



COMBINED EFFECTS OF POULTRY MANURE AND NPK FERTILIZER ON SOIL FERTILITY, GROWTH AND YIELD OF *CELOSIA ARGENTEA* L. IN RAINFOREST REGION OF SOUTHERN NIGERIA

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ABSTRACT

A field study was conducted to evaluate the combined effects of poultry manure (PM) and NPK 15:15:15 fertilizer on soil properties, growth and yield of *Celosia argentea* L. in the rainforest region of Southern Nigeria. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The treatments consisted of three rates of NPK (0, 150, 300 kg/ha) and three rates of poultry manure (PM) (0, 8, 16 t/ha) applied in combination, resulting in nine levels of fertilizer. *Celosia* was harvested 8 weeks after planting (WAP). Results indicated that the combined application of PM and NPK significantly ($P < 0.05$) enhanced soil chemical properties after harvesting *Celosia argentea*. The highest rates (16 t/ha PM + 300 kg/ha NPK) increased soil organic carbon (22.57 g/kg), total nitrogen (0.85 g/kg), available phosphorus (25.38 mg/kg), and exchangeable bases (K, Ca, Mg, Na) compared to the control. Plant growth and yield were also significantly ($P < 0.05$) improved. The combination of 16 t/ha PM + 300 kg/ha NPK resulted in the highest plant height (74.83 cm at 8 weeks after planting, WAP) and the highest marketable yield of 4.98 t/ha. While the number of leaves and stem girth showed less consistent significant ($P < 0.05$) differences, the overall trend favored the combined fertilizer rates. The study concludes that the combined application of PM (16 t/ha) and NPK (300 kg/ha) is highly effective in improving soil fertility and enhancing the productivity of *Celosia argentea*, offering a sustainable alternative to sole mineral fertilization.

Keywords: *Celosia argentea*, Poultry Manure, Soil Fertility.

INTRODUCTION

Low soil fertility is among the problems limiting crop production in the tropics, particularly high-value vegetables (Sánchez-Navarro *et al.*, 2019). In southern Nigeria, ultisols are among the most common soil orders and are characterized by high acidity, low cation exchange

capacity, and deficiencies in essential nutrients, which majorly reduce agricultural productivity (Obaro *et al.*, 2021). Traditional soil fertility restoration practices, such as long fallow periods, are no longer feasible due to population pressure and land scarcity, resulting in continuous cultivation and progressive soil

degradation (Van Kernebeek *et al.*, 2016). Inorganic fertilizers are commonly applied to curb nutrient deficiencies because of their rapid nutrient release and yield-enhancing effects. However, prolonged sole application has been linked to soil acidification, decline in soil organic matter, deterioration of soil structure, and environmental pollution, in addition to being costly and often inaccessible to smallholder farmers (Havlin, 2020; Javed *et al.*, 2022).

Organic amendments such as poultry manure offer a sustainable alternative by improving soil structure, water-holding capacity, and nutrient availability (Ehigiator *et al.*, 2015). Nonetheless, their use is limited by the large quantities required to meet crop nutrient demands. Consequently, combining organic and inorganic nutrient sources, has been reported as a balanced approach that enhances nutrient use efficiency, improves soil properties, and sustains crop yields (Selim, 2020; Darjee *et al.*, 2020).

Celosia argentea L. (cock's comb), locally known as *Soko*, is an important indigenous leafy vegetable in southwestern Nigeria due to its high nutritional and economic value (Adegbaaju *et al.*, 2020). Despite its importance, Nigeria's production is low compared to global production. Studies have examined the effects of sole organic or inorganic fertilizers on *Celosia*, but information on the effect of NPK 15:15:15 and poultry manure on the growth and yield of *Celosia argentea* as well as on the chemical properties of ultisols of Benin City, southern Nigeria are limited. Therefore, this study evaluated the effects of poultry manure and NPK fertilizer application on the properties of the soil as well as growth and yield parameters of *Celosia argentea*.

Materials and Methods

Study Location

The study was conducted at the Experimental Farm of the Faculty of Agriculture, University of Benin, Benin City, southern Nigeria. The site is located within the humid rainforest region (Latitude 06° 24' 03.4" and 06° 24' 03.6", Longitude 005° 37' 36.8" and 005° 37' 37.9") The site is within the tropical rainforest zone (Floyd *et al.*, 2016), with a mean annual rainfall of 2100 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 Ikator, 2019).

Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. (fertilizer as treatment factor and soil effect as block factor). The treatments include three rates of NPK 15:15:15 fertilizer (0, 150, and 300 kg/ha) and three rates of poultry manure (PM) (0, 8, and 16 t/ha), resulting in 9 combinations. *Celosia argentea* were planted at a spacing of 50 cm x 50 cm on plots measuring 1.5 m x 1.5 m (2.25 m²), with 1 m space in between plots and 1.5 m space at the boundaries. The total side measured 9.5 m x 24.5 m (232.75 m²). Wire mesh was used as the perimeter fence of the experimental site.

Treatment Details:

- T1: Control (No amendment)
- T2: 8 t/ha PM
- T3: 16 t/ha PM
- T4: 150 kg/ha NPK
- T5: 150 kg/ha NPK + 8 t/ha PM
- T6: 150 kg/ha NPK + 16 t/ha PM
- T7: 300 kg/ha NPK

- T8: 300 kg/ha NPK + 8 t/ha PM
- T9: 300 kg/ha NPK + 16 t/ha PM

Agronomic Practices

The poultry manure was applied uniformly to the designated plots two weeks before planting to allow for mineralization. *Celosia argentea* seeds (local variety) were sown at four seeds per hole and later thinned to two plants per stand after emergence, maintaining a spacing of 50 cm × 50 cm. The NPK fertilizer was applied in two equal splits at 2 and 4 weeks after planting (WAP). Weeding was done manually as required. Cropping was under rain-fed conditions, wire mesh was used as perimeter fence to reduce pests, while harvesting was manual and single (at 8 weeks after planting)

Data Collection

Soil Sampling and Analysis:

Initial composite soil samples (0-15 cm depth) were collected before treatment application. Post-harvest soil samples were taken from each plot at 0-15 cm depth. Soil samples were air-dried, sieved, and analyzed for pH, organic carbon, total nitrogen, available phosphorus, exchangeable bases (K, Ca, Mg, Na), and effective cation exchange capacity (ECEC) using standard laboratory procedures. pH was determined in 1:1 soil to water ratio using a glass electrode pH meter, particle size distribution was done using the hydrometer method of Bouyoucos (1962) as modified by Gee and Bauder (1986). Total organic carbon was determined by the wet dichromate acid oxidation method of Walkey and Black (1934). Available phosphorus was extracted using calcium chloride extraction method of Houben *et al.*, (2000) and determined by

molybdenum–blue colorimetric procedure and Riley and Murphy (1962). Total nitrogen was determined by the micro-Kjedahl digestion method (Bremner (1996); Exchangeable bases were extracted using 1N ammonium acetate at pH 7.0. Calcium and magnesium were determined volumetrically by EDTA titration method of Black (1965) while potassium and sodium were read using flame photometer; Exchange acidity was determined by titration method of Anderson and Ingram (1993); ECEC was determined as the summation of exchangeable bases and exchange acidity (Tan, 1996) while base saturation was calculated by dividing the sum of exchangeable bases by ECEC and multiplying the quotient by 100.

Plant Parameters:

Data on plant height (cm), number of leaves, and stem girth (cm) were collected at 4, 6, and 8 WAP. The marketable yield (fresh weight of leaves) was determined at harvest (8 WAP) and converted to tons per hectare (t/ha).

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT version 8. Treatment means were separated using Tukey's Honest test at a 5% probability level.

RESULTS AND DISCUSSION

Chemical Properties of Soil before sowing and Poultry Manure used in the Experiment

The result on Table 1 shows that the soil in the experimental plot was dominated by sand fraction (882.70 g/kg) and belong to the textural class: loamy sand. Airueghian *et al.* (2018); Omokaro *et al.* (2023) reported that soils in the Experimental Field

of Faculty of Agriculture, University of Benin were dominated by sand fraction and belong to the loamy sand textural class.

The soil before sowing was strongly acidic (pH 5.3), low in total organic carbon (9.96 g/kg), calcium (0.37 cmol/kg) and very low in total nitrogen content (0.28 g/kg), according to the ratings outlined in Chude *et al.*, (2011). This low nutrient status of the soil may be due to leaching of basic cations, weathering and extensive cultivation (Osunde, 2020).

According to the ratings outlined in Chude *et al.*, (2011), the poultry manure applied had slightly alkaline pH (7.3), high total organic carbon (14.35 g/kg), total nitrogen (3.52 g/kg), available phosphorus (34.31 mg/kg), potassium (5.71 cmol/kg), calcium (7.90 cmol/kg), and magnesium, (11.20 cmol/kg). These high contents of plant nutrients qualify poultry manure as a soil amendment (Rizzo *et al.*, 2022).

Soil Chemical Properties After Harvest

The application of PM and NPK fertilizers significantly ($P < 0.05$) influenced the soil's chemical properties after the harvest of *Celosia argentea* (Table 2). The highest values for organic carbon (22.57 g/kg), total nitrogen (0.85 g/kg), and available phosphorus (25.38 mg/kg) were recorded in treatment T9 (300 kg/ha NPK + 16 t/ha PM). This represents a substantial improvement from the initial soil status and the control plot (T1). This effect can be attributed to the direct nutrient supply from the NPK fertilizer and the mineralization of the organic manure, which releases nutrients gradually and enhance microbial activities, leading to improved soil organic matter content (Udom and Lale, 2017). The findings align with Ofori *et al.* (2021), who

reported similar improvements in soil N and P with combined nutrient sources in vegetable production.

Similarly, the exchangeable bases (K, Ca, Mg, Na) and the Effective Cation Exchange Capacity (ECEC) were significantly ($p < 0.05$) increased by the combined amendments. 300 kg/ha NPK + 16 t/ha PM consistently recorded the highest values for these cations. The increment in ECEC values after the harvest of *Celosia* may be due to the direct effect of the applied amendments (NPK 15:15:15 and poultry manure), which are rich in cations (Hoover *et al.* (2019). This increase in ECEC is crucial for ultisols because it enhances their ability to retain nutrients against leaching losses. The organic acids produced during the decomposition of PM help to solubilize fixed nutrients and increase the sites for cation retention (Almaz *et al.*, 2017). According to Lin *et al.* (2018), the application of poultry manure has the potential to enhance soil organic carbon and improve soil fertility. Continuous application of poultry manure helps improve crop yield, soil organic carbon and soil carbon sequestration (Hoover *et al.*, 2019). Soil pH also showed a slight improvement in amended plots compared to the control, which can be linked to the liming effect of the poultry manure (Mowrer *et al.*, 2020).

Table 1: Initial Physical and Chemical Properties of the Soil and Poultry Manure Used

Property	Soil Before Planting	Poultry Manure
Sand (g/kg)	882.70	-
Silt (g/kg)	59.33	-
Clay (g/kg)	57.33	-
Textural Class	Loamy sand	-
pH	5.3	7.3
Organic C (g/kg)	9.69	14.35
Total N (g/kg)	0.28	3.25
Available P (mg/kg)	9.49	34.31
K (cmol/kg)	0.55	5.71
Ca (cmol/kg)	1.53	7.9
Mg (cmol/kg)	0.37	11.2
Na (cmol/kg)	0.5	19.83
ECEC (cmol/kg)	4.83	46.49
Base Saturation (%)	61.08	96.02

Growth and Yield Parameters of *Celosia argentea*

The combined application of PM and NPK significantly enhanced the growth and yield of *Celosia argentea*. Plant height increased progressively from 4 to 8 WAP across all treatments, with the highest values consistently observed in treatments receiving the highest nutrient inputs (300 kg/ha NPK + 8 t/ha PM and 300 kg/ha NPK + 16 t/ha PM) (Table 3). At 8 WAP, 300 kg/ha NPK + 16 t/ha PM produced the tallest plants (74.83 cm), significantly outperforming the control (24.00 cm).

This enhanced vegetative growth is a direct response to the improved nutrient availability, particularly nitrogen, which is vital for cell division and elongation (Almaz *et al.*, 2017; Agbede, 2021).

The number of leaves and stem girth showed less consistent significant differences among treatments, though a general positive trend

was observed with increasing amendment rates (Data not shown in full for brevity, but available in original thesis Tables 4 and 5). The most critical parameter, marketable yield (fresh leaf weight), was significantly influenced by the treatments (Table 4). The control plot yielded only 1.28 t/ha, while all amendment treatments produced higher yields. The highest yield of 4.98 t/ha was obtained from T9 (300 kg/ha NPK + 16 t/ha PM), which was statistically similar to T8 (4.95 t/ha). This dramatic increase in yield underscores the superiority of the integrated approach. The combined application likely provided a more balanced and sustained nutrient supply, meeting the high nutrient demand of *Celosia* throughout its growth cycle, as previously reported by Law-Ogbomo *et al.*, (2017); Ipinmoroti, *et al.*, 2020; Falodun *et al.* (2022) for other vegetables.

Table 2: Effect of Treatments on Soil Chemical Properties After Harvest of *Celosia argentea*

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)
T1: Control	5.7 ^e	11.15 ^g	0.36 ^f	9.35 ^e	0.45 ^f	1.58 ^e	0.35 ^e	0.60 ^g	5.04 ^d
T2: 8 PM	6.0 ^{cd}	12.86 ^{ef}	0.38 ^f	14.06 ^d	0.55 ^{ef}	1.69 ^{cd}	0.51 ^d	0.62 ^{fg}	5.23 ^d
T3: 16 PM	6.2 ^{bc}	20.65 ^b	0.40 ^f	13.66 ^d	0.60 ^{de}	1.85 ^a	0.57 ^d	0.79 ^{cd}	6.03 ^c
T4: 150 NPK	5.9 ^d	12.50 ^{fg}	0.59 ^e	17.27 ^c	0.68 ^{cd}	1.63 ^d	0.68 ^c	0.69 ^{ef}	6.06 ^c
T5: 150 NPK+8 PM	6.4 ^a	14.04 ^{de}	0.76 ^{bc}	19.98 ^b	0.78 ^{ab}	1.75 ^{bc}	0.84 ^b	0.71 ^{de}	6.37 ^b
T6: 150 NPK +16 PM	6.5 ^a	15.23 ^d	0.75 ^{cd}	20.43 ^b	0.73 ^b	1.79 ^{ab}	0.81 ^b	0.85 ^{bc}	6.44 ^b
T7: 300 NPK	5.8 ^{de}	18.69 ^c	0.69 ^d	20.52 ^b	0.70 ^{bc}	1.84 ^a	0.89 ^{ab}	0.99 ^a	6.55 ^{ab}
T8: 300 NPK+8 PM	6.3 ^{ab}	19.50 ^{bc}	0.82 ^{ab}	24.55 ^a	0.85 ^a	1.70 ^c	0.90 ^a	0.86 ^b	6.57 ^a
T9: 300 NPK +16 PM	6.4 ^a	22.57 ^a	0.85 ^a	25.38 ^a	0.87 ^a	1.83 ^a	0.95 ^a	0.89 ^b	6.69 ^a
HSD (0.05)	0.26	1.53	0.06	0.91	0.09	0.08	0.10	0.08	0.21

Means in the same column followed by the same letter in same column are not significantly different at $P < 0.05$.

Table 3. Effect of Treatments on Plant Height (cm) of *Celosia argentea* at Different Intervals

Treatments	4 WAP	6 WAP	8 WAP
T1: Control	4.17 ^c	20.00 ^b	24.00 ^c
T2: 8 PM	8.00 ^{bc}	25.33 ^{ab}	34.33 ^{bc}
T3: 16 PM	7.50 ^{bc}	35.33 ^{ab}	38.33 ^{bc}
T4: 150 NPK	10.83 ^{ab}	34.00 ^{ab}	39.50 ^{bc}
T5: 150 NPK+8 PM	12.00 ^{ab}	23.00 ^b	39.67 ^{bc}
T6: 150 NPK+16 PM	13.67 ^a	32.33 ^{ab}	46.17 ^{bc}
T7: 300 NPK	11.50 ^{ab}	32.67 ^{ab}	68.50 ^a
T8: 300 NPK+8 PM	14.33 ^a	47.00 ^a	68.67 ^a
T9: 300 NPK+16 PM	14.00 ^a	45.00 ^a	74.83 ^a
HSD	4.129	15.247	23.731

Means in the same column followed by the same letter in same column are not significantly different at $P < 0.05$.

Table 4: Effect of Treatments on Marketable Yield (t/ha) of *Celosia argentea* at 8 WAP

Treatments	Leaf Yield (t/ha)
T1: Control	1.28 ^h
T2: 8 PM	1.64 ^g
T3: 16 PM	3.28 ^e
T4: 150 NPK	2.76 ^f
T5: 150 NPK+8 PM	3.53 ^d
T6: 150 NPK+16 PM	3.92 ^c
T7: 300 NPK	4.29 ^b
T8: 300 NPK+8 PM	4.95 ^a
T9: 300 NPK+16 PM	4.98 ^a
HSD	0.241

Means followed by the same letter in same column are not significantly different at $P < 0.05$.

CONCLUSION

The results of this study clearly demonstrated that the application of poultry manure and NPK fertilizer is a highly effective strategy for enhancing both the productivity of *Celosia argentea* and the fertility of the soil. Sole application of either amendment as well as their combination improved soil properties and crop performance compared to the control. The treatment rate comprising 300 kg/ha NPK 15:15:15 and 16 tons/ha poultry manure (T9) was the most effective, resulting in the highest improvements in key soil nutrients (organic carbon, total nitrogen, available phosphorus, and exchangeable cations) and the highest marketable yield of celosia.

The significant increase in soil organic

carbon and ECEC with combined application is particularly important for the sustainable management of Ultisols, as it addresses their inherent weaknesses of low nutrient retention capacity. The improvement in plant height and final yield is a result of enhanced soil fertility due to the application of NPK 15:15:15 and poultry manure.

Based on these findings, it is recommended that farmers in the rainforest zone of Nigeria, where Ultisols are common, should adopt the combined use of poultry manure and NPK fertilizer for cultivating *Celosia argentea* to achieve optimal yields while improving soil health.

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