Technoscience Journal for Community Development in Africa 4 (2025) 59–68
ISSN 2659-0573

Research Article

Combined effect of biochar and castor cake on soil properties and yield of Amaranthus caudatus L.

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Abstract: This study investigated the effects of combined applications of biochar and castor cake on soil chemical properties, growth, and yield of Amaranthus caudatus. Screenhouse and field experiments were conducted at Kwara State University, Malete, and the National Centre for Agricultural Mechanization (NCAM), Idofian, Kwara State. Screenhouse experiment was arranged in a Completely Randomized Design, while the field trial followed a Randomized Complete Block Design with three replicates. Treatments included different ratios of castor cake and biochar applied at 10 t/ha (30+70%, 40+60%, 50+50%, 60+40%, and 70+30%), NPK fertilizer at 100 kg N/ha, and a control. Results from the screenhouse study showed that combined applications of biochar and castor cake significantly enhanced growth and dry matter yield of amaranths. In the field experiment, the treatment comprising 60% castor cake + 40% biochar increased yield by 79.5% over NPK and 88.8% over the control after the first cropping. Its residual yield (12,094.3 kg/ha) was also significantly ($p < 0.05$) higher than that of NPK. The 70% castor cake + 30% biochar treatment significantly improved soil organic carbon, nitrogen, phosphorus, and potassium. Overall, application of 60% castor cake + 40% biochar at 10 t/ha is recommended for improving soil fertility and amaranth production.

Keywords: Amaranthus caudatus, biochar, castor cake, fertilizer, NPK

1. Introduction

Amaranthus (Amaranthus caudatus L.), has been reported to be one of the vegetables with the greatest protein content. Amaranthus has been shown in several studies to help prevent malnutrition, particularly in children's diets (Olowoake and Ojo, 2014). Carotene, protein, vitamins, calcium, iron, ascorbic acid, and a high concentration of trace minerals are only a few of the important biochemicals and nutrients found in vegetables. Chaudhari et al. (2022) and Nunes et al. (2020) reported that intense agricultural soil cultivation may result in soil deterioration, including decreased fertility, changes in soil acidity or alkalinity, organic matter loss, soil erosion, and pollution. Moreover, soil degradation results from the destruction of soil characteristics such as soil organic carbon, which also reduces the stability of soil aggregates (Nunes et al., 2020). Audette et al. (2021) reported that the use of NPK and organic material both increase the development and yield of three distinct amaranth species, but they have differing effects on proximate composition. According to Pham et al. (2021), organic amendments can be added in for soil reclamation processes. Additionally, using organic manures may result in methane and ammonia emissions, which would exacerbate global warming.

Castor cake (also known as castor meal) is a byproduct of castor oil extraction from Ricinus communis seed. It is increasingly recognized as a valuable organic fertilizer and soil amendment due to its high nutrient content, pest-repellent properties, and potential for sustainable agriculture (Liu et al., 2021). Among several uses, castor cake has been used by agriculturist to improve crop growth and yield especially in crops like okra, tomatoes and other vegetables (Zhang et al., 2021). According to research, castor cake has been used to improve soil fertility through increases organic

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carbon and cation exchange capacity (CEC), as well as improving nutrient retention (Zhang et al., 2021). This has also been used in integrated pest management particularly in controlling root-knot nematodes in crops like tomatoes (Gabhane et al., 2020). While castor is an efficient organic amendment, reports suggest that it lacks complete ability to meet the soil nutrient requirements whence combined with other organic fertilizer especially biochar due to its nutrient retention ability in the soil. Biochar's porous structure acts as a nutrient sponge, reducing leaching (Zhang et al., 2021). Biochar neutralizes acidity in acid soil to certain range thereby balancing soil pH for optimal nutrient uptake, hence, the application of castor cake and biochar improves soil pH buffering and soil structure (Al-Wabel et al., 2018).

Biochar is a solid, rich in black carbon that is created when biomass is thermally decomposed at temperatures between 300 and 700 °C while oxygen is scarce (Jiao et al., 2021; Peng et al., 2018). It is reported to be highly rich in carbon (C) and has a lot of nutrients (Liao et al., 2022). The substance was an organic alteration and the result of biomass being pyrolyzed at high temperatures with little oxygen present (Yang et al., 2020). Since biochar improves soil qualities and promotes plant development, it is a crucial technique for restoring damaged soils on agricultural land (Al-Wabel et al., 2018). Enhancing the physical, chemical, and biological characteristics of soils is largely dependent on organic matter by stimulating microbial activity and root growth, as well as by binding soil organic matter and clay particles through cation bridges, soil structure can be enhanced (Dalal & Bridge, 2020; Audette et al., 2021;). Due to its inherent recalcitrance, applying biochar may have two main effects: it may increase the overall amount of soil organic matter (Bi et al., 2021; Zhang et al., 2021) and decrease the pace at which native soil organic matter mineralizes (Palansooriya et al., 2019). Investigating the combine effects of these factors on crop performance and soil characteristics is necessary, given the potential benefits of castor cake in supplying essential nutrients and biochar in improving soil structure, water retention, and carbon storage (Zhang et al., 2021). Studies focusing on improving and restoring the fertility status of soils in Nigeria with biochar and castor cakes are limited. Thus, this study aims to investigate the effects of biochar and castor cake in combination on growth and yield, soil chemical properties, on Amaranthus caudatus as well its residual effects on the soil properties.

2. Materials and methods

2.1. Experimental site

The screenhouse experiment was conducted at the Faculty of Agriculture Nursery, Kwara state University, Malete, while the field experiment was conducted at the National Center for Agricultural Mechanization (NCAM), Idofian. Kwara State. The screenhouse of Kwara State University (KWASU), Malete, Kwara State is within latitude 08°43'N and longitude 4°28'E of the equator, at an elevation of 316.37 m above sea level. The land area of Kwara State University is a part of the Nigerian basement complex in the southwest, which is a region of plutonism and basement recurrence (Omanayin et al., 2023). The two locations are in the Southern Guinea Savannah agro ecological zone of Nigeria, which is characterized by distinct wet and dry seasons. The on-set of the rainy season is usually in the month of April and cessation is usually in the month of October. The rainfall season is always at its peak within the month of June to September. The dry season also commence from the month of November and ends in March. The mean annual rainfall of Ilorin is 990.3 mm, while the mean monthly maximum and minimum temperatures in Malete are 31ºC and 29.54ºC, respectively, with the highest temperatures recorded in the months of February through April (Oyedokun et al., 2022). The soils of Ilorin are predominantly derived from ferruginous and crystalline acidic rocks and are predominantly Alfisols (Olaniyan, 2001).

2.2. Soil sampling and analysis

Samples from the top soil (0-15 cm) were collected from the experimental sites. The soil samples were bulked, oven dried and screened with a 2 mm sieve and 0.5 mm for N and organic carbon determination. Soil analysis was carried out before and after the experiments. The particle size was determined by the hydrometer method (Bouyoucos, 1962), soil organic carbon was determined by (Walkley and Black, 1982), and total nitrogen was evaluated using the macro kjeldahl procedure. Phosphorus was determined by Bray's P method. Exchangeable K, Ca and Mg were determined by ammonium acetate extraction method (NH4OAC). The flame photometer measured K and Na concentrations, while the atomic absorption spectrophotometer determined Mg and Ca. The pH of the soil water was determined at 0.01M CaCl2 with a glass electrode pH meter and an electrical conductivity of 1:5 (w/v) in the deionized water suspension.

2.3. *Plant material, Treatment and Experimental Design*

The seeds of Amaranthus caudatus were purchased from agrochemical stores. The screenhouse experiment was laid out in a Completely Randomized Design (CRD) with three replications and seven (7) treatments while the field experiment was laid in Randomized Complete Block Design (RCBD). The chemical composition of the fertilizers is presented in (Table 1).

Table 1: Chemical composition of castor cake and biochar before combination

	----------------Nutrient (%) --------------------		
	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Castor cake	3.24	1.12	1.30
Biochar	1.08	0.22	0.45

The treatments used for the study were: Control, 50% castor cake + 50% Biochar -10t/ha, 60% castor cake + 40% biochar-10t/ha, 70% castor cake + 30% biochar- 10t/ha, 40% castor cake + 60% biochar- 10t/ha, 30% castor cake + 70% biochar -10t/ha and NPK-100 kgN/ha. In the screenhouse, 8 kg of soil samples already oven-dried and sieved through 2 mm sieve was weighed into twenty one (21) pots. Organic fertilizer (40 g/kg of soil) was incorporated into the soil two weeks before planting of amaranths seeds in each pot, the plants were thinned to 2 seedlings after 2 weeks of germination. Watering and weeding were done throughout the experimental period. The plants were grown for six weeks after which they were harvested and terminated. The field was ploughed and harrowed. The experimental was laid out in a randomized complete block design (RCBD) with three replications. The size of each sub plot was 2 x 1 m, with an inter plot space of 0.5 m. The field trials had 7 major treatments. The experimental plots were weeded manually with hoe two (2) times to avoid crop-weed competition. The residual effects of soil amendments on the yield of Amaranthus caudatus were determined both in the screenhouse and in the field

2.4. *Data collection and analysis*

Data were collected on the following parameters: plant height, number of leaves and stem girth and the weight of fresh and dry weight of Amaranthus caudatus. The parameters were taken at 4, 6, and 8 WAP from 2 plant samples. Plant height was measured from the root collar (zone between the stem and root) to the growing tip with a tape rule. Plant stem girth was determined using vernier caliper. Numbers of leaves were counted manually, fresh shoot weight were measured using the sensitive scale, dry weight was taken after oven dry using sensitive scale. All data collected were subjected to an analysis of variance using the DSAASTAT. 1.101 version software. The treatments means were separated using Duncan Multiple Range Test at 5% probability.

3. Results and discussion

Table 2: Physical and chemical properties of e xperimental soils

Soil Properties	Soil Test Value	
	Malete (Pot)	NCAM (Field)
pH	5.37	5.57
Organic carbon (g/kg)	1.56	1.60
Total nitrogen (g/kg)	0.20	0.30
Available Phosphorus (mg/kg)	17.64	18.20
Exchangeable bases (cmol/kg)		
K	0.31	0.33
Na	0.23	0.25
Ca	2.25	2.25
Mg	0.86	0.88
Extractable micronutrients (mg/kg)		
Fe	106.0	104.0
Cu	1..37	1.38
Zn	1.81	1.82
Mn	85.0	86.0
Particle size (%)		
Sand	79.0	79.0
Silt	12.0	12.0
Clay	9.0	9.0
Textural Class	Sandy Loam	Sandy Loam

3.1. *Soil analysis*

Table 2 shows the results of the physical and chemical analysis of the two experimental soils before planting. Soils of the two sites (NCAM and Malete) were generally acidic in nature, low in total N and organic carbon. Thus, the soil required fertilizers or soil amendment to improve its fertility. Although it was observed to be rich in available phosphorous. The available phosphorous of 17.64 and 18.20 mg/kg was higher than the critical level of 10-16mg kg-1 (Adeoye and Agboola, 1985, Olowoake et al., 2024). The K status of the soil which was 0.31 and 0.33cmol/kg was higher than the critical level of 0.2 cmol kg-1 (Adeoye, 1986). Exchangeable magnesium values of 0.86 and 0.88 cmol/kg were higher than the critical level of 0.20 - 0.40 cmol/kg-1

Table 3: Plant height of *Amaranthus caudatus* as influenced by the combination of biochar and castor cake during the first and second planting in the screenhouse and field

Treatment	Plant height (cm) Screenhouse			Plant height (cm) Field		
	------------- WAP ------------------			---------------WAP-----------------		
	2	4	6	2	4	6
			First Planting			
Control	1.5c	6.47d	16.9c	5.7b	19.9a	39.8b
C50+ B50	9.3a	26.0ab	53.5ab	7.0a	25.5a	52.3a
C60+B40	8.7ab	29.6a	61.3a	7.7a	29.4a	59.3a
C70+B30	7.7ab	29.87a	60.8a	7.1a	28.4a	56.7a
C40+B60	9.3a	28.0ab	54.0ab	9.8a	27.4a	56.3a
C30+B70	5.9b	23.6b	48.8b	7.6a	32.2a	62.7a
NPK	1.5 c	13.9c	22.2c	5.0b	24.9a	40.9b
			Second Planting			
Control	1.2b	2.8b	4.7b	3.1b	13.2b	29.7b
C50+ B50	2.8ab	8.6a	18.5a	6.3a	18.3a	40.5a
C60+B40	5.1a	12.1a	21.4a	6.3a	21.1a	48.1a
C70+B30	3.4ab	8.2a	19.8a	6.6a	20.5a	44.6a
C40+B60	3.3ab	8.7a	18.3a	8.5a	19.9a	43.7a
C30+B70	3.2ab	8.4a	19.1a	7.1a	23.4a	47.9a
NPK	1.9b	3.1b	6.1b	3.3b	13.6b	31.0b

Mean followed by the same letter(s) in a column are not significantly different at ($P<0.05$) by Duncan's Multiple Range Test (DMRT). C- Castor cake; B-Biochar

(Adeoye and Agboola, 1985). Calcium value of 2.25 and 2.25 cmol/kg was below the critical level of 2.6 cmol/kg (Agboola and Corey 1972, Olowoake et al., 2024). The findings indicate that the soil could be poor in nutrients supply except N. Furthermore, this points out that that the application of soil amendments may enhance the growth and yield characteristics of amaranths.

3.2. Growth and yield parameters of Amaranthus caudatus as influenced by the combination of biochar and castor cake during the first and second planting in the screenhouse and field

Table 3 shows the response of Amaranthus caudatus to combined application of castor cake and biochar at 2, 4 and 6 weeks after planting for both screen-house and field experiment. The heights of amaranths were significantly different ($P<0.05$) and also increased with the combined application of castor cake and biochar when compared to the application of NPK-100 kgN/ha and control in both screen-house and field experiment during the first planting cycle. At 2, 4 and 6 weeks after planting, it was observed that 50% castor cake + 50% biochar -10t/ha, 60% castor cake + 40% biochar -10t/ha, 70% castor cake + 30% biochar- 10t/ha, and 40% castor cake + 60% biochar- 10t/ha increased consistently and recorded the tallest height than control and NPK. Also, at the screen-house and field experiment, it was observed that the application of NPK-100 kgN/ha and control consistently produced slightly shorter plant height. This corroborates study by Liu et al. (2017) who suggests that the combined application of biochar and organic manure increases plant height in leafy vegetables by improving nitrogen availability and root development. Also, Olowoake and Ojo (2014) reported similar results, where organic amendments increased vegetative growth due to slow nutrient release, unlike NPK fertilizer, which may lead to rapid nutrient loss through leaching. At the second planting, the plant height of amaranths in both the field and screen-house varied significantly ($P<0.05$) at all weeks after planting with the application of organic and inorganic fertilizers. Similarly, it was observed that the combined application of organic fertilizers (50% castor cake + 50% biochar -10t/ha, 60% castor cake + 40% biochar -10t/ha, 70% castor cake + 30% biochar- 10t/ha, and 40% castor cake + 60% biochar- 10t/ha) produced the highest plant height from 2 to 6 weeks after planting than control and NPK treatments. Liu et al., (2017) reported that the

Table 4: Number of leaves of *Amaranthus caudatus* as influenced by the combination of biochar and castor cake during the first and second planting in the screenhouse and field

Treatment	Number of leaves Screenhouse			Number of leaves Field		
	WAP			WAP		
	2	4	6	2	4	6
			First Planting			
Control	4.0c	9.3c	12.2b	5.2b	6.2c	9.4d
C50+ B50	8.3ab	15.7a	17.8a	6.3ab	10.2a	20.2a
C60+B40	7.8ab	14.3ab	20.3a	6.5ab	11.7a	22.3a
C70+B30	7.8ab	14.2ab	17.0a	6.7ab	10.9a	21.5a
C40+B60	8.8a	13.7b	16.5a	7.3a	9.7b	18.2b
C30+B70	7.3b	8.3b	16.8a	7.0ab	10.4a	21.5a
NPK	4.0c	7.8c	11.2b	5.6b	7.1c	14.6c
			Second Planting			
Control	3.2c	5.2c	8.0c	3.0b	4.9b	7.8c
C50+ B50	5.7a	8.0a	12.2a	5.5a	7.1a	12.4ab
C60+B40	6.5a	8.2a	10.3b	5.1a	8.3a	13.3a
C70+B30	5.3b	7.3b	10.0b	4.9a	8.0a	11.7b
C40+B60	5.3b	6.8bc	10.2b	4.7a	7.1a	10.1b
C30+B70	6.3a	7.8a	10.7b	5.0a	7.5a	12.7ab
NPK	3.7c	5.8c	8.8c	3.5b	5.7b	8.3c

Mean followed by the same letter(s) in a column are not significantly different at ($P<0.05$) by Duncan's Multiple Range Test (DMRT). C- Castor cake B-Biochar

application of biochar and castor cake in combination increases growth of vegetables like amaranths which aligns with the findings from this study.

Table 4 shows that the number of leaves of Amaranthus caudatus plant at both the screen-house and field differed significantly ($P<0.05$) among the different fertilizer treatments. During first and second planting there were significant differences in the number of leaves of Amaranth at 2, 4 and 6 weeks after planting. Combined application of organic fertilizers (50% castor cake + 50% biochar -10t/ha, 60% castor cake + 40% biochar -10t/ha, 70% castor cake + 30% biochar- 10t/ha, and 40% castor cake + 60% biochar- 10t/ha) had higher number of leaves per plant both in the screen-house and field experiment than NPK and control. Adeniyan and Ojeniyi (2005) reported that organic manures increased leaf production in amaranth by 30% compared to NPK, attributing this to improved micronutrient availability. Similarly, a study conducted by Kayode et al. (2018) agrees with the findings that biochar-amended soils could improve phosphorus uptake, which is significant for leaf development. Also, Oyedeji et al. (2014) suggests that while NPK increased crude fiber and plant growth, organic treatments such as biochar and castor cake produced more leaves due to better nutrient retention.

In the first planting, the result obtained for Stem girth shows that there was significant difference ($P<0.05$) among the different fertilizer treatments at 2, 4 and 6 weeks after planting in both screenhouse and field experiments. However, it was observed that at 2 weeks after planting in the screenhouse, stem girth showed no significant difference ($P<0.05$) among some organic fertilizer treatments. It was observed that there was no significant difference between stem girth produced from combined application of 50% castor cake + 50% biochar -10t/ha and 40% castor cake + 60% biochar- 10t/ha. Also, at 4 and 6 weeks after planting, the application of 50% castor cake + 50% biochar -10t/ha, 60% castor cake + 40% biochar -10t/ha, 70% castor cake + 30% biochar- 10t/ha and 40% castor cake + 60% biochar- 10t/ha, and resulted in significantly higher stem girth of amaranth than other treatments. The lowest stem girth of amaranths was produced by control treatment. Furthermore, for field experiment, in the first planting, biochar combination with castor cake consistently produced the highest significant ($P<0.05$) stem girth across weeks after planting. Adekiya et al. (2020) reported that organic amendments increased stem diameter in okra by 25% compared to NPK due to better calcium and magnesium availability. Also, Olowoake and Ojo et al. (2014) suggested that due to biochar's high carbon content, there could be an improved lignin deposition which in turn strengthened stems girth. Audette et al. (2021) reported that biochar improved stem girth by enhancing soil porosity and root development.

In the second planting, there was significant difference among treatments (P<0.05) in both screenhouse and field experiments. In the screenhouse and field, the combined application of castor cake and biochar produced stem girth that were significantly higher than the stem girth produced from control and NPK-100 kgN/ha throughout the growing period. Biochar application in soil helps in soil aggregation, reducing mechanical stress on stems (Dalal & Bridge, 2020).

Table 6 shows that there were significant (P<0.05) differences in wet shoot weight and dry shoot weight of Amaranthus caudatus among the fertilizer treatments in first and second planting at the screenhouse. In the first planting, the value of wet shoot weight and dry shoot weight of amaranths produced from 50% castor cake + 50% biochar -10t/ha, 60% castor cake + 40% biochar -10t/ha and 70% castor cake + 30% biochar -10t/ha, was significantly higher than the values obtained from NPK fertilized pot, 40% castor cake + 60% biochar -10t/ha, 30% castor cake + 70% biochar -10t/ha and control. However, in the second planting, the application of organic fertilizer produced significantly (p<0.05) higher wet shoot weight and dry shoot weight than NPK and control treatment in the screenhouse. Liu et al. (2021) reported that castor cake + biochar application increases dry matter accumulation by 20% in leafy greens which is in agreement with this study. Similarly, Senevirath et al., (2019) suggest that application of biochar and compost contributed to the increment in total biomass by 16.52% in comparison to the control treatment in soybean plants and the reason behind the increase of biomass was due to the increase in plant growth parameters.

Similarly, the yield obtained on the field experiment showed significant variation among fertilizer treatments and control. Plants treated with 60% castor cake + 40% biochar -10t/ha produced the highest yield of amaranthus caudatus when compared to other treatments in this study in both first and second planting cycle. Control treated plants produced the lowest significant yield during the second planting period in the field. Olowoake et al. (2024) reported that organic amendments increased amaranth yield by 40% when compared to NPK fertilizer. Similarly, Adenawoola et al., (2005) reported

Table 5: Stem girth of *Amaranthus caudatus* as influenced by the combination of biochar and castor cake during the first and second planting in the screenhouse and field

Treatment	Stem girth (cm) Screenhouse			Stem girth (cm) Field		
	WAP			WAP		
	2	4	6	2	4	6
			First Planting			
Control	1.46c	4.29c	4.98d	1.28c	3.10b	7.06b
C50+ B50	4.45ab	10.26a	10.79a	3.86a	6.22a	10.79a
C60+B40	3.97b	11.15a	10.94a	3.97a	7.79a	12.12a
C70+B30	4.19b	10.89a	10.05ab	2.74a	6.66a	10.47a
C40+B60	4.97a	10.21a	10.42ab	3.62a	6.17a	10.84a
C30+B70	3.71b	8.27b	8.95b	3.30a	7.85a	11.56a
NPK	1.46c	2.46d	6.65c	1.38b	4.82b	8.12b
			Second Planting			
Control	1.36b	2.25c	3.19b	1.26b	3.68b	5.19c
C50+ B50	2.64a	3.93a	5.96a	2.57a	4.97a	8.98a
C60+B40	2.79a	3.67a	5.76a	2.68a	5.76a	7.98a
C70+B30	2.64a	3.19b	5.34a	2.34a	4.84a	7.86a
C40+B60	2.49a	3.82a	5.71a	2.01a	4.65a	7.83a
C30+B70	2.52a	3.19b	5.93a	2.84a	6.32a	9.61a
NPK	1.62b	2.51c	3.35b	1.36b	3.92b	6.42b

Mean followed by the same letter(s) in a column are not significantly different at (P<0.05) by Duncan's Multiple Range Test (DMRT). C- Castor cake B-Biochar

Table 6: Yield Parameters of *Amaranthus caudatus* as influenced by the combination of biochar and castor cake during the first and second planting in the screenhouse and field.

Treatment (t/ha)	Wet shoot weight (g/pot)	Dry shoot weight (g/pot)	Fresh shoot Yield (kg/ha)
	---------------- Screenhouse ----------------		Field
		First Planting	
Control	20.3c	4.1c	1,746.7e
C50+ B50	107.3a	12.7a	10,099.7b
C60+B40	109.0a	13.5a	15,532.7a
C70+B30	112.7a	14.5a	7,560.3c
C40+B60	88.7b	6.7b	6,669.7c
C30+B70	76.7b	6.3b	6,669.7c
NPK	27.7c	4.5c	3,175.7d
		Second Planting	
Control	1.3b	0.8b	419.33e
C50+ B50	13.3a	3.1a	8,403.3b
C60+B40	14.3a	3.8a	12,093.3a
C70+B30	13.0a	3.0a	5,126.7c
C40+B60	12.7a	3.5a	5,571.3bc
C30+B70	10.3a	2.3ab	5,266.7c
NPK	1.7b	0.4b	2,908.3d

Mean followed by the same letter(s) in a column are not significantly different at ($P<0.05$) by Duncan's Multiple Range Test (DMRT). C- Castor cake; B-Biochar

that organic fertilizer increased vegetable yield by 35% due to improved soil organic matter.

Table 7 shows the physical and chemical properties of soil on in the screenhouse after harvesting of amaranths. The pH ranges from 4.9 in the control pot to 6.1 in pot that received the application of 50% castor cake + 50% Biochar-10t/ha. This is consistent with Adeniyan and Ojeniyi (2005), who reported that organic fertilizers can mitigate soil acidity and improve nutrient availability. The rise in pH is particularly significant in acidic soils, as it enhances microbial activity and nutrient uptake (Al-Wabel et al., 2018). The EC of the soil range from 58 dS/m control to 76 dS/m in pot treated with 30% castor cake + 70% Biochar -10t/ha in first planting period. Also, organic carbon ranged from 0.7 g/kg in control pot to 1.7 in pot with combine application of Castor cake 50%+ biochar 50% and Castor cake 70%+ biochar 30% at 10 t/ha. The increase in soil organic carbon aligns with Zhang et al. (2021), who emphasized biochar's significance in carbon sequestration and soil organic matter stabilization. Total nitrogen varied significantly and range from 0.1 g/kg in control pot to 0.3 g/kg from the pot that received 70% castor cake + 30% biochar-10t/ha. The K content of soil range from 0.2 c mol/kg in control pot to 0.4 c mol/kg in pot treated with 70% castor cake + 30% Biochar -10t/ha, 40% castor cake + 60% biochar- 10t/ha, and 30% castor cake + 70% biochar-10t/ha and NPK plot. The available P range from 14.2 mg/kg in control pot to 34.2 mg/kg in pot treated with 60% castor cake + 40% Biochar-10t/ha.

In the second planting, the observation of soil nutrient after harvest in first planting also followed the same trend in in the second planting. The combine castor cake and biochar increased the pH, organic carbon, nitrogen, phosphorus and potassium. These findings corroborate the work of Adekiya et al. (2019), who reported that the interactive effect of biochar and poultry manure in increasing soil chemical properties can be explained by the fact that addition of poultry manure to biochar may facilitate surface oxidation of biochar by elevated temperature, especially at the beginning of the process. It also changes biochar properties biotically by the high microbial activity or the co-metabolic decay during the degradation of available carbon sources.

Table 8 shows the physical and chemical properties of soil on the field at harvesting. In the first planting, the pH ranges from 5.1 in control to 6.3 from the plot that received 60% castor cake + 40% Biochar- 10t/ha. This study suggests that the use of amendments such as castor cake and biochar have the tendency to accelerate the pH of soil significantly. The EC content of the soil also range from 55 dS/m in treatment 70% castor cake + 30% biochar- 10t/ha to 68 in the control field. Soil organic carbon ranges from 04 g/kg in control to 1.4 g/kg in the field with the application of 70% castor cake + 30% biochar-10t/ha. Furthermore, the combined application of castor cake and biochar significantly increased soil N, P and K . This improvement in soil fertility is consistent with findings from previous studies showing that the use of organic amendments improves soil organic matter, N, P, K, Ca and organic carbon (Adeniyan & Ojeniyi, 2005; Adenawoola & Adejoro, 2005). The significant increase in soil nutrients especially N, P, K and organic carbon in organic amendments compared with NPK fertilizer and control treatments may be due to leaching in NPK fertilizer treated plots (Adekiya et al., 2020).

In the second planting, the results show that pH ranges from 4.9 in control to 6.0 in the field treated with 60% castor cake + 40% biochar- 10t/ha. The total nitrogen content also ranges from 0.1 g/kg in the control plot to 0.3 g/kg from the plot that received 70% castor cake + 30% biochar-10t/ha. The potassium content ranges from 0.1 cmol/kg in the control plot to 0.4 cmol/kg from the plot treated with Castor cake 70%+ biochar 30% and 30% castor cake + 70% biochar -10t/ha. The higher levels of N, P, K, and OC obtained from the treatments with castor cake and biochar when compared to NPK fertilized plants and control plots was in line with the report of Palansooriya et al. (2019) which suggested that biochar's recalcitrant nature ensures long-term nutrient retention in soils. Similarly, Adekiya et al. (2020) attributed the decline in NPK's effectiveness to nutrient leaching, whereas organic amendments like biochar and castor cake release nutrients slowly, sustaining soil fertility over time

4. Conclusion

The study revealed that the combined application of castor cake and biochar improved the overall growth and yield characteristics. This suggests that biochar and castor cake have high potential for building up residual nutrients in the soil with time. The combined effects of castor cake and biochar on soil fertility were positive; it increased the soil available P, N, Exchangeable K and organic carbon of the soil after harvesting compared with NPK and control.

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Table 7: Physical and chemical properties of experimental soil (Pot Experiment) at harvest after first and second planting

Treatment	pH	EC (dS/m)	Org C	N	P (mg/ kg)	K c mol/ kg	Sand	Silt	Clay
			----- g/kg ------				--------- % -----------		
First Planting									
Control	4.9d	58e	0.7e	0.1c	14.2d	0.2c	81a	12a	7c
C50+ B50	5.2c	70b	1.7a	0.2b	26.4b	0.3b	78b	12a	10a
C60+B40	6.0a	66c	1.3c	0.2b	34.2a	0.3b	80a	11a	9a
C70+B30	5.2c	61c	1.7a	0.3a	29.4b	0.4a	81a	10a	9a
C40+B60	5.5b	71b	1.5b	0.2b	25.2b	0.4a	78b	12a	10a
C30+B70	5.2c	76a	1.4b	0.2b	28.1b	0.4a	81a	11a	8b
NPK	5.0d	61d	1.0d	0.1c	18.3c	0.4a	82a	10a	8b
Second Planting									
Control	5.2f	70a	1.1f	0.1c	18.1g	0.2c	80a	12a	8c
C50+ B50	6.1a	71a	1.5c	0.2b	19.8e	0.3b	81a	12a	7c
C60+B40	5.8c	62d	1.3d	0.2b	21.6c	0.3b	78b	12a	10a
C70+B30	5.9b	59e	1.6b	0.2b	23.6b	0.4a	81a	9b	9b
C40+B60	5.5d	71a	0.5g	0.2b	24.1a	0.4a	80a	11a	10a
C30+B70	5.8c	68b	1.9a	0.3a	20.8d	0.3b	80a	10a	10a
NPK	5.3e	66c	1.2e	0.2b	19.2f	0.3b	79b	11a	10a

Mean followed by the same letter(s) in a column are not significantly different at ($P<0.05$) by Duncan's Multiple Range Test (DMRT). C- Castor cake; B-Biochar

Table 8: Physical and chemical properties of experimental soil (Field) for first and second planting.

Treatment	pH	EC	Org C	N	P	K	Sand	Silt	Clay
		(dS/m)	----- g/kg ------		(mg/ kg)	c mol/ kg	--------- % -----------		
				First Planting					
Control	5.2e	68a	0.4d	0.1d	19.2f	0.2e	81a	11a	8a
C50+ B50	5.3d	57d	1.4a	0.2a	24.5b	0.3b	80a	10a	9a
C60+B40	6.3a	62c	1.1c	0.2a	23.6d	0.3b	79b	12a	10a
C70+B30	5.3d	55e	1.4a	0.2a	25.7a	0.3b	80a	10a	9a
C40+B60	5.7b	56e	1.3b	0.2a	21.9e	0.3b	78b	12a	9a
C30+B70	5.5c	65b	1.3b	0.2a	24.1c	0.4a	81a	10a	10a
NPK	5.3d	58d	1.2c	0.2a	18.1g	0.4a	80a	11a	10a
				Second Planting					
Control	4.9d	76a	0.7e	0.1c	16.1d	0.1b	81a	12a	7c
C50+ B50	5.2c	70b	1.7a	0.2b	24.5b	0.3a	78b	12a	10a
C60+B40	6.0a	61d	1.0d	0.2b	23.6b	0.2b	80a	10a	9abc
C70+B30	5.1c	71b	1.7a	0.3a	25.7a	0.4a	81a	12a	9abc
C40+B60	5.5b	58e	1.5b	0.2b	21.9c	0.3a	78b	12a	10a
C30+B70	5.2c	50f	1.3c	0.2b	24.1b	0.4a	82a	11a	7c
NPK	5.2c	66c	1.3c	0.1c	19.2c	0.3a	82a	10a	8ac

Mean followed by the same letter(s) in a column are not significantly different at ($P<0.05$) by Duncan's Multiple Range Test (DMRT). C- Castor cake B-Biochar

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