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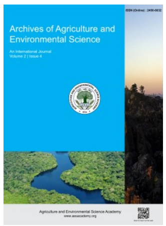

ORIGINAL RESEARCH ARTICLE

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Effects of organic fertilizers on the macropropagation, vegetative growth, and pest infestation on plantain (*Musa* sp.)

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ABSTRACT

One of the major constraints to the expansion of plantain cultivation has been the scarcity of healthy planting material. Decapitation, following macropropagation technology, stimulation of lateral bud development and plantlet production. This study aimed to evaluate the efficacy of decapitation, following macropropagation technology, to stimulate lateral bud development and plantlet production in *Musa* sp. The experiment was carried out at both the macropropagators' level and in the nursery. The experiment was laid out using the Randomized Complete Block Design (RCBD) with five treatments (Control, T_1 – Biozyme, T_2 – Radix Tim, T_3 – Compo, and T_4 – DI Grow) with 10 replicates in three blocks. All plants were administered equal amounts of each treatment. The results at the bud incubation level revealed that bud initiation was not significantly dependent on the treatment. Although not significant, the Biozyme® treatment had the highest mean number of plantlets (46 plants). The organic fertilizers had significant effects ($p = 0.001$) on the vegetative growth of nursery plants. The maximum vegetative growth (plant height of 7.86±0.32 cm, girth of 10.6±0.3cm, 4±0.12 number of leaves, leaf area of 144 ±5.00 cm^2) was recorded with plants treated with T_2 – Radix Tim® (50 ml/7.5 L of water). Snails were the only nursery pests identified, and plants treated with T_3 (Compo®) were more susceptible to snails, with a mean of 0.04±0.02. Net profit margin results for the different treatments were high for T_1 (60) and lowest for T_2 (24). The organic fertilizers have significant effects in improving the vegetative growth of plantains therefore, Radix Tim® and DI Grow® were the best treatments for the production of healthy, vigorous nursery plants.

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INTRODUCTION

Bananas and plantains are major staple food crops in humid West and Central Africa, particularly in countries like Cameroon, and they play a crucial role in ensuring food security (Monono *et al*., 2023). Additionally, banana and plantain cultivation significantly contribute to the economic and community development of these regions, serving as important sources of energy and revenue for the local population (Monono *et al*., 2018; Monono *et al*., 2023). With an increasing population, the number of local plantain farmers is on the rise, leading to an expansion of farmland to sustain the growing demand (Monono *et al*., 2018; Monono *et al*., 2023). However, plantain cultivation faces various challenges, including urbanization, soil nutrient depletion, drought, pests and diseases, and crop management factors (Monono *et al*., 2018; Okolle *et al*., 2019; Cheke *et al*., 2020; Monono *et al*., 2023). Plantains are known for their rich dietary nutrient content, containing polysaccharides, sugars, and vitamins such as vitamin A, C, B6, and trace amounts of others (Park *et al*., 2011). In Cameroon, banana and plantain cultivation is prevalent in large-scale commercial farms, primarily under sole cropping, across six regions, namely Centre, East, Littoral, South West, West, and South (Anon, 2005). One of the major challenges in banana and plantain cultivation is the limited availability of healthy planting material (Nkendah & Akyeampong, 2003). These crops are sterile and parthenocarpic, making conventional breeding methods challenging to implement for plantain improvement (Ali *et al*., 2011). As a result, farmers heavily rely on natural regeneration of plantain/ banana mats to obtain suckers, as there is a lack of formal seed systems for producing and distributing quality planting material. However, this traditional method of vegetative propagation is slow and often yields limited numbers of suckers, which may not meet the farmers' demand for specific varieties (Manju & Pushpalatha, 2020). Furthermore, these suckers are prone to contamination with soil-borne pathogens, insect pests, and nematodes. Transplanting contaminated material can lead to the spread of diseases, reducing productivity and increasing production costs due to the need for pest and disease control measures, ultimately shortening the lifespan of plantations (Manju & Pushpalatha, 2020).

Micropropagation has long been utilized in tissue culture procedures to generate a large number of high-quality planting materials. However, the majority of small-scale farmers have yet to profit from this technology because it requires advanced skills and is prohibitively expensive for them (Kwa, 2003; Manju & Pushpalatha, 2020). As a result, smallholder farmers must boost their plantain production by implementing low-cost and simple planting material production procedures. In vivo macropropagation of plantains and bananas provides a viable alternative method for mass production of planting material under in vivo circumstances, needing minimal cash and talent to produce large numbers of quality plantlets (Kwa, 2003; Manju & Pushpalatha, 2020). Plants from in Vitro Buds (PIF) is a macropropagation technology that stimulates the lateral growth of several latent buds in a corm under in vivo conditions. A misting system is utilized to improve ventilation and shade, lower temperatures, and raise humidity levels, preventing greenhouse overheating disasters (Ewané *et al*., 2019; Tatsegouock *et al*., 2020; González *et al*., 2022a).

The PIF technique utilizes the full potential of corms to produce a large quantity of healthy planting materials (plantlets) within a short period (2 to 3 months) and at a low cost. It can quickly generate 20 to 100 plantain plantlets from a single sucker, depending on the variety and the experience of the technician (Kwa, 2003; Kwa *et al*., 2009; Ewané *et al*., 2019; Tatsegouock *et al*., 2020; González *et al*., 2022a). Despite PIF seedlings being clean planting material, the technique still faces challenges related to acclimatization, contamination on farmlands, and the position of the shoot on explants, which can affect the vigor of the plant (Ewané *et al*., 2020; Tatsegouock *et al*., 2020). Tatsegouock *et al*. (2020) reported that these problems can lead to approximately 60% loss of plants on farms and may be rejected by farmers. Some of these problems can potentially be solved using organic and inorganic fertilizers. However, information about the response of plantain explants to plantlets in combination with selected fertilizers is limited (Tatsegouock *et al*., 2020). The use of chemical fertilizers and pesticides in agriculture has been associated with water and soil pollution, posing risks to human health and the environment (Tatsegouock *et al*., 2020). To address this issue, researchers have been developing bioorganic fertilizers for the micro and macropropagation of banana and plantain plantlets. Biological agents such as *Bacillus amyloliquefaciens* strains have shown the ability to colonize the rhizosphere of banana and plantain, inhibiting pathogen growth, particularly Fusarium wilt disease, and promoting plant growth (Tao *et al*., 2020). Soil amendments with *Tithonia diversifolia*, either alone or combined with clam shells, have also been effective in suppressing the development of *Mycosphaerella fijiensis* on PIF plantlet leaves and improving plant growth parameters (Ewané *et al*., 2020). Additionally, the use of growth regulators, such as Benzyl Aminopurine (BAP) alone or in combination with other growth regulators, has been reported to induce sprouting of axillary buds in plantain and banana during in vivo macropropagation (Patel & Rath, 2018; González *et al*., 2022b). Exploring the response of plantain to in vivo macropropagation techniques in combination with selected organic foliar fertilizers, such as Biozyme®, Radix Tim®, Compo®, and D.I Grow®, could provide a new approach to improve PIF performance. This study aims to evaluate the effect of selected organic foliar fertilizers on plantain plantlet production through the PIF method and their subsequent development in the nursery.

MATERIALS AND METHODS

Site description

The experiment was conducted at the Institute of Agricultural Research for Development (IRAD) Ekona (4°16'44''N and 9°17'50''E) in the Muyuka municipality, Fako Division of the South West Region, Cameroon. Ekona is situated at an altitude of approximately 450m above sea level. The area has a humid tropical climate, with mean temperatures ranging from 23.7°C in the rainy season to 24.4°C in the dry season. The average annual rainfall is around 2,500 mm. The rainy season typically extends from March to September, while the dry season spans from October to February. However, due to climate change, it is challenging to predict seasonal variations (Okolle *et al*., 2022). The primary economic activity in this area is agriculture, with small -scale farmers cultivating various crops such as bananas, plantains, cassava, cocoyam, sweet potatoes, maize, vegetables, cocoa, coffee, oil palm, rubber, fruits, poultry, pigs, small ruminants, fisheries, and traditional African vegetables (Okolle *et al*., 2022).

Table 1. The compositions of the treatments and description of their preparation methods.

Treatment	Type	Description
T_1	Tap water	Untreated pipe-borne water obtained from a local catchment source.
T_2	Biozyme®	A plant extract (biostimulant) that promotes flowering, enhances fruit setting, and aids in the growth of young fruits. It has been used for vegetables and coffee and is compatible with most other agricultural pesticides. The recommended application dose is 40-50 ml per backpack sprayer. This product is manufactured by GBM and distributed by Arysta Life Science Cameroon
T_3	Radix Tim®	An organic liquid product soluble in water, recommended for root growth. It is rich in phosphorus, potassium oxide, and amino acids, and it is compatible with other agricultural products. It is produced by Agro Solutions S.A. Forcrop and distributed by *Societe d'Engrais et de produits chimiques*-Cameroon. One liter (1L) of this chemical contains nitrogen (3.36%), phosphorus pentoxide (11.36%), potassium oxide (4.06%), zinc (0.23%), and amino acids (5.80%).
T_4	Basfoliar kelp S.L. (Compo®)	Compo is a biostimulant extract of Kelp (*Eckionia maxima*) that is applied as a foliar application. It is compatible with other agricultural products. It is produced by Compo VPERT SPAIN.S.E. One liter (1L) of this chemical contains proteins (1.95%), amino acids (0.25%), auxins (11 mg), and vitamins (traces).
T_5	D.I. GROW®	An organic foliar fertilizer highly compatible with other agricultural pesticides and fungicides. It is produced by dynapharmlab associate and distributed by dynapharm Mali. One liter (1L) of this chemical contains nitrogen (2.35%), phosphorus (4.44%), potassium oxide (1.75%), magnesium oxide (0.36%), boron (0.011), iron (867 ppm), manganese (223 ppm), copper (144 ppm), and zinc (153 ppm).

Experimental layout and treatments

A randomized complete block design (RCBD) was employed in both the propagator and the nursery. The growing medium consisted of uniform sawdust, and the different treatments were randomly applied within each block. There were five (05) treatments, each with three (03) replications. Each replicate plot comprised 10 explants, resulting in a total of 30 explants per treatment and 150 explants for the entire experiment. It was assumed that all plants within each block experienced similar environmental conditions. Each treatment was spaced 2 meters apart from the others, and each replicate was 2 meters apart to prevent edge effects and overlap during treatment application. The treatments (Table 1) used were as follows: T_1 (Tap water know as control), T_2 (Biozyme®), T_3 (Radix Tim®), T_4 (Compo®), and T_5 (D.I Grow®). All these treatments were purchased from a local agrochemical store in Muea.

Construction and maintenance of propagators

Propagators, measuring 4m in length, 1.5m in width, and 0.25m in height, were constructed using local wood. Three propagators were built, each divided into five compartments to accommodate the four treatments and a control. Each compartment had dimensions of 0.5m, and the propagators were spaced 1m apart from each other. Transparent polythene sheets were used to create a greenhouse structure over each propagator. The propagators were filled three-quarters full with fine sawdust obtained from sawmill located in the Bwitingi - Buea market area.

Shade house construction

A shade house, constructed using palm fronds and measuring 1.5m in height, and was built over the propagators. The purpose of the shade house was to reduce sunlight intensity on the propagators. High sunlight intensity can lead to excessive transpiration rates, which may cause the plants to wither and result in leaf burns (yellow-brown discoloration).

Selection, collection, and preparation of suckers

Sucker selection and collection: Suckers were carefully selected and collected from the CARBAP plot at IRAD Ekona. Diggers were used to extract suckers with narrow sword-shaped leaves and pseudostems ranging from 5 to 40 cm in height. The suckers were dug up from the base of fully grown, healthy, disease-free cultivars (French 'Clair'). Using a sharp machete, the sucker's pseudostem with a length of 10 cm was cut, and the remaining pseudostem was discarded. The suckers were then packed in bags and transported to the research site. Sucker preparation was carried out on the same day as harvest.

Sucker preparation: The sucker preparation procedure followed the propagation manual of IITA (2011). Roots were removed from the harvested suckers using a sharp machete. The outer leaf sheaths were also carefully removed one by one, 2 mm above the corm and from the leaf base, using a sharp knife. This process exposed all the buds and/or the meristem. The corms were scarified at the top by making an X-shaped cut (Kwa, 2003; Baiyeri & Aba, 2005). The peeled stems were then soaked in a mixture of fungicide and insecticide (KozeB and Cypercal TM 50 EC, 250 ml of each in 15L of water) and dried in a dry, shady place for 15 minutes. This treatment aimed to eliminate fungi, insects, and nematodes present on the prepared corms.

Propagation: The incised corms (explants) were placed side by side in the propagators with the crosscuts facing upward. They were buried 3 to 4 cm deep in the propagating medium. Each compartment accommodated ten (10) explants, resulting in a total of 50 explants per propagator, with each explant placed 30 cm apart from each other.

Propagator management: A day after placing the explants in the propagators, thorough watering was carried out with approximately 15L of water for each compartment. Subsequently, watering was conducted twice a week using 22L of water per replicate or compartment. In some weeks, the watering frequency was increased to three times when necessary. This occurred when there was no moisture present around the plastics, and the sawdust failed to clump together when pressed in the palm of the hand. The corms were monitored for sprouting, and a clean environment around the propagators was maintained through mechanical weeding.

Treatment application: For the application of treatments, 100 mL of each organic fertilizer was mixed with 15L of water. The mixture was then evenly applied over the medium containing the implanted corms using a spraying can. The first application was carried out 7 days after the initiation of incubation, followed by weekly applications for three weeks.

Harvesting of plantlets (Sprouted corms): A corm was considered sprouted when at least one root had developed or when both shoot and root differentiation were observed. Sprouted corms were harvested by gently pulling them from the initiation medium to ensure that shoots, especially very young plantlets, remained attached to the corms with intact roots. Plantlets with two or more leaves were carefully detached from the corms using a dissecting blade, ensuring that they still had roots attached. For very large plantlets, instead of detaching them from the root level, their pseudostems were cut approximately 4 cm from the corm. The remaining pseudostem attached to the corm was then reactivated by incising it. A larger knife (kitchen knife) was used for reactivation, while the dissecting blade was preferred for taking out the plantlets from the corms to prevent damage to the very young plantlets.

Preparation of growing medium: Topsoil was excavated from a fallowed farmland near the research site and transported in barrows to the experiment site. Polythene bags of size five (20.5 cm × 16.3 cm) were then filled with the soil, arranged in a randomized complete block design (RCBD) as shown above, and watered to facilitate planting.

Plantlets and nursery treatment application: Plantlets measuring 6 cm in height with two leaves were individually planted into polythene bags. The planting process followed the initial treatments applied during the incubation phase. This means that plantlets from Treatment 1 (T_1) were the same plantlets used for T_1 at the nursery level, and so on. This continuity ensured proper follow-up from propagation to the nursery, as the same treatments were involved in both the propagator and nursery phases of the work.

Application of treatments in the nursery: Each treatment was spaced 2m apart from one another, with each replicate also positioned 2 m apart to prevent treatment overlap. To apply the treatments, 50 mL of each treatment (the same treatments used in the propagators: T_1-T_5) was diluted in 7.5L of untreated pipe-borne water. The diluted treatments were then applied to the leaves using a hand pressure sprayer with a capacity of 2.5L. The first application took place 7 days after the plantlets were transferred to the nursery, followed by subsequent applications every two weeks for a duration of four months.

Routine management and cultural practices: Periodic manual weeding was carried out in the nursery. Watering of the plants was performed, particularly during dry periods, using a watering can. Inactive leaves that could not photosynthesize were pruned to reduce microbial load and prevent attracting pests such as snails. Any observed pests (snails) were manually removed and crushed using a stone.

Data collection

In the propagator: After harvesting the plantlets from each corm, the plantlets were counted, and the number was recorded per replication/treatment/block. Decayed corms were identified, removed, counted, and equally recorded per replication/treatment/block.

In the nursery: Data collection began two weeks after the plantlets were transferred into polythene bags in the nursery. Data was collected every two weeks following treatment application over a period of three months. The following growth parameters were recorded: Shoot height (cm) was measured using a measuring tape from the point of attachment to the pseudostem to the point of first leaf emergence. Pseudostem girth (cm) was measured 5 cm above the soil medium level using a veneer caliper. The leaf length and width were used to calculate the leaf area (LA) following the equation LA = (L × W) × 0.8 for banana plants as described by Monono *et al.* (2018) and Monono *et al.* (2023). Pests such as snails and aphids present in the nursery were counted and recorded per treatment and replication. Data collection occurred every two weeks until the end of the study.

Grading, selection, and planting of sprouted plantlets: Before planting the plantlets into the polythene bags, they were graded based on size, height, and number of leaves. This ensured that all plantlets used for the experiment were of the same size, height, and had the same number of leaves. Additionally, this step was taken to ensure that only healthy plantlets were used for the experiments.

Calculation of net profit margin: The calculation of net profit margin for the production of plantain plantlets from PIF involves several key steps. Firstly, all revenue generated from the sale of plantain plantlets is recorded for the specified period under consideration. This includes the total sales value of plantain plantlets after accounting for any discounts or returns. Next, the direct costs associated with the production of plantain plantlets are determined. These costs typically include expenses such as raw materials, labor, overheads, and any other variable costs directly attributed to the production process. Indirect costs, such as administrative expenses and marketing costs, are not included in the direct cost calculation. Once the direct costs are determined, they are subtracted from the total revenue to obtain the gross profit. To calculate the net profit margin, all other expenses, such as taxes, interest, and other non-operating costs, are deducted from the gross profit. Finally, the net profit is divided by the total revenue and multiplied by 100 to express the net profit margin as a percentage, providing a measure of the profitability of the plantain plantlet production process from PIF.

$$\text{Net Profit Margin} = \frac{\text{Net Profit}}{\text{Total Revenue}} \times 100$$

Construction of a nursery and its management: A nursery shade was constructed using traditional methods, utilizing palm branches and Indian bamboos. Palm branches were harvested from the Cameroon Development Corporation (CDC) palm plantation in Ekona. The purpose of the nursery shade was to reduce direct sunlight and protect the potted plants from rain droplets.

Data analysis

Data were analyzed using a one-way analysis of variance (ANOVA) at p = 0.05 in Minitab statistical software package version 17. The treatment means were compared and separated using Tukey method at 5% probability level.

RESULTS AND DISCUSSION

Effects of treatments on plantlet production

Plantlets are young or small plants produced through asexual reproduction or vegetative propagules of mature plants. This study, plantlets were harvested every three weeks for a period of 12 weeks. Figure 1 shows an exponential increase in the number of plantlets harvested over time, lasting for the first six weeks for Compo®, and nine weeks for Biozyme®, D.I. Grow®, Radix Tim®, and the control group. However, after nine weeks, there was a significant decrease in the number of plantlets produced per treatment. The reduction of plantlets number could be attributed to excess water in the propagator, which deprived the roots of oxygen and led to asphyxiation of the corm. This lead to an irreversible damage such as corm rotting occurred. A similar result was reported by González *et al.* (2022a), who found that the application of Benzyl-minopurine (BAP) did not significantly influence the sprouting time of plantain corms.

Number of plantlets per corm

The application of organic fertilizers did not result in a significant increase (p ≥ 0.05) in the number of plantlets per corm. Biozyme® had the highest mean number of plantlets (46), followed closely by the control with 45 plantlets. D.I. Grow®, Compo®, and Radix Tim® produced 43, 35, and 32 plantlets, respectively. This finding suggest that bud development in plantlets is primarily initiated by nutrient reserves within the corms. Due to the buds or corms do not have roots at the early stage of development, they are unable to take up nutrients from the substrate. Therefore, the application of fertilizers may not significantly impact the scarcity of planting materials. This findings is inconsistent with the results reported by Tao *et al.* (2020), Ewané *et al.* (2020), Tatsegouock *et al.* (2020), and Monono *et al.* (2023), where they found that additives such as bio-fertilizers and plant growth hormones influenced bud initiation by facilitating nutrient uptake from the substrate through the rooting properties of the bio-fertilizers.

Decay rate of corms following application of organic fertilizers

Decay refers to the process of rotting or decomposition of a substance. The trend of corm decay for all treatments showed a general pattern throughout the study, with a gradual increase from 3 weeks after initiation (WAI) to 6 WAI, followed by a drastic reduction in the decay rate at 9 WAI. From 9-12 WAI, the decay rates exponentially increased, but there was statistically no significant different (p ≥ 0.05) among the different treatments (Figure 2).

Decomposition of corms

The decomposition of corms varied across treatments; however, there was no significant increase (p ≥ 0.05) in the mean rate of decay among the different treatments (Table 2). The highest mean decay rate was observed in the substrate treated with Compo® (0.22±0.04), followed by the control (0.18±0.04). These findings indicate that, on average, one corm decayed per treatment during the course of the experiment. The rise in decay rates may be due to environmental factors like humidity and elevated substrate moisture levels, which enhance microbial activity and, as a result, speed up corm decomposition.

Table 2. Effect of organic fertilizer on mean number of decayed corms harvested.

Treatments	Mean number (±SE) of decayed corms
Control	0.18 ±0.04[a]
Biozyme® (T1)	0.13 ± 0.03[a]
Radix Tim® (T2)	0.15 ± 0.03[a]
Compo® (T3)	0.22± 0.04[a]
D.I. Grow® (4)	0.15 ± 0.03[a]

Values represent means were separated using Tukey HSD = 0.05; Mean with similar letters within column indicate no significant differences among treatments.

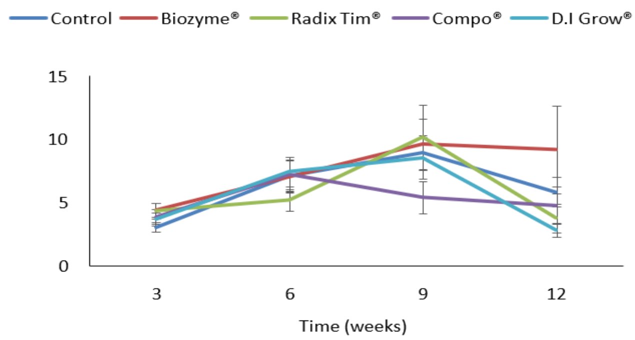

Figure 1. *The effect of organic fertilizers on mean number of plantlets over time.*

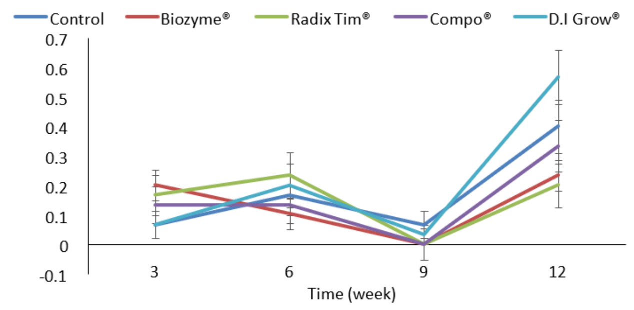

Figure 2. *The effect of organic fertilizer on corm decomposition rate with time.*

Effects of organic fertilizers on vegetative growth parameters in the nursery

In this study, several measurements were taken to assess vegetative growth, including plant height, plant girth, number of functional leaves, and actual leaf area. Plant height and plant girth exhibited an exponential growth pattern from 2-8 weeks after planting (WAP), followed by a decrease in the rate of growth from 10-12 WAP (Figure 3). This continuous growth can be attributed to the shoot system, which continually produces leaves until flower initiation occurs. The apical meristem, which is the primary plant meristem, acts as the source of all above-ground plant organs (Brukhin and Morozova, 2011).

Effects of organic fertilizers on vegetative growth parameters in the nursery

In terms of the number of functional leaves, there was an exponential increase in growth from 0-6 weeks after planting (WAP), followed by a slight decrease from 6-8 WAP, and a slight increase again from 8-12 WAP (Figure 3). The decrease in the number of functional leaves between 6-8 WAP could be attributed to environmental stress factors such as water and temperature (Monono *et al.*, 2023). Plant height measured at the end of the experiment showed a significant increase (p = 0.001) in height for plantlets treated with Radix Tim® and D.I. Grow® as compared to the control, Biozyme®, and Compo® (Table 3). Radix Tim® was the most effective fertilizer in terms of height, with a mean height of 7.86±0.32 cm, while the control plantlets had the lowest mean height of 4.38±0.13 cm. This increased in plant height with plantlets treated with Radix Tim® and D.I. Grow® can be attributed to the sufficient concentrations of nitrogen (N), phosphorus (P), and potassium (K), which significantly enhance photosynthesis and related growth processes. In addition, Radix Tim®, as a bio-stimulant for root growth, may have stimulated increased root growth, leading to improved nutrient uptake and subsequent plant height in the Radix Tim® treatment (T2). The results also suggest that Radix Tim® and D.I. Grow® provided superior nutrient contents. Generally, organic fertilizers are known to enhance nutrient uptake by plants, hence providing nutrients in readily available forms (Hassan *et al.*, 2022). These results are consistent with that of Monono *et al.* (2023), who reported that chicken manure, due to its high levels of nitrogen and phosphorus, resulted in increased final height of *Musa* species. Similar results were also observed by Akongte *et al.* (2019), who showed the superiority of Radix Tim® over other treatments in terms of height and pseudostem girth of the plants. Another study conducted in the Sultanate of Oman by Al-Harthi & Al-Yahyai (2009) demonstrated that increased levels of NPK resulted in increased stem height in *Musa*. The higher plant height with plantlet treated with T2 can be attributed to the larger leaf area of the T2 plants. Leaf area growth plays a crucial role in light interception and is an important parameter for determining plant growth and productivity (Monono *et al.*, 2018; Manju & Pushpalatha, 2020; Monono *et al.*, 2023).

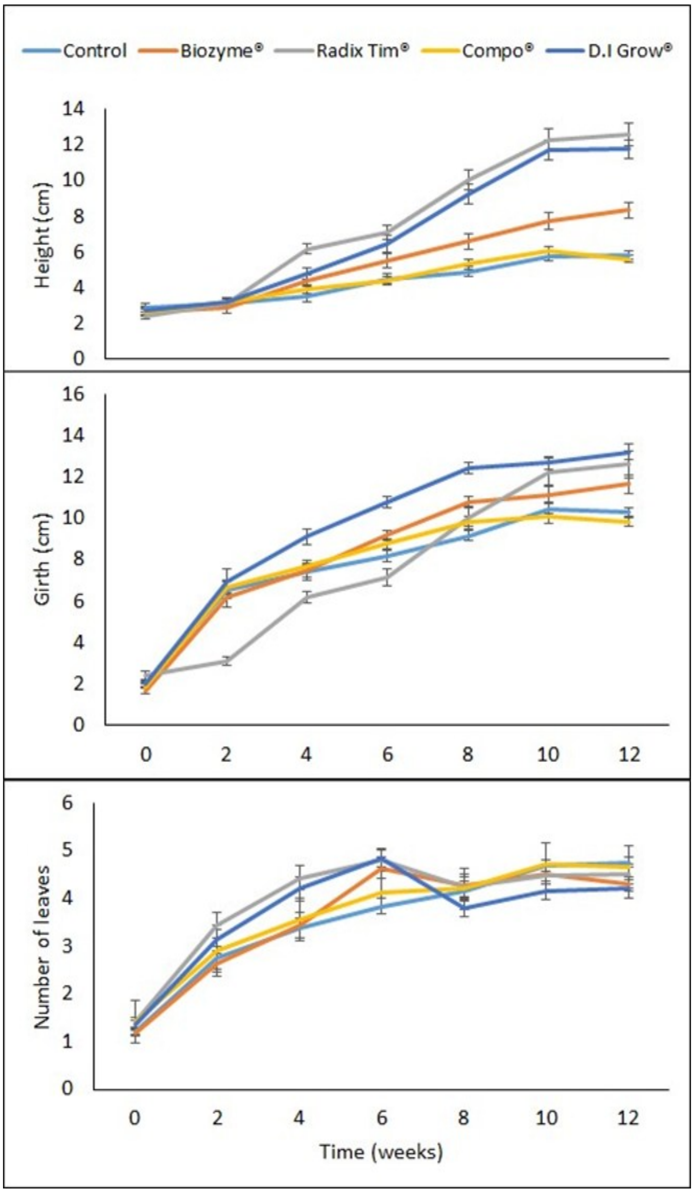

Figure 3. *Variation of growth parameters of plantain seedlings over time in the nursery.*

The plantlets treated with organic fertilizers did not significantly increased pseudostem girth and the number of functional leaves as compared to the control (p ≥0.05) across various treatments (Table 3). However, Radix Tim® exhibited the highest average pseudostem girth (10.6±0.3cm) and number of functional leaves (4±0.12). The lack of a substantial increase in pseudostem girth and leaf number could be attributed to the favorable substrate mixture, leading to lower bulk density and increased water retention capacity. Studies carried out by Monono *et al.* (2018) and Monono *et al.* (2023) highlighted that lower bulk density signifies less compact substrate and more pore spaces, facilitating improved root aeration, nutrient absorption, and subsequent growth enhancements like root length, plantlet height, girth, and leaf count. These observation aligns with the research of Najarian and Souri (2020), who found that a minimal concentration of sugarcane compost (20%) stimulated optimal morphological parameters in plant growth, including leaf count, stem count, flower initiation, flower count, inflorescence size, main shoot diameter, shoot biomass, and root biomass.

Table 3. Means of growth parameters of plantain plantlets affected by organic fertilizers.

Treatment	Plant Height (cm)	Plant girth (cm)	No Leaves	LA (cm^2)
Control	4.38 ± 0.13^{a}	7.80 ± 0.20^{a}	3.60 ± 0.10^{a}	34.64 ± 1.32^{a}
Biozyme® (T_1)	5.5 3± 0.20^{a}	8.40 ± 0.30^{a}	3.60 ± 0.10^{a}	60.90 ± 1.80^{b}
Radix Tim® (T_2)	7.86 ± 0.32^{b}	10.60 ± 0.30^{a}	4.00 ± 0.12^{a}	144.00 ± 5.00^{c}
Compo® (T_3)	4.50 ± 0.13^{a}	7.96 ± 0.21^{a}	3.70 ± 0.10^{a}	45.30 ± 2.42^{b}
D.I. Grow® (T_4)	7.25± 0.29^{b}	9.80 ± 0.30^{a}	3.70 ± 0.10^{a}	109.00 ± 3.40^{c}

Table 4. Effects of treatments on pests Control.

Treatment	Number of Snails
Control	0.02±0.01^{a}
Biozyme® (T_1)	0.01±0.01^{a}
Radix Tim® (T_2)	0.01 ±0.01^{a}
Compo® (T_3)	0.04±0.02^{b}
D.I. Grow® ($_4$)	0.01±0.01^{a}

Values represent means. Means separated through ANOVA with Dunnet multiple comparison tests with a control at α= 0.05; Mean with similar letters within column indicate no significant differences among treatments.

Table 5. Net profit margin calculation for treatments.

Income statement for the year end (all seasons in a year)		Control		T_1		T_2		T_3		T_4	
Revenue			Year 1 (%)		Year 1 (%)		Year 1 (%)		Year 1 (%)		Year 1 (%)
	Revenue from crop sales		1,458,000		1,991,520		1,040,040		1,296,000		1,386,720
Total revenue			1,458,000		1,991,520		1,040,040		1,296,000		1,386,720
Expenses											
Less	Costs of Goods sold	654,760		702,360		691,160		716,360		710,760	
Gross profit			803,240 (0.55)		1,289,160 (0.65)		348,880 (0.34)		579,640 (0.45)		675,960 (0.49)
Less	Indirect costs (Operating expenses)	103,096		103,096		103,096		103,096		103,096	
Net profit (Margin)			700,144 (48)		1,186,064 (60)		245,784 (24)		476,544 (37)		572,864 (41)

The relative leaf area significantly increased with the use of organic fertilizers compared to the control during the acclimatization period (p = 0.001) as indicated in Table 3. The largest leaf area was observed in plantlets treated with Radix Tim® (144 ±5.00 cm^2). These outcomes can be attributed to the adequate concentration of N, P, and K in Radix Tim®, which are crucial for leaf blade growth through cell division and protein synthesis. Nitrogen deficiency can hinder blade growth by prolonging the cell cycle and affecting mitotic and post-mitotic growth rates (Monono *et al.*, 2023). Nitrogen is vital for protein synthesis, which is essential for building plant cells (Kubota *et al.*, 2009). However, the results contradict those of Al-Harthi & Al-Yahyai (2009), who found that the control experiment without fertilizer application had the highest mean leaf area. The increased leaf area in the control group of Al-Harthi & Al-Yahyai (2009) study might have been caused by other factors not related to fertilizer application, such as intraspecific competition or sufficient soil nutrients.

Occurrence of pests (Aphids/Snails)

During acclimatization, the only pest observed in the study was snails (*Limicolaria* spp). Organic fertilizers showed a significant effect (p=0.001) on pest occurrence (Table 4). Plantlets that received Compo® (0.04±0.02) were more susceptible to snails. The application of fertilizers generally changes the agroecology of the plant environment and the nutrient composition of the plants. If the soil becomes more nutritive due to fertilizer application, the plants also become more nutritive, leading to increased vegetative growth and lower fiber content. This variation in nutrient and fiber contents in plants can attract different pests based on their nutrient requirements. The difference in the specific nutrient levels in host plants and herbivores plays a vital role in causing damage to the plant (Rashid *et al.*, 2016). Some reports have shown that stoichiometric mismatches between insects' requirements and their diet play an important role in the elemental concentrations of the insect body and their life history traits (Filipiak & Weiner, 2017). Although inorganic and organic fertilizers may have an impact on snails, it may not result in significant repellency or mortality. According to Cheke *et al.* (2020), revealed that certain synthetic molluscicides can induce increased mucus secretion in gastropods, which is an initial response to various stressors such as mechanical stimuli or chemical irritation caused by molluscicidal chemicals. The primary function of the extruded mucus is to create a protective barrier, which preventing direct contact between the toxins and the skin or digestive tract epithelia, thus reducing the toxicity of the chemicals. The substantial presence of pests in the Compo® treatment (T3) in this research can be attributed to the composition of Compo®, which is composed of high concentration of 1.57% ash and 1.95% protein, as well as a significant number of leaves. The low ash content in the soil may have led to a higher concentration of snails in these areas. Okolle *et al.* (2019) reported that snails are attracted to areas with abundant food sources. Snails require carbohydrates for energy, protein for growth, and calcium for shell development, which aligns with the findings of Rashid *et al.* (2016). They observed a significant decrease in rice water content due to the feeding behavior of the brown plant hopper (BPH) on NPK-treated plants. The BPH has a high nitrogen content, indicating its constant demand for this element, as host plants typically provide insufficient nitrogen. This suggests that nutrient application, particularly nitrogen, can significantly impact pest populations.

Net profit margin calculation for treatments

The net profit margin results for the different treatments indicated that the most profitable treatment was T_2 (60) followed by the control (48) and then T_4 (41). These values represent the profitability of the plantain plantlet production using the PIF technique. The study conducted on the macro-propagation of dessert bananas and plantains using the PIF technique in Togo, West Africa, provides insights into the economic aspects of plantain production and the efficiency of the PIF method in generating profit margins (Kwa *et al*., 2009; Olaghere *et al*., 2019). The profitability of plantain plantlet production is crucial for farmers and stakeholders in the plantain value chain. The net profit margin values obtained from the different treatments indicate variations in the economic returns associated with the PIF technique. These results highlight the importance of optimizing production methods to enhance profitability and sustainability in plantain cultivation (Monono *et al*., 2023). Furthermore, the study emphasizes the significance of innovative propagation techniques like the PIF method in increasing plantain plantlet production and improving economic outcomes for farmers. By analyzing the net profit margins across different treatments, the research underscores the potential of the PIF technique to enhance the efficiency and profitability of plantain propagation, contributing to the economic viability of plantain cultivation in the region (Okonkwo & Nwauzor, 2021). In line with these findings, recent studies have also highlighted the potential of the PIF technique in improving plantain production. For instance, a study conducted in Cameroon reported that the PIF technique resulted in a 40% increase in plantain plantlet production compared to conventional methods, leading to enhanced profitability for farmers. Another study in Nigeria found that the PIF technique was effective in producing healthy and disease-free plantain plantlets, which contributed to increased yields and profitability for farmers (Kwa *et al*., 2009; Lefranc *et al*., 2010).

Conclusion

In conclusion, the application of organic fertilizers did not have a significant impact on the number of plantlets produced per corm, but it did affect the vegetative growth aspects of the potted plants. The treatments involving Radix Tim and DI Grow showed significant influences on vegetative growth parameters such as leaf area, leaf number, and plant height. These parameters are crucial for the early growth stage of Musa species and contribute to their successful field establishment immediately after planting. The results of this study suggest that the application of organic fertilizers during macro propagation of plantains may not be necessary. However, the application of Radix Tim or DI Grow at a dosage of 50ml/7.5L (0.75L of solution per plant) at the nursery level for both treatments is recommended for the development of potted plantain plantlets, ensuring proper field establishment for the people of Muyuka sub-division and its surrounding areas. The net profit margin results offer valuable insights into the financial aspects of plantain plantlet production, emphasizing the importance of sustainable and profitable practices in the plantain industry.

DECLARATIONS

Author contribution statement

Conceptualization: J.N.O., E.Y.M. and L.D.L; Methodology: J.N.O. and M.E.M; Software and validation: M.E.M., E.Y.M and L.D.L; Formal analysis and investigation: J.N.O, E.Y.M and M.E.M; Resources: E.Y.M. and L.D.L; Data curation: M.E.M, E.Y.M, J.N.O and L.D.L.; Writing—original draft preparation: E.Y.M, J.N.O and L.D.L.; Writing—review and editing: E.Y.M., L.D.L and J.N.O; Visualization: J.N.O, E.Y.M and G.C.; Supervision: J.N.O and G.C; Project administration: M.E.M. All authors have read and agreed to the published version of the manuscript.

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