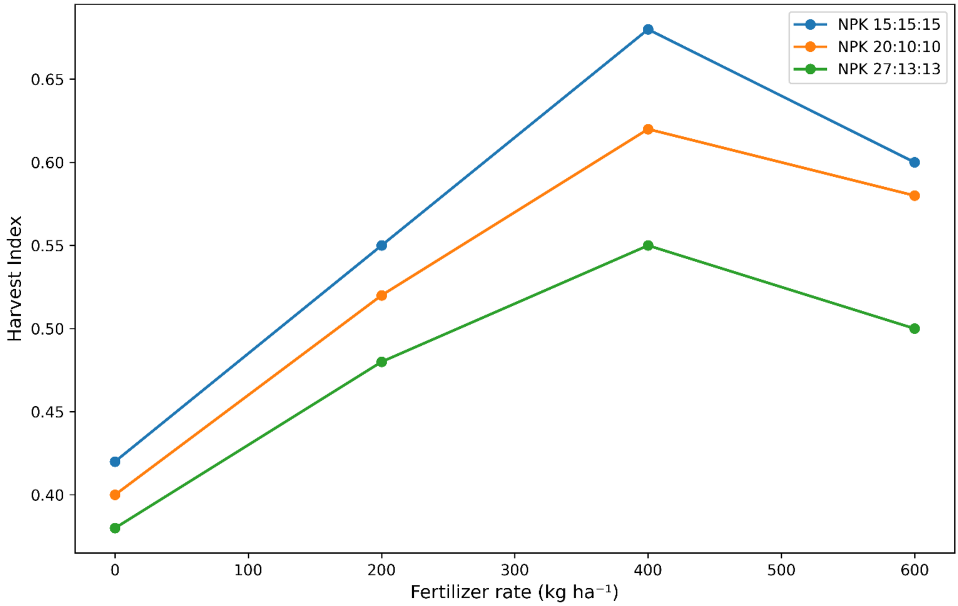

Figure 2: Line graph showing harvest index response to fertilizer rates for each fertilizer type, peaked at 400 kg ha^{-1} under NPK 15:15:15.

DISCUSSION

The response of Kpamyo yam minitubers to fertilizer type and application rate observed in this study confirms the strong dependence of seed yam productivity on balanced nutrient supply under low-fertility savanna soils. The sandy loam soil of the experimental site, characterized by low organic carbon and total nitrogen, provided conditions under which fertilizer effects on growth physiology and yield could be clearly expressed. These findings are in line with previous studies showing that inorganic fertilizers play a vital role in crop growth and yield, they may not directly influence early establishment rates under optimal field conditions (Opkara *et al.,* 2014*)*.

The significantly greater plant height and leaf area index recorded under NPK 27:13:13, especially at higher application rates, reflects the strong stimulatory effect of high nitrogen supply on vegetative growth. Nitrogen is a major structural component of amino acids and chlorophyll, and its abundance enhances cell division, internode elongation, and canopy expansion. However, the excessive vegetative growth observed under this fertilizer type was not matched by corresponding increases in tuber yield, indicating a shift in assimilate partitioning toward shoot biomass rather than storage organs. This supports the source–sink theory earlier described in this study, in which excessive nitrogen promotes source development (leaves and vines) but weakens sink strength in tuber crops when nutrient balance is distorted (Janardhan and Krishna, 2021)

In contrast, NPK 15:15:15 produced relatively moderate vegetative growth but superior yield attributes. This suggests that balanced nutrient ratios favor coordinated development of both photosynthetic organs and storage sinks, enabling efficient translocation of assimilates to developing tubers. Similar trends have been reported in yam fertilizer studies cited in the trial, where moderate vegetative growth combined with adequate potassium supply enhanced carbohydrate translocation and tuber bulking (Ndaeyo *et al*., 2021; Tapgun, 2025).

Chlorophyll content increased significantly with fertilizer rate across all fertilizer types, demonstrating improved nitrogen availability in plant tissues. The consistently higher SPAD values recorded under NPK 15:15:15 suggest superior nitrogen uptake efficiency or more favorable nutrient interactions compared with the other formulations. Balanced NPK supply is known to enhance chloroplast development and stabilize photosynthetic pigments, which in turn sustains higher photosynthetic rates during tuber bulking stages (Tapgun, 2025).

Although NPK 27:13:13 promoted large leaf area, its relatively lower chlorophyll efficiency per unit leaf area indicates that canopy size alone does not determine photosynthetic productivity. Instead, physiological quality of leaves, expressed through chlorophyll concentration and nutrient balance, appears more critical for effective assimilate production and partitioning. This observation corroborates earlier findings that chlorophyll content is a reliable indicator of nitrogen status and yield potential in yam minituber systems (Muoneke *et al.*, 2015; Tapgun, 2025).

The superiority of NPK 15:15:15 at 400 kg ha^{-1} in producing the highest fresh mean tuber weight, harvest index, and sett multiplication ratio confirms this combination as agronomically optimal for seed yam production under the prevailing soil and climatic conditions. The decline in yield at 600 kg ha^{-1} across fertilizer types suggests that excessive nutrient supply does not translate into proportional economic returns and may reduce sink efficiency by favoring vegetative growth.

The poor weight performance of NPK 27:13:13, despite its vigorous canopy development, further highlights the importance of potassium in tuber crops. Potassium plays a central role in carbohydrate transport, enzyme activation, and starch synthesis. A fertilizer formulation with disproportionately high nitrogen relative to potassium may therefore limit effective translocation of photosynthates to tubers, resulting in low harvest index, as observed in this study.

The findings provide strong empirical support for the use of balanced NPK fertilizers in minituber-based seed yam systems. The identification of 400 kg ha^{-1} NPK 15:15:15 as the optimum rate offers a practical recommendation that balances physiological efficiency, tuber weight, and fertilizer economy. Adoption of this nutrient management strategy can enhance multiplication rates, reduce seed yam scarcity, and improve profitability for farmers while minimizing risks of nutrient wastage and environmental degradation.

CONCLUSION

This study demonstrated that fertilizer type and application rate significantly influence growth physiology, chlorophyll dynamics, and mean tuber weight of Kpamyo yam minitubers under the low-fertility conditions of the Southern Guinea Savanna. Although NPK 27:13:13 promoted vigorous vegetative growth, it resulted in lower tuber yield and harvest index, indicating inefficient assimilate partitioning to storage organs. In contrast, NPK 15:15:15 produced higher chlorophyll content, superior tuber yield, greater mean tuber weight, and improved harvest index, reflecting a more balanced nutrient supply and efficient source–sink relationship.

Tuber weight increased with fertilizer rate up to 400 kg ha^{-1} and declined thereafter, showing that excessive fertilization does not translate into proportional weight benefits. Plant population density also affected yield attributes, with higher densities reducing individual tuber size due to increased competition. Overall, the study established that NPK 15:15:15 applied at 400 kg ha^{-1} is the optimum fertilizer regime for maximizing physiological efficiency and seed yam productivity in Kpamyo yam minituber systems.

Farmers and seed yam producers in similar agro-ecological zones are advised to apply NPK 15:15:15 at 400 kg ha^{-1} in split doses to achieve optimal growth and yield of yam minitubers. High-nitrogen fertilizer formulations such as NPK 27:13:13 should be avoided in minituber production due to their tendency to favor vegetative growth over tuber development. Moderate plant population densities should be maintained to reduce competition and enhance tuber size. Routine soil testing and further research on integrated nutrient management combining inorganic fertilizers with organic amendments are also recommended to improve long-term soil fertility and sustainability.

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