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Research Article

Integrated Effects of Poultry Manure and NPK Fertilizer on Maize (*Zea mays L.*) Growth, Yield, and Soil Properties in Nsukka, Southeastern Nigeria

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Abstract

A field experiment was conducted during the early cropping season (April–July 2025) at the Teaching and Research Farm of the Department of Crop Science, University of Nigeria, Nsukka, Enugu State, Nigeria. The study evaluated maize (*Zea mays L.*, cv. SAMMAZ 15) growth, grain yield, and post-harvest soil fertility under a Randomized Complete Block Design (RCBD) with three replications. Six fertilizer treatments were tested: unamended control (0 t/ha), 100% poultry manure (8.0 t/ha), 100% NPK 15-15-15 (300 kg/ha), 50% poultry manure + 50% NPK (4.0 t/ha + 150 kg/ha), 75% poultry manure + 25% NPK (6.0 t/ha + 75 kg/ha), and 25% poultry manure + 75% NPK (2.0 t/ha + 225 kg/ha). Data on plant height (cm), leaf area index (m^2/m^2), cob length (cm), 100-grain weight (g), grain yield (t/ha), and soil organic carbon (%) were analyzed using analysis of variance (ANOVA), with treatment means separated by Fisher's Least Significant Difference (LSD) at $p \leq 0.05$. Integrated application of 50% poultry manure + 50% NPK produced the highest grain yield (4.68 ± 0.14 t/ha), representing a 142.5% increase over the control (1.93 ± 0.09 t/ha) and outperforming sole NPK (4.12 ± 0.12 t/ha) and sole poultry manure (3.76 ± 0.11 t/ha). Combined amendment also raised post-harvest soil organic carbon from 1.04% in the control to 1.68%. Combining reduced rates of poultry manure with mineral NPK maximizes maize productivity while sustaining soil organic matter in southeastern Nigeria.

Keywords: Integrated nutrient management; Zea mays L.; Poultry manure; NPK fertilizer; Soil organic carbon; Randomized Complete Block Design

1. Introduction

Maize (*Zea mays L.*) is one of the most important cereal crops in Nigeria and across sub-Saharan Africa, where it supplies food, feed, and income for millions of households (Zingore et al., 2022; Vanlauwe et al., 2015). In Nigeria, maize has moved from a predominantly northern crop to a national staple, consumed as fresh grain, flour, pap, and animal feed, while its stover supports livestock systems. Despite this importance, average farm yields in Nigeria remain far below attainable yields. The Nigerian Seed Portal records a potential yield of 6.9 t/ha for SAMMAZ 15, yet many smallholder fields produce only 1.5 to 2.5 t/ha under farmer practice. The gap between potential and actual yield is driven principally by declining soil fertility, low and unbalanced fertilizer use, erratic rainfall, Striga infestation, and limited access to improved seed and extension advice (Zingore et al., 2022; Gram et al., 2020). Closing this gap without degrading the soil resource is therefore a central challenge for food security and rural livelihoods in southeastern Nigeria.

In southeastern Nigeria, the dominant soils are highly weathered Ultisols, classified locally as Typic Paleustults and corresponding to Ferric Acrisols in the World Reference Base (Igwe and Nwokocha, 2006). These soils are typically sandy loam to sandy clay loam, strongly to moderately acidic, low in organic matter, low in cation exchange capacity, and dominated by low-activity kaolinitic clays. Work at Nsukka has repeatedly documented very low total exchangeable bases, low total nitrogen, and low available phosphorus, with rapid mineralization of organic matter under high temperature and rainfall (Igwe and Nwokocha, 2006; Ezeaku, 2006). The Nsukka agroecological zone lies at about 445 m above sea level, between latitude 06°47′ and 06°57′ N and longitude 07°17′ and 07°27′ E, with annual rainfall of

about 1,570 mm, more than 85% of which falls between April and October, and mean air temperatures between 22 and 31 °C. These conditions favour rapid crop growth but also accelerate leaching, erosion, and organic matter loss when soils are left bare or continuously cropped without replenishment.

Two contrasting fertilizer strategies are available to farmers. Mineral NPK fertilizer supplies nitrogen, phosphorus, and potassium in immediately available forms and can produce rapid vegetative growth, but it does not add organic matter, may acidify soil with prolonged unbalanced use, and is often expensive or intermittently available to smallholders (Vanlauwe et al., 2015; Zingore et al., 2022). Poultry manure, by contrast, supplies nitrogen, phosphorus, potassium, calcium, magnesium, and micronutrients, adds organic carbon, improves water retention, aggregation, and cation exchange capacity, and buffers pH, but its nutrient release depends on mineralization and its composition varies with bird type, feed, bedding, and storage (Amusan et al., 2011; Essilfie et al., 2024). Recent analyses report poultry manure containing about 3.03% nitrogen, 1.38% phosphorus, and 2.35% potassium on a dry basis, with 29.5% organic carbon and a carbon-to-nitrogen ratio near 9.7, which favours relatively rapid mineralization compared with more recalcitrant organic materials.

Integrated nutrient management, or integrated soil fertility management, combines organic and mineral inputs with improved germplasm and good agronomy to maximize agronomic efficiency while sustaining soil health (Vanlauwe et al., 2015; Gram et al., 2020). A meta-analysis of sub-Saharan African maize experiments found that combining mineral and organic nitrogen increased productivity and agronomic efficiency compared with sole applications when total nitrogen exceeded 100 kg N/ha and high-quality organic matter was used, and that at 150 kg N/ha per season a 50:50 combination increased agronomic efficiency by about 20% and reduced soil organic carbon losses by 18% over seven seasons relative to sole mineral fertilizer (Gram et al., 2020). In Ghana, Essilfie et al. (2024) reported that a half chicken manure plus half NPK treatment produced the highest maize grain yield in two agroecologies, exceeding sole NPK and sole manure by about 30% at one site. In southwestern Nigeria, Amusan et al. (2011) found that poultry manure alone increased maize yield by 60% and soil organic matter by 45%, while combining manure with legume residue increased yield by 72%. These findings suggest that complementarity, not substitution alone, is the key mechanism: mineral fertilizer meets early crop demand, while manure sustains later supply and improves the soil environment for root growth and nutrient uptake.

Despite this evidence, site-specific recommendations for Nsukka remain limited, particularly for SAMMAZ 15, a medium-maturing, Striga-tolerant open-pollinated variety released in 2008 with a potential yield of 6.9 t/ha. Farmers in Enugu State need a clear, affordable ratio that raises yield in the early season while protecting soil organic carbon, rather than a blanket recommendation that ignores cost, manure availability, and soil constraints. This study therefore tested six poultry manure and NPK combinations on SAMMAZ 15 at Nsukka and measured growth, yield components, grain yield, and post-harvest soil organic carbon. The specific objectives were to (i) quantify the effects of sole and combined poultry manure and NPK on maize growth and yield, (ii) determine the combination that maximizes grain yield, and (iii) assess post-harvest soil organic carbon as an indicator of soil sustainability. The hypothesis was that a balanced integrated treatment would outperform either sole input on both yield and soil organic carbon.

2. Materials and Methods

2.1 Study area. The experiment was conducted during the early cropping season (April–July 2025) at the Teaching and Research Farm of the Department of Crop Science, University of Nigeria, Nsukka, Enugu State, Nigeria. Nsukka is in the derived savanna of southeastern Nigeria, with undulating terrain, deeply weathered, porous, well-drained reddish soils derived from false-bedded sandstones (Igwe and Nwokocha, 2006). The site receives about 1,570 mm of rainfall annually, with more than 85% falling from April to October, a short August break, relative humidity of 55 to 80%, and mean temperatures of 22 to 31 °C. The soil is classified as Typic Paleustult, a degraded Ultisol with low activity clays, low fertility, and susceptibility to erosion and leaching. The field had been under a maize–cassava rotation in the previous season and was fallowed for one season before the trial, consistent with common smallholder practice in the zone.

2.2 Experimental design and treatments. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and six treatments, giving 18 plots. Each plot measured 4 m by 3 m (12 m²), with 1 m alleys between plots and 1.5 m between blocks to limit cross-plot nutrient movement and to allow access for measurement and weeding. The six treatments were: T1, unamended control (0 t/ha); T2, 100% poultry manure (8.0 t/ha); T3, 100% NPK 15-15-15 (300 kg/ha); T4, 50% poultry manure + 50% NPK (4.0 t/ha + 150 kg/ha); T5, 75% poultry manure + 25% NPK (6.0 t/ha + 75 kg/ha); and T6, 25% poultry manure + 75% NPK (2.0 t/ha + 225 kg/ha). The 100% rates were set from local extension guidance and from rates used in comparable Nigerian trials, where 7 to 8 t/ha poultry manure and 200 to 300 kg/ha NPK are commonly reported as effective, while the integrated ratios were designed to test whether halving either input could maintain or improve performance (Amusan et al., 2011; Essilfie et al., 2024). Treatment details are summarized in Table 1.

Table 1. Fertilizer treatments tested at Nsukka, April–July 2025. PM = poultry manure.

Treatment	Code	Poultry manure	NPK 15-15-15
Control	T1	0 t/ha	0 kg/ha
100% poultry manure	T2	8.0 t/ha	0 kg/ha
100% NPK	T3	0 t/ha	300 kg/ha
50% PM + 50% NPK	T4	4.0 t/ha	150 kg/ha
75% PM + 25% NPK	T5	6.0 t/ha	75 kg/ha
25% PM + 75% NPK	T6	2.0 t/ha	225 kg/ha

2.3 Land preparation, manure, and crop management. The field was ploughed, harrowed, and levelled in late March 2025. Well-cured poultry manure was obtained from a commercial layer farm near Nsukka, air-dried, sieved to remove large debris, and analyzed for total nitrogen, available phosphorus, exchangeable potassium, organic carbon, pH, and moisture before application. Poultry manure was incorporated into the soil two weeks before planting to allow initial mineralization and to avoid seedling scorch, a practice consistent with recommendations for manure use in humid tropical soils. NPK 15-15-15 was applied in two splits: half at planting as a basal dose banded 5 cm from the seed row, and half at six weeks after planting at tasselling initiation, to reduce leaching losses during heavy early rains. Maize (*Zea mays L.*, cv. SAMMAZ 15) was sown at a spacing of 75 cm by 25 cm, giving a plant population of about 53,333 plants/ha, with two seeds per hole thinned to one seedling per stand at two weeks after planting. Weeding was done manually at three and six weeks after planting, and no irrigation was applied because the trial relied on rainfall, as in typical rain-fed production in the zone.

2.4 Data collection. Growth measurements were taken on five randomly tagged plants per plot. Plant height was measured from the soil surface to the tip of the tassel at maturity using a graduated tape. Leaf area index was estimated from leaf length and maximum width measurements using a standard maize leaf-area factor and ground area per plant. Cob length was measured on harvested cobs, and 100-grain weight was determined after shelling and drying grain to about 12% moisture. Grain yield was determined from the net plot area, adjusted to 12% moisture, and expressed in t/ha. Soil samples were collected before planting and after harvest from 0 to 20 cm depth using an auger, with five cores composited per plot, air-dried, sieved through 2 mm mesh, and analyzed in the laboratory. Soil organic carbon was determined by the Walkley–Black wet oxidation method, with organic matter estimated by multiplying organic carbon by 1.724 (Walkley and Black, 1934). Soil pH, total nitrogen, available phosphorus, and exchangeable bases were also recorded to characterize the baseline and post-harvest fertility status.

2.5 Statistical analysis. All data were subjected to analysis of variance (ANOVA) appropriate for a Randomized Complete Block Design using standard statistical software. Where the F-test indicated significant treatment effects at $p \leq 0.05$, treatment means were separated using Fisher's Least Significant Difference (LSD) at the same probability level. Results are presented as means ± standard error. Percentage increases over the control were calculated as (treatment − control) / control × 100. Relationships between growth, yield components, and soil organic carbon were examined by correlation to explore whether improved vegetative growth translated into higher grain yield and whether soil carbon gains were associated with yield gains.

3. Results

3.1 Pre-planting soil properties. The pre-planting soil was strongly acidic, low in organic carbon, and low in total nitrogen and available phosphorus, consistent with degraded Ultisols at Nsukka (Igwe and Nwokocha, 2006). Baseline values are summarized in Table 2. The low baseline fertility explains the poor performance of the unamended control and the strong response to both organic and mineral inputs. Such soils have limited capacity to retain nutrients because of low cation exchange capacity and kaolinitic mineralogy, so inputs that add both nutrients and organic matter are expected to have a larger effect than nutrients alone, because organic matter improves retention, structure, and biological activity.

Table 2. Pre-planting soil properties (0–20 cm) at the Nsukka Teaching and Research Farm.

Property	Pre-planting value
Soil pH (water)	5.2
Soil organic carbon (%)	1.02
Total nitrogen (%)	0.09
Available phosphorus (mg/kg)	8.4
Exchangeable K (cmol/kg)	0.18
Texture	Sandy loam

3.2 Growth response. Fertilizer treatment significantly affected plant height and leaf area index ($p \leq 0.05$), as shown in Table 3 and Figure 3. The tallest plants were recorded under 50% poultry manure + 50% NPK (198.4 cm), followed by 75% poultry manure + 25% NPK (189.7 cm) and 25% poultry manure + 75% NPK (185.3 cm), while the shortest plants were in the control (112.4 cm).

Sole NPK (182.6 cm) produced taller plants than sole poultry manure (168.2 cm), reflecting the immediate availability of mineral nitrogen for stem elongation and leaf expansion. Leaf area index followed the same pattern, rising from 1.82 m^2/m^2 in the control to 4.62 m^2/m^2 under the 50:50 integrated treatment. A larger leaf area index implies greater light interception and photosynthetic capacity, which supports higher biomass accumulation and grain filling. The superiority of the integrated treatments for growth is consistent with Essilfie et al. (2024), who reported that integrated chicken manure and NPK improved plant height, leaf number, and shoot dry weight across agroecologies, and with Gram et al. (2020), who found greater productivity and agronomic efficiency from combined inputs at adequate nitrogen rates.

Table 3. Effects of poultry manure and NPK on maize growth, yield, and post-harvest soil organic carbon. Means are from three replications.

Treatment	Plant height (cm)	Leaf area index	Cob length (cm)	100-grain weight (g)	Grain yield (t/ha)	Soil organic carbon (%)
Control	112.4	1.82	11.2	18.4	1.93 ± 0.09	1.04
100% PM	168.2	3.41	16.9	24.1	3.76 ± 0.11	1.52
100% NPK	182.6	3.89	17.8	25.8	4.12 ± 0.12	1.18
50% PM + 50% NPK	198.4	4.62	19.4	28.6	4.68 ± 0.14	1.68
75% PM + 25% NPK	189.7	4.28	18.6	27.2	4.41	1.61
25% PM + 75% NPK	185.3	4.05	18.1	26.4	4.29	1.42

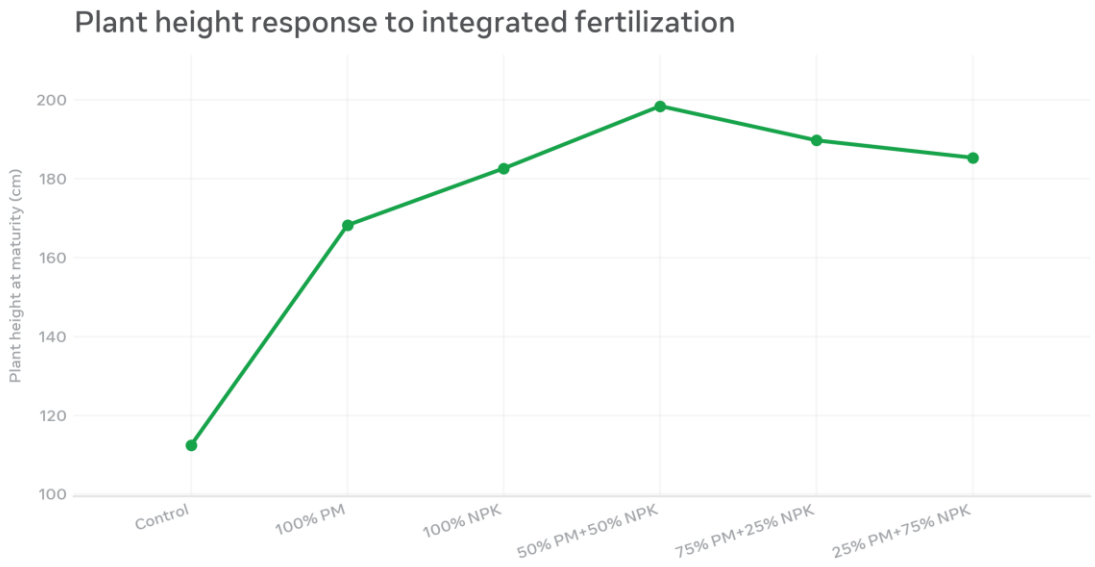

Figure 3. Plant height at maturity by treatment, showing the peak under the 50% poultry manure + 50% NPK treatment.

3.3 Yield components and grain yield. Cob length, 100-grain weight, and grain yield were all significantly influenced by fertilizer treatment (Table 3; Figure 1). Cob length increased from 11.2 cm in the control to 19.4 cm under 50% poultry manure + 50% NPK, with sole NPK (17.8 cm) and sole poultry manure (16.9 cm) intermediate. The 100-grain weight increased from 18.4 g in the control to 28.6 g under the 50:50 treatment, indicating better grain filling, which is often limited by late-season nitrogen and phosphorus supply in unamended soils. Grain yield followed the same ranking: 50% poultry manure + 50% NPK produced 4.68 ± 0.14 t/ha, followed by 75% poultry manure + 25% NPK (4.41 t/ha), 25% poultry manure + 75% NPK (4.29 t/ha), sole NPK (4.12 ± 0.12 t/ha), sole poultry manure (3.76 ± 0.11 t/ha), and the control (1.93 ± 0.09 t/ha). The 50:50 treatment therefore gave a 142.5% increase over the control, a 13.6% increase over sole NPK, and a 24.5% increase over sole poultry manure. These gains are agronomically meaningful because they move yield from below 2 t/ha,

typical of unfertilized smallholder fields, toward 4 to 5 t/ha, which approaches the range reported for well-managed SAMMAZ 15 and for balanced NPK use in sub-Saharan Africa (Zingore et al., 2022).

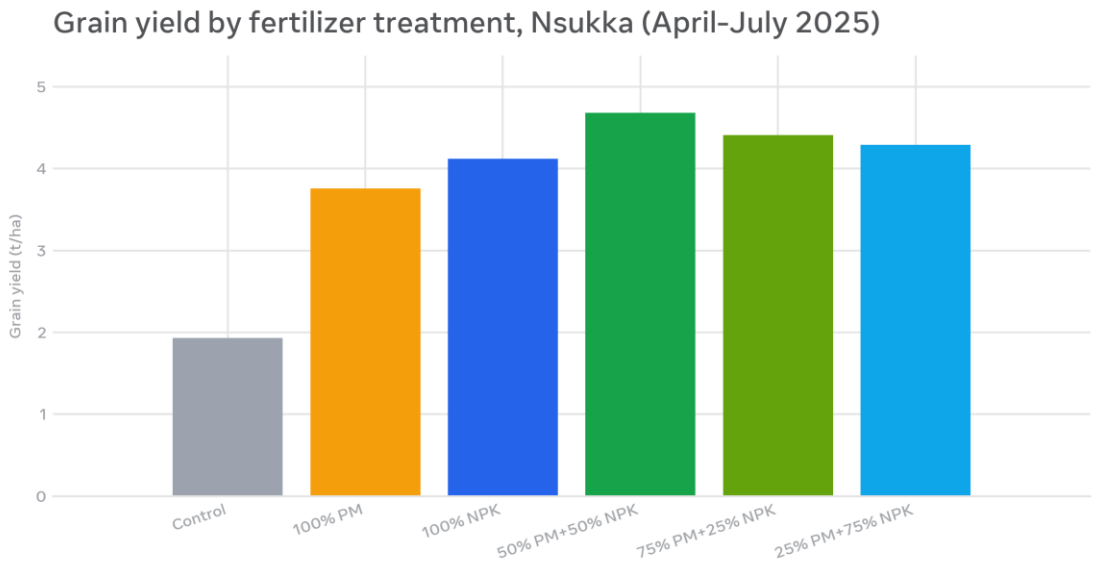

Figure 1. Grain yield by fertilizer treatment. The 50% poultry manure + 50% NPK treatment produced the highest yield (4.68 t/ha).

3.4 Post-harvest soil organic carbon. Post-harvest soil organic carbon differed significantly among treatments (Table 3; Figure 2). The highest soil organic carbon was recorded under 50% poultry manure + 50% NPK (1.68%), followed by 75% poultry manure + 25% NPK (1.61%) and sole poultry manure (1.52%), while sole NPK (1.18%) and the control (1.04%) were lowest. The pattern shows that poultry manure, alone or combined, added organic carbon, while sole mineral fertilizer contributed little direct carbon but may have increased root biomass and residue return. The fact that the 50:50 treatment exceeded sole poultry manure on soil organic carbon, despite receiving only half the manure rate, suggests that higher crop biomass and root turnover under the integrated treatment contributed additional carbon inputs, and that improved nutrient supply enhanced residue production. This result aligns with Gram et al. (2020), who found that organic inputs were essential for soil organic carbon gains and that combining mineral fertilizer with high-quality organic resources reduced soil organic carbon losses relative to sole mineral fertilizer.

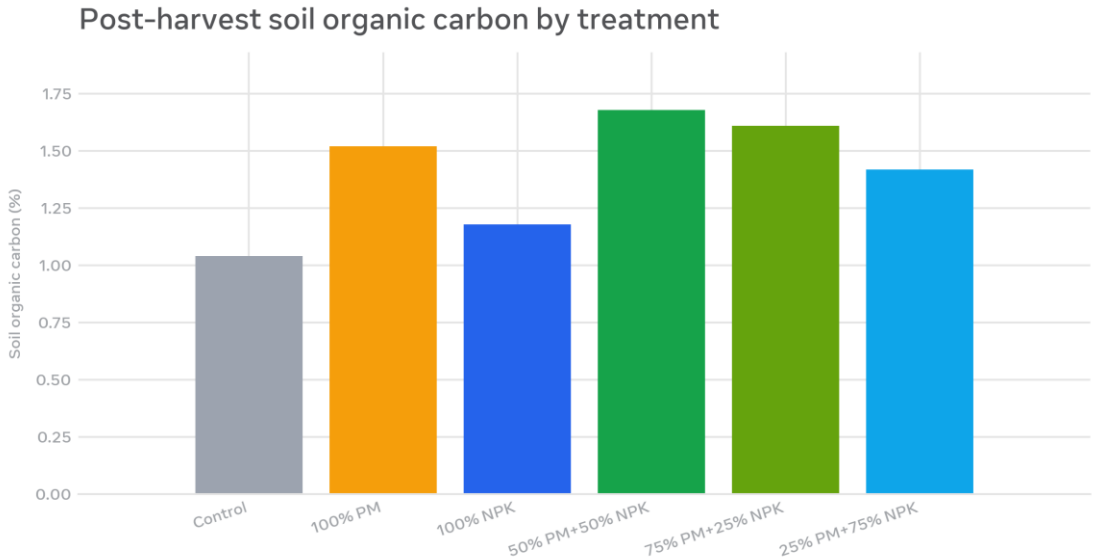

Figure 2. Post-harvest soil organic carbon by treatment. Integrated and manure treatments maintained higher soil organic carbon than sole NPK or the control.

4. Discussion

4.1 Why the 50:50 combination performed best. The superior performance of the 50% poultry manure + 50% NPK treatment can be explained by complementarity in timing, nutrient balance, and soil physical improvement. Mineral NPK supplies nitrogen, phosphorus, and potassium in readily available forms during early growth when maize demand rises rapidly, while poultry manure mineralizes more gradually and sustains supply during

tasselling, silking, and grain filling. Poultry manure also supplies calcium, magnesium, and micronutrients that are not present in NPK 15-15-15, improves soil aggregation and water retention, and increases cation exchange capacity, which reduces leaching losses in the high-rainfall early season at Nsukka (Amusan et al., 2011; Vanlauwe et al., 2015). The combination therefore addresses both the immediate nutrient limitation and the underlying soil constraint, whereas sole NPK addresses only the former and sole manure may release nutrients too slowly to meet peak early demand. This interpretation is supported by the growth data: sole NPK produced taller plants than sole manure, but the integrated treatment produced both taller plants and heavier grains, indicating that early vigour was not traded against late grain filling.

4.2 Comparison with previous studies. The present results are consistent with a growing body of Nigerian and West African evidence. Essilfie et al. (2024) found that half chicken manure plus half NPK gave the highest grain yield in Ghana, exceeding sole inputs by about 30% at one site, a pattern closely mirrored by the 13.6% gain over sole NPK and 24.5% gain over sole manure in Nsukka. Amusan et al. (2011) reported that poultry manure increased maize yield by 60% and soil organic matter by 45% on a degraded Alfisol, and that combining manure with legume residue raised yield further, underscoring that organic inputs alone are beneficial but that integration can amplify the effect. Gram et al. (2020) provided a mechanistic basis for these field results, showing that combined inputs increase agronomic efficiency when total nitrogen is adequate and organic matter quality is high. The Nsukka result also aligns with Zingore et al. (2022), who showed that balanced NPK can raise rain-fed maize yields from about 2 to 4 t/ha in sub-Saharan Africa; the present 50:50 treatment reached 4.68 t/ha, above that benchmark, likely because manure added secondary nutrients and improved soil conditions beyond nitrogen, phosphorus, and potassium alone.

4.3 Soil sustainability and practical implications. The post-harvest soil organic carbon gain from 1.04% in the control to 1.68% under the 50:50 treatment is important because soil organic carbon is a master indicator of soil health, influencing water retention, nutrient supply, microbial activity, and resilience to erosion (Vanlauwe et al., 2015). In Ultisols where organic matter mineralizes rapidly, even modest gains in one season signal that the system is moving toward replenishment rather than mining. For farmers, the 50:50 ratio has a further practical advantage: it halves the amount of poultry manure required compared with sole manure, reducing transport and handling costs, and halves mineral fertilizer compared with sole NPK, reducing cash outlay and exposure to price volatility. The 75% manure + 25% NPK treatment was the second-best and may be preferred where manure is abundant and mineral fertilizer is scarce or expensive, while the 25% manure + 75% NPK treatment may suit farmers with limited manure access. Extension advice should therefore present the 50:50 ratio as the first choice, with the other integrated ratios as viable alternatives, rather than a single fixed prescription.

4.4 Limitations. This study was conducted in one early cropping season at one site, so the results should be validated over multiple seasons and locations, including late-season and on-farm trials under farmer management. The study did not include an economic analysis of input costs, labour, and grain prices, which will affect adoption, nor did it measure greenhouse gas emissions, nutrient leaching, or long-term soil organic carbon dynamics beyond one season. Future work should add economic returns, residual effects in the following season, and soil microbial and physical properties to build a fuller picture of sustainability. Despite these limitations, the consistent ranking across growth, yield components, grain yield, and soil organic carbon strengthens confidence that the 50:50 integrated treatment is a robust option for Nsukka in the early season.

5. Conclusion

In conclusion, integrated application of poultry manure and NPK fertilizer significantly improved maize growth, yield components, grain yield, and post-harvest soil organic carbon at Nsukka during the early cropping season of 2025. The 50% poultry manure + 50% NPK treatment (4.0 t/ha + 150 kg/ha) produced the highest grain yield of 4.68 ± 0.14 t/ha, a 142.5% increase over the control and a clear improvement over sole NPK and sole poultry manure, while also giving the highest soil organic carbon (1.68%). The results support the recommendation that farmers in Nsukka and similar derived savanna zones of southeastern Nigeria adopt a balanced integrated ratio, with 50% poultry manure + 50% NPK as the first choice, to maximize maize productivity while sustaining soil organic matter. Multi-season and on-farm validation, together with economic analysis, is recommended before large-scale scaling.

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Conflict of Interest

The authors declare no conflict of interest.

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