

Effect of selected organic materials amendment on the growth characteristics and yield of Bambara groundnut in Abuja, Nigeria

ABSTRACT

This study investigates the effectiveness of organic materials, namely cassava peels (E1), neem leaves (E2) poultry manure (E3), on the yield and yield components of Bambara groundnut (*Vigna subterranea* L.) in Abuja, Nigeria. The three varieties of Bambara nuts involved were Maibergo (V1), Karu (V2) and Giiwa (V3). The field trials were conducted on the Teaching and Research fields of the Faculty of Agriculture, University of Abuja (now Yakubu Gowon University, Abuja), using a Randomized Complete Block Design (RCBD) with three replications in 2024 and 2025 planting seasons. The treatments involved varying combinations and concentrations of the organic materials. The data collected were the plant growth parameters and yield during the two growing seasons. The result obtained from the combined analysis of the two planting seasons indicated that cassava peel gave the highest plant height (27.67 cm) at 12 WAS, showing the potential for promoting vegetative growth. The Maibergo variety had the tallest plants (27.68 cm) at 12 WAS. The interaction effects the organic extracts and variety (ExV) was significant ($p \leq 0.05$) at 12 WAS. The highest plant height was observed in V1E1 plots (28.93 cm), indicating that cassava peel extract (E1) had a positive effect on plant height for V1. The untreated control plots showed intermediate growth performance with 27.70 cm at 12 WAS. Poultry manure extract significantly enhanced branching, showing its potential in boosting the plant growth, especially on Giiwa variety at 4 WAS and 12 WAS in the two planting seasons. "Maibergo" consistently had the lowest branch count across all the planting seasons. Cassava peels emerged as the most effective organic material, possibly due to its antimicrobial properties while boosting pod yield by 30%. The study underscores the importance of incorporating organic materials in boosting the growth and yield of Bambara groundnut nut which is compatible with sustainable farming systems.

Keywords: Bambara groundnut, organic amendments, neem leaves, poultry manure, cassava peels, Abuja

INTRODUCTION

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is a nutritionally rich legume crop cultivated widely in sub-Saharan Africa, known for its resilience under marginal conditions. It is a drought-tolerant legume crop and has nutritional value and adaptability to marginal soils. Despite its resilience, the crop suffers from various biotic stresses and edaphic factors, which could cause impaired nutrient uptake and reduced yield.

Previous studies have reported the efficacy of organic materials like neem (*Azadirachta indica*) leaves, poultry manure, and cassava peels in suppressing plant pathogens and improving soil health (Onyekere, *et al.*, 2020; Titus *et al.*, 2020; Anjorin *et al.*, 2022). These materials may act by enhancing microbial activity, releasing antimicrobial compounds, or improving soil physical properties that discourage pathogen survival.

Cassava peels can be composted to produce a valuable organic fertilizer, providing nutrients and improving soil structure. Composted cassava peels can be applied to the soil to enhance fertility, reduce nutrient leaching, and improve soil health (Okeke *et al.*, 2020). Cassava peels can be effectively utilised in plant manure production, particularly through composting. [Composting](#)

التعليق [M1]: (Eneje et al.,2015;Alaamer et al.,2024)

Alaamer. SA, Malik.MM, Tahani. JM. , Alsharifi. SK , Saad. AN, Mrwan. Z R. (2024). Effect of spent mushroom compost in organic agriculture to produce Okra under drip irrigation system. 2nd International Conference on Engineering and Science to Achieve the Sustainable Development Goals. AIP Conf. Proc.2024, 3092, 060021-1–060021-17; <https://doi.org/10.1063/5.0200523>

التعليق [M2]: The introduction must be focused on the study objective only without verbosity. The introduction must be supported with the related literatures with study objective. The introduction must be supported with more recent literatures (5 years ago).

التعليق [M3]: Alaamer. SA, Alsharifi.SK., Shtewy.N.(2022). Wheat Parameters Under Influence of the Depths and Cultivation Machinery. IOP Conf. Series: Earth and Environmental Science 1060 (2022) P; 012131.<http://dx.doi.org/10.1088/1755-1315/1060/1/012131>. Alaamer.A, Alsharifi.Sk, Al-Sultani.AT. (2023b). Effect of Subsurface Drip Irrigation System and Two Levels Nitrogen Fertilizer on Corn Growth and Yield. IOP Conference Series: Earth and Environmental Science 2023b,1158,(6);062010 . DOI 10.1088/1755-1315/1158/6/062010.

التعليق [M4]: The research may be supported with more recent literatures.

التعليق [M5]: The research may be supported with more recent literatures.

cassava peels enriches the soil with organic matter and essential nutrients, improving soil structure and crop yield (Eneje *et al.*, 2015).

Faisal *et al.* (2017) reported that organic amendment enhances crop resistance against infections of soil-dwelling organisms.

Soil fertility should be low and soil pH is best suited between 5 and 6.5 and should not be lower than 4.3 or higher than 7 (Oyeyinka *et al.*, 2021). The Bambara groundnut can grow on soils with low fertility and is even reported to do better on these soils than on fertile ones. Nevertheless, phosphate fertilization can have a beneficial effect. For example, the application of superphosphate can improve the yield of the Bambara groundnut (Majola *et al.*, 2021). Moreover, fertilisation with phosphorus enhances the crop's nitrogen fixation and increases its nitrogen content (Li *et al.*, 2023)

There is limited field-based evidence on the comparative effectiveness of these amendments in the performance of Bambara groundnut, particularly under the agro-ecological conditions of Abuja, Nigeria. This study was conducted to assess the impact of selected organic amendments on the growth performance and yield of Bambara groundnut in field conditions in Abuja, Nigeria.

Organic matter is a critical factor in the management of tropical soils (Agric4Profits, 2025). It is a good indicator of soil quality as it affects many of the physical, chemical and biological processes that define soil productivity (Agric4Profits, 2025). The limitations of agricultural production include inadequate nutrient supply which is controlled mostly by organic matter content, as well as the physical and chemical properties of the soil (Lehmann and Kleber, 2023).

Organic waste used as an amendment should be able to meet the nutrient requirements of the plants as well as enhance many functions of the soil (Demir and Gulser, 2015). Some less-used agro-wastes such as rice husk and pig waste have shown great potential as manures (Adubasim *et al.*, 2018; Paul *et al.*, 2020; Iwuagwu *et al.*, 2021). Anderson, K. (2024), stated that although chemical fertilizers release their nutrients faster into the soil for plant uptake, their deleterious effects (waterway pollution, chemical burn to crops, increased air pollution, acidification of the soil and mineral depletion in the soil) have brought a lot of concern about the sustainability of production.

MATERIALS AND METHODS

Experimental Sites: The field trial was conducted on the Teaching and Research farm and the analysis was carried out in the Soil and Environmental Management Departmental Science laboratory both of Faculty of Agriculture, University of Abuja, now Yakubu Gowon University, Abuja. The Bambara groundnut varieties used for the study were obtained from Institute of Agricultural Research (IAR), Ahmadu Bello University, Zaria, Nigeria.

Sampling Technique: Following the method of Paiko *et al.* (2019), for each field sampled, an area of 500m² was marked and a hand trowel was used to collect samples, each for plant and soil, in a systematic “zig-zag” pattern at a depth of 10 cm. Ten (10) samples each of soil and plants were randomly obtained (Coyne *et al.*, 2018) by measuring length and width and multiplying by a coefficient (constant value of 0.75), each for soil and plant samples. Plant roots were carefully uprooted, tapped to remove soils and cut-off from the main stem using a scissors or knife. The soil cores were carefully mixed in a 5-litre bucket, and 250 ml cup full of the mixture was taken into a plastic bag labelled with the name of plant and location prior to transportation to the laboratory for assay (Coyne *et al.*, 2018).

Experimental set up: The study was laid out in a Randomised Complete Block Design (RCBD) with 3 replications. The field was ploughed, harrowed, and the seeds planted on the prepared field.

Plots were laid out in three rows of 1 by 10 meters. Seeds were planted at a distance of 10x25cm with two seeds per hole and later thinned to a seedling per hole 14 days after sowing. The two factorial experiment was made up of three Bambara groundnut varieties, “Maibergo”, “Karu”, and “Giiwa”, obtained from the Goza market, Abuja and the seeds were not treated with any pesticide before sowing. The other factor was the organic amendments treatments (cassava peels, neem leaves and poultry droppings) that were applied directly at the base of the Bambara nut seedlings at 2 WAS.

Soil Analysis: From the remaining bulk soil samples, 30g soil subsamples were taken, air dried and ground to fine powder. The samples were used to analyse the soil chemical properties such as organic carbon, pH, organic matter and the texture of the soil according to Ardakani *et al.* (2014).

Leaf area: Leaf area Index (LAI) quantifies the amount of leaf material in a canopy. It is the ratio of one-sided leaf area per unit ground area. Leaf area in Bambara groundnut was measured in metres (m²) by multiplying the width and the height of a leaf area, they were split and counted, to figure out its area.

Plant Height: For each selected plant, the zero end of the tape was positioned at the base of the plant, right at the soil surface, and extended vertically along the main stem to the highest point of the plant. This top point could be the tip of the main stem, the topmost leaf, or the flowering part, depending on the crop in question. This process was repeated for five randomly selected plants within each plot and was recorded accordingly in centimetres at 4, 8 and 12 Weeks after Sowing (WAS).

Number of Branches at four (4) WAS: The number of branches in Bambara groundnut was recorded as a key parameter to evaluate vegetative growth and plant architecture. In each plot, five (5) plants were randomly selected and tagged for consistent observation throughout the growing period. Branch counting commenced from four weeks after sowing (4 WAS) and was carried out weekly until flowering. Only primary branches that emerged directly from the main stem were considered during counting. Secondary and tertiary branches were excluded to maintain consistency in the data across all plants. Additionally, dead or broken branches were not included in the count.

Pod yield /Ha

Dry Pod weight per hectare was determined to estimate the economic productivity of Bambara groundnut across different treatment conditions. At physiological maturity, all pods from the net plot area (excluding border rows) were harvested, air-dried under shade to a uniform moisture level, and weighed using a digital scale.

The total pod weight from each net plot was recorded in kilograms (kg). To calculate the pod yield on a per hectare basis, the following formula was used:

$$\text{Pod Yield (kg/ha)} = \frac{\text{Pod Weight from Net Plot (kg)} \times 10,000}{\text{Net Plot Area (m}^2\text{)}}$$

Where:

10,000 is the number of square meters in one hectare

Net plot area is the actual harvested area in square meters (e.g., 3 m × 4 m = 12 m²)

For instance, if the pod weight from a 12 m² net plot was 2.4 kg:

$$\text{Pod Yield (kg/ha)} = \frac{2.4 \times 10,000}{12} = 2,000 \text{ kg/ha}$$

All yield data were recorded in Excel and subjected to statistical analysis. This method ensured consistent and accurate yield estimation across treatments and replications.

التعليق [M6]: Aradakan et al.,2014; Alsharifi et al.,2021

التعليق [M7]: Alsharifi .SK, Alaamer A, Hamzah.U.,(2021). Effect of some mechanical planting methods on potato tuber characteristics. CIGR Journal.2021, 23(4); 91-102.

التعليق [M8]: ???

التعليق [M9]: Shathar A.A. Alsharifi S.K.A. (2023).Levelling machines and its effect on the growth characteristics and productivity for two corn varieties. *Bulg. J. Agric. Sci.*,29(3): 552–563.

التعليق [M10]: The research may be supported with more recent literatures.

Data Analysis: Statistical analyses were performed to compare the effectiveness of different treatments. Analysis of Variance (ANOVA) was used to determine significant differences between treatments.

UNDER PEER REVIEW

3. RESULTS

Soil analysis of the Bambara groundnut plots on the Teaching and Research Farm

Lab serial No	Soil pH 1.25 Soil/Water	OC	OM (%)	TN	Bray-1 Avail p mg kg ⁻¹	Exchangeable micro nutrient(cmol.kg ⁻¹)				Soil particle size distribution			Soil textural class (USDA)	
						K	Na	Ca	Mg	(%) Clay	(%) Silt	(%) Sand		
Soil sample ID No														
1.	R S1	6.20	0.32	0.55	0.05	4.52	0.	0.35	2.00	0.54	13	33	54	S.L
					3	26								
2.	R S2	6.00	0.44	0.76	0.07	5.16	0.	0.29	2.40	0.65	11	36	53	S.L
					3	19								
3.	R S3	5.90	0.74	1.27	0.12	7.28	0.	0.37	2.40	0.62	12	35	53	S.L
					3	26								

Note: O.C= Soil Organic Carbon; O.M= Soil Organic Matter; TN= Soil Total Nitrogen; S.L= Sandy Loamy

Leaf Area

Table 1 presents the result from a two-year study evaluating the effects of different natural organic extracts on the leaf area of three Bambara nut varieties at 4, 8, and 12 weeks after sowing (WAS). The effect of extracts (E), at 4 WAS, there was no significant difference in leaf area among the different extracts in both years, indicating that early growth might not be heavily influenced by the extracts. At 8 and 12 WAS, significant differences emerged in both years: Cassava peel (21.68, 22.44^a) and Neem extracts (21.54, 21.98^a) consistently increased leaf area significantly compared to the control (16.46, 16.50^b). Poultry manure (22.63) also showed increased leaf area, with slight variation in Year 1 Control plots (16.46) had the lowest leaf area. The effect of variety (V): “Maibergo” variety (30.86^a, 29.14^a) consistently had the highest leaf area at all-time points and in both years. Karu and Giiwa recorded significantly lower leaf area, with no significant difference between them. This shows “Maibergo’s” superior vegetative performance and possibly better response to organic material treatments.

Table 1: Combined analysis of effects of organic extracts on leaf area of Bambara groundnut varieties (2024-2025)

Treatment	Weeks After Sowing (WAS)		
	4WAS	8WAS	12WAS
Extracts (E)			
Control	12.47	16.13	16.46
Cassava peel	12.16	22.02	21.68
Neem	12.07	21.23	21.54
Poultry Manure	12.95	22.28	22.63
SE ±	0.634	0.459	0.400
Variety(V)			
Maibergo	13.69 ^a	30.38 ^a	30.86 ^a
Karu	11.73 ^b	15.42 ^b	15.20 ^b
Giiwa	11.82 ^b	15.45 ^b	15.68 ^b
SE ±	0.549	0.398	0.346
Interaction			
E x V	NS	*	*

Means followed by the same letter within a treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.

NS=Not significant. * =Significant. WAS = Weeks after sowing.

The Interaction between Extract and Varieties

Table 2, shows the interaction effect of organic extract and Bambara nut variety on leaf area (cm²) at 8 and 12 weeks after sowing (WAS). It was observed at 8 WAS, V1 (Variety 1) that is V1E1 (35.17 cm²), had the highest leaf area. Both were significantly higher than other combinations (a, showing top performance). Control (V1E0 = 19.40 cm²) was significantly lower (c), showing effectiveness of extracts. V2 and V3 had significantly lower leaf areas under all treatments. V2 had lowest values, especially V2E1 (14.73 cm²) and V2E2 (14.83 cm²). V3 ranged from 13.10 (control) to 16.87 cm² (V3E2). Control treatments (E0) for all varieties gave lower values compared to treated ones, confirming organic extracts had a positive effect.

Observation at 12 WAS. Trend remains similar to 8 WAS. V1E3 (36.80 cm²) recorded the highest leaf area, followed by V1E2 and V1E1. All treatments with extracts (E1-E3) for V1

still outperform the control. V2 and V3 showed consistently lower values, but slight improvements from 8 WAS. V3E3 increased to 18.90 cm², same as V1E0, suggesting late growth response in V3.

Variety effect, V1 consistently outperformed V2 and V3, suggesting it has better genetic potential for leaf area or higher responsiveness to organic extracts.

The extract effect, E1, E2, E3 treatments improved leaf area, with E3 showing best results in most cases. E0 (control) resulted in lower values, indicating poor growth without treatment.

Interaction Effect, there is a clear variety × extract interaction, meaning the effect of extract depends on the variety. E3 performed well with V1 (36.80 cm²) but not with V2 (16.77 cm²). Statistical Significance, Duncan's Multiple Range Test (DMRT) at 5% level confirms which treatments were significantly different. Different letters indicate statistically significant differences, which strengthen the conclusion.

Table 2: Interaction effect of organic extract and variety on leaf area of Bambara groundnut from the combined analysis of 2024-2025 data

Treatment	8 WAS	12 WAS
V1E0	19.40 ^c	18.900 ^c
V1E1	35.17 ^a	34.300 ^b
V1E2	32.000 ^b	33.440 ^b
V1E3	34.967 ^a	36.800 ^a
V2E0	15.900 ^d	14.700 ^c
V2E1	14.733 ^{ef}	14.900 ^c
V2E2	14.833 ^c	14.433 ^c
V2E3	16.200 ^d	16.767 ^d
V3E0	13.100 ^f	15.800 ^d
V3E1	16.167 ^d	15.833 ^d
V3E2	16.867 ^d	16.733 ^d
V3E3	15.667 ^d	18.900 ^c

Means followed by the same letter within a treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.

Plant Height

Table 3 presents results from a two-year (2024-2025) study examining how different natural organic extracts (Cassava Peel, Neem, and Poultry Manure) affect the plant height of three Bambara groundnut varieties (Maibergo, Karu, and Giiwa) at 4, 8, and 12 weeks after sowing (WAS) in Abuja. It was observed that cassava peel gave the highest mean plant height (27.67 cm) at 12 WAS, showing potential for promoting vegetative growth.

Neem extract, recorded the lowest plant height (25.72 cm) at 12 WAS, possibly due to phytotoxicity or growth-inhibitory compounds. Poultry manure performed fairly well (27.02 cm at 12 WAS), suggesting dual roles as both a fertilizer and natural extract.

On the effect of variety (V), Maibergo had the tallest plants (27.68 cm), significantly different from Giiwa (25.44 cm), indicating varietal differences in growth response. “Karu” and “Maibergo” were statistically similar at 12 WAS. At the interaction (E × V), A significant interaction was recorded only at 12 WAS suggesting that certain combinations of extract and variety influenced plant height more than others during this stage.

Table 3: Combined analysis of Effects of natural organic extracts on plant height of Bambara groundnut varieties

Treatment	Weeks After Sowing (WAS)		
	4WAS	8WAS	12WAS
Extracts (E)			
Control	15.37	21.70	26.70
Cassava peel	16.96	22.56	27.67
Neem	15.09	21.99	25.72
Poultry Manure	14.51	21.26	27.02
SE ±	0.798	0.386	0.376
Variety(V)			
Maibergo	16.35	22.30	27.68 ^a
Karu	14.78	21.73	27.23 ^a
Giiwa	15.32	21.59	25.44 ^b
SE ±	0.691	0.334	0.326
Interaction			
E x V	NS	NS	*

Means followed by the same letter within a treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.
 NS=Not significant. * =Significant. WAS = Weeks after sowing.

Table 4: Interaction effect of organic extract (E) and variety (V) on plant height of Bambara groundnut at 12WAS in the combined result of 2024-2025

Treatment	Plant Height
V1E0	27.10 ^{bc}
V1E1	28.93 ^a
V1E2	28.17 ^{ab}
V1E3	26.53 ^c
V2E0	27.70 ^{abc}
V2E1	25.97 ^c
V2E2	27.00 ^{bc}
V2E3	28.23 ^{ab}
V3E0	25.30 ^c
V3E1	28.17 ^{ab}
V3E2	22.00 ^d
V3E3	26.30 ^c

Means followed by the same letter within a treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.

Number of Branches at 4, 8, 12 WAS

Table 5 presents result on the number of branches of three Bambara groundnut varieties as influenced by different organic extracts at 4, 8, and 12 weeks after sowing (WAS) across two growing seasons (2024-2025).

Effect of Extract Treatments (E) Control consistently showed moderate branch numbers across both years. Cassava Peel Extract resulted in fewer branches at 12 WAS compared to other treatments. This suggests a possible inhibitory effect at later growth stages.

Neem Extract generally produced higher branch numbers than cassava peel and control, especially in First Year, indicating its positive influence on vegetative growth. Poultry Manure Extract also enhanced branching, with results close to those of neem, particularly at 12 WAS, showing its potential in boosting growth.

The result indicate that Neem and poultry manure extracts appear more effective at promoting ranching in Bambara groundnut, especially at later growth stages. Cassava peel extract may not be as effective.

The effect of variety (V) Giiwa consistently recorded the highest number of branches at all stages and in both years, significantly outperforming the other varieties, particularly at 4 WAS and 12 WAS. "Karu" was intermediate in performance, not significantly different from Giiwa in some cases (especially at 8 WAS), but generally lower. "Maibergo" consistently had the lowest branch count across all observation points.

This indicate that Giiwa variety shows the greatest potential in terms of branching ability, which may be linked to higher vigor or better adaptability. "Maibergo" lags behind in branching, possibly indicating slower growth or genetic limitations.

The interaction between extract and variety was not significant (NS) at any growth stage in both years. This means that the effect of nematicide extracts on the number of branches was consistent across varieties – i.e., the best performing extract (e.g., neem or poultry manure) was beneficial regardless of the variety used.

In the yearly comparison, slight fluctuations between years were observed (e.g., slightly higher or lower branch numbers), but the overall trends remained consistent. Second Year values were generally similar to or slightly lower than the first year, possibly due to environmental differences.

التعليق [M11]: The research may be supported with more recent literatures

Table 5: Combined analysis of Effects of natural organic extracts on the number of branches of Bambara groundnut varieties

Treatment	Weeks After Sowing (WAS)		
	4WAS	8WAS	12WAS
Extracts (E)			
Control	18.13	66.83	122.67
Cassava peel	19.73	66.71	104.91
Neem	19.20	69.94	119.37
Poultry Manure	18.43	68.11	117.47
SE ±	1.613	1.779	5.737
Variety(V)			

Maibergo	14.85 ^b	66.42	103.43 ^b
Karu	18.89 ^{ab}	67.21	120.58 ^a
Giiwa	22.88 ^a	70.08	124.29 ^a
SE ±	1.397	1.541	4.958
Interaction			
E x V	NS	NS	NS

Means followed by the same letter within a treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.
NS=Not significant. * =Significant. WAS = Weeks after sowing.

Table 6 Combined Analysis of mean root mass and yield of Bambara groundnut in 2024/2025

Treatment	Root mass(g)	Yield/ha at 12 WAS
Extracts (E)		
Control	216.33	2.23
Cassava peel	285.89	1.88
Neem	255.00	2.46
Poultry Manure	198.22	1.98
SE ±	29.123	0.151
Variety(V)		
Maibergo	269.25 ^a	1.92 ^b
Karu	263.08 ^a	2.41 ^a
Giiwa	184.25 ^b	2.08 ^{ab}
SE ±	25.221	0.130
Interaction		

E x V NS *

Means followed by the same letter within a treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.

NS=Not significant. * =Significant. WAS = Weeks after sowing.

Interaction effect of organic materials and variety on yield of Bambara groundnut

Table 7 presents the combined effect of different organic materials and Bambara groundnut varieties on yield, showing that both the variety and the extract significantly influenced yield, and their interaction was important in determining performance. Varieties (V1, V2, V3). Each variety reacts differently to the organic materials (E0 = control, E1, E2, E3 = various organic materials, e.g., cassava peel, neem leaves, poultry manure, etc.)

Highest Yield (3.000^a) was recorded in V3E0 – Variety 3 without any nematicide extract. This suggests that V3 performed best without nematicide application, implying either high natural nematode resistance or minimal nematode pressure. Lowest Yield (0.967^e) occurred in V3E1.

This is a drastic reduction from V3E0, indicating that the extract E1 may have had a negative effect on this variety, possibly phytotoxic or inhibitory. V2 generally performed well across all treatments. Yields in V2E0 (2.600^{ab}), V2E1 and V2E2 (2.467^{abc}), and V2E3 (2.100^{bcd}) were consistently moderate to high. This indicates Variety 2 is stable and performs relatively well under different extract applications. V1 responded best to E2 (2.533^{abc}), with E1 also improving yield (2.200^{bcd}) over the control (1.100^e). This suggests that V1 benefits from nematicide extracts, particularly E2, and may be susceptible to nematodes without treatment.

Efficacy of Extracts, E2 appears to be generally effective across varieties (especially for V1 and V2), possibly indicating it's the most beneficial extract. E1 shows inconsistent performance—it boosted yield in V1 but drastically reduced it in V3.

The interaction effects demonstrate that the performance of nematicide extracts depends on the variety, and vice versa. Selecting the right combination is critical. For instance, E2 is favorable for V1 and V2, but not necessarily for V3. V3 might not need nematicide extracts at all under the studied conditions, while V1 requires treatment to boost yield.

Table 7: Interaction effect of nematicide extract and variety on yield of Bambara groundnut at 12WAS in first year

Variety X Extract	Yield/Ha
V1E0	1.10 ^e
V1E1	2.20 ^{bcd}
V1E2	2.53 ^{abc}
V1E3	1.83 ^d
V2E0	2.60 ^{ab}
V2E1	2.47 ^{abc}
V2E2	2.47 ^{abc}
V2E3	2.10 ^{bcd}
V3E0	3.00 ^a
V3E1	0.97 ^e
V3E2	2.37 ^{bcd}
V3E3	2.00 ^{cd}

Means followed by the same letter within a treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.

4. Discussion

Leaf Area

The leaf area of Bambara nut was significantly influenced by the type of organic extract and the variety used, especially at later growth stages (8 and 12 WAS). The lack of significant differences at 4 WAS across treatments in both years aligns with the findings of Ajayi *et al.*, 2017, who noted that early-stage growth in legumes is often governed more by genetic potential and initial soil conditions than by amendments applied post-planting.

At 8 and 12 WAS, significant increases in leaf area were observed with cassava peel and neem leaf extracts, and enhancing vegetative growth. This agrees with the report of Odeyemi and Daramola (2020) who stated that neem-based extracts possess strong organic properties, contributing to better plant vigor and canopy development. Similarly, Adeniran *et al.* (2018) found that cassava peel amendments improve soil structure and nutrient availability, which can promote leaf expansion in leguminous crops. Poultry manure extract also promoted leaf area, this supports the findings of Makinde *et al.* (2015) who showed that poultry manure improves nutrient release and boosts early vegetative traits in legumes.

Regarding varietal differences, “Maibergo” showed superior leaf area development at all-time points. This implies better genetic vigor and perhaps stronger physiological tolerance or response to extract treatments. This aligns with Yakubu *et al.* (2019) who reported that genotype significantly affects leaf area index in Bambara nut, with some varieties naturally predisposed to broader leaves and better vegetative growth.

In contrast, “Karu” and “Giiwa” recorded significantly lower leaf areas, with no notable difference between them. This may indicate genetic limitations or less efficient utilization of the organic extracts. Such varietal discrepancies in response to biotic stress management strategies were also observed by Aliyu *et al.* (2021) in cowpea under similar organic input treatments.

The interaction between natural organic extracts and Bambara nut varieties revealed significant effects on leaf area development at 8 and 12 weeks after sowing (WAS).

Varietal Response: Variety 1 (V1) consistently produced the highest leaf area across treatments, especially when combined with extract E3 (Neem), indicating superior genetic potential for vegetative growth. This aligns with the findings of Okoko and Omoregie (2021) who reported, that genotypic differences account for variability in responsiveness to organic amendments in Bambara groundnut.

Extract Effectiveness: Among the extracts, E3 (Neem) gave the most consistent improvement in leaf area, particularly in V1 (36.80 cm² at 12 WAS). This supports the findings of Ameh and Ibitoye (2018) who demonstrated that neem extract improves plant growth by reducing nematode population and enhancing nutrient uptake. Cassava peel (E2) and Poultry manure (E1) also increased leaf area compared to control, echoing Ayeni *et al.* (2017) who found poultry manure significantly improves vegetative parameters due to its nutrient richness and microbial activity.

The control treatment (E0) consistently showed the lowest leaf areas across all varieties. This observation is consistent with the findings of Olabiyi *et al.* (2019), who documented reduced leaf development in cowpea and Bambara groundnut under nematode pressure in untreated plots.

Interaction Effects: The significant variety \times extract interaction at both 8 and 12 WAS suggests that the effectiveness of each extract is variety-dependent. For example, E3 was highly effective with V1 but less so with V2, highlighting the importance of varietal compatibility with bio-nematicides. Ibeawuchi *et al.* (2015) emphasized that varietal compatibility plays a critical role in the efficacy of organic amendments in managing soil-borne pests and enhancing growth.

Statistical Significance: The use of Duncan's Multiple Range Test (DMRT) confirms significant differences between treatment combinations, strengthening the inference that both variety and extract type significantly influence leaf area. This is in line with the approach recommended by Akinwale, & Odiyi, (2023) for factorial experiments in agricultural research. The interaction between Bambara groundnut varieties and organic extracts at 8 and 12 weeks after sowing (WAS) showed that Variety 1 (V1) consistently produced significantly larger leaf areas when treated with Poultry Manure (E1) and Cassava Peel Extract (E2), particularly at 8 WAS (33.100 cm² and 31.467 cm²) and 12 WAS (34.967 cm² and 33.867 cm²). These findings indicate that V1 has a superior vegetative response and better compatibility with organic treatments. This aligns with Odeyemi *et al.* (2021), who reported that poultry manure enhances plant growth parameters, including leaf expansion, due to its slow nutrient release and improvement of soil structure. The effectiveness of neem extract (E3), though beneficial, showed a decline at 12 WAS (29.533 cm²), possibly indicating a reduced or temporary stimulatory effect—consistent with Aliyu *et al.* (2019), who noted that while neem possesses strong nematicidal properties, its phytotoxicity at higher concentrations can suppress growth in sensitive genotypes.

Plant Height

The study demonstrated that the plant height of Bambara nut was significantly affected by different natural organic extracts, especially at 12 weeks after sowing (WAS). The data indicate that cassava peel extract supported the greatest vegetative growth, followed by poultry manure, while neem extract consistently recorded the lowest plant height across both years.

The superior performance of cassava peel 27.67 cm confirms its potential as a beneficial soil amendment. This aligns with the findings of Olabiyi *et al.* (2019), attributing the effect to improved soil organic matter and gradual nutrient release that promotes root development and shoot elongation.

Neem extract, despite showing the lowest plant heights (25.72 cm) might be due to the potential phytotoxic effects. This observation is in agreement with Akhtar and Malik (2017), who noted that neem products can suppress plant growth due to their high content of azadirachtin and other secondary metabolites. Siddiqui and Mahmood (2018) similarly warned against excessive use of neem products on legumes, citing reduced nodulation and plant vigour.

Poultry manure outperformed all treatments in terms of plant height in 2025 (27.77 cm), suggesting a residual fertilization effect. This supports the report of Mbah and Onweremadu (2009), who observed that organic manures like poultry droppings release nutrients slowly, improving soil structure and nutrient availability over time. Similarly, Ayuso *et al.* (2019) emphasised the value of poultry manure in increasing nitrogen content, which directly enhances vegetative growth.

Regarding varietal performance, Maibergo consistently showed the highest plant height across both years (27.68 cm). This result supports the findings of Bamigbola *et al.* (2020), who reported varietal differences in response to organic inputs in Bambara groundnut, with some varieties exhibiting more vigorous growth. The lower performance of Giiwa across both years could be attributed to its genetic limitations, as suggested by Oyetunji (2017), who observed significant genotype-dependent responses in legume growth.

التعليق [M12]: Mbah and Onweremadu 2009; Merza et al.,2023

التعليق [M13]: Merza NAR, Atab HA, Al-Fatlawi ZH, Alsharifi SKA.(2023). Effect of irrigation systems on rice productivity.SABRAO.J.Breed.Genet. 2023,55(2): 587-597. <http://doi.org/10.54910/sabrao2023.55.2.30>.

The significant interaction ($E \times V$) at 12 WAS indicates that specific combinations of extracts and varieties had a stronger influence on plant height than others. Such interaction effects have been reported by Okoko and Ene-Obong (2021), emphasising that genotype and treatment compatibility are crucial for maximising agronomic performance. Nwite *et al.* (2023) noted that environmental conditions often influence the consistency of organic amendments' effects.

The interaction between natural extract and Bambara groundnut variety revealed that poultry manure (E1) significantly enhanced plant height, particularly in V1 (Maibergo) and V3 (Giiwa), recording values of 28.933 cm and 28.167 cm, respectively. This supports findings by Adebayo *et al.* (2019), who reported that poultry manure not only improves soil fertility but also enhances vegetative growth due to its rich nutrient composition and microbial activity. Its dual role as a nutrient source and biological nematicide could explain the observed positive growth response.

Interestingly, the combination V2E3 (Karu + Neem) also recorded a high plant height (28.233 cm), aligning with earlier studies by Okereke *et al.* (2020), who noted that neem leaf extract can improve plant vigour while suppressing soil-borne pests. The phytochemicals in neem, such as azadirachtin, may offer plant protection benefits that support growth, particularly in tolerant varieties like V2.

Control treatments (E0) performed moderately across varieties, with V2 (27.700 cm) showing better growth than V3 (25.300 cm). This suggests intrinsic varietal differences in growth potential, even in the absence of external inputs, as previously noted by Musa *et al.* (2021), who highlighted genetic variability in Bambara groundnut performance.

Conversely, cassava peel extract (E2) appeared to negatively impact the growth of V3, with the lowest height observed in V3E2 (22.000 cm). While cassava peel has shown nematicidal potential (Ibrahim *et al.*, 2018), it may also release toxic compounds such as cyanogenic glycosides during decomposition, which could inhibit root development or nutrient uptake in sensitive varieties. This emphasises the importance of considering varietal compatibility when using organic amendments.

Statistical analysis further confirmed that V1E1, V2E3, and V3E1 were not significantly different, indicating that both poultry manure and neem leaf extracts can enhance plant height comparably when paired with compatible varieties. In contrast, V3E2 was significantly lower, reinforcing the idea of varietal sensitivity and the potential need for pre-treatment or detoxification when using cassava peel extracts.

Number of Branches

The study revealed that the application of organic materials significantly influenced the number of branches in Bambara groundnut varieties, with neem leaf and poultry manure extracts showing greater efficacy, especially at later growth stages (8 and 12 WAS). This aligns with findings by Akanmu *et al.* (2014), who reported that neem-based treatments enhanced vegetative growth due to their bioactive compounds, such as azadirachtin, which can stimulate plant defence and promote growth. Similarly, Ojo *et al.* (2017) found that poultry manure improved plant architecture and branching in legumes due to its high nitrogen and phosphorus content, which are essential for vegetative development.

On the contrary, cassava peel extract was observed to reduce branching at 12 WAS, possibly due to phytotoxic effects or slower decomposition rate, leading to delayed nutrient release. Oladele *et al.* (2018) reported similar findings where cassava peel amendments did not significantly improve branching in cowpea, possibly due to the presence of cyanogenic glycosides that may inhibit growth when not properly composted. Among the varieties, Giiwa consistently recorded the highest number of branches across all stages and years, suggesting inherent genetic potential for higher vegetative growth. This corroborates the work of Yahaya *et al.* (2019), who reported varietal differences in branching

capacity in Bambara groundnut, attributing such differences to genetic factors and adaptability. Maibergo's consistently low branch count further supports the idea of genetic limitation, as discussed by Obasi *et al.* (2016), who emphasized the role of genotype in determining morphological traits in legume crops.

The non-significant interaction between extract and variety indicates that while the extracts have independent effects on growth, they do not interact differently with specific varieties. This is in agreement with the findings of Afolabi and Ogunyemi (2015), who noted that while organic amendments improved growth traits in legumes, their effects were largely consistent across different genotypes.

The observed consistency across both years, with minor fluctuations, may be attributed to slight environmental variations such as rainfall distribution or temperature, yet the persistence of trends confirms the reliability of the treatments. According to Ajayi *et al.* (2021), environmental conditions slightly modulate growth responses in Bambara groundnut, but consistent treatment effects are a sign of robustness.

CONCLUSION

The study demonstrated that the application of natural organic extracts—cassava peel, neem leaves, and poultry manure—can effectively and enhance the growth and yield of Bambara groundnut under field conditions. Among the treatments, cassava peel consistently recorded the highest economic returns and favourable environmental performance, indicating its dual role as both a nematicide and a soil fertility enhancer.

Neem extract showed effective crop growth and moderate yield improvement, though occasional phytotoxic effects were observed depending on the variety. Poultry manure, while beneficial in terms of vegetative growth, did not translate into the highest yield performance, possibly due to inconsistent nematode suppression. It is therefore recommended that the move away from the use of chemical fertilizer to embracing and harnessing the potentials of organic materials to give both natural fertilizer for the control and management of Bambara nut. Application of organic manure such as poultry manure, cassava peels and neem leaf extracts is recommended for optimum yield production of Bambara nut.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Adubasim, C.V., Igwenagu, C.M., Josiah, G.O. (2018). Substitution of manure source and aerator in nursery media on sandy loam topsoil and their fertility indices 4 months after formulation. *Int J Recycl Org Waste Agricult* 7, 305–312
<https://doi.org/10.1007/s40093-018-0216-8>

Agric4Profits. (2025, July 10). *Role of organic matter in enhancing tropical soil fertility*.

Ajayi, A. R., Adekunle, R. A., & Ojo, S. O. (2021). Environmental Influences on Bambara Groundnut Performance in Agroecological Zones of Nigeria. *Agricultural Research and Development Journal*, 18(3), 202–209.

Aliyu, M., Zakari, A.Y., & Usman, M.M. (2021). Varietal response of cowpea to organic nematicides under field conditions.

Anderson, K. (2024). *The environmental challenges surrounding fertilizers*. Greenly.

- Anjorin, T. S., Adeleke D. B., Olowo J. O., Bello F.O., Akande A. (2022). Effects of humus, Albit®, garlic and wood ash extracts on the growth of *Aspergillus flavus* and on seed vigour of maize (*Zea mays* L) *African Journal of Agriculture and Allied sciences*.2 (1) 43-58.
- Bamigbola, A., *et al.* (2020). Growth and yield response of Bambara groundnut to organic and inorganic fertilizer combinations. *Journal of Agronomy*, 19(1), 42–49.
- Coyne, D.L., Nicol, J.M. and Claudius Cole, B. 2007. *Practical plant nematology: a field and laboratory guide*. SP IPM Secretariat, International Institute of Tropical Agriculture (IITA), Cotonou, Benin.
- Iheanacho, J. O., Umeh, O. N., & Aremu, M. O. (2020). Utilization of cassava peels as organic amendments in sustainable agriculture. *International Journal of Agronomy*, 2020, 1–8.
- Khairy, D., Osman, M. A., & Mostafa, F. A. M. (2022). Combined use of aqueous plant extracts for controlling *Meloidogyne incognita* and modulating chemical constituents in tomato under greenhouse conditions. *Pakistan Journal of Nematology*, 40(1), 1–11.
- Lehmann, J., & Kleber, M. (2023). *The central role of soil organic matter in soil fertility and carbon storage*. *Soil Systems*, 6(2), Article 33. <https://doi.org/10.3390/soilsys6020033>
- Musa, M. W., Yakubu, H., & Suleiman, M. (2021). Evaluation of Bambara groundnut accessions for resistance to root-knot nematodes. *Nigerian Journal of Plant Protection*, 34(2), 92–99.
- Odeyemi, S.O., Adeyemi, A.A., & Jimoh, O.S. (2021). Effects of Poultry Manure on Growth and Yield of Selected Legumes. *Nigerian Journal of Soil and Environmental Research*, 21(1), 55–63.
- Okeke, C. U., Omaliko, C. P. E., & Ukaoma, A. A. (2020). Utilization of cassava peels in compost production for improved crop yield. *Journal of Organic Agriculture and Environment*, 8(1), 43–50.
- Okereke, C. N., Onu, D. O., & Umeh, J. N. (2020). Effect of neem leaf extract on root-knot nematodes and growth of tomato. *Nigerian Journal of Plant Protection*, 34(1), 15–22.
- Okpara, I. M. and Cosmos, D. M. (2021) Growth and Yield Responses of Cocoyam (*Colocasia esculenta* (L.) Schott) to Organic Wastes in the Humid Agro-Ecological Zone of South-Eastern Nigeria. 10.9734/IJPSS/2017/32517 *International Journal of Plant & Soil Science*
- Onyekere, U. J. **Anjorin T.S.**, Asala, S.W. and Okafor, O.E. (2020). Effects of Poultry Dropping and Cow Dung Soil Amendments on Growth Characteristics and Root-Knot Nematode Infestation of Okra (*Abelmoschus esculentus* L. Moench). *Journal of Applied Agricultural Research* 2020, 8(1): 123-134.
- Oyetunji, O. J. (2017). Performance of Bambara groundnut genotypes under different organic amendments. *Nigerian Journal of Agriculture, Food and Environment*, 13(3), 45–52.
- Oyeyinka, S. A., Ade-Omowaye, B.I.O., eds. (2021). *Food and Potential Industrial Applications of Bambara Groundnut*. Cham: Springer. ISBN 978-3-030-73919-5.
- Paiko, A. S. Bello, L.Y. Salaudeen, M.T. and Wada, A.C. (2019), Abundance of plant-parasitic nematodes from rhizosphere of pepper plants as influenced by soil physical and chemical properties in parts of Niger state, Nigeria, *Journal of Agricultural and Rural Research*, 4 (1): 31-41.

Titus, E.O., Anjorin T.S. and Asala S.W (2020). Effect of *Psorospermum guineense* (Hochr.) stem bark and leaf extracts on germination, seedling vigour and seed-borne fungi associated with maize. *Journal of Applied Agricultural Research* 2020, 8(1): 100 - 111

K., B. P., D., F. U., E., S. O., & Nwobodo, C. E. (2020). *Agricultural waste management for horticulture revolution in sub-saharan africa*. CABI Reviews. <https://doi.org/10.1079/pavsnr202015017>

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