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The influence of poultry manure extract on okra growth and yield

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Abstract: Okra is important for its nutritional value, economic significance, and adaptability to diverse farming systems. However, low soil fertility in tropical soils results in poor okra yields, and using poultry manure raises environmental concerns. Therefore, exploring poultry manure extract (PME) could be a sustainable practice to ensure good yield. The objective was to determine okra's response to PME. The experiment, conducted in 2022 and 2023 used a 2×6 factorial design involving two okra varieties (NHAe47-4 and LD88) and six fertilizer treatments [0 (Control: T1), 840 L/ha (T2), 1680 L/ha (T3), and 2520 L/ha PME (T4), 60 kg N/ha poultry manure (T5), and 60 kg N/ha NPK 15:15:15 (T6)]. A randomized complete block design with six replicates and plant spacing of 50×30 cm was used. Growth and yield data were analyzed using ANOVA. Results indicated NHAe47-4 had significantly lower height, pod length, and fruit yield, but higher stem diameter, number of leaves, and leaf area, compared to LD88. Applying T4 treatment significantly increased the growth and yield of okra compared to lower levels and control, although T5 and T6 were better. In 2022 and 2023, fresh shoot weights were highest in NHAe47-4×T6 (5151.07 and 5080.56 kg/ha), and fruit yields in LD88×T6 (45408.34 and 45617.60 kg/ha), while NHAe47-4×T4 had 3554.17 and 3527.78 kg/ha, and LD88×T4 had 27269.91 and 27327.78 kg/ha, respectively. Though T6 and T5 optimize the vegetative and reproductive performances in okra, applying 2520 L/ha of poultry manure extract was considered an environmentally friendly alternative for sustainable LD88 okra production.

Key-words: climate resilience, okra varieties, sustainable agriculture, tropical soils.

Influência do extrato de esterco de aves no crescimento e na produtividade do quiabo

Resumo: O quiabo é importante por seu valor nutricional, significância econômica e adaptabilidade a diversos sistemas agrícolas. No entanto, a baixa fertilidade do solo em solos tropicais resulta em baixos rendimentos de quiabo, e o uso de esterco de aves levanta preocupações ambientais. Portanto, explorar o extrato de esterco de aves (EAP) pode ser uma prática sustentável para garantir um bom rendimento. O objetivo foi determinar a resposta do quiabo ao EAP. O experimento, conduzido em 2022 e 2023, utilizou um delineamento fatorial 2×6 envolvendo duas variedades de quiabo (NHAe47-4 e LD88) e seis tratamentos de fertilizantes [0 (Controle: T1), 840 L/ha (T2), 1680 L/ha (T3) e 2520 L/ha EAP (T4), 60 kg N/ha esterco de aves (T5) e 60 kg N/ha NPK 15:15:15 (T6)]. Foi utilizado um delineamento em blocos casualizados com seis repetições e espaçamento de plantas de 50×30 cm. Os dados de crescimento e produtividade foram analisados por ANOVA. Os resultados indicaram que a cultivar NHAe47-4 apresentou altura, comprimento de vagem e produtividade de frutos significativamente menores, mas maior diâmetro do caule, número de folhas e área foliar, em comparação com a cultivar LD88. A aplicação do tratamento T4 aumentou significativamente o crescimento e a produtividade do quiabo em comparação aos níveis mais baixos e ao controle, embora T5 e T6 tenham sido melhores. Em 2022 e 2023, os pesos de brotos frescos foram maiores em NHAe47-4×T6 (5151,07 e 5080,56 kg/ha), e as produtividades de frutos em LD88×T6 (45408,34 e 45617,60 kg/ha), enquanto NHAe47-4×T4 teve 3554,17 e 3527,78 kg/ha, e

LD88×T4 teve 27269,91 e 27327,78 kg/ha, respectivamente. Embora T6 e T5 otimizem os desempenhos vegetativo e reprodutivo do quiabo, a aplicação de 2520 L/ha de PME foi considerada uma alternativa ambientalmente correta para a produção sustentável de quiabo LD88.

Key-words: resiliência climática, variedades de quiabo, agricultura sustentável, solos tropicais.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is a vital vegetable crop in tropical and subtropical regions, important for its nutritional value, economic significance, and adaptability to diverse farming systems (MAITI & SINGH, 2021). It constitutes a crucial component of dietary staples for millions, particularly in developing countries, contributing essential vitamins, minerals, and fiber (FAO, 2021). The crop is mainly grown and harvested for the young pods, which are eaten in various ways (fresh, dried, and roasted) depending on consumer preference (ASAMANI & MAALEKUU, 2023). Furthermore, okra farming provides livelihood opportunities for smallholder farmers, often serving as a readily marketable source of income (AYODELE & SHITTU, 2013). However, its production is increasingly threatened by the convergence of inherent challenges associated with tropical soils and the escalating impacts of climate change (MASSRIE, 2025). These constraints threaten food security and rural livelihoods. Thus, there is a need to address Sustainable Development Goals (SDGs) 2 (Zero Hunger) and 13 (Climate Action) (MESCHEDE, 2020). Therefore, exploring sustainable and resilient agricultural practices is paramount to securing okra yields and ensuring food security in the face of these complex pressures.

Tropical soils reportedly have natural limitations that pose significant threats to achieving optimal production of okra (KOME *et al.*, 2019). Characterized by low organic matter content, high acidity, nutrient deficiencies (particularly phosphorus and nitrogen), and susceptibility to erosion, these soils often fail to provide the necessary support for optimum plant growth (KOREDE *et al.*, 2025). These were a result of intense weathering and leaching processes, accelerated by high temperatures and rainfall, leading to depletion of essential soil nutrients and exacerbated soil degradation. Moreover, the predominance of clay minerals in many tropical soils leads to poor drainage, aeration, and increased susceptibility to compaction, further hindering root development and nutrient uptake by crops like okra plants (KOME *et al.*, 2019). Addressing these inherent soil constraints is crucial for enhancing okra productivity and ensuring sustainable agricultural practices in tropical regions.

Climate change further complicates the adverse environmental conditions faced by okra farmers in the tropics. Compounding the challenges posed by tropical soils, climate change introduces a suite of factors that negatively impact okra production. Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events, such as droughts and floods, are disrupting traditional farming systems and jeopardizing crop yields (SOLANKEY *et al.*, 2021). Elevated temperatures can shorten the okra's vegetative phase, accelerate flowering, and reduce pod size and quality, ultimately leading to lower yields. Erratic rainfall patterns, including prolonged dry spells followed by intense downpours, can induce water stress, nutrient leaching, and soil erosion, further compromising okra growth and productivity (RAO *et al.*, 2016). Most often, okra cultivation in these environments relies heavily on synthetic fertilizers to meet the plant's nutrient demands.

The application of synthetic fertilizers has been used to provide readily available nutrients to crops, but their excessive and indiscriminate use poses significant environmental risks (HARIHARAN, 2020; EJEDEGBA, 2024). The development of sustainable and environmentally friendly alternatives to synthetic fertilizers is therefore paramount for ensuring the long-term viability of okra production in tropical regions. Organic amendments, poultry manure is a readily available agricultural byproduct that is cost-effective and rich in essential nutrients, organic matter, and beneficial microorganisms (IBIRONKE & AKINRINOLA, 2025). However, the direct application of raw poultry manure can pose environmental risks, including nutrient runoff, ammonia volatilization, and the potential spread of pathogens (GRŽINIĆ *et al.*, 2023). Therefore, the extraction of nutrients from poultry manure, followed by application as a liquid fertilizer, presents a more environmentally sound and agronomically efficient approach.

The Poultry Manure Extract (PME) produced through the anaerobic or aerobic digestion of poultry manure offers a multitude of benefits for okra production in tropical soils. The extraction process solubilizes nutrients, making them more *readily* available for plant uptake, while simultaneously reducing the volume and odor of the raw manure (PAVITHIRA & HITINAYAKE, 2022). The resulting extract contains a balanced blend of essential nutrients, including nitrogen, phosphorus, potassium, and micronutrients, crucial for supporting okra growth and development. Furthermore, PME harbors a diverse community of beneficial microorganisms, which can enhance nutrient cycling, suppress soilborne pathogens, and improve soil structure, ultimately contributing to healthier and more resilient okra plants (PEIRIS & WEERAKKODY, 2015). The application of poultry manure extract had been reported for cucumber improvement in Iraq and Nigeria (ADESIDA et al., 2020; AL-JAF et al., 2025).

The application of PME to okra plants has the potential to mitigate the adverse effects of climate change by enhancing the plant's resilience to environmental stressors (SOLANKEY *et al.*, 2021; ASANTE *et al.*, 2024). By improving soil fertility and nutrient availability, PME can strengthen the okra plants' ability to withstand drought conditions, resist pest and *disease* infestations, and recover from extreme weather events. Moreover, the organic matter content of PME can improve soil water retention, reduce soil erosion, and enhance carbon sequestration, contributing to overall soil health and mitigating the impacts of climate change on agricultural ecosystems (PEIRIS & WEERAKKODY, 2015). The judicious use of PME, therefore, represents a promising strategy for promoting sustainable okra production and ensuring food security in tropical regions facing the challenges of climate change. However, the appropriate application level for optimum okra yield is not adequately documented.

In many parts of sub-Saharan Africa, farming systems rely heavily on local crop varieties and limited soil inputs, often leaving them vulnerable to poor yields, soil degradation, and shifting climate conditions (BEDEKE, 2023). As weather patterns grow more unpredictable and soils continue to lose fertility, there's a growing need to understand how different crop types respond to varying nutrient levels. Studies that explore the interaction between plant genetics and fertilizer use can help identify combinations that work well under local conditions, maximizing output without harming the soil (BAILEY-SERRES *et al.*, 2019). Such research and understanding are crucial as farmers seek ways to adapt to drought, irregular rainfall, and other climate-related pressures. By focusing on efficient, adaptable, and sustainable farming practices, such investigations offer a practical path toward long-term food security in the region. By addressing these knowledge gaps, we can harness the full potential of PME as a sustainable and climate-smart fertilizer for enhancing okra production and securing food security for smallholder farmers in tropical regions facing soil degradation and climate variability. Therefore, the objective of the study was to determine the level of PME application required for achieving optimal okra yields.

2. MATERIAL AND METHODS

Experimental Site

The field experiment was carried out during the 2022 and 2023 cropping seasons at the Department of Crop and Horticultural Sciences Research field (07° 27'37"N and 3° 53'33"E at an elevation of 162 m) in the University of Ibadan, Ibadan, Oyo State, Nigeria. The Koppen-Geiger climate classification of the location falls within the tropical savanna (BECK *et al.*, 2018).

Physical and Chemical Analysis of Soil and Poultry Manure Liquid Fertilizer Samples

Determination of the soil's physical and chemical properties were done using standard laboratory techniques according to the study by Msibi et al. (2014). Soil samples were collected at a 30 cm depth from five sampling points on the site and combined to create a composite sample. A composite sample was taken and brought to the Departmental lab, where it was analyzed for its physical and chemical properties to assess the soil's feel using a core sampler. Specifically, the systematic core sampling method along with a hydrometer test on its settled sediment (GEE & OR, 2002). Organic matter content was determined with the aid of the Walkley Black method using the dichromate wet digestion technique by Nelson and Sommers (1996). Total N was estimated by the micro-Kjeldahl digestion method of Bremner (1982), while available phosphorus was analyzed by Bray P-1 extraction, after which it was stained with molybdenum blue reagent as described by Bray and Kurtz (1945). Here, exchangeable potassium, calcium, and magnesium were extracted by water-soluble ammonium acetate. Thereafter, potassium was assayed by flame photometer while calcium and magnesium were assayed with an atomic absorption spectrophotometer, as described by Okalebo *et al.* (2002). The result of the soil physical and chemical analysis and the values of the minimum soil concentrations for healthy okra growth are presented in Table 1. The chemical composition of the poultry manure and N in PME used was analyzed before use and presented in Table 1. All the assessments were done in the laboratory of the Department of Soil Resources Management, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria.

Treatments, Experimental Designs, and Crop Establishment

The layout of the field experiment was a 2×6 factorial arrangement consistent of two okra varieties (LD88 and NHAe47-4) and four fertilizer applications [0 (Control), 840 L/ha, 1680 L/ha, and 2520 Liters/ha of the poultry extracts, 60 kg N/ha of poultry manure (at 1,428.57 kg/ha), and 60 kg N/ha of NPK 15:15:15) using a randomized complete block design with six replicates. The level of N application was based on Ayodele and Shittu's (2013) recommendation for okra.

There were 72 plots, each measuring 2 × 1 meters, with 1 meter of space allowed between plots and blocks. Each plot had four rows and four stands per row, thus, a total of 16 stands per plot. The intra- and inter-stand spacing of 0.5 × 0.5 m was used.

Experimental Materials

The source of poultry manure used for the study was broiler droppings obtained from the Teaching and Research Farm of the University of Ibadan, Ibadan, Nigeria. The okra varieties were obtained from the National Institute for Horticultural Research (NIHORT), Ibadan, Nigeria. The two okra varieties selected were LD88 and NHAe47-4.

Table 1. Particle size analysis and chemical properties of the experimental soil and poultry manure before planting.

Soil properties	Value	Critical level (Brandenberger et al., 2015)	Remark	Poultry manure	Poultry manure extract
Sand (%)	84.10				
Silt (%)	10.20				
Clay (%)	5.70				
Textural Class	Sand Silt				
Soil pH	6.58	< 6.9	Slightly acidic		
Organic C (%)	2.276	> 1.86	High	32.96	
N (g/kg)	0.205	< 52	Low	4.20	47.6
Available P (mg/kg)	121	> 51	High	1.99	
K (cmol/kg)	0.17	>0.078	High	1.205	
Ca (cmol/kg)	1.19	>0.043	High	5.85	
Mg (cmol/kg)	1.10			0.75	
Na (cmol/kg)	0.83			0.26	
Fe (mg/kg)	29.20				

Preparation of Poultry Manure Liquid Fertilizer

The PME was produced under the shade of a tree using a remodeled approach based on Peiris and Weerakkody (2015). Cured poultry manure of 5 kg was placed inside a permeable sack, securely fastened, and submerged in 50 L of water within a covered bucket to prevent contamination. The mixture was manually agitated on a daily basis to ensure thorough blending and filtration. After three weeks, the extract was filtered and analyzed in the laboratory to determine its nitrogen content.

Planting

The field for experimentation was then leveled, cleared to avoid any interferences/rises, and ensured proper installation of ridges/stakes. At the onset of the rainy season, healthy seeds were selected at random and sown perfectly in seed beds. Seeding was initially done with 2-3 seeds per stand and was followed by thinning to one plant per stand.

Post-planting operations

The solid manure was prepared, weighed properly, and incorporated into the soil at the standard rate two weeks before planting, according to Abdulmaliq (2016), while the ring method was used for NPK applications. The PME was applied to the leaves of the plants at 2, 4, and 6 Weeks After Planting (WAP). The PME application commenced two weeks after planting and then at 3 and 5 WAP. Weeding was carried out on a biweekly basis with the use of a hand-held hoe at a three-week interval to ensure a weed-free condition.

Data collection

Data from each plot were collected non-destructively, and the averages per plant were computed. This entailed choosing four plants randomly from the last rows of each plot. These parameters were plant height, measured from ground level to the tips of the youngest expanded leaves on the main stem using a meter rule, and the number of fully expanded leaves per plant, counted directly. Leaf area per plant was measured with a ruler, and the value is obtained by multiplying the length and width of four leaves per plant and then averaging the product by a factor given by Musa and Usman (2016) as 0.62. Furthermore, the measurement of immature fruit yield and yield components was made on five occasions at four-day intervals.

Data analysis

Data collated included the number of pods, pod length, stem diameter, and leaf area, and expressed in kg/ha. The data were subjected to analysis of variance (ANOVA) in the SAS statistics software version 9.0. Means of the treatments, where significant, were compared using Duncan's Multiple Range Test at a 0.05 probability level.

3. RESULTS AND DISCUSSION

Soil properties

The soil test results before planting showed that the soil had very high sand content but was low in clay, hence falling into the loamy sand textural class (Table 1). The soil analysis showed that the soil is sandy loam with 84.10% sand, 10.20% silt, and 5.70% clay. The soil is slightly acidic with a pH of 6.58, low in nitrogen and phosphorus contents, but with a high available potassium of 121. The poultry manure and PME content of nitrogen are 4.2 and 4.79, respectively.

Effect of fertilizers on the height and stem diameter of okra.

The varieties vary in their height and respond differently to fertilizer application during the 2022 and 2023 cropping seasons (Table 1). The LD88 okra variety had significantly taller plants (71.95 and 72.66 cm) than NHAe47-4 (65.90 and 66.05 cm) during the 2022 and 2023 planting seasons, respectively. This suggests that the plants may differ in their genetic composition for height, which may affect their ability to capture light for photosynthetic processes. The result is consistent with Omolade *et al.* (2024) findings that LD88 had significantly taller plants than NHAe47-4. Stem elongation and plant height, which are controlled by hormones like gibberellins, auxins, and brassinosteroids, are most likely higher in LD88 than in NHAe47-4. The height advantage in LD88 could make it a better choice for inclusion in the intercropping system, as it can favorably compete for light interception.

The effect of fertilizer applications on the height of okra differed significantly among the treatments during the two cropping seasons. While the control treatments had significantly shorter plants, increasing PME application resulted in a significant increase in okra heights during the two seasons. However, the T5 (PM) and T6 (NPK) treatments resulted in the tallest plants, with T5 reaching 83.29 cm and 86.30 cm, and T6 reaching 71.97 cm and 83.45 cm in 2022 and 2023, respectively. These findings align with studies showing that nutrient-rich fertilizers like NPK and PM enhance plant growth by improving nutrient availability relative to PME (EL-HAMDI *et al.*, 2017). The increase in nutrient application (like nitrogen and phosphorus) supports vertical growth through cell elongation and chlorophyll synthesis, which directly affects these growth parameters (OLUGBEMI & AKINRINOLA, 2020; PAVITHIRA & HITINAYAKE, 2022).

The interaction effects of varieties and fertilizers showed that despite higher responses observed with PM and NPK fertilizers, PME also promoted okra heights than the control in the two varieties. The two varieties had significantly taller plants, with T5 and T6 treatments having taller plants, but PME was also efficient in promoting height at T4. These indicated a synergistic effect between the NHAe47-4 and LD88 varieties, with higher values observed with LD88. The consistent performance of LD88 over NHAe47-4 suggests varietal differences in nutrient uptake efficiency or variation in nutrient use efficiency (RAO *et al.*, 2016). The lower response in NHAe47-4 suggests either a lower nutrient use efficiency or genetic limitation in height expression. However, NHAe47-4 still responded positively to nutrient input, indicating that even less vigorous varieties could benefit from fertilizer application. A similar observation was reported by Badamasi *et al.* (2023) that LD88 responded more to N fertilizer application than the resulting increase from the NHAe47-4 variety.

The NHAe47-4 okra variety had significantly thicker stem diameters than LD88 during the 2022 and 2023 cropping seasons (Table 2). This result indicated that the okra varieties may differ in their genetic composition for radial stem increase. It is possible that favoring sturdiness over vertical elongation in NHAe47-4 could support heavier reproductive, while LD88 prioritizes height over girth to intercept light for photosynthesis. The increase in the girth observed in NHAe47-4 implies that the gene responsible for cell division and enlargement in the cambial tissue of the stems was more active. According to Yang *et al.* (2024) report on maize, differences in gene expression related to cell wall synthesis and lignin deposition are responsible for stem thickness. The chances that such variety would lodge when combined with taller plants like maize in the intercropping settings as practiced by small scale farmers are minimal (BAMBORIYA *et al.*, 2022).

The T5 (PM) and T6 (NPK) treatments significantly promoted the largest stem diameters compared to the other treatments. However, PME (T4) applications also increased stem diameter significantly than the control, except PME (T2) in the two years of cropping. According to Ajayi *et al.* (2020), vegetative traits in legumes and oilseeds are highly nutrient-responsive. This finding indicated that PME was also efficient in promoting okra stem diameter, although PM and NPK applications were better. The adequate nutrient supply enhances stem development, which is vital for nutrient transport, mechanical support, and lodging resistance (OLUGBEMI & AKINRINOLA, 2020; YANG *et al.*, 2024).

Table 2. Effect of fertilizers on plant height and stem diameter of two okra varieties.

	Plant height (cm)		Stem diameter (cm)	
	2022	2023	2022	2023
Varieties				
NHAe47-4	65.90b	66.05b	2.73a	2.74a
LD88	71.95a	72.66a	2.52b	2.49b
SE	0.42	0.65	0.03	0.04
Fertilizer applications				
T1	51.87 e	51.25e	1.75d	1.85d
T2	58.37d	59.00d	1.78d	1.68d
T3	62.44c	64.29c	2.37c	2.28c
T4	73.11b	72.27b	2.71b	2.80b
T5	83.29a	86.30a	3.49a	3.48a
T6	84.47a	83.45a	3.62a	3.67a
SE	0.74	1.13	0.06	0.07
Variety×Fertilizer Interactions				
NHAe47-4×T1	52.44h	53.11h	1.78e	1.82e
NHAe47-4×T2	55.51g	55.16f	1.85e	1.79e
NHAe47-4×T3	56.76g	58.24f	2.35d	2.33d
NHAe47-4×T4	71.34d	71.19d	2.76c	2.91c
NHAe47-4×T5	79.56b	80.26c	3.72a	3.62b
NHAe47-4×T6	79.79b	78.34c	3.90a	3.98a
LD88×T1	51.30h	49.39h	1.72e	1.88e
LD88×T2	61.23e	62.84e	1.71e	1.56e
LD88×T3	68.12f	70.33d	2.40d	2.24d
LD88×T4	74.88c	73.35d	2.66c	2.68c
LD88×T5	87.03a	93.25a	3.27b	3.35b
LD88×T6	89.15a	88.48b	3.34b	3.32b
SE	1.04	1.60	0.08	0.10

Treatment means assigned similar letter(s) along the same columns are not significantly different at the 0.05 probability level, T1 = control, T2 = 840 L/ha extract, T3 = 1680 L/ha extract, T4 = 2520 L/ha, T5 = Poultry manure, T6 = NPK 15:15:15.

The variety × fertilizer interactions revealed that NHAe47-4 × T6 (3.92 cm in 2022, 3.98 cm in 2023) and NHAe47-4 × T5 (3.72 cm in 2022, 3.62 cm in 2023) had the largest stem diameter values, suggesting that PM and NPK fertilizers favored NHAe47-4. Also, the significant increase in NHAe47-4 and LD88 stem diameter by T4 treatment compared to the lower levels of PME and control suggested a better condition for growth. These results are consistent with research indicating that nitrogen-rich fertilizers like NPK, PM, and increasing PME levels promote cell division and structural development in stems (RAO *et al.*, 2016). The enhanced performance of NHAe47-4 over LD88 may reflect genetic advantages in stem tissue formation, as noted in similar studies (BABAJIDE *et al.,* 2018; PAVITHIRA & HITINAYAKE, 2022). The response of NHAe47-4 under nutrient-rich treatments also indicates it to be ideal for farming systems that appreciate vegetative biomass or face high wind exposure, where sturdier stems are necessary (FAO, 2021; YANG *et al.,* 2024).

Effect of fertilizers on okra number of leaves and leaf area

The variation in the number of leaves between the varieties was significant in 2022 and 2023 (Table 3). The NHAe47-4 variety had significantly more leaves than LD88 during the two years of observation. This finding suggests that, genetically, LD88 was comparatively lower in initiating new leaves compared to the NHAe47-4 variety, which is essential for photosynthesis and biomass accumulation. This variation in leaf number is considered important for breeders to develop crop varieties with improved photosynthetic capacity, growth rates, and yield potential (BAMBORIYA *et al.*, 2022). However, this finding contradicts Omolade *et al.* (2024) that LD88 had more number of leaves than NHAe47-4. The variation could be attributed to either differences in the environment or soil nutrient conditions. The substantial supply of nutrients through fertilizer may favor NHAe47-4 over LD88, which requires relatively modest fertilizer application (SARMA *et al.*, 2024). However, lower number of leaves could be an appreciated trait under moisture limiting situation, such as commonly experienced even during raining season in the tropical and subtropical regions (BEDEKE, 2023).

A significantly higher number of leaves was observed by applying T5 (PM) and T6 (NPK) compared to the other treatments. However, PME at the T4 treatment equally had plants with significantly higher leaf counts than the control in 2022 and 2023. This result indicated that increasing PME could enhance the number of leaves in okra. This finding corroborates the Chaudhari *et al.* (2021) report that organic amendments promote leaf development by stimulating root growth and increasing nutrient uptake. The improvement in the number of leaves due to increased fertilizer application was also reported by Badamasi *et al.* (2023). They reported that an adequate supply of nutrients enhances the accumulation of photoassimilates that support the initiation of leaves and minimizes leaf senescense in okra.

The interactive effects of variety and fertilizers showed that both NHAe47-4 and LD88 at T5 and T6 treatments had similar leaf counts that were significantly greater than those of the other treatment combinations. The NHAe47-4 and LD88 varieties with T4 also had plants with significantly higher leaf counts than the other treatments. The control plots, which received no fertilizer, had the fewest leaves during both years of cropping. These findings suggest that despite the higher values observed for PM and NPK, T4 also enhances leaf production across varieties, likely due to increased photosynthesis and nutrient assimilation (ASANTE *et al.*, 2024). The minimal difference between NHAe47-4 and LD88 at varying fertilizer interactions indicated that leaf number may be less variety-dependent than other traits, which is consistent with previous research on leaf development (BAILEY-SERRES *et al.,* 2019). The lack of varietal differences indicates that leaf production is genetically driven.

Table 3. Influence of fertilizers on okra number of leaves and leaf area during the 2022 and 2023 cropping seasons.

	Number of leaves		Leaf area (cm^2)	
	2022	**2023**	**2022**	**2023**
Varieties				
NHAe47-4	19.81 a	20.10a	4212.72a	4079.22a
LD88	19.17 b	19.14b	3829.36a	3773.04b
SE	0.22	0.31	166.42	65.33
Fertilizer applications				
T1	11.67d	11.83d	1772.55d	1802.45d
T2	14.69c	15.46c	2329.43cd	2439.53c
T3	15.69c	15.37c	2671.21c	2564.53c
T4	18.85b	19.08b	4280.90b	3623.25b
T5	28.08a	28.50a	6506.02a	6656.61a
T6	27.94a	27.83a	6566.14a	6587.69a
SE	0.38	0.54	288.25	113.16
Variety×Fertilizer Interactions				
NHAe47-4×T1	13.17f	13.67d	2009.38de	2082.92e
NHAe47-4×T2	14.08ef	14.75cd	2312.43c-e	2409.21de
NHAe47-4×T3	14.54ef	14.25cd	2545.53c-e	2518.44de
NHAe47-4×T4	20.96b	21.83b	5406.37b	4233.83b
NHAe47-4×T5	28.04a	28.33a	6404.60ab	6578.37a
NHAe47-4×T6	28.04a	27.75a	6597.97a	6652.56a
LD88×T1	10.17g	10.00e	1535.71e	1521.97f
LD88×T2	15.29de	16.17c	2346.43c-e	2469.85de
LD88×T3	16.83c	16.50c	2796.88cd	2610.62cd
LD88×T4	16.75cd	16.33c	3155.43c	3012.67c
LD88×T5	28.12a	28.73a	6607.43a	6742.82a
LD88×T6	27.83a	27.92a	6534.30ab	6527.78a
SE	0.54	0.77	407.66	160.04

Treatment means assigned similar letter(s) along the same columns are not significantly different at the 0.05 probability level, T1 = control, T2 = 840 L/ha extract, T3 = 1680 L/ha extract, T4 = 2520 L/ha, T5 = Poultry manure, T6 = NPK 15:15:15.

During the 2022 cropping season, the NHAe47-4 okra variety had a larger leaf area than LD88 in 2023, but the difference was significant during the 2023 cropping season. This implied that the NHAe47-4 variety favored leaf expansion over LD88, which could be a genetically controlled attribute. This result affirms Eshiet and Brisibe's (2015) findings that NHAe47-4 had substantially higher canopy development than LD88 at flowering. The higher canopy development observed for NHAe47-4 over LD88 could suggest better reproductive growth that might lead to yield increase.

The application of T5 and T6 significantly increased okra leaf areas, while the control (T1) treatment had the lowest leaf areas during the 2022 and 2023 seasons. However, the impact of PME treatments on leaf area increased with the increase in the level of application. These findings consolidated the importance of nutrient availability for promoting expansive foliar growth. The response of okra across the two years of cropping suggests that both organic and mineral nutrients can effectively promote canopy development. The result conformed with Babajide *et al.* (2018), and Ibironke and Akinrinola (2025) that nitrogen-rich fertilizer sources significantly boost foliar expansion in a nutrient-demanding system.

The interactions between variety and fertilizers varied significantly among the treatments, with LD88 × T5 and NHAe47-4 × T6 having the largest leaf area values, while LD88 × T1 had the smallest values during the 2022 and 2023 cropping seasons. This result suggests that LD88 could have a higher leaf area by encouraging leaf morphogenesis and development than NHAe47-4 under optimal treatments. However, although the T4 treatment had lower leaf area compared to T5 and T6 under NHAe47-4 and LD88, it significantly increased the okra leaf area compared to other lower levels of PME in the two varieties. This result affirms that the increased leaf area enhanced photosynthetic capacity, which would likely contribute to greater biomass accumulation (MSIBI *et al.*, 2014). Sarma *et al.* (2024) report affirmed that nutrient management should be tailored to genotype characteristics and to optimize growth responses and sustain productivity. This trait would be most appreciated by regions where okra is cultivated for its foliage rather than its fruit yield.

Effect of fertilizers on okra yield components

The values for the number of pods between the two okra varieties were similar, but relatively higher in LD88 than NHAe47-4 during the 2022 and 2023 cropping seasons. The difference was not significant, suggesting that LD88 could have a more efficient reproductive process or better assimilate partitioning toward reproductive organs. Although both varieties indicate reproductive trait stability for the number of pods. Omolade *et al.* (2024) also reported higher pod count in LD88 than NHAe47-4. According to Rafiq *et al.* (2025), variation in genes controlling cell elongation, cell division, and fruit development is responsible for pod length differences. The hormones (auxins, gibberellins, and cytokinins) that regulate fruit development are more pronounced in LD88.

Table 4. Influence of fertilizers on two varieties of okra yield components.

	Number of pods per ha		Length per pod (cm)	
Treats	2022	2023	2022	2023
Varieties				
NHAe47-4	981.48a	981.48a	4.50b	4.41b
LD88	991.51a	983.02a	5.26a	5.12a
SE	9.21	11.72	0.07	0.08
Fertilizer applications				
T1	638.88e	606.48f	3.61d	3.36e
T2	736.11d	740.74e	4.30c	4.18d
T3	886.57c	907.41d	4.49c	4.52cd
T4	1060.19b	1055.56c	4.98b	4.80c
T5	1277.78a	1259.26b	6.02a	6.15a
T6	1319.44a	1324.07a	5.87a	5.55b
SE	15.95	20.31	0.12	0.14
Variety×Fertilizer Interactions				
NHAe47-4×T1	634.26e	583.33e	3.05d	2.76g
NHAe47-4×T2	717.59d	731.48d	3.72c	3.43f
NHAe47-4×T3	875.00c	907.41c	3.92c	4.13e
NHAe47-4×T4	1074.07b	1074.07b	4.75b	4.83cd
NHAe47-4×T5	1282.41a	1268.52a	5.82a	5.87ab
NHAe47-4×T6	1305.56a	1324.07a	5.73a	5.40bc
LD88×T1	643.52e	629.63e	4.17c	3.97ef
LD88×T2	754.63d	750.00d	4.80b	4.93cd
LD88×T3	898.15c	907.41c	5.07b	4.90cd
LD88×T4	1046.30b	1037.04b	5.20b	4.77d
LD88×T5	1273.15a	1250.00a	6.22a	6.43a
LD88×T6	1333.33a	1324.07a	6.00a	5.70b
SE	22.56	28.73	0.18	0.20

Treatment means assigned similar letter(s) along the same columns are not significantly different at the 0.05 probability level, T1 = control, T2 = 840 L/ha extract, T3 = 1680 L/ha extract, T4 = 2520 L/ha, T5 = Poultry manure, T6 = NPK 15:15:15.

Fertilizer applications significantly enhanced pod counts in okra. The highest number of pods was observed under NPK (1324.07 pods/ha in 2023), closely followed by PM (1259.26 pods/ha). Similarly, the response observed from T4 was significantly higher than that of T1, T2, and T3 for the number of pods/ha. This result indicated that the trait is subject to nutrient availability for improvement. The reduction in pod count for PME-treated plants (T4) compared to T5 and T6 may be attributed to insufficient nutrient availability at flowering, which has been shown to affect pod set and water retention (ASANTE *et al.*, 2024).

The interactions of variety and fertilizers were significant for the number of pods during the two production seasons. The application of NPK and PM promoted a higher number of pods than the PME applications and the control. However, PME at T4 significantly increased pod counts in the two varieties compared to T3 and T2, with the control having the lowest counts during the two years of cropping. Comparatively, LD88 had more pod counts than NHAe47-4 under the same treatments. These findings suggest that LD88 has a greater capacity for pod development when given optimal nutrition, indicating a difference in reproductive efficiency (BAILEY-SERRES *et al.,* 2019).

The LD88 okra variety had significantly longer pods than NHAe47-4 during the 2022 and 2023 cropping seasons, implying a potential genetic advantage in LD88 pod sizes over NHAe47-4. This corroborates the findings of Okocha and Chinatu (2008) that NHAe47-4 had shorter pods compared to the LD88 okra variety. The result was associated with genetic variation between varieties.

Fertilizer application varied in its effect on okra pod length during the two crop seasons, with T5 and T6 resulting in the longest pods (6.02 and 6.15 cm) in 2022 and 2023, respectively, while T1 had the shortest. This result suggests that PME at the highest level of application was less comparable with PM and NPK fertilizer. However, PME at T4 also enhanced pod length significantly than the control. A previous study by El-Hamdi *et al.* (2017) substantiated that PME was not as efficient as PM in promoting crop growth.

For the interactive effects, LD88 × T5 had the longest pods (6.22 and 6.43 cm) in 2022 and 2023 cropping seasons, while the control had the smallest values. This finding suggests that LD88's advantage in pod development is under optimal treatments. However, the length of pods for T4 in the two varieties was next to PM and NPK influences on pod length. Despite lower pod length values observed in NHAe47-4, the response to fertilizer applications was similar to that of LD88 This further substantiates the importance of adequate nutrient availability for enhanced pod length.

Effect of fertilizers on the shoot biomass and fruit yields of two okra varieties

The result for shoot weight indicated that NHAe47-4 had significantly higher shoot weight (3513.34 and 3475.86 kg/ha) than LD88 (1113.12 and 1193.52 kg/ha) in 2022 and 2023 (Table 5). This indicated greater biomass accumulation, which could suggest better yield potential in NHAe47-4 than LD88. This corroborates the need for sturdiness, as earlier observed for NHAe47-4 in stem diameter, which could support biomass load. The findings of Badamasi *et al.* (2023) also affirmed that LD88 produced a substantially greater amount of fruit weight than NHAe47-4. According to Omolade *et al.* (2024), LD88 promotes flower production, which, under adequate soil nutrient status, would result in higher fruit yield.

The variation in shoot biomass was significant for fertilizer applications. The T5 and T6 treatments were similar and yielded the highest shoot weights (3419.21 and 3350.93 kg/ha in 2023) kg/ha in 2022, while T1 and T2 had the lowest. This study consolidated the supporting role of NPK and PM in promoting vegetative vigor. The T4 treatment during 2022 and 2023 also yielded significantly higher shoot biomass than the other PME applications and the control. This indicated that increasing nutrient availability promotes photosynthetic activities, leading to assimilates that enhance vegetative growth. However, the increasing shoot weight with an increase in PME implied inadequate nutrient supply, even at T4, was not similar to T5 and T6. This conforms with Mihoub *et al.* (2022) report on wheat, that Pigeon manure tea as a soil amendment enhanced P availability, thus leading to increased biomass production.

The interaction effects showed that NHAe47-4 x T6 (5151.07 and 5080.56 kg/ha) and NHAe47-4 x T5 (3029.97 and 4951.85) treatments gave the highest shoot biomass during the 2022 and 2023 cropping seasons, respectively. Similar trend was observed for LD88 during the two cropping seasons. These results are consistent with studies showing that NPK and PM enhance biomass accumulation (IBIRONKE & AKINRINOLA, 2025). Likewise, the T4-treated plants had a significant biomass increase compared to the lower levels of PME application for the two varieties. The varietal difference suggests NHAe47-4 has a higher capacity for biomass production (AJAYI *et al.*, 2020).

Table 5. Influence of fertilizers on the shoot biomass and fruit yields of two okra varieties during the 2022 and 2023 cropping seasons.

	Shoot weight (kg/ha)		Fruit yield (kg/ha)	
Treats	**2022**	**2023**	**2022**	**2023**
Varieties				
NHAe47-4	3513.34a	3475.86a	23890.05b	23763.74b
LD88	1113.12b	1193.52b	28390.43a	28458.95a
SE	51.98	71.81	72.64	113.76
Fertilizer applications				
T1	1383.33d	1462.49d	15798.38e	15790.28e
T2	1461.34d	1403.24d	16659.72d	16471.76d
T3	1856.85c	1907.22c	18612.04c	18622.69c
T4	2424.77b	2469.44b	24584.49b	24539.82b
T5	3419.21a	3350.93a	40544.45a	40557.41a
T6	3333.87a	3414.82a	40642.36a	40686.11a
SE	90.03	124.39	125.83	197.05
Variety×Fertilizer Interactions				
NHAe47-4×T1	2238.88d	2356.48c	15335.65j	15165.74j
NHAe47-4×T2	2368.06d	2213.89cd	16122.22i	15943.52ij
NHAe47-4×T3	2738.70c	2724.63c	17505.09h	17628.71g
NHAe47-4×T4	3554.17b	3527.78b	21899.08f	21751.85e
NHAe47-4×T5	5029.17a	4951.85a	36601.85c	36337.97c
NHAe47-4×T6	5151.07a	5080.56a	35876.39d	35754.63c
LD88×T1	527.78h	568.52h	16261.11i	16414.82hi
LD88×T2	554.63h	592.59gh	17197.22h	17000.00gh
LD88×T3	975.00g	1089.81fg	19718.98g	19616.67f
LD88×T4	1295.37fg	1411.11ef	27269.91e	27327.78d
LD88×T5	1809.26e	1750.00de	44487.04b	44776.86b
LD88×T6	1516.67ef	1749.07de	45408.34a	45617.60a
SE	127.33	175.92	177.95	278.67

Treatment means assigned similar letter(s) along the same columns are not significantly different at the 0.05 probability level, T1 = control, T2 = 840 L/ha extract, T3 = 1680 L/ha extract, T4 = 2520 L/ha, T5 = Poultry manure, T6 = NPK 15:15:15.

During the 2022 and 2023 cropping seasons, LD88 variety had significantly more fruit weight than NHAe47-4 (Table 5). This trend conforms with earlier observations, where LD88 variety had longer pods and higher pod count despite its lower biomass and vegetative performance. This suggests that the genetic orientation of LD88 is toward reproductive efficiency, which explains the consistent yield advantage over NHAe47-4 during the two cropping seasons. The observed genotype divergence indicated that NHAe47-4 may possess greater vigor, but LD88 converts more of its assimilates into harvestable yield. This finding is supported by Badamasi *et al.* (2023) report that the yield observed for LD88 is substantially higher than NHAe47-4. The variation in fruit yield could be attributed to the genetic makeup of the two varieties. While NHAe47-4 promotes vegetative growth, LD88 is better for fruit yield, thus suggesting higher assimilate partitioning in LD88 (ESHIET *et al.,* 2015). Also, the lower vegetative development in LD88 could suggest the preservation of resources for yield, which is an appreciated attribute for crops growing in the tropical and subtropical environments with limited available resources. Similar observation was made by Makinde et al. (2020), that the canopy structure of LD88 okra variety suppresses weeds than NHAe47-4.

Poultry manure extract applications significantly increased the yield of okra over the control, with the highest value observed with T4 application. However, the fruit yield from T4-treated plants was significantly lower than PM and NPK fertilizer treatments. The increase in response observed with higher PME application suggests that the plateau at which additional nutrients would not result in significant yield gains is not yet attained (Sarma *et al.*, 2024). Consequently, using T4-treatment could offer a sustainable path toward improved productivity without the economic burden of full-intensity input.

The interactions between variety and fertilizer application were significantly different for fruit yield during the two cropping seasons. The interactions involving LD88 had higher fruit yields than NHAe47-4 across fertilizer levels, indicating differences in genetic nutrient responsiveness between the varieties. According to Sarma *et al.* (2024), site-specific nutrient management tailored to genotype characteristics optimizes growth responses and sustains productivity. Bailey-Serres *et al.* (2019) and Ayodele and Shittu (2013) also reported a substantial yield increase resulting from N fertilizer application in LD88 than in NHAe47-4. The relatively small yield differences between T5 and T6 in the two varieties may suggest that the two sources of fertilizer had a similar influence, since they both contained the same recommended N/ha. The parity of PM and NPK fertilizer on crop performance was reported by Al-Hussainy and Manea (2019). These findings support the Sustainable Development Goals (SDGs) 2 (Zero Hunger) and 13 (Climate Action) by promoting resilient farming practices (Meschede, 2020). However, the limitations of the study were that the focus was on two seasons and one soil type, which limits generalizing findings. Long-term impacts on soil microbial diversity and economic feasibility were not assessed.

4. CONCLUSIONS

The results in this study revealed that LD88 gave higher plant height, pod length, and yield, while NHAe47-4 was better in terms of stem diameter, leaf number, and shoot weight. These differences suggest LD88 may be better suited for yield-focused production, while NHAe47-4 could be preferred for biomass-related uses. Although PM and NPK fertilizer promoted better okra performance across both varieties, the PME application at 2520 L/ha consistently enhanced all measured traits than the other levels of application. The interactive effects showed that the two okra varieties (NHAe47-4 and LD88) performed better with the application of 2520 L/ha of poultry manure extract. In conclusion, 2520 L/ha is suggested considering ease of handling and environmental risk reduction. Further investigation into higher levels of poultry manure extract application that would be at par with PM and NPK fertilizer, test PME on other tropical soil types, and evaluate cost-benefit ratios should be considered to enhance practical adoption.

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