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Research article

Growth and yield attributes of cowpea accessions grown under different soil amendments in a derived Savannah zone

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Abstract: Malnutrition and severe food insecurity are on the rise in sub-Saharan Africa. Cowpea (*Vigna unguiculata* L.), an indigenous plant from Africa with a good nutritional composition, can be a strategic tool in the fight against hunger. Hence, the objective of this study was to assess the yield response of different cowpea accessions to soil amendments. The study adopted a 5 × 4 factorial in a randomized complete block design with three replications. The factors comprise five cowpea accessions (BBL, BBR, BCB, EBL and EBC) and four soil amendments (poultry manure [PoM], pig manure [PgM], NPK 15:15:15 fertilizer and control). There are significant differences among the cowpea accessions in all the studied attributes. The stability and mean performance analyses revealed that the top-ranked accessions were EBL and EBC, while BBL, BBR and BCB were below the population mean. The ranking order of the soil amendments was PoM > PgM > population mean > NPK > control. Accession EBL amended with PoM gave the highest plant weight (106.4 g), which was statistically similar to the same accessions amended with NPK (104.9 g) and PgM (100.4 g), but significantly higher than the other treatment combinations. Plant weight has a significant and positive correlation with pod length (r = 0.919**), number of leaves (0.623**), vine length (0.361**) and hundred seed weight (0.329*). The findings of this study showed that cowpea accessions responded differently to the soil amendments. This study recommends the use of additional nutrients as a supplement in the production of cowpea rather than relying solely on its self-fixed nitrogen.

Keywords: food security; genetic diversity; manure; sustainability; *Vigna unguiculata* L. Walp

1. Introduction

Malnutrition and food insecurity is a high priority for most global and national governments. While malnutrition and food insecurity are decreasing globally, the situation in Nigeria is the opposite. Using a three-year average, FAOSTAT [1] estimated that the prevalence of malnutrition in Nigeria increased from 6.6% in 2006–2008 to 12.7% in 2019–2021. Furthermore, severe food insecurity grew from 11% in 2014–2016 to 19% in 2019–2021. This problem is not unique to Nigeria but is shared by the majority of Africa's developing nations.

Cowpea (*Vigna unguiculata* [L.] Walp), a multipurpose food security crop, has a vital role to play in improving malnutrition and food insecurity conditions in most developing countries. Cowpea is indigenous to Africa with high genetic diversity in different parts of the continent [2–4]. The crop can be consumed in a variety of ways, while its nutritional makeup has an important role in the battle against malnutrition. African countries dominate global cowpea production, with Nigeria (3.6 million metric tons), Niger (2.7 million metric tons) and Burkina Faso (0.7 million metric tons) leading the way in 2021 [5]. Despite its global supremacy in cowpea production, Africa's cowpea yield has yet to attain its full potential and remains lower than the global average [6,7].

Land expansion rather than an improvement in yield per unit of area has been the primary driver of agricultural productivity in Nigeria [8]. Due to competition from other land use activities, an increase in yield from expanding the land is not sustainable. Hence, increasing yield output per unit area is preferable to expanding land area [9]. Planting high-yielding cultivars or enhancing soil productivity can both improve yields. Low soil productivity is a major factor in the low yields of cowpeas. In West Africa, low soil productivity had been made worse by the lack of and high cost of mineral fertilizers, as well as the little usage of external agriculture inputs [10]. As a result, there is a need to use locally available and easily accessible soil amendments to boost soil productivity in relation to cowpea production. Organic soil amendments like poultry droppings and pig waste are readily available in Nigeria due to the high demand for these animal proteins. The use of these animal wastes in cowpea production will help reduce environmental pollution due to improper waste disposal.

The addition of organic soil amendments has been reported to improve crop yield, soil water holding capacity and other soil physicochemical properties [11–13]. Improving cowpea yield through the addition of organic soil amendments will help reverse the upward trend in the prevalence of malnutrition and food insecurity in Nigeria. The objective of this study was to assess the yield response of different cowpea accessions to soil amendment.

2. Materials and methods

2.1. Description of the experimental site

The field experiment took place at the University of Nigeria's Department of Crop Science research farm in Nsukka, Enugu State, Nigeria. Nsukka (07°29 N, 06°51 E, and 400 miles above sea level) is characterized by lowland humid tropical conditions with a bimodal annual rainfall distribution that ranges from 1,155 to 1,955 mm, a mean annual temperature of 29 ℃ to 31 ℃, and a relative humidity of 69% to 79% [14]. The weather data for the duration of the study obtained from the Meteorological Unit, Department of Crop Science (Figure 1) is typical of the region with no threat to the cowpea's growth and yield. The soil at the experimental site, classified as Ultisol according to the soil taxonomy of the USDA [15], is a sandy clay loam that contains low organic carbon (≈1.46%) and low contents of nitrogen, phosphorous, basic cations (potassium, magnesium, calcium) and base saturation contents but high exchangeable acidity [16]. Nsukka, Enugu State, is located in the derived Savannah Zone.

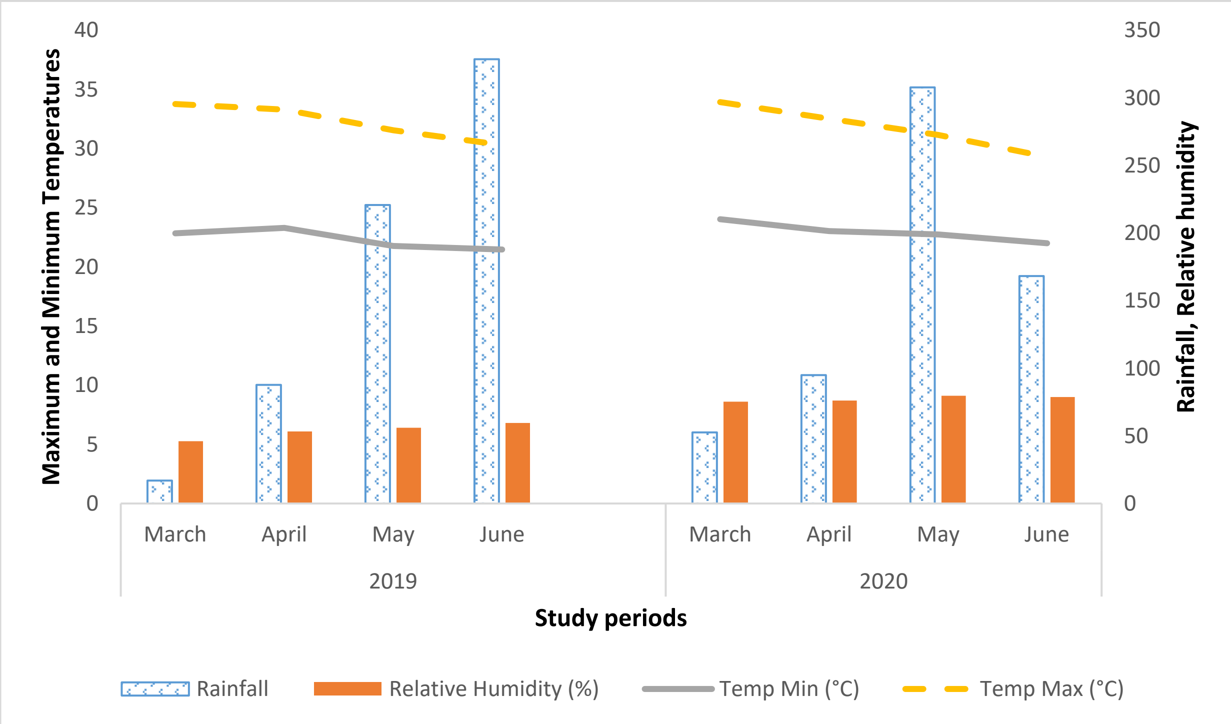

Figure 1. Weather data for the study periods.

2.2. Experimental design, layout, and treatments

The study adopted a 5 × 4 factorial design in a randomized complete block design with three replications. Factor A consists of five cowpea accessions obtained from Benue State and Enugu State (see Table 1). Factor B was four soil amendments, which included two organic manure sources (poultry manure and pig manure), NPK 15:15:15 fertilizer (positive control) and no amendment (negative control).

A field measuring 40 m x 12.6 m (504 m^2) was manually prepared and demarcated into three equal blocks (replications). Each block contained 20 plots (3 m × 1.6 m), with 0.5m between plots and 1m between blocks. Each plot contained 32 plants that represented a treatment combination. The dry organic manures were applied at 3 kg/ha two weeks before planting, while NPK (15:15:15) fertilizer was applied at 0.5 kg/ha at planting. The study duration was from March 2019 to June 2019 and March 2020 to June 2020.

2.3. Data collection

Data were collected from the eight middle sampling plants. The number of leaves (NL) was obtained by counting, while vine length (VL) was determined by measuring the plant from its base to the tip of the longest vine. At maturity, the plants were harvested from the base above the soil surface, bagged, taken to the laboratory and weighed to obtain plant weight (PTW) in grams. The length of the pods (PL) was measured with a meter rule in cm. 100 seeds were counted from each treatment combination and weighed to obtain the hundred seed weight (100SW).

Table 1. Characterization of cowpea accessions.

Accession Code	Pod Shape	Pod Color	Seed Color	Leaf texture	Growth Pattern	State
BBL	Straight	Brown	Black	Smooth	Determinate	Benue State
BBR	Straight	Brown	Brown	Rough	Determinate	Benue State
BCB	Straight	Brown	Cream with black spots	Smooth	Determinate	Benue State
EBL	Well curved	Purple	Black	Smooth	Determinate	Enugu State
EBC	Slightly curved	Cream/brown	Black and cream	Smooth	Determinate	Enugu State

2.4. Data analysis

The collected data for 2019 and 2020 planting seasons were combined and subjected to analysis of variance using GenStat software according to the procedure for factorial in a randomized complete block design. Significant means were separated using Fisher's least significant difference (F-LSD) at the 5% probability level. The Pearson's correlation coefficient was calculated using SPSS version 18. The graphic views of which-won-where, mean performance and stability, discriminatory and representativeness of the accessions and manure types were plotted using GGEBiplot software. GenStat software was used to perform the cluster analysis.

3. Results

3.1. The main effect of soil amendment on the growth and yield attributes of cowpea

Figure 2 revealed that the growth and yield attributes explained 97.8% (PC 1 = 91.5% and PC 2 = 6.3%) of the variation in the soil amendment regardless of the accession. In the which-won-where graphic view, each soil amendment occupied a polygon vertex. The pig manure was in the poultry manure section, while NPK and the control had their own sections. The number of leaves (NL), vine length (VL), plant weight (PWT), pod length (PL) and 100 seed weight (100SW) are within the poultry manure section. The stability and mean performance graphic view (Figure 3) ranked the soil amendments along the average tester axis (the horizontal red line with a single arrow and small circle) based on their performance and the consistency of the performance across the studied attributes. The poultry manure ranked ahead of the other soil amendments and was followed by the pig manure. The average tester ordinate (the vertical blue double arrow line) represents the population mean as well as separates the high- and low-performing soil amendments. The control amendment gave the least performance among the soil amendments, followed by the NPK amendment. The plants amended with poultry manure produced 16%, 12%, 3% and 7% higher VL, PWT, PL and 100SW respectively than the control plants. The discriminatory and representative graphic view (Figure 4) assessed the ability of the measured attributes to account for the variation in the soil amendments. This assessment is based on the attributes' vector from the biplot origin as well as its closeness (short angle) to the average tester (the small circle on the average tester axis). The studied attributes had long vectors, while the shortest angle was obtained from VL, which was followed by PWT.

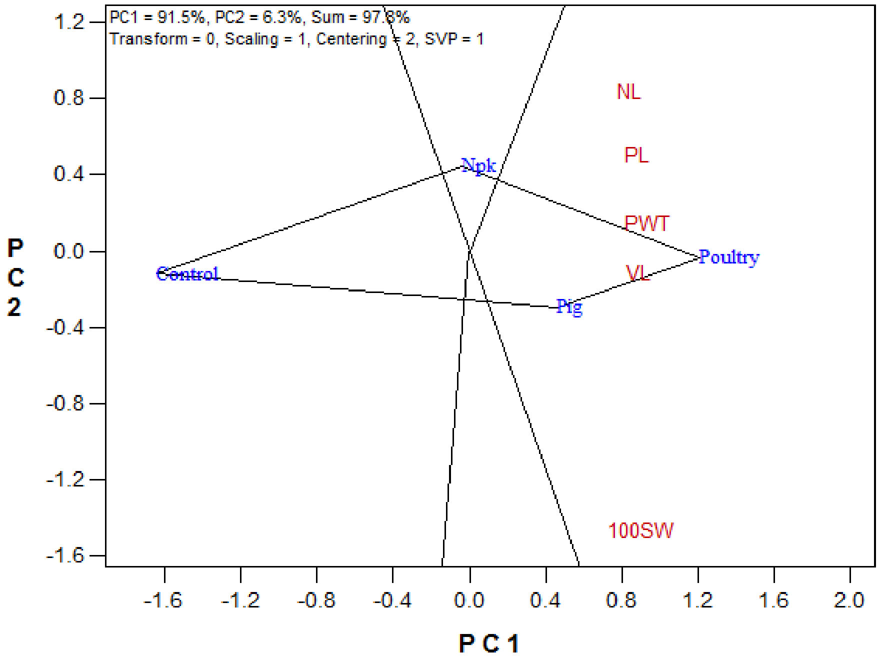

Figure 2. The which-won-where view of the soil amendments.
NL: Number of leaves, VL: Vine length, PWT: Plant weight, PL: Pod length, 100SW: 100 seed weight.

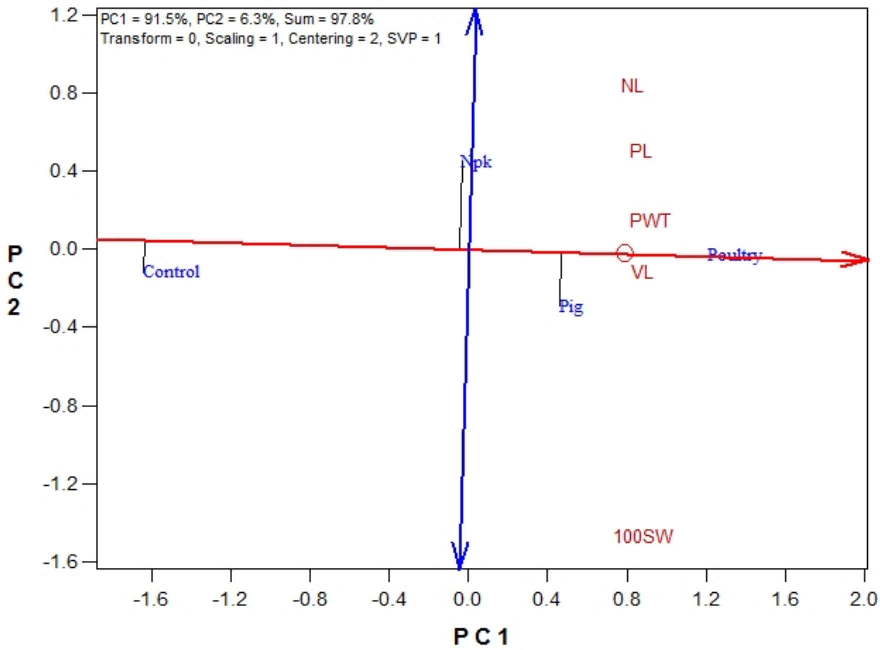

Figure 3. The stability and mean performance view of the soil amendment.
NL: Number of leaves, VL: Vine length, PWT: Plant weight, PL: Pod length, 100SW: 100 seed weight.

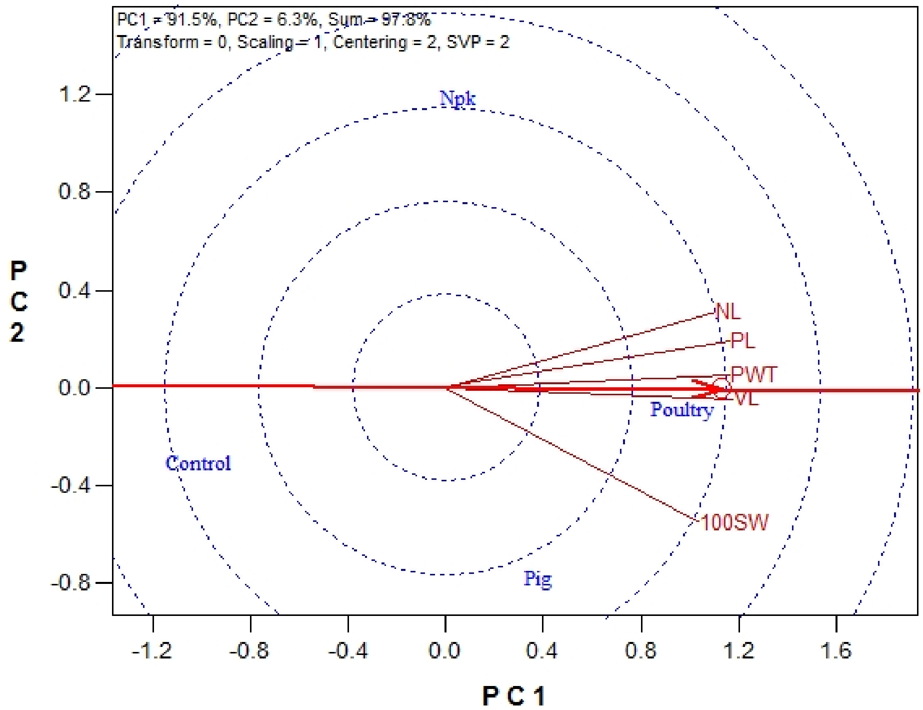

Figure 4. The discriminatory and representative graphic view of the soil amendment. NL: Number of leaves, VL: Vine length, PWT: Plant weight, PL: Pod length, 100SW: 100 seed weight.

3.2. Accessional effect on the growth and yield attributes of cowpea

There are significant differences among the cowpea accessions in all the studied attributes regardless of the soil amendment. Accession EBL was significantly higher than the other four accessions in NL, PWT and PL (Table 2). It produced the second-highest VL and 100SW after EBC and BBL, respectively. Among the accessions, the principal component analysis explained 82.9% of the variation (PC 1 = 63.2% and PC 2 = 19.7%) based on the growth and yield attributes measured (Figure 5). The stability and mean performance graphic view (Figure 5) revealed that the top-ranked accessions were EBL followed by EBC along the average tester axis. The average tester ordinate separated the top-performing accessions from the low-performing accessions BBL, BBR and BCB.

Table 2. Accessional effect on cowpea's growth and yield attributes.

Accessions	NL	VL (cm)	PWT (g)	PL (cm)	100SW (g)
BBL	46.4^{c}	82.4^{c}	33.91^{d}	14.73^{e}	13.70^{a}
BBR	48.0^{b}	71.6^{d}	31.33^{d}	15.85^{c}	8.96^{e}
BCB	34.0^{e}	69.6^{d}	52.08^{c}	15.55^{d}	9.43^{d}
EBL	63.1^{a}	92.5^{b}	100.04^{a}	20.18^{a}	12.71^{b}
EBC	43.3^{d}	108.8^{a}	56.18^{b}	17.32^{b}	11.68^{c}
F-LSD $_{(0.05)}$	0.77	9.19	3.41	0.17	0.36

Means with different alphabets (superscripts $^{a–e}$) in a column are significantly different at 5% probability level, NL: Number of leaves, VL: Vine length, PWT: Plant weight, PL: Pod length, 100SW: 100 seed weight.

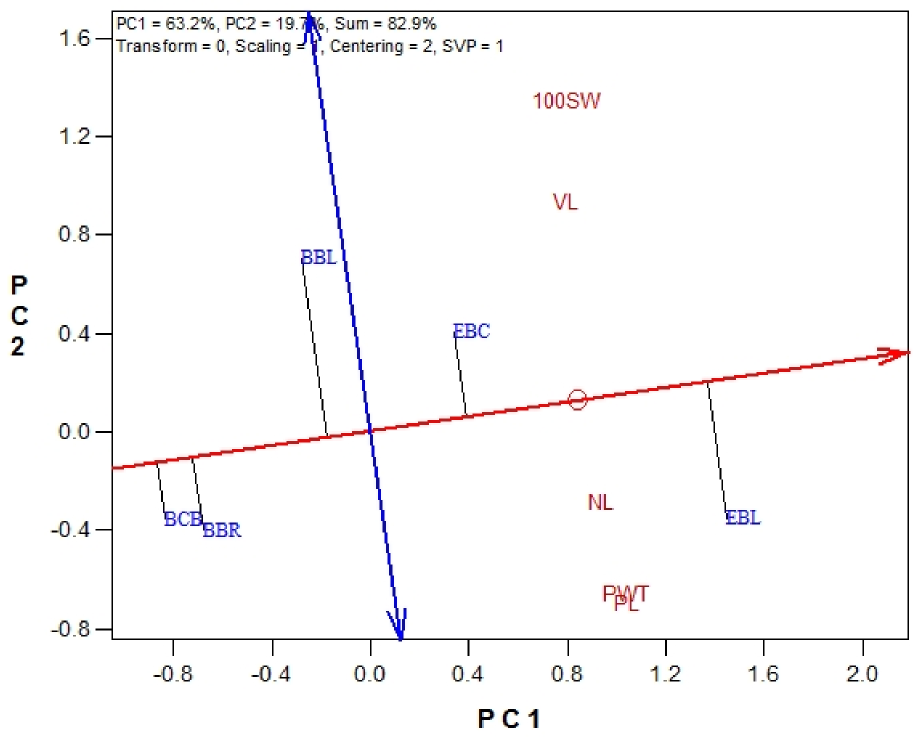

Figure 5. The stability and mean performance view of the cowpea accessions.
NL: Number of leaves, VL: Vine length, PWT: Plant weight, PL: Pod length, 100SW: 100 seed weight.

3.3. The interaction of accession and soil amendment on the growth and yield attributes of cowpea

Table 3 contained the responses of the different cowpea accessions to the various soil amendments. The values for the measured attributes ranged from 34–63.8 for NL, 65.7–118.3 cm for VL, 25.9–106.4 g for PWT, 14.5–20.6 cm for PL and 8.4–14.4 g for 100SW. Accession EBL amended with poultry manure gave the highest PWT (106.4 g), which was statistically similar to the same accessions amended with NPK (104.9 g) and pig manure (100.4 g), but significantly higher than the other treatment combinations. For the PL, accession EBL amended with NPK gave the highest mean (20.6 cm), which was similar to EBL amended with poultry manure (20.3 cm). Both treatment combinations were significantly higher than the other treatment combinations. The cluster analysis indicated that at 90% similarity, five clusters were formed based on the five accessions (Figure 6).

3.4. Correlation Coefficients

Table 4 showed that the highest positive correlation was observed between PWT and PL (r = 0.919**) and between NL and PL (r = 0.751**). Also. PWT was significantly and positively related to NL, VL and 100SW. A low, significant positive relationship was observed between 100SW and NL, VL and PL.

Table 3. Interaction of accession and soil amendment on the growth and yield attributes of cowpea.

Accession	Soil amendment	NL	VL (cm)	PWT (g)	PL (cm)	100SW (g)
BBL	Control	45.5^{e}	80.0^{i}	32.57^{ef}	14.6^{f}	13.23^{b}
BBL	NPK	46.7^{d}	77.7^{k}	34.25^{e}	14.5^{f}	13.23^{b}
BBL	Pig manure	46.7^{d}	81.7^{h}	32.58^{ef}	14.9^{def}	14.40^{a}
BBL	Poultry manure	46.7^{d}	90.3^{g}	36.23^{e}	14.9^{def}	13.92^{a}
BBR	Control	48.0^{c}	67.0^{r}	31.77^{ef}	15.5^{cde}	8.37^{i}
BBR	NPK	48.0^{c}	70.0^{o}	25.85^{f}	15.8^{cd}	8.83^{hi}
BBR	Pig manure	48.0^{c}	73.3^{n}	31.9^{ef}	15.9^{cd}	9.43^{g}
BBR	Poultry manure	48.0^{c}	76.0^{l}	35.80^{e}	16.2^{c}	9.19^{gh}
BCB	Control	34.0^{g}	65.7^{s}	49.64^{d}	15.2^{def}	9.28^{gh}
BCB	NPK	34.0^{g}	69.7^{p}	51.07^{cd}	15.7^{cd}	8.82^{hi}
BCB	Pig manure	34.0^{g}	73.7^{m}	53.57^{cd}	15.8^{cd}	9.53^{fg}
BCB	Poultry manure	34.0^{g}	69.3^{q}	54.03^{cd}	15.6^{cde}	10.08^{f}
EBL	Control	62.8^{b}	79.7^{j}	88.47^{b}	19.9^{a}	12.25^{cd}
EBL	NPK	62.8^{b}	98.3^{e}	104.90^{a}	20.6^{a}	12.95^{b}
EBL	Pig manure	62.8^{b}	90.3^{g}	100.43^{a}	19.9^{a}	12.81^{bc}
EBL	Poultry manure	63.8^{a}	101.7^{d}	106.37^{a}	20.3^{a}	12.82^{bc}
EBC	Control	43.3^{f}	96.0^{f}	53.48^{cd}	17.2^{b}	11.03^{e}
EBC	NPK	43.3^{f}	105.7^{c}	56.65^{c}	17.2^{b}	11.28^{e}
EBC	Pig manure	43.3^{f}	115.0^{b}	56.97^{c}	17.3^{b}	12.17^{d}
EBC	Poultry manure	43.3^{f}	118.3^{a}	57.63^{c}	17.6^{b}	12.22^{d}
F-LSD $_{(0.05)}$		0.28	0.29	6.83	0.72	0.58

Means with different alphabets (superscripts $^{a–e}$) in a column are significantly different at 5% probability level, NL: Number of leaves, VL: Vine length, PWT: Plant weight, PL: Pod length and 100SW: 100 seed weight

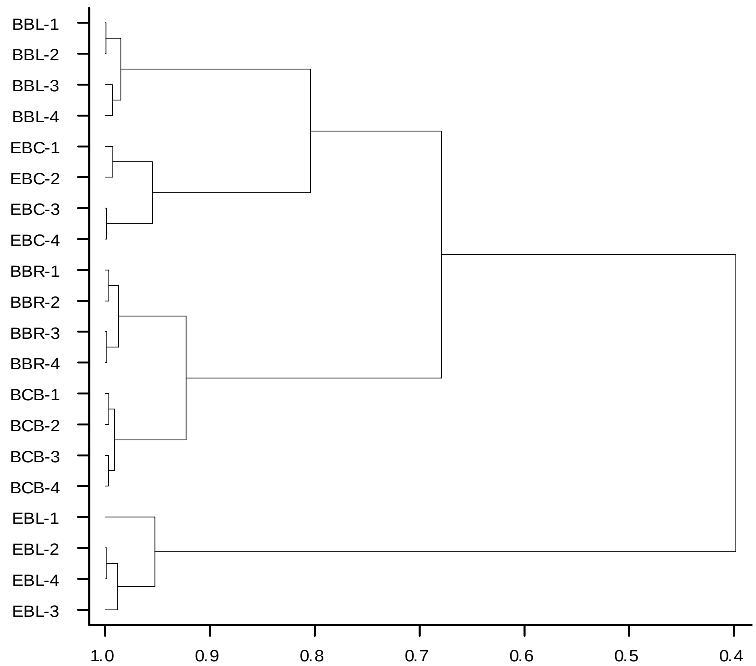

Figure 6. Hierarchical cluster analysis of the interaction between cowpea accession and soil amendment.

Table 4. Correlation coefficient of growth and yield traits of cowpea.

	NL	VL	PL	100SW	PWT
NL	1	0.262*	0.751**	0.462**	0.623**
VL		1	0.434**	0.446**	0.361**
PL			1	0.261*	0.919*
100SW				1	1
PLTWT					

** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed), NL: Number of leaves, VL: Vine length, PWT: Plant weight, PL: Pod length, 100SW: 100 seed weight.

4. Discussion

4.1. Main effect of soil amendment on growth and yield attributes of cowpea

Cowpea is a leguminous plant that fixes nitrogen from the atmosphere to the soil with the help of nitrogen-fixing bacteria. This nitrogen-fixing ability had encouraged farmers to grow cowpea without fertilizers. This practice of fertilizer skipping is exacerbated by the belief that nitrogen is not a limiting factor for cowpea production. However, studies have shown cowpea yield losses due to a lack of fertilizer application. In Nigeria, Nkaa et al. [17] recommend the addition of N, P and K, especially N, in soils with poor N content to achieve high yields in cowpea. An earlier study in West Africa indicated a significant response of cowpea to nitrogen application [18]. These observations aligned with the findings from this study, where the control (no amendment) gave the lowest cowpea yield compared to the organic and inorganic soil amendments. According to Anago et al. [7], average cowpea grain yields rarely reach 400 kg ha^{-1} in the absence of fertilizer application but may attain 800 kg ha^{-1} with the application of approximately 50 and 25 kg ha^{-1} of NPK and urea, respectively. Kamara et al. [19] attribute the low cowpea grain yield in the farmer's field to low soil fertility and a lack of inputs. The significant differential response of vine length to the soil amendments in this study was corroborated by Ayodele and Oso [20], who reported increased vine length due to soil amendment.

Among the soil amendments studied, poultry manure ranked ahead of the other amendments. In addition, organic manure (poultry and pig manures) ranked better than inorganic manure (NPK) and no amendment (see Figure 3). The superior performance of poultry manure over pig manure and NPK is due to its composition. Chukwudi et al. [11] observed a higher yield in poultry manure-amended plants compared to NPK-amended plants. Organic amendment slowly releases its nutrients for plant use as well as improving soil fertility and soil water holding capacity [9]. The challenge to food security in West Africa is its underdeveloped agricultural sector, which is characterized by low fertility soils and minimal use of external farm inputs, which induce degradation of the environment and low crop productivities [10].

4.2. Main effects of varieties on growth and yield attributes of cowpea

The Africa continent, particularly the West African region, is the proposed center of origin of cowpea [21]. Hence, the dominance of West Africa in global cowpea production is expected. In this study, the presence of significant differences in all the attributes measured indicates genetic variability among the accessions. Genetic variability is essential for species survival and adaptation to a changing environment. The presence of genetic diversity in cowpea has been reported in Kenya [4], Togo [2], Zambia and Malawi [3]. Genetic diversity of crops plays an important role in sustainable development and food security because it serves as a source of genes needed in the development of better-performing and better-adapted varieties [22]. Food production and security depend on the conservation and wise use of agricultural biodiversity.

The mean performance and stability analysis (Figure 5) ranked EBL and EBC accessions ahead of BBL, BBR and BCB accessions. This ranking separated the accessions along the source of collection, namely Enugu State for EBL and EBC, while BBL, BBR and BCB were from Benue State. In addition, the accessions with black seed coats (EBL and BBL) performed better than the other accessions from the same source of collection. The placement of accession BBL after the average tester ordinate (the double-arrow blue line in Figure 5) is due to its low growth attributes, as the accession produced the highest 100-seed weight. Accession BBL is a good seed yielder with low forage production. However, the top-ranked accession, EBL, gave the second-highest 100-seed weight as well as the highest number of leaves, plant weight and pod length. Variability in cowpea growth and yield attributes was reported in earlier studies [2,3,23,24].

4.3. The interaction of accession and soil amendment on the growth and yield attributes of cowpea

The growth and yield attributes of cowpea can be influenced by a combination of factors, including the genetic makeup of the crop as well as the type and amount of soil amendment applied. Understanding the effects of different soil amendments on cowpea growth and yield, including the use of organic amendments such as compost and manure and inorganic amendments such as fertilizers, has been of interest to researchers. Anago et al. [7] suggest that the type and amount of soil amendment used can significantly affect the growth and yield of cowpea. These observations aligned with the findings in this study, where there was a significant effect of accession and soil amendment on all the growth and yield traits studied.

Therefore, the interaction of cowpea accession and soil amendment has a significant impact on the growth and yield attributes of cowpea. This implied that a particular cowpea accession may perform better when grown in soil that has been amended with a particular type of organic fertilizer, while another cowpea accession may perform better when grown in soil that has been amended with a different type of fertilizer. Specifically in this study, accessions BBL, EBL, and EBC grown without soil amendments had reduced PWT and 100SW. However, under poultry manure amendment, EBL and EBC produced their highest PWT and 100SW while the highest PWT and 100SW for BBL were under pig manure amendment. This finding showed that some accessions may respond better to specific types of soil amendments or may have greater nutrient requirements that can be met through specific soil amendments. The clustering of the treatment combinations along the accession line is an indication of the diversity of the accessions and the lesser influence of the soil amendments compared to the genetic makeup in influencing cowpea yield.

Overall, the interaction between accession and soil amendment can have significant effects on the growth and yield attributes of cowpea. Therefore, careful selection of both factors based on specific soil conditions and desired outcomes can help optimize cowpea production.

5. Conclusions

The findings of this study showed that cowpea accessions responded differently to the soil amendments. The poultry manure ranked ahead of the other soil amendments and was followed by the pig manure. The top-ranked accession was EBL, followed by EBC. Genetic make-up contributed more to the variations in the treatment combinations than the effect of soil amendment. This study recommends the use of additional nutrients as a supplement in the production of cowpea rather than relying solely on its self-fixed nitrogen.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflicts of Interest

The authors declare no conflict of interest.

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