



Soil chemical properties and growth response of *Moringa oleifera* to different sources and rates of organic and NPK fertilizers

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Abstract

Purpose The need for increasing production of *Moringa oleifera* in Nigeria can be achieved through adequate fertilization. This study investigated the effects of sources and rates of NPK (15:15:15) and compost on soil properties and productivity of *Moringa* at National Horticultural Research Institute, Ibadan, Nigeria.

Methods NPK was applied at 30, 60, and 90 kg N/ha, cow dung (CD), poultry manure (PM) and organomineral (OM) were applied at 10, 20 and 30 tons/ha. The experimental design was a randomized complete block design with three replicates. Organic fertilizers were incorporated into the soil 2 weeks before sowing; NPK was split applied at 2 and 5 weeks after sowing. Seeds were sown at 75 cm × 75 cm spacing. Data were taken on plant height (cm), stem girth (cm), number of leaves, leaf biomass, stems weight and post-planting soil properties.

Results Growth values for NPK and compost treatments were higher than the control. PM applied at 30 tons ha^{-1} resulted in highest growth values: plant height (65.91 cm), stem girth (1.51 cm) and number of leaves (14.20). PM applied at 30 tons ha^{-1} gave higher stem weight (2249.9 g) and leaf biomass (3610.5 g). Post-planting soil analysis indicated that nitrogen, phosphorus, calcium, sodium, manganese, iron and zinc contents were higher in plots with organic and inorganic fertilizers except for potassium and magnesium.

Conclusion PM proved more superior to CD manure and others because it produced better growth attributes such as shoot height, stem girth and number of leaves and leaf biomass than its counterparts produced.

Keywords Soil amendments · *Moringa oleifera* · Vegetative growth · Leaf biomass · Soil nutrient

Introduction

Moringa oleifera, also known as horseradish tree, is a medium-sized tree belonging to the family Moringaceae; it is adapted to a wide range of soil types, but grows best in well-drained loam to clay loam, neutral to slightly acidic soils, but cannot withstand prolonged water logging. It grows where temperature ranges from 26 to 40 °C and annual rainfall totals at least 500 mm.

According to Fuglie (1999), the uses of *Moringa* included, but not limited to alley cropping (biomass production), animal forage (leaves and treated seed-cake), biogas (leaves), domestic cleaning agent (crushed leaves), blue dye (wood), fencing (living trees), fertilizer (seed-cake), foliar nutrient (juice expressed from the leaves), green manure (leaves), gum (tree trunks), honey and sugar cane juice-clarifier (powdered seeds), medicine (all plant parts), ornamental plantings, biopesticide (soil incorporation of leaves to prevent seedling damping off), pulp (wood), rope (bark), tannin for tanning hides (bark and gum), water purification (powdered seeds) and *Moringa* seed oil (yield 30–40% by weight). It is a good source of vitamin A, vitamins B and C, essential minerals, and the sulphur-containing amino acids, methionine and cysteine (Bosch et al. 2004). The composition of the amino acids in

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the leaf protein is well balanced (Foidl et al. 2001). The available data (Yazzie et al. 1994; Nordeide et al. 1996) show that leaves contain 13–15% protein, 60–70% carbohydrate, 4–10% fat, around 11% fiber, 16% ash and the energy value varies from 1180 to 1900 kJ/100 g of which 80% are metabolisable energy.

Interest in *Moringa* in recent times is skewed towards its medicinal properties. Hence, researchers focus on its value as medicine. Consequently, the demand for the plant products has been on ascendance (Imoro et al. 2012). However, not much research has been done on its cultivation and fertilization in Nigeria with respect to its growth and productivity using different types of inorganic and organic manures commonly used by local farmers and more so, until recently *M. oleifera* was not popular in southwestern Nigeria despite its acclaimed economic and health importance (Odeyinka et al. 2007); hence, very little research has been done on the species, although it is widely used by the rural poor as a food resource.

Note This research was carried out in the southwestern part of Nigeria, where before now *M. oleifera* was not a popular field crop.

Nigeria is among countries with low to medium productivity soils (Eswaram et al. 1997) and are classified as being generally infertile (Aduayi et al. 2002), thus, necessitating the addition of fertilizers for optimum yield. Amelioration of soil by the use of inorganic or organic fertilizers is considered as a component of intervention for increased crop production around the world (Chand et al. 2006). The positive effects of organic manures on soil structure, aggregate stability, water-holding capacity and crop yield were reported in several studies (Togun and Akanbi 2003; Jedidi et al. 2004; Odilare et al. 2008). Low cost and ready availability of materials for their preparation, gradual release of plant nutrients, aeration, the ability of the soil to hold nutrients and being environmental friendly have made organic fertilizers popular among farmers.

This experiment was carried out to investigate the effects of different sources and rates of organic and inorganic fertilizers on early growth of *M. oleifera* and soil characteristics.

Materials and methods

Field experiments were carried out at the National Horticultural Research Institute (3°54'E, 7°30'N, and 213 m above sea level), Ibadan, to determine the optimum rate at which different rates and sources of fertilizers can be applied to soil to increase its productivity and growth of *M. oleifera*. The experiment comprises thirteen treatments:

NPK (15:15:15) applied at 30, 60 and 90 kg N ha⁻¹, cow dung (10, 20 and 30 tons ha⁻¹), poultry manure (10, 20 and 30 tons ha⁻¹) and organomineral (10, 20 and 30 tons ha⁻¹) along with the control. The experimental design was a randomized complete block design (RCBD) with three replicates. Organic fertilizers (poultry manure and cow dung) were incorporated into the soil 2 weeks before planting to allow for their mineralization, while NPK fertilizer was split applied at 2 and 5 weeks after planting while organominerals were applied at 2 weeks after planting to enable the seedlings absorb the mineral nutrients. Three seeds were directly sown per hole at 75 cm × 75 cm spacing, on plots of size 9 m². The seedlings were thinned to one plant per stand at 2 weeks after sowing (2WAS). Data on growth parameters (plant height, stem girth and number of leaves) were taken fortnightly from 4WAS for ten (10) weeks. Also leaf biomass was determined by cutting four stands per plot at 1 m above ground level; the pruned shoot were separated into leaves and stems, air dried at room temperature until uniform weight was achieved. This process was repeated every fortnight and the total sum of the leaf weight over time was recorded as leaf biomass. Samples of soil from each plot were taken before and 14WAS for laboratory analysis to determine the effects of treatments on soil properties. The soil samples were air dried, crushed and sieved through 2 mm mesh for the determination of the physical and chemical properties of the soil. Total nitrogen (N) was determined by Kjeldhal method after digestion of material (A.O.A.C. 1999). Available P was determined using Bray 1 method (Murphy and Rikey 1962). Exchangeable bases were done by extraction with 1 m NH₄OAC. Calcium (Ca) and magnesium (Mg) in the extract were determined by atomic absorption spectrophotometer (AAS). Effective CEC was the summation of exchangeable bases (Ca, Mg, K, and Na); potassium (K) was determined by flame photometer, and pH (H₂O) using a pH meter. Percentage organic carbon was estimated by chromic acid digestion. Data were subjected to analysis of variance and the mean data were compared using the least significant difference (LSD) at $p > 0.05$.

Results

Pre-field soil analysis

The results of the physical and chemical analysis of the potted soil before cropping are presented in Table 1. The soil was mostly sandy loam in texture with pH of 7.7. Total N content was 0.9 mg g⁻¹, available P was 1.95 mg g⁻¹, K 0.21 c mol kg⁻¹, Fe 6.15 mg g⁻¹, Zn 1.18 mg g⁻¹ and Mn value was 45.45 mg kg⁻¹ (Table 1).



Table 1 Pre-cropping physical and chemical properties of soils

Soil property	
pH	7.7
Sand (mg g ⁻¹)	770
Clay (mg g ⁻¹)	56
Silt (mg g ⁻¹)	174
Ca (cmol kg ⁻¹)	1.80
Mg (cmol kg ⁻¹)	0.74
Na (cmol kg ⁻¹)	0.35
K (cmol kg ⁻¹)	0.21
Exch. acidity	0.06
ECEC me/100 g	3.16
C (mg g ⁻¹)	11.1
N (mg g ⁻¹)	0.9
Av. P (mg kg ⁻¹)	1.95
Cu (mg g ⁻¹)	0.34
Zn (mg g ⁻¹)	1.18
Fe (mg g ⁻¹)	6.15
Mg (mg g ⁻¹)	45.45

Analysis of organic material

The nutrient content of poultry manure, cow dung and organomineral used in the experiment is represented in Table 2. It indicated that there were differences in nutrient composition of organic components. N, P and K contents of poultry manure were higher in value than cow dung and organomineral.

Effects of soil amendments on vegetative growth of *M. oleifera*

Plant height

There were significant ($p > 0.05$) differences in the plant height between those treated with fertilizers and the control. Results indicated that at all growth stages, plant height observed for all the fertilizer types and rates were all higher than the control, where the average values for control were 13.0, 26.1, 47.5 and 74.7 cm for 5, 7, 9 and 11WAS; plant height for 20 tons ha⁻¹ of poultry manure (PM) was 27.2, 61.3, 111.6 and 157.4 cm, respectively. At 11WAS, 30 tons ha⁻¹ PM had the highest plant height. This performance was followed in ranking by 20 tons ha⁻¹ PM (157.4 cm) and 10 tons ha⁻¹ PM (Table 3).

Table 2 Chemical properties of the different types of organic materials used

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	C (%)
Cow dung	0.85	0.12	1.49	1.57	0.51	0.09	30
Poultry manure	1.18	0.99	1.71	2.87	0.61	0.78	17
Org. mineral	0.45	0.55	0.89	1.44	0.74	1.41	40

Stem girth

Stem girth values obtained for all organic and NPK rates were higher than the control at all stages of data measurements, where the values obtained for control were 0.3, 0.5, 0.9 and 1.4 cm; the highest values of 0.8, 2.0, 2.2 and 2.5 cm were obtained from 20 tons ha⁻¹ PM. At 11WAS, 30 tons ha⁻¹ PM application resulted in the highest value of stem girth obtained in the experiment. Poultry manure at all levels of application in the study resulted in stronger stem. Performance of PM was followed by application of 20 and 30 tons ha⁻¹ cow dung (Table 3).

Number of leaves

The number of leaves produced by *M. oleifera* was highly influenced by application of fertilizers (Table 3). Pots without any fertilizer application had the least number of leaves at 5, 7, 9 and 11WAS (8.1, 9.3, 12.8 and 17.8), respectively, while pots with 20 tons ha⁻¹ of PM had the highest number of leaves at 5WAS but pots with 30 tons ha⁻¹ application had the highest number of leaves from 7WAS (15.6, 24.8, 32.3). Generally, PM at all rates produced higher number of leaves than all rates of OM, CD and NPK. The performance of seedlings with 30 tons ha⁻¹ PM application was followed by 20 tons ha⁻¹ OM and 30 tons ha⁻¹ of CD in descending order. The higher the rate of poultry manure, the higher the number of *M. oleifera* leaves produced.

Effects of soil amendments on stem and leaf biomass

All treatments with organic manure had higher stem weight and leaf biomass than the NPK rates and the control, but among the organic manures, *M. oleifera* treated with 30 tons ha⁻¹ poultry manure (30 tons ha⁻¹ PM) had the maximum stem weight (2249.9 g) and leaf biomass (3610.5 g). This performance was followed in descending order 30 tons ha⁻¹ OM (3335.7 g) > 20 tons ha⁻¹ OM (3276.2 g) > 20 tons ha⁻¹ PM (3254.5 g). So also for stem weight, it was 30 tons ha⁻¹ PM (2249.9 g) > 20 tons ha⁻¹ OM (2181.1 g) > 20 tons ha⁻¹ PM (1992.3 g) (Table 4).



Table 3 Growth response of *Moringa oleifera* to different sources and rates of organic and inorganic fertilizers

TRT	Weeks after sowing											
	Plant height (cm)				Stem girth (cm)				Number of leaves			
5	7	9	11	5	7	9	11	5	7	9	11	
PM10	28.4	56.6	105.4	154.2	0.7	1.1	1.8	2.2	13.2	15.6	22.0	27.3
PM20	27.7	61.3	111.6	157.4	0.8	2.1	2.0	2.5	13.8	15.1	20.6	24.6
PM30	27.9	57.2	108.8	161.6	0.7	1.3	1.8	2.6	13.7	15.6	24.8	32.3
OM10	18.4	39.7	77.8	126.9	0.5	1.8	1.5	2.0	10.2	13.5	19.8	23.3
OM20	22.0	46.2	88.4	136.4	0.6	1.0	1.5	1.9	10.3	14.1	21.4	30.1
OM30	17.9	34.5	63.1	98.5	0.5	0.8	1.1	1.4	9.2	11.3	16.2	22.6
CD10	20.2	39.3	75.2	104.4	0.5	0.8	1.3	1.7	10.8	12.4	19.4	22.5
CD20	19.5	39.6	75.4	121.2	0.5	0.8	1.5	2.0	11.3	13.7	19.7	22.3
CD30	25.6	53.2	93.8	131.4	0.6	1.0	1.5	2.0	13.0	14.6	21.8	25.8
NPK30 (kg N ha ⁻¹)	15.0	28.4	58.4	98.6	0.4	0.7	1.1	1.5	9.5	10.8	17.2	19.7
NPK60 (kg N ha ⁻¹)	24.0	47.0	87.9	131.2	0.6	1.0	1.5	2.0	11.8	13.8	21.0	24.0
NPK90 (kg N ha ⁻¹)	18.8	39.2	76.8	123.2	0.5	0.8	1.3	1.8	11.0	12.7	20.2	22.8
CT	13.0	26.1	47.5	74.7	0.3	0.5	0.9	1.4	8.1	9.3	17.8	17.8
LSD	8.4	20.3	35.92	47.5	1.0	1.1	0.6	0.7	3.1	4.0	4.5	6.6

Table 4 Effects of different sources and rates of NPK and organic fertilizers on leaf and stem biomass of *Moringa oleifera*

Treatment	Stem biomass (g)	Leaf biomass (g)
PM10	1541.5	2641.5
PM20	1992.3	3254.5
PM30	2249.9	3610.5
OM10	1813.3	2712.4
OM20	2181.1	3276.2
OM30	1912.8	3335.7
CD10	1091.5	2240.5
CD20	1256.5	2071.1
CD30	1825.2	2437.2
NPK30 (kg N ha ⁻¹)	1095.5	1871.3
NPK60 (kg N ha ⁻¹)	1129.2	1808.7
NPK90 (kg N ha ⁻¹)	1130.1	2147.0
CT	888.5	1271.3
LSD	738.8	532.9

Effects of different sources and rates of nutrients on post-field soil properties

Soil nitrogen (N), phosphorus (P) and potassium (K) were significantly influenced by different rates and sources of fertilizers. For post-planting soil N and P, addition of both organic and NPK fertilizers resulted in the higher N and P soil contents than the control plots except for K (Fig. 1). Organomineral (OM) applied at 10 tons ha⁻¹ had higher residual soil N content; this was followed by poultry manure applied at 30 tons ha⁻¹. For K and P, it was also

OM applied at 30 tons ha⁻¹; this performance was followed by poultry manure. Other soil properties were determined which were significantly influenced by different rates and sources of fertilizers include: Ca, Na, Mn, Fe and Zn. Application of 30 kg ha⁻¹ of NPK resulted in the higher residual soil content of Ca; this was followed by 30 tons ha⁻¹ application of OM. 20 tons ha⁻¹ application of CD on *M. oleifera* resulted in the higher residual content of Mg and Mn in the soil, while for Fe, it was 10 tons ha⁻¹ application of CD; this was followed by PM applied at 30 and 20 tons ha⁻¹ application, respectively (Fig. 2).

Discussion

The pre-planting major nutrient content of the soil was inadequate, where the minimum critical level required for crop growth in the area is 0.6–1.0 mg kg⁻¹ for N, 3–7 mg kg⁻¹ for P, and 0.21–0.3 cmol kg⁻¹ for K (Adeoye and Agboola 1985). This nutrient status of the soil agreed with the results of Aduayi et al. (2002) who reported that most Nigerian soils are deficient in major nutrient, thus emphasis the need for use of sustainable soil amendments. Also nutrient analysis of organic manure (Table 2) indicated that poultry manure is higher in content in major nutrients required for optimum plant growth, such as N, P and K. This may have been responsible for significance performance by Moringa plants treated with higher rates of poultry manure. Addition of fertilizers either organic or inorganic improves Moringa growth and productivity of soils, but their performance depends on the crop type, the environment, season, variety, fertilization, and irrigation



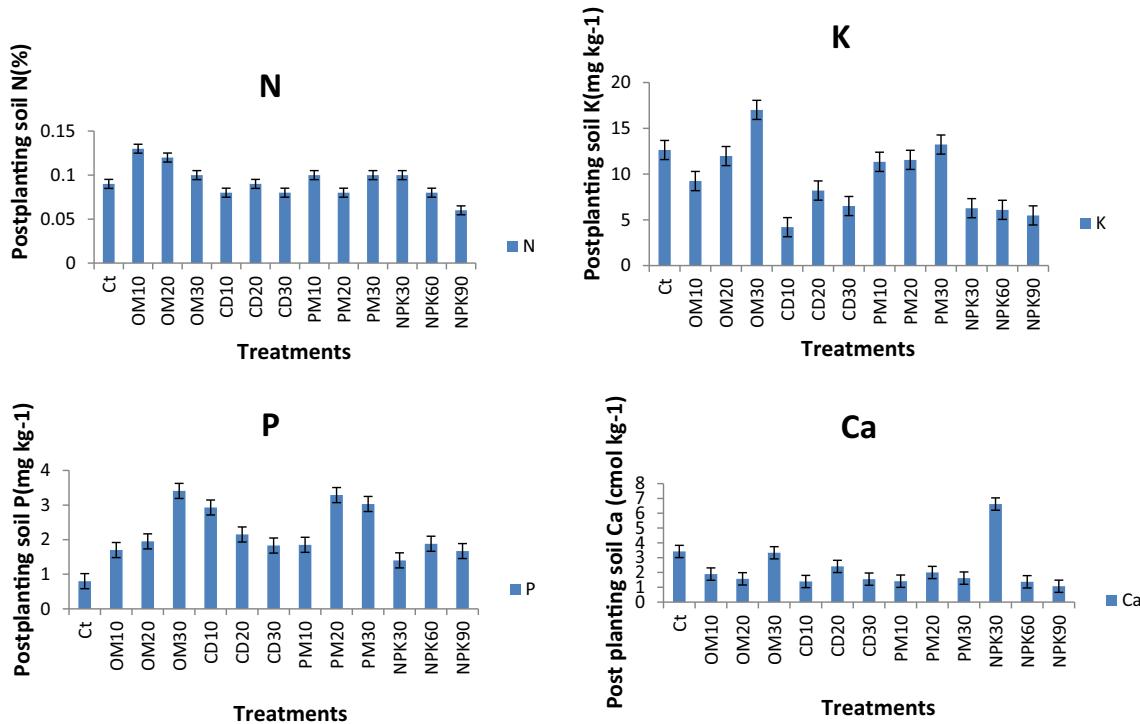


Fig. 1 Effect of different sources and rates of organic and inorganic fertilizers on post-planting soil properties of *Moringa oleifera*

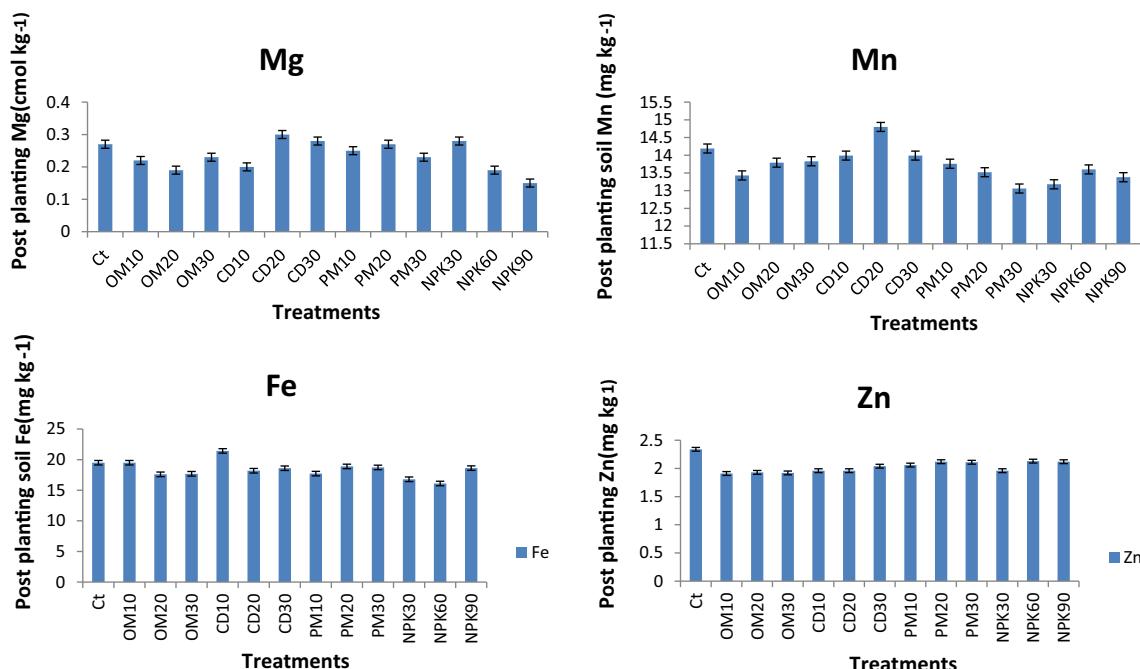


Fig. 2 Effect of different sources and rates of NPK and organic fertilizers on post-planting soil properties of *Moringa oleifera*

regime. *Moringa* yields best under warm, dry conditions, with some supplemental fertilizer and irrigation (Radovich and Paul 2008). In this experiment, poultry manure applied at 20 tons ha⁻¹ treated seedlings showed a significant

($p > 0.05$) difference over other amendments and the control in terms of height, girth, number of leaves and leaf biomass; this observation was similar to Usman (2015) report, when he compared the performance of tomato crop



treated with 20 tons ha^{-1} of cow dung, goat droppings and poultry manure, respectively; application of poultry manure (PM) resulted in the higher growth parameters and fruit yield of tomato plants. The increasing effects of PM on *moringa* development and soil properties in this study also corroborated the observation of Gupta et al. (1997), Adeniyani and Ojeniyi (2005), Akanbi et al. (2005), Adenawoolla and Adejoro (2005) and Agyenim-Boateng et al. (2006) that poultry manure is very rich animal manure that releases considerable soil organic matter, available P and exchangeable cations when applied to soil. Poultry manure contains all the essential plant nutrients that are used by plants; these include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), manganese (Mn), copper (Cu), zinc (Zn), chlorine (Cl), boron (B), iron (Fe) and molybdenum (Mo) (Amanullah et al. 2010). It increases the moisture holding capacity of the soil and improves lateral water movement, thus improving irrigation efficiency and decreasing the general droughtiness of sandy soils. Poultry manure application improves soil retention and uptake of plant nutrients (Amanullah et al. 2010). It increases the number and diversity of soil microorganisms, particularly in sandy conditions. This effect enhances crop health by increasing water and nutrient availability, as well as suppressing harmful levels of plant parasitic nematodes, fungi and bacteria. The cumulative effect supports the observation that poultry manure added organic matter and nutrients to the soil. This may probably be due to the fact that poultry manure contains concentrated nutrients and hence led to enhanced plant growth in those seedlings treated with poultry manure. The nutrient quality in poultry manure might surpass the ones in cow dung manure leading to more enhanced plant growth in those treated with poultry manure. This observation was between week 5 and 7 after planting. This generally implies that the plant is a fast growing species and this conforms to the earlier findings by Odee (1998) and Imoro et al. (2012) that *Moringa* is a fast growing plant and grows between 6 to 7 m per annum even in areas receiving less than 400 mm of rainfall. The significance influence of organomineral (OM) on residual soil content of N, P and K may also be because, OM was fortified with mineral N, P and K. The bulk of cow dung manure might probably be materials that do not significantly enhance plant growth as compared to those found in poultry manure. Other authors found significant improved height in *M. oleifera* using poultry manure (Agyenim-Boateng et al. 2006; Imoro et al. 2012). The organic matter component of poultry manure were higher, and when decomposed in soil, nutrients were released to soil. Hence the findings that poultry manure increased soil N, P, K, Ca, and Mg significantly.

Conclusion

Application of poultry manure, cow dung manure, organomineral and NPK had significant effects on the growth of *M. oleifera* over controls. However, poultry manure treatments had the best growth attributes for optimal yield. Therefore, the treatment with 20 tons ha^{-1} is recommended for sustainable leaf dry matter production of *M. oleifera* in South-West, Nigeria.

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References

- Adenawoolla AR, Adejoro SA (2005) Residual effects of poultry manure and NPK fertilizer residues on soil nutrient and performance of jute (*Corchorus olitorius* L.). Niger J Soil Sci 15:133–135
- Adeniyani ON, Ojeniyi SO (2005) Effect of poultry manure, NPK (15:15:15) and combination of their reduced levels on maize growth and soil chemical properties. Niger J Soil Sci 15:34–41
- Adeoye GO, Agboola AA (1985) Critical levels for soil pH, available phosphorus (P), potassium (K), zinc (Zn) and manganese (Mn) and maize ear leaf content of boron (B), copper (Cu) and manganese (Mn) in sedimentary soils of south western, Nigeria. Fert Res 6:65–71
- Aduayi EA, Chude VO, Adebisiya BA, Olayiwola SO (2002) Fertilizer use and management in Nigeria. Produced by Federal Ministry of Agriculture Rural Development, Abuja, p 188
- Agyenim-Boateng S, Zickerman J, Kornahrens M (2006) Poultry manure effect on growth and yield of maize. West Afr J Appl Ecol 9:61–70
- Akanbi WB, Akande MO, Adediran JA (2005) Suitability of composted maize straw and mineral nitrogen fertilizer for tomato production. J Veg Sci 11(1):57–65. doi:[10.1300/484v11n01-06](https://doi.org/10.1300/484v11n01-06)
- Amanullah MM, Sekar S, Muthukrishnan P (2010) Prospects and potential of poultry manure. Asian J Plant Sci 9:172–182. doi:[10.3923/ajps.2010.172.182](https://doi.org/10.3923/ajps.2010.172.182)
- Association of Official Analytical Chemists (A.O.A.C) (1999) Official methods of analysis, 11 edn. Washington, D.C. <https://www.ajol.info/index.php/wajae/article/viewFile/45682/29162>
- Bosch CH, Sié K, Asafa BA (2004) *Adansonia digitata* L. Record from protabase. In: Grubben GJH, Denton OA (eds) PROTA (Plant resources of tropical Africa). Wageningen, Netherlands
- Chand S, Anwar M, Patra DD (2006) Influence of long-term application of organic and inorganic fertilizer to build up soil fertility and nutrient uptake in mint-mustard cropping sequence. Commun Soil Sci Plant Anal 37:63–76. <http://www.tandfonline.com/doi/abs/10.1080/00103620500408704>
- Eswaram H, Almaraz R, van den Berg E, Reich P (1997) An assessment of the soil resources of Africa in relation to



productivity. *Geoderma* 77:1–18. <http://www.sciencedirect.com/science/article/pii/S0016706197000074>

Foidl N, Makkar HPS, Becker K (2001) The potential of *Moringa oleifera* for agricultural and industrial uses. In: Fuglie LJ (ed) The miracle tree/the multiple attributes of Moringa. CTA, USA

Fuglie LJ (1999) The miracle tree: *Moringa oleifera*: natural nutrition for the tropics. Dakar, Church World Service, p 68 (revised in 2001 and published as The Miracle Tree)

Gupta G, Borowee J, Okoh J (1997) Toxicity identification of poultry litter aqueous leachate. *Poult Sci* 76:1364–1367. doi:10.1093/ps/76.10.1364

Imoro WM, Sackey I, Abubakar AH (2012) Preliminary study on the effects of two different sources of organic manure on the growth performance of *Moringa oleifera* seedling. *J Biol Agric Healthc* 2(10):147–158

Jedidi N, Hassen A, van Cleemput O, M'Hiri A (2004) Microbial biomass in a soil amended with different types of organic wastes. *Waste Manag Res* 22:93–99. journals.sagepub.com/doi/pdf/10.1177/0734242X04043930

Murphy J, Rikey JP (1962) A modified single solution method for the determination of phosphate in natural water. *Anal Chem Acts* 27:31–36

Nordeide MB, Hatloy A, Folling M, Lied E, Osbaug A (1996) Nutrient composition and nutritional importance of green leaves and wild food resources in an agricultural district, Koutiala, in southern Mali. *Int J Food Scand Nutr* 47:455–468. <https://www.ncbi.nlm.nih.gov/pubmed/8933199>

Odee D (1998) Forest biotechnology research in drylands of Kenya: the development of *Moringa* species. *Dryland Biodivers* 2:7–12

Odeyinka SM, Torimiro DO, Oyedele JO, Asaolu VO (2007) Farmer's awareness and knowledge of *Moringa oleifera* in Southwestern Nigeria: a perceptual analysis. *Asian J Plant Sci* 6:320–325. doi:10.3923/ajps.2007.320.325

Odlare M, Pell M, Swenson K (2008) Changes in soil chemical and microbiological properties during 4 years of application of various organic residues. *Waste Manag* 28:1246–1253. doi:10.1016/j.wasman.2007.06.005

Radovich TJK, Paul R (2008) Early growth, leaf yield, protein content and pod yield of four Moringa accessions in Hawaii. *Hortic Sci* 43:1135

Togun AO, Akanbi WB (2003) Comparative effectiveness of organic-based fertilizers to mineral fertilizers on tomato growth and fruit yield. *Compost Sci Util* 11:337–42. <http://www.tandfonline.com/doi/pdf/10.1080/1065657X.2003.10702143>

Usman M (2015) Cow dung, goat and poultry manure and their effects on the average yields and growth parameters of tomato crop. *J Biol Agric Healthc* 5(5). <http://www.iiste.org>. 04/01/2017. <http://www.iiste.org/Journals/index.php/JBAH/article/viewFile/20621/21555>

Yazzie D, Vander Jagt DJ, Pastuszyn A, Okolo A, Glew RH (1994) The amino acid and mineral contents of baobab (*Adansonia digitata* L.) leaves. *J Food Compos Anal*. doi:10.1006/jfca.1994.1018

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