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EFFECT OF TYPE AND APPLICATION RATE OF LIQUID ORGANIC FERTILIZERS ON THE ROOT DEVELOPMENT OF SELECTED CROPS (RICE AND BEAN) IN ABUJA, NIGERIA

IBRAHIM Nmadzuru B[1] and EDICHA Nasiru[2]

[1,2] *Department of Soil Science and Land Resources Management, University of Abuja, Nigeria*
Corresponding Author: ibrahim.nmadzuru@uniabuja.edu.ng, ORCID: 0009-0002-1581-1925 | *DOI: https://doi.org/10.5281/zenodo.18067394*

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ABSTRACT: *Declining soil fertility and high costs of chemical fertilizers reduce crop production in Nigeria. Liquid organic fertilizers (LOFs) from plant extracts and compost are a low-cost alternative that can improve early crop growth. This study tested two LOFs, Moringa leaf extract (MLE) and Sapphire Liquid Fertilizer (SLF), at two application rates (10 ml and 20 ml) on the root growth of rice (Oryza sativa var. FARO 44) and bean (Phaseolus vulgaris var. SAMPEA 9). A screenhouse experiment was conducted at the University of Abuja using a 2 x 2 x 2 factorial design plus control, with three replications. Root length, fresh weight, and dry weight were measured at 8 weeks after sowing. Data were analysed using ANOVA and Fisher's LSD ($p < 0.05$). Both fertilizers significantly improved root growth. MLE at 20 ml gave the highest root length (32.73 cm), fresh weight (10.65 g), and dry weight (2.80 g), outperforming the control by 46%, 65%, and 79%, respectively. Rice had larger roots than beans, and fertilizer rate × crop interactions were significant. Moringa leaf extract at 20 ml is the most effective, low-cost fertilizer for improving root development in rice and bean seedlings in nutrient-poor soils.*

KEYWORDS: *Biofertilizer, Moringa oleifera, root growth, smallholder farming, Oryza sativa, Phaseolus vulgaris*

INTRODUCTION

The challenge of food security in many developing nations is fundamentally linked to declining soil fertility and the high dependence on unsustainable, costly, and often inaccessible inorganic fertilizers

(Adepetu *et al.*, 1990). Prolonged reliance on chemical fertilizers has resulted in soil degradation, environmental concerns, and an elevated cost of production, making farming unprofitable for smallholder farmers (Eneji *et al.*, 2021). Consequently, there is an increasing global emphasis on integrated soil fertility management (ISFM) practices that incorporate organic amendments and bio-stimulants to enhance soil health and crop productivity in an environmentally sustainable manner (Glick *et al.*, 2017; Olaniyi *et al.*, 2010).

Liquid organic fertilizers (LOFs) and plant growth regulators derived from natural sources, such as compost extracts and plant biomass, have emerged as viable alternatives. *Moringa oleifera* leaf extract (MLE) is particularly renowned for its rich composition of plant hormones (e.g., zeatin), vitamins, amino acids, and minerals, which stimulate cell division and root proliferation (Fuglie, 2001; Nouman *et al.*, 2014). Similarly, commercial organic liquid products like Sapphire, often derived from enhanced animal manure composts, provide a concentrated source of macro and micronutrients in a readily available form for plant uptake (Abdullahi *et al.*, 2015). Recent studies have highlighted the efficacy of biostimulants in improving stress tolerance and overall plant growth (Rouphael *et al.*, 2017; Igiehon *et al.*, 2019).

While the benefits of organic fertilizers on shoot growth and final yield are well-documented, specific data regarding their quantitative effects on root architectural traits, such as length, biomass, and overall vigor, in critical staple crops under Nigerian savanna conditions remain limited (Oluwatosin *et al.*, 2012; Parikh and James, 2012). Root development is a foundational determinant of crop productivity, directly influencing the plant's capacity for water and nutrient uptake, anchoring, and resilience to environmental stress. Quantifying the impact of specific LOF types and concentrations on root parameters is critical for developing precise, low-cost fertilization recommendations for smallholder farmers (Marschner, 2012; Bairagi *et al.*, 2023).

The broad objective of this study was to evaluate the efficacy of different types and application rates of liquid organic fertilizers on the root development of rice and bean seedlings. Specifically, the study aimed to determine the effect of *Moringa oleifera* leaf extract and Sapphire organic fertilizer on the root growth parameters (root length, fresh weight, and dry weight) of the rice variety FARO 44 and the bean variety SAMPEA 9. To investigate the potential of Moringa leaf extract as a superior, low-cost biofertilizer compared to a commercial organic liquid fertilizer for enhanced crop establishment.

Specific Objectives were to:

i. Compare MLE and SLF on root length, fresh weight, and dry weight of rice and bean seedlings;
ii. Examine the effect of two application rates (10 ml and 20 ml); and
iii. Identify whether MLE is a superior, affordable fertilizer for smallholder farmers.

MATERIALS AND METHODS

This research was conducted in a screenhouse at the Faculty of Agriculture, University of Abuja, Nigeria (Latitude: 8.98ºN, Longitude: 7.17ºE during the 2025 planting season. The screenhouse provided a controlled environment to minimize external variability from weather, pests, and large herbivores. The experiment was laid out as a 2 x 2 x 2 factorial (two crops, two fertilizers, two rates) with an additional control (no fertilizer) group, fitted into a Completely Randomized Design (CRD) with three replicates.

Treatments and Source of Materials

The experimental factors and levels were:

- Factor A (Crop): Rice (*Oryza sativa* var. FARO 44) and Bean (*Phaseolus vulgaris* var. SAMPEA 9).
- Factor B (Fertilizer Type): *Moringa oleifera* Leaf Extract (MLE) and Sapphire Liquid Fertilizer (SLF).
- Factor C (Application Rate): 10 (ml) and 20 (ml) per application.

The total number of treatments was (2 x 2 x 2) + 1 (Control) = 9 treatments, giving 27 experimental units. Commercial SLF was sourced from a certified Abuja agro-input dealer. MLE was prepared using established protocols.

Preparation of Fertilizer Solutions

The concentrated LOFs were diluted based on treatment specification: the 10 ml rate was diluted in 100 ml of water, and the 20 ml rate was diluted in 250 ml of water. The Sapphire fertilizer used nitrogen-rich animal manures and molasses, enhanced by urine, and subjected to control thermophilic composting. MLE was prepared by blending fresh Moringa leaves and filtering the extract. All solutions were prepared immediately before application to minimize nutrient loss.

Crop Establishment and Management

Plastic buckets (5 litres capacity) were filled with 6 kg of sterilized sandy loam Ultisol topsoil, which is a common soil type in the region. Two seeds were sown per pot for both rice (1 cm depth) and bean (2 cm depth). Plants were later thinned to one healthy plant per pot two weeks after sowing (WAS). All pots received equal amounts of distilled water to maintain soil moisture at field capacity. Fertilizer application commenced at 2 WAS and was repeated bi-weekly for a total of four applications, using the soil drench method to target the root zone. An organic spray (vinegar, salt, and baking powder in distilled water) was applied weekly for uniform pest and disease management across all units, including the control, to ensure that only the fertilizer effect was measured.

Soil and Fertilizer Analysis

Soil samples were collected from the field before planting and analysed for physicochemical properties. Standard laboratory procedures were used:

- Total Nitrogen (TN): Determined by the macro-Kjeldahl method.
- Available Phosphorus (P): Measured using the Micro-Vanadate-Molybdate method (colorimetric).
- Available Potassium (K): Extracted with 1(N) ammonium acetate and analysed using an Atomic Absorption Spectrophotometer.
- pH: Measured in water using an electronic pH meter.
- Organic Carbon (OC): Determined by the Walkley-Black method.

The LOF solutions were also subjected to a similar analysis to quantify their N, P, and K content.

Data Collection

Data on root development were collected at 8 WAS. Plants were carefully uprooted, and the following parameters were measured:

- Root Length (cm): Measured from the base of the shoot to the tip of the longest root using a tape measure.

- Root Fresh Weight (g): Measured immediately after uprooting and gentle washing, using a digital weighing balance (pm 0.01 g).
- Root Dry Weight (g): Obtained after sun-drying the root samples to a constant weight.

Statistical Analysis

All collected data were subjected to Analysis of Variance (ANOVA) using the General Linear Model (GLM) procedure in SAS software (version 9.4). The factorial structure was analyzed to test the main effects and all interaction effects of Crop, Fertilizer Type, and Application Rate. Treatment means were separated using Fisher's Least Significant Difference (LSD) test at a 5% probability level ($p < 0.05$). No missing data or outliers were reported. Ethical approval was not required as the study involved non-hazardous crop experiments.

RESULTS AND DISCUSSION

Fertilizer Effects on Root Growth

Both fertilizers significantly improved root growth ($p < 0.001$). The 20 ml rate outperformed 10 ml for both fertilizers.

Table 1. Root Development at 8 WAS

Treatment	Root Length (cm)	Root Fresh Weight (g)	Root Dry Weight (g)
MLE 20 ml	$32.73^a \pm 0.13$	$10.65^a \pm 0.06$	$2.80^a \pm 0.04$
SLF 20 ml	$31.35^b \pm 0.13$	$9.83^b \pm 0.06$	$2.57^b \pm 0.04$
MLE 10 ml	$29.47^c \pm 0.13$	$8.85^c \pm 0.06$	$2.30^c \pm 0.04$
SLF 10 ml	$27.80^d \pm 0.13$	$8.27^d \pm 0.06$	$2.05^d \pm 0.04$
Control	$22.47^e \pm 0.13$	$6.47^e \pm 0.06$	$1.57^e \pm 0.04$
Crop			
Rice	$31.47^a \pm 0.08$	$10.39^a \pm 0.04$	$2.73^a \pm 0.02$
Bean	$26.05^b \pm 0.08$	$7.29^b \pm 0.04$	$1.78^b \pm 0.02$
Fertilizer Rate × Crop	F=4.37*	F=5.02*	F=4.11*

Different letters indicate significant differences ($p \leq 0.05$)

Pre-planting Soil Properties

Table 2. Screenhouse Soil Properties

Parameter	Soil Content	Rating
pH (H_2O)	6.5	Favourable
Total Nitrogen (g/kg)	0.10	Low
Available P (mg/kg)	8.19	Low
Available K (cmol/kg)	0.13	Low
Organic Carbon (g/kg)	1.41	Very Low
CEC (cmol/kg)	11.64	Medium
Ca (cmol/kg)	6.7	Moderate
Mg (cmol/kg)	3.2	Moderate

Fertilizer Nutrient Composition

Table 3. Fertilizer Properties

Parameter	pH	N (%)	P (mg/100g)	K (mg/kg)
MLE 20 ml	6.34	20.50	3.10	2750.57
MLE 10 ml	6.10	17.50	2.24	2480.84
SLF Rice 20 ml	6.40	10.50	3.05	2252.27
SLF Rice 10 ml	6.35	10.50	2.44	2225.47
SLF Bean 20 ml	6.55	20.25	2.48	1321.09
SLF Bean 10 ml	6.32	8.75	2.20	1936.13

The primary finding of this study is the highly significant and positive influence of both Moringa Leaf Extract (MLE) and Sapphire Liquid Fertilizer (SLF) on the root development of rice and bean, with the 20 ml rate of MLE being the most effective across all measured parameters. This outcome is critically important because it confirms the efficacy of low-cost, locally-sourced biofertilizers as viable alternatives to supplement nutrient-poor soils.

The superior performance of MLE, particularly at the higher concentration, can be mechanistically linked to its unique biostimulant composition. MLE is a known reservoir of cytokinins, especially zeatin, which are phytohormones directly involved in promoting cell division, root growth, and overall plant vigor (Fuglie, 2001; Nouman *et al.*, 2014). The higher concentration likely provided a supra-optimal level of these growth promoters, resulting in enhanced root length and biomass accumulation compared to the other treatments. Furthermore, the fertilizer analysis (Table 3) showed MLE at 20 ml contained the highest concentrations of N, P, and K, essential nutrients that synergize with phytohormones to boost growth. This finding is strongly supported by recent research linking *Moringa oleifera* biostimulants to improved root and shoot growth in maize and other staple crops (Phiri, 2010; Bairagi *et al.*, 2023).

While SLF also significantly improved root traits, its lower effectiveness compared to MLE may be due to differences in nutrient form and biostimulant content. SLF, as a compost-based extract, mainly supplies easily available mineral nutrients, but its concentration of key phytohormones might be lower than that of the pure MLE extract. The highly significant response of both crops to fertilization is supported by the pre-planting soil analysis (Table 2), which showed critical deficiencies in N, P, K, and Organic Carbon, conditions typical of weathered Ultisols in the Southern Guinea Savanna (Oluwatosin *et al*., 2012; Eneji *et al*., 2021).

The crop-specific response, where rice consistently exhibited greater root biomass and length than beans, suggests a differential physiological capacity to utilize the applied nutrients. As a monocot, the fibrous root system of rice has a higher potential for biomass accumulation in the early stages compared to the taproot system of the dicot bean. However, the root growth in beans, though lower in magnitude, is crucially linked to N_2 fixation via nodulation (Peoples *et al.*, 2009). The observed significant interaction between Fertilizer Rate x Crop indicates that a universal recommendation is suboptimal; instead, the highest rate of MLE is most beneficial for maximizing root development across both species.

The primary strength of this study lies in its controlled screenhouse design, which successfully minimized environmental confounding variables, thereby strengthening the internal validity of the treatment effects. The use of a standard CRD and robust statistical analysis (ANOVA and LSD) further supports the reliability of the findings. A limitation is the use of sun-drying for root dry weight, which, while conventional, is less precise than oven-drying to a constant weight. Furthermore, the screenhouse setting, while controlled, limits the external validity of the precise yield gains under full field-level environmental stresses.

The findings advance the knowledge base by providing specific, quantitative evidence that MLE is a superior organic biostimulant for root development compared to a commercial alternative, particularly important for regions where commercial inputs are expensive. The practical implication is a direct, low-cost recommendation for smallholder farmers to enhance crop establishment using locally available resources.

CONCLUSION

The application of both Moringa leaf extract (MLE) and Sapphire Liquid Fertilizer (SLF) significantly enhanced the root length, fresh weight, and dry weight of both rice and bean seedlings compared to the control. Moringa leaf extract at the 20 ml application rate was the most effective treatment, producing the highest quantitative values for all root traits in both crops. Rice exhibited a significantly stronger root growth response than beans across all treatments. The results confirm the direct linkage between the nutrient composition of MLE (high N, P, K, and biostimulant content) and the improved root development of staple crops grown in nutrient-deficient soils. MLE is therefore highly recommended as a cost-effective biofertilizer for enhancing crop establishment and productivity in the Abuja agro-ecological zone.

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