# Influence of organic manures and NPK fertilizer on soil properties and crop performance of Amaranthus *cruentus L. and Celosia argentae L. in a Nigerian ultisol*

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**Abstract**
A field study was conducted at the University of Benin, Nigeria, to evaluate the effects of organic manures (poultry, pig, cattle) and NPK 15:15:15 fertilizer on soil chemical and physical properties as well as the growth and yield of *Amaranthus cruentus* and *Celosia argentae*. The experiment, which was conducted between April and July, 2021, was laid out in a Randomized Complete Block Design (RCBD) with three replications. Treatments included 20 t/ha of each manure and 300 kg/ha of NPK 15:15:15, alongside a control. Soil analysis after harvest of crops revealed that all amendments significantly ($p<0.05$) improved soil fertility. Poultry manure (PM) resulted in the highest increase in soil organic carbon (21.76 g/kg for amaranth, 19.75 g/kg for celosia) compared to the control (9.95 g/kg and 9.27 g/kg, respectively). NPK fertilizer led to the highest available phosphorus (23.62 mg/kg) and total nitrogen (0.83 g/kg) for amaranth. For *Amaranthus*, PM produced the highest growth parameters: plant height (64.11 cm), number of leaves (21.83), and marketable leaf yield (7459 kg/ha), significantly outperforming other treatments. For *Celosia*, PM, Pig manure (PgM), Cattle manure (CM), and NPK produced statistically similar growth, but PM and NPK gave the highest numerical yields (2099 kg/ha and 2717.67 kg/ha, respectively). The study concludes that while all amendments improved soil health and crop performance, poultry manure was the most effective single amendment for enhancing the productivity of *Amaranthus cruentus*, whereas for *Celosia argentae*, PM, PgM, CM, and NPK were equally effective.
**Keywords:** Organic manures, leafy vegetables, soil fertility, ultisol.

## Introduction

Leafy vegetables are crucial for food and nutritional security in Nigeria, providing vital vitamins, minerals, and income, especially for urban and rural households. *Amaranthus cruentus* L. (African spinach) and *Celosia argentae* L. (Lagos spinach) are two of the most important indigenous leafy vegetables due to their adaptability, short growth cycle, and high nutritional value (Wolosik and Markowska, 2019). The yield of these vegetables from Sub-Saharan Africa (Nigeria inclusive) is relatively low due to low inherent soil fertility and unsustainable farming practices (Javed *et al*., 2022).

The traditional practice of long fallow periods to restore soil health is no longer feasible due to population pressure, leading to intensive cultivation on dwindling land resources. This has resulted in widespread soil degradation, characterized by declining organic matter, nutrient mining, and increased erosion (Masso *et al.*, 2017). To combat this, the reliance on inorganic fertilizers has increased. While effective in boosting short-term yields, their high cost, potential for soil acidification, and environmental hazards make them inaccessible and undesirable for many smallholder farmers who dominate the agricultural sector (Ande *et al*., 2017).

The use of animal wastes as fertilizer improves soil physical properties, enhances cation exchange capacity, and buffers soil pH, thereby creating a more favorable environment for crop growth. The integration of organic and inorganic nutrient sources is increasingly seen as a viable strategy for achieving well-balanced soil fertility and sustainable crop yields (Adekiya *et al*., 2020).

Several studies have documented the positive response of these vegetables to fertilizer application. For instance, Iren *et al*. (2016) reported increased yield of *Amaranthus* with pig manure and urea application. Komolafe *et al*., (2021) reported that compost significantly enhanced the growth and yield of *Celosia argentea*. However, direct comparative studies evaluating the efficacy of different animal manures (poultry, pig, cattle) alongside NPK fertilizer on both soil properties and the productivity of these two important vegetables in an Ultisol is important. Such information is vital for providing tailored recommendations to farmers. Therefore, this study was designed to determine the effects of poultry manure, pig manure, cattle manure, and NPK 15:15:15 fertilizer on the growth, yield, and post-harvest soil chemical properties of *Amaranthus cruentus* and *Celosia argentae* in a Nigerian Ultisol.

## Materials and Methods

### Study Site

The study was conducted at the University of Benin, Benin City, Edo State, Nigeria. The area is geographically located between latitudes 6° 23' 53" and 6° 24' 40" N and longitudes 5° 37' 24" and 5° 37' 34" E. The site is within the tropical rainforest zone (Floyd *et al*., 2016), with a mean annual rainfall of 1900 mm and an average temperature of 27°C (Balogun *et al*., 2023). The soils are classified as Ultisols, derived from coastal plain sands (Benin Formation) (Okunsebor and Umweni, 2021).

### Experimental Design and Treatment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. *Amaranthus* and *Celosia* were raised as separate experiments. The treatments for each crop were:

- **Control** (No fertilizer/manure)
- **Poultry Manure (PM)** at 20 t/ha
- **Pig Manure (PgM)** at 20 t/ha
- **Cattle Manure (CM)** at 20 t/ha
- **NPK 15:15:15** at 300 kg/ha

Each plot measured 2 m x 2 m. The organic manures were analyzed for their nutrient composition (Table 1) and incorporated into the soil two weeks before planting to allow for decomposition. The NPK fertilizer was applied in two equal splits at 2 and 5 weeks after planting (WAP).

### Crop Establishment and Management

Seeds of *Amaranthus cruentus* and *Celosia argentae* (local varieties) were obtained from the Agricultural Development Project (ADP), Benin City.

They were planted at a spacing of 50 cm x 50 cm at a rate of three seeds per hole and later thinned to two plants per stand. Weeding was done manually with a hoe as necessary.

**Data Collection**

**Soil and Manure Analysis**

Pre-planting and post-harvest soil samples (0-30 cm depth) were collected and analyzed for pH, organic carbon, total nitrogen, available phosphorus, exchangeable bases (K, Ca, Mg, Na), and effective cation exchange capacity (ECEC) using standard labouratory procedures outlined in A.O.A.C. (1990). The manures were similarly analyzed (Table 1). Particle size distribution was determined by the hydrometer of Buoyoucos (1962) as modified by Gee and Bauder (1986). Soil pH was measured in a 1:1 soil-to-water ratio using a glass electrode pH meter (McLean, 1982). Total Organic Carbon (TOC) was determined by the Walkley and Black (1934) wet oxidation method (Nelson and Sommers, 1996). Total Nitrogen (TN) was analyzed using the micro-Kjeldahl digestion method (Bremner, 1996). Available Phosphorus (Av. P) was extracted using (Houba *et al*., 2000) method and determined colorimetrically by (Bray and Kurtz, 1945). Exchangeable bases (K, Ca, Mg, and Na) were extracted with 1N ammonium acetate (NH4OAc) at pH 7.0. Potassium and Sodium were determined by flame photometry, while Calcium and Magnesium were determined by EDTA titration (Black, 1965).

**Growth and Yield Parameters**

Data were collected from five randomly selected plants per plot.

- **Plant Height (cm):** Measured from base to tip at 4, 6, and 8 WAP.
- **Number of Leaves:** Counted at 4, 6, and 8 WAP.
- **Stem Girth (cm):** Measured at the collar level at 4, 6, and 8 WAP.
- **Marketable Leaf Yield (kg/ha):** The fresh weight of leaves harvested per plot was recorded and converted to kg/ha.

**Statistical Analysis**

Data collected were subjected to Analysis of Variance (ANOVA) using IBM SPSS Statistics. Treatment means were separated using the Duncan Multiple Range Test (DMRT) at a 5% probability level.

**Table 1: Physical and Chemical Properties of Soil before Planting and Nutrient Content of Manures used.**

| Parameters | Soil Before Planting | Poultry Manure | Pig Manure | Cattle Manure |
|---|---|---|---|---|
| pH (1:1 in water) | 6.30 | 7.30 | 7.25 | 7.21 |
| Organic C (g/kg) | 9.69 | 14.35 | 13.55 | 13.23 |
| Total N (g/kg) | 0.28 | 3.25 | 2.10 | 2.23 |
| Avail. P (mg/kg) | 9.49 | 34.31 | 30.32 | 30.23 |
| K (cmol/kg) | 0.55 | 5.71 | 5.21 | 5.01 |
| Ca (cmol/kg) | 1.53 | 7.90 | 6.95 | 5.59 |
| Mg (cmol/kg) | 0.37 | 11.20 | 10.91 | 9.99 |
| Na (cmol/kg) | 0.50 | 19.83 | 18.50 | 17.56 |
| Sand (g/kg) | 769.00 | - | - | - |
| Silt (g/kg) | 99.00 | - | - | - |
| Clay (g/kg) | 132.00 | - | - | - |
| Textural Class | Sandy Loam | - | - | - |

**Results and Discussion**

**Effect of Amendments on Post-Harvest Soil Properties**

The application of organic and inorganic amendments significantly ($p<0.05$) enhanced the chemical properties of the soil after the harvest of both crops (Tables 2 and 3). For the amaranth plots, soil pH ranged from moderately acidic (5.7) in the CM plot to neutral (7.0) in the PgM plot (Table 2). This aligns with Adekiya *et al.* (2020), who reported that organic manures can help moderate soil pH. The organic carbon content increased markedly from an initial 9.69 g/kg to a high of 21.76 g/kg with PM application. This substantial increase is consistent with the findings of Li *et al.* (2021), who attributed it to the direct addition of organic materials and the stimulation of microbial activity.

NPK fertilizer application resulted in the highest total nitrogen (0.83 g/kg) and available phosphorus (23.62 mg/kg) in the amaranth soil (Table 2). This immediate nutrient release from inorganic sources is well-documented (Ehigiator *et al*., 2016). However, the fertilizers also significantly improved N and P levels over the control, corroborating reports by Ehigiator *et al*., (2015); Adekiya *et al.*, (2019); Adekiya *et al*., (2020). Similarly, exchangeable bases (K, Ca, Mg, Na) and ECEC were higher in amended soils, with PM often recording the highest values among the organic treatments, leading to increased base saturation. This underscores the role of organic manures in improving the nutrient-holding capacity of soils, a crucial factor in highly leached Ultisols (Iren *et al*., 2016). The physical properties Pig manure (PgM) was the next best treatment for amaranth yield (3530 kg/ha), followed by NPK and CM, which were statistically similar. The control plot recorded the poorest growth and yield (98.33 kg/ha), emphasizing the nutrient-deficient nature of the soil and the necessity for external inputs for profitable amaranth production

**Growth and Yield Response of *Celosia argentae***

The response of *Celosia* to the amendments differed from that of *Amaranthus* (Table 5). For plant height, number of leaves, and stem girth, all amendment treatments (PM, PgM, CM, NPK) performed statistically similarly at most sampling periods but were significantly better than the control. This suggests that *Celosia* is less sensitive to the

**Table 2: Physical and Chemical Properties of Soil after Harvest of Amaranthus**

| Treatments | pH | Org. C (g/kg) | Total N (g/kg) | Avail P (mg/kg) | K (cmol/kg) | Ca (cmol/kg) | Mg (cmol/kg) | Na (cmol/kg) | ECEC (cmol/kg) | BS (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Control | 5.80$^{d}$ | 9.95$^{d}$ | 0.28$^{c}$ | 9.25$^{d}$ | 0.46$^{c}$ | 1.61$^{b}$ | 0.26$^{d}$ | 0.35$^{d}$ | 4.99$^{c}$ | 53.71$^{c}$ |
| CM | 5.70$^{d}$ | 13.87$^{c}$ | 0.33$^{c}$ | 12.11$^{c}$ | 0.55$^{bc}$ | 1.61$^{b}$ | 0.41$^{c}$ | 0.54$^{c}$ | 6.40$^{a}$ | 48.59$^{d}$ |
| PgM | 7.00$^{a}$ | 17.85$^{b}$ | 0.34$^{c}$ | 14.23$^{b}$ | 0.55$^{bc}$ | 1.75$^{a}$ | 0.55$^{b}$ | 0.79$^{b}$ | 6.44$^{a}$ | 56.52$^{b}$ |
| PM | 6.10$^{c}$ | 21.76$^{a}$ | 0.41$^{b}$ | 15.17$^{b}$ | 0.56$^{b}$ | 1.76$^{a}$ | 0.61$^{b}$ | 1.25$^{a}$ | 6.37$^{a}$ | 65.46$^{a}$ |
| NPK | 6.30$^{b}$ | 12.87$^{c}$ | 0.83$^{a}$ | 23.62$^{a}$ | 0.72$^{a}$ | 1.62$^{b}$ | 0.73$^{a}$ | 0.71$^{b}$ | 5.85$^{b}$ | 64.44$^{a}$ |
| LSD (0.05) | 0.18 | 1.30 | 0.11 | 1.27 | 0.1 | 0.08 | 0.09 | 0.15 | 0.29 | 2.1 |
| PgM | 7.00$^{a}$ | 17.85$^{b}$ | 0.34$^{c}$ | 14.23$^{b}$ | 0.55$^{bc}$ | 1.75$^{a}$ | 0.55$^{b}$ | 0.79$^{b}$ | 6.44$^{a}$ | 56.52$^{b}$ |
| PM | 6.10$^{c}$ | 21.76$^{a}$ | 0.41$^{b}$ | 15.17$^{b}$ | 0.56$^{b}$ | 1.76$^{a}$ | 0.61$^{b}$ | 1.25$^{a}$ | 6.37$^{a}$ | 65.46$^{a}$ |
| NPK | 6.30$^{b}$ | 12.87$^{c}$ | 0.83$^{a}$ | 23.62$^{a}$ | 0.72$^{a}$ | 1.62$^{b}$ | 0.73$^{a}$ | 0.71$^{b}$ | 5.85$^{b}$ | 64.44$^{a}$ |
| LSD (0.05) | 0.18 | 1.30 | 0.11 | 1.27 | 0.1 | 0.08 | 0.09 | 0.15 | 0.29 | 2.1 |

* Means with the same letter in same column are not significantly different (P <0.05)

**Table 3: Physical and Chemical Properties of Soil after Harvest of Celosia**

| Treatments | pH | Org. C (g/kg) | Total N (g/kg) | Avail P (mg/kg) | K (cmol/kg) | Ca (cmol/kg) | Mg (cmol/kg) | Na (cmol/kg) | ECEC (cmol/kg) | BS (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Control | 5.7$^{c}$ | 9.27$^{d}$ | 0.23$^{c}$ | 9.41$^{d}$ | 0.43$^{d}$ | 1.59$^{c}$ | 0.37$^{c}$ | 0.54$^{c}$ | 1.25$^{c}$ | 0.79$^{a}$ |
| CM | 6.2$^{b}$ | 16.36$^{b}$ | 0.36$^{b}$ | 11.83$^{c}$ | 0.44$^{cd}$ | 1.63$^{c}$ | 0.44$^{c}$ | 0.49$^{c}$ | 1.76$^{a}$ | 0.46$^{b}$ |
| PgM | 6.1$^{b}$ | 13.94$^{c}$ | 0.38$^{b}$ | 13.81$^{b}$ | 0.53$^{bc}$ | 1.72$^{b}$ | 0.53$^{b}$ | 0.66$^{b}$ | 1.57$^{b}$ | 0.21$^{c}$ |
| PM | 6.0$^{b}$ | 19.75$^{a}$ | 0.42$^{b}$ | 14.43$^{b}$ | 0.55$^{b}$ | 1.86$^{a}$ | 0.53$^{b}$ | 0.89$^{a}$ | 1.61$^{b}$ | 0.53$^{b}$ |
| NPK | 6.5$^{a}$ | 13.97$^{c}$ | 0.82$^{a}$ | 20.45$^{a}$ | 0.73$^{a}$ | 1.71$^{b}$ | 0.80$^{a}$ | 0.73$^{b}$ | 1.83$^{a}$ | 0.50$^{b}$ |
| LSD | 0.27 | 1.52 | 0.06 | 0.91 | 0.09 | 0.09 | 0.09 | 0.09 | 0.12 | 0.149 |

* Means with the same letter in same column are not significantly different (P <0.05)

**Table 4: Response of *Amaranthus spp.* to Applied Treatments.**

| Treatments | Plant Height (cm) | | | Number of Leaves | | | Plant Girth (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4WAP | 6WAP | 8WAP | 4WAP | 6WAP | 8WAP | 4WAP | 6WAP | 8WAP |
| Control | 5.37$^{c}$ | 9.43$^{d}$ | 10.93$^{d}$ | 8.17$^{b}$ | 7.17$^{b}$ | 9.43$^{c}$ | 0.35$^{c}$ | 0.72$^{d}$ | 1.38$^{d}$ |
| Poultry Manure | 25.17$^{a}$ | 48.30$^{a}$ | 64.11$^{a}$ | 12.33$^{a}$ | 19.00$^{a}$ | 21.83$^{ab}$ | 1.40$^{a}$ | 5.16$^{a}$ | 6.05$^{a}$ |
| Pig Manure | 17.97$^{b}$ | 33.03$^{b}$ | 46.23$^{ab}$ | 11.67$^{ab}$ | 18.50$^{a}$ | 25.33$^{a}$ | 0.61$^{b}$ | 3.06$^{b}$ | 3.53$^{b}$ |
| NPK 15:15:15 | 13.23$^{b}$ | 17.67$^{cd}$ | 19.03$^{cd}$ | 6.17$^{b}$ | 9.67$^{b}$ | 12.50$^{bc}$ | 0.62$^{b}$ | 2.10$^{c}$ | 2.60$^{bc}$ |
| Cattle manure | 14.00$^{b}$ | 23.78$^{bc}$ | 34.40$^{bc}$ | 9.67$^{ab}$ | 12.00$^{b}$ | 13.67$^{b}$ | 0.65$^{b}$ | 1.84$^{c}$ | 2.39$^{c}$ |
| LSD (0.05) | 5.341 | 10.314 | 14.735 | 3.027 | 5.013 | 3.534 | 0.251 | 0.523 | 0.671 |

* Means with the same letter in same column are not significantly different (P <0.05)

**Table 5. Response of *Celosia spp.* to Applied Treatments.**

| Treatments | Plant Height(cm) | | | No of Leaves | | | Plant Girth (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4WAP | 6WAP | 8WAP | 4WAP | 6WAP | 8WAP | 4WAP | 6WAP | 8WAP |
| Control | 2.82$^{b}$ | 5.57$^{b}$ | 23.00$^{b}$ | 4.00$^{c}$ | 5.90$^{b}$ | 9.00$^{b}$ | 0.70$^{c}$ | 0.71$^{c}$ | 0.90$^{c}$ |
| Poultry Manure | 7.83$^{a}$ | 20.97$^{a}$ | 44.67$^{a}$ | 7.93$^{ab}$ | 14.53$^{a}$ | 23.00$^{a}$ | 2.47$^{a}$ | 2.87$^{a}$ | 3.07$^{a}$ |
| Pig Manure | 7.73$^{a}$ | 18.63$^{a}$ | 44.33$^{a}$ | 9.67$^{a}$ | 15.40$^{a}$ | 25.33$^{a}$ | 1.20$^{bc}$ | 1.98$^{ab}$ | 2.17$^{ab}$ |
| NPK 15:15:15 | 5.97$^{a}$ | 25.73$^{a}$ | 41.33$^{a}$ | 5.57$^{bc}$ | 13.93$^{a}$ | 23.00$^{a}$ | 0.98$^{bc}$ | 1.31$^{bc}$ | 1.83$^{b}$ |
| Cattle manure | 7.57$^{a}$ | 21.50$^{a}$ | 42.00$^{a}$ | 8.00$^{ab}$ | 13.26$^{a}$ | 21.00$^{a}$ | 1.60$^{b}$ | 1.93$^{ab}$ | 2.33$^{ab}$ |
| LSD (0.05) | 2.061 | 5.798 | 14.631 | 3.417 | 6.767 | 8.974 | 0.627 | 0.610 | 0.901 |

* Means with the same letter in same column are not significantly different (P <0.05)

specific nutrient source than amaranth, provided a basic level of fertility is met. This finding aligns with Falodun *et al*. (2022), who reported significant improvements in *Celosia* growth with various manure applications.

For marketable yield (Table 6), NPK (2717.67 kg/ha) and PgM (2602 kg/ha) recorded the highest, though statistically similar, yields. PM and CM followed with 2099 kg/ha and 1521 kg/ha, respectively, while the control was lowest (872 kg/ha). The high yield from NPK can be attributed to the immediate availability of nitrogen, which is crucial for leafy vegetable growth (Ehigiator *et al*., 2016). The good performance of PgM indicates its high fertilizer value, comparable to inorganic NPK for celosia production in this soil type (Ehigiator *et al*., 2015).

**Conclusion and Recommendations**

This study demonstrates that the application of organic manures (poultry, pig, cattle) and NPK 15:15:15 fertilizer significantly enhances the fertility of an Ultisol by increasing pH, organic carbon, total nitrogen, available

**Table 6: Yield Response of Amaranthus and Celosia**

| Treatments | Amaranthus Leaf Yield (kg/ha) | Celosia |
|---|---|---|
| Control | 98.33$^{d}$ | 87.20$^{c}$ |
| Poultry Manure | 7459.00$^{a}$ | 2099.00$^{ab}$ |
| Pig Manure | 3530.00$^{b}$ | 2602.00$^{a}$ |
| NPK 15:15:15 | 790.67$^{c}$ | 2717.67$^{a}$ |
| Cattle Manure | 704.67$^{c}$ | 1521.00$^{b}$ |
| LSD (0.05) | 104.34 | 98.617 |

*Means in the same column followed by the same letter are not significantly different at p<0.05*

phosphorus, and exchangeable bases. These improvements in soil health translated directly into superior growth and yield for both *Amaranthus cruentus* and *Celosia argentae* compared to the unamended control.

For *Amaranthus cruentus*, poultry manure was unequivocally the most effective amendment, producing the highest growth metrics and a marketable yield (7459 kg/ha) that far exceeded other treatments. This positions poultry manure as a superior, sustainable soil amendment for amaranth production in this agro-ecology. In contrast, the growth and yield of *Celosia argentae* were not significantly different among the various amendment treatments, although NPK and pig manure gave the highest numerical yields. This indicates that *Celosia* is more flexible and can thrive well with any of the tested nutrient sources.

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