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Tomato yield optimization using fertilizer sources and sowing dates in Okitipupa, Southwest Nigeria

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ABSTRACT

Tomato (*Solanum lycopersicum L.*) productivity in rainforest agroecology is limited by climatic conditions, soil nutrient management, and sowing windows. Thus, a rainfed experiment was conducted to evaluate the effects of nutrient sources and sowing dates (SD) on the growth and yield of tomato varieties in Okitipupa, in 2022–2023. A split-plot experiment; 4NS (10 t/ha organomineral fertilizer - OMF, 15 t/ha organic fertilizer - ORF, and 300 kg/ha NPK) and tomato varieties ('Platino', 'Ibadan Local', 'Beske', and 'Roma') sown on 4 SD (19 May, 29 May, 8 June, and 18 June) were arranged in a RCBD replicated thrice, at T&R Farm of Olusegun Agagu University of Science and Technology. Growth, yield, and yield metrics were collected. The results revealed significant interactions: 'Platino' treated with OMF achieved the tallest plants (126.19 cm), 'Ibadan Local' produced the highest leaf number (610/plant) and branches (28.81/plant). 'Platino' and 'Ibadan Local' varieties, treated with ORF, yielded the highest fruit weight, 696.2 g and 638.80 g, respectively, and a superior harvested yield of 3946.5 kg/ha and 3452.80 kg/ha, respectively. Conversely, 'Roma' under control conditions recorded the lowest fruit weight (1196.5 kg/ha). SD significantly influenced yield attributes. 18-June SD extends the anthesis days but produced the highest fruit number and weight. Furthermore, growth and yield-contributing attributes were positively correlated with soil nitrogen levels. The OMF proved to be the most effective in enhancing soil fertility and tomato performance. 'Platino' and 'Ibadan Local' varieties demonstrated optimal adaptation and yield potential. Given the prevailing environmental conditions, SD 18-June emerged as the most suitable for maximizing tomato productivity in this region.

Contribution/Originality: This study reveals that organomineral fertilizer improves tomato phenology and yield in rainforest soils. 'Platino' and 'Ibadan Local' varieties adapted best to coastal conditions, with mid-June planting optimal. Enhanced soil nitrogen positively influenced growth and productivity, underscoring its importance in local tomato cultivation.

1. INTRODUCTION

Tomato (Solanum lycopersicum L.), a member of the Solanaceae family, is one of the most economically important vegetable crops worldwide because of its role in food and nutrition security, income generation, and employment creation, especially in rural and peri-urban farming systems [1, 2]. Global fresh tomato production was estimated at 180 million tons in 2019, grown on approximately 5 million hectares of land. In Africa, production reached 20.78 million tons in 2018, with Nigeria contributing about 3.91 million tons [3]. Despite this contribution, tomato yields in Nigeria remain below optimal levels, averaging 10 t ha^{-1} in the savanna and derived savanna zones, and as low as

7.1 t ha^{-1} in most lowland agroecologies [4]. These yields are considerably below the global average, highlighting the urgent need for improved and sustainable production systems to combat food insecurity.

The coastal lowland agroecology of Okitipupa in southwestern Nigeria is characterized by a humid rainforest climate with bimodal rainfall, often torrential in distribution. Soils in this region are predominantly sandy surface soils underlain by sandy clay subsoils, making them highly prone to erosion and nutrient depletion. They are inherently low in nitrogen (N), phosphorus (P), potassium (K), and calcium (Ca), which are essential for vegetable crop production [5]. These constraints, compounded by erratic climatic conditions and inadequate management practices, limit the productivity of tomatoes in this region. Hence, enhancement of soil fertility through the application of external amendment materials, such as organic materials, organomineral, and inorganic fertilizers, has therefore become essential for sustaining vegetable crop production in coastal rainforest environments [6].

Climatic variables, particularly solar radiation, rainfall, and temperature patterns during sowing, further influence tomato growth and productivity in a sensitive microecological environment such as the rainforest region. Sowing dates have been shown to affect vegetative growth, phenological development, and fruit yield and quality, with cultivar response varying according to genotype–environment interactions [7].

The enormous potential of most fruit and vegetable production in terms of soil, water, and weather resources to bridge gaps for both social and economic benefits, especially during the rainy season in the coastal part of southwest Nigeria, is imminent. However, the production of tomato is limited by biophysical growth factors such as cultivar and genetic composition, sowing season and dates, soil fertility status, and quality. These issues could be addressed and upscaled with good agronomic practices and appropriate fertilizer applications in organic and inorganic forms [8, 9]. Therefore, the objective of this study was to evaluate the response of tomato varieties to fertilizer sources and sowing dates in the coastal agroecology of Okitipupa, southwestern Nigeria, with a view to optimizing yield under rainforest conditions.

2. MATERIALS AND METHODS

2.1. Study Area

The experiment was conducted during the 2022 and 2023 rainy seasons at the Teaching and Research Farm, Olusegun Agagu University of Science and Technology (OAUSTECH), Okitipupa, Nigeria. The site is located at latitude 06°25′N and longitude 04°35′–04°50′E, within the rainforest zone of southwestern Nigeria. The climate is characterized by a seven-month wet season (April–October) with bimodal rainfall peaks in May–July and September November [10]. The mean daily temperature is approximately 27°C, relative humidity ranges from 60–80%, and average solar radiation is about 17 MJ m^{-2} day^{-1} (see Figure 1-3). Soils in the area are derived from Precambrian basement complex rocks and tertiary sandy sediments, with elevations generally below 300 m above sea level [11].

2.2. Experimental Layout

2.2.1. Soil Analysis

Soil samples from the 0–30 cm layer were collected at multiple points within the experimental field, composited, and analyzed for physical and chemical properties both pre-planting, as shown in Table 1, and post-harvest (Table 2). Fertilizer samples were subjected to proximate analysis. The post-planting soil analysis was performed at the end of the cropping season to evaluate the effects of soil amendments on the growth and yield of the test crop. The samples were tested for pH; nitrogen, carbon, and organic matter contents; as well as concentrations of phosphorus, calcium, and magnesium. Soil pH was measured using distilled water and KCl with a soil-to-water ratio of 1:2.5.

The suspension was thoroughly mixed and allowed to stand for 30 minutes. The pH was then measured with an electronic pH meter (Benchtop pH Meter, PH-B600L). Total nitrogen was determined using the micro Kjeldahl digestion method, as described by the AOAC [12]. Cations such as calcium and magnesium were measured via atomic absorption, following the procedures outlined by the AOAC [12].

2.3. Fertilizer Treatments

The fertilizer treatments were: mineral fertilizer, NPK (15:15:15) at 300 kg/ha, organomineral fertilizer (OGM) at 10 t/ha, and organic fertilizer (ORF) at 15 t/ha. The organic fertilizers are primarily produced from farmyard manure, which includes animal excrement and litter, domestic organic wastes, wastes from the food and agriculture industries, wastes from wood processing and harvesting, compost, mosses, and any other form of organic waste. The organomineral fertilizer (OGM), composed of bio-organic components like animal excreta (cow dung, chicken feces, etc.), fortified with ammonium compounds. The organic and organomineral fertilizers were both incorporated into the soil 14 days before transplanting, while the NPK fertilizer was applied at 2 WAT, and the second dose was applied at 6 WAT [13].

2.4. Experimental Design and Plot Management

The seeds of the tomato varieties ('Platino', Ibadan Local, 'Beske', and 'Roma') obtained from NIHORT, Nigeria, and a registered Agro-Allied Company were sown on four sowing dates (May 19, May 29, June 8, and June 18) to identify the most suitable sowing window for the study area. The experiment was designed as a split-plot arrangement within a randomized complete block design (RCBD) with three replications. Main-plot treatments included four fertilizer sources: control (no application), organomineral fertilizer (OMF) at 10 t ha^{-1}, organic fertilizer (ORF) at 15 t ha^{-1}, and mineral NPK fertilizer at 300 kg ha^{-1}. Sub-plot treatments consisted of four tomato varieties ('Platino', 'Ibadan Local', 'Beske', and 'Roma') and four sowing dates (19 May, 29 May, 8 June, and 18 June). Each plot measured 1.5 m × 2 m, with intra-plot spacing of 30 cm × 90 cm (one plant per hole, resulting in 37,037 stands per hectare). Seedlings were transplanted 28 days after sowing.

Agronomic practices implemented included manual weeding after transplanting. Application of pesticides at two weeks after transplanting and plant staking to mitigate lodging, particularly during the fruiting phase. Organic and organomineral fertilizers were incorporated 14 days before transplanting, while mineral NPK fertilizer was applied at 2 weeks after transplanting (WAT) and again at 6 WAT [13]. Standard agronomic practices (weeding, pesticide application, staking) were applied uniformly across all plots.

2.5. Data collection and Statistical Analysis

Growth data (plant height, stem girth) were collected weekly from three randomly tagged plants per plot. Stem girth was measured using a vernier caliper. Flower and fruit counts per plant were recorded from two weeks after transplanting and continued weekly until harvest. Fresh-weight yields from the net plot were extrapolated to a per-hectare basis. Data were subjected to analysis of variance (ANOVA) using SAS (SAS Institute, Cary, NC, USA). Treatment means that differed significantly ($p \leq .05$) were separated using Fisher's Least Significant Difference (FLSD) test.

Table 1. Physical and chemical characteristics of the soil at the study site (0–30 cm depth).

Parameters	% Sand	% Clay	% Silt	Texture	Bulk Density (kg/m^{-3})	pH (H_2O)	Organic carbon (%)	Organic matter (%)	N (%)	P (mg/ Kg)	Na^+ (cmol /kg)	K^+ (cmol/ Kg)	Ca2+ (cmol /kg)	Mg^{2+} (cmol/ Kg)
	40.5	39.5	20	Clayloam	1.5	5.23	1.12	3.07	0.35	10.1	0.54	0.48	4.2	1.8

3. RESULTS AND DISCUSSION

3.1. Weather Conditions at the Experimental Site

The monthly variations in rainfall, minimum and maximum temperature, and relative humidity at the experimental site across 2022 and 2023 (Figure 1) reveal distinct seasonality, most notably with rainfall peaks in June 2022 and a broader wet season during June to August 2023. The higher rainfall variability observed in 2023, including a wetter start and end of the season, suggests increased climate inconsistency, potentially impacting crop establishment and yield potential. Relative humidity paralleled rainfall peaks, exceeding 90% during the rainy season, particularly in 2023, and dropped during dry months, aligning with classic tropical seasonal dynamics. Maximum temperatures decreased with the onset of wet months, while minimum temperatures remained stabilized in rainy periods, highlighting the moderating influence of cloud cover and humidity on the diurnal temperature range. These combined trends underscore how seasonal and interannual climate variability may affect soil moisture, plant development, and disease risk, informing adaptive strategies in site-specific agricultural management.

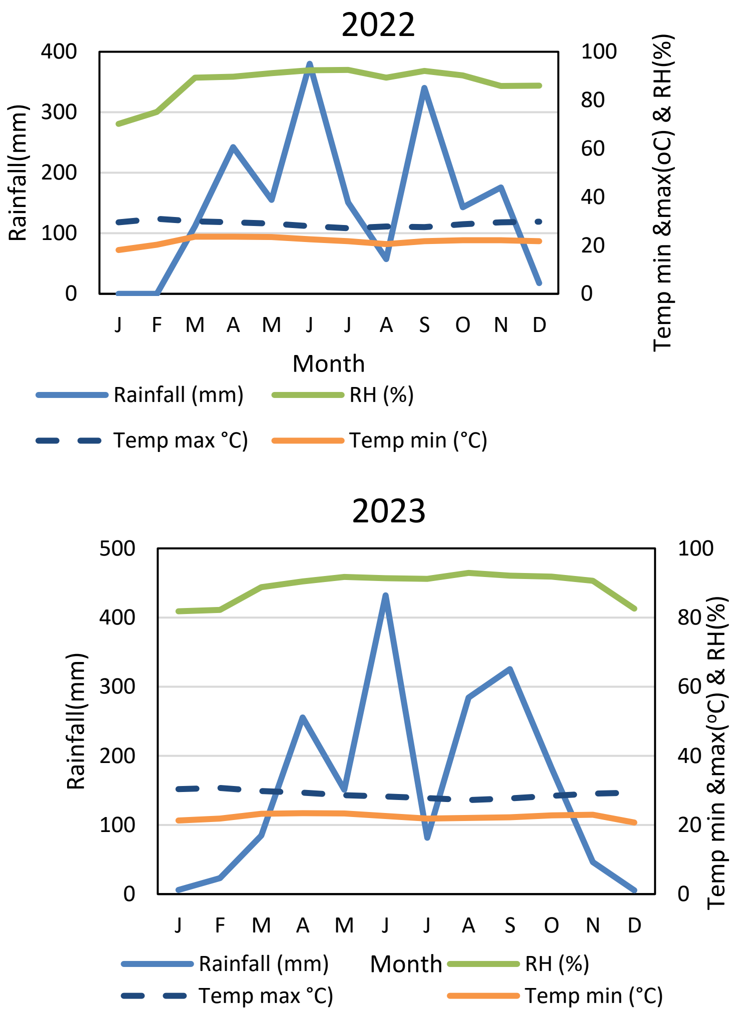

Figure 1. Monthly variations of rainfall, minimum temperature, maximum temperature, and relative humidity at the experimental site during the 2022 and 2023 seasons.

Monthly solar radiation data for 2022 and 2023 (Figure 2) indicate higher and steadier radiation during dry months (January–March, October–December), with a marked reduction during peak rainfall periods. This is consistent with increased cloud cover limiting incoming solar radiation. This inverse relationship explains the increased risk of reduced photosynthetic rates and slower crop growth during wet conditions, thereby requiring consideration for crop selection and timing of key field operations in planning climate-resilient agriculture.

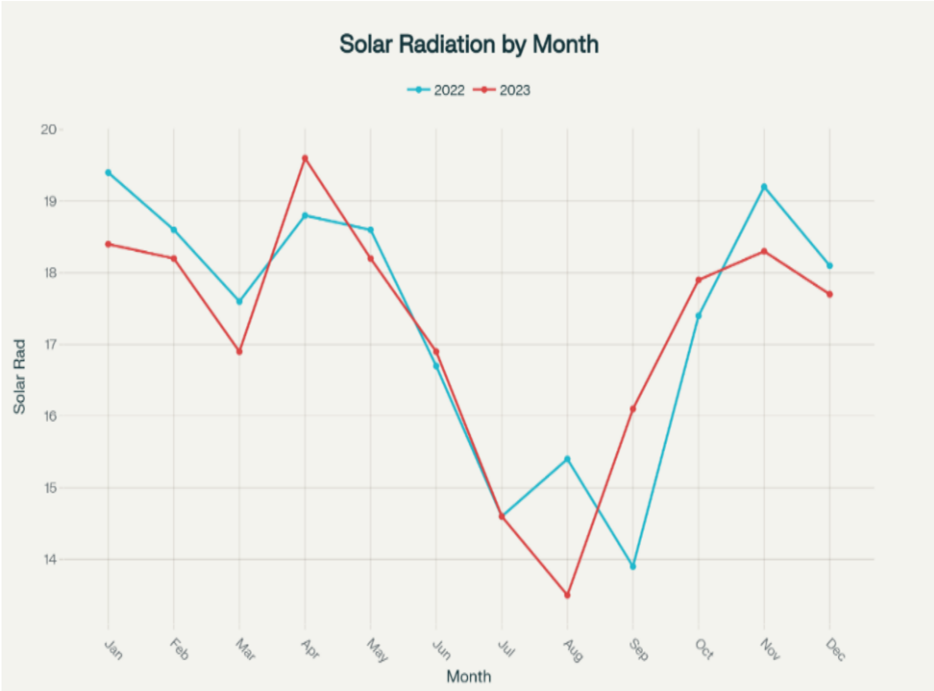

Figure 2. Monthly variation of solar radiation during the 2022 and 2023 seasons at the experimental site.

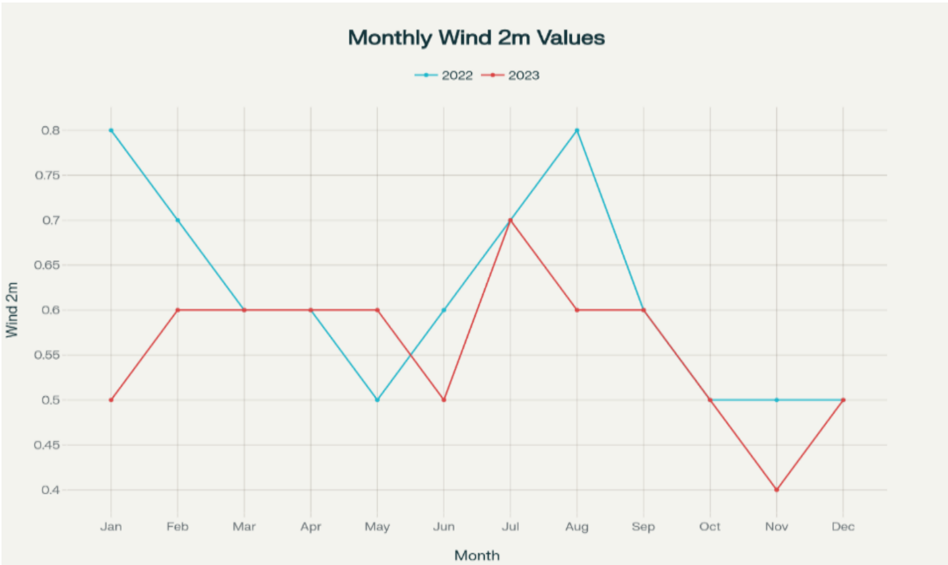

Figure 3. Monthly variation of wind speed at 2m during the 2022 and 2023 seasons at the experimental site.

Figure 3 illustrates that wind speeds at 2 meters above ground fluctuated throughout the months in both 2022 and 2023, but with noticeable differences. In 2022, the wind speeds started high in January (0.8), dipped slightly mid-year, and peaked again in August (0.8), then remained stable at lower levels from September to December (0.5–0.6). Conversely, in 2023, wind speed was low at the beginning of the year (0.5), but steadily increased in March and April, peaked in July (0.7), and then decreased into November (0.4). Overall, wind speeds in 2023 were generally lower than in 2022, with a less distinct summer peak. The monthly wind speed at 2 meters varied seasonally in both years, but with clear differences between them. In 2022, higher wind speeds occurred at the beginning and end of the year, with a peak in August. In 2023, values were lower and more stable, with a small peak in July followed by a decline into November. These patterns suggest stronger seasonal wind events in 2022 compared to 2023, potentially indicating larger atmospheric changes. Variations in wind speed influence evapotranspiration, disease spread, and the risk of soil erosion, highlighting the importance of continuous monitoring to support climate-resilient farming practices.

The soil sample (Pre-sowing), as shown in Table 2, at the surface soil was classified as clay loam with a slightly acidic pH of 5.23 and a relatively high bulk density of 1.5 g/cm³. The cation exchange capacity (CEC) measured 6.15 cmol/kg, while total nitrogen and organic carbon contents were 0.35% and 1.12%, respectively; all values were below Food and Agriculture Organization of the United Nations [14] critical thresholds of 0.2% N and 3% organic matter. Available phosphorus was similarly deficient, measuring below the critical range (8–20 mg/kg). Exchangeable cations were evenly distributed, with calcium and magnesium concentrations of 4.2 and 1.8 cmol/kg, respectively.

Table 2. The compositions of the fertilizers.

Parameters	Organic fertilizer	Organomineral	Mineral fertilizer
Total (N%)	3.17	2.58	0.45
P (%)	1.25	1.10	76.92
Na (%)	0.85	0.88	0.85
K (%)	1.75	0.68	1.75
Ca^{2+} (%)	3.47	3.68	3.44
Mg^{2+} (%)	4.38	3.87	6.39
pH $_{(H2O)}$	6.7	6.5	5.99

Proximate analysis of organic and organomineral fertilizers (Table 3) revealed high levels of nitrogen, phosphorus, potassium, calcium, magnesium, and total organic carbon, indicating their capacity to enhance soil fertility and support crop growth [15].

The application of fertilizer significantly modified soil texture and physical properties (Table 4). Sand content increased markedly from 40% in the control to approximately 71%, 68%, and 67% under organomineral, organic, and NPK fertilizer treatments, respectively. Correspondingly, clay and silt fractions decreased by 10.8% and 20.0%. Bulk density exhibited a decreasing trend in the order: control > NPK > organomineral > organic fertilizer, reflecting improvements in soil structure, pore distribution, and overall physical condition following fertilizer amendments.

Table 3. Effects of fertilizer sources on soil properties.

Parameters	Unit	Control	OGM	N.P. K	ORF
Texture		CL	SL	SL	LL
Sand	%	40.5 ± 0.71^{a}	68.7 ± 0.38^{c}	66.9 ± 0.04^{b}	70.6 ± 0.62^{d}
Clay	%	39.5 ± 0.71^{d}	$12.30.26^{a}$	14.49 ± 0.11^{c}	11.69 ± 0.37^{b}
Silt	%	$20.00+0.00^{b}$	18.96 ± 0.06^{c}	18.61 ± 0.56^{c}	16.71 ± 0.41^{a}
pH$_{(H2o)}$		5.00 ± 0.00^{a}	5.02 ± 0.02^{a}	4.77 ± 0.33^{a}	5.74 ± 0.37^{b}
TN	%	0.59 ± 0.58^{a}	0.58 ± 0.59^{a}	0.59 ± 0.59^{a}	0.56 ± 0.63^{a}
Available P	mg/kg	5.76 ± 0.34^{a}	11.97 ± 0.42^{c}	9.98 ± 0.04^{b}	9.77 ± 0.33^{b}
Na	mg/kg	0.25 ± 0.42^{a}	0.95 ± 0.08^{b}	0.93 ± 0.11^{b}	0.76 ± 0.34^{b}
K	kg/kg	0.57 ± 0.61^{a}	1.99 ± 0.21^{b}	1.90 ± 0.15^{b}	1.70 ± 0.43^{b}
Ca^{2+}	cmol/kg	1.20 ± 0.28^{a}	3.89 ± 0.15^{b}	3.63 ± 0.53^{b}	4.00 ± 0.03^{b}
Mg^{2+}	cmol/kg	0.80 ± 2.82^{a}	4.60 ± 0.57^{c}	3.74 ± 0.37^{bc}	2.75 ± 0.36^{b}
CEC	cmol/kg	6.40 ± 1.14^{a}	9.60 ± 0.60^{c}	8.00 ± 0.01^{b}	8.00 ± 0.30^{b}
CU	g/kg	1.62 ± 0.53^{a}	1.82 ± 0.26^{a}	1.75 ± 0.34^{a}	1.63 ± 0.52^{a}
AL	g/kg	0.06 ± 0.06^{a}	0.70 ± 0.04^{a}	0.06 ± 0.06^{a}	0.07 ± 0.05^{a}
TOC	g/kg	0.90 ± 0.14^{a}	0.96 ± 0.04^{a}	1.10 ± 0.14^{a}	1.00 ± 0.06^{a}
BD	g/cm³	1.51	1.34	1.42	1.31

Note: Means with the same superscript along the rows are not significantly different at P<0.05. TN = total nitrogen; BD = bulk density; T= texture; clay-loam; sandy-loam; organomineral fertilizer = OGM; organic fertilizer = ORF; TOC = total organic matter.LS- loamy sandy.

Table 4. Effects of fertilizer and sowing date on the number of leaves of different tomato varieties (means of the 2022 and 2023 trials).

Treatments	Weeks after planting					
	2	4	6	8	10	12
Varieties						
'Platino'	93.44ᵃ	123.15ᵇ	259.10ᵇ	424.12ᵇ	588.29ᵇ	336.30ᵇ
Ibadan local	91.50ᵇ	135.21ᵃ	269.50ᵃ	470.42ᵃ	612.92ᵃ	368.17ᵃ
'Beske'	83.50ᶜ	101.21ᶜ	226.60ᶜ	423.63ᶜ	490.87ᶜ	327.21ᶜ
'Roma'	70.92ᵈ	81.55ᵈ	176.00ᵈ	307.83ᵈ	427.39ᵈ	258.00ᵈ
Fertilizers						
OGM	90.51ᵃ	146.97ᵃ	227.10ᵇ	436.94ᵇ	624.56ᵃ	418.05ᵃ
ORF	86.08ᵇ	177.56ᵃ	252.70ᵃ	437.71ᵃ	591.71ᵇ	328.64ᵇ
N.P. K	82.18ᶜ	99.89ᵇ	228.20ᵇ	417.68ᶜ	489.07ᶜ	308.46ᶜ
Control	79.58ᵈ	93.35ᵇ	179.20ᶜ	387.66ᵈ	479.15ᵈ	294.53ᵈ
Sowing date						
May 19	81.62ᵈ	106.97ᶜ	215.70ᵇ	395.52ᵈ	512.23ᵈ	332.83ᵈ
May 29	82.64ᶜ	108.31ᶜ	218.40ᵃᵇ	400.54ᶜ	518.66ᶜ	337.00ᶜ
June 8	85.81ᵇ	112.59ᵇ	227.20ᵃᵇ	415.85ᵇ	538.90ᵇ	349.86ᵇ
June 18	88.29ᵃ	115.89ᵃ	233.90ᵃ	428.08ᵃ	554.69ᵃ	360.00ᵃ
L. S. D	0.074	1.18	13.45	0.422	0.533	2.50
Interactions						
Varieties by fertilizer	*	*	*	*	*	*
Varieties by SD	*	*	NS	*	*	*
Fertilizer by SD	NS	NS	NS	NS	NS	NS
Varieties by fertilizer by SD	NS	NS	NS	NS	NS	NS

Note: Means with similar letters along the column in the same treatment are not significantly different at p< 0.05 (DMRT) * significant level at P> 0.05; ** significant at P> 0.01 Sowing Date =SD. NS = Not Significant

The effects of fertilizer application and sowing date on tomato leaf production are summarized in Table 4. Significant differences ($P < 0.05$) were observed among the varieties. Throughout the evaluation period, 'Platino' consistently produced the highest leaf numbers, closely followed by 'Ibadan local', 'Beske', and 'Roma'. An exception occurred at 2 WAP, where 'Ibadan local' recorded the highest leaf number. The control treatment consistently produced the fewest leaves and was significantly different from all fertilizer treatments. Among fertilizers, there were significant differences; the organomineral application was significantly different, producing the highest leaf number, followed by organic and NPK fertilizers. The sowing date also had a significant effect ($P < 0.05$), with the 18 June planting producing the highest leaf numbers and being significantly different from the earlier sowing dates (8 June, 29 May, and 19 May). No significant interaction was detected between fertilizer treatments and sowing dates. However, significant interactions between variety and fertilizer treatment were observed throughout the evaluation period, except at 6 WAP, highlighting differences in both magnitude and direction of response.

Table 5. Effects of fertilizers and sowing dates on the height (cm) of tomato varieties (Mean of 2022 and 2023 trials).

Treatments	Weeks after planting					
	2	4	6	8	10	12
Varieties						
'Platino'	39.87ᵇ	60.25ᵃ	69.96ᵃ	91.69ᵃ	99.58ᵇ	126.19ᵃ
Ibadan local	42.42ᵃ	56.13ᵇ	68.55ᵇ	84.94ᵇ	109.98ᵃ	116.95ᵇ
'Beske'	29.74ᵈ	39.38ᶜ	62.66ᶜ	77.32ᵈ	95.81ᶜ	116.71ᵇ
'Roma'	30.77ᶜ	40.57ᵈ	63.53ᵈ	78.55ᶜ	94.16ᵈ	117.83ᶜ
Fertilizers						
Organomineral	41.71ᵃ	53.58ᵃ	73.30ᵃ	95.67ᵃ	114.73ᵃ	133.72ᵃ
Organic	39.53ᵇ	51.5ᵇ	67.19ᵇ	85.91ᵇ	103.82ᵇ	125.89ᵇ
N.P.K	33.21ᶜ	47.87ᶜ	64.31ᶜ	77.82ᶜ	93.74ᶜ	118.95ᶜ
Control	28.35ᵈ	43.24ᵈ	59.89ᵈ	73.09ᵈ	87.26ᵈ	99.12ᵈ
Sowing date						
May 19	31.84ᵈ	44.89ᵈ	61.6³ᵈ	77.47ᵈ	91.52ᵈ	108.48ᶜ
May 29	34.45ᶜ	46.62ᶜ	66.01ᶜ	83.52ᶜ	98.48ᶜ	119.10ᵇ

Treatments	Weeks after planting					
	2	4	6	8	10	12
June 8	39.64^{a}	53.65^{a}	68.04^{b}	87.45^{b}	104.74^{a}	125.23^{a}
June 18	36.86^{b}	51.08^{b}	69.02^{a}	84.04^{a}	104.86^{a}	124.89^{a}
L.s.d	0.18	0.24	0.32	0.259	0.185	0.404
Interactions						
Varieties by fertilizer	*	*	*	*	*	*
Varieties by sowing dates	*	*	*	*	*	*
Fertilizer by sowing dates	*	*	*	*	*	*
Varieties by fertilizer by sowing dates		*	*	*	*	*

Note: Means with similar letters along the column in the same treatment are not significantly different at p< 0.05 (DMRT) * significant level at P> 0.05; ** significant at P> 0.01 Sowing Date =SD. NS = Not Significant

The effects of fertilizer application and sowing date on plant height (cm) for the tomato varieties are presented in Table 5. Plant height differed significantly (P<0.05) among the varieties; 'Ibadan local' and 'Platino' consistently noted for the tallest plant heights, followed by 'Beske' and 'Roma' in decreasing order throughout the period of measurement for the experiment. Similarly, significant differences (P < 0.05) were observed among the fertilizer types, with organomineral fertilizer significantly outperforming organic fertilizer (125.89 cm), followed by NPK (118 cm) and the control (99.12 cm). The effect of sowing date on plant height was statistically similar, but was significantly different (P<0.05). Sowing dates 8 June and 18 June produced the tallest plants, which were significantly different from May 19 and May 29, in decreasing order. The interaction effects among the three factors on plant height were significantly different (P<0.05) throughout the evaluation period, similar to the interaction effects of variety * fertilizer, variety * sowing date, and fertilizer * sowing date, which were also significantly different.

Table 6. Effects of fertilizer and sowing date on the number of branches of different tomato varieties (Mean of the 2022 and 2023 trials).

Treatments	Weeks after transplanting			
	4	6	8	10
Varieties				
'Platino'	18.44^{b}	18.90^{b}	24.40^{b}	25.82^{b}
Ibadan local	20.17^{a}	22.22^{a}	27.09^{a}	28.81^{b}
'Beske'	15.01^{c}	15.51^{c}	18.68^{c}	20.05^{d}
'Roma'	13.84^{d}	15.37^{c}	18.15^{d}	21.14^{c}
Fertilizers				
Organomineral	20.04^{a}	20.42^{a}	26.19^{a}	28.37^{a}
Organic	18.58^{b}	19.60^{b}	24.32^{b}	27.04^{b}
N.P.K	14.35^{d}	15.82^{d}	18.66^{c}	19.81^{d}
Control	14.50^{c}	16.16^{d}	19.16^{d}	20.59^{c}
Sowing date				
May 19	15.17^{d}	16.14^{c}	19.90^{d}	21.25^{d}
May 29	16.78^{c}	17.77^{c}	22.11^{c}	23.93^{c}
June 8	17.57^{b}	18.65^{b}	22.75^{b}	24.83^{b}
June 18	17.9^{5a}	19.53^{a}	23.57^{a}	25.82^{a}
LSD	0.201	0.158	0.313	0.187
Interactions				
Variety x Fertilizer	*	*	*	*
Variety x sowing date	*	*	*	*
Fertilizer x sowing date	*	*	*	*
Variety x fertilizer x sowing date	*	*	*	*

Note: Means with similar letters along the column in the same treatment are not significantly different at p< 0.05 (DMRT) * significant level at P> 0.05; ** significant at P> 0.01; Sowing Date =SD. NS = Not Significant

The effects of fertilizer application and sowing date on branch number are presented in Table 6. Significant varietal differences (P < 0.05) were observed. 'Ibadan local' produced the highest mean branch number (28.81), followed by 'Platino' (25.82), 'Beske' (21.14), and 'Roma'. Fertilizer application significantly increased branching compared with the control. Organomineral fertilizer resulted in the highest mean branch number (28.37), followed by organic fertilizer, NPK, and the control, in decreasing order.

Sowing date also exerted a significant effect ($P < 0.05$). The 8 June planting produced the highest branch number, followed by 18 June, 29 May, and 19 May, showing a consistent declining trend with earlier sowing. Interaction effects were significant ($P < 0.05$) for variety × fertilizer, variety × sowing date, fertilizer × sowing date, and variety × fertilizer × sowing date across all measurement intervals, indicating complex responses to combined factors.

Table 7. Effects of fertilizers and sowing dates on the yield and yield components of tomato varieties (mean of 2022-2023 trials).

Parameters	Anthesis day	Fruit weight per plant (g)	Number of fruits (m²)	Weight of harvested fruits (kg/ha)	Shoot dry weight (g)	Harvest index
Treatment						
Varieties						
Platino	20.520ᵃ	85.951ᵃ	696.201ᵃ	3946.50ᵃ	24.8625ᵇ	0.05042ᵇ
Ibadan local	21.571ᵇ	78.710²ᵇ	638.801ᵇ	3452.80ᵇ	25.3725ᵃ	0.07271ᵃ
'Beske'	21.512ᵇ	51.480ᶜ	623.601ᶜ	3197.80ᶜ	22.6278ᵈ	0.0678ᵇ
'Roma'	20.503ᵃᵇ	26.481ᵈ	431.501ᵈ	953.20ᵈ	19.235c	0.0358ᶜ
Fertilizers						
Organomineral	22.712ᵇ	97.492ᵃ	691.701ᵃ	3543.901ᵃ	23.575ᵇ	0.053ᵃ
Organic	22.741ᵃ	94.071ᵇ	653.402ᵇ	3573.202ᵃ	23.645ᵃ	0.057ᵃ
N.P. K	20.232ᵈ	36.990ᶜ	519.801ᶜ	2056.801ᶜ	21.242ᶜ	0.053ᵃ
Control	20.812⁴c	29.832ᵈ	352.101ᵈ	1196.502ᵈ	19.641ᵈ	0.043ᵇ
Sowing date						
May 19	20.791ᵇ	76.202ᶜ	543.501ᶜ	2326.401ᵈ	24.697ᵃ	0.024ᵈ
May 29	21.702ᵃ	78.801ᵇ	550.112bᶜ	2375.303ᶜ	22.759ᵇ	0.031ᶜ
June 8	21.712ᵃ	87.602ᵃ	557.123ᵃᵇ	3399.801ᵇ	21.082ᶜ	0.060ᵇ
June 18	21.792ᵃ	87.901ᵃ	566.404ᵃ	3448.801ᵃ	19.565ᵈ	0.091ᵃ
LSD	0.163	0.066	8.581	7.0721	0.033	0.003
Interactions						
Variety x fertilizer	*	*	*	*	*	*
Variety x SD	NS	*	*	*	*	*
Fertilizer x SD	NS	NS	NS	*	*	*
Variety X fertilizer x SD	NS	NS	NS	NS	*	NS

Note: Means with similar letters along the column in the same treatment are not significantly different at p< 0.05 (DMRT) * significant level at P> 0.05; ** significant at P> 0.01; Sowing Date =SD. NS = Not Significant.

The effects of fertilizer application and sowing date on yield and yield components of tomato varieties are presented in Table 7. Varietal differences in anthesis were significant ($P < 0.05$). 'Platino' (21.52 days) and 'Ibadan local' (21.50 days) differed slightly but significantly, whereas 'Roma' did not differ from 'Beske'. Fertilizer application significantly influenced anthesis. The longest time to anthesis was observed with organic fertilizer (22.74 days), followed by organomineral fertilizer (22.71 days), significantly different from the control, which had the earliest anthesis (20.81 days).

Varieties differed significantly ($P < 0.05$) in mean fruit weight. 'Platino' recorded the highest (85.95 g), followed by 'Ibadan local' (78.72 g), 'Beske' (51.48 g), and 'Roma' (26.42 g). Fertilizer application also had a significant effect, with organomineral fertilizer producing the highest fruit weight (4.74 g), and the control recorded the lowest fruit weight (2.98 g). Sowing date had no significant effect on fruit weight. Significant varietal differences ($P < 0.05$) were recorded for fruit number. 'Platino' (696.2 fruits m^{-2}) was highest, followed by 'Ibadan local' (638.8), 'Beske' (623.6), and 'Roma' (431.0).

Fertilizer application significantly affected fruit number, with organomineral fertilizer yielding the most, followed by organic fertilizer, significantly different from NPK and the control. Sowing date effects showed that 8 June and 18 June were statistically similar, but both significantly exceeded the earlier sowing dates (29 May and 19 May). The marketable yield was significantly different among varieties ($P < 0.05$). 'Platino' produced the highest yield (3946.5 kg ha^{-1}), while 'Roma' produced the lowest (953.3 kg ha^{-1}). Fertilizer effects were also significant, with organomineral fertilizer giving the maximum yield (3503.9 kg ha^{-1}), followed by organic fertilizer (2903.8 kg ha^{-1}) and NPK (1197.8 kg ha^{-1}). The control recorded the lowest yield (2.0 kg ha^{-1}). Among sowing dates, 18 June produced the highest yield, followed by 8 June, 19 May, and 29 May in decreasing order.

Shoot dry weight differed significantly among varieties ($P < 0.05$). 'Platino' and 'Beske' recorded the highest biomass (23.64 g), followed by 'Ibadan local', while 'Roma' had the lowest. Fertilizer treatments significantly affected shoot dry weight; the control recorded the minimum (19.64 g). Sowing date effects were also significant, with 19 May producing the heaviest shoot dry weight and 8 June the lowest.

The Harvest Index for the varieties was significantly different ($P < 0.05$). The 'Ibadan local' variety had the highest HI (0.072), followed by 'Beske' and 'Platino' (0.050), while 'Roma' was lowest. Fertilizer application treatments on the also affected HI were significantly different, with the control consistently recording the lowest. A significant difference was observed for HI, with the maximum HI recorded on SD at 18 June and the minimum at SD 19 May.

3.2. Discussion

The soils from the experimental sites were classified as an oxic paleustalf with low-activity clay, a dominant soil group in Southwest Nigeria [16, 17]. It was moderately acidic (pH 5.5–6.0) and nutrient-deficient. However, this pH range enhanced nutrient availability for most crops [18]. The acidic nature of the soil likely results from high annual rainfall, which ranges between 1800-3000 mm. This promotes leaching of base cations and increases exchangeable Al^{3+} and H^{+} activity, thereby reducing soil pH. Soil organic matter was very low (0.3–0.6%), far below the critical threshold (<2%), and declined with depth, reflecting residue concentration at the surface and rapid decomposition under continuous cultivation [19]. Both total N (<2%) and available P (<10 mg kg^{-1}) were also below critical levels for humid tropical soils, consistent with nutrient depletion from continuous farming, leaching, erosion, and poor fertilizer use efficiency [20]. The total available P (7.39 mg kg^{-1}) concentration is much higher in the soil than the critical level. It could be the heavy reliance on organic matter as a P source and losses from fixation and erosion [21, 22]. Exchangeable bases and CEC were generally low, reflecting organic matter depletion and intensive soil use, in agreement with Ogunjinmi, et al. [23]. The bulk density was reduced with the application of both organic and organomineral fertilizers. This is attributed to high microbiological activity. Thus, there is an increase in the organic matter content and residue accumulation, which improves soil aggregation and porosity [24]. The soil characteristics indicate a fragile, nutrient-poor system requiring integrated fertility management to sustain crop productivity. For tomato production in particular, the low levels of N, P, and organic matter underscore the crop's strong dependence on external nutrient inputs. The significant yield response observed in this study is attributed to fertilizer application, especially organomineral amendments. This highlights the necessity of balanced nutrient management in such fragile soils to achieve sustainable production.

Variation in phenological stages among tomato varieties was influenced by both genetic factors and environmental conditions, consistent with previous reports [25, 26]. Crop development is strongly regulated by weather parameters such as temperature, photoperiod, solar radiation, and cloud cover. The genotype × environment interactions, which determine flowering time, fruit morphology, and maturity period, are also crucial factors. Determinate varieties ('Platino' and 'Roma') flowered earlier, while indeterminate types ('Ibadan Local' and 'Beske') exhibited prolonged flowering, reflecting both genetic control and ecological adaptability.

Fertilizer application significantly enhanced vegetative growth and reproductive performance by correcting soil nutrient deficiencies [4]. Organomineral and organic fertilizers maintained superior growth and yields in comparison to the yield outputs from the inorganic source. This is attributable to their balanced nutrient composition and gradual nutrient release [27, 28]. The organomineral fertilizer, in particular, provided additional nutrient fortification (e.g., N = 8.34%; Ca = 4.42%; Mg = 3.87%), which improved biomass production and fruit yield [29]. Similar positive effects of integrated nutrient management have been reported for okra, fluted pumpkin, maize, and other fruit vegetables [21, 30, 31].

The absence of significant effects of sowing date × fertilizer interaction on anthesis suggests that native soil fertility and prevailing climatic conditions buffered treatment effects. However, combined variety × fertilizer and variety × sowing date interactions significantly influenced dry shoot weight and yield, indicating that fertilizer application remains a key determinant of assimilate production and partitioning [31].

Among the tested cultivars, 'Platino', 'Ibadan Local', and 'Beske' produced higher fruit numbers and yield per plant under organic nutrient sources, outperforming 'Roma' by approximately 30%. This superior performance reflects both the enhanced adaptability of local hybrids and the efficiency of organic inputs in improving soil–plant nutrient dynamics. Similar findings on varietal adaptability under organic fertilization were reported by Mihalache, et al. [32] and Assefa and Tadesse [33].

Furthermore, these results demonstrate that phenology development in tomato is governed by genotype × environment interactions, while sustained productivity depends on nutrient management. Organomineral and organic fertilizers offer a superior and more sustainable strategy for enhancing tomato performance in nutrient-poor tropical soils compared with sole inorganic inputs.

Sowing date emerged as a critical determinant of crop performance in this microecologically variable region [34]. The 8 June and 18 June sowings aligned with periods of frequent rainfall when soils were at or near field capacity, thereby enhancing nutrient release, water retention, and plant uptake. These factors are favorable for robust vegetative and reproductive development [31, 35]. Flowering and fruit set commenced approximately six weeks after transplanting, coinciding with the onset of the "August break," a short dry spell during the rainy season in southwestern Nigeria. This period favors tomato production because there is a reduction in rainfall amount and intensity, optimization of nutrient and water use, a decrease in disease incidence, and excessive solar radiation. Soil moisture, air, and soil temperature are maintained at adequate levels [10]. In contrast, earlier sowing exposed plants to excessive rainfall, leading to flower abortion, increased disease incidence, and reduced yield potential [36]. These results highlight the importance of aligning sowing windows with seasonal weather patterns to minimize production risks [37].

Nutrient application, management, and varietal response, particularly from nitrogen-rich organic sources, significantly enhanced tomato growth and yield. This finding supports earlier reports on the positive role of organic fertilizers in vegetable productivity [28, 38]. Indeterminate cultivars ('Beske' and 'Ibadan Local') demonstrated stronger responses to organic fertilization compared with 'Roma' and Platino' varieties, suggesting greater compatibility with slow nutrient release and microbial-mediated nutrient cycling.

The superior performance of 'Platino' and 'Ibadan Local' under organic fertilization is likely linked to their genetic adaptability, superior vegetative vigor, and better physiological efficiency under the microclimatic conditions of the study sites. This observation is consistent with Amirahmadi, et al. [39], who emphasized the central role of genotypic and environmental interactions in determining yield outcomes.

Conversely, 'Roma' consistently produced lower yields despite fertilizer application, indicating poor ecological compatibility with the prevailing soil and climate conditions. This result underlines the necessity of cultivar selection based on environmental adaptation rather than the universal adoption of improved varieties.

Overall, tomato performance was determined by the combined effects of soil fertility, varietal traits, fertilizer type, and sowing date under tropical rainforest conditions. The results suggest that sowing between early and mid-June maximizes yield potential in the agroecology related to the study area. The superior performance of 'Ibadan local', 'Beske', and 'Platino' under organic and organomineral fertilization highlights the value of integrated soil fertility management for sustaining tomato productivity in nutrient-deficient tropical soils. The experiment also provides evidence-based guidance for optimizing tomato production in smallholder systems vulnerable to climate variability. These findings reaffirm that both genetic adaptability and judicious use of fertilizer are critical for improving yield potential in rain-fed tomato production systems.

4. CONCLUSION

This study demonstrates that soil nutrient availability, moderated by fertilizer application, sowing date, and genotype selection, plays a decisive role in tomato productivity under rainforest agroecosystems. Soil pH and cation exchange capacity remain key diagnostic indicators of soil fertility status, guiding nutrient management strategies for phosphorus, potassium, and magnesium across variable soil textures.

Results confirm that tomato growth and yield can be significantly enhanced through the use of organic and organomineral fertilizers, which offer both agronomic benefits and advantages compared with sole reliance on inorganic inputs. The adoption of such sustainable nutrient sources is critical for improving soil health, optimizing fertilizer selection, and supporting long-term productivity.

Genotypic choice was equally decisive, with locally adapted cultivars Platinum and Ibadan Local showing greater yield potential than improved introductions, underscoring the importance of genotype–environment interactions. The strong correlation observed between total yield and marketable yield highlights the economic implications of cultivar selection for smallholder farmers.

Furthermore, sowing date emerged as a critical management factor, influencing phenological development, vegetative growth, yield components, and overall fruit quality. Mid-June sowing consistently optimized growth and yield, confirming the need for calendar-based recommendations aligned with local rainfall patterns and microclimatic conditions. Taken together, these findings provide a practical guide for improving tomato production in the rainforest zone of Southwest Nigeria. The adoption of optimal sowing dates, sustainable fertilizer strategies, and environment-specific genotypes can enhance yield stability, fruit quality, and profitability, while contributing to food security and resilience of smallholder farming systems in Okitipupa and similar agroecologies.

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