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Growth Responses and Yield of Two Varieties of *Corchorus* to Biochar and Organic Fertilizers as Soil Amendments

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ABSTRACT: This study assessed the effects of biochar and organic fertilizers on the growth and yield of Corchorus varieties (NHCo-01 and NHCo-02). The treatments: two commercially available organic fertilizers coded A and B, biochar (C), and combination of all the three (D), each applied at 0, 5, 10, and 15 t ha^{-1} two weeks before sowing. The experiment followed Randomized Complete Block Design (RCBD) with three replicates. Data obtained were analyzed using ANOVA ($p < 0.05$). Results showed that organic amendments significantly improved growth and yield compared to control. A at 15 t ha^{-1} produced the highest yields, with 17.17 g/pot for NHCo-01 and 17.57 g/pot for NHCo-02. The yield ranking was A > D > C > B for NHCo-01 and A > C> D > B > Control for NHCo-02. Biochar enhanced NHCo-02 yield more than Apata fertilizer (B), suggesting varietal differences in nutrient uptake. Although the combination improved performance, it was less effective than A alone. This study highlights the importance of organic amendments for optimizing Corchorus growth and productivity, with A organic fertilizer emerging as the best amendment for both varieties.

Keywords: Corchorus varieties, Biochar, Organic fertilizers, Growth, Yield.

Introduction

Corchorus, a leafy vegetable from the Malvaceae family, is widely valued for its culinary, medicinal, and economic benefits. When cooked, it has a mucilaginous texture, making it a key ingredient in soups and stews (Tareq *et al*., 2020). Beyond its dietary significance, Corchorus is also an important source of natural fiber, used in jute production (Mukul *et al.,* 2021). Rich in essential nutrients, Corchorus contains thiamine, riboflavin, niacin, folate, and antioxidants, all of which contribute to reducing the risk of cardiovascular diseases, cancer, diabetes, and hypertension (Baiyeri *et al*., 2023a). Studies have also highlighted its high phenolic content, which is linked to a lower incidence of type-2 diabetes (Awuchi *et al*., 2020). With its abundant iron and folate content, Corchorus is beneficial for preventing anemia (Ahmed, 2021). Traditionally, its root scrapings have been used to relieve toothaches, while seed-based concoctions serve as natural purgatives (Baiyeri *et al*., 2023a).

Despite its nutritional and medicinal value, Corchorus cultivation is often constrained by poor soil fertility. Addressing this challenge is essential for maximizing its agricultural potential.

Enhancing soil productivity is crucial for sustainable agriculture, and organic amendments offer a viable solution. Organic materials play a key role in restoring soil organic carbon, improving nutrient content, and boosting plant growth.

One of the most effective methods for improving soil fertility is the incorporation of plant residues, manure, compost, and biochar (Samoraj *et al*., 2023). Biochar, a carbon-rich material produced by heating organic matter at temperatures between 300 and 600 °C, has gained significant attention for its soil-enhancing properties

(Samoraj *et al*., 2022). When applied to soil, biochar improves fertility, enhances water retention, reduces greenhouse gas emissions, and aids in carbon sequestration (Tijani *et al*., 2023).
As an environmentally friendly and cost-effective soil amendment, biochar contributes to raising soil pH levels, improving cation exchange capacity, and enhancing crop productivity (Mansoor *et al*., 2021). When combined with organic fertilizers, biochar further enhances the physical, chemical, and biological properties of the soil, making it a sustainable and renewable option for long-term agricultural productivity (Virk *et al*., 2021).

Materials and methods

Experimental setup and description of the study site: This study was conducted in the screenhouse of the Faculty of Agriculture, Obafemi Awolowo University (OAU), Ile-Ife, Nigeria. Bulk surface soil samples (0–15 cm depth) were collected from the back of the Institute of Ecology and Environmental Studies. The samples were air-dried for seven days and sieved using a 2 mm sieve before use. Three soil amendments were utilized in this study: Organic Fertilizer (A), obtained from Alesinloye Market, Ibadan, Organic Fertilizer (B), sourced from the Oyo State Agricultural Development Programme, Apata, Ibadan, and Biochar, produced from Milicia excelsa (C). Each soil amendment was analyzed for its chemical properties using standard laboratory methods. The experiment comprised four treatments: A (100%), B (100%), C (100%), and D- mixture of A, B, and C, and control (without amendment) was also included. These treatments were applied at four different rates: 0, 5, 10, and 15 t ha^{-1}. Each treatment was replicated three times in a Completely Randomized Block Design (CRBD), resulting in 96 experimental units (polythene pots). Each pot was filled with 3 kg of the prepared soil, and amendments were applied two weeks before sowing to enhance mineralization. Seeds of Corchorus varieties (NHCo-01 and NHCo-02) were obtained from the National Horticultural Research Institute (NIHORT), Ibadan, Nigeria. The seeds were sown directly into each pot and thinned to two plants per pot at two weeks after sowing (WAS). Growth performance data were collected weekly from 3 WAS to 6 WAS,
including (Plant height, Number of leaves, and Stem girth). At 6 WAS, fresh biomass was measured immediately after harvest using a weighing balance. The fresh shoots were then oven-dried at 70°C to a constant weight, after which the dry biomass yield was recorded. A repeat experiment was conducted to evaluate the residual effects of soil amendments on the growth and yield of the two Corchorus varieties. The properties of soil, biochar, and organic fertilizers were analyzed using standard procedures: pH Measurement determined in a 1:1 soil-water suspension using a glass electrode pH meter, Total Nitrogen measured using the macro-Kjeldahl method, available phosphorus, extracted via the ascorbic acid-molybdate blue method and quantified using an Atomic Absorption Spectrophotometer (AAS). Organic carbon, analyzed using the Walkley-Black wet oxidation method, Exchangeable Base Cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), extracted and determined using a Bulk Scientific 210/211 VGP Atomic Absorption Spectrophotometer, Na^{+} and K^{+} were also quantified using a Genway flame photometer. Collected data were subjected to analysis of variance (ANOVA) using GraphPad 5.0 statistical software. Treatment means were separated at a 95% confidence level ($p \leq 0.05$) to determine significant differences.

Results

Properties of soil and the soil amendments used before planting in experimental sites: The physical and chemical properties of the soil at the experimental sites before planting, along with the analysis of biochar and two organic fertilizers used in the study, are summarized in Tables 1 and 2. The findings in this study show that the experimental site's soil is sandy loam (79% sand, 8% clay, 13% silt), offering good drainage but limited nutrient retention. It has a slightly alkaline pH (7.9) and contains moderate organic carbon (15.55 g/kg), nitrogen (1.48 g/kg), and phosphorus (10.77 mg/kg). The cation exchange capacity (CEC) is low (4.23 cmol/kg), meaning the soil has limited ability to retain essential nutrients. Micronutrient levels include Mn (156 mg/kg), Fe (143 mg/kg), Cu (5.63 mg/kg), and Zn (11.96 mg/kg). In table 2, three amendments; A, B, and C, vary in their chemical properties and impact on soil health. Alesinloye (pH 7.9), high phosphorus (265.28 mg/kg) and potassium, making it ideal for root growth and flowering crops, while Apata (pH 7.9), balanced nutrients with higher acidity (0.40 cmol/kg), which may slightly lower soil pH over time, but Milicia excelsa biochar (pH 7.08), rich in organic carbon (157.32 g/kg) and nitrogen (10 g/kg), promoting long-term fertility. However, high sodium (877.27 cmol/kg) could cause soil salinity issues. Each amendment has unique benefits: Soil amendment A boosts phosphorus and potassium, soil amendment B provides moderate nutrients but increases acidity, and soil amendment C enhances carbon retention and nitrogen supply but may lead to salinity concerns.

Table 1: Soil properties prior to experiment

Parameters	Mean
pH (1:1 soil / water)	7.9
Organic Carbon (g kg^{-1})	15.55
Total Nitrogen (g kg^{-1})	1.48
Available Phosphorus (mg kg^{-1})	10.77
Exchangeable Acidity (cmol kg^{-1})	0.80
H^+	0.40
Al^{+++}	0.40
Exchangeable Basicity (cmol kg^{-1})	4.23
Ca^{++}	1.74
Mg^{++}	1.14
K^+	0.24
Na^+	1.11
Mn (mg kg^{-1})	156.00
Fe (mg kg^{-1})	143.00
Cu (mg kg^{-1})	5.63
Zn (mg kg^{-1})	11.96
Sand (g kg^{-1})	790.0
Silt (g kg^{-1})	130.0
Clay (g kg^{-1})	80.00
Textural class	**Sandy Loam**

Table 2: Chemical compositions of the organic fertilizers and *Milicia excelsa* biochar

Parameters	A	B	C
C (g kg^{-1})	79.26	74.75	157.32
N (g kg^{-1})	6.97	5.68	10.00
P (mg kg^{-1})	265.28	172.41	207.00
Ca (cmol kg^{-1})	84.45	46.41	10.57
Mg (cmol kg^{-1})	39.66	11.02	2.91
K (cmol kg^{-1})	61.57	10.90	12.48
Na (cmol kg^{-1})	16.43	3.62	877.27
Mn (mg kg^{-1})	4.00	2.34	2.60
Fe (mg kg^{-1})	163.0	131.0	110.0
Cu (mg kg^{-1})	2.60	1.73	1.66
Zn (mg kg^{-1})	0.77	1.00	0.79

Legend: A and B = Two commercial organic fertilizers, C = *Milicia excelsa* biochar

Growth and yield of Corchorus varieties

Analysis of number of leaves in Corchorus varieties under different treatments and application rates: This analysis examines how different organic fertilizer and biochar treatments influence leaf growth in two Corchorus varieties (NHCo-01 and NHCo-02) over two planting periods. The number of leaves was recorded from 3 to 6 weeks after sowing (WAS) under different application rates (0, 5, 10, and 15 t ha^{-1}). These are charts to visualize how the number of leaves changed over the different organic fertilizers and Biochar treatments and application rates.

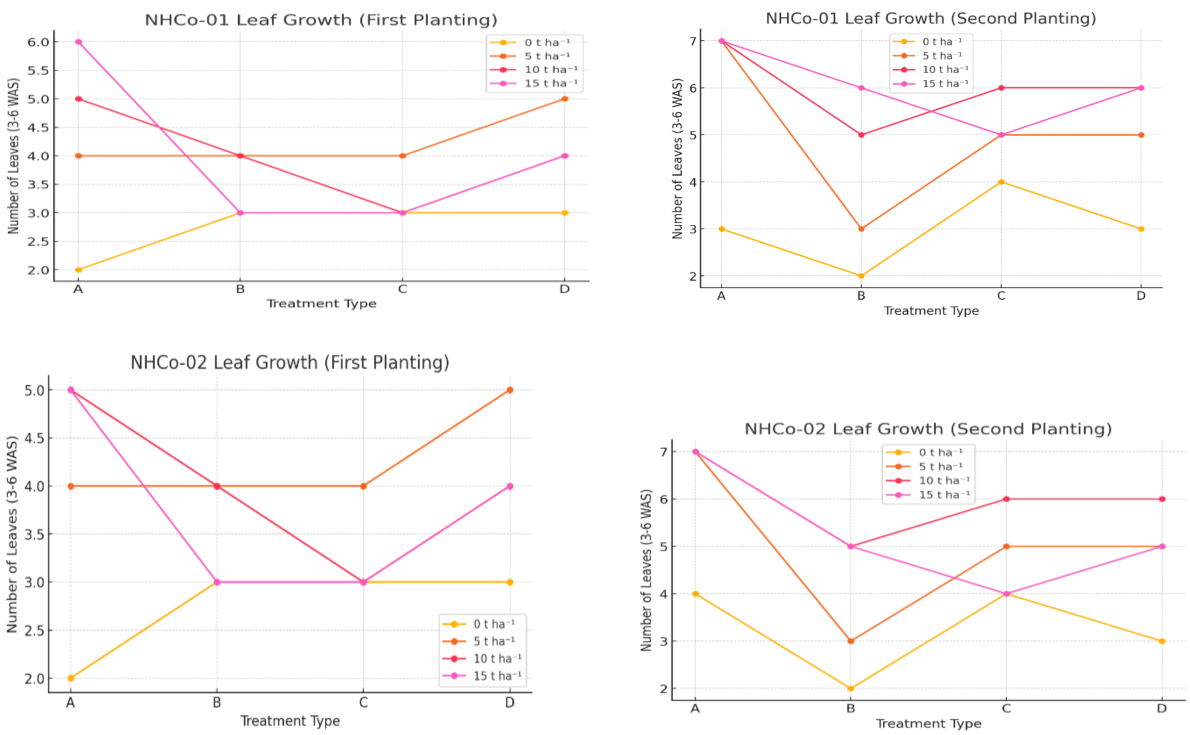


Figure 1: Effect of organic fertilizer (A), organic fertilizer (B), Biochar (C), and a Combination (D) of A, B, and C, on the number of leaves of two Corchorus variety (NHC0-0I). X I and X2 represent the first and second planting results. Legend: NHC0-01 = National Horticultural Corchorus One.A = Alesinloye Organic Fertilizer, B = Apata Organic Fertilizer, C = Milicia excelsa Biochar D = combination of all the treatments, t ha-[1] = Tonne per hectare.

Effect of treatments on leaf growth: The pot treatment soil organic fertilizer A consistently resulted in the highest number of leaves across all application rates, particularly at 5 t ha⁻¹ and 15 t ha⁻¹. This suggests that organic fertilizers provide adequate nutrients for leaf production. Treatment D (biochar + two organic fertilizers mix) showed significant improvement at 10 t ha⁻¹, especially in NHCo-02, indicating that soil organic amendment C might enhance nutrient retention and availability.

Effect of application rate on leaf growth: At low application (0 t ha⁻¹), the plants had the fewest leaves at 0 t ha⁻¹, confirming that fertilizers are necessary for optimal leaf development. Moderate application (5 t ha⁻¹ & 10 t ha⁻¹) showed a rapid increase in leaves, with 5 t ha⁻¹ showing high performance across most treatments. High application (15 t ha⁻¹). For both varieties, 15 t ha⁻¹ resulted in the highest leaf count, particularly with Treatment A in NHCo-01 and NHCo-02.

First vs. second planting: The second planting generally had more leaves than the first, especially with Treatment A and Treatment D, possibly due to residual soil nutrients from the first planting. NHCo-01 had slightly higher leaf counts than NHCo-02, indicating possible varietal differences in nutrient uptake. Pots treatment soil amendment A at 15 t ha⁻¹ produced the highest number of leaves, making it the most effective treatment. Pots treatment with D performed best at 10 t ha⁻¹, suggesting that treatment C enhances nutrient efficiency. Higher fertilizer application rates (10-15 t ha⁻¹) generally led to increased leaf production. The second planting produced more leaves than the first, possibly due to improved soil conditions.

Plant height analysis for Corchorus varieties (NHCo-01 & NHCo-02): This study analyzed the effect of two organic fertilizers (A and B) and biochar (C) on the plant height of two Corchorus varieties (NHCo-01 and NHCo-02) over two planting seasons as shown in Figure 1. Measurements were taken from 3 to 6 weeks after sowing (WAS) at four application rates (0, 5, 10, and 15 t ha⁻¹).

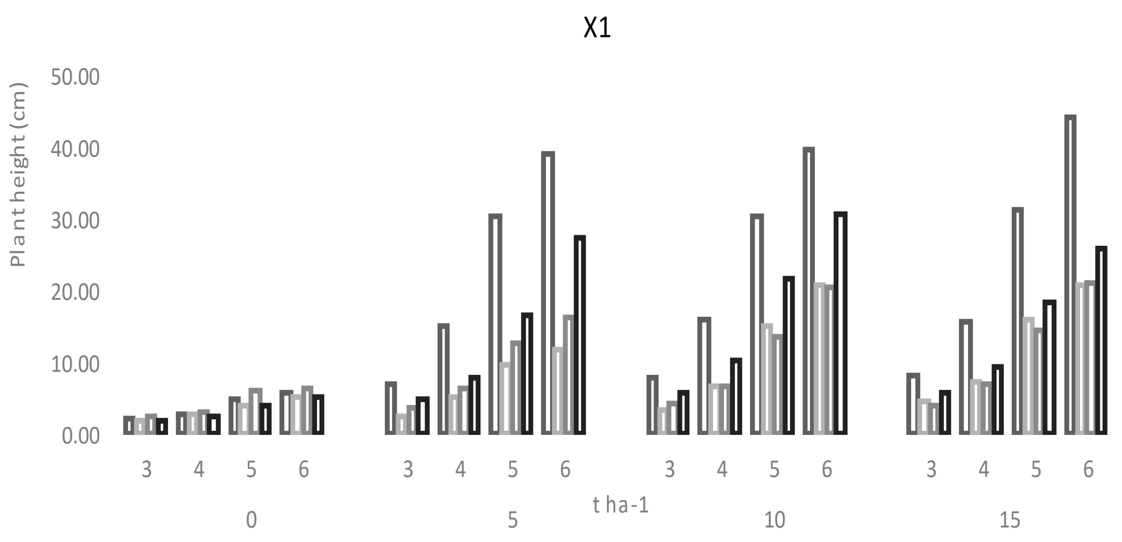
NHCo-01 Plant height trends, in first planting, at 0 t ha⁻¹, plant height followed C > A > B > D, with treatment C producing the tallest plants (8.0 cm at 6 WAS). At 5 t ha⁻¹, pots treated with soil amendment A showed the best performance. At 10 and 15 t ha⁻¹, pots treatment with A recorded the tallest plants (50.0 cm at 6 WAS), followed by D > B > C. In the second planting, at 0 t ha⁻¹, plant height was lower (2.3 – 2.6 cm). At 5 t ha⁻¹, the trend was A > D > B > C. At 10 and 15 t ha⁻¹, treatment A remained the most effective.

In the HCo-02 plant height trends, the First Planting, at 0 t ha⁻¹, pots treatment B produced the tallest plants (8.5 cm at 6 WAS). At 5 t ha⁻¹, the order was A > D > B > C. At 10 and 15 t ha⁻¹, treatment A recorded the best plant growth, followed by D > C > B.

Second Planting at 0 t ha⁻¹, plant height followed A > C > B > D. At 5 t ha⁻¹, the trend was A > D > C > B. At 10 and 15 t ha⁻¹, treatment A consistently produced the tallest plants.

Higher fertilizer rates (10 – 15 t ha⁻¹) led to increased plant height. Treatment A was the most effective across both varieties and planting seasons. Treatment B was effective at lower rates but was outperformed at higher levels. Pots treated with C showed strong performance at 0 t ha⁻¹ but was less effective at higher application rates. The combination of amendments D improved growth but did not outperform treatment A alone.

NHCo-01



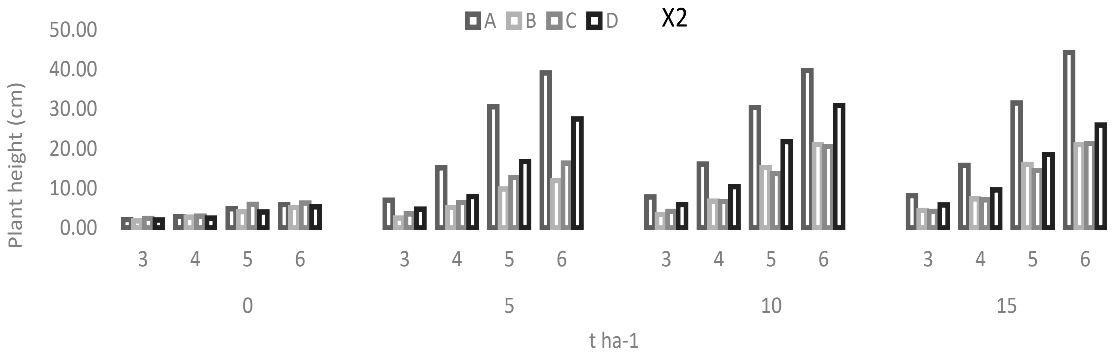
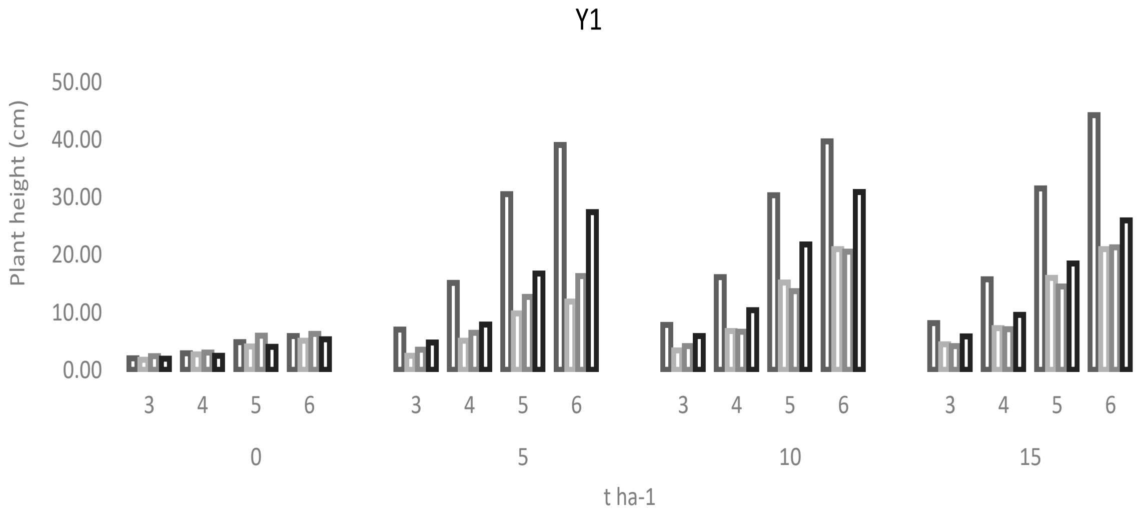


Figure 2: Effect of organic fertilizer (A), organic fertilizer (B), Biochar (C), and a Combination (D) of A, B, and C, on the plant height of two Corchorus variety (NHCO-01). X1 and X2 represent the first and second planting results.
Legend: NHCO-01 = National Horticultural Corchorus One.
A = Alesinloye Organic Fertilizer, B = Apata Organic Fertilizer, C = Milicia excelsa Biochar
D = combination of all the treatments, t ha^{-1} = Tonne per hectare.

NHCo-02



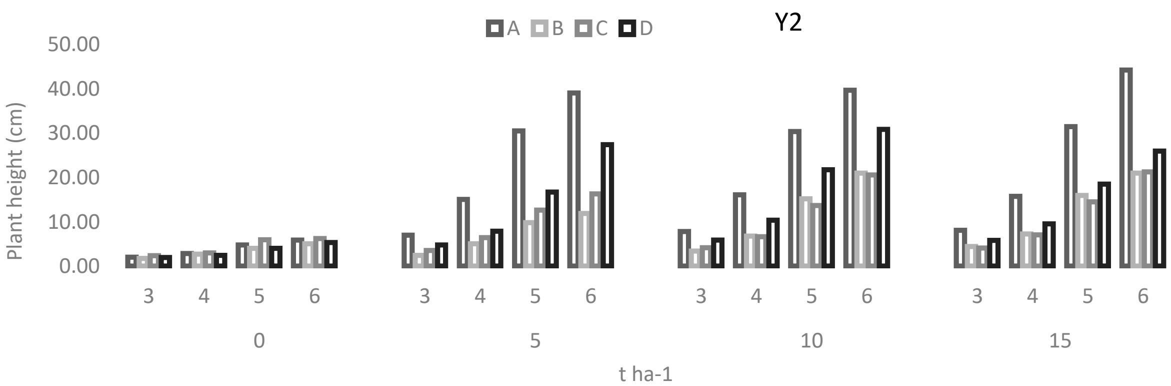


Figure 3: Effect of Organic Fertilizer (A), Organic Fertilizer (B), Biochar (C), and a Combination (D) of A, B, and C, on the plant height of two Corchorus variety (NHCO-02). Y1 and Y2 represent the first and second planting results.
Legend: NHCO-02 = National Horticultural Corchorus Two.
A = Alesinloye Organic Fertilizer, B = Apata Organic Fertilizer, C = Milicia excelsa Biochar
D = combination of all the treatments, t ha^{-1} = Tonne per hectare.

Effects of organic fertilizers and Milicia excelsa Biochar on the yield of two Corchorus varieties (NHCO-01 and NHCO-02) during first and second planting: The mean fresh and dry matter yields of Corchorus varieties NHCO-01 and NHCO-02 during the first and second planting cycles are presented in Tables 3 & 4.

NHCO-01 yield performance: During the first planting cycle, plants treated with organic fertilizer A at a rate of 15 t ha^{-1} recorded the highest fresh and dry weights, measuring 17.17 g/pot and 6.90 g/pot, respectively. In contrast, lowest fresh and dry weights (0.50 g/pot and 0.20 g/pot) were observed in plants receiving no fertilizer treatment (0 t ha^{-1}). For the second planting cycle, NHCO-01 plants treated with organic fertilizer A at 15 t ha^{-1} again exhibited the highest fresh and dry weights, with values of 15.50 g/pot and 6.20 g/pot, respectively. The lowest fresh and dry weights (0.40 g/pot and 0.20 g/pot) were recorded at 0 t ha^{-1}.

NHCO-02 yield performance: The fresh and dry matter yields of NHCO-02 followed a similar trend. During the first planting cycle, plants treated with organic fertilizer A at 15 t ha^{-1} achieved the highest fresh and dry weights, 17.57 g/pot and 7.03 g/pot, respectively. Conversely, the lowest fresh and dry weights (0.50 g/pot and 0.26 g/pot) were recorded at 0 t ha^{-1}. In the second planting cycle, NHCO-02 plants treated with organic fertilizer A at 15 t ha^{-1} continued to produce the highest fresh and dry weights, reaching 15.60 g/pot and 6.20 g/pot, respectively. The lowest fresh and dry weights (0.40 g/pot and 0.24 g/pot) were again recorded at 0 t ha^{-1}.

Table 3: Fresh and dry matter yields of NHCO-01 during first and second planting

Treatments	Rates (t ha^{-1})	Fresh (1)	Dry (1)	Fresh (2)	Dry (2)
A	0	0.70e	0.30d	0.65e	0.26d
	5	16.30abc	6.53ab	14.20abc	5.42ab
	10	15.67abc	6.27ab	13.56abc	5.30ab
	15	17.17a	6.90a	15.50a	6.20a
B	0	0.53e	0.27d	0.51e	0.25d
	5	14.73abc	5.73ab	12.62abc	4.54ab
	10	15.43abc	6.20ab	13.50abc	4.56ab
	15	17.00ab	6.80a	15.30ab	5.56a
C	0	0.50e	0.20d	0.40e	0.20d
	5	13.57c	5.40b	12.47c	4.40b
	10	14.87abc	5.97ab	13.80abc	4.50ab
	15	16.57abc	6.63ab	14.56abc	5.30ab
D	0	0.63e	0.30d	0.53e	0.23d
	5	16.10abc	6.43ab	14.30abc	5.20ab
	10	14.97abc	6.07ab	12.69abc	5.00ab
	15	16.67abc	6.63ab	14.40abc	5.30ab

Mean values within the same column that share identical letters are not significantly different, as determined by Duncan's Multiple Range Test at $p < 0.05$.

Legend: NHCo-01 = National Horticultural Corchorus 1, A = Alesinloye organic fertilizer, B = Apata organic fertilizer, C = Milicia excelsa biochar, D = combination of all the treatments, t ha^{-1} = Tonne per hectare.

Table 4: The fresh and dry matter yields of NHCO-02 during first and second planting

Treatments	Rates (t ha^{-1})	Fresh (1)	Dry (1)	Fresh (2)	Dry (2)
A	0	0.80e	0.37d	0.60e	0.32d
	5	16.37abc	6.57ab	14.37abc	4.23ab
	10	15.90abc	6.37ab	13.70abc	3.78ab
	15	17.57a	7.03a	15.60a	6.20a
B	0	0.63e	0.30d	0.42e	0.20d
	5	10.30d	4.13c	8.20d	3.40c
	10	14.73abc	5.90ab	12.72abc	4.60ab
	15	16.93ab	6.80a	14.40ab	5.50a
C	0	0.50e	0.26d	0.40e	0.24d
	5	14.17bc	5.67ab	12.16bc	4.30ab
	10	15.07abc	6.07ab	12.50abc	4.50ab
	15	16.73abc	6.70ab	13.71abc	4.61ab
D	0	0.57e	0.27d	0.49e	0.25d
	5	15.53abc	6.23ab	13.10abc	5.20ab
	10	14.40abc	5.77ab	12.52abc	4.60ab
	15	16.37abc	6.57ab	14.43abc	6.00a

Mean values within the same column that share identical letters are not significantly different, as determined by Duncan's Multiple Range Test at $p < 0.05$.

Legend: NHCo-02 = National Horticultural Corchorus 2, A = Alesinloye organic fertilizer, B = Apata organic fertilizer, C = Milicia excelsa biochar, D = combination of all the treatments, t ha^{-1} = Tonne per hectare.

Discussion

The application of organic soil amendments (A) (Alesinloye organic fertilizer), (B) (Apata organic fertilizer), (C) (Milicia excelsa biochar), and combination of the three treatments (D) significantly influenced plant height and the number of leaves compared to the control. Organic materials improve soil structure, enhance microbial activity, and provide essential nutrients, which contribute to plant growth and yield improvements (Kumar *et al*., 2022). For the Corchorus NHCo-01 variety, plants treated with A exhibited the highest mean plant height of 46.00 cm in the first planting and 50.00 cm in the residual experiment. Conversely, the control treatment recorded the lowest mean plant height in both trials, reinforcing the importance of organic amendments in soil fertility improvement (FAO, 2023).

In the Corchorus NHCo-02 variety, plants treated with A attained the highest plant height (46.00 cm) in the first planting and 47.00 cm in the repeat experiment. The combine treatments (D) promoted the highest number of leaves (27) in the first planting, whereas treatment (A) pots recorded the highest mean number of leaves (29) in the repeat experiment. The residual effects of soil amendments from the first planting likely contributed to increased plant height and leaf production, further demonstrating the long-term benefits of organic fertilizers and biochar (Sarker *et al*., 2021).

The overall growth performance in both Corchorus varieties suggests that treatment A (Alesinloye organic fertilizer), Treatment B (Apata organic fertilizer), and C (biochar) improved soil nutrient availability and plant growth. However, Corchorus NHCo-01 exhibited superior mean plant height, potentially due to genetic traits, while no significant differences were observed in the number of leaves between the two varieties in both planting cycles.

In NHCo-01 variety, the highest mean fresh yield (17.17 g/pot) was obtained at 15 t ha^{-1} of treatment A alone. Similarly, in the repeat experiment, the highest mean fresh yield (15.50 g/pot) was also recorded under the same treatment and application rate. In contrast, the lowest fresh mean weight was recorded in the control treatment.

For NHCo-02 variety, pots with treatment A also exhibited the highest mean fresh yield (17.57 g/pot) at 15 t ha^{-1}, with a slightly lower yield (15.60 g/pot) in the repeat experiment. Again, the lowest yield was observed in control pots. The significant differences in mean yield across treatments in both Corchorus varieties suggest that organic amendments enhance biomass accumulation and productivity by improving soil nutrient retention, microbial activity, and organic matter content (Chowdhury *et al*., 2023).

The positive response of Corchorus varieties to organic amendments is consistent with studies showing that composted organic fertilizers significantly increase crop yield due to improved nutrient release and soil structure enhancement (Wang *et al*., 2022). The observed variation between NHCo-01 and NHCo-02 in terms of yield and growth parameters suggests potential differences in their nutrient uptake efficiency and adaptation to soil amendments.

The findings highlight the role of organic fertilizers and biochar in enhancing soil fertility and promoting sustainable vegetable production. The residual effects observed in the repeat experiment underscore the long-term benefits of organic amendments, reducing the need for chemical fertilizers and improving soil health over time. These results align with global efforts to promote organic farming and mitigate the adverse environmental impacts of synthetic fertilizers (FAO, 2023).

Moreover, integrating biochar with organic fertilizers has been shown to improve soil carbon sequestration, enhance water retention, and boost microbial diversity, making it a valuable strategy for sustainable crop production (Lehmann et al., 2021). Future research should explore the long-term effects of organic amendments on soil microbial dynamics and nutrient cycling in Corchorus cultivation.

This study demonstrates that organic soil amendments, particularly organic soil amendment A and the combination of the two other organic soil amendments, significantly enhance Corchorus growth and yield. The residual effects observed in the repeat experiment indicate that organic fertilizers and biochar can improve soil fertility beyond a single cropping cycle. These findings support the adoption of organic amendments as a sustainable alternative to synthetic fertilizers, contributing to improved crop productivity and environmental sustainability.

Acknowledgement

Not applicable

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