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**Original Article**

# INFLUENCE OF INORGANIC AND ORGANIC FERTILIZERS ON GROWTH, YIELD, AND SEED QUALITY OF FOUR GROUNDNUT (*Arachis hypogaea L.*) VARIETIES

**Olayinka, B. U.[1,*], Ogundare, G. O.[1], Babatunde, M. O.[1], Muhammed, G. Y. [1], Lawal, A. R.[2], and Ayinla, A.[3]**

[1]Department of Plant Biology, Faculty of Life Sciences, University of Ilorin, Ilorin, Nigeria.
[2]Department of Plant and Environmental Biology, Kwara State University, Malete, Kwara State.
[3]Department of Biological Sciences, Al-Hikmah University, Ilorin, Kwara State.

[*]*Corresponding author, E-mail:*olayinka.bu@unilorin.edu.ng (Tel: +234-8035670285)

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**ABSTRACT**

Groundnut (*Arachis hypogaea L.*) is a vital oilseed and protein crop in sub-Saharan Africa. As a legume, groundnut can fix atmospheric nitrogen into its root nodules. However, fertilizer application is still necessary when other essential nutrients needed for improving the quality and productivity of the seeds are limited in the soil. This study therefore investigated the effects of organic (Super GRO at 200 ml/ha) and inorganic fertilizers (NPK 15:15:15 at 200 kg/ha, single superphosphate (SSP) at 60 kg/ha) on the growth, yield, and seed quality of four groundnut varieties (SAMNUT 23, SAMNUT 24, SAMNUT 25, and SAMNUT 28). Data collected were subjected to two-way analysis of variance to test significant differences among the varieties and fertilizer treatments at $p<0.05$. The inorganic fertilizers (NPK and SSP) had a marked influence on both pod and seed yield when compared to the organic fertiliser (Super GRO), where the latter promoted higher vegetative growth. Varietal differences indicated that pod and seed yield were significantly highest in SAMNUT 24 and lowest in SAMNUT 23. Regardless of variety and fertiliser, the percentage moisture, ash, fibre, protein, fat, and carbohydrate ranged from 9.60-9.91%, 1.22-1.19%, 2.20-2.10%, 18.63-19.47%, 39.67-40.58%, and 27.20-28.38%, respectively. SAMNUT 24 had the highest protein content in its seeds, while SAMNUTS 28 and 23 had the highest fat and energy values when they were compared to other varieties. The organic Super Gro promoted higher carbohydrate accumulation with limited protein, fat, and fibre and energy values when compared to inorganic fertilisers. The foregoing results indicated that SAMNUT 24 and SAMNUT 25 responded positively to fertiliser application, most importantly, the inorganic fertilisers. The cultivation of these varieties under inorganic fertilisers should be encouraged where there is low soil fertility.

**Keywords:** Groundnut, fertilizer types, growth, yield, seed quality, SAMNUT varieties, Ilorin

## 1. INTRODUCTION

Groundnut (*Arachis hypogaea L.*), also known as peanut, is one of the most economically and nutritionally important leguminous crops grown worldwide. It is a major source of edible oil, protein, besides being a source of income for smallholder farmers, particularly in the semi-arid and sub-humid tropics (Olayinka and Etejere, 2015; Melesse *et al*., 2023). In Nigeria, groundnut plays a key role in the agricultural economy, ensuring food security, improving soil fertility, and providing livelihoods in rural areas. However, productivity still remains low due to nutrient depletion, erratic rainfall, and poor adoption of improved agronomic practices.

Fertilizer management is among the most critical determinants of groundnut growth, yield, as well as seed quality. Although groundnut can fix atmospheric nitrogen through symbiotic relationships with Rhizobium, other essential nutrients, especially phosphorus, and to a lesser extent potassium, often limit growth in Nigerian soils (Kayode, 2009; Ibrahim, 2016; Suleiman, 2021). Inorganic phosphorus fertilizer in the form of single superphosphate (SSP) provides readily available phosphorus, which enhances both vegetative and reproductive growth in peanut (Naab *et al*., 2009). Organic fertilizer, such as composts and manures, enhance soil structure, stimulate microbial activity, and improve nutrient retention in soil (Litterick *et al*., 2003). A balanced use of organic and inorganic nutrient sources through integrated nutrient management (INM) has been shown to enhance sustainable groundnut production by improving soil biological health, nutrient uptake, and long-term yield (Ushasri et al., 2023). Several earlier works have focused on the impact of fertilizer types on growth and yield (Reddy et al., 2011) and on seed quality characteristics such as protein and oil content (Gulluoglu et al., 2016), scarcely any have addressed the effect of different fertilizer types on both agronomic and quality parameters across improved groundnut varieties. This study integrated the mentioned aspects to evaluate the impact of organic and inorganic fertilizers on the growth, yield, and seed quality of four groundnut varieties. The overall intention is to unravel varietal responses and isolate the fertilizer types that promote higher biological productivity without compromising seed quality.

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## 2. MATERIALS AND METHODS

### Experimental Site:

The experiment was conducted at the University of Ilorin Botanical Garden, Ilorin, Nigeria (8°30′N, 4°33′E), under rainfed in 2024 cropping season. The site falls within the Southern Guinea Savanna ecological zone with a bimodal rainfall pattern, amounting to an average annual rainfall of 900-1,200 mm and an average temperature of 27°C.

### Experimental Design and Treatment Details:

The experiment was laid out as a 4 × 4 factorial in a Randomized Complete Block Design (RCBD) with three replications, giving a total of 48 experimental plots. The first factor was variety at four levels (SAMNUT 23, SAMNUT 24, SAMNUT 25, and SAMNUT 28), and the second factor was fertilizer at four levels: NPK (15:15:15) at 200 kg/ha, single superphosphate (SSP) at 60 kg/ha, organic Super Gro at 200 ml/ha, and an unfertilized control. Each plot contained eight plants, giving 24 plants per fertilizer treatment per variety across the three replications (n = 3 plot means per treatment combination). NPK and SSP were applied as side-dressings at two weeks after planting, and Super Gro was applied as a foliar spray at two weeks after planting and again at anthesis (between the fourth and fifth week after planting). The active ingredient of Super Gro was ethoxylated alkyl phenol (20%).

### Data Collection:

#### Morphological and Yield Characters:

The morphological growth parameters such as plant height, number of leaves, number of branches, Leaf area and total dry weight were recorded at harvest period. The yield attributes such as number of pods per plant, pod weight per plant, number of seeds per plant and seed weight per plant and 100-seed weight, were determined on the harvested pods. Pod and seed yield in kg/ha and harvest index as measures of economical yield over biological yield were also determined. The Mettler balance of precision of 0.01 was used, where the weight was to be determined.

#### Seed Quality:

The proximate of the seeds was determined by the methods of the Association of Official Analytical Chemists (AOAC, 2005). Moisture content was determined using the air oven method after drying at 103-105 ºC. The ash content was determined by incinerating it in a muffle furnace until the sample turned to ash. The crude protein and fat were determined using the micro-Kjeldahl method and Soxhlet apparatus, respectively. The crude fibre was determined by taking the lipid free sample obtained after ether extraction. Subsequently, the sample was serially heated with dilute acid and alkali to hydrolyze the digestible portion. The residual sample dried and weighed was the fiber content which is less the weight of the ash. The total carbohydrate was calculated as 100 - (Sum of the percentages of moisture, ash, fat, protein, and crude fiber). Energy value was calculated by multiplying protein and carbohydrate by 4kcal/g and fat by 9 kcal/g.

### Data Analysis:

Data collected were subjected to Two-way ANOVA using Statistical Package for Social Science (SPSS v.25). Means of treatments were separated using Duncan's Multiple Range Test, $p < 0.05$ level of significance.

## RESULTS

### Fertilizer Effect on Growth and Physiological Characters:

Growth and physiological characters in terms of plant height, number of leaves, and number of primary branches, leaf area and above-ground dry weight varied significantly by variety. Fertilizer treatment did not significantly affect the foregoing parameters except for leaf area (Table 1). The interaction effect was significant only for above-ground dry weight where the influence of fertilization application was not too pronounced on SAMNUTS 25 and 28. Varietal differences indicated that SAMNUTS 23 and 24 showed significantly higher growth and physiological attributes when compared to other varieties (Table 1). SAMNUT 25 had significantly lowest values of all the mentioned attributes. As earlier mentioned, parameters such as plant height, number of leaves, number of primary branches were not significantly affected by fertilizers application when compared with the control. However, the effect of fertilizer was only pronounced on leaf area where all the fertilizers had higher values of leaf area than the control (Table 1).

**Table 1:** Growth and physiological characteristics of four groundnut varieties as influenced by different fertilizers.

| Variety (V) | No. of Leaves | Plant Height (cm) | No. of Branches | Leaf Area ($m^2$) | Above-ground dry weight (g) |
|---|---|---|---|---|---|
| SAMNUT 23 | $110.67^{a}$ | $27.26^{ab}$ | $9.08^{a}$ | $13.03^{a}$ | $20.18^{a}$ |
| SAMNUT 24 | $108.25^{a}$ | $29.67^{a}$ | $6.42^{b}$ | $13.40^{a}$ | $18.24^{a}$ |
| SAMNUT 25 | $87.33^{ab}$ | $25.00^{b}$ | $4.75^{c}$ | $9.10^{b}$ | $11.60^{b}$ |
| SAMNUT 28 | $79.67^{b}$ | $26.75^{ab}$ | $5.42^{bc}$ | $11.51^{a}$ | $11.14^{b}$ |
| SEM | 7.713 | 1.160 | 0.389 | 0.637 | 1.267 |
| **Treatment (T)** | | | | | |
| Control | $101.5^{a}$ | $26.33^{a}$ | $6.75^{a}$ | $11.06^{b}$ | $15.06^{a}$ |
| NPK (200kg/ha) | $94.58^{a}$ | $26.92^{a}$ | $6.50^{a}$ | $11.49^{ab}$ | $14.35^{a}$ |
| Phosphate (60 kg/ha) | $93.00^{a}$ | $28.33^{a}$ | $6.00^{a}$ | $13.08^{a}$ | $14.28^{a}$ |
| Super Gro (200 ml/ha) | $96.83^{a}$ | $27.29^{a}$ | $6.42^{a}$ | $11.36^{ab}$ | $17.47^{a}$ |
| SEM | 7.71 | 1.16 | 0.39 | 0.64 | 1.27 |
| **Interaction** | | | | | |
| V | 0.017 | 0.037 | < 0.0001 | 0.041 | < 0.0001 |
| T | 0.875 | 0.668 | 0.593 | 0.159 | 0.262 |
| V * T | 0.165 | 0.356 | 0.105 | 0.245 | < 0.0001 |

Values followed by the same superscript across columns are not significantly different at $p < 0.05$.
Values are represented by the mean. SEM = Standard error of the mean. Number of replicates (n=3).

### Fertilizer Effect on Yield Component

The results of yield attributes differed significantly by variety. Variation in yield attributes were statistically similar under fertilizer except for 100-seed weight (Table 2). The interaction effect showed similar patterns as recorded for fertilizer effect. Varietal mean indicated that SAMNUT 24 had significantly higher number of pods per plant (20.75), pod weight per plant (15.90 g), number of seeds per plant (37.67) and seed weight per plant (11.66 g) when compared to other varieties. 100-seed weight was significantly highest in SAMNUT 28 (52.60g) and followed in decreasing order of magnitude by those SAMNUT 25 (47.48g) and SAMNUT 23 (47.29 g). Lowest value of 100-seed weight was recorded for SAMNUT 24 (34.86 g). As earlier mentioned, significant difference was only recorded for 100-seed weight under fertilizer effect where NPK and Single Super Phosphate recorded higher values of 48.65 g and 45.15 g respectively when compared to Super Gro and control with respective mean values of 43.49 g and 44.95 g (Table 2). A significant variety × fertilizer interaction was recorded only for 100-seed weight ($p < 0.0001$), where SAMNUT 24 showed a weaker response to fertilizer application than the other three varieties. For number of pods, pod weight per plant, seed weight per plant, and number of seeds per plant, the interaction effect was not significant ($p > 0.05$), indicating that varietal performance for these attributes was consistent across fertilizer treatments.

### Fertilizer Effect on Yield and Harvest Index:

Yield and harvest index differed significantly by variety and fertilizer application. The interaction effect was also significant for all the parameters. Varietal mean indicated that significantly highest pod (1024.92 kg/ha) were recorded in SAMNUT 24 and followed in decreasing order of magnitude by those of SAMNUT 23 (898.76), SAMNUT 25 (887.44 kg/ha) and SAMNUT 28 (875.16 kg/ha.). The results of seeds yield followed similar pattern except that significantly lower seed yield value of 548.24 kg was recorded in SAMNUT 23 when compared with other varieties, with ranged values of 592.28 kg/ha in SAMNUT 28, 599.40 kg/ha in SAMNUT 25, to 707.16 kg/ha in SAMNUT 24 (Table 3). The results of harvest index showed significantly higher values in SAMNUTS 24, 25 and 28 when compared to SAMNUT 23. The interaction effect indicated that all the varieties in terms of forgoing parameters were influenced by fertilizer application (Table 3).

### Fertilizer Effect on Seed Quality:

The results of proximate composition and energy value of the seeds differed significantly by variety and fertilizer application, except for ash and protein, as indicated in Table 4. The interaction effects were significant. Regardless of the varieties and fertilizer application, percentage moisture, ash, fibre, protein, fat, and carbohydrate ranged from 9.60-9.91%, 1.19-1.22%, 2.10-2.20%, 18.63-19.47%, 39.67-40.58%, and 27.20-28.38% respectively. Varietal and Fat means indicated that SAMNUT 23 had significantly higher fibre (2.20%) and fat (40.45%) contents in its seed when compared to other varieties. However, the fat content of SAMNUT 23 was at par with that of SAMNUT 28 (40.43%) (Table 4). Percentage moisture content was significantly highest in SAMNT 25 (9.90%) and followed in decreasing order of magnitude by those of SAMNUT 28 and SAMNUT 24 with mean values of 9.86% and 9.69%, respectively. The lowest moisture value of 9.67 was recorded for SAMNUT 23. Protein content did not differ significantly among varieties ($p = 0.053$), with values ranging from 18.76% in SAMNUT 25 to 19.47% in SAMNUT 24. SAMNUT 25 showed a significantly higher carbohydrate value of 28.30% than all other varieties, which ranged from 27.20% in SAMNUT 28 to 27.61% in SAMNUT 23. The results of energy values followed the same pattern as that of fat content (Table 4). The effect of fertilizer on seed quality did not follow a definite pattern. However, the organic fertilizer Super Gro generally limited all the proximate composition parameters and energy value except for carbohydrate, where it was significantly higher when compared to other fertilizers and control (Table 4). Among the fertilizers, SSP and NPK generally had a marked influence on most of the proximate composition parameters, as indicated in Table 4. The interaction effect clearly showed that the accumulation of biochemical compounds in seeds varied from one variety to another under fertilizer application.

## 3. DISCUSSION

These results indicate that there is substantial variation in growth and yield characteristics among groundnut varieties, with fertilizer applications exerting an influence but not eliminating these differences. SAMNUT 24 emerged as the superior performing variety in terms of overall productivity, achieving the highest pod yield (1024.92 kg/ha) and seed yield (707.16 kg/ha), despite not exhibiting the most vegetative growth. These findings align with previous reports by Ibrahim *et al*. (2021), who noted enhanced yield and growth traits in SAMNUT 24 under optimized spacing and irrigation. Similarly, Suleiman (2021) has demonstrated that SAMNUT 24 responds well to combined input treatments in the savanna zones.

**Table 2:** Yield components of groundnut varieties as influenced by fertilizer types.

| Variety | No. of Pods | Pod Weight per Plant (g) | Seed Weight per plant (g) | No. of seeds per plant | 100 seeds weight (g) |
|---|---|---|---|---|---|
| SAMNUT 23 | 13.67$^{b}$ | 12.30$^{b}$ | 7.49$^{bc}$ | 20.33$^{b}$ | 47.29$^{c}$ |
| SAMNUT 24 | 20.75$^{a}$ | 15.90$^{a}$ | 11.66$^{a}$ | 37.67$^{a}$ | 34.86$^{d}$ |
| SAMNUT 25 | 11.75$^{b}$ | 9.09$^{c}$ | 6.30$^{c}$ | 18.00$^{b}$ | 47.48$^{b}$ |
| SAMNUT 28 | 11.58$^{b}$ | 13.14$^{ab}$ | 9.15$^{b}$ | 19.42$^{b}$ | 52.60$^{a}$ |
| SEM | 0.786 | 0.984 | 0.719 | 1.640 | 0.027 |
| **Treatment** | | | | | |
| Control | 15.17$^{a}$ | 12.34$^{a}$ | 8.61$^{a}$ | 24.25$^{a}$ | 44.95$^{c}$ |
| NPK (200kg/ha) | 14.67$^{a}$ | 13.80$^{a}$ | 9.53$^{a}$ | 25.25$^{a}$ | 48.65$^{a}$ |
| Phosphate (60kg/ha) | 13.58$^{a}$ | 12.73$^{a}$ | 8.87$^{a}$ | 23.17$^{a}$ | 45.15$^{b}$ |
| Organic (200ml/ha) | 14.33$^{a}$ | 11.55$^{a}$ | 8.61$^{a}$ | 22.75$^{a}$ | 43.49$^{d}$ |
| SEM | 0.786 | 0.984 | 0.719 | 1.640 | 0.027 |
| **Interaction** | | | | | |
| V | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 |
| T | 0.551 | 0.448 | 0.306 | 0.705 | < 0.0001 |
| V * T | 0.10 | 0.879 | 0.468 | 0.543 | < 0.0001 |

Values followed by the same superscript across columns are not significantly different at $p < 0.05$.
Values are represented by the mean. SEM = Standard error of the mean. Number of replicates (n=3).

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**Table 3:** Yield parameters and Harvest index of groundnut varieties as influenced by fertilizer types.

| Variety | Pod yield (kg/ha) | Seed yield (kg/ha) | Harvest Index (%) |
|---|---|---|---|
| SAMNUT 23 | 898.76[b] | 548.24[d] | 27.92[b] |
| SAMNUT 24 | 1024.92[a] | 707.16[a] | 31.75[a] |
| SAMNUT 25 | 887.44[c] | 599.40[b] | 31.82[a] |
| SAMNUT 28 | 875.16[d] | 592.28[c] | 32.09[a] |
| SEM | 0.015 | 0.007 | 0.163 |
| **Treatment** | | | |
| Control | 927.80[c] | 610.84[c] | 30.84[b] |
| NPK (200kg/ha) | 948.92[b] | 651.64[a] | 31.78[a] |
| Phosphate (60kg/ha) | 970.80[a] | 640.48[b] | 30.95[b] |
| Super Gro (200ml/ha) | 838.84[d] | 544.12[d] | 30.00[c] |
| SEM | 0.015 | 0.007 | 0.163 |
| **Interaction** | | | |
| V | < 0.0001 | < 0.0001 | < 0.0001 |
| T | < 0.0001 | < 0.0001 | < 0.0001 |
| V * T | < 0.0001 | < 0.0001 | < 0.0001 |

Values followed by the same superscript across columns are not significantly different at $p < 0.05$.
Values are represented by the mean. SEM = Standard error of the mean. Number of replicates (n=3).

**Table 4:** Proximate composition of groundnut varieties as influenced by fertilizer types.

| Variety | Moisture (%) | Ash (%) | Fibre (%) | Protein (%) | Fat (%) | Carbohydrate (%) | Energy (kcal/100g) |
|---|---|---|---|---|---|---|---|
| SAMNUT 23 | 9.67[c] | 1.21[a] | 2.20[a] | 18.86[ab] | 40.45[a] | 27.61[ab] | 483.15[a] |
| SAMNUT 24 | 9.69[c] | 1.20[a] | 2.16[b] | 19.47[a] | 39.97[b] | 27.50[b] | 480.26[b] |
| SAMNUT 25 | 9.90[a] | 1.21[a] | 2.10[d] | 18.76[b] | 39.72[b] | 28.30[a] | 479.27[b] |
| SAMNUT 28 | 9.86[b] | 1.20[a] | 2.13[c] | 19.12[ab] | 40.43[a] | 27.20[b] | 482.34[a] |
| SEM | 0.011 | 0.007 | 0.007 | 0.210 | 0.114 | 0.234 | 0.614 |
| **Treatment** | | | | | | | |
| Control | 9.91[a] | 1.21[a] | 2.17[a] | 19.25[a] | 40.52[a] | 26.85[c] | 482.19[ab] |
| NPK (200kg/ha) | 9.69[b] | 1.20[ab] | 2.18[a] | 19.32[a] | 40.02[b] | 27.65[b] | 480.64[bc] |
| Phosphate (60kg/ha) | 9.92[a] | 1.22[a] | 2.12[b] | 19.03[ab] | 40.58[a] | 27.54[bc] | 483.42[a] |
| Super Gro (200ml/ha) | 9.60[c] | 1.19[b] | 2.12[b] | 18.63[b] | 39.67[c] | 28.38[a] | 479.81[c] |
| SEM | 0.011 | 0.007 | 0.007 | 0.210 | 0.114 | 0.234 | 0.614 |
| **Interaction** | | | | | | | |
| V | < 0.0001 | 0.616 | < 0.0001 | 0.053 | 0.001 | 0.033 | 0.002 |
| T | < 0.0001 | 0.057 | < 0.0001 | 0.074 | < 0.0001 | 0.001 | 0.009 |
| V * T | < 0.0001 | 0.002 | < 0.0001 | 0.009 | < 0.0001 | < 0.0001 | < 0.0001 |

Means followed by the same letter (s) along the column are statistically the same at $p < 0.05$.

In contrast, SAMNUT 23 displayed the most pronounced vegetative growth, recording the highest leaf number, branch count and total dry matter accumulation. However, this did not translate proportionally into superior yield like SAMNUT 24. This lack of proportion between the vegetative growth and reproductive output in SAMNUT 23 may suggest a limitation in its ability to translocate photosynthates to reproductive parts like the developing pods. The higher vegetative growth observed in SAMNUT 23 under organic manure treatment tallies with observations made by Obabire *et al*. (2024), who reported that poultry manure and NPK fertilizer produced statistically comparable vegetative growth and yield in groundnut, and corroborates with broader evidence that composts and manures improve biological activity and nutrient release in soils through the improvement of structure and porosity (Litterick *et al*., 2003).

While fertilizer treatments did not produce outstanding differences in most vegetative parameters, they exert a substantial influence on yield components and seed quality. However, phosphate fertilizer application significantly enhanced leaf area, which has implications for the photosynthetic capacity and efficiency during very critical growth stage. The increase in pod yield and 100-seed weight from NPK fertilizer application agrees with reports by Patil *et al*. (2017), who reported similar yield improvements. Phosphorus application via SSP significantly enhances peanut growth and yield, highlighting the vital role of phosphorus in seed development and yield, a finding consistent with the observations of Naab *et al*. (2009). Phosphorus plays essential roles in energy transfer, nucleic acid synthesis, and membrane integrity, all of which are crucial during the rapid cell division and expansion that characterizes seed development.

The organic fertilizer treatment produced seeds with elevated carbohydrate content. This outcome reflects the fact that organic fertilizers enhance carbohydrate accumulation due to a more gradual nutrient supply and the promotion of photosynthetic activity (Chaudhary *et al*., 2020; Zhang *et al*., 2023). The proximate analysis also revealed that fertilizer type most importantly SSP and NPK influenced seed nutritional composition. NPK fertilization enhanced both protein content and crude fiber suggesting an improvement in nitrogen assimilation. Groundnut protein quality is important given the crop's role as a protein source in resource-limited settings, making this fertilizer effect nutritionally significant. The moisture content of the four varieties of groundnut showed minimal variation, indicating generally uniform dryness across samples. Values obtained in this study were somewhat different from those reported by Musa *et al*. (2010) and Olayinka *et al*. (2025), which were expected due to varietal characteristics, agronomic practices, drying conditions, and the duration of drying before analysis, as earlier noted by Olayinka *et al*. (2023).

The ash content in the groundnut varieties was quite uniform, as would be expected from their similar mineral composition, presumably controlled by genetic rather than external treatment factors. The values fall within ranges reported for Nigerian groundnuts (Yusuf *et al*., 2017; Olayinka & Etejere, 2013) and may indicate these varieties are a reliable source of minerals in the diet.

## 4. CONCLUSION

The foregoing results indicated that SAMNUT 24 and SAMNUT 25 responded positively to fertiliser application, most importantly, the inorganic fertilisers. The inorganic fertilisers (NPK and SSP) had a marked influence on both pod and seed yield, protein content, fat, and energy values when compared to the organic fertiliser (Super GRO), where the latter promoted higher vegetative growth and carbohydrate accumulation. However, fertilizer application is still necessary when other essential nutrients needed for improving the quality and productivity of the seeds are limited in the soil. The cultivation of these varieties under inorganic fertilisers should be encouraged where there is low soil fertility.

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### Ethical Statement:

Ethical approval was not required for this study, as it involved only field experimentation on cultivated crop plants and did not include human participants, human tissue, or animal subjects.

### Conflict of Interests:

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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### Author Contributions:

B. U. O. conceptualized and designed the study, supervised the experiment, and prepared the original draft. G. O. O. conducted the field experiment and collected data. M. O. B. and G. Y. M. contributed to data collection, laboratory analyses, and data curation. A. R. Lawal performed the statistical analysis and contributed to interpretation of the results. A. Ayinla contributed to methodology, interpretation of results, and manuscript revision. All authors read and approved the final version of the manuscript.

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