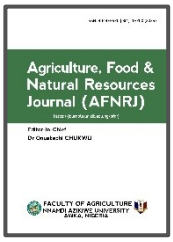
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Original Article

# Effects of cropping system and fertilizer application on growth and yield of sorghum and groundnut in Igbariam, Nigeria

OPEN ACCESS

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**ABSTRACT**

*This study evaluated the effects of cropping system and Nitrogen: Phosphorus: Potassium (NPK) fertilizer application on the growth and yield of sorghum (Sorghum bicolor L. Moench) and groundnut (Arachis hypogaea L.) under sole and intercropping systems in Igbariam, southeastern Nigeria. Field experiments were conducted during the 2024 and 2025 cropping seasons using a factorial arrangement in a randomized complete block design with three replications. Four NPK (12:12:17 + 2MgO) fertilizer rates (0, 100, 200 and 300 kg ha$^{-1}$) were evaluated under sole and intercrop production systems. Data collected on growth and yield components were subjected to analysis of variance, and treatment means were separated using the Least Significant Difference test at the 5% probability level. Results obtained showed that the cropping system and fertilizer application significantly influenced the growth and yield of both crops. Sole sorghum generally exhibited superior vegetative growth and yield attributes compared to intercropped sorghum, while sole groundnut consistently outperformed intercropped groundnut in plant height, leaf production, and reproductive development. Fertilizer application significantly enhanced crop growth and yield, with the greatest responses generally recorded at 200-300 kg ha$^{-1}$. Although intercropping resulted in some competitive effects that reduced crop performance, adequate fertilizer application partially mitigated these effects and improved crop productivity. These results indicated that balanced nutrient management is essential for sustaining productivity in sorghum–groundnut intercropping systems. Under the conditions of this study, application of 200–300 kg ha$^{-1}$ NPK (12:12:17 + 2MgO) is recommended for improved growth and productivity, particularly where sole cropping or well-managed intercropping systems are practiced.*

**KEYWORDS:** *Arachis hypogaea, Cropping system, Intercropping, NPK fertilizer, Sorghum bicolor.*

## INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) and groundnut (*Arachis hypogaea* L.) are important crops in Nigeria, contributing to food security, rural livelihoods and agro-industrial development. Sorghum is particularly valued for its drought tolerance, adaptability to low-input production and diverse uses as food, livestock feed and industrial raw material (Maman *et al*., 2017; FAOSTAT, 2024). Groundnut provides protein-rich seeds and edible oil and contributes to soil fertility through biological nitrogen fixation (Ajeigbe *et al*., 2015; Okello *et al*., 2010). Both crops therefore have important roles in sustainable production and household income, especially where mixed cropping is widely practiced (Ngonadi & Okoli, 2023).

Sorghum-groundnut intercropping is common among smallholder farmers because it improves land-use efficiency,

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diversifies production, suppresses weeds and can reduce production risks associated with climate variability (Nweke, 2018; Egbe, 2010; Abba *et al*., 2024). It can also improve resource-use efficiency and biodiversity. However, its success depends on the balance between complementarity and competition. Competition for light, moisture and nutrients can reduce groundnut growth and yield when associated with the more competitive sorghum crop (Mucheru-Muna *et al*., 2010; Maman *et al*., 2017). Appropriate agronomic management is therefore needed to improve resource use while minimizing competition.

Cropping arrangement, plant density and soil fertility influence the productivity of cereal-legume intercrops, with nutrient management playing a particularly important role (Agele *et al*., 2018; Abba *et al*., 2024; Obabire *et al*., 2024). Balanced NPK fertilization supports crop growth through the complementary roles of nitrogen in vegetative development, phosphorus in root and reproductive growth, and potassium in assimilate movement, water regulation and stress tolerance (Brady & Weil, 2016). Previous studies have reported improved sorghum growth and yield with NPK fertilization (Ibrahim *et al*., 2022; Ngala *et al*., 2021), as well as improved groundnut growth and productivity (Azu *et al*., 2019; Maman *et al*., 2017).

Despite these findings, limited information is available on the interactive effects of cropping system and NPK rates on the growth and yield of both crops under the same production conditions. This information is important for developing fertilizer strategies that improve productivity while reducing interspecific competition. Therefore, this study evaluated the effects of cropping system and NPK fertilizer application on the growth and yield of sorghum and groundnut under sole and intercropping systems in Igbariam, southeastern Nigeria.

## MATERIALS AND METHOD

**Study Area**: The field experiment was conducted during the 2024 and 2025 cropping seasons at the Teaching and Research Farm of the Department of Crop Science and Horticulture, Chukwuemeka Odumegwu Ojukwu University, Igbariam Campus, Anambra State, Nigeria. The experimental site is located at approximately 6.39° N latitude and 6.95° E longitude, within the humid rainforest agroecological zone of southeastern Nigeria, at an altitude of about 120 m above sea level. The area is characterized by a bimodal rainfall pattern with favourable conditions for cereal and legume production.

**Experimental Design and Treatments**: The experiment was factorial laid out in a Randomized Complete Block Design (RCBD) with three replications during the 2024 and 2025 cropping seasons. Seeds of adapted sorghum (Samsorg 52) and groundnut (Samnut 27) varieties commonly cultivated by farmers in Igbariam were used for the study. The treatments consisted of cropping system (Sole sorghum, sole groundnut and sorghum-groundnut intercrop) and four rates of NPK fertilizer (12:12:17 + 2MgO): 0, 100, 200 and 300 kg ha$^{-1}$. The treatment combinations were randomly allocated within each replication according to the experimental design.

**Land Preparation and Crop Establishment**: The experimental field was manually cleared, ploughed and harrowed, after which ridges were constructed according to the experimental layout. Soil samples were collected randomly from the experimental site before planting for physicochemical analysis. Planting was carried out at the onset of the rainy season in each cropping year to ensure adequate soil moisture for seed germination and crop establishment. The Sorghum was planted at a spacing of 75 cm × 25 cm, while groundnut was planted at 75 cm × 30 cm, in accordance with the recommended agronomic practices for the crops under Nigerian conditions. Three seeds were sown per hole and later thinned two weeks after planting to one plant per stand for sorghum and two plants per stand for groundnut to obtain a uniform plant population.

**Plot Size and Crop Management**:

Each experimental plot measured 2 m × 2 m (4 m²). Based on the adopted planting geometry, each sole sorghum plot accommodated approximately 24 plants, while each sole groundnut plot accommodated approximately 32 planting stands (64 plants after thinning). Plant population in the intercrop plots depended on the row arrangement adopted for the respective treatment combinations. NPK (12:12:17 + 2MgO) fertilizer was applied three weeks after sowing (3 WAS) using the band placement method immediately after the first manual hoe weeding. The fertilizer was placed approximately 5 - 8 cm away from the crop rows and lightly covered with soil to reduce nutrient losses and improve fertilizer-use efficiency.

Weeds were controlled manually using a hand hoe. The first hoe weeding was carried out three weeks after sowing before fertilizer application, while subsequent weeding operations were undertaken as required to maintain a relatively weed-free field throughout the crop growth period.

**Data Collection**

***Plant height:*** This was measured from the soil surface to the tip of the youngest fully expanded leaf at 4, 8 and 12 weeks after planting (WAP). Measurements were taken from six randomly selected plants per plot using a meter ruler.

***Number of leaves per plant:*** Fully expanded green leaves was counted on six randomly selected plants per plot at 4, 8 and 12 WAP.

***Number of panicles per plant:*** Sorghum panicles per plant on the six randomly sampled plants was taken at maturity per plant.

***Number of pods per plant:*** Number of pod per plant on the six randomly sampled plants was taken at maturity per plant.

**Data analysis**

Data collected were subjected to analysis of variance (ANOVA) using GenStat statistical software. Treatment means were separated using the Least Significant Difference (LSD) test at the 5% probability level.

## RESULTS AND DISCUSSION

**Physical and Chemical Properties of Soil at the Experimental Site**

The selected physical and chemical properties of the experimental soil before planting are presented in Table 1. In both cropping seasons, the soil was classified as sandy clay loam, with slightly acidic pH values of 5.98 in 2024 and 6.15 in 2025, which are suitable for sorghum and groundnut production. Organic nitrogen was generally low, while available phosphorus was moderate. Calcium and magnesium were the dominant exchangeable bases, whereas sodium and potassium were relatively low. The ECEC and base saturation indicated moderate nutrient-retention capacity and satisfactory soil fertility. Bulk density (1.39 and 1.35 g $cm^{-3}$) and total porosity (48.92 and 47.57%) in 2024 and 2025, respectively, suggested favourable conditions for root growth, water movement and aeration. The relatively similar soil properties across seasons provided a uniform basis for assessing the effects of cropping system and fertilizer application.

**Table 1: Selected physical and chemical properties of the experimental soil before planting**

| Parameters | 2024 | 2025 |
|---|---|---|
| Clay (g/kg) | 230 | 250 |
| Silt (g/kg) | 210 | 230 |
| Fine sand (g/kg) | 420 | 450 |
| Coarse sand (g/kg) | 160 | 200 |
| Textural class- | Sandy clay loam | Sandy clay loam |
| Bulk Density ($gm^{-3}$) | 1.39 | 1.35 |
| Total porosity (%) | 48.92 | 47.57 |
| Moisture Content (%) | 20.52 | 20.75 |
| Dispersion Ratio (%) | 0.87 | 0.74 |
| Aggregate Stability (%) | 17.02 | 16.51 |
| Hydraulic-conductivity ($cmhr^{-1}$) | 4.59 | 5.1 |
| pH (H2O 1:1) | 5.98 | 6.15 |
| Nitrogen (%) | 0.055 | 0.025 |
| Available Phosphorus ($mgkg^{-1}$) | 3.89 | 5 |
| Calcium ($Ca^{2+}$) ($cmolkg^{-1}$) | 1.5 | 1.3 |
| Magnesium ($Mg^{2+}$) ($cmolkg^{-1}$) | 1.3 | 1.15 |
| Sodium ($Na^{+}$) ($cmolkg^{-1}$) | 0.24 | 0.18 |
| Potassium ($K^{+}$) ($cmolkg^{-1}$) | 0.26 | 0.2 |
| ECEC ($cmolkg^{-1}$) | 4.99 | 5.45 |
| Base Saturation (%) | 87 | 89 |

*ECEC: Effective Cation Exchange Capacity*

The slightly acidic reaction and sandy clay loam texture are typical of cultivated soils in southeastern Nigeria, where high rainfall promotes leaching of basic cations and gradual acidification. Although the soil pH was suitable for both crops, the low nitrogen status supports the need for NPK fertilization, particularly because nitrogen is often limiting in tropical soils. The favourable bulk density and porosity also suggest adequate conditions for root development and soil aeration. Similar soil characteristics and positive crop responses to balanced fertilization have been reported in southeastern Nigeria (Brady & Weil, 2016; Nweke, 2019).

**Effect of Cropping System and NPK Fertilizer on Sorghum Plant Height**

The interaction effects of cropping system and NPK fertilizer rate on sorghum plant height are presented in Table 2. Plant height increased significantly ($P \leq 0.05$) with increasing NPK rates in both seasons. In 2024, sole sorghum was taller than intercropped sorghum, with the highest height recorded at 300 kg $ha^{-1}$ NPK at 12 WAP. In 2025, however, intercropped sorghum was taller at 200 and 300 kg $ha^{-1}$ NPK. Significant interactions occurred from 8 WAP in both seasons, except at 4 WAP in 2025, showing that treatment effects became more evident as vegetative growth progressed.

The increased plant height with NPK application reflects the importance of balanced nutrition for sorghum growth. Nitrogen promotes cell division, chlorophyll formation and stem elongation, while phosphorus and potassium support root development, energy transfer and assimilate movement (Brady & Weil, 2016). Similar responses to NPK fertilization were reported by Ibrahim *et al*. (2022) and Ngala *et al*. (2021).

The better performance of sole sorghum in 2024 may have resulted from reduced competition for light, water and nutrients, consistent with the findings of Mucheru-Muna *et al*. (2010). In contrast, the greater height of intercropped sorghum at higher NPK rates in 2025 suggests that adequate nutrient supply reduced competition and enhanced resource complementarity between sorghum and groundnut. Similar responses have been reported under improved soil fertility management in cereal-legume systems (Maman *et al*., 2017; Obabire *et al*., 2024). Overall, NPK at 200–300 $kgha^{-1}$ (12:12:17 + 2MgO) supported improved sorghum growth under both cropping systems.

**Groundnut Plant Height under Cropping System and NPK Fertilizer Rates**

The interaction effects of cropping system and NPK fertilizer rate on groundnut plant height are presented in Table 2. Sole groundnut consistently produced significantly taller plants than intercropped groundnut in both seasons, with the greatest height recorded at 300 kg $ha^{-1}$ NPK. Significant interaction effects occurred at 8 and 12 WAP but not at 4 WAP, indicating that treatment effects became more evident as growth progressed.

The increase in plant height with higher NPK rates highlights the importance of balanced nutrition for groundnut growth. Nitrogen supports chlorophyll formation and vegetative

development, while phosphorus and potassium promote root growth, energy transfer, water regulation and assimilate movement (Brady & Weil, 2016). Similar improvements in groundnut growth following NPK application were reported by Azu *et al*. (2019) in southeastern Nigeria and by Ibrahim *et al*. (2022) in grain crops.

The consistently greater height of sole groundnut suggests that intercropping with sorghum increased competition for light, moisture and nutrients. This agrees with Mucheru-Muna *et al*. (2010), who reported reduced legume growth under cereal-legume competition, and Rabiu *et al*. (2021), who observed similar reductions in groundnut vegetative growth when associated with cereals. The stronger interaction from 8 WAP indicates that competition increased during active vegetative growth. Thus, although intercropping improves land-use efficiency, NPK application at 200–300 kg ha$^{-1}$ appears important for maintaining vigorous groundnut growth under competition.

**Table 2: Interaction effects of cropping system and NPK fertilizer rates on plant height and intercropping system of sorghum and groundnut**

| Cropping system x NPK Rates | 2024 Cropping Season | | | 2025 Cropping Season | | |
|---|---|---|---|---|---|---|
| | 4WAP | 8WAP | 12WAP | 4WAP | 8WAP | 12WAP |
| Sole sorghum + 0 | 11.35 | 51.7 | 76.5 | 9.80 | 28.9 | 84.3 |
| Sole sorghum + 100 | 17.25 | 83.3 | 119 | 14.0 | 43.5 | 109.8 |
| Sole sorghum + 200 | 20.46 | 106.1 | 161 | 45.8 | 52.1 | 116.2 |
| Sole sorghum + 300 | 21.33 | 114.6 | 181.2 | 15.3 | 55.3 | 124.0 |
| Sorghum/groundnut intercrop + 0 | 9.28 | 36.7 | 81.6 | 11.0 | 51.3 | 78.45 |
| Sorghum/groundnut intercrop + 100 | 12.95 | 81.4 | 110.5 | 22.1 | 81.0 | 123.2 |
| Sorghum/groundnut intercrop + 200 | 13.15 | 89.6 | 125.3 | 23.6 | 101.0 | 162.6 |
| Sorghum/groundnut intercrop + 300 | 13.45 | 94.6 | 143.4 | 23.6 | 105.7 | 164.5 |
| $LSD_{0.05}$ | 1.41 | 4.83 | 9.40 | ns | 4.87 | 7.43 |
| | | | | | | |
| Sole groundnut + 0 | 6.85 | 22.9 | 35.3 | 6.85 | 18.2 | 36.4 |
| Sole groundnut + 100 | 8.05 | 28.2 | 53.7 | 8.35 | 36.4 | 54.2 |
| Sole groundnut + 200 | 8.47 | 31.9 | 55.6 | 8.63 | 37.2 | 58.1 |
| Sole groundnut + 300 | 8.40 | 33.5 | 55.7 | 8.68 | 38.3 | 58.4 |
| Sorghum/groundnut intercrop + 0 | 6.23 | 10.9 | 15.2 | 7.00 | 16.7 | 23.7 |
| Sorghum/groundnut intercrop + 100 | 7.23 | 13.8 | 19.3 | 8.75 | 19.7 | 28.3 |
| Sorghum/groundnut intercrop + 200 | 7.85 | 14.2 | 19.1 | 8.98 | 19.9 | 32.2 |
| Sorghum/groundnut intercrop + 300 | 8.10 | 15.2 | 20.6 | 8.88 | 19.8 | 32.5 |
| $LSD_{0.05}$ | ns | 1.83 | 3.70 | ns | 1.02 | 2.01 |

*Note: WAP-Weeks after planting, ns- Not significant*

**Number of Leaves in sorghum under Cropping System and NPK Fertilizer Rates**

The interaction effects of cropping system and NPK fertilizer rates on sorghum leaf number are presented in Table 3. Leaf production generally increased with increasing NPK rates under both cropping systems. In 2024, intercropped sorghum recorded the highest leaf numbers at 200 and 300 kg ha$^{-1}$ NPK, although the interaction was not significant ($P > 0.05$). In 2025, intercropped sorghum produced significantly more leaves at the higher fertilizer rates, particularly at 8 and 12 WAP, with the highest value (21.5 leaves plant$^{-1}$) recorded at 300 kg ha$^{-1}$. Significant interactions occurred only at 8 and 12 WAP, while differences at 4 WAP were not significant.

The increase in leaf production with NPK application reflects the importance of balanced nutrition for sorghum canopy development. Nitrogen promotes chlorophyll formation, leaf initiation and expansion, while phosphorus and potassium support root development, energy transfer and assimilate partitioning (Brady & Weil, 2016). Similar improvements in leaf production and canopy development following NPK application were reported by Ibrahim *et al*. (2022) and Ngala *et al*. (2021).

The lack of significant interactions in 2024 and at 4 WAP in 2025 suggests limited effects of cropping system during early growth. However, the greater leaf production of intercropped sorghum at higher NPK rates later in 2025 indicates that adequate nutrient supply helped reduce competitive effects and improve resource use. This agrees with Maman *et al*. (2017) and Obabire *et al*. (2024), who reported improved vegetative growth and canopy development in cereal-legume systems under better nutrient management. Overall, NPK application at 200–300 kg ha$^{-1}$ promoted vigorous sorghum canopy development under both cropping systems.

**Number of Leaves in Groundnut under Cropping System and NPK Fertilizer Rates**

The interaction effects of cropping system and NPK fertilizer rates on groundnut leaf number are presented in Table 3. Leaf production increased significantly ($P \leq 0.05$) with increasing NPK rates in both seasons. Sole groundnut consistently produced more leaves than intercropped groundnut, with the highest values at 300 kg ha$^{-1}$ NPK in both 2024 and 2025. Significant interactions occurred at 4, 8 and 12 WAP in both seasons, indicating that fertilizer response depended on the cropping system throughout crop growth.

**Table 3: Interaction effect of cropping system and NPK fertilizer rates on number of leaves and intercropping system of sorghum and groundnut**

| Cropping system x NPK Rates | 2024 | | | 2025 | | |
|---|---|---|---|---|---|---|
| | 4WAP | 8WAP | 12WAP | 4WAP | 8WAP | 12WAP |
| Sole sorghum + 0 | 3.25 | 11.7 | 14.0 | 4.75 | 14.7 | 17.2 |
| Sole sorghum + 100 | 4.25 | 13.7 | 14.7 | 6.25 | 16.0 | 18.2 |
| Sole sorghum + 200 | 4.25 | 14.7 | 15.7 | 6.25 | 15.7 | 18.5 |
| Sole sorghum+ 300 | 4.50 | 15.0 | 16.0 | 6.75 | 16.0 | 18.7 |
| Sorghum/groundnut intercrop + 0 | 5.50 | 11.2 | 15.2 | 4.75 | 12.0 | 18.2 |
| Sorghum/groundnut intercrop + 100 | 6.00 | 13.7 | 15.2 | 4.75 | 14.0 | 19.5 |
| Sorghum/groundnut intercrop + 200 | 6.25 | 14.7 | 17.0 | 5.00 | 14.7 | 20.7 |
| Sorghum/groundnut intercrop + 300 | 7.00 | 14.7 | 17.0 | 4.75 | 15.5 | 21.5 |
| $LSD_{0.05}$ | ns | ns | ns | ns | 1.14 | 1.01 |
| | | | | | | |
| Sole groundnut + 0 | 18.25 | 35.7 | 46.2 | 20.7 | 39.0 | 48.2 |
| Sole groundnut + 100 | 29.00 | 48.5 | 61.5 | 24.7 | 50.2 | 59.7 |
| Sole groundnut + 200 | 30.25 | 52.0 | 67.2 | 27.0 | 50.2 | 59.7 |
| Sole groundnut + 300 | 30.75 | 52.0 | 69.2 | 26.5 | 50.2 | 61.5 |
| Sorghum/groundnut intercrop + 0 | 8.00 | 15.5 | 20.5 | 15.5 | 33.2 | 41.5 |
| Sorghum/groundnut intercrop + 100 | 9.50 | 16.7 | 22.0 | 16.0 | 41.2 | 48.0 |
| Sorghum/groundnut intercrop + 200 | 11.75 | 19.0 | 25.0 | 18.0 | 44.2 | 53.5 |
| Sorghum/groundnut intercrop + 300 | 9.75 | 19.0 | 26.2 | 19.0 | 45.2 | 55.7 |
| $LSD_{0.05}$ | 2.15 | 2.82 | 2.93 | 2.09 | 2.39 | 2.77 |

*Note: WAP - Weeks after planting, ns - Not significant*

The increase in leaf production with NPK application reflects the importance of balanced nutrition for canopy development. Nitrogen promotes leaf initiation and chlorophyll formation, while phosphorus supports root development and energy transfer and potassium enhances assimilate movement and water-use efficiency (Brady & Weil, 2016). Similar improvements in groundnut leaf production under improved soil fertility were reported by Azu *et al*. (2019).

The greater leaf production of sole groundnut suggests that intercropping with sorghum increased competition for light, moisture and nutrients, thereby limiting canopy development. Similar effects of cereal competition on legume growth have been reported by Mucheru-Muna *et al*. (2010) and Maman *et al*. (2017). The significant interactions throughout the growth period further indicate that groundnut responded differently to fertilizer under the two cropping systems. Although NPK improved leaf production in both systems, the stronger response under sole cropping suggests more efficient nutrient use in the absence of interspecific competition. Thus, NPK at 200–300 kg $ha^{-1}$ (12:12:17 + 2MgO) is important for maintaining vigorous groundnut growth in sorghum-groundnut intercrops.

**Sorghum Yield and Yield Components**

The main effects of cropping system and NPK fertilizer rates on sorghum yield and yield components are presented in Table 4. Sole sorghum generally produced significantly higher numbers of panicles, fresh panicle weight and total biomass than intercropped sorghum in both seasons. Increasing NPK rates also improved most yield parameters, with the highest values generally recorded at 200 and 300 kg $ha^{-1}$. However, gains beyond 200 kg $ha^{-1}$ were generally small, suggesting a yield response plateau at higher rates.

The superior performance of sole sorghum likely resulted from reduced competition for light, moisture and nutrients, allowing greater biomass production and assimilate allocation to panicle development. Similar effects of interspecific competition on cereal yield have been reported by Mucheru-Muna *et al*. (2010) and Egbe (2010).

The positive response to NPK reflects the roles of nitrogen in vegetative growth and photosynthesis, phosphorus in root and reproductive development, and potassium in assimilate translocation and grain filling. Similar improvements in sorghum yield under balanced NPK fertilization were reported by Ibrahim *et al*. (2022) and Ngala *et al*. (2021). The small difference between 200 and 300 kg $ha^{-1}$ suggests that 200 kg $ha^{-1}$ NPK (12:12:17 + 2MgO) may be sufficient for efficient sorghum production under the conditions of southeastern Nigeria.

**Table 4: Main effects of cropping system and NPK fertilizer rates on sorghum yield and yield components**

| Cropping system | Weight of fresh stalk (g) | Weight of dry stalk (g) | Total weight of fresh stalk (g) | No. of panicles | Fresh weight of panicles (g) | Dry weight of panicles (g) | Seed moisture content |
|---|---|---|---|---|---|---|---|
| **2024 Cropping season** | | | | | | | |
| Sole Sorghum | 1.61 | 0.41 | 7.06 | 24.44 | 5.20 | 1.50 | 3.67 |
| Sorghum + Groundnut | 1.55 | 0.36 | 5.27 | 11.56 | 3.07 | 1.38 | 1.69 |
| $LSD_{0.05}$ | 0.03 | 0.03 | 0.71 | 2.77 | 0.19 | 0.06 | 0.18 |
| *NPK Rate (kg/ha)* | | | | | | | |
| 0 | 1.38 | 0.35 | 5.63 | 16.88 | 3.45 | 1.28 | 2.17 |
| 100 | 1.57 | 0.37 | 5.66 | 15.50 | 4.13 | 1.45 | 2.67 |
| 200 | 1.66 | 0.40 | 6.63 | 19.25 | 4.39 | 1.44 | 2.89 |
| 300 | 1.70 | 0.42 | 6.75 | 20.38 | 4.57 | 1.58 | 2.99 |
| $LSD_{0.05}$ | 0.05 | 0.04 | 0.99 | ns | 0.26 | 0.08 | 0.25 |
| **2025 Cropping season** | | | | | | | |
| Sole Sorghum | 1.60 | 0.39 | 6.96 | 21.50 | 4.34 | 1.44 | 2.93 |
| Sorghum+ Groundnut | 1.59 | 0.40 | 5.71 | 16.56 | 3.19 | 1.39 | 1.80 |
| $LSD_{0.05}$ | 0.02 | ns | 0.16 | 1.89 | 0.54 | ns | 0.47 |
| *NPK Rate (kg/ha)* | | | | | | | |
| 0 | 1.39 | 0.34 | 5.59 | 16.62 | 3.14 | 1.34 | 1.83 |
| 100 | 1.61 | 0.39 | 6.29 | 17.00 | 3.37 | 1.35 | 2.01 |
| 200 | 1.69 | 0.41 | 6.70 | 21.38 | 4.23 | 1.50 | 2.73 |
| 300 | 1.70 | 0.44 | 6.76 | 21.12 | 4.32 | 1.45 | 2.87 |
| $LSD_{0.05}$ | ns | 0.02 | 0.22 | 2.67 | 0.77 | 0.10 | 0.66 |

*ns: Not significant at 5% probability level*

**Groundnut Yield and Yield Components**

The main effects of cropping system and NPK fertilizer rates on groundnut yield and yield components are presented in Table 5. Sole groundnut generally produced significantly more pods and total fresh biomass than intercropped groundnut in both seasons. Increasing NPK rates also improved most yield components, with the highest values generally recorded at 200 and 300 kg $ha^{-1}$. However, differences between these two rates were relatively small, suggesting a yield response plateau at higher fertilizer rates.

The better performance of sole groundnut indicates that intercropping with sorghum increased competition for light, moisture and nutrients, thereby reducing pod production and biomass. Similar reductions in legume reproductive performance under cereal-legume competition were reported by Mucheru-Muna *et al*. (2010) and Maman *et al*. (2017).

The positive response to NPK reflects the roles of nitrogen in vegetative growth and photosynthesis, phosphorus in flowering, pod formation and seed development, and potassium in assimilate translocation and seed filling (Brady & Weil, 2016). Similar improvements in groundnut yield under enhanced soil fertility were reported by Azu *et al*. (2019) and Obabire *et al*. (2024). The small yield difference between 200 and 300 kg $ha^{-1}$ suggests that approximately 200 kg $ha^{-1}$ NPK (12:12:17 + 2MgO) may provide an appropriate balance between productivity and fertilizer-use efficiency under the conditions of this study.

**Table 5: Main effects of cropping system and NPK fertilizer rates on groundnut yield and yield components**

| Cropping system | Weight of fresh stalk (g) | Weight of dry stalk (g) | Total weight of fresh stalk (g) | No. of pods | Fresh weight of pods (g) | Dry weight of pods (g) | Seed moisture content |
|---|---|---|---|---|---|---|---|
| **2024 cropping season** | | | | | | | |
| Sole Groundnut | 1.48 | 0.40 | 21.62 | 32.88 | 0.28 | 0.16 | 0.12 |
| Sorghum + Groundnut | 1.30 | 0.68 | 3.30 | 23.56 | 1.27 | 0.78 | 0.49 |
| $LSD_{0.05}$ | 0.04 | 0.03 | 0.85 | 1.84 | 0.03 | 0.03 | 0.02 |
| NPK Rate (kg/ha) | | | | | | | |
| 0 | 1.22 | 0.44 | 9.98 | 18.00 | 0.59 | 0.35 | 0.24 |
| 100 | 1.41 | 0.57 | 12.46 | 27.62 | 0.77 | 0.47 | 0.31 |
| 200 | 1.44 | 0.57 | 13.38 | 32.88 | 0.85 | 0.53 | 0.33 |
| 300 | 1.49 | 0.58 | 14.02 | 34.38 | 0.89 | 0.54 | 0.35 |
| $LSD_{0.05}$ | 0.06 | 0.04 | 1.21 | *-2.61 | 0.04 | 0.04 | 0.02 |
| **2025 cropping season** | | | | | | | |
| Sole Groundnut | 1.47 | 0.37 | 19.94 | 17.00 | 0.16 | 0.07 | 0.11 |
| Sorghum + Groundnut | 1.30 | 0.69 | 3.31 | 21.12 | 1.31 | 0.44 | 0.86 |
| $LSD_{0.05}$ | 0.05 | 0.04 | 3.95 | 3.97 | 0.18 | 0.13 | 0.07 |
| NPK Rate (kg/ha) | | | | | | | |
| 0 | 1.25 | 0.40 | 8.03 | 16.50 | 0.66 | 0.23 | 0.43 |
| 100 | 1.40 | 0.54 | 13.01 | 19.12 | 0.70 | 0.25 | 0.45 |
| 200 | 1.43 | 0.57 | 13.93 | 20.38 | 0.78 | 0.25 | 0.52 |
| 300 | 1.46 | 0.61 | 11.51 | 20.25 | 0.78 | 0.30 | 0.53 |
| $LSD_{0.05}$ | 0.07 | 0.06 | ns | ns | ns | ns | 0.10 |

*ns: Not significant at 5% probability level.*

## CONCLUSION AND RECOMMENDATIONS

The study showed that cropping system and NPK fertilizer application significantly affected the growth and yield of sorghum and groundnut at Igbariam, southeastern Nigeria. Sole cropping generally produced better vegetative growth and higher yields than sorghum-groundnut intercropping, particularly for groundnut, probably because of reduced interspecific competition for growth resources. However, intercropping remains useful where land-use efficiency and enterprise diversification are priorities.

NPK (12:12:17 + 2MgO) application consistently improved plant height, leaf production and yield components of both crops. Although 300 kg $ha^{-1}$ often produced the highest values, differences from 200 kg $ha^{-1}$ were generally small, indicating that crop performance approached optimum levels at 200 kg $ha^{-1}$ under the study conditions.

Based on these findings, 200 kg $ha^{-1}$ NPK (12:12:17 + 2MgO) is recommended for sorghum and groundnut production at Igbariam, as it provided substantial yield benefits with limited additional response at higher rates. Sole cropping is recommended where maximum individual crop yield is the priority, while sorghum-groundnut intercropping can be adopted for improved land-use efficiency, provided adequate fertilization is maintained. Further studies should assess the economic returns of fertilizer rates and the long-term effects of integrating organic amendments with mineral fertilizers.

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**Ethical Statement**

Not applicable

**AI Declaration Statement**

The authors declare that Artificial Intelligence (AI) tool(s), ChatGPT and Grammarly, were used for improving manuscript structure and language editing/grammar correction, respectively. All outputs were critically reviewed, verified, and approved by the authors, who accept full responsibility for the content of the manuscript.

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