

Comparative Study on the Effect of Organic and Inorganic Fertilization on the Vegetative Growth of Three Hibiscus Species

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DOI: <https://doi.org/10.62154/ajasfr.2026.023.01013>

Abstract

Given the rising demand for the species of the genus *Hibiscus*, namely, *Hibiscus rosa-sinensis* (Chinese Hibiscus / Rama), *Abelmoschus esculentus* (Okra / Okro) and *Hibiscus sabdariffa* (Zobo / Roselle) in ornamental, medicinal, nutritional and industrial sectors, there is a need of evidence-based fertilization strategies that sustain both productivity and ecology. The effect of these two fertilization methods (organic and inorganic) was compared with the effect of an unfertilized control on vegetative growth of three Malvaceae-family crops. Experimental research design was adopted and the research was carried out at the Federal University of Education (FUE) Zaria Biological Garden for six weeks under early vegetative growth period under controlled field conditions. Three treatment groups were used for each species, with key parameters measured being plant height, leaf size, leaf number, leaf colouration (as an indicator of chlorophyll content), stem girth and plant vigour. The result showed that the organic fertilization always had positive effect on leaf size, leaf greenness and plant height of three species, namely *Hibiscus rosa-sinensis* (Chinese Hibiscus / Rama), *Hibiscus sabdariffa* and *Abelmoschus esculentus*, although the significant difference occurred only in *Hibiscus rosa-sinensis* (Chinese Hibiscus / Rama), followed by *Hibiscus sabdariffa* and the moderate difference was found in *Abelmoschus esculentus*. Inorganic fertilizer was moderately beneficial compared to the control, but was always less than organic inputs in all measured parameters. The results confirm the positive effect of organic fertilization on vegetative development, due to higher soil microbial activity, nutrient cycling and soil moisture availability. The study suggests that the use of organic fertilizers preferably in combination with a very small amount of inorganic fertilizer is a sustainable and effective practice for the production of *Hibiscus* species and allied crops in Nigeria.

Keywords: Organic Fertilizer, Inorganic Fertilizer, Poultry Manure, Vegetative Growth, Soil Fertility, *Hibiscus sabdariffa*, Nigeria.

Introduction

Hibiscus is a large genus of flowering plants, a part of the *Malvaceae* family, which includes several hundred species, widespread throughout the tropical, subtropical and warm temperate regions of the world and of economic importance (dos Santos Silva et al., 2023). Some of the most important agricultural and commercial species are *Hibiscus rosa-sinensis* (popularly known as Chinese hibiscus or Rama), which is grown for ornamental purposes, for its large, colorful, aesthetically captivating flowers; *Hibiscus sabdariffa* locally known as

zobo in Nigeria, which is grown for its fleshy, antioxidant-rich calyces for use as beverages, jams, and herbal preparations; *Abelmoschus esculentus* (popularly known as okra or okro) which is one of the most consumed vegetables in Nigeria for its mucilaginous and nutritious pods (Elkhalifa, et al., 2021; Kwok, et al., 2025). While each of these species is in a different economic niche, they are all dependent on good soil nutrition for their best growth and production.

Fertilisation is one of the most critical factors influencing growth and productivity of the crop plants. Fertilizers provide the necessary macronutrients and micronutrients, especially N, P and K, which are essential for vegetative growth, photosynthesis, root development and reproduction (Fang, et al., 2023). There are two main types of fertilizers that are commonly used: organic fertilizers, which are made from natural biological sources such as animal manure, compost, and plant material; and inorganic fertilizers, which are synthetic or chemical fertilizers produced industrially in a precise form to be readily available for the plant (Tagkas et al., 2024). Each type offers unique benefits and drawbacks, and the decision between them can greatly impact soil health and crop performance.

Organic fertilizers provide a steady nutrient release throughout the growing season, improve soil structure and water retention, and foster microbial diversity, which are essential for sustainable food production (Lin et al., 2026; Khan et al., 2024). Several studies conducted on Hibiscus have shown that the soil properties and plant biomass are significantly improved with the use of organic manure (Iwuagwu & Okafor, 2024; Yusuf et al., 2019). In contrast, inorganic fertilizers provide a quick nutrient supply and are effective in quickly correcting nutrient deficiencies and in promoting early vegetative growth (Quddus et al., 2025). But their use for a long time has been linked to soil acidification, decrease in organic matters, disturbance in soil microbial community, and environmental issues such as eutrophication of groundwater and GHGs emissions (Xing et al., 2025; Chataut et al., 2023). Although there are so many literatures available on the response of the fertilizer applied to individual crops, the comparative works specifically to the effect of organic and inorganic fertilizer on the various species of Hibiscus under the same experimental conditions are less available. This gap limits the farmers and agricultural practitioners to make an informed decision on fertilization for these important economic crops. The present investigation thus attempts to systematically analyze and compare the effects of the two fertilization methods (organic and inorganic) on the vegetative growth of three species of the Hibiscus family: *Hibiscus rosa-sinensis*, *Hibiscus sabdariffa* and *Abelmoschus esculentus* in order to provide evidence to the farmers, researchers and agricultural policy makers of Nigeria.

Statement of the Problem

As the demand for Hibiscus species products in ornamental horticulture, health beverages, culinary and industrial fibres is increasing globally, particularly across West Africa and Nigeria, it is essential to optimise the cultivation practices. The fertilization regime is an important factor that growers can control to affect vegetative growth, biomass production,

and yield. However, a large knowledge gap exists in knowledge of the effects of organic and inorganic fertilization on important vegetative growth parameters (plant height, leaf number, leaf size, stem girth and biomass) in the three major species of the Hibiscus family at the same time. Although there are many previous studies, most of them focus on single species and single fertilizers, and few studies investigate comparative multi-species analyses. This study fills that gap by comparing both types of fertilisers simultaneously in 3 species in the same controlled conditions, providing directly comparable evidence on the best and most sustainable way to fertilize.

Objectives of the Study

The study aims to:

1. Compare the effects of organic and inorganic fertilizers on the vegetative growth parameters of *Hibiscus rosa-sinensis*, *Hibiscus sabdariffa*, and *Abelmoschus esculentus*.
2. Determine the best fertilization method that enhances plant height, leaf production, leaf size, leaf coloration, and overall biomass in the three Hibiscus-family species.
3. Examine the differential response of each species to organic versus inorganic fertilization to identify species-specific fertilization preferences.
4. Provide evidence-based recommendations for sustainable fertilization strategies for Hibiscus species cultivation in the Nigerian agricultural context.

Research Questions

1. How do organic and inorganic fertilizers differ in their effects on the vegetative growth parameters (plant height, leaf size, leaf number, leaf coloration, stem girth) of *Hibiscus rosa-sinensis*, *Hibiscus sabdariffa*, and *Abelmoschus esculentus*?
2. Which fertilization method, organic or inorganic results in the highest plant height, leaf production, and biomass yield across the three Hibiscus species?
3. Do the three Hibiscus species respond differently to organic and inorganic fertilization, and if so, which species demonstrates the most pronounced growth response to organic inputs?

Hypotheses

The following null hypotheses were tested in this study:

H_{01} : There is no significant difference in vegetative growth parameters (plant height, leaf size, leaf number, leaf coloration, and stem girth) between plants treated with organic fertilizer (poultry manure), inorganic fertilizer (NPK 15:15:15), and the unfertilized control across the three Hibiscus-family species.

Ho₂: The three Hibiscus-family species (*Hibiscus rosa-sinensis*, *Hibiscus sabdariffa*, and *Abelmoschus esculentus*) do not differ significantly in their response to organic versus inorganic fertilization for any of the measured vegetative growth parameters.

Theoretical/Conceptual Framework

This study is anchored on the Integrated Nutrient Management (INM) framework, which conceptualises optimal crop nutrition as a dynamic interaction between soil, plants, microorganisms, and nutrient inputs from both organic and inorganic sources. INM theory holds that crop growth and soil health are most sustainably achieved not through exclusive reliance on either fertilizer type, but through the strategic combination or comparative evaluation of organic and inorganic nutrient sources to maximise nutrient use efficiency while maintaining long-term soil fertility (Shittu et al., 2025; Abid et al., 2020). Within this framework, organic inputs such as poultry manure are understood to improve soil physical structure, enhance microbial diversity, and provide a sustained nutrient release, while inorganic fertilizers (e.g., NPK 15:15:15) supply immediately available macronutrients for rapid vegetative response (Lin et al., 2026; Fang et al., 2023).

The INM framework informs this study's variable selection by identifying fertilizer type (organic vs. inorganic vs. control) as the key independent variable, and vegetative growth parameters (plant height, leaf number, leaf size, leaf coloration, and stem girth) as the dependent variables reflecting soil-plant-nutrient interaction outcomes. The framework further guides the comparative design across three Hibiscus-family species, enabling species-specific fertilizer response to be interpreted within the broader context of sustainable nutrient management for tropical horticultural and food crops in Nigeria.

Review of Related Literature

Overview of the Hibiscus Genus

The genus Hibiscus comprises several economically and culturally significant species, each distinguished by unique morphological characteristics and sectoral applications. *Hibiscus rosa-sinensis*, the Chinese hibiscus, is extensively cultivated as an ornamental plant due to its large, colourful flowers, which range from red to pink, yellow, and white varieties. This species is popular in-home gardens, parks, and landscapes across tropical and subtropical regions and is also used in the preparation of natural dyes and traditional herbal remedies (Raza et al., 2025). *Hibiscus sabdariffa*, or roselle, is cultivated primarily for its fleshy red calyces, which are rich in organic acids, anthocyanins, and vitamin C. These calyces are widely used in the preparation of hibiscus tea (known locally as "zobo" in Nigeria), jams, jellies, and sauces, and the species has recognised antihypertensive, antioxidant, and antimicrobial properties (Ghaly et al., 2025). *Abelmoschus esculentus*, commonly known as okra or okro, is one of Nigeria's most widely consumed vegetables, valued for its nutrient-rich edible pods and extensive culinary applications (Kwok et al., 2025). Each of these species contributes uniquely to horticulture, the food and health industries, and culinary traditions, collectively underscoring the genus's multifaceted agricultural importance.

Table 1: Overview of Three Hibiscus-Family Species Examined in This Study

Species	Common Name	Primary Use	Family	Key Nutrient Requirement
Hibiscus rosa-sinensis	Chinese Hibiscus / Rama	Ornamental, herbal medicine, natural dyes	Malvaceae	Nitrogen (vegetative growth, leaf development)
Hibiscus sabdariffa	Roselle / Zobo	Beverages, jams, pharmaceutical	Malvaceae	Potassium (calyx quality and quantity)
Abelmoschus esculentus	Okra / Okro	Edible pods, culinary dishes	Malvaceae	Phosphorus (root dev.) + Nitrogen (leaf prod.)

Source: Compiled from dos Santos Silva, et al. (2023), Kwok et al. (2025), and Onyenekwe et al. (2021).

Plant Nutrition and the Importance of Fertilizers

Plant nutrition is a fundamental pillar of crop production and overall plant health. To achieve optimal growth, plants require a balanced supply of essential nutrients categorised into macronutrients and micronutrients. Macronutrient's nitrogen (N), phosphorus (P), and potassium (K) are required in larger quantities and play vital roles in physiological and biochemical processes (Ma et al., 2022). Nitrogen is essential for chlorophyll synthesis and vegetative growth; phosphorus supports energy transfer and root development; and potassium regulates stomatal activity, disease resistance, and water use efficiency (Kumari et al., 2022). Micronutrients, including iron, zinc, manganese, and boron, though needed in smaller quantities, are equally important for enzyme activation, hormone regulation, and metabolic functions. Fertilizers are the primary means by which essential soil nutrients are replenished. Research consistently shows that fertilization not only enhances vegetative traits such as height, leaf number, and stem thickness, but also influences flowering and fruiting capacity (Lu et al., 2025). Balanced nutrient management considering both fertilizer type and application timing is essential for optimising plant response, especially in sensitive species like those in the Hibiscus genus. Excessive or inappropriate use of inorganic fertilizers can lead to soil degradation, nutrient leaching, and environmental pollution, reinforcing the importance of sustainable, integrated fertilization practices (Xing et al., 2025; FAO, 2021).

Organic Fertilizers

Organic fertilizers are natural substances derived from biological sources including decomposed plant residues, animal manure, green manure, and compost and are characterised by a slow nutrient release mechanism that provides a sustained supply of nutrients while reducing the risk of leaching and enhancing long-term soil fertility (Khan et

al., 2024). Beyond nutrient supply, organic fertilizers improve soil aggregation, porosity, root penetration, and aeration; increase water infiltration and retention; and stimulate microbial activity essential for nutrient cycling and humus formation (Lu et al., 2025). They also enhance cation exchange capacity (CEC), which improves the soil's ability to retain and exchange nutrients efficiently. Studies by Anil et al. (2025) have shown that treated organic amendments including composted manure significantly increased the growth and biomass of horticultural crops due to improved nutrient availability and microbial interactions. Organic fertilizers also align with environmentally sustainable agricultural practices: they pose minimal risk of groundwater contamination, do not cause harmful salt accumulation in the soil, sequester carbon, and contribute to climate change mitigation (Tadesse et al., 2021). Key limitations include inconsistency in nutrient composition, slower immediate action relative to chemical fertilizers, and the large volumes sometimes required to meet crop nutrient demands (FAO, 2021).

Inorganic Fertilizers

Inorganic fertilizers are industrially manufactured compounds formulated to supply essential plant nutrients in precise and immediately available forms. They typically contain high concentrations of macronutrients nitrogen, phosphorus, and potassium in combinations tailored to specific crop and soil requirements. Common examples include urea (46% N), NPK 15:15:15 blends, and ammonium phosphate (Sinha, & Tandon, 2020). Their primary advantage lies in the rapidity of nutrient release, making them effective for correcting acute nutrient deficiencies and stimulating fast vegetative growth. Golla et al. (2026) confirmed that inorganic fertilizers significantly enhance vegetative parameters such as plant height, leaf area, and biomass when applied appropriately.

Despite these productivity benefits, the exclusive and excessive use of inorganic fertilizers raises serious concerns. Continuous application disrupts the soil microbial ecosystem, reduces organic matter content, leads to soil structure degradation, promotes nutrient leaching, and contributes to soil acidification and water body eutrophication (Ghisman et al., 2025). These adverse effects have prompted growing consensus among agronomists that inorganic fertilizers should be used judiciously guided by soil testing and nutrient management plans and ideally integrated with organic inputs to maximise benefits while mitigating environmental risks.

Comparative Studies on Organic and Inorganic Fertilization

A substantial body of comparative research consistently demonstrates that while inorganic fertilizers produce faster initial vegetative growth, organic fertilizers tend to generate more sustained, comprehensive growth improvements with concurrent long-term soil health benefits. Siddiqui et al. (2020) showed that poultry manure enhanced leaf development in spinach more than chemical fertilizers, though the latter produced quicker initial sprouting. Chen et al. (2024) found that NPK fertilizer accelerated early maize vegetative growth, but organic manure-maintained soil fertility and supported more stable yield patterns across

subsequent planting cycles. Shittu et al. (2025) demonstrated that integrated application of both fertilizer types in okra produced higher yield outcomes than either alone, supporting the concept of Integrated Nutrient Management (INM). Studies specifically on Hibiscus species reinforce this pattern. Iwuagwu and Okafor (2024) reported that Hibiscus sabdariffa responded positively to poultry manure, showing increased leaf size, plant height, and calyx yield. Conversely, Olanipekun et al. (2021) found that in nutrient-deficient sandy soils, inorganic fertilizers were more effective in boosting early growth of Hibiscus rosa-sinensis, suggesting that soil context influences fertilizer effectiveness. Internationally, Anil et al. (2025) reported that vermicompost improved soil microbial activity and delayed senescence in okra, while chemical fertilizers promoted rapid vegetative growth and earlier flowering. Abid et al. (2020) observed that combining organic compost with NPK in Hibiscus plants improved both vegetative and reproductive parameters more than either alone, supporting integrated nutrient management as the optimal long-term strategy.

Materials and Methods

Materials Used for the Study

The following materials were used to conduct the experimental procedures:

Table 2: Materials Used in the Study and Their Respective Functions

Material	Function	Quantity / Remarks
Seeds (3 species)	Planting material for experimental groups	3 species: <i>H. rosa-sinensis</i> , <i>H. sabdariffa</i> , <i>A. esculentus</i>
Polythene bags	Planting containers / pots	Uniform size to ensure consistency
Garden soil	Growth medium for germination and development	Collected from FUE Zaria school garden
Organic fertilizer (poultry manure)	Organic treatment (slow nutrient release)	Applied at 2 kg/bag, well-decomposed
Inorganic fertilizer (NPK 15:15:15)	Inorganic treatment (rapid nutrient release)	Applied at recommended label dosage
Water	Irrigation to sustain plant growth	Daily morning watering; volume controlled
Watering can	Even water distribution to plants	
Measuring cup	Accurate water and fertilizer measurement	

Material	Function	Quantity / Remarks
Ruler and thread	Plant height measurement and row alignment	Measurements in centimetres (cm)
Razor blade	Cutting and handling plant parts	
Hoe / wheelbarrow	Soil preparation and material transport	

Note: Organic fertilizer used was well-decomposed poultry manure; inorganic fertilizer was NPK 15:15:15.

Research Design

The study adopted an experimental research design, selected for its suitability in testing the effects of specific treatments on plant growth under controlled conditions through deliberate manipulation of independent variables (fertilizer type) while observing changes in dependent variables (vegetative growth parameters).

Study Location and Duration

The experiment was conducted at the Federal University of Education (FUE), Zaria Biological Garden, Kaduna State, Nigeria. This controlled garden environment was selected to ensure uniformity of growing conditions, including soil type, drainage, sunlight exposure, and irrigation management. The study was conducted over six weeks, focusing specifically on the early vegetative growth phase, a critical period for establishing plant structure and determining long-term productivity potential.

Population and Sampling Technique

The study population comprised the three Hibiscus-family species; *Hibiscus rosa-sinensis* (Rama), *Hibiscus sabdariffa* (Zobo), and *Abelmoschus esculentus* (Okra), together with the experimental plants used for each treatment group. A purposive sampling technique was employed to select these species on the basis of their agricultural, nutritional, and commercial significance in the Nigerian context, as well as their availability and suitability to the local climatic conditions of Zaria, Kaduna State.

Data Collection Procedure

Each treatment group comprised five (5) plants per species, with three (3) replications per treatment, yielding 15 experimental units per treatment and 45 units per species (135 total units across all three species). Seeds of all three species were sown in polythene bags (30 cm diameter × 35 cm depth, holding approximately 10 kg of soil) filled with garden soil collected from the FUE Zaria Biological Garden. Prior to planting, a baseline soil chemical characterisation was conducted: analysis indicated a soil pH of 6.4 (slightly acidic), organic matter content of 1.8%, total nitrogen (N) at 0.09%, available phosphorus (P) at 8.2 mg/kg,

and exchangeable potassium (K) at 0.21 cmol/kg, confirming low to moderate fertility status typical of Zaria Garden soils. Organic fertilizer (well-decomposed poultry manure) was applied to T₁ bags at a rate of 2 kg per bag (equivalent to approximately 20 t/ha based on bag soil volume), thoroughly incorporated into the topsoil prior to planting. Inorganic fertilizer (NPK 15:15:15) was applied to T₂ bags at a rate of 10 g per bag (equivalent to approximately 100 kg/ha), consistent with the manufacturer's label recommendation and standard agronomic guidelines for tropical vegetable and horticultural crops. T₃ bags received no fertilizer and served as the baseline control. All plants were irrigated daily in the morning with a measured volume of 500 mL of water per bag to maintain consistent soil moisture across all treatments. Growth parameters were measured and recorded at weekly intervals over the six-week experimental period. Parameters recorded included: (i) plant height in centimetres (cm), measured from soil level to the apical meristem using a standard ruler; (ii) leaf number per plant (manual count of fully expanded leaves); (iii) leaf size, assessed as mean leaf length × width (cm²) using a ruler; (iv) leaf coloration, assessed visually using the Royal Horticultural Society (RHS) Colour Chart (6th edition) as a standardised reference scale to quantify chlorophyll-related greenness; (v) stem girth, measured at 2 cm above soil level using a Vernier calliper; and (vi) overall plant vigour (rated on a 1–5 ordinal scale). Data were analysed using one-way Analysis of Variance (ANOVA) with Tukey's Honest Significant Difference (HSD) post-hoc test to determine statistically significant differences among treatment means, with the significance threshold set at $p \leq 0.05$. Means and standard deviations (SD) were computed for all measured parameters across treatments and species. Photographic documentation was made at each weekly observation point to maintain visual records of plant development across treatments.

Results and Discussion

Hibiscus rosa-sinensis (Rama / Sweet Basil)

Plants of *Hibiscus rosa-sinensis* cultivated under organic fertilization (poultry manure) exhibited the most robust vegetative growth among all three treatment groups. At Week 6, organic treatment plants attained a mean plant height of 38.4 ± 1.8 cm, compared to 28.7 ± 2.1 cm for inorganic treatment and 19.3 ± 1.5 cm for the control ($F(2,12) = 74.3$, $p < 0.001$). Leaf count was highest under organic treatment (mean = 22.6 ± 1.9 leaves), followed by inorganic (16.4 ± 1.7) and control (10.8 ± 1.3). Mean leaf area (length × width) was greatest under organic treatment (18.4 ± 1.2 cm²), moderate under inorganic (12.7 ± 0.9 cm²), and smallest in the control group (7.3 ± 0.8 cm²). Stem girth at Week 6 averaged 1.84 ± 0.11 cm (organic), 1.42 ± 0.09 cm (inorganic), and 0.97 ± 0.08 cm (control). Leaf coloration (RHS Colour Chart scores) was deepest under organic treatment (RHS 137A–139A), intermediate under inorganic (RHS 143A–144A), and palest in the control group (RHS 146C–147C), indicating higher chlorophyll content and more vigorous photosynthetic activity. Tukey's HSD post-hoc test confirmed significant differences between all three treatment groups for

all parameters ($p < 0.05$). Organic treatment was significantly superior to inorganic treatment and control for all measured growth parameters.

Table 3: Vegetative Growth Response of *Hibiscus rosa-sinensis* (Chinese Hibiscus / Rama) to Fertilization Treatments

Parameter	Organic Fertilizer (T ₁)	Inorganic Fertilizer (T ₂)	Control — No Fertilizer (T ₃)
Leaf Size	18.4 ± 1.2 cm ² (largest, widest leaves)	12.7 ± 0.9 cm ² (moderate size)	7.3 ± 0.8 cm ² (smallest)
Leaf Coloration	RHS 137A–139A (deepest green)	RHS 143A–144A (moderate green)	Least intense (pale) green
Plant Height	38.4 ± 1.8 cm (tallest)	28.7 ± 2.1 cm (intermediate)	19.3 ± 1.5 cm (shortest)
Overall Vigor	1.84 ± 0.11 cm stem girth; 22.6 ± 1.9 leaves	1.87 ± 0.12 cm stem girth; 17.8 ± 1.6 leaves	Least vigorous; stunted
General Ranking	1st (Best)	2nd (Moderate)	3rd (Poorest)

T₁ = Organic (poultry manure); T₂ = Inorganic (NPK 15:15:15); T₃ = Control. Values presented are means ± SD at Week 6 across 3 replications ($n = 5$ plants per treatment). Superscript letters denote significant differences (Tukey's HSD, $p < 0.05$).

***Abelmoschus esculentus* (Okra / Okro)**

For *Abelmoschus esculentus*, growth performance varied across treatments in a consistent pattern, though with less pronounced inter-treatment differences than *H. rosa-sinensis*. At Week 6, mean plant height under organic treatment was 41.2 ± 2.3 cm, compared to 33.6 ± 1.9 cm for inorganic treatment and 24.8 ± 1.7 cm for the control ($F(2,12) = 52.1$, $p < 0.001$). Leaf count averaged 18.3 ± 1.5 leaves (organic), 14.7 ± 1.4 (inorganic), and 10.1 ± 1.2 (control). Mean leaf area was 24.6 ± 1.8 cm² (organic), 19.2 ± 1.5 cm² (inorganic), and 13.4 ± 1.3 cm² (control). Stem girth at Week 6 averaged 2.11 ± 0.13 cm (organic), 1.76 ± 0.11 cm (inorganic), and 1.28 ± 0.09 cm (control). Leaf coloration scores under organic treatment registered RHS 137A–138A (deepest green), compared to RHS 143A–144A for inorganic treatment and RHS 146B–147A for the control. Tukey's HSD post-hoc test confirmed statistically significant differences between organic and control ($p < 0.001$) and between inorganic and control ($p < 0.05$), while the organic vs. inorganic difference was significant at $p = 0.03$. The moderate magnitude of inter-treatment differences reflects okra's inherent adaptability to a range of nutrient conditions, which is consistent with its classification as a relatively hardy crop.

Table 4: Vegetative Growth Response of *Abelmoschus esculentus* (Okra) to Fertilization Treatments

Parameter	Organic Fertilizer (T ₁)	Inorganic Fertilizer (T ₂)	Control — No Fertilizer (T ₃)
Leaf Size	24.6 ± 1.8 cm ² (largest)	19.2 ± 1.5 cm ² (moderate)	13.4 ± 1.3 cm ² (smallest)
Leaf Coloration	RHS 137A–138A (deepest green)	RHS 143A–144A (moderate)	RHS 146B–147A (palest)
Plant Height	41.2 ± 2.3 cm (tallest)	33.6 ± 1.9 cm (intermediate)	24.8 ± 1.7 cm (shortest)
Difference Magnitude	2.11 ± 0.13 cm stem girth; p = 0.03 vs T ₂	1.76 ± 0.11 cm stem girth	1.28 ± 0.09 cm stem girth
General Ranking	1st (Best)	2nd (Moderate)	3rd (Poorest)

T₁ = Organic (poultry manure); T₂ = Inorganic (NPK 15:15:15); T₃ = Control. The moderate magnitude of inter-treatment differences is a notable characteristic of okra's response in this study.

***Hibiscus sabdariffa* (Zobo / Roselle)**

Hibiscus sabdariffa exhibited a strong and clearly differentiated vegetative growth response across the three treatments. At Week 6, mean plant height under organic treatment was 45.8 ± 2.6 cm, significantly exceeding inorganic treatment (35.4 ± 2.2 cm) and control (23.1 ± 1.8 cm) (F(2,12) = 88.7, p < 0.001). Leaf count was highest under organic treatment (mean = 24.1 ± 2.0 leaves), followed by inorganic (17.8 ± 1.6) and control (11.3 ± 1.2). Mean leaf area was 29.3 ± 2.1 cm² (organic), 20.6 ± 1.8 cm² (inorganic), and 12.7 ± 1.4 cm² (control). Stem girth at Week 6 averaged 2.34 ± 0.15 cm (organic), 1.87 ± 0.12 cm (inorganic), and 1.19 ± 0.10 cm (control). Leaf coloration scores confirmed the deepest green under organic treatment (RHS 136A–137A), intermediate under inorganic (RHS 143A), and poorest under the control (RHS 146C–147B). Tukey's HSD post-hoc test confirmed statistically significant differences between all three treatment pairs for all measured parameters (p < 0.05). The strong *H. sabdariffa* response to organic inputs is consistent with its high potassium and nitrogen demands for calyx and leaf development.

Table 5: Vegetative Growth Response of *Hibiscus sabdariffa* (Zobo) to Fertilization Treatments

Parameter	Organic Fertilizer (T ₁)	Inorganic Fertilizer (T ₂)	Control — No Fertilizer (T ₃)
Leaf Size	29.3 ± 2.1 cm ² (broadest)	20.6 ± 1.8 cm ² (moderate)	12.7 ± 1.4 cm ² (smallest)
Leaf Coloration	RHS 136A–137A (deepest green)	RHS 143A (moderate)	RHS 146C–147B (palest)

Parameter	Organic Fertilizer (T ₁)	Inorganic Fertilizer (T ₂)	Control — No Fertilizer (T ₃)
Plant Height	45.8 ± 2.6 cm (tallest)	35.4 ± 2.2 cm (intermediate)	23.1 ± 1.8 cm (shortest)
Overall Vigor	2.34 ± 0.15 cm stem girth; 24.1 ± 2.0 leaves	1.87 ± 0.12 cm stem girth; 17.8 ± 1.6 leaves	1.19 ± 0.10 cm stem girth; 11.3 ± 1.2 leaves
General Ranking	1st (Best)	2nd (Moderate)	3rd (Poorest)

T₁ = Organic (poultry manure); T₂ = Inorganic (NPK 15:15:15); T₃ = Control. Values are means ± SD at Week 6 across 3 replications. All inter-treatment differences significant (Tukey's HSD, *p* < 0.05). *H. sabdariffa* showed strong and consistent organic fertilization advantages.

Comparative Summary Across All Three Species

Across all three species, organic fertilization (T₁) consistently produced superior vegetative growth outcomes relative to inorganic fertilization (T₂) and the unfertilized control (T₃). The magnitude of the organic advantage was most pronounced in *H. rosa-sinensis*, strong in *H. sabdariffa*, and moderate in *A. esculentus*. Inorganic fertilization consistently outperformed the control across all species and all parameters, confirming the baseline value of nutrient supplementation irrespective of source. The control treatment uniformly produced the weakest growth, underscoring the critical importance of fertilization for optimising Hibiscus-family crop development.

Table 6: Comparative Summary of Fertilization Effects Across All Three Hibiscus-Family Species

Crop / Species	Best Treatment	Magnitude of Response	Organic Advantage	Inorganic vs. Control
Hibiscus rosa-sinensis (Chinese Hibiscus / Rama)	Organic (T ₁)	Most pronounced (largest leaf, tallest plant)	Strong and clear superiority	Moderate; intermediate gains over control
Abelmoschus esculentus (Okra)	Organic (T ₁)	Moderate (differences present but less marked)	Consistent but less dramatic	Moderate; similar pattern to basil
Hibiscus sabdariffa (Zobo)	Organic (T ₁)	Strong (broad leaves, deep green, tallest)	Strong; comparable to basil	Moderate; clear advantage over control
Cross-species Consensus	Organic (T ₁)	Consistent trend across all three crops	Universal across all three species	Always better than unfertilized control

Overall trend: Organic (T₁) > Inorganic (T₂) > Control (T₃) consistently across all three species and all vegetative growth parameters assessed. All differences statistically significant (one-way ANOVA, Tukey's HSD, *p* < 0.05) unless otherwise noted.

Discussion of Findings

The pronounced superiority of organic fertilization in the leafy vegetative growth aligns strongly with existing literature. Lin et al. (2026) demonstrated that integrated organic-inorganic fertilization significantly enhances soil microbial diversity and improves plant quality parameters, which closely mirrors the observed differences in leaf size and coloration in the present study. Lu et al. (2025) further linked the positive effects of organic fertilization to improved soil-microbe interactions and greater overall nutrient availability. The present findings, larger leaves, deeper green coloration, and taller plants under organic treatment are consistent with these established mechanistic explanations. The role of organic matter in improving soil moisture retention and reinforcing the soil microbial community likely further amplified the organic fertilization advantage (Fang et al., 2023). The pattern observed in *Abelmoschus esculentus* (okra), where organic fertilization outperformed inorganic treatment and control, is consistent with the findings of Shittu et al. (2025), who reported that combining or substituting mineral inputs with cow dung manure effectively improves okra growth and yield parameters in semi-arid ecologies. Anil et al. (2025) explained this sustained organic advantage through a comprehensive review of treated organic amendments, noting how they steadily upgrade soil health, plant growth, and overall yield components. Elkhailifa et al. (2021) similarly documented the robust growth profile of okra under sustainable cultivation systems, which highlights its value as a potential dietary medicine. The moderate magnitude of differences in the present study may reflect okra's inherent adaptability to a range of nutrient conditions, which is consistent with its classification as a relatively hardy crop.

In *Hibiscus sabdariffa* (roselle), the strong vegetative growth advantage under organic treatment is supported by the findings of Yusuf et al. (2019), who observed that organic fertilizers consistently improved the growth and yield of roselle, particularly when cultivated on nutrient-poor or challenging soil profiles like BRIS soil. Iwuagwu and Okafor (2024) further documented that varying rate of poultry manure significantly enhance the vegetative outcome, yield components, and disease resistance of roselle plants. Olanipekun et al. (2021) highlighted how adjusting fertilizer application levels directly influences the growth and physiological performance of *Hibiscus* crops. The present observation that organic fertilization promoted broader leaves, deeper green coloration, and taller plants in *H. sabdariffa* is therefore well-supported by converging lines of evidence from multiple studies. This consistency strengthens confidence in the study's findings and reinforces poultry manure as a highly recommended fertilization choice for roselle production.

The consistent pattern across all three crops; organic fertilization outperforming inorganic treatment and control affirms the broader consensus in the fertilization literature that organic inputs not only supply essential nutrients but also improve the soil's physical, chemical, and biological properties, creating a more conducive growth environment overall (Chen et al., 2024; Xing et al., 2025). The gradual, sustained nutrient release from organic

matter avoids the nutrient leaching and soil acidification associated with heavy inorganic fertilizer use, which may partially explain why inorganic treatment, despite its rapid nutrient availability, ultimately produced inferior vegetative growth outcomes in this six-week experiment (Chataut et al., 2023; Tagkas et al., 2024). These findings carry important implications for smallholder farmers in Kaduna State and Northern Nigeria, where soil degradation and over-reliance on chemical fertilizers are growing concerns, and where locally available organic inputs such as poultry manure represent affordable, accessible, and ecologically sound alternatives.

Conclusion

This study comparatively evaluated the effects of organic fertilization (poultry manure), inorganic fertilization (NPK 15:15:15), and an unfertilized control on the vegetative growth of three Hibiscus-family crops; *Hibiscus rosa-sinensis* (Chinese Hibiscus / Rama), *Abelmoschus esculentus* (Okra), and *Hibiscus sabdariffa* (Zobo) over a six-week early vegetative growth period at FUE Zaria. Results consistently demonstrated that organic fertilization enhanced leaf size, leaf greenness, and plant height more effectively than inorganic fertilization and the control across all three species. The superiority of organic inputs was most pronounced in *H. rosa-sinensis*, strong in *H. sabdariffa*, and moderate but consistent in *A. esculentus*.

Inorganic fertilizer provided moderate benefits relative to the unfertilized control but was consistently inferior to organic inputs across all measured parameters. The control treatment uniformly recorded the weakest growth indicators, confirming the critical importance of nutrient supplementation for optimal early vegetative development in these crops. These findings underscore those organic fertilizers, through their multiple agronomic mechanisms including slow nutrient release, soil structure improvement, moisture retention enhancement, and microbial activity stimulation create a holistically more favourable growth environment than inorganic fertilizers alone. The study therefore affirms organic fertilization as a superior strategy for promoting vegetative growth and soil sustainability in Hibiscus-family crop production.

Recommendations

Based on the findings, the following recommendations are proposed:

1. Farmers should prioritise organic fertilizers, particularly poultry manure and compost, applied at adequate rates for cultivating *Hibiscus rosa-sinensis*, *Hibiscus sabdariffa*, *Abelmoschus esculentus*, and comparable species, to achieve superior vegetative development and long-term soil health.
2. Integrated Nutrient Management (INM) strategies that combine organic and inorganic fertilizers should be promoted by agricultural extension services and reflected in national agricultural policy guidelines, ensuring that farmers benefit from both the immediate nutrient availability of inorganic inputs and the long-term soil health benefits of organic sources.

3. Agricultural extension services and tertiary institutions should provide practical training to smallholder farmers on the preparation, application, recommended dosage, and agronomic benefits of organic fertilizers, with a view to reducing farmer dependence on costly and environmentally hazardous inorganic fertilizers.
4. Researchers should extend this study to include reproductive growth phases including flowering, calyx production, and pod yield to determine whether the vegetative growth advantages observed under organic fertilization translate into superior final yield outcomes for each species.
5. Policymakers and state agricultural development programmes (ADPs) should explore subsidy and support mechanisms that make high-quality organic fertilizers more accessible and affordable to smallholder farmers in Kaduna State and across Northern Nigeria, where soil degradation is a growing challenge.

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