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Nutrient Release Pattern of FertiGroe Nanofertilizer and Conventional Fertilizer in Different Growth Media and Their Effect of the Growth Performance of Banana (*Musa acuminata* Colla (AAA) "Cavendish")

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Abstract

The nutrient release pattern of nanofertilizer in different growth media and their effect on the growth performance of "Cavendish" banana seedlings were evaluated. The experiment was laid out in a Split-Plot in Randomized Complete Block Design with media namely: garden soil (GS), coconut coir dust (CCD) and 1:1 volume mixture of Garden soil and coconut coir dust (GS + CCD 1:1 v/v) as the main plots, while types of fertilizer, FertiGroe (F) a nanofertilizer and Conventional fertilizer (C) as the sub-plots. For 28 days, the release of nutrients was observed. By day 28, FertiGroe had released more nitrogen (0.48%) into the garden soil than conventional fertilizer (0.23%). In other mediums, however, release patterns were similar. The release of potassium and phosphorus was usually consistent across fertilizer kinds and media. The type of medium used had a substantial impact on plant growth; after 8 weeks, the soil-coir mixture produced the tallest plants (16.9 cm) and most leaves (6.6). Most growth characteristics were not significantly affected by the kind of fertilizer, while conventional fertilizer resulted in longer roots (19.8 cm versus 17.7 cm). The findings show that, depending on the growing media employed, nanofertilizer can deliver nutrient release and plant growth outcome that are either equivalent to or better than those of conventional fertilizer. When applying either fertilizer, the soil-coir mixture is ideal for producing banana seedlings.

Keywords

Nanofertilizer, Conventional, Release Pattern, "Cavendish" Banana, FertiGroe

1. Introduction

Fertilizer is any material in a natural or synthetic form that is applied to soil or plant tissues to provide one or more nutrients needed for plant growth and development. The most commonly used commercial fertilizers are water-soluble quick-release fertilizers (QRFs) whose nutrients are predictively readily available for plants when properly placed in soil. Controlled release fertilizers (CRF) are typically coated or encapsulated with inorganic or organic materials that control the rate, pattern, and duration of plant nutrient release.

The slow rates of nutrient release can keep available nutrient concentrations in soil solutions at a lower level, reducing runoff and leaching losses. Nanofertilizer, which are controlled release fertilizers, improve crop growth, yield and quality parameters as they increase nutrient use efficiency and reduce fertilizer wastage [1].

Growth media are solid substrates that provide a substitute for natural soil to aid in root growth and the development of plants as the plants regularly extract water and nutrients from it [2]. Several substances can be used for growth media preparation, but deciding on the substances depends on their characteristics in relation to agronomic functions such as the ability to sustain plant growth [3]. An ideal growth media must physically support the plant, stimulate oxygen exchange for root respiration through good porosity, allow easy drainage to prevent water logging, and also have a high cation exchange capacity to meet the nutritional requirements of plants.

In the world today, agricultural production systems intensively use large amounts of fertilizer to achieve more production per unit area. But using more doses than the optimum amount leads to several problems like environmental pollution (*i.e.*, soil, water, and air pollution), low input use efficiency, decreased quality of food, developed resistance in different weeds, diseases, insects, less income from production, soil degradation, deficiency of micro nutrient in soil, toxicity to different beneficial living organism present above and below the soil surface, among others. In addition to these problems, there is also the challenge of having to feed the growing population of the world [4].

In Philippines, banana production for the fourth quarter of 2018 accounted for 2.42 million metric tons of total crop production, 0.6 % higher than the previous year's level of 2.41 million metric tons. The "Cavendish" variety had the highest share during the period at 51.9% percent [5]. Bananas are fast-growing plants which require a continuous supply of nutrients and water for high yield. These nutrients may be partly supplied by the soil and through cycling within banana plantations, but fertilizer application is generally needed to satisfy plant requirements for obtaining profitable production. Bananas require large amounts of macronutrients such as nitrogen, phosphorus and potassium [6]. The recovery of applied inorganic fertilizer by plants is low in many soils. Estimates of overall efficiency of these applied fertilizers are about 50% or lower for N, less than 10% for P and close to 40% for K [7]. These lower efficiencies are due to significant losses of nutrients by leaching, run-off, gaseous emission and fixation by soil. These losses can potentially contribute to the degradation of soil, and water quality and eventually lead to overall environmental degradation.

The objective of this study is to determine the nutrient release pattern of nanofertilizer (FertiGroe) in different growth media and their effect on the growth performance "Cavendish" banana.

2. Materials and Methods

2.1. Preparation of Potting Container and Growth Media

A plastic bottle was cut crosswise (**Figure 1**) with the portion having a narrow end was used as a potting container and the other half was used to regularly collect the leachate after every watering. Three (3) different growth media were used for this experiment namely: coconut coir dust (CCD), garden soil (GS), and a 1:1 mixture of coconut coir dust and garden soil (GS + CCD 1:1 v/v) by volume. These media were individually placed in halved plastic bottles filled up to the rim, while the narrow opening at the bottom was covered with a cheese cloth. Banana cv "Cavendish" meriplants were planted in each bottle and watered to above field capacity. Thereafter, the potted banana was placed in the other halved portion of the bottle.

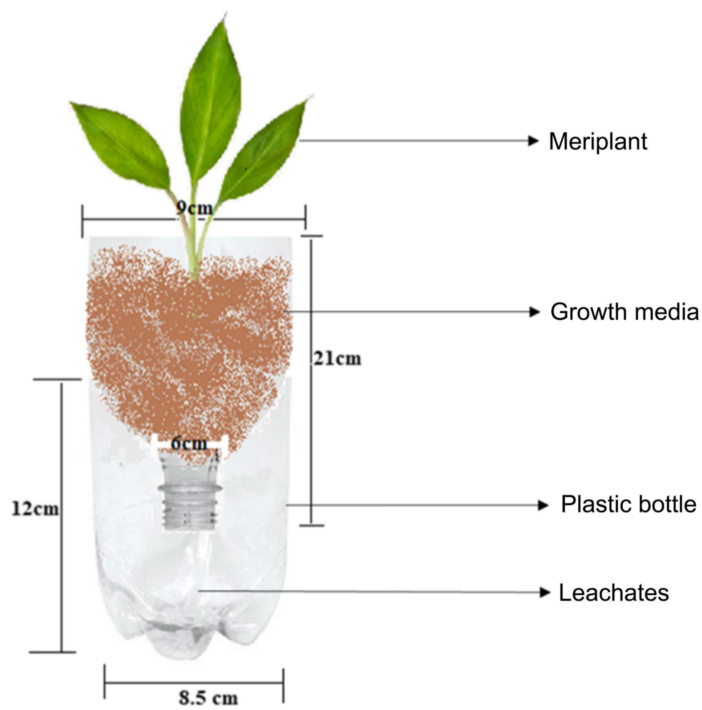

Figure 1. Set-up for nano fertilizer (FertiGroe) and growth media.

The garden soil and coconut coir dust were each sterilized by steam sterilization for a period of 3 hours. Samples from each medium were collected, prepared, and analyzed for pH, N using the Kjeldahl method, Olsen P using vanadomolybdate method, and K by flame photometry.

2.2. Preparation and Transplanting of "Cavendish" Banana Meriplants

Meriplants of "Cavendish" banana were procured and planted immediately in the three media that were used in the experiment, and covered with transparent plastic cups to maintain favorable humidity during acclimatization. The plastic cup cover is loose enough to allow air exchange between the internal and external environment of the potted plants. The newly planted meriplants were raised under a screen house for a period of four (4) weeks, which is when they reached potting age.

2.3. Preparation and Application of Fertilizer

Two types of fertilizers were used: conventional synthetic fertilizer, and nanofertilizer. The conventional fertilizer included complete fertilizer (14-14-14) as a source of N, P and K. For nanofertilizer, FertiGroe, a brand name given by research team technology for nanofertilizer developed in UP Los Banos was used. Fertigroe was developed by encapsulating nutrients in the nano spaces or voids of nanomaterial like zeolite. Zeolite particles are not nano in scale but the arrangement of silicon oxide and aluminium oxide tetrahedra creates that are within nanoscale (Angeles et al, 2020) It is available as Fertigroe N (28-0-0), FertiGroe P (0-8-0), and FertiGroe K (0-0-41. Two grams (2 g) of complete N, P, and K (14:14:14) were side-dressed and an equivalent rate of FertiGroe N (1 g), P (3.5 g) and K (0.68 g) was applied four (4) weeks after transplanting.

2.4. Design of the Experiment

The experiment was laid out in a Split-Plot in Randomized Complete Block Design with three (3) media treatments (GS only, CCD only and 1:1 by volume mixture of GS + CCD 1:1 v/v), as the main plots, and fertilizer type (FertiGroe and Conventional fertilizer) as the sub-plots. Each media treatment had fifteen (15) meriplants and was replicated four (4) times. In total, three hundred and sixty (360) meriplants were used for the experiment. The set-up was arranged in a screen house.

2.5. Determining Nutrient Release Pattern

Water (150 ml) was added at each period of leachate collection and allowed to elute through the column. Subsequently, 100 ml of leachates were collected at 0, 24 and 48 hours and at 7, 14 and 21 and 28 days from three potted plants in each treatment and replicate. The N (%), P (%) and K (%) concentrations of the leachates samples were determined using the Kjeldahl method, Vanadomolybdate method and flame photometry, respectively. The total N (g), total P (g), and total K (g) of the leachate were then computed by multiplying the nutrient concentration to the weight of the leachate. The nutrients released for a specific time were computed using the formula below.

$$NR_n = \frac{\sum_{i=0}^{n}(C_i)}{M} \times 100$$

NR_n = Nutrient Released for n days (n = 0, 1, 2 7, 14, 21 and 28 days).

C_i = Total nutrient (N, P or K) in the leachate, g.

M = Amount of nutrient applied (g).

2.6. Growth Parameters Gathered

Parameters gathered included, plant height, pseudostem diameter, number of functional leaves and root length from three (3) meriplants randomly selected and tagged in each treatment and replicate.

2.7. Statistical Data Analysis

The results from the experiment were analyzed using the analysis of variance (ANOVA) of split-plot in Randomized Complete Block Design and comparison of means determined using Tukey's HSD test at $P \leq 0.05$.

3. Results and Discussion

3.1. Initial Soil Characteristics

The Lipa loam soil type was used for the experiment. The soil has the best physical characteristics among soil types in Laguna. The soil is characteristically brown to dark brown in appearance, it is a loose and very friable fine granular loam. The soil has a moderately well drainage capability. It is also estimated to have a moderate hydraulic conductivity and infiltration rate [8]. Based on the analysis and assessment made by the Analytical Service Laboratory of the Division of Soil Science, Agricultural Systems Institute, College of Agriculture and Food Science, University of the Philippines Los Baños, the soil had very low N (0.15%), very high P (59 mg/kg) and very high K (2.88 Cmol/kg). However, the soil pH of 5.46, as recorded, is within the requirements of banana.

3.2. Percent Nitrogen (N) Released from FertiGroe and Conventional Fertilizer

Garden soil Leachates: Garden soil leachates were monitored from day 1 until day 28 after transplanting (**Figure 2(A)**). From this leachate N was determined in every monitoring period. The release pattern represents the total nutrient release with time. Nanofertilizers are typically coated or encapsulated with inorganic or organic materials that control the rate, pattern, and duration of plant nutrient release.

The release pattern of FertiGroe nanofertilizer and conventional fertilizer are shown in **Figure 2(A)**. The trend of release of N was higher in FertiGroe compared to conventional fertilizer beginning day 0. Both fertilizers continued to increase in percent N and peaked at day 14. The release pattern flattened thereafter with

FertiGroe releasing high N (0.48%) compared to conventional fertilizer (0.23%) at day 28.

The higher release rate N in FertiGroe compared to the conventional fertilizer could be attributed to the fact that in the production of FertiGroe nanofertilizer, excess urea particles adheres to the surface of the zeolite when the adsorption capacity for ammonium of zeolite is reached, and this attached urea in the surface can be easily released when moisture is available.

This high release of N in FertiGroe compared to the conventional fertilizer in garden soil media agreed with the findings of [9] who conducted a similar experiment on release pattern of nitrogen nanofertilizer in a garden soil media.

Coconut coir dust: The release pattern of FertiGroe and conventional fertilizer in CCD is shown in Figure 2(B). The results indicate that at day zero the release of N in CCD was (0.07%) compared to conventional fertilizer (0.06%). However, release of N from FertiGroe increased to 0.09% but continued to decrease from thereon until day 28. In case of conventional fertilizer, the decrease in N on the first day remains consistent until day 20. Thereafter N released started to increase until day 28. The release pattern from day zero to day 28 shows that FertiGroe release rate was comparable to conventional fertilizer.

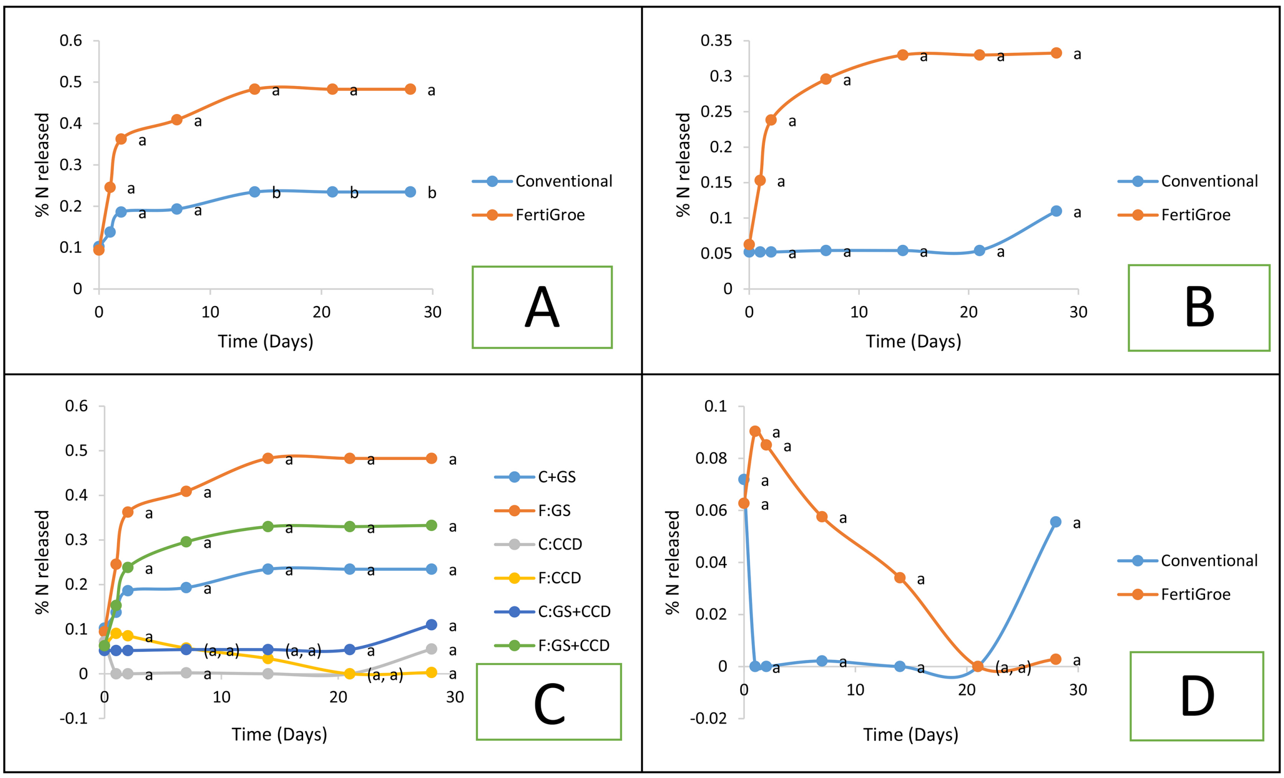

Figure 2. Percent N released from FertiGroe and conventional fertilizer in the leachates of GS, CCD and GS + CCD. Means with the same letter between treatment in each period are not significantly different.

Garden soil + Coconut coir dust: The percent release of FertiGroe and conventional fertilizer in mixed media (GS + CCD) is shown in Figure 2(D). The results show that the release rate of conventional fertilizer was (0.06%) compared to FertiGroe (0.05%) at day zero. However, while FertiGroe continued an increase in release of N from day zero, conventional fertilizer maintained a flat release pattern. The release rate of FertiGroe peaked at day 14 and flattened thereafter releasing 0.33% N at day 28. Conventional fertilizer increased its N release rate at 21 days and finally released 0.1% at 28 days. The release rate of FertiGroe N in GS + CCD media was similar to conventional fertilizer at the end of 28 days after fertilizer application.

Fertilizer type and growth media interaction: The release pattern of N in all media types used within 28 days after fertilizer application is shown in **Figure 2(C)**. The rates of release from FertiGroe and conventional fertilizers varied. The least release rate of N (0.003%) was observed when FertiGroe was applied in CCD media; this was followed by an increase in N release with conventional fertilizer in GS + CCD (0.06%), conventional fertilizer in GS + CCD (0.11%), conventional in GS (0.23%), FertiGroe in GS + CCD (0.33%) and FertiGroe in GS (0.48%).

3.3. Phosphorus (%) Released from FertiGroe and Conventional Fertilizer

Garden soil: Phosphorus (P) is one of the essential plant nutrients needed for plant growth. It is an important constituent of substances that are building blocks of genes and chromosomes. Phosphorus plays an important role in almost every plant process. An adequate supply of phosphorus is needed for optimum growth and reproduction.

The release pattern of P (%) in GS media within 28 days after fertilizer application (**Figure 3(A)**). The results show that conventional fertilizer released 05.018% of P compared to FertiGroe 0.015% at day zero. However, both fertilizers showed a steep decrease in release rate of P with FertiGroe showing a slower release rate until day 28 wherein FertiGroe showed a release of (0.003%) compared to conventional fertilizer (0.004%).

Coconut coir dust: The release pattern of FertiGroe and conventional fertilizer in coconut coir dust media within 28 days after fertilizer application (**Figure 3(B)**). The results showed that conventional fertilizer indicated a comparable release rate of P compared to FertiGroe with a release rate of 0.03% and 0.01% respectively at day zero. Release of P (%) steeply increased up to 48 hours and then gradually increased until day 28 with conventional fertilizer having a higher increase than FertiGroe. The release rate of P (%) was not different at each stage of leachate collection in conventional fertilizer compared to FertiGroe. However, at 28 days FertiGroe released P at a rate of 0.09% compared to conventional fertilizer at 0.31%.

Garden soil + coconut coir dust: Phosphorous (P) release in the mixture of GS + CCD showed that FertiGroe P showed a similar release pattern as conventional P within 28 days after fertilizer treatment although starting days 7, the rate of release from conventional fertilizer was higher than FertiGroe (**Figure 3(C)**). At day zero, FertiGroe release rate was (0.007%) compared to conventional fertilizer (0.012%). Both fertilizer treatments showed comparable release at day 28 with FertiGroe releasing 0.05% P while conventional fertilizer releasing 0.04%.

Fertilizer type and growth media interaction: The release pattern of FertiGroe and conventional fertilizers at different growth media is shown in Figure 3(D). Except F:GS, whose trend was stable from 24 hours to 28 days, the trend for the rest of the treatments was characterized by steep increase within 48 hours followed by slow but increasing increase up to 28 days. The rate of increase was highest in conventional fertilizer in CCD. At 28 days, conventional fertilizer released 0.31% of P when applied in GS. This was followed by FertiG4roe in CCD (0.09%), conventional in GS (0.05%), FertiGroe in GS + CCD (0.04%), conventional in GS + CCD (0.003%) and FertiGroe in GS releasing P (0.003%). The release pattern of FertiGroe P in GS, CCD and GS + CCD media was comparable with that of conventional fertilizer at 28 days.

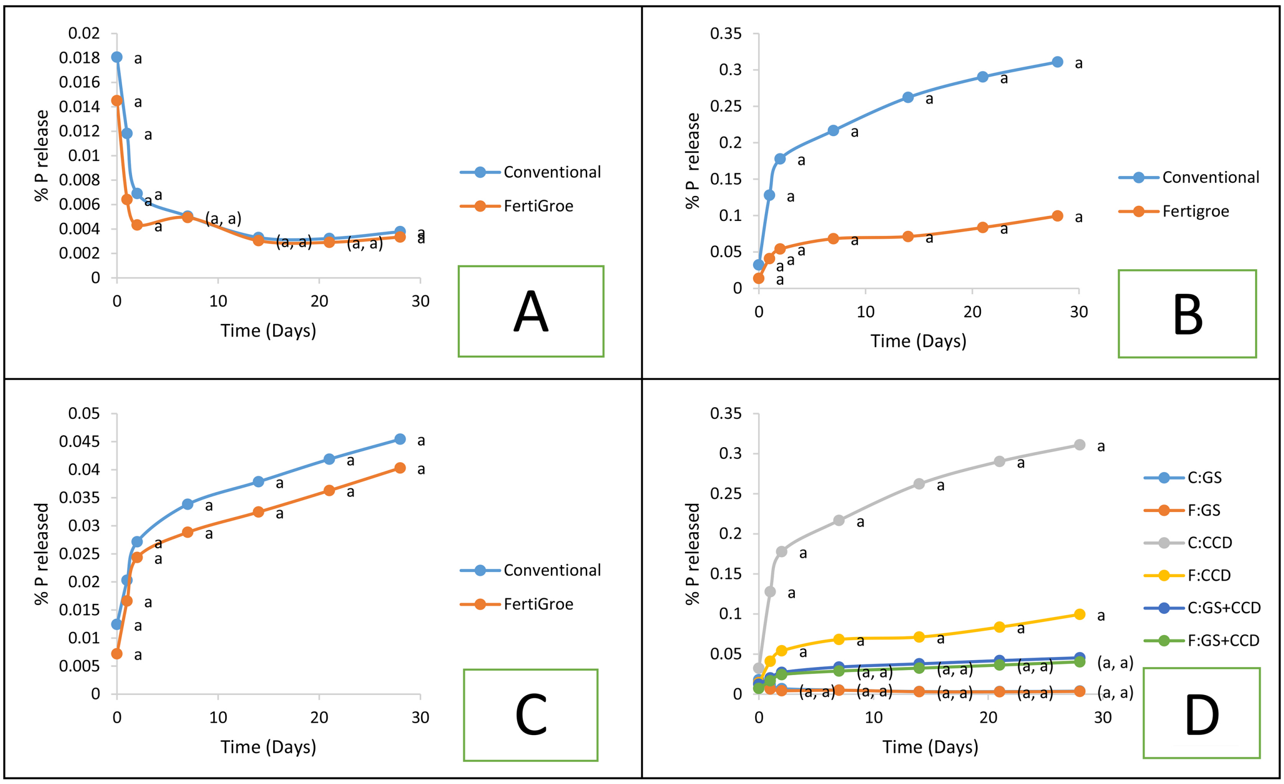

Figure 3. Percent P released from FertiGroe and conventional fertilizer in the leachates of GS, CCD and GS + CCD. Means with the same letter between treatments in each period are not significantly different.

3.4. Percent K Released from FertiGroe and Conventional Fertilizer

Garden soil: Figure 4(A) shows the nutrient release pattern of FertiGroe and conventional fertilizers in garden soil media. K released from FertiGroe was 0.04% while conventional fertilizer released 0.03% at day zero. The release rate of K increased rapidly in both types of fertilizer until 48 hours and continued steadily until 28 days. A higher rate of release was noted in conventional than nanofertilizer. At 28 days, K release was 0.19% for conventional fertilizer and 0.14% for FertiGroe (Figure 4(A)).

Coconut coir dust: The release pattern of K in FertiGroe and conventional fertilizer in CCD media is shown in Figure 4(B). The release of K in conventional fertilizer was 0.05% compared to the release of K in FertiGroe (0.08%) at day zero. However, at day 1, this trend changed with FertiGroe releasing much slower percentage of K compared to the conventional fertilizer. The release pattern of both types of fertilizer steadily increased until the 28 days. At 28 days, FertiGroe released 0.51% K compared to conventional fertilizer which released 0.50%. These release rates were not statistically significant.

Garden soil + coconut coir dust: The release pattern of K in GS + CCD is shown in Figure 4(C). The release of K from FertiGroe was much lower at day 0 and 1 compared to conventional fertilizer. However, the trends changed at day 2 with conventional fertilizer releasing at a higher rate (0.19%) compared to FertiGroe (0.16%). This percent release rate of K was maintained in conventional fertilizer until after 14 days when the trend changed, with FertiGroe releasing K at a rate of 0.44% compared to 0.42% of conventional fertilizer at day 28.

Fertilizer type and growth media interaction: The release pattern of K in all growth media used is shown in Figure 4(D). A generally increasing trend more rapid from until 48 hours and continued steadily until 28 days. A higher rate of release was noted until 28 days from conventional fertilizer in CCD, followed by conventional fertilizer in CCD + GS, and closely by FertiGroe in CCD and FertiGroe in CCD + GS. The least release was noted in FertiGroe in GS and conventional fertilizer in GS. At 28 days, FertiGroe in CCD released 0.51% K at 28 days followed in decreasing order by conventional fertilizer in CCD (0.50%), FertiGroe in GS + CCD (0.44%), conventional fertilizer in CCD + GS (0.42%), conventional fertilizer in GS (0.19%) and FertiGroe in GS (0.14%). Irrespective of growth media K release from FertiGroe was comparable to conventional fertilizer.

The type of growing media, soil moisture, temperature, and soil pH are factors that can influence the nutrient release pattern of fertilizers. The release rate of FertiGroe N in garden soil was higher compared to the release rate of conventional fertilizer beginning the 14^{th} to the 28^{th} day of leachate collection. However, this trend was different with conventional N releasing a comparable rate in with FertiGroe in CCD media.

In the case of P, the general release rate in CCD media for both FertiGroe and conventional fertilizers was comparable. Also, the release rate of FertiGroe P (0.003%) and conventional P in GS media (0.004%) at 28 days were not statistically different ($p > 0.05$). Apart from this, the release rate of K in CCD, GS + CCD and GS media for both fertilizer treatments were comparable. The release rates of P, and K in the FertiGroe were not statistically different compared to conventional fertilizer in CCD and in GS media in the whole leaching experiment.

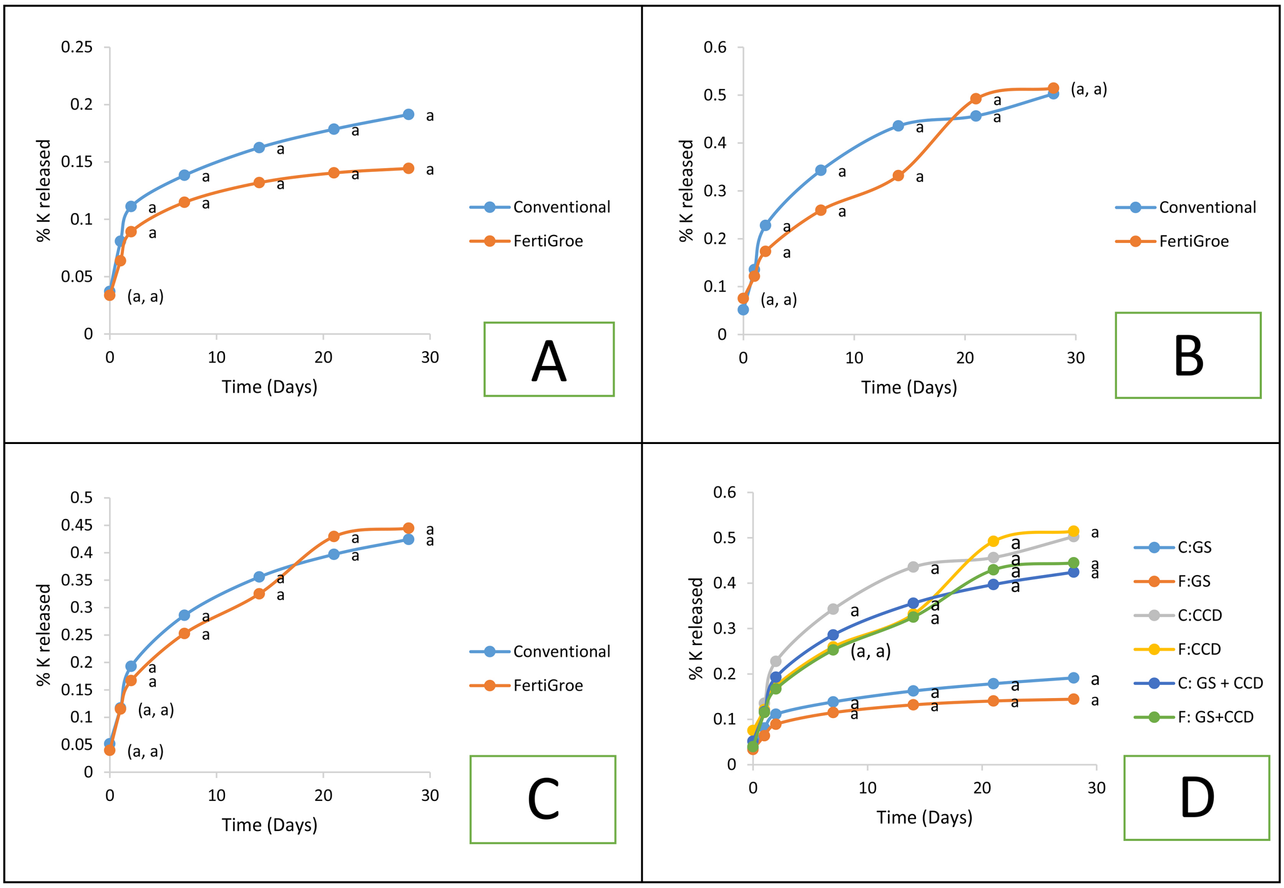

Figure 4. Percent K released from FertiGroe and conventional fertilizer in the leachates of GS, CCD and GS + CCD. Means with the same letter between treatments in each period are not significantly different.

3.5. Effect of Media and Fertilizer Type on Vegetative Characteristics of "Cavendish" Bananas

Number of functional leaves: Table 1 shows the average number of functional leaves of 8-week-old "Cavendish" banana plantlets. Plantlets grown in the mixture of GS + CCD significantly ($p < 0.05$) produced the highest average number of leaves (6.6) compared to those grown on GS (6.2) and CCD (5.5) over the period regardless of fertilizer type. Fertilizer type also played a role in the production of leaves of banana. However, both types of fertilizer were not significantly different in the number of leaves produced over the period.

Coconut coir dust has been recognized to have higher water holding capacity, which results in low aeration within the medium, and reduced diffuse oxygen for root growth [10]. This might have led to the lower number of leaves produced in the coconut coir duct media. The highest number of leaves was observed in GS + CCD. This could be a result of the fact that coconut coir dust, when mixed with garden soil improves moisture retention and increases the availability of nutrients, infiltration rate, total porosity, and hydraulic conductivity of the media, hence improving growth of the plant [11] [12]. The media and fertilization interaction did not show any significant difference in relation to the number of leaves produced.

Table 1. Number of functional leaves of "Cavendish" banana plantlets, as affected by media and fertilizer treatments, 8 weeks after transplanting.

Media Type	Fertilizer Type		Average
	Conventional	FertiGroe	
CCD	5.5	5.6	5.5[c]
GS	6.0	6.3	6.2[b]
GS + CCD	6.6	6.4	6.6[ab]
Average	6.1[a]	6.1[a]	

Means within column and row with the same letters are not significantly different at 5% LSD level.

Height of plantlets: Table 2 indicates the plant height of "Cavendish" bananas as influenced by media and fertilizer types. Over the period of eight (8) weeks, the media treatments significantly ($p < 0.05$) influenced the height of "Cavendish" banana plantlets. Among the potting media used, the mixture of GS + CCD showed the highest plant height of 16.7 cm compared to plantlets grown in GS and GS + CCD. As mentioned earlier, coconut coir dust can significantly improve the growth and development of plants when mixed with garden soils.

The effect of conventional fertilizer and FertiGroe on plant height was not significant as shown in Table 2. Apart from this, the interaction between the media and fertilizer was not significantly different at 5%.

Table 2. Plant height (cm) of "Cavendish" banana plantlets, as affected by media and fertilizer treatments, 8 weeks after transplanting.

Media Type	Fertilizer Type		Average
	Conventional	FertiGroe	
CCD	10.6	8.9	9.7[c]
GS	12.3	13.1	12.7[b]
GS + CCD	17.2	16.8	16.9[a]
Average	13.3[a]	12.9[a]	

Means within column and row with the same letters are not significantly different at 5% LSD level.

Root length: Table 3 shows the average root length of 'Cavendish' banana plantlets as affected by media and fertilizer treatments, 8 weeks after transplanting, the root length of plantlets grown in CCD media was similar to those grown in GS and GS + CCD media at 5% significance level. The average root length of "Cavendish" banana plantlets fertilized with conventional fertilizer was longer at 19.8 cm compared to FertiGroe, which had an average of 17.7 cm. The effect of

FertiGroe and conventional fertilizer irrespective of the media type was statistically different. However, root length over the period as affected by growth media x fertilizer interaction was not significantly different.

Table 3. Root length (cm) of "Cavendish" banana blantlets, as affected by media and fertilizer treatments, 8 weeks after transplanting.

Media	Type of fertilizer		Average
	Conventional	FertiGroe	
CCD	22.7	17.0	19.9[a]
GS	17.7	18.1	17.9[a]
GS + CCD	18.9	17.8	18.4[a]
Average	19.8[a]	17.7[b]	

Means within column and row with the same letters are not significantly different at 5% LSD level.

Pseudostem diameter: Table 4 shows the summary of the pseudostem diameter of "Cavendish" banana plantlets as affected by media and fertilizer treatments 8 weeks after transplanting. The highest pseudostem diameter was recorded in plantlets grown in GS + CCD media compared to plantlets grown in CCD. However, the average pseudostem diameter of plantlets grown in GS and GS + CCD were not statistically different at 5% significant level.

The effect of FertiGroe and conventional fertilizer on root length was not significantly different. The interaction between the media and fertilizer did not also show significant difference.

Table 4. Pseudostem diameter (mm) of "Cavendish" banana plantlets, as affected by media and fertilizer treatments, 8 weeks after transplanting.

Media	Fertilizer Type		Average
	Conventional	FertiGroe	
CCD	0.8	0.8	0.8[c]
GS	1.0	1.1	1.0[b]
GS + CCD	1.0	1.3	1.2[ab]
Average	1.0[a]	1.1[a]	

Means within column and row with the same letters are not significantly different at 5% LSD level.

Shoot Dry matter: Growth media also played a role in the production of dry matter, Table 5 shows that the shoot dry weight of plantlets grown in GS, GS + CCD and CCD media types were not statistically different at 5% significant level.

The average dry matter accumulation in "Cavendish" banana plantlets fertilized with FertiGroe produced a similar shoot dry matter compared to conventional fertilizer irrespective of the media type. The media and fertilizer interactions were not statistically different in dry matter production.

Table 5. Dry matter (g) of "Cavendish" banana plantlets, as affected by media and fertilizer treatments, 8 weeks after transplanting.

Media Type	Fertilizer Type		Average
	Conventional	FertiGroe	
CCD	1.4	1.8	1.6[a]
GS	2.9	3.3	3.1[a]
GS + CCD	2.0	4.2	3.1[a]
AVERAGE	2.1[a]	3.1[a]	

Means within column and row with the same letters are not significantly different at 5% LSD level.

Bananas are fast-growing plants and require large amounts of macro nutrients such as N, P and K for its growth and development [13]. The application of FertiGroe and conventional N, P and K on "Cavendish" banana plantlets in different growth media had an interrelated relationship in shoot and root growth characteristics. Release patterns could have a carryover effect on shoot and root growth. The release rate of P and K in FertiGroe was not different from that of conventional fertilizer. However, FertiGroe nanofertilizer had a higher N release pattern compared to the conventional nitrogen in garden soil. The amount of N (%) released during the early stages of plant growth triggered the growth of the banana plantlets a few weeks after fertilizer application.

The lowest shoot growth parameters and the longest root length were observed in plantlets growing in CCD media. Although the functions of roots are to absorb nutrients and water from the media and transport them to the shoots [14], the absorption of the nutrients in CCD was poor, leading to poor shoot growth. The longest roots in CCD is a response mechanism of the plant to its limited amount of nutrients. Even this root response failed to reverse the poor shoot growth performance of the plant.

The current study observed that CCD is general poor in fertility. It is highly lignified and thus could not be decomposed easily. Moreover, it has a higher water holding capacity, which results in low aeration within the medium, affecting the diffuse oxygen level for root growth as reported by [10].

The highest shoot growth parameters (plant height, number of leaves, pseudostem diameter and shoot dry matter) were observed in plantlets grown in GS + CCD media which affirms the tissue culture nurseries use of it as potting medium for banana plantlets. The addition of garden soil produces a medium that is fertile, and well aerated and suitable for banana.

4. Conclusions

This study examined the nutrient release patterns of nanofertilizer in different growth media and their effect on growth performance. The release patterns of FertiGroe N and conventional N were not significantly different in CCD and GS + CCD media. However, the release pattern of N (%) in GS media was significantly different starting day 14 to 28 days period of leachate collection.

The release patterns of FertiGroe and conventional P (%) and K (%) were comparable in all media types used in the whole leachate collection period. The amounts of N, P and K released during the early stages of plant growth triggered a faster rate of growth a few weeks after fertilizer application. The least shoot growth parameters were observed in plantlets growing in CCD media. However, the longest root was observed in plantlets growing in CCD. The effect of media was significant ($p < 0.05$), with high shoot growth performance observed in GS and the lowest growth observed in CCD media. The effect of FertiGroe and conventional fertilizer on shoot growth characteristics was not significant.

Recommendation

The study acknowledges a limitation that all comparisons are relative between the two fertilizer types rather than the absolute effects of fertilization. Future studies should include unfertilized control treatments to establish baseline nutrient release patterns and growth performance in each growth medium.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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