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Growth Response of Cashew Seedlings and Soil Properties to Cocoa Pod Husk and Cashew Leaf Litter Amendments at the Nursery Stage in South Western Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors CEO and OA-D were responsible for conceptualization, experimental design, and initial drafting of the original manuscript. Author YMO, with support from others, was responsible for data collection. Author SAJ-O contributed to methodology development, data curation, and formal analysis. Author FEA provided a critical review of the manuscript and validated the final intellectual content. All authors read and approved the final manuscript.

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Abstract

Background: Cashew (*Anacardium occidentale* L.) is an important tropical plantation crop, yet productivity remains below potential due to poor nutrient management and underutilization of available organic residues.
Aim: The study aims to assess the influence of cocoa pod husk (CPH) and cashew leaf litter (CLL) on cashew seedling growth and soil properties.
Objectives: The objectives of the study were to: i. Determine the effects of different rates of cocoa pod husk and cashew leaf litter on the growth of cashew seedlings; ii. Assess the effects of the organic amendments on selected soil properties; and iii. Identify the amendment and application rate that gives the best response in cashew seedling growth under nursery conditions.

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Study Design: A completely randomised design (CRD) was adopted. Seven treatments were evaluated: no organic amendment (control), 26.67 kg/t CPH, 40 kg/t CPH, 26.67 kg/t CLL, 40 kg/t CLL, 13.33 kg/t CPH + 13.33 kg/t CLL and 20 kg/t CPH + 20 kg/t CLL, each replicated three times. Data were collected on plant height, number of leaves, stem diameter and leaf area. Soil samples were analysed before and after the experiment.
Place and Duration of Study: A screen house experiment was conducted at the Cocoa Research Institute of Nigeria, Ibadan, Oyo State, for three months.
Methodology: The CLL was air-dried, milled and sieved prior to use. Polythene bags measuring 25 cm × 12.5 cm were each filled with 1.5 kg of topsoil, watered to field capacity, and arranged on a raised platform.
Statistical Analysis: Data were subjected to analysis of variance (ANOVA) using Minitab 17 statistical software, and treatment means were separated using Duncan's multiple range test (DMRT) at the 5% level of probability.
Results: The results showed that organic amendments improved seedling growth performance relative to the unamended control. Seedlings receiving 20 kg/t CPH + 20 kg/t CLL recorded the highest values for plant height, stem diameter and leaf area at 12 weeks after treatment application. Post-experimental soil analysis revealed notable improvements in organic matter, calcium and magnesium contents in most amended soils. Progressive seedling growth improvement was attributed to continuous nutrient release from decomposing organic materials and enhanced soil conditions.
Conclusion: The combined application of 20 kg/t CPH + 20 kg/t CLL demonstrated the greatest potential for optimizing cashew seedling growth and soil fertility, suggesting that it may be a viable organic nutrient management option for nursery production.

Keywords: Cocoa pod husk; cashew leaf litter; organic amendment; cashew seedlings; soil fertility.

1. Introduction

Cashew (*Anacardium occidentale* L.) is an important tropical plantation crop widely cultivated for its edible nuts, which are highly valued in international trade due to their nutritional and economic importance (Azam-Ali & Judge, 2001; Dendena & Corsi, 2014). In many producing countries, including Nigeria, cashew farming has become a major source of livelihood because of its adaptability to marginal soils, relatively low input requirement and high export value. Despite its adaptability, the assumption that cashew can thrive under any condition has led to poor orchard management practices. In many plantations, limited attention is given to pruning, nutrient management and pest control, resulting in low productivity. In addition, large quantities of biomass such as leaf litter, prunings and fallen cashew apples accumulate in the field and are often poorly managed. This situation contributes to nutrient loss and declining soil fertility over time. Improper disposal of these residues, especially through burning, not only leads to environmental degradation but also results in the loss of valuable organic nutrients that could otherwise improve soil quality. Organic amendments such as compost, manure, wood ash and plant residues have been reported to enhance soil structure, increase organic matter content and improve nutrient availability. Recent reviews have shown that organic amendments can improve soil quality and crop productivity through changes in soil physicochemical properties, nutrient cycling and soil organic carbon dynamics (Matisic *et al.,* 2024). The effects, however, depend on the type, rate and characteristics of the amendment and the properties of the soil to which it is applied. Organic amendments such as compost, manure, wood ash and plant residues have been reported to enhance soil structure, increase organic matter content and improve nutrient availability. Recent reviews have shown that organic amendments can improve soil quality and crop productivity through changes in soil physicochemical properties, nutrient cycling and soil organic carbon dynamics (Matisic *et al.*, 2024). The effects, however, depend on the type, rate and characteristics of the amendment and the properties of the soil to which it is applied. Globally, cashew production exceeds 3 million tonnes annually, with Nigeria ranking among the leading producers (Food and Agriculture Organization of the United Nations, 2023). However, productivity remains below potential, highlighting the need for sustainable soil fertility management practices. The recycling of agricultural wastes into organic fertilisers has gained attention as a viable strategy for improving soil health while addressing waste disposal challenges (Moyin-Jesu & Atoyosoye, 2002). For instance, the conversion of agricultural residues into bio-organic fertilisers has been shown to enhance plant growth and reduce dependence on inorganic fertilisers. Historically, soil fertility was maintained through the natural recycling of organic matter before the widespread adoption of chemical fertilisers. The reintroduction of organic inputs is therefore essential for sustaining long-term productivity. Organic amendments improve soil physical properties, stimulate microbial activity and enhance nutrient cycling (Bekchanova *et al.*, 2024). Recent reviews have emphasized that materials such as vermicompost and biochar significantly improve soil biological activity and overall crop performance. Cashew plantations, like cocoa systems, generate substantial quantities of biomass annually, offering great potential for nutrient recycling. Leaf litter production in cashew plantations has been estimated to range from 1.38 to 5.20 t ha^{-1} depending on tree age. Kalaivanan *et al.* (2017) reported that about 5.5 t ha^{-1} of available cashew biomass waste could be converted into approximately 3.5 t ha^{-1} of compost or vermicompost, which could help to meet about 50% of the nutrient requirement of cashew. However, the rate at which nutrients become available from organic materials depends on the characteristics of the amendment and the processes of decomposition and mineralisation. Nitrogen release from organic fertilisers and composts, for example, varies considerably among materials because of differences in their composition and decomposition characteristics (Geisseler *et al.*, 2021). Therefore, differences in amendment type and application rate may influence the timing and magnitude of nutrient availability to growing plants. In many cases, farmers do not utilise these residues effectively due to labour constraints and slow decomposition rates. Instead, residues are often burned, which reduces soil organic matter and increases the risk of fire outbreaks during the dry season. Proper collection and conversion of these wastes into compost or other organic amendments would not only reduce environmental hazards but also improve soil fertility and support sustainable production. Recent studies on organic amendments have demonstrated their potential to improve soil properties, nutrient availability and plant growth. For example, organic manure and other organic amendments have been reported to improve seedling growth and nutritional status in perennial crops, while organic nutrient sources have also been shown to improve cashew seedling performance (Nduka *et al.*, 2019). Recent studies have further reported that cocoa pod husk compost and biochar influenced soil nutrient availability, although the response varied with the form in which the residue was applied (Mwafulirwa *et al.,* 2024). Given the abundance of organic residues in cashew and cocoa production systems, there is a need to explore their utilization as soil amendments, particularly at the nursery stage where early plant

growth determines field performance. The use of cocoa pod husk and cashew leaf litter as organic amendments offers a sustainable and cost-effective approach to improving seedling growth and soil fertility. However, information on their combined effects on cashew seedling performance is still limited. This study was therefore undertaken to evaluate the effect of cocoa pod husk and cashew leaf litter as an organic soil amendment on the growth of cashew seedlings and soil properties under nursery conditions.

The specific objectives were to:

i. Determine the effects of different rates of cocoa pod husk and cashew leaf litter on the growth of cashew seedlings;
ii. Assess the effects of the organic amendments on selected soil properties; and
iii. Identify the amendment and application rate that gives the best response in cashew seedling growth under nursery conditions.

2. Methodology

2.1 Experimental Design, Leaf Litter Amendment and Experimental Setup

The experiment was conducted in a screen house at the Cocoa Research Institute of Nigeria (CRIN), Ibadan, located in the south-western agro-ecological belt of Nigeria. CRIN, Ibadan is located at approximately 7.38°N latitude and 3.87°E longitude. The area has a humid tropical climate with two seasons: a wet season from March to October/early November, with a short dry spell of about two weeks in August, and a dry season from November to March, characterized by intense sunshine and scanty rainfall. The maximum temperature in Ibadan ranges from 26°C to 35°C, with a mean daily temperature of 30°C. Relative humidity remains high throughout the year, ranging from 60–85% in the wet season and 46–60% in the dry season. Cocoa pod husk (CPH) was sourced from the CRIN Fermentary Section, while cashew leaf litter (CLL) was collected from within the Institute's cashew plantations. The CLL was air-dried, milled and sieved prior to use. Polythene bags measuring 25 cm × 12.5 cm were each filled with 1.5 kg of topsoil, watered to field capacity, and arranged on a raised platform in the screen house. The medium cashew nut biotype was used for the study, and watering was carried out twice per week throughout the experimental period. The experiment was laid out in a completely randomised design (CRD) comprising seven treatments: an unamended control (NF), 26.67 kg/t CPH, 40 kg/t CPH, 26.67 kg/t CLL, 40 kg/t CLL, 13.33 kg/t CPH + 13.33 kg/t CLL, and 20 kg/t CPH + 20 kg/t CLL. Each treatment was replicated three times, with five seedlings per replicate, giving 35 seedlings per full replicate block (7 treatments × 5 seedlings) and a total of 105 seedlings across the three replicates. All organic amendments were thoroughly incorporated into the soil before pot filling to ensure uniform distribution and consistent treatment effects across experimental units.

2.2 Soil Sampling and Treatment Analysis

Before the commencement of the experiment, topsoil (0–20 cm depth) was collected from within the Institute estate, air-dried, sieved through a 2 mm sieve, and analysed for physico-chemical properties. Organic amendments were also analysed. At the end of the experiment, post-experimental soil samples were collected and analysed.

2.3 Data Collection

Agronomic parameters assessed included plant height (cm), number of leaves, stem diameter (mm) and leaf area (cm^2). These growth parameters were recorded at 4, 6, 8, 10 and 12 weeks after treatment application. Leaf area was determined non-destructively using the length × width method, in which the length and maximum width of each leaf were measured and multiplied by a correction factor to estimate leaf area. Weed control was carried out manually throughout the experiment.

2.4 Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) using Minitab 17 statistical software, and treatment means were separated using Duncan's multiple range test (DMRT) at the 5% level of probability. Standard ANOVA assumptions of normality and homogeneity of variance were assumed to hold and were not formally tested; this is noted as a limitation of the statistical analysis.

3. Results and Discussion

The pre-cropping soil physical and chemical properties are presented in Table 1. The soil was acidic (pH 4.12) which is suitable for the cashew crop. However, the optimum value ranges between 5.2-7.5 (Dedzoe *et al.,* 2001). The soil organic carbon content of 1.13 g/kg is below the critical value of >2% considered suitable for cashew cultivation. The total N content of the soil is below the 0.1% N required for cashew cultivation (Aikpokpodion *et al.*, 2010). The low N content could be attributed to low organic matter content of the soil. Hence, it is expected that the application of organic amendment would enhance soil fertility and the performance of cashew crop. Available P 2.49 mg/kg of the soil is low for optimum cashew cultivation 3.7 mg/kg (Egbe *et al.*, 1989). The soil K (0.81) and Mg (2.50) contents are above the critical value for an ideal soil of K 0.12 cmol/kg and Mg 0.08 cmol/kg. The soil Ca content of 5.3 cmol/kg and Na content of 0.93 were far above the critical value for an ideal soil Ca 0.8 cmol/kg and Na 0.12cmol/kg (Egbe *et al.*, 1989).

Table 1. Pre-cropping Soil physical and chemical properties

Parameters	Values
Depth	0-20cm
pH (1:2 H_2O)	4.12
Organic carbon (g/kg)	1.13
Organic matter (g/kg)	1.95
Nitrogen (g/kg)	0.22
Phosphorus (mg/kg)	2.49
Exchangeable Bases	
Calcium (cmol/kg)	5.30
Magnesium (mg/kg)	2.50
Sodium (cmol/kg)	0.93
Potassium (cmol/kg)	0.81
H^{3+} (cmol/kg)	2.40
Al^{3+} (cmol/kg)	0.50
CEC (cmol/kg)	9.54
EA (cmol/kg)	2.9
ECEC(cmol/kg)	12.44
Particle size	
Sand (g/kg)	608
Silt (g/kg)	120
Clay (g/kg)	272
Textural class	Sandy Clay loam

Table 2. Impact of organic amendment on cashew plant height (cm)

Treatment	Weeks after application				
	4 Weeks	6 Weeks	8 Weeks	10 Weeks	12 Weeks
A (NF)	19.47 ^{a}	21.17 ^{ab}	21.93 ^{b}	24.33 ^{b}	25.73 ^{b}
B (26.67 kg/t CPH)	20.20 ^{a}	22.80 ^{ab}	25.20 ^{ab}	28.27 ^{ab}	30.53 ^{ab}
C (40 kg/t CPH)	19.53 ^{a}	22.50 ^{ab}	25.07 ^{ab}	27.57 ^{ab}	30.03 ^{ab}
D (26.67 kg/t CLL)	20.83 ^{a}	22.87 ^{ab}	25.67 ^{ab}	28.73 ^{ab}	32.17 ^{ab}
E (40 kg/t CLL)	19.50 ^{a}	21.80 ^{ab}	24.77 ^{ab}	24.47 ^{ab}	29.73 ^{ab}
F (13.33 kg/t CPH+13.33 kg/t CLL)	15.53 ^{a}	18.93 ^{b}	19.90 ^{b}	22.53 ^{b}	24.07 ^{b}
G (20 kg/t CPH + 20 kg/t CLL)	21.07 ^{a}	26.43 ^{a}	29.60 ^{a}	32.97 ^{a}	34.97 ^{a}
SED	3.01	3.104	3.481	3.734	4.18

Means on the same column with same prescript are not significantly different by Duncan multiple range test at 5% probability level

The effect of organic amendments on cashew plant height at different weeks after application is presented in Table 2. The results showed that plant height increased progressively with time across all treatments, indicating a normal growth pattern of cashew seedlings under improved nutrient conditions. At 4 weeks after application, there were no significant differences among treatments; plant height ranged from 15.53 cm in treatment F to 21.07 cm in treatment G. This suggests that at the early stage of growth, the effect of organic amendments had not yet become evident, likely due to the slow rate of nutrient release associated with organic fertilisers (Geisseler *et al.*, 2021). At 6 weeks after application, some variation was observed. Treatment G recorded the highest plant height (26.43 cm) and was significantly different from treatment F (18.93 cm), which had the lowest value. Other treatments were statistically similar. The superior performance of treatment G at this stage may be attributed to enhanced nutrient mineralization, which improves nutrient availability for plant uptake (Adekiya *et al.,* 2019). At 8 weeks, treatment G recorded a significantly higher plant height (29.60 cm), while treatments A (21.93 cm) and F (19.90 cm) recorded significantly lower values. This indicates that the beneficial effects of organic amendments become more pronounced over time as decomposition progresses and nutrients such as nitrogen are released into the soil (Moyin-Jesu, 2018). A similar trend was observed at 10 weeks, where treatment G (32.97 cm) significantly outperformed all other treatments. Treatments A (24.33 cm) and F (22.53 cm) remained significantly lower, while treatments B, C, D and E showed intermediate performance. At 12 weeks after application, treatment G continued to record the highest plant height (34.97 cm), although it was statistically similar to treatments B, C, D and E. Treatments A (25.73 cm) and F (24.07 cm) remained significantly lower. The sustained performance of treatment G indicates its ability to provide a continuous supply of nutrients required for optimal growth, which is a key advantage of organic fertilisers (Adekiya *et al.,* 2019).

Table 3. Impact of organic amendment on cashew number of leaves

Treatment	Weeks after application				
	4 Weeks	6 Weeks	8 Weeks	10 Weeks	12 Weeks
A (NF)	6.167^{a}	7.167a	9.50^{a}	27.47^{ab}	29.73^{ab}
B (26.67 kg/t CPH)	7.833^{a}	8.833 ^{a}	12.00^{a}	27.90^{ab}	32.17^{ab}
C (40 kg/t CPH)	7.333^{a}	8.167^{a}	10.33^{a}	24.33^{b}	25.73^{b}
D (26.67 kg/t CLL)	7.667^{a}	9.667^{a}	11.67^{a}	28.27^{ab}	30.53^{ab}
E (40 kg/t CLL)	5.500^{a}	7.33^{a}	8.67^{a}	32.97^{a}	34.96^{a}
F (13.33 kg/t CPH+13.33 kg/t CLL)	4.883^{a}	7.16^{a}	9.17^{a}	22.53^{b}	24.07^{b}
G (20 kg/t CPH + 20 kg/t CLL)	7.00^{a}	6.833^{a}	9.17^{a}	27.57^{ab}	30.03^{ab}
SED	1.37	1.59	1.81	3.38	3.43

Means on the same column with same prescript are not significantly different by Duncan multiple range test at 5% probability level.

The effect of organic amendments on the number of leaves is presented in Table 3. The results showed that leaf production increased progressively with time across all treatments, indicating active vegetative growth of cashew seedlings. At 4, 6 and 8 weeks after application**,** there were no significant differences among treatments. This suggests that, at the early stages of growth, the applied organic amendments had not exerted a measurable influence on leaf initiation. This may be attributed to the slow decomposition rate of organic materials and the gradual release of nutrients, particularly nitrogen, which is essential for leaf formation (Geisseler *et al.*, 2021). However, at 10 weeks after application**,** clear differences began to emerge. Treatment E recorded the highest number of leaves (32.97), which was significantly higher than treatments C (24.33) and F (22.53), while other treatments showed intermediate performance. This trend continued at 12 weeks, where treatment E (34.96) maintained superiority, although it was statistically similar to treatments A, B, D and G. Treatments C and F consistently recorded lower values. The improved leaf production observed in treatment E at the later stages suggests that it provided a more favourable nutrient supply, particularly nitrogen, which promotes vegetative growth and leaf expansion. The delayed response further supports the notion that organic amendments release nutrients gradually through mineralization, resulting in more pronounced effects at later growth stages (Adekiya *et al.,* 2019; Moyin-Jesu, 2018).

Table 4. Impact of organic amendment on cashew stem diameter (mm)

Treatment	Weeks after application				
	4 Weeks	6 Weeks	8 Weeks	10 Weeks	12 Weeks
A (NF)	3.967[a]	4.867 [a]	5.100 [a]	5.367 [ab]	5.60 [a]
B (26.67 kg/t CPH)	4.80[a]	5.033 [a]	5.33 [a]	5.567 [ab]	5.83 [a]
C (40 kg/t CPH)	4.033[a]	4.93 [a]	5.267[a]	5.533 [ab]	5.67 [a]
D (26.67 kg/t CLL)	5.00[a]	5.233 [a]	5.400 [a]	5.633 [ab]	6.133 [a]
E (40 kg/t CLL)	4.033[a]	4.933 [a]	5.167 [a]	5.533 [ab]	5.63 [a]
F (13.33 kg/t CPH+13.33 kg/t CLL)	3.700[a]	4.733 [a]	4.833 [a]	4.933 [b]	5.27 [a]
G (20 kg/t CPH + 20 kg/t CLL)	5.100[a]	5.367 [a]	5.467 [a]	5.867 [a]	6.133 [a]
SED	0.871	0.394	0.406	0.341	0.412

Means on the same column with same prescript are not significantly different by Duncan multiple range test at 5% probability level

The influence of organic amendments on stem diameter is presented in Table 4. The results showed a steady increase in stem diameter across all treatments with increasing weeks after application. At 4, 6 and 8 weeks after application, there were no significant difference**s** among treatments. This suggests that the applied organic amendments did not significantly influence stem diameter during the early growth stage of the seedlings. At 10 weeks after application, a significant difference was observed between treatment G (5.867 mm) and treatment F (4.933 mm). The reduced performance observed under Treatment F suggests that the lower amendment rate may not have supplied sufficient nutrients required for vigorous stem development. Treatment G consistently recorded relatively higher values, particularly at 12 weeks (6.133 mm), while treatment F had the lowest values. The absence of significant differences may indicate that stem diameter development in cashew seedlings is less sensitive to short-term nutrient variations or may require a longer period to respond to soil amendments. In the present study, stem diameter was less responsive to the amendments than plant height over the 12-week nursery period. At 12 weeks after application, stem diameter increased across all treatments, although the differences were not statistically significant. Treatments D and G recorded the highest values of 6.133 mm, while the lowest value of 5.27 mm was obtained from Treatment F. The steady increase in stem diameter observed with increasing weeks after application indicates that the organic amendments contributed to gradual nutrient release and improved soil conditions that enhanced vegetative growth of cashew seedlings. The comparatively better performance of treatments containing cashew leaf litter either alone or in combination with cocoa pod husk may be associated with improved nutrient mineralization and enhanced soil physical properties such as moisture retention and aeration. Organic materials can improve soil physical and chemical properties while supplying nutrients needed for plant growth and development. Similar findings were reported by Boudjabi and Chenchouni (2023), who found that organic amendments improved soil fertility and promoted wheat growth through increased nutrient availability. Comparable findings were reported by Mwafulirwa *et al.* (2024), who demonstrated that cocoa pod husk-derived compost and biochar improved nutrient availability in cocoa soils, highlighting the potential of cocoa pod husk residues as organic soil amendments for enhancing soil fertility. In perennial crops, improved stem girth following organic nutrient application has also been associated with enhanced microbial activity and gradual nutrient release in the root zone.

The effect of organic amendments on leaf area is shown in Table 5. Leaf area is an important growth parameter because it influences the photosynthetic capacity of the plant. At 4 and 6 weeks after application**,** there were no significant differences among treatments, although treatment G recorded the highest numerical values. This again reflects the delayed effect of organic amendments at early growth stages. At 8 week**s**, treatment G (48.56 cm^2) recorded a significantly higher leaf area compared to treatment B (27.77 cm^2), while other treatments were statistically similar. This indicates improved leaf expansion under treatment G, possibly due to better nutrient availability. At 10 week**s**, treatments D (44.76 cm^2) and G (47.63 cm^2) recorded significantly higher values compared to treatment C (29.87 cm^2), while other treatments were intermediate. By 12 week**s**, treatment G maintained the highest leaf area (48.10 cm^2), although differences were not statistically significant. The generally higher leaf area observed in treatments D and G suggests that these treatments enhanced leaf expansion and photosynthetic surface area. This may be linked to improved nutrient supply, particularly nitrogen and phosphorus, which are known to promote cell division and enlargement (Adekiya *et al.,* 2019).

Table 5. Impact of different rate of organic amendment on cashew leaf area (cm^2)

Treatment	Weeks after application				
	4 Weeks	6 Weeks	8 Weeks	10 Weeks	12 Weeks
A (NF)	40.17[a]	41.61 [a]	40.73 [ab]	42.13 [ab]	40.62 [a]
B (26.67 kg/t CPH)	37.12[a]	38.50 [a]	27.77 [b]	37.47 [ab]	38.94 [a]
C (40 kg/t CPH)	33.63[a]	34.53 [a]	35.50 [ab]	29.87 [b]	34.72 [a]
D (26.67 kg/t CLL)	41.55[a]	41.53 [a]	44.77 [ab]	44.76 [a]	47.63
E (40 kg/t CLL)	33.31[a]	35.00 [a]	34.90 [ab]	35.56 [ab]	41.60 [a]
F (13.33 kg/t CPH+13.33 kg/t CLL)	32.28[a]	34.79 [a]	36.25 [ab]	36.47 [ab]	39.33 [a]
G (20 kg/t CPH + 20 kg/t CLL)	45.43[a]	48.58 [a]	48.56 [a]	47.63 [a]	48.10 [a]
SED	7.27	6.36	6.24	5.68	6.28

Means on the same column with same prescript are not significantly different by Duncan multiple range test at 5% probability level

Table 6. Impact of different rate of organic amendment on soil properties

Treatment	pH (1:2 H_2O)	OC g/kg	OM g/kg	N g/kg	P mg/kg	K g/kg	Na cmol/kg	Ca cmol/kg	Mg cmol/kg	EA cmol/kg	Sand g/kg	Silt g/kg	Clay g/kg	TC
A (NF)	4.20	1.30	2.25	0.30	5.91	0.75	0.91	4.80	2.20	3.33	568	272	160	SCL
B (26.67 kg/t CPH)	4.29	1.09	1.88	0.20	6.14	0.78	0.95	5.30	2.50	3.2	528	312	160	SCL
C (40 kg/t CPH)	4.22	1.05	1.82	0.18	5.13	0.88	1.08	5.50	2.70	3.6	608	232	160	SCL
D (26.67 kg/t CLL)	4.24	1.23	2.11	0.26	1.40	0.75	0.90	5.30	2.50	3.2	568	312	120	SCL
E (40 kg/t CLL)	4.23	0.96	1.65	0.14	1.88	0.45	0.54	5.40	2.60	2.58	528	272	200	SCL
F (13.33 kg/t CPH+13.33 kg/t CLL)	4.22	1.13	1.95	0.24	3.58	0.92	1.08	6.00	2.90	3.48	488	312	200	SCL
G (20 kg/t CPH + 20 kg/t CLL)	4.25	1.23	2.11	0.28	5.91	0.83	0.97	6.10	3.00	4.11	568	272	160	SCL

The pre-cropping soil analysis showed that the soil was strongly acidic (pH 4.12), with low organic carbon (1.13 g/kg), organic matter (1.95 g/kg), nitrogen (0.22 g/kg) and available phosphorus (2.49 mg/kg), indicating poor inherent fertility typical of highly weathered tropical soils. Following the application of organic amendments, noticeable changes were observed in both chemical and physical properties of the soil. A slight increase in soil pH was recorded across all treatments (4.20–4.29; Table 6). Although the soil remained strongly acidic, this improvement suggests a mild ameliorative effect of the organic amendments. This may be attributed to the release of basic cations such as calcium and magnesium during the decomposition of organic materials, which can help neutralize soil acidity (Adekiya *et al.*, 2019; Nduka *et al.*, 2019). Organic carbon and organic matter contents showed marginal improvement in some treatments, particularly A and G, where values exceeded the initial levels. This increase reflects the contribution of organic residues from the applied manure and supports the role of organic inputs in improving soil organic matter status. However, slight reductions observed in some treatments may be due to rapid mineralization under tropical environmental conditions, where high temperature and moisture accelerate decomposition (Geisseler *et al.*, 2021). Total nitrogen content also improved in selected treatments, notably A and G, compared to the initial soil condition. This suggests that the manure served as a source of nitrogen and enhanced nutrient cycling within the soil. The variability observed among treatments may be linked to differences in the rate of decomposition, nitrogen release and possible losses through leaching or volatilization (Moyin-Jesu, 2018). A more pronounced effect was observed in available phosphorus. Treatments A, B, C and G recorded higher phosphorus levels compared to the pre-cropping soil, with values reaching up to 6.14 mg/kg. This improvement is likely due to mineralization of organic phosphorus and the ability of organic matter to reduce phosphorus fixation, which is common in acidic soils. In contrast, the lower values observed in treatments D and E suggest limited phosphorus release or continued fixation (Adekiya *et al.,* 2019). The status of exchangeable bases (Ca, Mg, K and Na) varied following the application of amendments.In particular, calcium and magnesium showed slight increases in several treatments, indicating that the manure contributed to the replenishment of essential nutrients. Such soil nutrient responses have also been reported following the use of enriched organic fertilizers (Ayoola & Makinde, 2009). Exchangeable acidity varied across treatments, with a reduction observed in treatment E, whereas higher values in treatment G may indicate differences in soil chemical responses to organic amendment application. Organic materials can influence soil acidity and other chemical properties through decomposition and changes in nutrient availability. Such variations reflect the dynamic effects of organic amendments on soil chemical properties (Zhang *et al.*, 2023). The particle size distribution remained within the sandy clay loam textural class across all treatments, indicating that the manure had little effect on soil texture. However, improvements in soil structure, aggregation and moisture retention are expected, even though these were not directly measured. Such benefits are commonly associated with the addition of organic materials to soil (Blanco-Canqui & Lal, 2004).

Table 7. Critical levels of cashew soils

Nutrient element	Critical Level	Source
N (g/kg)	1	Egbe *et al.,* 1989
P (mg/kg)	3.7	Egbe *et al.,* 1989
K (cmol/kg)	0.12	Egbe *et al.,* 1989
Ca (cmol/kg)	0.8	Egbe *et al.,* 1989
Mg (cmol/kg)	0.08	(Tandon, 1999)
Organic Carbon (g/kg)	Low 8.7 Medium 8.7-14.5 High 25	Tandon, 1999
Zinc	0.6	(Tandon,1999)
Iron	2.5-4.5 (0.4-0.12)	(Tandon, 1999)
Manganese	2.0	(Tandon, 1999)
Copper	0.2	(Tandon, 1999)
Boron	0.5	(Tandon, 1999)
Molybdenum	0.2	(Tandon, 1999)

Table 8. Nutrient composition of the organic amendments

Treatment	OM	OC	N	P	K	Na	Ca	Mg	Fe	Zn
			(g/kg)	(Mg/kg)	(Mg/kg)	(Mg/kg)	(Mg/kg)	Ppm	ppm	ppm
Cocoa Pod Husk	93.9		25.2	7.89	2.69	2.1	3.76	1.86	0.26	0.21
Cashew Leaves	73.9		10.5	51.16	12.04	7.51	9.86	4.56	2.47	10.3

4. Conclusion

The application of cocoa pod husk (CPH) and cashew leaf litter (CLL) influenced the growth of cashew seedlings and brought about changes in the chemical properties of the soil under screen-house conditions. Among the treatments evaluated, the combined application of 20 kg/t CPH + 20 kg/t CLL generally gave the best overall growth response, particularly in plant height and leaf area, and was also associated with relatively favourable soil nutrient status after the experiment. This indicates that combining the two organic residues may provide a useful source of nutrients for cashew seedlings during the nursery stage.

The responses to the individual amendments and the lower combined rate were less consistent, showing that both the type and amount of organic material applied can influence seedling performance. The observed changes in soil pH, organic matter, nitrogen, phosphorus and exchangeable bases further suggest that the amendments influenced the soil nutrient environment during the experimental period.

Overall, cocoa pod husk and cashew leaf litter, particularly when combined at 20 kg/t each, show potential for use as organic nutrient sources in cashew nursery production. Further field studies over longer periods and under different soil and environmental conditions are needed to confirm the consistency of the observed responses and to establish suitable application rates for practical cashew production.

5. Recommendations

Based on the results obtained under the conditions of this study, the combined application of cocoa pod husk and cashew leaf litter at 20 kg/t each is recommended as a promising organic amendment option for cashew seedlings at the nursery stage. The treatment gave the strongest overall growth response and was associated with favourable changes in some soil properties. For practical nursery production, cocoa pod husk and cashew leaf litter may therefore be considered as locally available organic materials for improving the growing environment of cashew seedlings. Proper processing and uniform incorporation of the amendments should be maintained to ensure consistent application. Further studies should evaluate the 20 kg/t CPH + 20 kg/t CLL treatment under field conditions and across different locations and soil types.

6. Limitations

The experiment was conducted under screen-house conditions over a three-month nursery period, so the findings do not establish longer-term growth responses or performance after field transplantation. The study assessed selected growth measurements and soil properties, rather than longer-term nutrient dynamics. In addition, the manuscript states that the assumptions of normality and homogeneity of variance for the analysis of variance were not formally tested. These considerations limit the extent to which the observed treatment differences can be generalised beyond the experimental conditions.

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Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

The authors declare that no competing interests, financial or otherwise, exist with respect to the research, authorship and publication of this article. The study was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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