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Original Article

Growth and yield response of cassava TME 419 to biochar and inorganic fertilizer applications

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ABSTRACT

Cassava (Manihot esculenta) is a staple crop valued for its adaptability and yield potential, yet optimizing its growth requires effective soil fertility management. This study evaluated the influence of biochar, compost, NPK 15-15-15 fertilizer, and their combinations on the growth and yield of TME 419 cassava, focusing on plant height, stem girth, leaf production, and tuber yield. Data collected were subjected to Analysis of variance and significant means were separated using Duncan multiple range test at $P < 0.05$. Treatments applied to cassava TME 419 did not significantly influence the growth parameters. However, NPK 15-15-15 application resulted in the tallest cassava plant (124.60 cm), while biochar and compost treatment improved stem girth (1.72 cm), suggesting enhanced soil aeration, moisture retention, and structural support. However, leaf production peaked under NPK treatment (21.00 leaves), reinforcing its critical role in chlorophyll synthesis and canopy development. In terms of tuber yield, cassava treated with biochar and compost treatment recorded the highest yield (22.82 t/ha), indicating significant effects of organic amendments on storage root formation. The moderate yield observed with compost and NPK treatments further confirms their contributions to carbohydrate accumulation and root development in cassava cultivation. It is recommended that further studies should be carried out to know the residual effect of biochar on cassava cultivation and soil health dynamics to enhance productivity while maintaining environmental sustainability.

KEYWORDS: *Organic amendments, Soil fertility, Tuber, Yield*

INTRODUCTION

Cassava (*Manihot esculenta*) is a staple crop in tropical and subtropical regions, serving as a primary source of carbohydrates for millions worldwide (FAO, 2021). It is particularly vital in Africa, where it plays a crucial role in food security and economic stability (IITA, 2020). Among the numerous cassava varieties developed to enhance yield and resilience, TME 419 stands out due to its high productivity, disease resistance, and adaptability to various agro-ecological conditions (Nweke *et al*., 2002).

Soil fertility remains a key factor in optimizing cassava growth and yield, necessitating sustainable soil management strategies (Lal, 2020). Biochar, a carbon-rich material derived from the pyrolysis of organic matter, has gained attention for its potential to improve soil properties, enhance nutrient retention, and promote microbial activity (Lehmann *et al*., 2011). Jeffery et al. (2015) showed that biochar can mitigate soil degradation, enhance water retention, and improve root development, which is critical for tuber crops like cassava.

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In contrast, inorganic fertilizers, particularly NPK, play a crucial role in supplying essential nutrients that directly influence plant metabolism, growth rate, and tuber development (Ndor *et al.*, 2019). The application of NPK fertilizers has been found to significantly enhance cassava yield when applied at optimal rates, improving starch content and tuber size (Howeler *et al.,* 2013).

This research aimed to evaluate the comparative effects of biochar and inorganic fertilizers on the growth and yield of cassava TME 419, specifically analyzing parameters such as plant height, stem girth, number of leaves, and yield of tubers (Olasanmi *et al*., 2022). By assessing these factors, the research seeks to determine the effectiveness of biochar as a soil amendment relative to conventional inorganic fertilizer application, providing insight into sustainable agronomic practices for enhanced cassava production in Malete, Kwara State, North-Central Nigeria (Audu *et al*., 2021).

MATERIALS AND METHOD

Experimental location

This research was conducted at Bioresources Development Center (BIODEC), University Road, Malete-Ilorin, Kwara State, North-Central Nigeria, located at 8.72123° N, 4.48251° E. The area experiences a tropical climate characterized by distinct wet and dry seasons, with an annual rainfall of approximately 852 mm (33.5 inches), and the average temperature is around 28°C.

Experimental Design

A randomized complete block design (RCBD) was adopted, consisting of five treatments replicated three times, with each plot measuring 2 m by 3 m (6 m²). The total experimental plot size was 90 m² with a spacing of 1 m by 1 m, which gave 6 plant populations per plot.

Experimental Materials

The cassava variety TME 419 was obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. This variety was carefully selected to ensure uniformity in size and vigor. Stem cuttings, each measuring 25 cm in length, were treated with a fungicide to prevent fungal infections before planting. The cuttings were established using the ridge planting method.

Biochar used in this study was derived from dried cassava peels, collected from Shao Cassava Factory, Shao, Kwara State. The peels were thoroughly air-dried for 14 days before undergoing slow pyrolysis at 450°C in an oxygen-limited environment. The pyrolyser used in producing the biochar for the study has three compartments: an insulated outer metal box with a cover, an inner cylinder with a separate cover, and a lower lid where the charred product comes out. Cassava peel biochar possesses favorable physicochemical properties such as neutral to slightly alkaline pH, high surface area, and substantial cation exchange capacity, which together enhance soil fertility, nutrient retention, and plant growth.

The organic compost applied in this experiment was poultry manure. Poultry manure was selected due to its high nitrogen content, which is essential for cassava's vigorous growth and yield formation. Poultry droppings were sourced from a nearby farm, composted for four (4) months to ensure microbial stability and nutrient optimization before application. The composted poultry manure with a carbon-to-nitrogen ratio of 15:1 and a pH range of 6.5 to 8.0 was utilized as an organic amendment, selected for its consistent nutrient capacity to enhance soil fertility and plant nutrition.

A commercially formulated NPK (15-15-15) fertilizer was sourced from a reputable agro-input supplier in Ilorin, Kwara State, ensuring consistency in nutrient composition.

Treatments, application method, and rates

1. Control
2. Biochar - 5 t/ha was used, and biochar was incorporated into the soil three (3) weeks before planting to allow proper interaction with the soil.
3. NPK 15:15:15 – 0.8 t/ha was used and applied in split doses (0.4 t/ha at 2 weeks after planting and 0.4 t/ha at 6 weeks after planting).
4. Compost - 5 t/ha was applied before planting and mixed thoroughly with the soil to enhance microbial activity and nutrient availability.
5. Biochar + Compost - 2.5 t/ha and 2.5 t/ha of each treatment was applied to the soil before planting.

Data Collection

Growth parameters were recorded at four-week intervals throughout the study period. The following variables were measured:

Plant height (cm) - Measured from the base of the stem to the terminal bud using a calibrated meter rule.

Stem girth (cm) - Determined using a Vernier caliper, measured at 5 cm above ground level to ensure consistency.

Number of leaves per plant – This was counted manually at each interval to assess vegetative growth.

Tuber yield (kg/ha) - Harvested tubers were cleaned, weighed, and recorded per plot at maturity, 10 months after planting (March 2024 – January 2025).

Additional soil parameters, such as pH, organic matter content, and nutrient compositions, were analyzed before and after the experiment to evaluate the impact of biochar and inorganic fertilizer on soil fertility. The particle size analysis was determined by using Bouyouco's hydrometer method to ascertain the relative amounts of sand, silt, and clay. pH was measured using a glass electrode pH meter. Organic carbon was determined using the Walkley Black wet oxidation method. Total nitrogen was determined using the Kjeldahl method. Available phosphorus was determined with the aid of a spectrophotometer using Mehlich III as the extractant. Exchangeable bases (K, Ca, Mg, and Na) and micronutrients (Fe, Mn, Cu) were determined with the aid of an atomic absorption spectrometer.

Statistical analysis: Data collected were subjected to Analysis of variance (ANOVA) using General Statistics Package (GENSTAT) 4th edition, 2015, while significant means were separated using Duncan multiple range test (DMRT) at $P < 0.05$.

RESULTS AND DISCUSSION

Results

The physiochemical characteristics of the experimental soil before and after planting are presented in Tables 1 and 2. The soil was slightly acidic (pH 5.83) before planting and remained slightly acidic (pH 6.3) after planting. Organic carbon and total nitrogen increased from 5.81 to 9.76 g/kg, respectively. Available phosphorus remained high. The textural class changed from sandy loam to loamy sand.

Table 1: Particle size distribution and chemical properties of the experimental soil before planting

Properties	Values	Critical levels (Chude *et al.*, 2012)	Remark
pH (1:1, H_2O)	5.83	6.6 – 7.2	Slightly acidic
Organic carbon (g/kg)	5.81	10 - 14	Low
Total Nitrogen (g/kg)	0.49	1.6 – 2.0	Low
Available Phosphorus (mg/kg)	28.10	7 - 20	High
Exchangeable Cations (cmol/kg)			
Ca	2.24		
Mg	1.10		
K	0.17	0.3 – 0.6	Very low
Na	0.87		
Exchangeable Acidity	0.40		
Extractable Micronutrient (mg/kg)			
Fe	38.00	30 - 35	Slightly high
Mn	78.50		High
Cu	0.93		Low
Zn	1.14		Low
Particle size distribution (g/kg)			
Sand	79.00		
Silt	13.00		
Clay	8.00		
Textural class			Sandy loam

Table 2: Particle size distribution and chemical properties of the experimental soil after planting

Properties	Values	Critical levels (Chude *et al.*, 2012)	Remark
pH (1:1, H_2O)	6.3	6.6 – 7.2	Slightly acidic
Organic carbon (g/kg)	9.76	10 - 14	Moderate
Total Nitrogen (g/kg)	1.40	1.6 – 2.0	Slightly low
Available Phosphorus (mg/kg)	32.60	7 - 20	High
Exchangeable Cations (cmol/kg)			
Ca	4.79		
Mg	1.06		
K	0.25	0.3 – 0.6	Slightly low
Na	0.88		
Exchangeable Acidity	0.47		
Extractable Micronutrient (mg/kg)			
Fe	51.00	30 - 35	High
Mn	79.40		High
Cu	1.03		Low
Zn	1.17		Low
Particle size distribution (g/kg)			
Sand	81.00		
Silt	13.00		
Clay	6.00		
Textural class			Loamy sand

As shown in table 3, application of NPK 15:15:15 produced the tallest plants (124.60 cm), while the highest stem girth (1.72 cm) and number of leaves (19.58) were observed with the biochar + compost treatment.

Table 3: Effect of treatment application on growth parameters of TME 419 Cassava

Treatments	Plant height (cm)	Stem girth (cm)	Number of leaves
Control	100.6	1.61	17.6
Biochar	111.35	1.62	18.1
NPK 15-15-15	124.6	1.67	21
Compost	119	1.71	20.67
Biochar + Compost	116.4	1.72	19.58
SED	NS	NS	NS

NS- Not significant

Table 4 shows that biochar + compost gave the highest weigh (22.82 t/ha) and number (9.10 t/ha) of tubers, followed closely by NPK 15:15:15. The lowest yield parameters were observed in the control treatment.

Table 4: Effect of treatment application on the yield parameters of TME 419 Cassava

Treatments	Weight of Tuber (t/ha)	Number of Tuber (t/ha)
Control	15.70^{c}	8.58^{b}
Biochar	18.00^{bc}	7.90^{c}
NPK 15-15-15	22.50^{a}	9.00^{a}
Compost	19.20^{b}	8.90^{ab}
Biochar + Compost	22.82^{a}	9.10^{a}
SED	0.9800	0.2002

Means in the same column followed by different superscript letters are significantly different by DMRT at (P<0.005)

Discussion

The application of biochar, NPK 15-15-15 fertilizer, and compost significantly improved soil properties after planting, enhancing nutrient availability and overall soil health. The total nitrogen levels increased from 0.49 to 1.40 g/kg, indicating enhanced mineralization and retention, which is essential for plant growth and microbial activity (Chude *et al.,* 2012). The organic carbon remained slightly low. Available phosphorus, which was already high before planting (28.10 mg/kg), further increased to 32.60 mg/kg, reinforcing the effectiveness of NPK in phosphorus mobilization. This ensures improved root development and energy transfer within plant systems (Sanchez *et al.,* 2024). The exchangeable cations, particularly calcium, showed notable improvement, strengthening soil aggregation and enhancing nutrient retention, while biochar and compost helped stabilize magnesium and potassium levels (Brady & Weil, 2023). Micro nutrients also reflected treatment influence, with Fe increasing from 38 to 51 mg/kg after harvest, which is due to the solubility effect of organic amendment. Mn remained consistently high, supporting enzymatic activity throughout the cassava development (Brady & Weil, 2023). However, Zn and Cu remained low, which may suggest hidden micronutrient deficiencies that could constrain future cassava productivity. A shift was observed in the soil texture from sandy loam to loamy sand, suggesting improved drainage while maintaining adequate moisture-holding capacity, enhancing root proliferation and plant uptake efficiency (Clark, 2023).

Table three shows the effect of treatment application on growth parameters of TME 419 Cassava. The application of biochar, compost, and NPK 15-15-15 fertilizer did not significantly influence the growth parameters of TME 419 cassava, which include the plant height, stem girth, and number of leaves. Plant height, which is a key determinant of vegetative vigor, was highest in cassava treated with NPK 15-15-15 (124.60 cm), followed by compost (119.00 cm) and biochar + compost (116.40 cm). The control treatment recorded the lowest plant height (100.60 cm). The highest height observed with NPK 15-15-15 treatment aligns with the findings of Chude *et al*. (2012), which confirms that balanced nutrient application enhances cell elongation and overall plant growth. The stem girth, which reflects structural strength and nutrient transport efficiency, ranged from 1.61 cm (control) to 1.72 cm (biochar + compost). The biochar + compost treatment resulted in the highest stem girth, highlighting the synergistic effect of organic amendments in promoting stem thickening and mechanical support. Brady and Weil (2023) reported that organic matter additions enhance soil aeration and microbial activity, leading to improved cassava structural development. The number of leaves plays a crucial role in photosynthesis and overall cassava productivity. The highest leaf count was observed in TME 419 cassava treated with NPK 15-15-15 (21.00 leaves), followed closely by compost (20.67 leaves) and biochar + compost (19.58 leaves), while the control treatment recorded the lowest count (17.60 leaves). This aligns with the findings of Adegbite *et al*. (2023), who emphasize the importance of balanced soil nutrition in promoting leaf expansion and chlorophyll synthesis. This finding suggests that nutrient and organic inputs influence cassava physiology, while their effects on vegetative traits may require a longer duration or a controlled condition. Additionally, biochar's water retention capacity may have contributed to low improvements in leaf production, as suggested by Lehmann *et al*. (2023).

Table four shows the effect of treatment applications on cassava tuber yield. The application of various treatments significantly influenced cassava tuber yield per hectare, with distinct variations observed among the treatments. The weight of tuber ranged from 15.70 tons per hectare (control) to 22.82 tons per hectare (Biochar + Compost). The highest yield observed under the Biochar + Compost treatment suggests that organic amendments can enhance soil fertility, moisture retention, and nutrient availability, contributing to increased tuber formation. This is consistent with the findings by Lehmann *et al*. (2023), who report that biochar improves soil structure and microbial activity, leading to enhanced crop yield. The NPK 15-15-15 treatment (22.50 tons per hectare) also resulted in improved yield, likely due to its balanced nutrient composition. According to Chude *et al.* (2022), NPK fertilizer enhances root development and carbohydrate accumulation in tubers, promoting higher productivity. Similarly, compost alone (19.20 tons per hectare) provided moderate yield improvement, supporting studies by Sanchez *et al*. (2024) that highlight compost's role in enriching organic matter content and improving soil moisture-holding capacity. The results also show that there were no significant differences among the treatments applied; however, findings showed biochar and compost may provide long-term benefits in sustainable cassava production.

CONCLUSION AND RECOMMENDATIONS

The application of biochar, compost, and NPK 15-15-15 and their combinations influenced both the growth and yield of TME 419 cassava. NPK exhibited the greatest plant height, suggesting improved nutrient absorption and cell elongation, while biochar and compost-based treatments contributed to increased stem girth, reflecting enhanced soil structure and moisture retention. This research shows the importance of a balanced approach in integrating organic amendments with mineral fertilizers to offer a sustainable pathway for improving cassava growth, ensuring better productivity and soil health for long-term cultivation. However, further studies will be carried out to ascertain the residual effect of biochar on the yield of cassava TME 419.

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Authors' Contributions

AAO conceptualized the study. AAO & DAA designed the experiment, AAO, OAO & ORI collected data, performed data analysis, and wrote the first draft of the manuscript. SS & GOA performed literature searches and reviewed the first draft of the manuscript. All authors read and approved the final draft of the manuscript.

Ethical Statement

Not applicable

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