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Research article

Exploring the Influence of Growing Media and FertiGroe Nanofertilizer on Root Development in Cavendish Banana Plants (*Musa acuminata* Colla (AAA) 'Cavendish')

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Abstract
This study investigated the impact of different growing media (soil, coconut coir dust, and a soil-coir dust mixture) and nanofertilizer application on root growth and nutrient uptake in Cavendish bananas (*Musa acuminata* AAA Cavendish). The research was conducted at the University of the Philippines in Los Baños, Philippines, using tissue-cultured banana plantlets. The plantlets were grown in various conditions and treated with either nanofertilizer (FertiGroe) or conventional fertilizer. The results showed that soil-grown plantlets had superior root growth, with a 28.9% increase in root number and a 54.3% increase in root length compared to coconut coir dust (CCD). However, CCD produced finer roots, with an 87.3% higher specific root length. Nanofertilizer did not significantly affect root parameters compared to conventional fertilizer. The optimal combination of soil and nanofertilizer resulted in roots that were 97.4% longer and 79% larger in diameter compared to CCD with conventional fertilizer. This study provides valuable insights into optimizing growing media and fertilizer techniques to enhance root development and nutrient acquisition in Cavendish banana cultivation.
Key words: Cavendish banana, Root development, Nanofertilizer, Growing media, Nutrient acquisition

Introduction

The worldwide significant fruit crop known as the Cavendish banana (*Musa acuminata* Colla AAA 'Cavendish') is grown in a variety of soil types and growth, and environments (Robinson and Saúco, 2010). The root system plays a crucial role in banana plant growth and yield, as it facilitates nutrient and water uptake (Draye et al., 2007). However, root development and function can be influenced by various factors, including the cultivation medium (Oliveira et al., 2005).

Traditionally, soil has been the primary medium for growing bananas, offering a complex matrix of organic matter, minerals, and microbes (Taulya, 2013). Nevertheless, soil quality can vary widely, leading to issues such as poor drainage, illnesses carried by the soil, and nutritional deficiencies (Rishirumuhirwa and Roose, 1998). Coconut coir dust, a byproduct of the coconut industry, has emerged as a promising alternative growing medium for banana plants. According to Kabir *et al.* (2013), It offers advantages like high water-holding capacity, good aeration, and relative resistance to pests and pathogens, making it a potential solution to overcome soil-related challenges Despite the widespread use of soil and coconut coir dust as growing media for banana cultivation, there is a lack of understanding about their impact on root development and nutrient uptake in Cavendish bananas. This knowledge gap is particularly significant in the context of emerging nanofertilizer technologies, which have the potential to enhance nutrient delivery and uptake. Further research is needed to explore how these growing media interact with nanofertilizers and affect the root system of Cavendish bananas, ultimately informing strategies to optimize nutrient uptake and plant growth (Raliya et al., 2018). Optimizing root development and nutrient acquisition is crucial for producing high-yielding and high-quality bananas (Nyombi, 2020).

This study aims to provide valuable insights for improving nutrient management strategies and boosting banana productivity by investigating the impact of different growing media and the potential benefits of nanofertilizers on root development and nutrient uptake Increased nutrient utilization efficiency, controlled release, and enhanced bioavailability are just a few potential benefits that nanofertilizers which contain nutrients in the form of nanoparticles may have over traditional fertilizers (DeRosa et al., 2010; Dimkpa and Bindraban, 2018). The distinct properties of nanofertilizers, such as their nanoparticle size and high surface-to-volume ratio, may enhance the interface between roots and nutrients, facilitating improved nutrient uptake and plant nutrition (Raliya et al., 2017; Rastogi et al., 2019). This research investigates the impact of nanofertilizer application and different growing media (soil and coconut coir dust) on the root growth and nutrient uptake of Cavendish bananas, with the goal of understanding how these factors influence plant development and nutrition.

Methodology

Experimental area.

The study was carried out at the University of the Philippines Los Baños (UPLB), specifically in the Fruits Crops Nursery and the Crops Physiology Greenhouse, Institute of Crop Science (ICrops), College of Agriculture and Food Science. Located at 140 10' N latitude and 120 15' E longitude, UPLB has a tropical climate with an average elevation of 40 meters above sea level, an average annual temperature of 27°C, and an average annual rainfall of 2200 mm. The Fruits Crops Nursery serves as a hub for asexually propagated plants, offering various fruit crop seedlings for research and public sale. The nursery also maintains a collection of mature fruit crops for use as nurse plants and scion sources. Adjacent to the nursery, the Crops Physiology Greenhouse conducts research on herbs and selected plantation crops under controlled conditions.

Experimental plants

Meriplants of 'Cavendish' banana was propagated from the Tissue Culture Laboratory of the Lapanday Food Corporation located in Barangay Callawa, Davao City. The meriplants were propagated from explants of Fusarium Wilt-resistant strains of 'Cavendish' banana. The plants were about 3-cm long with two undeveloped leaves.

Preparation and transplanting of 'Cavendish' banana meriplants

'Cavendish' banana meriplants were planted immediately in individual polybags 10.16 cm x 10.16 cm x 17.78 cm filled with sterilized garden soil (GS), coconut coir dust (CCD) and a mixture of garden soil and coconut coir dust (GS+ CDD 1:1 v/v). The newly planted meriplants were acclimatized by covering them with transparent plastic cups for a period of four weeks to maintain a relative humidity that would favor the immediate recovery of the plantlets. The cover is loose enough to allow gas exchange between the internal and external environment. After four weeks, the plastic cap cover was removed and the first fertilizer rate was applied. The experiment was maintained inside a screen house for 8weeks.

Fertilizer Application Regime

Two types of fertilizer were used, namely: conventional fertilizer and nanofertilizer available as FertiGroe. Table 1 shows the quantity of fertilizer applied at 4 to 8 weeks after transplanting. The amount applied was based on the fertilizer rates used in commercial farms in Mindanao which use 5 g of complete fertilizer and 5 g of urea per seedling. An equivalent amount was used for FertiGroe NPK (28-8-41nanofertilizer.

Table 1. Weekly Fertilizer Application Rates for Cavendish Banana Experiment

Week	Conventional fertilizer (g/plant)		FertiGroe (g/plant)		
	Complete 14:14:14	Urea	Nano N (28%)	Nano P (8%)	Nano K (41%)
Initial	2	0.0	1	3.5	0.68
1	0.0	2.3	3.8	0.0	0.0
2	5	0.0	2.5	8.75	1.71
3	0.0	5	8.2	0.0	0.0
4	0.0	2.3	3.8	0.0	0.0
5	5	0.0	2.5	8.75	1.71
6	0.0	5	8.2	0.0	0.0
7	0.0	2.3	3.8	0.0	0.0
8	0.0	2.3	3.8	0.0	0.0

Fertilizer was side dressed at about 2 cm from the base of the plant. For FertiGroe, the individual N, P, and K fertilizers were mixed thoroughly before application. Fertilizers were covered with soil and then irrigated. Irrigation was performed weekly up to field capacity until the termination of the experiment or 12 weeks after planting.

Experimental Design

The experiment was laid out in split-plot in Randomized Complete Block Design with growth media as the main plot and type of fertilizer as the sub-plot. Each treatment was replicated four times with 15 meriplants per replicate per treatment.

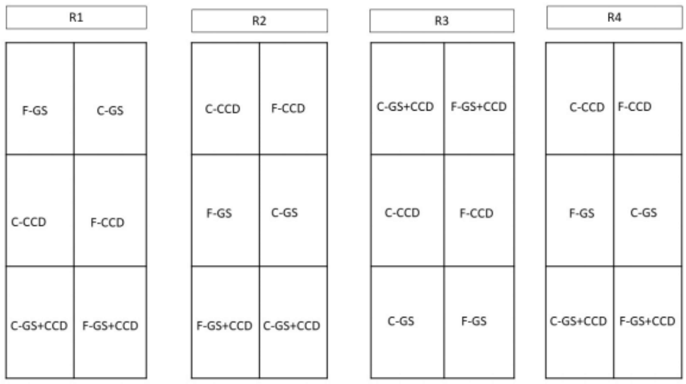

Figure 1: Experimental layout: GS-Garden soil only: CCD- Coconut coir dust only: GS +CCD - Coconut coir dust + garden soil 1:1 v/v; F- fertigroe fertilizer: C- Conventional Fertilizer

Data Collection

Root growth data, including root fresh weight (g), root dry weight (g), number of adventitious roots, longest root length (cm), and root diameter (mm), were collected every two weeks for a period of 8 weeks using two plants per treatment per replicate, with root diameter measured using a Vernier Caliper, and Specific Root Length (SRL) calculated using Fitter's (1996) formula

$$\text{Specific root length(SRL)}\,\frac{cm}{g} = \frac{\text{Root length (cm)}}{\text{Dry mass of fine roots } (g)}$$

Results and Discussion

The root system plays a crucial role in water and nutrient uptake from the soil. The experiment showed that plantlets grown in GS medium produced the highest average number of roots (13.4), while those grown in CCD medium produced the lowest (10.4). However, the average number of roots in GS+CCD medium was comparable to both GS and CCD. Additionally, the longest root length was observed in GS medium (28.7 cm), while the shortest was in CCD medium (18.6 cm). Root diameter was similar across all media types.

Root growth is significantly influenced by environmental conditions in the root zone (Nagel *et al*., 2009). The lower number of roots developed in CCD medium may be attributed to its poor fertility and high water-holding capacity (Bilderback *et al*., 2005), which limits aeration.

Specific Root Length (SRL) is the ratio of root length to fine root dry mass (Fitter, 1991). A higher SRL indicates more root length for a given dry mass, typically resulting in finer roots with higher rates of nutrient and water uptake (Fitter, 2001). Table 2 shows that CCD medium had the highest SRL (1.48 m/g), followed by GS+CCD medium (1.18 m/g), and GS medium had the lowest (0.79 m/g). The high SRL in CCD and GS+CCD media may be a response mechanism to poor fertility, encouraging plants to explore more nutrients in nutrient-limiting media.

Fine roots exert less penetrative force on media and transport less water, whereas roots with low tissue density have lower longevity but greater rates of uptake under high nutrient conditions (Fitter, 2001). The high SRL in CCD medium indicates poor fertility, resulting in fewer leaves, shorter root length, smaller root diameter, and smaller root-shoot ratios compared to GS and GS+CCD media (Table 2).

The root-shoot ratio (RSR) is the ratio of supportive tissues to growth tissues. Plants with a higher proportion of roots can compete more effectively for nutrients, while those with a higher proportion of shoots can collect more light energy (Chapin, 1980). The experiment showed that media types had a comparable effect on RSR, regardless of fertilizer application.

Table 2. Average root growth parameters of Cavendish Banana Plantlets 12 weeks after transplanting

Growth Parameters	Media Type		
	CCD	GS	GS + CCD
Number of roots	10.4^{b}	13.4^{a}	11.8^{ab}
Root length (cm)	18.6^{b}	28.7^{a}	25.9^{ab}
Root diameter (mm)	3.4^{a}	4.3^{a}	4.2^{a}
Root dry weight (g)	0.2^{b}	0.5^{a}	0.3^{ab}
Root-Shoot ratio	0.17^{a}	0.19^{a}	0.15^{a}
Specific root length (m^{-g})	1.48 ^{a}	0.79^{c}	1.18^{b}

Means within a row with the same letters (a, b, c) are not significantly different at 5% level of significance

The results of the study show that the FertiGroe and conventional fertilizer treatment had no significant effect on all 'Cavendish' banana root growth parameters irrespective of the media type used at 5% level of significance (Table 3). Roots are important because they absorb the water and nutrients up out of the growing media and into the plant. No significant difference was found in specific root length (SRL) between 'Cavendish' banana plantlets fertilized with conventional fertilizer (1.20 m/g) and FertiGroe (1.03 m/g) (Table 3). The root-shoot ratio of 'Cavendish banana plantlets was unaffected by fertilizer type, as evidenced by similar values between plantlets treated with FertiGroe and those receiving conventional fertilizer (Table 3). This suggests that both fertilizers have an equivalent impact on the allocation of resources between root and shoot growth.

Table 3. Root Growth Response of Cavendish Banana Plantlets to fertilizer Treatments, evaluated 12 weeks following Transplanting

Growth Parameter	Fertilizer Type	
	Conventional	FertiGroe
Number roots	11.3^{a}	12.5^{a}
Root length (cm)	24.6^{a}	24.4^{a}
Root diameter (mm)	3.8^{a}	4.0^{a}
Root –shoot ratio	0.2^{a}	0.2^{a}
Specific root length (m/g)	1.26^{a}	1.02^{a}
Root dry weight	0.3^{a}	0.4^{a}

Means within a row with the same letters (a, b, c) are not significantly different at 5% level of significance

Table 4: The effects of Fertilizer and Media Interactions on Root Growth Characteristics of Cavendish Banana Plantlets

Treatments	No. of roots	Root length (cm)	Root diameter (mm)	Root dry weigh (g)	Specific root length (m^{-g})	Root - shoot-ratio
CxCCD	7.65^{ab}	12.71^{b}	2.06^{ab}	0.11^{bc}	2.68^{a}	0.11^{c}
CxGS	8.84^{ab}	17.74^{ab}	2.44^{ab}	0.24^{b}	1.43^{ab}	0.16^{ab}
CxGS+CCD	7.43^{b}	15.27^{ab}	1.93^{ab}	0.12^{bc}	2.38^{ab}	0.12^{bc}
FxCCD	7.56^{ab}	11.09^{b}	1.62^{b}	0.06^{bc}	2.51^{ab}	0.19^{a}
FxGS	9.94^{ab}	21.89^{a}	2.90^{a}	0.39^{a}	1.35^{b}	0.18^{a}
FxGS+CCD	10.00^{a}	17.37^{ab}	2.70^{ab}	0.22^{b}	1.45^{ab}	0.15^{abc}

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

The effect of fertilizer and media interactions on root growth characteristics of 'Cavendish' banana plantlets are shown in Table 4. The FxGS+CCD interaction yielded the highest number of roots, significantly surpassing CxGS+CCD. However, no significant differences were observed among FxGS, FxCCD, CxGS, and CxCCD at the 5% level. The F x GS interaction produced the longest roots, outperforming FxCCD and CxCCD. All other interactions showed no significant differences in root length at the 5% level (Table 4). Interaction (F x GS) resulted in the largest root diameter, significantly differing from F x CCD. No significant differences were found among other treatment combinations at the 5% level (Table 4).

F x GS interaction achieved the highest root dry weight, surpassing F x CCD, C x GS+CCD, C x GS, C x CCD, and F x GS+CCD (Table 4). These findings highlight the importance of root morphology in nutrient uptake, aligning with previous research (Rostelato *et al*., 2020).

The highest specific root length (SRL) was observed in plantlets grown in C x CCD interactions compared to plantlets grown in F x GS. However, the SRL of plants grown in F x CCD, F x GS, F x GS+CCD, C x GS+CCD and C x GS were not significantly different ($p<0.05$). The results also support the use of organic amendments like coconut coir dust to increase SRL (Delgado *et al*., 2021; Pal *et al*., 2015). Though high porosity and low bulk density in organic media may promote the growth of finer lateral roots.

The fertilizer media interactions of the root-shoot ratio were high in plantlets grown in F x CCD compared to plantlets grown in C x GS+CCD and C x CCD. However, there was no significant differences between the root-shoot ratios of plantlets grown in F x GS, F x GS+CCD and C x GS at 5% significant level. Additionally, the root-shoot ratio is related to drought tolerance, indicating better soil moisture access (Niu *et al*., 2017).

Conclusion

This study investigated the impact of alternative growing conditions and nanofertilizer application on the root development and nutrient uptake in Cavendish bananas. The results revealed that growing medium significantly influenced root growth parameters, with soil-grown plantlets exhibiting superior root growth metrics compared to those cultivated in coconut coir dust. The soil-coir dust mixture showed moderate performance, suggesting its potential as a substitute growing medium. Nanofertilizer (FertiGroe) application did not distinctly impact root growth indices. However, the combination of fertilizer type and growing media significantly affected root properties. The optimal combination of soil and nanofertilizer produced plantlets with the greatest root length, diameter, and dry weight. These findings highlight the importance of selecting the appropriate growing medium to maximize root growth and nutrient uptake in Cavendish banana cultivation. While soil remains the superior medium, a soil-coir dust blend may offer advantages like enhanced water-holding capacity and reduced disease pressure. Additionally, nanofertilizers may improve root development and nutrient uptake when used in conjunction with the suitable growing medium, leveraging their unique properties of increased nutrient bioavailability and regulated release.

This study provides valuable insights for developing strategies to enhance nutrient management and root development in Cavendish banana production. Future research can explore the underlying mechanisms of the observed effects and evaluate the efficacy of nanofertilizers in practical applications.

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