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Preliminary Investigation on Effects of Climate-Smart Integrated Fertilizer Management on Nutrient Composition and Sensory Attributes of Watermelon (*Citrullus lanatus*) Varieties Grown in Sandy Loam Soil

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Abstract

This study investigated effects of climate-smart integrated fertilizer management (CSA-IFM) on nutritional composition and sensory attributes of three varieties of watermelon grown in sandy loam soil in Nsukka agricultural zone, Nigeria. A 3 × 6 factorial experiments arranged in a split-plot design within a randomized complete block design (RCBD) with three replications, was employed. Fertilizer treatments comprised varying combinations of goat manure (GM) and NPK (15:15:15), including sole and integrated applications. Fertilizer treatments included: I (50 kg/ha NPK + 15 t/ha goat manure), II (100 kg/ha NPK + 10 t/ha goat manure), III (150 kg/ha NPK + 5 t/ha goat manure), IV (200 kg/ha NPK), V (20 t/ha goat manure) and VI (control: 0 kg/ha). Data was collected using appropriate instruments and procedures. Data were analyzed using ANOVA with mean separation by Duncan's Multiple Range Test at $P \leq 0.05$. Results reveal that varietal differences, fertilizer treatments and their interactions significantly influenced both nutritional composition and sensory properties of watermelon fruits. Among others, treatment V produced the highest phosphorus content (26.60 g/100 g), while Treatment I recorded the highest potassium (7.30 g/100 g), calcium (6.26 g/100 g) and magnesium (18.85 g/100 g). Charleston Grey had the highest mean phosphorus content (21.70 g/100 g), whereas Sugar Baby recorded the highest potassium (6.75 g/100 g), calcium (5.61 g/100 g) and magnesium (18.48 g/100 g).

Keywords: Climate-smart, Agriculture, Integrated, Fertilizer, Management, Watermelon, Nutrient Composition, Sensory Attributes.

Introduction

Watermelon (*Citrullus lanatus* Thumb.) is a highly cherished fruit vegetable and an annual vine-like crop with oval, succulent fruits consumed by both humans and animals when ripe. It belongs to the family *Cucurbitaceae*, genus *Citrullus* and species *lanatus* (Ojo et al., 2014; Ali et al., 2023). Believed to have originated from the Kalahari and Sahara deserts of Africa, the crop later spread to other parts of the world, including Nigeria, where Sugar

Baby, Koalack and Charleston Grey are among the commonly cultivated varieties (Sabo et al., 2013; Ali et al., 2020). Globally, watermelon is among the most consumed fruit vegetables owing to its high water content (about 90–93%) and its content of vitamins A, B-complex and C and minerals such as potassium, calcium and magnesium (Burdulis et al., 2025; FAO, 2022). It also contains bioactive compounds such as lycopene and beta-carotene, which act as antioxidants and help reduce the risk of cardiovascular diseases and certain cancers (Olalekan et al., 2025). These nutritional and medicinal benefits have driven increasing demand for the crop both globally and within Nigeria.

In Nigeria, watermelon production is concentrated in the northern region because of favourable high temperatures and well-drained soils, although demand is rising in the southern and eastern regions, including Enugu State, where supply remains insufficient (Awere & Onyeacholem, 2014; Onyemekonwu et al., 2025). In the Nsukka agricultural zone, production is constrained by climate variability, limited access to improved production practices and declining soil fertility (Ali et al., 2023). The sandy loam soils that dominate the area are suitable for watermelon because of their good drainage and aeration, but they are typically low in organic matter and essential nutrients and are prone to nutrient leaching and reduced productivity without proper soil fertility management (Nasreen et al., 2025; Rusan et al., 2026).

Traditionally, farmers rely on either inorganic fertilizers or organic manures. Inorganic fertilizers such as NPK 15:15:15 supply readily available nutrients that enhance rapid growth and yield (Njoroge et al., 2026), but their continuous use can cause soil degradation, nutrient imbalance, environmental pollution and high production costs. Organic manures such as goat manure improve soil structure, microbial activity and organic matter (Wu et al., 2026; Maltas, 2025), but release nutrients slowly and are less efficient when used alone (Oloso et al., 2023). To address these limitations, climate-smart agriculture (CSA) has emerged as a sustainable approach that increases productivity, enhances resilience to climate change and reduces greenhouse gas emissions (FAO, 2021), and contributes to Sustainable Development Goals 1, 2 and 3. One important component of CSA is climate-smart integrated fertilizer management (CSA-IFM).

Climate-smart integrated fertilizer management is the combined and efficient use of organic and inorganic fertilizers to improve soil fertility, enhance crop productivity and ensure environmental sustainability under changing climatic conditions (Zheng et al., 2024). In this study, CSA-IFM involves applying goat manure alongside NPK 15:15:15 in sandy loam soil for watermelon production. Goat manure supplies organic matter that improves soil structure, water retention and microbial activity, while NPK supplies nutrients required for rapid growth and fruit development; their integration ensures both immediate nutrient availability and sustained soil fertility, thereby overcoming the limitations of their individual use. Beyond growth and yield, CSA-IFM influences the nutrient composition and sensory qualities of watermelon fruits. Nutrient content here refers to mineral elements such as phosphorus, potassium, calcium and magnesium, while sensory attributes comprise flavour, texture, colour, aroma and general acceptability, which are used to evaluate food quality (Chumngoen & Tan, 2015).

Recent studies provide useful context. Ali et al. (2023) reported that combining 15 t/ha goat manure with 50 kg/ha NPK enhanced soil fertility and yield of watermelon over single treatments, while Ali et al. (2020) recorded significant nutrient and quality improvements in three watermelon varieties grown under CSA-IFM in sandy loam soil. Eifediyi et al. (2017) demonstrated the potential of organic alternatives in improving watermelon growth and yield in north-central Nigeria, and Ter et al. (2024) showed compost to be an effective, eco-friendly option in the Guinea savanna. Despite these advances, information on the combined effects of CSA-IFM on the nutrient composition and sensory attributes of watermelon varieties grown in sandy loam soils, particularly in the Nsukka agricultural zone, remains limited, as most previous studies focused mainly on growth and yield, hence the need for this study.

Objectives of the Study

This study investigated effects of climate-smart integrated fertilizer management on nutritional contents and sensory attributes of watermelon varieties grown in sandy loam soil in the Nsukka agricultural zone, Nigeria. Specifically, the study determined preliminary effects of climate-smart integrated fertilizer management on:

1. nutrient contents of three varieties of watermelon.
2. sensory attributes of three varieties of watermelon

Hypotheses (HOs)

The following null hypotheses were formulated and tested at 0.05 level of significance.

HO$_1$: The interaction effects of fertilizer levels and varieties of watermelon on mean value of nutritional contents does not differ significantly**.**

HO$_2$: The interaction effect of fertilizer levels and varieties of watermelon on mean values of sensory properties does not differ significantly.

Material and Methods

***Design of the Study*:** The study employed an experimental design using a split-plot arrangement in a randomized complete block design (RCBD) with three replications. A 3 × 6 factorial layout was used, comprising three watermelon varieties as the main-plot factor and six climate-smart integrated fertilizer treatments as the sub-plot factor, giving 18 treatment combinations replicated three times across the three blocks. Study plan outlined is as follows:

Main-plot factor (varieties): Sugar Baby, Koalack and Charleston Grey.

Sub-plot factor (fertilizer treatments): I = 50 kg/ha NPK + 15 t/ha goat manure (GM); II = 100 kg/ha NPK + 10 t/ha GM; III = 150 kg/ha NPK + 5 t/ha GM; IV = 200 kg/ha NPK; V = 20 t/ha GM; and VI = control (0 kg/ha).

Replication and layout: three blocks (replications), each divided into sub-plots and beds, giving 54 beds in a 600.3 m^2 field.

***Study Area*:** The experiment was conducted at the Teaching and Research Farm, Department of Agricultural

Education, University of Nigeria, Nsukka, Enugu State. The area lies between latitude 7°21′–7°36′ N and longitude 6°45′–7°00′ E, and is characterized by a tropical climate with distinct wet and dry seasons and annual rainfall of 1,680–1,700 mm. The soil is sandy loam and slightly acidic, with low levels of nitrogen, phosphorus and potassium.

Materials: The materials used were three watermelon varieties (Sugar Baby, Koalack and Charleston Grey), goat manure and NPK fertilizer (15:15:15). Karate insecticide was used for pest control. The physical and chemical properties of the soil of the study site and of the goat manure were determined before the experiment, as described below.

Field Preparation: The experimental field, measuring 600.3 m^2, was cleared, ploughed and divided into three blocks. Each block was further split into sub-plots and beds, giving a total of 54 beds. Goat manure was incorporated into the soil two weeks before planting, while NPK fertilizer was applied two weeks after planting using the ring method.

Soil and Manure Analysis: Composite soil samples were collected from the 0–15 cm depth of the study site, and representative goat manure samples were taken and analysed before treatment application. The soil was strongly acidic, with a pH (water) of 4.5 and pH (KCl) of 3.6, whereas the goat manure was near-neutral (pH 7.3 in water and 7.1 in KCl). The soil contained 1.43% organic carbon, 2.43% organic matter, 0.20% total nitrogen and 11.19 mg/kg available phosphorus, while the goat manure was markedly richer, with 17.08% organic carbon, 29.44% organic matter, 2.56% total nitrogen and 9.81 mg/kg available phosphorus. Exchangeable bases of the soil were 0.07, 1.40, 0.04 and 0.60 me/100g for K, Mg, Na and Ca, respectively, with exchangeable acidity of 0.80 (Al) and 2.20 (H) me/100g and a cation exchange capacity of 14.00 me/100g. The soil comprised 79% sand, 8% silt and 13% clay, confirming a sandy loam textural class (Ali et al., 2023). These results indicated an inherently acidic, low-fertility sandy loam soil that would benefit from the organic and integrated fertilizer treatments evaluated in this study.

Planting and Treatment Application: Two seeds were sown per hole at a spacing of 75 cm × 90 cm and later thinned to one plant per stand, resulting in eight stands per plot, of which four were randomly selected for data collection. The six fertilizer treatments were applied as described above. Routine agronomic practices, including manual weeding and pest control with Karate insecticide, were carried out, and harvesting was done at fruit maturity based on standard ripeness indices.

Nutrient Analysis: Fruit samples from each treatment were washed, deseeded and homogenized, and the pulp was oven-dried and milled for mineral analysis following standard AOAC (2023) procedures. Four mineral elements were determined: phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Potassium, calcium and magnesium were determined using atomic absorption spectrophotometry after wet digestion of the samples, whereas phosphorus was determined colorimetrically using the molybdenum-blue (vanado-molybdate) method, with absorbance read on a spectrophotometer against a standard phosphorus curve. All determinations were carried out in triplicate, and the mineral contents were expressed in grams per 100 grams (g/100g) of sample. The reagents used were of analytical grade, and blank determinations were run alongside the samples to correct for background interference.

Sensory Evaluation: Sensory evaluation of the watermelon fruits was carried out by a seven-member semi-trained panel purposively drawn from staff and students of the Department of Agricultural Education, University of Nigeria, Nsukka, who were familiar with watermelon, willing and available throughout the evaluation period. A 9-point hedonic instrument was used for data collection. Five sensory attributes such as flavour (taste), texture (softness), colour (appearance), aroma (smell) and general acceptability were assessed using a nine-point Hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely). Panelists were briefed on the attributes to be assessed before the exercise. Coded fruit samples from each treatment were presented to the panelists in a well-lit, odour-free room. Each panelist scored the coded samples independently on the structured on the 9-point hedonic scale. They rinsed the mouth with clean water between samples to minimize carry-over bias. The scores for each attribute were then averaged across the panelists for statistical analysis.

***Statistical Analysis*:** Data collected on the mineral elements and sensory attributes were subjected to analysis of variance (ANOVA) appropriate for a split-plot factorial experiment using SPSS (version 16.0). Treatment means were separated using Duncan's Multiple Range Test (DMRT) at the 5% level of significance (P ≤ 0.05), and correlation analysis was conducted to examine the relationships among the variables.

Result

Table 1: Preliminary effects of climate-smart integrated fertilizer management on the nutrient (element) content (g/100g) of three watermelon varieties and their interaction (DMRT, P ≤ 0.05)

Fertilizer	Phosphorus (g/100 g)				Potassium (g/100 g)				Calcium (g/100 g)				Magnesium (g/100 g)			
	1	2	3	x̄	1	2	3	x̄	1	2	3	x̄	1	2	3	x̄
FI	25.50	24.73	25.23	25.16**	7.93	6.30	7.67	7.30**	6.60	6.57	5.60	6.26***	19.77	19.73	17.07	18.85**
FII	18.20	16.40	23.50	19.37***	6.63	5.17	7.23	6.34**	5.83	5.07	5.57	5.49**	18.47	18.20	16.90	17.86**
FIII	23.57	22.40	24.30	23.42**	5.90	5.03	6.63	5.86***	5.30	4.23	5.03	4.86**	19.07	17.60	16.40	17.68**
FIV	16.27	15.20	22.83	18.10***	5.63	4.93	5.47	5.34***	4.47	3.53	4.17	4.06*	18.20	15.63	15.27	16.37***
FV	28.20	26.50	25.10	26.60**	9.30	4.93	6.37	6.87**	7.43	3.53	5.60	5.52**	20.13	18.20	16.53	18.29**
FVI	10.17	11.47	9.23	10.29*	5.10	4.53	4.07	4.57*	4.03	3.97	3.30	3.77*	15.27	16.13	13.30	14.90*
x̄	20.32*	19.45*	21.70**		6.75*	5.15**	6.24*		5.61*	4.48**	4.88**		18.48*	17.58**	15.91***	

*FI = 50kg/ha NPK + 15t/ha GM; FII = 100kg/ha NPK + 10t/ha GM;F III = 150kg/ha NPK + 5t/ha GM; FIV = 200kg/ha NPK; FV 20t/ha NPK=; FVI = 0kg/ha GM; 1 = Sugar Baby; 2 = Koalack; 3 = Charleston Grey; **x̄** = Mean; Means followed by the same number of asterisk (*) along the column are statistically similar (DMRT, 5%)*

Table 1 shows that fertilizer treatments, varieties and their interactions significantly (P ≤ 0.05) influenced the elemental composition of the watermelon fruits. Phosphorus was highest in Charleston Grey (21.70 g/100g) and, among treatments, in 20 t/ha goat manure (26.60 g/100g) and 50 kg/ha NPK + 15 t/ha goat manure (25.16 g/100g); the highest interaction value (28.20 g/100g) occurred in Sugar Baby under 20 t/ha goat manure. Potassium, calcium and magnesium were highest in Sugar Baby (6.75, 5.61 and 18.48 g/100g, respectively), with the best treatment values under 50 kg/ha NPK + 15 t/ha goat manure and 20 t/ha goat manure, and the highest interaction values consistently recorded in Sugar Baby under 20 t/ha goat manure. Control plots recorded the lowest values for all four minerals.

Table 2: Preliminary effects of climate-smart integrated fertilizer management on the sensory properties of three watermelon varieties and their interaction (DMRT, P ≤ 0.05)

Fertilizer	Flavour			Texture			Colour			Aroma			General Acceptability		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
I	8.43**	8.00*	8.14***	8.43**	8.43**	7.71***	8.00*	8.14**	8.43***	7.86**	7.57***	7.86**	8.14***	7.57*	8.14***
II	7.57**	8.43***	7.57**	7.71***	6.86**	7.00***	8.43*	7.43**	6.86***	7.57**	7.14*	7.57**	7.57***	7.43**	7.43***
III	5.43**	6.00**	6.43**	6.43**	6.43**	6.00**	6.29**	6.14**	6.00**	6.57*	6.29**	5.29*	6.29*	6.57*	5.43*
IV	5.00*	6.29**	5.14*	4.71**	5.71**	5.29**	4.43**	5.71***	4.43**	4.86**	6.00***	4.86**	5.29**	6.29***	4.57**
V	7.86**	7.57**	6.71**	7.86***	7.29***	6.43**	7.71*	7.14**	7.14***	7.86**	7.71**	6.86**	8.14***	8.29***	7.14***
VI	4.29***	2.57***	2.29***	4.00*	2.71*	2.86*	4.14***	2.71**	3.71***	4.14**	2.57**	3.14**	3.29**	2.71*	3.29**
x̄	6.43a	6.31b	5.62c	6.52a	6.17b	5.76c	6.50a	6.21b	5.74c	6.48a	6.29b	5.57c	6.45a	6.59a	5.55c

I–VI as in Table 1; 1 = Sugar Baby; 2 = Koalack; 3 = Charleston Grey. Column means (x̄) followed by different letters (a, b, c) differ significantly; means with the same number of asterisks (*) within a column are statistically similar (DMRT, 5%).

Table 2 shows that varieties, fertilizer treatments and their interactions significantly (P ≤ 0.05) influenced the sensory properties of the fruits. Across flavour, texture, colour and aroma, Sugar Baby and Koalack were significantly superior to Charleston Grey, while general acceptability was highest for Koalack (6.59) and Sugar Baby (6.45). The integrated treatment of 50 kg/ha NPK + 15 t/ha goat manure consistently produced the highest sensory scores (up to 8.43), followed closely by 20 t/ha goat manure, whereas the control recorded the lowest scores for all attributes. These results indicate that both varietal choice and integrated nutrient management strongly shaped consumer-preferred sensory quality.

Discussion of the Findings

The findings showed that varietal differences, fertilizer treatments and their interactions significantly influenced the mineral composition of watermelon fruits. Sugar Baby recorded higher potassium, calcium and magnesium under integrated and organic treatments, whereas Charleston Grey was superior in phosphorus, and the highest interaction values occurred in Sugar Baby treated with 20 t/ha goat manure. The enhanced mineral composition under goat manure and integrated treatments may be attributed to improved soil organic matter, increased microbial activity and enhanced nutrient mineralization and availability, which facilitate efficient nutrient uptake and translocation. This agrees with Meng et al. (2022), who reported that organic fertilization enhances phosphorus uptake in watermelon through increased root-associated phosphatase activity, and with Zhao et al. (2023), who found that combining organic amendments with reduced mineral fertilizer improves nutrient uptake and fruit quality. Mesquita et al. (2024) similarly confirmed that biofertilizer application enhances fruit nutrient composition and overall quality.

The statistical similarity between 50 kg/ha NPK + 15 t/ha goat manure and 20 t/ha goat manure indicates that both integrated and sole organic applications are effective in improving fruit nutritional quality, supporting the evidence that climate-smart nutrient management enhances both yield and quality of horticultural crops (Ali et al., 2023; Abubakar et al., 2020). For the sensory attributes, both varietal differences and fertilizer treatments significantly influenced flavour, texture, colour, aroma and general acceptability, confirming that fruit quality in watermelon is a function of both genetic potential and nutrient management. The superiority of Sugar Baby and Koalack over Charleston Grey in flavour, aroma and general acceptability reflects strong varietal influence on consumer-preferred traits, consistent with reports that cultivars differ in sugar accumulation and volatile compounds responsible for flavour (Oloso et al., 2023).

The consistent performance of the integrated treatment of 50 kg/ha NPK + 15 t/ha goat manure indicates the beneficial role of combined organic and inorganic nutrient sources in improving sensory quality, in agreement with Hou et al. (2024), who reported that reduced mineral fertilizer combined with organic amendments enhances fruit quality and maintains soil fertility. The improved performance under goat manure-based treatments may be due to enhanced soil organic matter, improved microbial activity and gradual nutrient release, which promote efficient uptake of nitrogen, phosphorus and potassium essential for fruit development (Santoso et al., 2025). The superiority of integrated treatments over sole chemical fertilizer or control also aligns with Zhang et al. (2024), who reported that organic fertilizer application improves soil structure, nutrient availability and plant physiological processes. Overall, the results confirm that integrated nutrient management enhances both nutritional and sensory quality in watermelon through improved nutrient-use efficiency and soil health.

Conclusion

Climate-smart integrated fertilizer management significantly improved both the nutrient composition and sensory attributes of watermelon grown in sandy loam soil, with performance depending jointly on variety and fertilizer treatment. Sugar Baby and Koalack combined superior mineral content and consumer-preferred sensory quality, and the integrated application of 50 kg/ha NPK + 15 t/ha goat manure, together with the sole application of 20 t/ha goat manure, emerged as the most effective nutrient strategies. The study implies that integrating modest inorganic fertilizer with goat manure offers watermelon farmers in sandy loam soils a practical, climate-smart means of raising fruit quality and market value while reducing dependence on inorganic fertilizers and safeguarding soil health.

Recommendations

Based on the findings, it was recommended that:

1. farmers should cultivate Sugar Baby and Koalack using 50 kg/ha NPK + 15

t/ha goat manure to enhance sensory quality and consumer acceptability;
2. farmers aiming to improve nutrient composition should use 20 t/ha goat manure, particularly with Sugar Baby, for enhanced mineral content;
3. agricultural extension agents should promote climate-smart integrated fertilizer management to improve adoption among farmers; and
4. government and stakeholders should support farmers through subsidies, organic manure supply and training, and establish demonstration farms to showcase integrated fertilizer management and improved watermelon varieties.

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