



Effects of Organo-Mineral Fertilizer on the Growth and Yield of *Terminalia Ivorensis* A. Chev. Seedlings

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ABSTRACT: The use of organo-mineral fertilizers as a method of sustaining soil fertility management strategy has drawn more attentions in the agroforestry system. Hence, this study investigated the growth and yield performance of *Terminalia ivorensis* A. Chev. seedlings under nursery conditions using standard methods. Results obtained from the growth parameters revealed a significance difference in stem diameter from 5-8 Weeks After Transplanting (WAT) when compared with control (no treatment), plant height shows a significant difference from 2-8 WAT while number of leaves also revealed a significant difference among the seedlings from 4-8WAT when compared with control. In contrast, total biomass results for both dry and wet weight of *Terminalia ivorensis* seedlings shows no significant differences but recorded highest wet leaf and root biomass of 13.17g, 10.46g for treatment CD2 (cow dung only) and stem biomass recorded 5.51g for treatments CB8 (Cow dung+ NPK) respectively. The total dry leaf and roots biomass also recorded 11.76g, 9.06g for treatments CD2 and stem dry biomass of 4.50g for treatments CB8 respectively. Conclusively, the response of organic and inorganic manure nutrients sources integration in *Terminalia ivorensis* seedlings reveals a long-term contribution of soil fertility, forest sustainability as well as seedling vigor.

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The declining sustainable forest regeneration and agroforestry practices are seriously threatened by the decreasing productivity of tropical soils spurred by nutrient depletion and low organic matter content (FAO, 2020). Combining the nutrient-richness of inorganic fertilizers with the soil-ameliorating qualities of organic matter, organo-mineral fertilizers are one promising way to address these issues (Adekiya *et al.*, 2019). Tree species are very essential for reducing soil erosion, mitigating the effects of climate change, removing carbon dioxide from the atmosphere, and sequestering of carbon. The

preservation and sustainable management of urban woodlands, rainforests, and trees: such as parks and forest reserves are very advantageous in maintaining climate conditions while halting the depletion of natural resources (Crowther *et al.*, 2015). The use of organo-mineral fertilizers promotes improved plant establishment and growth by increasing soil fertility as well as water retention, microbial activity, and nutrient usage efficiency (Olatunji *et al.*, 2021). *Terminalia ivorensis* A. Chev., also known as Idigbo or Black Afara, is recognized for its ecological and economic significance in West and Central Africa and

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also a rapidly growing native hardwood species prized for its superior timber, capacity for replanting (Orwa *et al.*, 2009). Its timber is frequently used in joinery, building projects, and furniture production because of its strength, ease of handling, and attractive grain pattern (Salami *et al.*, 2023; Masoko *et al.*, 2005).

In its indigenous habitat, *Terminalia ivorensis* contributes significantly to biodiversity and ecosystem services, hence its sustainable management is crucial. Despite its ecological and economic significance, low seedling vigor and suboptimal development on damaged soils frequently make it difficult to cultivate *Terminalia ivorensis* (Asante and Teklehaimanot, 2017). Therefore, the effectiveness of afforestation and agroforestry depends on improving seedling performance through efficient nutrient management.

Nevertheless, the survival and subsequent efficacy of seedlings in the field are directly impacted by their slow early growth stages and high nutrient needs (Ojo *et al.*, 2020). Previous studies revealed that integrating organic and mineral fertilizers can enhance biomass accumulation and root development in tree seedlings by providing a consistent and balanced nutrient supply (Gichangi *et al.*, 2021; Bhunia *et al.*, 2021; Yang *et al.*, 2020; Akinnifesi *et al.*, 2007).

However, limited information is available on how *Terminalia ivorensis* seedlings react to organo-mineral fertilizer treatments. As a result, this study therefore examines how organo-mineral fertilizer affects *Terminalia ivorensis* seedling growth and yield variables in an effort to offer empirical support for sustainable nursery methods and soil fertility improvement in the restoration of forest ecosystems.

MATERIALS AND METHODS

Study Area: This experiment was carried out in the Forestry Research Institute of Nigeria Jericho, Ibadan's screen house of the Sustainable Forest Management Department. It is located between latitude 07°23'N and longitude 03°56'E.

The research location experiences an annual rainfall pattern of 1400–1500 mm, a mean maximum temperature of 31.9°C, a minimum temperature of 24.2°C, and a relative humidity of 74.55% (FRIN annual Meteorological Report 2018).

Sample Collection and treatments: The 2.5kg topsoil used was collected from the FRIN Arboretum, air-dried and gently crushed and sieved through a 2mm

sieve. The seedlings used for the experiment was sourced from the Sustainable Forest Management Department of Forestry Institute of Nigeria, Ibadan. For this experiment, two types of fertilizer were used: inorganic fertilizer (NPK 15:15:15) and organic fertilizer (cow dung).

The organic fertilizer (cow dung) was then incorporated into the top soil for 2weeks to breakdown and mineralized before the seedlings were then transplanted into a 3kg polyethylene bag soil. The chemical composition of the cow dung was analyzed (shown in Table 1).

Laboratory Analysis: The topsoil sampled was subjected to Physico-chemical analysis which include: A glass electrode pH meter (Udo and Ogunwale, 1986) was used to measure the pH of the soil in a 1:1 soil-to-water ratio, and the Bouyoucos hydrometer technique (Bouyoucos, 1962) was used to evaluate the Particle Size distribution.

The Total Nitrogen content was ascertained using the Kjeldahl (1883) technique, and the Available Phosphorus was determined using a spectrophotometer using the Mehlich III extraction method (Mehlich, 1984). The exchangeable cations (K, Ca, Na, and Mg) were extracted using Ammonium Acetate.

An Atomic Absorption Spectrophotometer was utilized for determining calcium and magnesium, while a flame photometer was used to measure Potassium and Sodium.

The extractable micronutrients (Fe, Mn, Cu, and Zn) were extracted using 0.1N HCl solution, and their amounts were measured using an Atomic Absorption Spectrophotometer machine (shown in Table 2).

Data Analysis: The experiment was laid out in a Randomized Complete Block Design (RCBD), having nine treatments replicated five times making a total of 45 experimental units. The following parameters were taken into consideration: Stem diameter (mm), Plant height (cm), Number of leaves and Plant biomass (Wet Weight and Dry weight) at the end of the experiment. The treatments used were presented in Table 1.

The parameters were collected at 3weeks intervals for the period of 27weeks. With the use of R programming software, all the data were analyzed using analysis of variance (ANOVA) and multiple comparison treatment (Steel *et al.*, 1997) was used to separate the mean at 5% Level of significance.

Table 1: Treatments used for the experiment

S/N	Treatments	t/ha	Kg P/ha	Cow dung (g/pot)	NPK (g/Pot)
1	Cowdung	5	50	40.4	-
2	Cowdung	10	100	80.8	-
3	Cowdung	15	150	121.2	-
4	NPK	5	50	-	0.37
5	NPK	10	100	-	0.74
6	NPK	15	150	-	1.12
7	Cow dung + NPK	5	50	40.4 +0.37	
8	Cow dung + NPK	10	100	80.8 +0.74	
9	Control	No application			

RESULTS AND DISCUSSIONS

The experimental soil was sandy soil with a pH level (6.12) which was slightly acidic. The overall physico-chemical analysis (shown in Table 2) revealed that Total Nitrogen (T.N) and Available phosphorus (A.P) were high in comparison with the critical level of 0.2% and 15–20 mg/kg respectively. The exchangeable cations (Ca, Mg, K and Na) ranges from moderate to high when compared with the critical level obtained for soil in South Western Nigeria (Kayode and Agboola1985; Landon, 1991; FAO, 2006).

Table 2: Physico-chemical analysis of soil sample and chemical analysis (cow dung)

Parameters	Soil	Cow dung (%)
pH in H ₂ O	6.12	-
Total Nitrogen (g/kg)	1.25 g/kg	1.18
Available Phosphorus (mg/kg)	22.49 mg/kg	0.14
Exchangeable cations (cmol/kg)	2.27	(%)
Ca	1.28	0.59
Mg	0.21	2.81
K	0.72	0.84
Na	0.72	0.84
Extractable Micronutrients (mg/kg)	45.00	0.02
Mn	35.21	1.33
Fe	0.91	0.02
Cu	18.70	0.03
Zn		
Particle size distribution (g/kg)		
Sand	82.5	
Silt	7.8	
Clay	9.7	
Textural class	Loamy sand	

The high level of micro nutrients (Cu, Mn, Fe and Zn) can be attributed to long fallow period, parent material, organic manure accumulation and pH conditions related to soil formation (Alloway 2012; Shahid *et al.*, 2016). The Nitrogen level in cow dung was moderate when compared with the typical range of raw cow dung 0.5–1.5% N (FAO, 2001; Gichangi *et al.*, 2021). The Available Phosphorus was very low when compared with the range of 10–50mg/kg while the exchangeable cations range between the low to high range when compared with the cow dung ranges

(K: 1.0–3.0cmol/kg, Ca: 1–5cmol/kg, Mg: 0.5–2cmol/kg). The extractable micronutrients range between very low to low when compared with the typical value of cow dung nutrients (Gichangi *et al.*, 2021; FAO, 2001).

Impacts of organo-mineral fertilizers on the growth parameters (Height, Collar diameters and Numbers of leaves) of Terminalia ivorensis: The stem diameter of *Terminalia ivorensis* seedlings demonstrated a high significance difference probability at weeks 5, 6, 7 and 8 Weeks After Transplanting (WAT) (presented in Table 3). In contrast, there were no significance differences between the treatments during the first 4 WAT. This early lack of significant variance may have resulted from the applied organic and organo-mineral fertilizers' delayed mineralization and nutrient release (Ayeni *et al.*, 2012). Dhiman *et al.*, (2021) reported that organic nutrients such as cow dung must undergo microbial breakdown before essential nutrients will be release for plant absorption, which might take several weeks depending on the environmental conditions. At 8WAT, treatments CB8 (cow dung + NPK) exhibit the largest stem diameter (7.33mm) in comparison to control (CT9), which measures 3.68mm. This result suggested that the combined effect of both organic and inorganic nutrient sources enhanced nutrient uptake and availability, leading to better development of the stem girth. Inorganic fertilizers offer instantly available nutrients for quick plant growth, whereas organic amendments enhance soil structure, microbial activity, and moisture retention (Sher *et al.*, 2022; Zhang *et al.*, 2020). The plant height of *Terminalia ivorensis* seedlings (as shown in Table 4) revealed a significance difference at 2, 4, 5, 6, 7, and 8 WAT, in contrast no significant difference at weeks 1 and 3 were observed. The notable variations among the treatments point to high-quality nutrients that are readily available in adequate amounts. When compared to the control (CT9), which is 22.76 cm, treatment CB8 (cow dung + NPK) exhibits the maximum plant height of 39.78 cm. According to Milošević *et al.*, (2022), manure and organo-mineral fertilizer resulted in balanced nutritional values in the leaves, which raised the fertility and quality of the soil. Early seedling vigor is indicated by plant height, and the combined impacts of organo-minerals enhanced biomass accumulation and growth performance in tropical tree species (Eifediyi *et al.*, 2017).

The number of leaves of *Terminalia ivorensis* (as shown in Table 5) showed a significant difference at weeks 4, 5, 6, 7, and 8 WAT, in contrast no significant differences at the first 3WAT. Treatment CB8 (cow

dung + NPK) shows the highest number of leaves of 37.20 when compared with the control (CT9) of 15.80. This result is consistent with Ojo *et al.*, (2009), who found that when *Adansonia digitata* was grown

with both organic and inorganic fertilizers, poultry manure resulted in the highest mean height and leaf output.

Table 3: Impacts of organo-mineral fertilizers on the stem diameter (mm) of *Terminalia ivorensis*

Treatments	Weeks After Transplanting (WAT)							
	1	2	3	4	5	6	7	8
CD1	1.13a	1.50a	1.44ab	1.98ab	3.25ab	4.44ab	4.96a-c	6.15a-c
CD2	1.28a	1.48a	1.53ab	2.02ab	2.29c	4.78a	5.01a-c	6.50ab
CD3	1.23a	1.28a	1.24b	1.44b	2.69bc	3.43bc	4.15cd	4.94cd
NP4	1.38a	1.42a	1.49ab	2.14ab	2.84bc	4.00a-c	4.31bc	5.00cd
NP5	1.24a	1.51a	1.51ab	1.83ab	2.41bc	4.04a-c	4.37bc	5.70bc
NP6	1.29a	1.37a	1.70a	2.38a	4.05a	4.82a	5.69a	6.67ab
CB7	1.34a	1.32a	1.41ab	1.83ab	2.53bc	5.07a	5.35ab	7.20a
CB8	1.29a	1.50a	1.55ab	1.82ab	3.11bc	4.96a	5.42ab	7.33a
CT9	1.25a	1.31a	1.37ab	1.65ab	2.40bc	3.02c	3.11d	3.68d
LSD	0.41	0.36	0.46	0.86	0.91**	1.13**	1.18**	1.32***
Mean	1.27	1.41	1.47	1.90	2.84	4.28	4.71	5.91

*NB means CD-Cow dung, NP- NPK 15:15:15, CB- Cow dung +NPK, CT- control

Table 4: Impacts of organo-mineral fertilizers on the plant height (cm) of *Terminalia ivorensis*

Treatments	Weeks After Transplanting (WAT)							
	1	2	3	4	5	6	7	8
CD1	9.90ab	12.40ab	14.40a-c	17.16a-d	21.38a-c	25.97a-c	28.66a-c	32.90a-c
CD2	11.50a	13.40a	15.36ab	18.12ab	23.62ab	31.02a	34.16ab	38.00ab
CD3	9.40ab	10.60bc	11.90c	13.84d	16.84c	21.42cd	27.64bc	37.56ab
NP4	8.30b	10.60bc	13.10a-c	16.74a-d	19.34bc	21.34cd	22.28cd	25.14cd
NP5	10.10ab	11.70ab	14.82a-c	17.62a-c	21.38a-c	23.18b-d	24.72cd	25.64cd
NP6	11.10a	13.00ab	15.40ab	20.00a	25.88a	28.88ab	29.84a-c	31.68a-c
CB7	8.00b	8.50c	12.04c	16.14b-d	22.30a-c	26.40a-c	27.42bc	29.52b-d
CB8	11.20a	13.70a	15.98a	19.48ab	23.04ab	32.34a	36.14ab	39.78a
CT9	9.50ab	11.20a-c	12.30bc	14.12cd	16.56c	17.84d	19.26d	22.76d
LSD	2.80	2.74*	3.14	3.55*	5.82*	6.79**	7.74**	8.78**
Mean	9.89	11.68	13.92	17.02	21.15	25.38	27.79	31.44

*NB means CD-Cow dung, NP- NPK 15:15:15, CB- Cow dung +NPK, CT- control

Table 5: Impacts of organo-mineral fertilizers on the number of leaves of *Terminalia ivorensis*

Treatments	Weeks After Transplanting (WAT)							
	1	2	3	4	5	6	7	8
CD1	7.80a	10.00a	11.80a	15.00a	18.60a	23.20ab	27.00b	30.40a-c
CD2	6.80ab	9.40ab	11.00ab	14.60a	18.80a	26.60a	35.40a	31.20ab
CD3	6.20b	7.20b	8.60b	10.80c	14.20bc	19.40bc	24.20bc	29.00a-c
NP4	6.40ab	9.40ab	11.60a	14.40a	15.60a-c	17.40cd	19.60cd	21.00cd
NP5	7.00ab	8.80ab	10.40ab	13.20a-c	15.60a-c	18.80b-d	21.40b-d	21.00cd
NP6	7.60ab	9.60a	12.00a	15.20a	19.40a	23.40ab	26.20bc	26.00bc
CB7	7.00ab	8.40ab	10.40ab	13.80ab	16.60ab	23.40ab	27.40b	29.60a-c
CB8	6.80ab	9.20ab	11.20a	14.20a	17.00ab	27.00a	36.60a	37.20a
CT9	6.40ab	8.20ab	9.80ab	11.20bc	11.40c	14.40d	16.40d	15.80d
LSD	1.43	2.24	2.56	2.83*	4.40*	4.94***	7.07***	9.59**
Mean	6.89	8.91	10.76	13.60	16.36	21.51	26.02	26.80

*NB means CD-Cow dung, NP- NPK 15:15:15, CB- Cow dung +NPK, CT- control

Impacts of organo-mineral fertilizers on the Total Biomass (Wet and Dry Wet) of Terminalia ivorensis: Figure 1 reveals there was no significant difference between the total biomass (Wet weight) of *Terminalia ivorensis* seedlings. The treatment CD2 (cow dung) had the highest wet leaf biomass (13.17g), whereas NP4 (NPK) had the lowest (3.43g).

Similar to this, stem biomass had lowest in NP4 (NPK) at 1.95g and highest in CB8 (cow dung + NPK) at 5.51g. The control (CT9) recorded the lowest value for root biomass (3.27g), while CD2

(cow dung) recorded the highest value (10.46g). The result of the biomass indicates cow dung efficiently contributed to the accumulation of biomass, whereas the significantly lower biomass in NPK alone was caused by the probable leaching and quick nutrient release associated with inorganic fertilizers (Frank *et al.*, 2020; Adekiya and Agbede 2009). Figure 2 reveals there was no significant difference between the total biomass (Dry weight) of *Terminalia ivorensis* seedlings. The highest dry leaves of 11.76g was recorded at treatments CD2 (Cow dung) while the lowest of 2.48g at treatments NP5 (NPK).

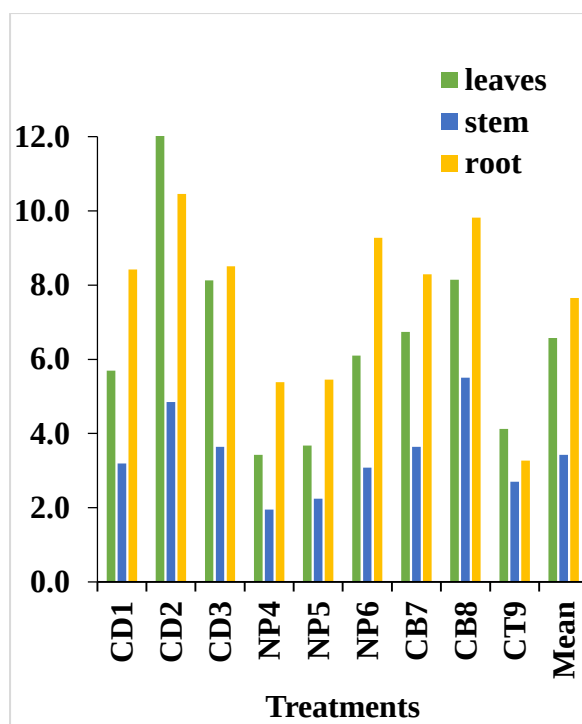


Fig 1: Impacts of organo-mineral fertilizers on the Total Biomass (Wet Weight) of *Terminalia ivorensis*.

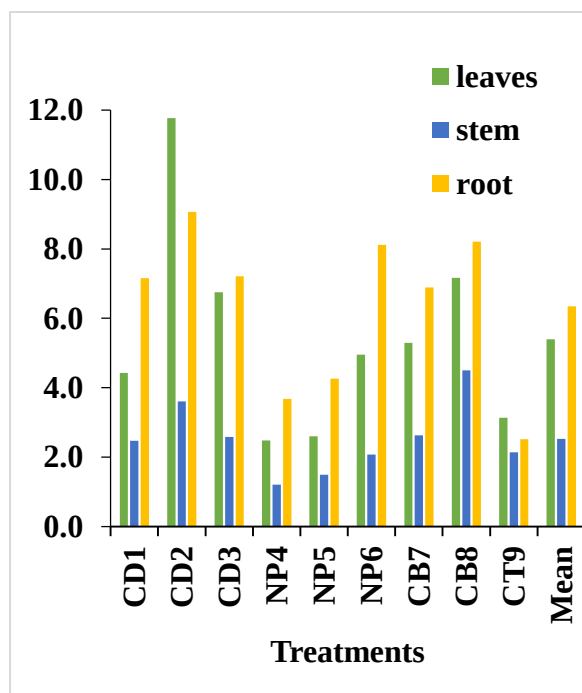


Fig 2: Impacts of organo-mineral fertilizers on the Total Biomass (Dry Weight) of *Terminalia ivorensis*.

Similarly, the dry stems recorded 4.50g at treatment CB8 (Cow dung+ NPK) while the lowest treatments at NP4 (NPK) of 1.21g, the roots biomass recorded the highest value of 9.06g at treatments CD2 (Cow dung) and the lowest at CT9 (Control) of 2.52g.

Conclusion: In conclusion, using cow dung alone or in combination with NPK suggests more sustainable ways to improve *Terminalia ivorensis* seedlings' early growth than using NPK alone. The enhanced growth response can be ascribed to the immediate nutritional supply from inorganic fertilizers as well as the benefits of organic matter in improving soil structure, moisture retention, and nutrient cycling. Future studies should investigate field validation in various soil types to support suggestions for the establishment of large-scale plantations.

DECLARATIONS

Ethical Approval: This study did not involve human participants or animal experimentation and therefore did not require formal ethical approval. All procedures involving data handling and analysis were conducted responsibly and in accordance with standard academic and institutional guidelines.

Disclaimer (Artificial Intelligence): Author(s) hereby declare that no generative Artificial Intelligence (AI) technologies such as Large Language Models (ChatGPT, COPILOT, XLNet, Ernie 3.0, Titan etc.) and text-to-image generators have been used during writing or editing of this manuscript.

Declaration of Conflicts of Interest: The authors declare that no known conflict of interest or personal relationships that could have influence the work reported in this paper (if none).

Declaration of Data Availability: Data are available upon request from the corresponding author.

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