Comparative Effect of Organic and Inorganic Soil Amendments on Some Growth and Bioactive Constituents of Dura and Tenera Oil Palm (Elaeis guineensis Jacq) in Abak, Nigeria.

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Abstract- Efficient nutrient management is crucial for sustainable oil palm (Elaeis guineensis) cultivation. This study examined the comparative effect of organic (cow dung, poultry droppings) and inorganic (NPK Mg 12:12:17:2) soil amendments on growth and bioactive constituent of dura and tenera oil palm (Elaeis guineensis Jacq.) seedlings under nursery conditions. A randomized complete block design was used with four treatments: cow dung, poultry droppings, NPK Mg (12:12:17:2), and control (topsoil), replicated four times per variety. Growth parameters (plant height, leaf number, leaf area, butt circumference, and total dry weight) were measured for five months. Phytochemical analysis was conducted to determine bioactive compounds (flavonoids, tannins, alkaloids, and saponins). Results showed that organic amendments significantly ($p < 0.05$) improved all growth parameters compared to inorganic and control treatments. Tenera seedlings exhibited superior performance, with highest leaf height(43.70cm). Phytochemical screening revealed higher flavonoid and saponin contents in organically treated seedlings. Poultry droppings produced the most consistent improvements. Organic amendments, particularly poultry droppings, are recommended for sustainable oil palm seedling production and enhanced physiological function.

Keywords: Oil Palm, Cow Dung, Poultry Droppings, NPK Fertilizer, Phytochemicals, Seedling Growth, Elaeis Guineensis.

I. INTRODUCTION

Oil palm (Elaeis guineensis Jacq.) is one of the world's most important perennial oil-bearing crops, cultivated primarily in tropical regions for its high-yielding palm oil and palm kernel oil. These oils serve as vital raw materials for the food industry, cosmetic formulations, pharmaceuticals, biofuel production, and industrial lubricants (Corley & Tinker, 2016). Nigeria, along with Malaysia, Indonesia, and Thailand, has been a key producer; however, despite vast suitable land, Nigeria's productivity remains low due to poor agronomic practices, limited fertilizer input, and declining soil fertility (Uwumarongie-Ilori et al., 2012). Soil fertility management plays a pivotal role in the early growth and physiological performance of oil palm seedlings. The nursery stage is especially critical, as vigorous seedlings are essential for successful field establishment, early yield onset, and long productivity.

However, nursery soils in most oil palm-growing regions are typically acidic, low in organic matter, and deficient in macronutrients such as nitrogen (N), phosphorus (P), and potassium (K) (Ng et al., 1999). Conventional nursery management often relies on inorganic fertilizers such as NPK Mg (12:12:17:2) to replenish these nutrients. While these fertilizers supply nutrients rapidly and improve early seedling growth, they are often associated with short-lived fertility benefits, nutrient leaching, and soil acidification under tropical rainfall conditions (Adekiya et al., 2020). Over time, such practices can reduce soil biological activity and structural stability, limiting nutrient use efficiency and long-term soil sustainability. The global shift toward sustainable agriculture has renewed interest in the use of organic soil amendments as viable alternatives or complements to inorganic fertilizers. Organic materials such as cow dung and poultry droppings enhance soil fertility through multiple mechanisms: they increase organic matter content, improve soil texture, stimulate microbial activity, and release nutrients slowly through mineralization (Ofosu et al., 2018). Cow dung is known for improving soil water-holding capacity and cation exchange, while poultry droppings decompose rapidly, releasing readily available N and P (Uwumarongie-Ilori et al., 2012). Consequently, organic fertilizers contribute not only to short-term plant growth but also to the long-term improvement of soil health, aligning with global goals for sustainable oil palm cultivation and climate-smart agriculture. However, despite the recognized potential of organic amendments, there is still limited comparative data on their effectiveness relative to inorganic fertilizers, particularly in relation to the growth and biochemical composition of oil palm seedlings. Furthermore, oil palm exists in several genetically distinct varieties, including Dura, Tenera, and Pisifera, each with unique growth patterns and nutrient requirements. Tenera—a hybrid of Dura × Pisifera—is the preferred commercial variety due to its hybrid vigor, higher oil-to-bunch ratio, and superior nutrient-use efficiency (Agyei-Dwarko et al., 2012). Dura, though less productive, remains widely cultivated in traditional systems. Understanding how these two varieties respond to different soil amendment regimes is crucial for optimizing nutrient management in nursery operations. Beyond vegetative growth, soil nutrient management may also influence the biosynthesis of phytochemicals—secondary metabolites that contribute to plant defence, stress tolerance, and physiological balance. Compounds such as flavonoids, alkaloids, tannins, and saponins play important roles in antioxidant defence systems and are influenced by nutrient availability and soil conditions (Harborne, 1998; Adekiya et al., 2020). Organic amendments, which enhance soil microbial activity and nutrient cycling, may stimulate the synthesis of these bioactive compounds, improving plant health and resilience. However, research examining how different soil amendment strategies affect the bioactive composition of oil palm seedlings remains scarce, particularly in the context of comparing genetic varieties.

II. MATERIALS AND METHODS

The study was conducted at the Nigerian Institute for Oil Palm Research (NIFOR), Abak Substation, Akwa Ibom State, Nigeria (latitude 5°01′ N, longitude 7°48′ E, and altitude 69 m above sea level). The research was conducted from January to August (transcending the dry and wet season) in two stages (pre-nursery and main nursery). Topsoil was collected from a depth of 0–15 cm from the nursery site, organic amendments (cow dung and poultry droppings) were sourced from nearby livestock farms, air-dried for two weeks, to reduce ammonia volatilization and pathogen load.

The treatments included:

- T_1: Cow dung (organic 3:1 v/v)
- T_2: Poultry droppings (organic 3:1 v/v)
- T_3: NPK Mg fertilizer (12:12:17:2 formulation) (inorganic) applied at 2g/ polybag
- T_4: Control (unamended topsoil with)

2.1. Pre-Nursery Stage

Certified viable oil palm germinated seeds of Dura and Tenera varieties were obtained from seed production department (SPD), NIFOR main office, Benin City, Nigeria.

Germinated seeds (radicle length ≈1–2 cm) were sown into small perforated black polyethylene bags (15 cm × 23 cm) containing topsoil, using randomized design. The pre-nursery was shaded with palm fronds to reduce heat stress and watered daily using a fine spray nozzle. Shading intensity was gradually reduced after six weeks to harden seedlings. No fertilizer was applied at this stage to prevent nutrient toxicity and encourage uniform early root establishment. Routine management such as manual weeding was implemented. Seedlings with uniform growth and good vigour were selected at the end of the third month for transplanting to the main nursery stage.

2.2 Nursery Stage

Three-month-old seedlings from the pre-nursery were carefully uprooted and transplanted into the main nursery bags, one seedling per bag. Each seedling was placed centrally in the bag, ensuring the root ball remained intact to minimize transplant shock. Randomized complete block design with four treatment, two varieties and four replications with 32 plots and a plot size of 40 palms (arranged at 90cm triangle pattern) were transplanted into NIFOR perforated poly bags of 35.6cm x45.7cm, giving a total of 1,280 palms for the two varieties.

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Seedlings were watered immediately after transplanting; the main nursery phase lasted five months, during which the soil amendment treatments were applied and growth parameters bioactive constituents evaluated

2.3. Data collection

Growth parameters

Growth data were collected at four and five months after trans planting from randomly selected seedlings per treatment per replicate. Parameters included:

- Plant Height (cm): measured from the soil surface to the tip of the youngest fully expanded leaf using a measuring tape.
- Number of Leaves: total count of fully opened fronds per seedling.
- Leaf Area (cm²): computed as L × B × 0.75, where L = leaf length
- (cm) and B = leaf breadth (cm) (Tarmizi & Mohd Tayeb, 2006).
- • Butt Circumference (cm): measured at 2 cm above the soil surface using a flexible tape.
- Total Dry Weight (g): at harvest (5 MAT), seedlings were partitioned into roots, stems, and leaves, oven-dried at 65°C to constant weight, and summed.

Phytochemical Analysis

Phytochemical composition of fronds was analysed using qualitative methods described by Sofowora (1993) and Harborne (2005):

- Flavonoids: detected by Shinoda test (appearance of reddish-pink color).
- Tannins: identified using ferric chloride test (blue-black coloration).
- Saponins: determined by frothing test.
- Steroids: confirmed by Salkowski test (red coloration).
- Cardiac Glycosides: detected by Keller–Killiani test (reddish-brown ring).

Statistical Analysis

Data were analysed using SPSS version 23. A one-way ANOVA was conducted to test for significant differences among treatments. When significant, Duncan's Multiple Range Test (DMRT) was applied for mean separation at $p < 0.05$.

III. RESULTS

Growth Performance of Dura and Tenera Seedlings

Significant differences ($p < 0.05$) were observed among the various soil amendment treatments for both oil palm varieties at 4 and 5 months after transplanting (Tables 1–3). Organic amendments, particularly poultry droppings, consistently enhanced all growth parameters compared with inorganic fertilizer and the control.

Table 1. Four months after transplanting (4 MAT), Tenera seedlings treated with poultry droppings attained the greatest mean height (43.70 cm), number of leaves (8.50), leaf area (34.05 cm²), and butt circumference (5.25 mm) which were significantly ($p < 0.05$) greater than NPK Mg and control. Dura seedlings under the same treatment showed lower but comparable trends, attaining a height of 39.12 cm and leaf area of 29.04 cm².

Table 1. Comparative growth of Dura and Tenera seedlings at 4 months under different soil amendments

Variety	Treatment	Height (cm)	No. of Leaves	Leaf Area (cm²)	Butt Circumference (mm)
Dura	Cow Dung	38.24 ± 1.05b	7.60 ± 0.18b	28.31±0.90b	4.65 ± 0.13b
	Poultry Droppings	39.12 ± 1.10b	7.85 ± 0.20b	29.04±0.88b	4.72 ± 0.15b
	NPK Mg	30.42 ± 0.88a	6.80 ± 0.16a	24.18±0.72a	4.10 ± 0.11a
	Control	28.65 ± 0.80a	6.55 ± 0.15a	23.30±0.70a	3.90 ± 0.10a
Tenera	Cow Dung	42.85 ± 1.20c	8.35 ± 0.20c	33.40±1.02c	5.12 ± 0.16c
	Poultry Droppings	43.70 ± 1.22c	8.50 ± 0.19c	34.05±1.05c	5.25 ± 0.18c

Variety	Treatment	Height (cm)	No. of Leaves	Leaf Area (cm^2)	Butt Circumference (mm)
	NPK Mg	34.22 ± 0.95b	7.20 ± 0.17b	27.15±0.80b	4.55 ± 0.12b
	Control	32.80 ± 0.90b	7.05 ± 0.16b	26.80±0.78b	4.42 ± 0.11b

Means with different superscripts differ significantly at $p < 0.05$ (DMRT)

Table 2. five months after transplanting (5 MAT, tenera seedlings grown with poultry droppings where significantly ($p < 0.05$) different than cow dung with plants height (56.18 cm and 54.04 cm, respectively), highest leaf numbers (9.75 and 9.60), and largest butt circumferences (6.41 mm and 6.35 mm). In contrast, seedlings supplied with NPKMg (12:12:17:2) displayed moderate growth, while the control maintained the least performance.

Table 2. Comparative growth of Dura and Tenera seedlings at 5 months under different soil amendment

Variety	Treatment	Height (cm)	No. of Leaves	Leaf Area (cm^2)	Butt Circumference (mm)
Dura	Cow Dung	45.52 ± 1.20b	8.40 ± 0.21b	32.18 ± 1.02 b	5.12 ± 0.18b
	Poultry Droppings	47.23 ± 1.30b	8.63 ± 0.18b	33.25 ± 1.15 b	5.38 ± 0.21b
	NPK Mg	37.80 ± 0.88a	7.21 ± 0.15a	26.14 ± 0.94 a	4.32 ± 0.16a
	Control	35.64 ± 0.90a	7.00 ± 0.17a	25.80 ± 0.88 a	4.01 ± 0.13a
Tenera	Cow Dung	54.04 ± 1.42c	9.60 ± 0.19c	38.12 ± 1.12 c	6.35 ± 0.19c
	Poultry Droppings	56.18 ± 1.50c	9.75 ± 0.16c	39.27 ± 1.20 c	6.41 ± 0.20c
	NPK Mg	43.12 ± 1.05b	8.25 ± 0.13b	30.25 ± 0.95 b	5.02 ± 0.18b
	Control	40.45 ± 1.00b	8.00 ± 0.15b	29.84 ± 0.90 b	4.73 ± 0.15b

Means with different superscripts differ significantly at $p < 0.05$ (DMRT).

Table 2. shows the total dry mass of teneral and dura varieties as affected by different soil amendments. Tenera seedlings treated with poultry droppings recorded the highest total dry weight (40.23 g), with root (8.18), shoot (13.32) and leaves (18.73). Followed by cow dung (36.59 g), while Dura seedlings reached 31.78 g and 26.67 g under the respective organic treatments. The least biomass was observed in the control.

Table 3. Biomass (g) of Dura and Tenera oil palm seedlings at 5 months after planting.

Variety	Treatment	Root (g)	Shoot (g)	Leaf (g)	Total Dry Weight (g)
Dura	Cow Dung	5.20	10.13	11.34	26.67
	Poultry Droppings	5.43	8.12	18.23	31.78
	NPK	3.30	9.5	10.42	23.22
	Control	2.23	4.23	9.13	15.59
Tenera	Cow Dung	8.32	15.63	12.64	36.59
	Poultry Droppings	8.18	13.32	18.73	40.23
	NPK	5.53	12.10	11.42	29.04
	Control	3.9	8.53	5.23	17.66

Effect of Soil Amendments on Phytochemical Composition

Phytochemical screening showed marked differences in the concentration of secondary metabolites among treatments (Tables 4 and 5). Organic amendments, particularly poultry droppings, enhanced the accumulation of flavonoids, saponins, tannins, and cardiac glycosides in both oil palm varieties. Tenera seedlings recorded the highest intensity of these bioactive constituents (++ to +++), especially for flavonoids and saponins under poultry droppings, whereas control plants showed only trace levels (+).

Table 4. Phytochemical Composition of dura

Phytochemical	Control	Cow Dung	Poultry Droppings	NPK Mg
Flavonoids	+	+	++	+
Tannins	+	+	+	+
Saponins	+	++	++	+
Steroids	+	++	+	+
Cardiac Glycosides	+	++	++	+

(+ = trace; ++ = moderate; +++ = high)

Table 5. Phytochemical Composition of dura

Phytochemical	Control	Cow Dung	Poultry Droppings	NPK Mg
Flavonoids	+	+	++++	+
Tannins	+	++	+++	++
Saponins	+	++	+++	++
Steroids	+	++	++	+
Cardiac Glycosides	+	++	+++	++

(+ = trace; ++ = moderate; +++ = high.

IV. DISCUSSION

4.1 Influence of Soil Amendments on Growth Performance

The present study revealed that the application of organic soil amendments, particularly poultry droppings, significantly enhanced the growth parameters of Dura and Tenera oil palm seedlings compared with inorganic fertilizer (NPK Mg 12:12:17:2) and the control. Parameters such as plant height, leaf number, leaf area, butt circumference, and total dry weight all responded positively to organic amendments (cow dung), demonstrating the superior nutrient-supplying capacity and soil-improving effects of these materials.

The improvement in vegetative growth observed under poultry droppings can be attributed to its ability to enhance soil physical, chemical, and biological properties. Organic materials improve soil structure, water-holding capacity, and cation exchange capacity, facilitating root proliferation and nutrient uptake (Adekiya et al., 2020). The gradual mineralization of organic matter also provides a slow-release source of essential nutrients, maintaining a steady nutrient supply throughout the nursery period (Ofosu et al., 2018). This aligns with the findings of Uwumarongie-Ilori et al. (2012), who reported that oil palm seedlings grown in soils amended with organic fertilizers exhibited significantly higher growth indices compared to those treated with inorganic fertilizers alone.

Conversely, the comparatively lower performance of seedlings under NPK Mg treatment could be attributed to rapid nutrient release and leaching losses, a common problem in tropical soils with high rainfall. While NPK fertilizers provide an immediate boost to early seedling growth, their effects tend to diminish over time, as observed by Tarmizi and Mohd Tayeb (2006). Moreover, the absence of organic carbon in inorganic fertilizers leads to a decline in soil microbial activity, further reducing nutrient retention and availability over the growth period.

The control treatment, which received no fertilizer input, recorded the lowest growth values across all parameters, underscoring the inherently low fertility status of the nursery soil. The results corroborate the findings of Ng et al. (1999), who reported that unamended soils in tropical regions are often deficient in nitrogen and phosphorus, both critical for chlorophyll synthesis and root establishment during the early growth stages of oil palm.

4.2 Comparative Growth Response Between Dura and Tenera Varieties

A major highlight of this study was the consistent superiority of the Tenera seedlings over the Dura variety in nearly all measured parameters. Tenera recorded greater plant height, number of leaves, leaf area, and total dry weight across all soil amendments. This observation agrees with Agyei-Dwarko et al. (2012), who attributed the superior performance of Tenera to hybrid vigor (heterosis) resulting from its Dura × Pisifera parentage.

The genetic advantage of Tenera manifests in improved growth, and biomass accumulation.
The higher total dry weight recorded in Tenera seedlings suggests more efficient partitioning of assimilates to both aboveground and belowground organs. This supports reports by Corley and Tinker (2016) that Tenera palms typically exhibit stronger vegetative vigor, which translates to enhanced field establishment and eventual yield advantage. The observed varietal differences also reflect distinct physiological responses to soil nutrient availability; Tenera appears more adaptive under both organic and inorganic nutrient regimes, indicating its broader genetic adaptability.

Interestingly, the Dura variety showed relatively moderate growth under organic amendments but declined more under inorganic fertilizer and control treatments. This trend suggests that Dura seedlings benefit more from the gradual nutrient release and improved soil conditions associated with organic matter than from the short-term nutrient pulse of inorganic inputs. This finding underscores the importance of matching variety-specific nutrient management strategies to maximize seedling growth and development.

prone to losses through leaching, especially in sandy loam soils typical of the experimental site. The control treatment exhibited the lowest nutrient uptake, confirming that unamended soils cannot support optimal nutrient absorption for oil palm growth under nursery conditions.

4.4 Influence of Soil Amendments on Bioactive (Phytochemical) Constituents
Phytochemical analysis revealed that organic amendments significantly influenced the accumulation of bioactive compounds, including flavonoids, saponins, tannins, and alkaloids. Seedlings treated with and poultry droppings exhibited the highest concentrations of flavonoids and saponins, followed by NPK Mg and the control. This suggests that organic amendments not only improve physical growth but also enhance biochemical processes linked to plant metabolism and stress defence.

The increased synthesis of flavonoids and saponins under organic amendments may be linked to the higher nitrogen availability from organic sources, which supports amino acid and phenolic compound synthesis pathways (Harborne, 1998). These compounds play vital roles in antioxidative defence, protecting plant cells from reactive oxygen species generated under environmental stress. Moreover, the microbial activity stimulated by organic amendments can increase root exudates, which in turn enhances secondary metabolism and the accumulation of phytochemicals. These findings are consistent with Adekiya et al. (2020), who reported that organic inputs enhance phytochemical synthesis in crops by promoting balanced nutrient release and improving enzymatic activities involved in secondary metabolite production. The higher bioactive compound levels under cow dung suggest that slower nutrient mineralization provided a more sustained nutrient supply, optimizing metabolic pathways associated with secondary compound synthesis. Seedlings under NPK Mg treatment exhibited lower phytochemical contents, likely due to nutrient imbalance and the absence of organic carbon that supports enzymatic and microbial processes. The control group recorded the lowest bioactive values, reflecting nutrient deficiency and limited metabolic activity.

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