

International Journal of Plant & Soil Science

Volume 38, Issue 11, Page 362-373, 2026; Article no.IJPSS.169939
ISSN: 2320-7035

Utilization of Yellow Mombin (*Spondias mombin L.*) Leaves as Organic Soil Amendment for Enhanced Growth of Cashew (*Anacardium occidentale L.*) Seedlings

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2026/v38i116432

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/169939

Original Research Article

Received: 03/09/2026
Accepted: 09/11/2026
Published: 16/11/2026

Abstract

The use of locally available organic materials may provide a practical approach to improving nursery soil conditions and nutrient status during cashew (Anacardium *occidentale* L.) seedling production. This study evaluated the effects of ground, dried yellow mombin (Spondias *mombin* L.) leaf amendment on the growth, soil properties, plant nutrient composition, proximate composition and biomass of cashew seedlings. The experiment was conducted at the Cocoa Research Institute of Nigeria (CRIN) nursery, Idi-Ayunre, Ibadan, using three treatment rates: 0 g (control, AR), 11.5 g (BR) and 22.5 g (CR). Growth parameters were monitored, while soil and plant samples were analysed for selected chemical and physical properties. Treatment means were compared using Tukey's HSD test at the 5% probability level. Plant height, leaf area, stem girth and number of branches increased numerically during the observation period, although monthly differences were not significant. The number of leaves increased significantly

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Cite as: *Nduka, B. A., Akanbi, O. S. O., Ogunlade, M. O., Ugioro, O., Adeosun, S. A., Asowata, F. E., ... Shuaib, T. (2026). Utilization of Yellow Mombin (Spondias mombin L.) Leaves as Organic Soil Amendment for Enhanced Growth of Cashew (Anacardium occidentale L.) Seedlings. International Journal of Plant & Soil Science, 38(11), 362–373. https://doi.org/10.9734/ijpss/2026/v38i116432*

between selected months, whereas monthly differences in leaf area and stem girth were not significant. The 22.5 g treatment recorded the largest leaf area, whereas the control recorded the greatest stem girth. Among the soil properties presented in Table 3, available phosphorus differed significantly, with BR recording the highest value; the other reported properties were not significantly affected. Plant nutrient concentrations responded selectively to amendment rate. BR recorded the highest calcium concentration, whereas CR recorded the highest phosphorus and potassium concentrations. No significant treatment effects were observed for sodium, magnesium, zinc, iron, copper or nitrogen. Moisture, fat, ash, protein and crude fibre contents differed significantly among treatments. Carbohydrate contents calculated from the displayed component means were 11.77%, 10.81% and 19.91% for AR, BR and CR, respectively. Fresh weight, dry weight and root weight did not differ significantly at harvest. Overall, ground yellow mombin leaf amendment influenced selected soil, growth and plant-composition characteristics of cashew seedlings but did not produce a consistent improvement across all measured parameters. Further studies should evaluate additional application rates, longer nursery periods and field conditions.

Keywords: Cashew; seedling growth; yellow mombin; organic amendment; soil properties; nutrient composition.

1. Introduction

Cashew (*Anacardium occidentale* L.) is an economically important tree crop valued for its nuts, apples and industrial by-products, and its cultivation has expanded because of its adaptability to a range of tropical soil and climate conditions (Dendena & Corsi, 2015; Babatunde *et al*., 2023; Ipinmoroti *et al*., 2024). Sustained cashew productivity depends on adequate soil fertility, while nursery-stage seedling vigour is important for successful field establishment and subsequent growth (Havlin *et al*., 2014; Amamatou *et al*., 2026). However, the cost and environmental concerns associated with synthetic fertilisers have increased interest in low-cost, locally available organic amendments that can improve soil nutrient status and support sustainable nursery management (Aminu *et al*., 2021). Reviews indicate that organic amendments, including crop residues, composts and manures, can contribute nutrients and support soil physical and biological functions, although their effects vary with material characteristics and management conditions (Singh *et al*., 2024; Xu *et al*., 2025). The biological source of an organic fertiliser can also influence rhizosphere microbial communities and plant root development, underscoring the need to evaluate plant-derived inputs according to their specific properties (Yu *et al*., 2024).

At the Cocoa Research Institute of Nigeria (CRIN), organic soil amendments have been investigated across the Institute's mandate tree crops, including cashew, cocoa and coffee, with positive effects reported on seedling growth and soil fertility. Akanbi *et al*. (2013) reported that organic fertilisers of animal and plant origin significantly improved the growth of cashew seedlings on degraded soil in Ibadan. Ipinmoroti and Akanbi (2014) similarly found that organic nutrient sources compared favourably with NPK fertiliser in promoting cashew seedling growth, supporting the development of organic cashew farming in Nigeria. Nduka *et al*. (2015) demonstrated that coffee husk, applied alone or in combination with NPK, significantly enhanced cashew seedling development in the nursery. Nduka *et al*. (2019) further showed that biochar and compost-based organic manure improved cashew seedling performance and soil pH, nitrogen, phosphorus, potassium, calcium and magnesium status. In cocoa, Adejobi *et al*. (2014) reported that cowpea pod husk and other tree-crop wastes significantly enhanced soil and leaf chemical properties and the growth performance of cocoa seedlings, with results comparable to NPK fertiliser. Akanbi *et al*. (2014) found that cocoa pod husk and oil-palm bunch ash significantly improved nutrient uptake, growth and dry matter yield in cocoa. More recently, this line of research has been extended to other CRIN mandate and ornamental crops, including an evaluation of the pre-nursery response of king palm (*Archontophoenix alexandrae*) to organic soil amendment. In a separate study, Ipinmoroti *et al*. (2024) evaluated the effects of fertiliser treatments on the germination and growth of cashew biotypes in a greenhouse at Jalingo, Taraba State. Studies in other horticultural crops have likewise reported effects of enriched organic manures on nutrient uptake and yield, with responses depending on the manure source and treatment combination (Sindhu *et al*., 2024; Toundou *et al*., 2021). Recent work in cashew nursery systems has also examined decayed and fermented cashew apple materials and food-market-waste fertiliser as organic inputs, reporting differences in seedling growth and soil nutrient status following their application (Mbasaa *et al*., 2024; Oyediran *et al*., 2024). Collectively, these studies provide a basis for evaluating locally sourced organic materials as potential alternatives to inorganic fertilisers in tree-crop nurseries.

Yellow mombin (*Spondias mombin* L.), a fast-growing tree widely distributed across tropical agroecosystems, produces leaf litter that may serve as a locally available organic resource for soil enrichment. A study of tree-leaf mulches that included *Spondias mombin* reported decomposition and nitrogen-mineralisation patterns for this leaf material, indicating its potential contribution to nutrient cycling when used as mulch (Adeyekun *et al*., 2022). Organic fertiliser rate has also been reported to influence plant survival and mineral properties in greenhouse-grown plants (Christophe *et al*., 2019). The phytochemical characteristics of hydroethanolic extracts from *Spondias mombin* leaves have also been investigated (Pérez-Portero *et al*., 2021). In a separate study, cashew leaf and stem-bark materials showed allelopathic effects on seed germination and seedling growth (Tetteh *et al*., 2026). These findings highlight the need to evaluate the practical effects of yellow mombin leaf amendment under controlled nursery conditions before recommending it for wider use.

Although organic amendments derived from crop and agro-industrial residues, including mango-waste compost and biochar-based materials, have been explored for cashew seedling and orchard management (Amamatou *et al.,* 2026; Nduka *et al.,* 2019; Oyediran et al., 2024), the use of yellow mombin leaves as a soil amendment for cashew seedling production remains largely undocumented. Given the wide natural occurrence of yellow mombin in Nigerian agroecosystems, and building on CRIN's established work on organic soil amendments across cashew, cocoa and other tree crops, there is a need to investigate its suitability as a nursery amendment. This study was therefore conducted to determine the effects of ground, dried yellow mombin leaves, applied at different rates, on the growth performance, nutrient uptake and biomass yield of cashew seedlings, as well as on the physicochemical properties of the nursery soil.

2. Materials and Methods

2.1 Experimental Design and Treatments

The experiment was conducted using a Completely Randomised Design (CRD) under nursery conditions. Three treatments of ground yellow mombin (Spondias *mombin* L.) leaf amendment were evaluated:

- **AR:** Control (0 g ground yellow mombin leaf);
- **BR:** 11.5 g ground yellow mombin leaf; and
- **CR:** 22.5 g ground yellow mombin leaf.

The experiment lasted six months. All treatments were subjected to similar nursery management practices throughout the experimental period.

2.2 Preparation and Application of Yellow Mombin Leaf Amendment

Fresh, mature leaves of yellow mombin (Spondias mombin L.) were collected, cleaned to remove extraneous material and air-dried under ambient conditions. The dried leaves were ground into a relatively uniform powder. The required quantities of the powdered material were accurately weighed and incorporated into the soil before planting. The control treatment received no yellow mombin leaf amendment. The preparation and incorporation of plant-derived organic materials into soil follow commonly used procedures for evaluating the effects of organic amendments on soil fertility and plant growth (Weil & Brady, 2017; Palm *et al.,* 2001).

2.3 Soil Preparation and Seedling Establishment

Soil was collected from the nursery soil source, air-dried, gently crushed and passed through a 2-mm sieve. The prepared soil was thoroughly mixed and weighed into nursery bags. Equal quantities of soil were used for all experimental units. Soil preparation, homogenisation and sieving were carried out to minimise variation among experimental units and ensure relatively uniform growing conditions (Carter & Gregorich, 2008).

Healthy, uniform cashew (*Anacardium occidentale* L.) seedlings were established in the prepared nursery bags. Each treatment was replicated according to the original experimental layout. The nursery bags were randomly arranged and maintained under uniform environmental and management conditions. Watering and manual weeding were carried out as necessary throughout the six-month experimental period. The use of uniform seedlings, randomisation and controlled nursery management is consistent with accepted principles of agricultural experimentation (Gomez & Gomez, 1984; Steel *et al*., 1997).

2.4 Measurement of Growth Parameters

Growth observations were taken monthly for six months. The parameters measured included plant height, stem girth, number of leaves, leaf area, and number of branches.

Plant height was measured from the soil surface to the terminal growing point using a calibrated ruler. Stem girth was measured at a consistent position above the soil surface using a vernier calliper or measuring tape. The numbers of fully expanded leaves and branches were counted manually. Leaf area was determined using the method adopted in the original experiment. Repeated measurement of plant height, stem dimensions, leaf production, branching and leaf area is widely used to assess the growth and development of nursery-grown plants (Hunt, 1990; Poorter *et al.,* 2012).

2.5 Soil Analysis

Soil samples were collected before the experiment to determine the initial physical and chemical properties of the soil. At the end of the six-month experimental period, soil samples were collected from each treatment for post-experiment analysis.

The soil properties determined included pH, total nitrogen, available phosphorus, exchangeable potassium, sodium, magnesium, copper, hydrogen, aluminium, organic carbon, cation exchange capacity, particle-size distribution, and water-holding capacity.

Soil samples were analysed using the standard procedures adopted by the Soil and Plant Nutrition Laboratory of the Cocoa Research Institute of Nigeria. The analytical methods were based on established procedures for soil chemical and physical analysis, including the determination of soil pH, organic carbon, total nitrogen, available phosphorus, exchangeable cations, cation exchange capacity and particle-size distribution (Black *et al.,* 1965; Bouyoucos, 1962; Bremner & Mulvaney, 1982; Carter & Gregorich, 2008; Nelson & Sommers, 1996; Page *et al.,* 1982; Rhoades, 1982; Sparks *et al.,* 1996; Thomas, 1982; Walkley & Black, 1934). Water-holding capacity was determined using the laboratory procedure adopted by the Soil and Plant Nutrition Laboratory of the Cocoa Research Institute of Nigeria. The specific extraction, digestion, detection and calculation procedures should correspond to the laboratory records used for the original experiment.

2.6 Plant Nutrient Analysis

At harvest, representative cashew seedling samples were collected from each treatment. The samples were washed with distilled water to remove adhering soil particles, oven-dried at 70 °C to constant weight, ground, and stored in clean labelled containers pending laboratory analysis.

The concentrations of sodium, calcium, magnesium, zinc, iron, copper, phosphorus, nitrogen and potassium were determined using the standard analytical procedures adopted by the laboratory. Nitrogen concentration was determined using an appropriate digestion and distillation procedure. Phosphorus concentration was determined using a suitable acid-digestion and colorimetric method, while potassium, calcium, magnesium, sodium, zinc, iron and copper concentrations were determined following acid digestion and appropriate instrumental or spectrophotometric procedures, depending on the analytical facilities available in the laboratory (Jones, 2001; Kalra, 1998; Mills & Jones, 1996).

2.7 Proximate Composition Analysis

The dried and milled plant samples were analysed for moisture, crude fat, ash, crude protein, crude fibre and carbohydrate contents using standard proximate-analysis procedures described by Latimer (2019).

Moisture content was determined by oven-drying the samples to constant weight. Ash content was determined by incineration in a muffle furnace. Crude protein was estimated from total nitrogen using an appropriate nitrogen-to-protein conversion factor. Crude fat was determined by solvent extraction, while crude fibre was determined using the conventional fibre-analysis procedure (Latimer, 2019).

Carbohydrate content was calculated by difference using the following equation:

$$\text{Carbohydrate (\%)} = 100 - [\text{Moisture (\%)} + \text{Ash (\%)} + \text{Protein (\%)} + \text{Fat (\%)} + \text{Crude fibre (\%)}]$$

The calculation of carbohydrate content by difference follows the conventional proximate-composition approach described by Greenfield and Southgate (2003).

2.8 Biomass Determination

At the end of the six-month experimental period, selected seedlings were harvested destructively. The seedlings were carefully removed from the nursery bags, and adhering soil was gently washed from the roots.

The harvested seedlings were separated into shoot and root portions. Fresh weight was recorded immediately using a sensitive weighing balance. The plant materials were subsequently oven-dried at 70 °C until a constant weight was attained, after which dry weight was recorded. Root weight was also determined separately. All biomass measurements were expressed in grams per seedling. Fresh and dry biomass determination through destructive harvesting is a widely accepted method for assessing plant growth and biomass accumulation (Poorter *et al.,* 2012).

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2.9 Statistical Analysis

Data collected for growth parameters, soil properties, mineral nutrient concentrations, proximate composition and biomass were subjected to analysis of variance (ANOVA) appropriate for a Completely Randomised Design (CRD), following the principles of experimental design and statistical analysis described by Gomez and Gomez (1984) and Steel et al. (1997).
The statistical model used was:

$$Yij = \mu + Ti + eij$$

where Yij is the observation from the jth replicate receiving the ith treatment, μ is the overall mean, Ti is the effect of the ith treatment, and eij is the random experimental error.

Treatment means were separated using Tukey's Honestly Significant Difference (HSD) test at the 5% probability level ($p < 0.05$) (Tukey, 1949).

3. Results and Discussion

3.1 Results of the Pre-experiment Soil Sample Analysis

The initial soil analysis indicated an acidic sandy loam with a pH of 4.81 (Table 1). Total nitrogen was 0.09%, available phosphorus was 7.48 mg kg^{-1}, and exchangeable potassium was 0.20 cmol kg^{-1}. Organic carbon was 0.73%, while exchangeable magnesium, copper, exchangeable hydrogen and exchangeable aluminium were 0.04 cmol kg^{-1}, 0.71 mg kg^{-1}, 0.79 cmol kg^{-1} and 0.54 cmol kg^{-1},

respectively. Water-holding capacity was 41.58 g kg^{-1}. These values provide a baseline description of the soil before treatment application and serve as a reference for interpreting the post-treatment results.

Table 1. Initial physicochemical properties of the soil before experimentation

Parameter	Initial value
pH	4.81
Total N (%)	0.09
Available P (mg kg^{-1})*	7.48
Exchangeable K (cmol kg^{-1})	0.20
Organic carbon (%)	0.73
Exchangeable Mg (cmol kg^{-1})	0.04
Cu (mg kg^{-1})*	0.71
Exchangeable H (cmol kg^{-1})	0.79
Exchangeable Al (cmol kg^{-1})	0.54
WHC (g kg^{-1})*	41.58
Textural class	Sandy loam

3.2 Effects of Ground Yellow Mombin Leaf Amendment on the Growth Parameters of Cashew Seedlings

Table 2 presents the effects of month, year and ground yellow mombin leaf amendment on selected growth parameters of cashew seedlings.

Table 2. Effects of Grounded Yellow Mombin (*Spondias mombin* L.) Leaf Amendment on Growth Parameters of Cashew (*Anacardium occidentale* L.) Seedlings

Source of variation	Plant height (cm)	Stem girth (cm)	Leaf area (cm^2)	Number of leaves	Number of branches
Months					
1	15.29a	0.59a	40.89a	10.55b	0.38a
2	17.35a	0.70a	44.83a	13.28ab	0.56a
3	18.38a	0.76a	48.62a	14.44ab	0.61a
4	20.34a	0.78a	44.83a	15.94a	0.94a
5	21.38a	0.82a	54.97a	15.56ab	1.11a
Years					
1	54.33a	0.72a	43.46b	13.98a	0.80a
2	54.36a	0.69a	55.27a	14.59a	0.87a
Treatments					
AR (Control)	36.37a	0.79a	42.21b	13.19a	0.53a
BR (11.5 g)	36.33a	0.67b	45.05ab	15.81a	1.31a
CR (22.5 g)	36.37a	0.67b	54.84a	13.19a	0.67a
Month × Year (F-value)	1.84	2.32	2.05	1.37	2.68
Error	0.99	0.38	0.26	0.27	1.01

Means within the same column under the same source of variation followed by different letters are significantly different according to Tukey's HSD test at $\alpha = 0.05$; Abbreviations: AR = control; BR = 11.5 g grounded yellow mombin leaf; CR = 22.5 g grounded yellow mombin leaf; PH = plant height; SG = stem girth; LA = leaf area; NOL = number of leaves; NOB = number of branches.

The application of ground yellow mombin leaves was associated with a numerical increase in cashew plant height from 15.29 cm in month 1 to 21.38 cm in month 5. However, the differences among months were not statistically significant. The year effect was also not significant, with mean plant heights of 54.33 and 54.36 cm recorded in years 1 and 2, respectively. Treatment did not significantly affect plant height; the control, BR and CR treatments recorded mean heights of 36.37, 36.33 and 36.37 cm, respectively.

Stem girth increased numerically across the months, from 0.59 cm in month 1 to 0.82 cm in month 5. These monthly differences were not significant, and the year effect was also non-significant. However, treatment significantly affected stem girth. The control recorded the highest mean stem girth (0.79 cm), whereas BR and CR each recorded 0.67 cm. The amended treatments therefore had significantly lower stem girth than the control, although the two amendment rates did not differ from each other.

Leaf area varied among months without a significant monthly effect. The highest monthly value was 54.97 cm^2 in month 5. A significant year effect was observed: leaf area was higher in year 2 (55.27 cm^2) than in year 1 (43.46 cm^2). Treatment also significantly affected leaf area. CR recorded the highest value (54.84 cm^2) and differed significantly from the control, which recorded 42.21 cm^2. BR, with 45.05 cm^2, was statistically intermediate.

The number of leaves increased from 10.55 in month 1 to 15.94 in month 4. The value for month 1 differed significantly from that for month 4, while month 5 was statistically similar to the other months. Year and treatment effects were not significant. The mean numbers of leaves were 13.98 and 14.59 in years 1 and 2, respectively. Treatment means were 13.19 for AR, 15.81 for BR and 13.19 for CR.

The number of branches showed a numerical increase from 0.38 in month 1 to 1.11 in month 5, but the monthly differences were not significant. Neither year nor treatment significantly affected branch number. The treatment means were 0.53, 1.31 and 0.67 branches for AR, BR and CR, respectively.

The steady increases in plant height, stem girth, leaf number and branch number across the months, with few significant differences between months, reflect normal seedling development over time rather than a response to the amendment (Hunt, 1990). The absence of a treatment effect on plant height suggests that ground yellow mombin leaves did not supply sufficient readily available nutrients during the study period. Fresh plant residues release nutrients gradually, and their effects depend on their chemical quality, particularly their nitrogen, lignin and polyphenol contents (Palm *et al.,* 2001). Where decomposition is slow or microbes temporarily immobilise nitrogen, early seedling growth may not respond.

The lower stem girth in amended seedlings (0.67 cm) than in the control (0.79 cm) requires careful interpretation. *Spondias mombin* leaves contain secondary metabolites (Ayoka et al., 2008). Plant phenolics can interfere with growth processes in other plants (Inderjit, 1996), so a mild inhibitory effect on radial growth is possible. This explanation is speculative, however, because the leaf-extract chemistry and soil phenolic concentrations were not measured. An alternative explanation is a change in biomass allocation, whereby amended seedlings invest relatively more in foliage than in stem thickening (Poorter *et al.,* 2012). This would be consistent with the larger leaf area under CR.

The significant leaf-area response to the higher amendment rate (54.84 cm^2 for CR versus 42.21 cm^2 for the control) is consistent with the established roles of nitrogen and phosphorus in leaf expansion and cell division (Marschner, 2012; Taiz & Zeiger, 2010). The higher leaf phosphorus and potassium concentrations in CR seedlings (Section 3.4) support this interpretation. The greater leaf area in year 2 than in year 1 may reflect year-to-year differences in rainfall, temperature or radiation, which strongly affect leaf expansion (Fageria *et al.,* 2010). Since leaf number did not differ among treatments, the larger leaf area under CR may have resulted from larger individual leaves rather than a greater number of leaves.

3.3 Effects of Ground Yellow Mombin Leaf Amendment on Soil Properties

Table 3 presents the effects of yellow mombin (*Spondias mombin* L.) leaf amendment on selected chemical and physical properties of the soil used for cashew (*Anacardium occidentale* L.) seedling production.

Soil pH ranged from 4.84 in the control (AR) to 6.42 under BR (11.5 g amendment), while CR (22.5 g amendment) recorded 5.75. Although BR and CR had higher numerical pH values than the control, the differences were not statistically significant at the 5% probability level. Total nitrogen followed a similar numerical pattern, with values of 0.15%, 0.26% and 0.22% under AR, BR and CR, respectively. These differences were also not statistically significant.

Available phosphorus differed significantly among treatments. BR recorded the highest value (3.72 mg kg^{-1}), which was significantly higher than the values recorded under AR (1.55 mg kg^{-1}) and CR (1.89 mg kg^{-1}). AR and CR did not differ significantly from each other. This result suggests that the 11.5 g amendment treatment was associated with the highest measured available phosphorus concentration under the conditions of the experiment.

Exchangeable potassium ranged from 0.10 cmol kg^{-1} under AR to 0.18 cmol kg^{-1} under CR, with BR recording 0.17 cmol kg^{-1}. Exchangeable sodium ranged from 0.70 cmol kg^{-1} under BR to 0.80 cmol kg^{-1} under AR. Neither parameter differed significantly among treatments. Organic carbon was numerically highest in the control (0.86%), followed by CR (0.73%) and BR (0.68%). Exchangeable magnesium, copper, exchangeable hydrogen and exchangeable aluminium also showed no significant differences among treatments. Exchangeable magnesium ranged from 0.04 to 0.09 cmol kg^{-1}, copper from 0.84 to 1.19 mg kg^{-1}, exchangeable hydrogen from 0.93 to 4.18 cmol kg^{-1}, and exchangeable aluminium from 0.62 to 3.03 cmol kg^{-1}, based on the values presented in Table 3. Water-holding capacity was 48.92 g kg^{-1} under both AR and CR and 32.83 g kg^{-1} under BR. Although BR recorded a lower numerical value, the differences were not significant. Consequently, the experiment did not establish a significant effect of the amendment treatments on water-holding capacity.

The higher soil pH values under BR and CR than under the control may indicate a potential liming effect of the yellow mombin leaf amendment. Organic amendments can influence soil acidity through their chemical composition and decomposition products (Whalen et al., 2000). However, because the pH differences were not statistically significant, this interpretation should be treated as a possible trend rather than a confirmed treatment effect.

The significantly higher available phosphorus under BR suggests that the lower amendment rate may have enhanced phosphorus availability under the experimental conditions. Possible mechanisms include the release of phosphorus during residue decomposition and interactions between organic compounds and soil phosphorus-sorption sites (Nziguheba *et al.,* 1998). The lower value under CR than under BR indicates that the response was not proportional to the quantity of amendment applied. Similar variation in nutrient availability following organic amendment application has been reported in other cropping systems (Raza et al., 2021; Toundou et al., 2021).

The absence of significant differences in organic carbon suggests that the amendment treatments did not produce a measurable short-term effect on this property. Organic carbon accumulation depends on the quantity and composition of the added material, its decomposition rate and the duration of the experiment (Bot & Benites, 2005; Brady & Weil, 2008). Soil organic matter is also associated with available water capacity (Hudson, 1994). Similarly, the lack of significant differences in water-holding capacity indicates that any treatment-related changes in this property were not statistically demonstrated during the study period.

Table 3. Effect of grounded yellow mombin (*Spondias mombin* L.) leaf amendment on soil properties under cashew (*Anacardium occidentale* L.) seedling production

Treatment	pH	Total N (%)	Av. P (mg kg⁻¹)	Exch. K (cmol kg⁻¹)	Exch. Na (cmol kg⁻¹)	OC (%)	Exch. Mg (cmol kg⁻¹)	Cu (mg kg⁻¹)	Exch. H (cmol kg⁻¹)	Exch. Al (cmol kg⁻¹)	WHC (g kg⁻¹)
AR (Control)	4.84a	0.15a	1.55b	0.10a	0.80a	0.86a	0.04a	0.84a	0.93a	0.63a	48.92a
BR (11.5 g)	6.42a	0.26a	3.72a	0.17a	0.70a	0.68a	0.09a	1.19a	4.18a	3.03a	32.83a
CR (22.5 g)	5.75a	0.22a	1.89b	0.18a	0.77a	0.73a	0.08a	1.10a	1.22a	0.62a	48.92a

Means within the same column followed by different letters are significantly different according to Tukey's HSD test at α = 0.05.
Abbreviations: OC = organic carbon; WHC = water-holding capacity.

Table 4. Effect of Grounded Yellow Mombin (*Spondias mombin* L.) Leaf Amendment on Mineral Nutrient Concentration and Proximate Composition of Cashew (*Anacardium occidentale* L.) Seedlings

Treatment	Na	Ca	Mg	Zn	Fe	Cu	P	N	K	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Crude fibre (%)	Carbohydrate (%)
	mg g⁻¹ dry matter						mg g⁻¹ dry matter								
AR (Control)	4.40_a	27.95_b	2.34_a	0.54_a	0.72_a	0.48_a	3.23_b	3.46_a	37.99_b	9.30_c	7.89_b	15.59_a	19.45_b	36.00_a	11.77
BR (11.5g)	4.00_a	52.45_a	2.31_a	0.54_a	0.68_a	0.49_a	4.46_b	3.37_a	35.25_b	10.30_b	7.93_b	15.60_a	20.70_{ab}	34.66_b	10.81
CR (22.5g)	3.80_a	19.45_b	2.37_a	0.59a	0.72_a	0.51_a	6.75_a	3.83_a	58.95_a	12.65_a	9.25_a	13.85_b	21.55_a	22.79_c	19.91

Note: Means within the same column followed by different letters are significantly different according to Tukey's HSD test at α = 0.05

Although organic amendments can influence exchangeable aluminium and other soil chemical properties through complexation reactions and changes in soil acidity (Hue *et al.,* 1986; Hue & Amien, 1989), no significant treatment differences were observed for exchangeable aluminium in this experiment. Therefore, the results do not establish that yellow mombin leaf amendment reduced exchangeable aluminium under the conditions studied.

3.4 Effects of Ground Yellow Mombin Leaf Amendment on Mineral Nutrient Concentrations and Proximate Composition of Cashew (*Anacardium occidentale* L.) Seedlings

Table 4 presents the effects of ground yellow mombin leaf amendment on the mineral nutrient concentrations and proximate composition of cashew (*Anacardium occidentale* L.) seedlings. The concentrations of sodium, magnesium, zinc, iron, copper and nitrogen did not differ significantly among treatments. Sodium ranged from 3.80 in CR to 4.40 in AR. Magnesium values were narrowly distributed, between 2.31 and 2.37, while zinc, iron and copper ranged from 0.54 to 0.59, 0.68 to 0.72 and 0.48 to 0.51, respectively. Nitrogen ranged from 3.37 in BR to 3.83 in CR, but the difference was not significant.

Calcium concentration differed significantly among treatments. BR recorded the highest value (52.45) and differed significantly from AR (27.95) and CR (19.45). Thus, the 11.5 g amendment rate was associated with the highest measured calcium concentration. Phosphorus concentration was also significantly affected. CR recorded the highest value (6.75), followed by BR (4.46) and AR (3.23). CR differed significantly from both AR and BR, whereas AR and BR were statistically similar.

Potassium concentration differed significantly among treatments. CR recorded 58.95, which was significantly higher than the values for AR (37.99) and BR (35.25). The higher amendment rate therefore produced the highest measured plant phosphorus and potassium concentrations.
Moisture, fat, ash, protein and crude fibre contents were significantly affected by treatment. Moisture content was highest in CR (12.65%), followed by BR (10.30%) and AR (9.30%), with all three treatments differing significantly. Fat content was also highest in CR (9.25%), while AR and BR recorded 7.89% and 7.93%, respectively.

Ash content was highest in BR (15.60%) and AR (15.59%), which did not differ significantly, whereas CR recorded a significantly lower value (13.85%). Protein content was highest in CR (21.55%), followed by BR (20.70%) and AR (19.45%). CR differed significantly from AR but was statistically similar to BR.

Crude fibre content differed significantly among all treatments. AR recorded the highest value (36.00%), followed by BR (34.66%) and CR (22.79%). Carbohydrate content, recalculated by difference from the displayed component means, was 11.77% in AR, 10.81% in BR and 19.91% in CR.

The selective effects on tissue composition indicate that the amendment influenced nutrient uptake and metabolism more than visible growth. The higher phosphorus and potassium concentrations in CR seedlings suggest greater nutrient availability at the higher amendment rate. Potassium is not a structural element and is released rapidly from decomposing plant residues, making it readily available for uptake (Marschner, 2012). Because soil potassium did not differ significantly among treatments, the plant potassium response may reflect the greater sensitivity of tissue analysis compared with a single soil measurement. Differences between nutrient availability and biomass responses have also been reported following organic amendment application in other crops (Raza et al., 2021).

The highest calcium concentration under BR (52.45) and the lowest under CR (19.45) may be consistent with competition among cations during uptake. A high potassium supply commonly suppresses the uptake of calcium and magnesium (Fageria *et al.,* 2010; Mengel & Kirkby, 2001), and CR had the highest potassium and lowest calcium concentrations. This is a plausible but untested explanation, as soil calcium was not reported.

For proximate composition, the higher moisture content in CR may be related to the role of potassium in osmotic regulation and water relations (Marschner, 2012). The higher protein content in CR is consistent with its numerically higher nitrogen and higher phosphorus concentrations, which support amino acid and protein synthesis (Taiz & Zeiger, 2010). The lower crude fibre and higher carbohydrate contents in CR are consistent with the view that adequate nitrogen and potassium nutrition favour less structural, more succulent tissue (Mengel & Kirkby, 2001). Proximate fractions are determined using standard methods (Horwitz, 2005), and crude fibre and carbohydrate are partly calculated by difference. Differences in one fraction therefore affect the others, so these trends should be interpreted together.

3.5 Effects of Ground Yellow Mombin Leaf Amendment on Biomass Yield

Table 5 presents fresh weight, dry weight and root weight at harvest. Fresh weight ranged from 0.50 g in CR to 0.99 g in BR, while AR recorded 0.58 g. Although BR had the highest numerical fresh weight, all treatments shared the same statistical grouping, indicating no significant treatment effect.

Dry weight was numerically highest in AR (0.51 g), closely followed by BR (0.50 g), while CR recorded 0.12 g. These differences were not statistically significant. Similarly, root weight ranged from 0.006 g in BR and CR to 0.007 g in AR. The treatments did not differ significantly in root weight.

The lack of significant differences in fresh, dry and root weights indicates that the changes in tissue nutrient composition did not translate into measurable biomass gains. This agrees with the growth results, in which height, branching and leaf number were

unaffected, and with evidence that biomass is the cumulative outcome of many processes and may respond slowly to short-term changes in nutrient availability (Poorter *et al.,* 2012). Several factors could have masked treatment effects. The experimental period was short, the weights recorded were very small for seedlings, and variability among plants may have been large, reducing the power of Tukey's HSD test to detect differences (Tukey, 1949).

Table 5. Effect of Grounded Yellow Mombin (*Spondias mombin* L.) Leaf Amendment on Biomass Yield of Cashew (*Anacardium occidentale* L.) Seedlings at Harvest

Treatment	Fresh weight (g)	Dry weight (g)	Root weight (g)
AR (Control)	0.58_a	0.51_a	0.007_a
BR (11.5 g)	0.99_a	0.50_a	0.006_a
CR (22.5 g)	0.50_a	0.12_a	0.006_a

Note: Means within the same column followed by the same letter are not significantly different according to Tukey's HSD test at α = 0.05.

4. Conclusion

Ground yellow mombin (Spondias *mombin* L.) leaf amendment produced selective effects on the growth, soil properties, nutrient composition and proximate characteristics of cashew (Anacardium *occidentale* L.) seedlings. The amendment treatments significantly affected leaf area and stem girth, although the responses were not uniform across treatments. The higher amendment rate produced the largest leaf area, whereas the control recorded the greatest stem girth. Leaf number increased significantly between selected months, but treatment effects on leaf number and branch number were not significant.

Among the soil properties reported in Table 3, available phosphorus differed significantly among treatments, with BR recording the highest value. The other soil properties presented in Table 3, including pH, total nitrogen, exchangeable potassium and sodium, organic carbon, magnesium, copper, exchangeable hydrogen, exchangeable aluminium and water-holding capacity, did not differ significantly among treatments.

Plant nutrient composition also responded differently to the amendment rates. The 11.5 g treatment recorded the highest calcium concentration, while the 22.5 g treatment recorded the highest phosphorus and potassium concentrations. Moisture, fat, ash, protein and crude fibre contents differed significantly among treatments. Carbohydrate contents calculated from the displayed component means were 11.77%, 10.81% and 19.91% for AR, BR and CR, respectively; However, these changes were not accompanied by significant differences in fresh weight, dry weight or root weight.

The findings suggest that ground yellow mombin leaves have potential as a locally available organic soil amendment for modifying selected soil nutrient and plant-composition characteristics during cashew nursery production. Nevertheless, the present study does not establish an optimum application rate or demonstrate consistent improvement in overall seedling biomass or growth. Further research should examine a wider range of application rates, amendment-incorporation periods, nutrient-release patterns, longer nursery periods, and subsequent field establishment and growth.

5. Limitations

The study covered a six-month nursery period and evaluated only three amendment rates, including the untreated control. The manuscript does not report the number of replicates or provide detailed analytical protocols for each soil and plant measurement. The chemical composition and decomposition characteristics of the yellow mombin leaf material were not reported, and subsequent field establishment was not assessed.

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. ChatGPT, Claude and Perplexity 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

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.

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