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Optimization of Liquid Organic Fertilizer Based on Banana Pseudostems and Coconut Fiber with MA-11 Bioactivator for Enhancing Plant Growth

Ida Ayu Putu Suryanti[1*], I Made Pasek Anton Santiasa[1]

[1] Biology Study Program, Department of Biology and Marine Fishery, Faculty of Mathematics and Natural Sciences, Universitas Pendidikan Ganesha, Bali, Indonesia.

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Corresponding Author:
Ida Ayu Putu Suryanti
ayu.putu@undiksha.ac.id

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Abstract: The sustainable utilization of agricultural residues remains challenging because the combined application of banana pseudostem, coconut fiber, and the MA-11 bioactivator for liquid organic fertilizer production has not been systematically investigated. This research aims to analyze the formulation of liquid organic fertilizer from banana pseudostem and coconut fiber, using MA-11 as a bioactivator to enhance plant growth. First part of research focusing on analysing macronutrients, micronutrients, and the total bacterial count (CFU/mL). The best results were liquid organic fertilizer made from varying concentrations (5%, 10%, 15%, 20%, and 25%) as a treatment and a control (0%), each of which was added with 1 L of coconut water, 125 mL of molasses, and 125 mL of MA-11 to be tested on Marigold in the greenhouse. This research uses an experimental method with a Completely Randomized Design. Plant growth responses were assessed by measuring plant height, leaf number, and the dry biomass of roots, stems, and leaves. The research results showed that the combination 3 (K3) with 125 gr of banana stems and 375 gr of coconut fiber had macronutrients (N, P, and K) according to the standard (2-6%), which is 3.38%. The content of micronutrients Cl, Na, Zn, and B was according to standards. The best formulation in this research that can encourage plant growth is K3 with a concentration of 15%. These findings indicate that the success of liquid organic fertilizer is not only determined by the composition of the raw materials but also by the interaction between nutrient content, microorganism activity, and appropriate application concentration.

Keywords: Banana pseudostem; Coconut fiber; Liquid organic fertilizer; MA-11 bioactivator

Introduction

Excessive use of chemical fertilizers damages soil structure and reduces long-term fertility, thus encouraging the development of biofertilizers and microbial compost as environmentally friendly alternatives (Ahmed et al., 2023). Intensive use of chemical fertilizers can increase crop productivity in the short term, but in the long term, it can cause degradation of the physical, chemical, and biological properties of the soil, including a decrease in soil organic matter content and microbial activity. Several related studies have shown that soil organic matter content in intensive tropical agricultural land is often below 2%, far from the ideal level (> 3%) for maintaining soil fertility (Neuenkamp et al., 2024; Sharma et al., 2013). This situation emphasizes the importance of organic fertilizer-based innovations to sustainably improve soil quality.

Indonesia, as an agricultural country, generates substantial amounts of agricultural waste each year. Banana production exceeds 8 million tons annually, producing banana pseudostem waste that accounts for approximately 60–70% of the post-harvest biomass

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(Mohapatra et al., 2010.). Although this biomass is often discarded or left to decompose, banana pseudostems contain about 90% moisture and are rich in lignocellulosic, including cellulose (30–40%), hemicellulose (15–25%), and lignin (10–15%), making them a valuable source of organic matter and carbon for microbial fermentation (Fatmawati et al., 2026; Huang et al., 2024; Kiruba & Saeid, 2022).

Similarly, coconut fiber is an abundant agricultural by-product in Indonesia, where coconut production reaches approximately 17 million tons annually, and fiber constitutes around 35% of the fruit (Fitriyano et al., 2022). Rich in lignin (≈ 45%) and cellulose (≈43%), coconut fiber improves substrate porosity and water-holding capacity by up to six to eight times its dry weight (Abad et al., 2005). Rich in lignin (≈45%) and cellulose (≈43%), coconut fiber improves substrate porosity and water-holding capacity by up to six to eight times its dry weight (Rosalina et al., 2025). highlighting its potential as a complementary material for producing high-quality organic fertilizers.

Effective Microorganisms (EM)-based bioactivators accelerate the decomposition of organic wastes by introducing microorganisms that produce cellulase and ligninase, thereby enhancing nutrient mineralization and compost quality (Hastuti et al., 2021; Kiruba & Saeid, 2022; Ulhasanah et al., 2022). Effective Microorganisms (EM)-based bioactivators accelerate the decomposition of organic wastes by introducing microorganisms that produce cellulase and ligninase, thereby enhancing nutrient mineralization and compost quality (Chieb & Gachomo, 2023). One promising bioactivator is MA-11 (Microbacter Alfa-afa), which contains a consortium of decomposer and plant growth-promoting microorganisms.

Several studies have shown that the separate use of banana stem waste or coconut fiber can improve plant growth. A banana stem-based liquid organic fertilizer was reported to increase plant height and leaf number by more than 20% compared to the control (Riyandani et al., 2021). Likewise, banana pseudostem has been applied as compost to improve soil fertility and sweet corn yield, whereas coconut fiber has been widely used as a growing medium or organic fertilizer for crops such as bell pepper, forest seedlings, and shallots. However, these materials have generally been used separately rather than formulated together to optimize the physical properties and nutrient content of the growing medium (Chan et al., 2024; Singh et al., 2025; Tuckeldoe et al., 2023). Research on the combined use of banana pseudostem and coconut fiber for liquid organic fertilizer production remains scarce despite extensive studies on each material individually.

The application of microbial bioactivators, particularly those containing beneficial consortia such as *Bacillus* spp. and *Pseudomonas fluorescens*, has gained attention for their role in accelerating the decomposition of organic matter and promoting nutrient mineralization (Febria et al., 2023). However, bioactivators such as MA-11 (Microbacter Alfa-afa) applied to a banana stem-coconut fiber mixture have not been evaluated for decomposition dynamics, compost/media quality, or growth response. Most previous studies used general bioactivators such as EM4 and focused more on compost quality or soil chemical parameters, without an in-depth evaluation of their effects on plant growth directly.

Unlike previous studies, this research integrates banana pseudostem compost, coconut fiber, and the MA-11 bioactivator into a single organic fertilizer formulation and evaluates its effects on the growth of testing plants. This integrated approach provides new insights into the utilization of agricultural waste and microbial bioactivators for sustainable horticultural production.

Therefore, this study was conducted to analyze the formulation of banana pseudostem and coconut fiber formulas with the MA-11 bioactivator as an innovative organic fertilizer based on agricultural waste. By converting banana pseudostem and coconut fiber with MA-11 bioactivator into value-added liquid organic fertilizer, this study contributes to more sustainable agricultural waste management, with implications for SDGs 12 (Responsible Consumption and Production) through improved resource utilization and the promotion of circular bioeconomy practices.

Method

Formulating a Liquid Organic Fertilizer from Banana Pseudostems and Coconut Fiber with the MA-11 Bioactivator

Banana stems, coconut fiber, and coconut water were collected around Singaraja City in Buleleng Regency, Bali. The MA-11 (Microbacter Alfa-afa) bioactivator was collected from the Mini Laboratory of the Tampak Siring Agricultural Extension Center in Gianyar, Bali. This research was conducted for 6 months in the microbiology laboratory and greenhouse of the Faculty of Mathematics and Natural Sciences, Universitas Pendidikan Ganesha. Three combinations were used to determine the appropriate formula for further research:

- Combination 1 (K1): 250 gr of banana pseudostems and 250 gr of coconut fiber;
- Combination 2 (K2): 375 gr of banana pseudostems and 125 gr of coconut fiber;
- Combination 3 (K3): 125 gr of banana pseudostems and 375 gr of coconut fiber.

Each combination was placed in a sterile plastic jar and supplemented with 1 L of coconut water, 125 g of molasses, and 125 mL of MA-11. Stir until homogeneous every 2 days, then tightly seal the container and leave it at room temperature (28–30°C) for 14 days to ferment and analyze the N, P, K, and C content (Muniappan et al., 2023; Zakaria et al., 2023).

Total Bacterial Colonies of Liquid Organic Fertilizer Formulated from Banana Pseudostems and Coconut Fiber with MA-11 Bioactivator

The total microbial count was performed using the Total Plate Count (TPC) method using Nutrient Agar (NA) media with a dilution of 10^{-8}, repeated twice (duplicate). The Petri dishes were incubated for 2 x 24 hours, and the number of colonies counted was between 30 and 300 (CFU/mL) (Jossefa et al., 2026).

Measuring Nutrient Contents of the Liquid Organic Fertilizer Formulated from Banana Pseudostems and Coconut Fiber with the MA-11 Bioactivator

Nitrogen (total N) content was measured using the Kjeldahl method with a spectrophotometer. Phosphate (P_2O_5) was measured using the Dry Ashing-HNO_3 method with a spectrophotometer, potassium (K_2O) analysis using a flame photometer, and organic carbon using the Walkley and Black method (Nursuci et al., 2025). Additional nutrients, namely Mg, Ca, S, and the micronutrients Mo, Mn, Co, Cl, Cu, Zn, Na, Fe, and B, were measured using atomic absorption spectrophotometry in the Chemistry Laboratory, University of Muhammadiyah Malang.

Testing of Plant Growth in the Greenhouse

The study used marigold or *gemitir (Tagetes erecta* L.) seedlings of the Cassanova" variety as a test plant, which is widely found and used in Bali as a widely cultivated ornamental and medicinal plant valued for its vibrant flowers and phytochemical properties (Mann et al., 2023). Soil and rice husk charcoal as a sterile planting medium were put into 15 x 20 cm polybags with a ratio of 1:1 (400 gr per polybag) (Syawal et al., 2018). The results of liquid organic fertilizer formulation testing showed that combination 3 (125 grams of banana stems and 375 grams of coconut fiber) had the best results in terms of macronutrient content (N, P, K, and C); most of the micronutrients that met the standards were used as treatment. This study used a Completely Randomized Design (CRD) arranged in six fertilizer concentration treatments (v/v): 0% (control), 5%, 10%, 15%, 20%, and 25%, with 10 replications. Marigold seedlings, aged 2 weeks and measuring ±10 cm in height, were planted in polybags in a greenhouse with a temperature of 25–30°C. Treatments with varying concentrations were poured into each polybag with 25 mL on the 7^{th} and 14th day after planting in the polybag (Haryuni, et al., 2025).

Parameters Observation

In testing the liquid organic fertilizer formula using banana pseudostems and coconut fiber, the observed parameters included macronutrients, supplementary nutrients, micronutrients, and total bacterial colonies. After obtaining the appropriate formulation and varying concentration treatments, on the 50th day after planting, growth variables were measured: plant height (cm) from the soil surface to the base of the apical shoot; number of leaves (leaf); and dry weight of roots (gr), stems (gr), and leaves (gr) (Li et al., 2020; Undang et al., 2025).

Statistical Analysis

The data obtained from this study will be analyzed using a quantitative approach. The data will be presented systematically in tables and graphs. One-way ANOVA was conducted, along with Tukey's test for multiple treatment comparisons for plant growth data (Suryanti et al., 2024). The statistical analyses were executed using R and RStudio version 4.3.1. The significance level was set at $p < 0.05$. The results were visualized using boxplot visualizations through the "ggpubr" R package.

Result and Discussion

The results of the analysis of variations in the formulation of banana stems and coconut fiber in this study affect the macronutrient content in the liquid organic fertilizer produced. Table 1 shows that the total nitrogen (total N) content increased along with the increasing proportion of coconut fiber. The K3 formulation (125 gr banana pseudostems and 375 gr coconut fiber) produced the highest N-total value (0.54%) and has met the minimum liquid fertilization standard (≥ 0.5%) in accordance with the Decree of the Minister of Agriculture, Number 261/ KPTS/SR.310/M/4/2019 concerning the minimum technical requirements for organic fertilizers, biofertilizers, and soil improvement. In contrast, the K1 formulation (250 gr banana pseudostems and 250 gr coconut fiber) and K2 (375 gr banana pseudostems and 125 gr coconut fiber) treatments were still below the standard, indicating that the composition of the raw materials greatly determines the availability of nitrogen. The total NPK value in K3, which is within the standard range, indicates that this formulation has the potential to be an effective liquid organic fertilizer. Banana pseudostem is a moisture-rich lignocellulosic biomass containing soluble carbohydrates and exchangeable potassium (K^+), which are readily mobilized during microbial fermentation through the enzymatic degradation of cellulose, hemicellulose, and lignin. The released soluble sugars support microbial metabolism, while mineral nutrients become more bioavailable in the fermentation medium (Patil et al., 2024; Pillai et al., 2024). In contrast, coconut fiber contains higher proportions of lignin and cellulose and exhibits a high cation exchange capacity (CEC), enabling the gradual release and retention of potassium during decomposition (Abad et al., 2005; Izydorczyk et al., 2024). This finding aligns with previous research that found that utilizing banana stem and coconut fiber waste can increase nutrient availability in the soil (Riyandani et al., 2021).

Table 1. Macronutrient Content in the Formulation of Banana Pseudostems and Coconut Fiber with Bioactivator Ma-11 as Liquid Organic Fertilizer

Element	Ingredients in the Formulation (%)			Standard
	K1	K2	K3	
Total N (%)	0.11	0.25	0.54	Min 0.50 %
P (%)	0.48	0.58	0.66	-
K (%)	1.37	1.83	2.18	-
NPK w/v (%)	1.96	2.66	3.38	2.00 – 6.00 %
Organic C (%)	0.14	0.13	0.12	Min 4.50 %
C/N	12.81	6.91	2.32	10.00-12.00
pH	6.00	6.00	6.50	4.00 – 9.00

Notes: Comparison of banana pseudostems and coconut fiber (gr): K1= 250 gr banana stem + 250 gr coconut fiber; K2= 375 gr banana stems + 125 gr coconut fiber, and K3= 125 gr banana stems + 375 gr coconut fiber. To each treatment, 1 L of coconut water, 125 mL of molasses, and 125 mL of MA-11 were added.

A similar trend was also seen in phosphorus (P) and potassium (K), which showed a gradual increase from K1 to K3. The highest potassium content in K3 (2.18%) indicated a contribution from coconut fiber, which is known to be rich in potassium. Previous research stated that potassium in coconut fiber-based liquid fertilizer significantly affected growth and was present in plant tissue with the highest average of 2.55% (Rahma et al., 2019). The total NPK value showed a progressive increase from 1.96% (K1) to 3.38% (K3), where K2 and K3 met the standard range for liquid fertilizer in the Ministry of Agriculture (2.00–6.00%). However, the organic carbon content in all treatments was very low (0.12–0.14%), indicating that the decomposition process was very intensive, resulting in significant organic material degradation. The C/N ratio showed a drastic decreasing trend from K1 (12.81) to K3 (2.32), indicating a very high level of fertilizer maturity at K3, although too low a value could indicate nitrogen (N) loss through mineralization (Aloo et al., 2022). The pH values for all treatments were in the neutral range (6–6.5) and were appropriate with the liquid organic fertilizer standard, thus supporting microbial stability and nutrient availability (Table 1).

The content of additional macronutrients such as magnesium (Mg), calcium (Ca), and sulfur (S) was relatively stable across all treatments (Table 2). Mg and S contents showed constant values (0.02% and 0.01%, respectively), indicating that variations in raw material composition did not contribute to these two elements. Meanwhile, Ca content slightly increased in treatments K2 and K3 (0.05%) compared to K1 (0.04%), possibly influenced by the contribution of coconut fiber as a mineral source. The relatively stable concentrations of Mg, Ca, and S across all treatments indicate that varying the proportions of banana pseudostem and coconut fiber had little effect on the total availability of these nutrients. The microbial activity of MA-11 primarily promotes the mineralization of organic compounds, converting nutrients into more plant-available forms during fermentation. Consequently, fermentation is more likely to influence nutrient availability than the absolute concentrations of Mg, Ca, and S, resulting in similar values among treatments. Similar observations have been reported in studies showing that microbial fermentation enhances nutrient solubility without significantly changing the total concentration of mineral elements (Backer et al., 2018; Izydorczyk et al., 2024). The presence of Mg, Ca, and S remains important in supporting plant physiological functions, such as chlorophyll formation (Mg), cell wall strengthening (Ca), and protein synthesis (S) (Sarraf et al., 2026; Shah et al., 2022).

Table 2. Additional Macronutrient Content in the Combination of Banana Pseudostems and Coconut Fiber with Bioactivator MA-11 as Liquid Organic Fertilizer

Element	Ingredients in The Formulation (%)		
	K1	K2	K3
Mg	0.02	0.02	0.02
Ca	0.04	0.05	0.05
S	0.01	0.01	0.01

Notes: Comparison of banana pseudostems and coconut fiber: K1= 250 gr banana stem + 250 gr coconut fiber; K2= 375 gr banana stems + 125 gr coconut fiber, and K3= 125 gr banana stem + 375 gr coconut fiber. To each treatment, 1 L of coconut water, 125 mL of molasses, and 125 mL of MA-11 were added.

The data in Table 3 show that micronutrient content consistently increased from K1 to K3 across almost all parameters. Elements such as Zn, Cu, B, and Mn showed a significant upward trend, with Zn reaching its highest value in K3 (45.69 ppm), which met the POC standard (25–500 ppm). Similarly, boron (B) increased from 14.13 ppm to 20.70 ppm, well within the optimal range. However, several micronutrients, such as Mo, Mn, Cu, and Fe, remained below the liquid organic fertilizer standard. The present formulation was developed exclusively from banana pseudostem and coconut fiber. Consequently, the concentrations of several micronutrients remained below the recommended standards. Micronutrients play an important role in plant physiological processes, including enzyme and growth hormone synthesis, thus contributing to increased plant growth (Jayakumar et al., 2024). Future studies should investigate the incorporation of micronutrient-rich organic materials or compatible mineral supplements to improve the nutritional balance of the fertilizer.

Table 3. Micronutrient Content in the Combination of Banana Stems and Coconut Fiber with Bioactivator MA-11 as Liquid Organic Fertilizer

Micro Element	Ingredients in the Formulation (ppm)			Standard
	K1	K2	K3	
Mo	0.45	0.50	0.53	2.00-10.00
Mn	0.54	0.57	0.59	25.00-500.00
Co	0.36	0.38	0.40	-
Cl	0.63	0.70	0.76	Max 2000
Cu	14.69	15.86	17.71	25.00-500.00
Zn	36.29	40.45	45.69	25.00-500.00
Na	7.69	8.91	9.61	Max 2000
Fe	0.43	0.49	0.51	90.00-900.00
B	14.13	18.07	20.70	12.00-250.00

Notes: Comparison of banana pseudostems and coconut fiber: K1= 250 gr banana stem + 250 gr coconut fiber; K2= 375 gr banana stems + 125 gr coconut fiber, and K3= 125 gr banana stem + 375 gr coconut fiber. To each treatment, 1 L of coconut water, 125 mL of molasses, and 125 mL of MA-11 were added.

The results in Table 4 show differences in the total bacterial count between treatments. The K3 treatment produced the highest bacterial count at 8.20×10^7 CFU/ml, and the K2 treatment had the lowest (0.03×10^7 CFU/ml). The high bacterial count in the K3 treatment indicates that the higher proportion of coconut fiber creates a more optimal environment for microbial growth, especially with the addition of the MA-11 bioactivator. Conversely, the low bacterial count in the K2 treatment indicates that the unbalanced composition inhibits microbial activity. This is likely related to substrate availability and environmental conditions that are less conducive to bacterial proliferation.

Overall, these results indicate that the K3 formulation is the most optimal combination for supporting microbial activity, particularly bacteria, which play a crucial role in the decomposition of organic matter and improving fertilizer quality. A high bacterial population also has the potential to increase the effectiveness of organic fertilizer in supporting plant growth through biological mechanisms such as nitrogen fixation and phosphate solubilization (Zhao et al., 2024). So there is a positive relationship between increased microbial activity and the availability of nutrients, both macro and micro.

Table 4. Total Number of Bacteria in the Combination of Banana Pseudostem and Coconut Fiber with MA-11 Bioactivator

Formulation	Total Colony Number of Bacteria (CFU/mL)	Standard
K1	0.69×10^7	10^7
K2	0.03×10^7	10^7
K3	8.20×10^7	10^7

The K3-formulated liquid organic fertilizer is a mixture containing the best macronutrients, micronutrients, and total bacterial count (CFU/mL), allowing for application to plants at varying concentrations. Figure 1 shows that applying liquid fertilizer based on the K3 formulation at varying concentrations significantly impacted plant height compared to the control. Generally, there was a trend of increasing plant height as the liquid fertilizer concentration increased from 5% to an optimum point at a specific concentration (generally 15% or 20%), before declining or stagnating at the highest concentration (25%). The highest average merygold height was found at the 15% concentration, at 51.6 ± 11.3 cm, and the lowest at the 5% concentration and the control, at 43.0 ± 5.31 cm and 28.2 ± 2.21 cm, respectively. Treatments at 15% and 20% concentrations showed significant differences compared to the control and low concentrations, indicating that nutrient availability and microbial activity were at optimal levels to support vegetative growth. This increase in plant height aligns with previous results in Tables 1 and 4, where the K3 formulation had a high macronutrient content and significant bacterial count. During the fermentation process, cellulolytic and ligninolytic microorganisms in the MA-11 bioactivator degrade cellulose, hemicellulose, and lignin into simpler organic compounds, accelerating the mineralization of organic matter and the release of essential nutrients, particularly exchangeable potassium (K^+), phosphorus (P), and nitrogen (N) into the liquid fertilizer (Izydorczyk et al., 2024; Pillai et al., 2024; Rahma et al., 2019). In addition to enhancing nutrient availability, the microbial consortium in MA-11 is expected to function as plant growth-promoting microorganisms by producing phytohormones such as indole-3-acetic acid (IAA), solubilizing phosphate, and improving nitrogen availability. These biological activities stimulate root elongation, lateral root formation, and nutrient uptake, thereby enhancing plant growth and the agronomic effectiveness of the resulting liquid organic fertilizer (Backer et al., 2018; Chieb & Gachomo, 2023).

For plant height, concentrations of 10% and 20% showed significantly different results compared to the other treatments. A similar pattern was also seen for leaf number, where the optimal concentration produced the highest average leaf number at 15% (24.4 ± 6.4 leaves) (Figure 2). This indicates that at this concentration, nutrient availability and microbial activity are optimal to support vegetative growth. Available nitrogen plays a role in plant tissue formation, while microorganisms in the bioactivator contribute to the production of phytohormones such as auxins, which stimulate plant growth (Spaepen et al., 2007).

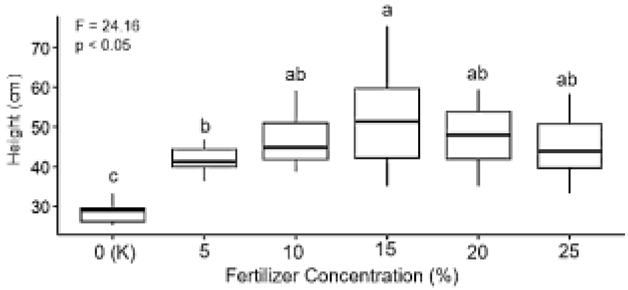

Figure 1. Variation of fertilizer concentration based on banana pseudostems and coconut fiber with bioactivator MA-11 on the average of plant height. All treatments based on formulation K3. Different letters signify substantial differences in the average values of plant height, with a statistical significance level of P<0.05, as determined by ANOVA and Tukey's test. The bars represent the standard deviations

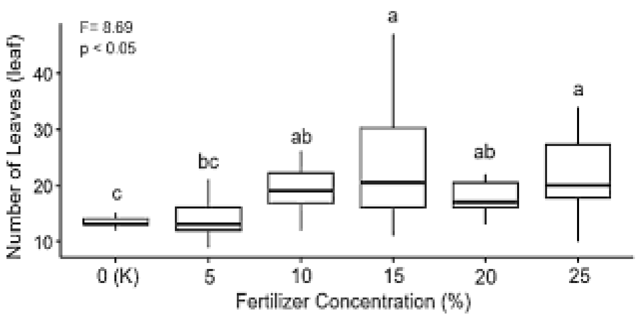

Figure 2. Variation of fertilizer concentration based on banana pseudostems and coconut fiber with bioactivator MA-11 on the number of leaves. All treatments based on formulation K3. Different letters signify substantial differences in the average values of leaves, with a statistical significance level of P<0.05, as determined by ANOVA and Tukey's test. The bars represent the standard deviations

Figure 2 shows a relatively similar pattern to plant height, where leaf number increased significantly in treatments with certain liquid fertilizer concentrations compared to the control, with p < 0.05. K3 concentrations of 10–20% showed a significantly higher leaf number, while low concentrations (5%) did not produce a maximum effect, and high concentrations (25%) tended to show a decrease or no significant difference. This trend indicates that the increase in leaf number is closely related to the availability of nitrogen and microelements such as Zn and B (Table 3), which play a role in cell division and new tissue formation. Furthermore, the high microbial activity in the K3 formulation (Table 4) has the potential to produce phytohormones such as auxins and cytokinins, which stimulate leaf growth. However, at high concentrations, there is a possibility of accumulation of certain compounds that actually inhibit optimal leaf formation.

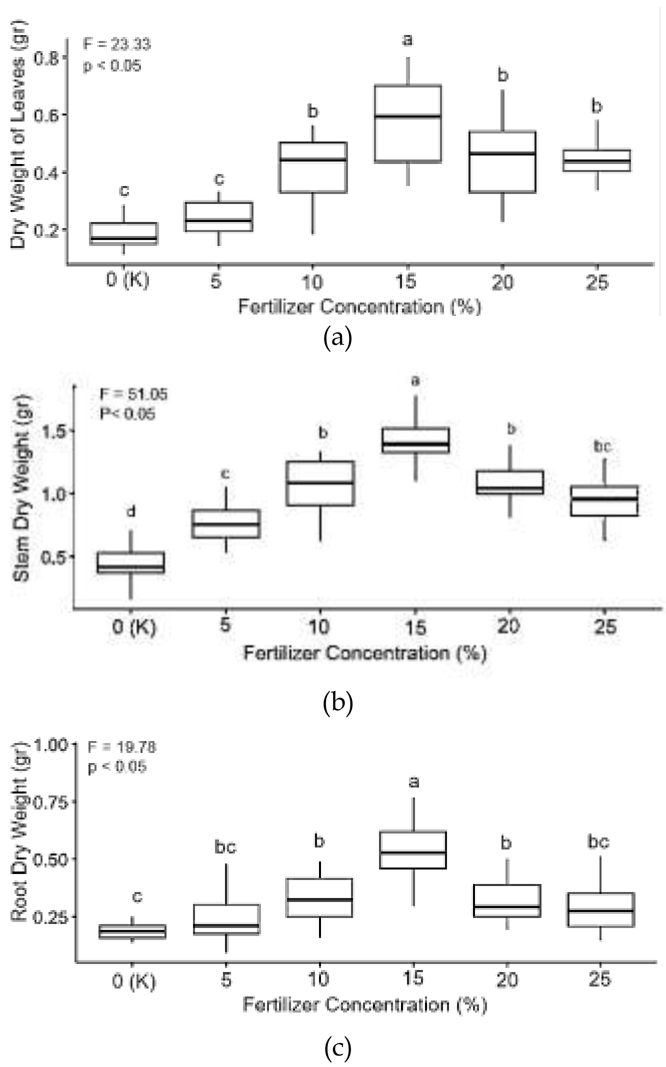

Figure 3. The Effect of Banana Pseudostems and Coconut Fiber Formulation with Bioactivator MA-11 on the Average of (a) Leaf Dry Weight; (b) Stem Dry Weight and (c) Root Dry Weight. All treatments based on formulation K3. Different letters indicate substantial differences in average plant height, with a statistical significance level of P<0.05, as determined by ANOVA and Tukey's test. The bars represent the standard deviations

Leaf dry weight increased significantly in treatments with concentrations of around 10–20% compared to the control (Figure 3a). The highest average leaf dry weight was found at a concentration of 15%, at 0.6 ± 0.1 gr. This indicates that photosynthesis occurs more optimally at this concentration, supported by adequate availability of macro and micro nutrients. The trend in stem dry weight followed a similar pattern, with an increase at the optimal concentration and a decrease at the highest concentration (Figure 3b). This indicates that plant structural growth is strongly influenced by nutrient balance, especially potassium (Table 1), which plays a role in strengthening plant tissue (Rahma et al., 2019). Root dry weight showed a significant increase at medium concentrations, indicating that liquid fertilizer not only enhances the growth of the upper part of the plant but also the root system (Figure 3c). This is related to microbial activity (Table 4), which plays a role in increasing nutrient absorption through mechanisms such as phosphate solubilization and root hormone production. Previous research has shown that in corn (*Zea mays*), legumes (*Phaseolus vulgaris*), and soybeans (*Glycine max*), axial roots grow toward phosphorus-rich areas (Lynch, 2011). Overall, there is a very clear relationship between fertilizer quality and plant growth response (Figures 1 to 3). The K3 formulation, previously proven to have the highest nutrient content and microbial activity, demonstrated maximum effectiveness at a specific concentration, not at the highest concentration. This results in a dose-response curve pattern, where plant growth increases to an optimum point, then declines due to excess nutrients or toxic effects.

In terms of biomass parameters, the dry weight of leaves, stems, and roots showed an increasing trend at optimal concentrations and a decreasing trend at higher concentrations. Increased leaf biomass indicates increased photosynthetic activity, while increased root biomass indicates improved plant nutrient uptake. However, at high concentrations (25%), a decrease occurred, possibly due to nutritional imbalances or toxicity from excess nutrients, which can inhibit plant growth.

Overall, there is a close relationship between liquid organic fertilizer quality and plant growth responses and biological activity (Aloo et al., 2022; Pii et al., 2015; Riyandani et al., 2021). The K3 formulation, which contains higher macro and micronutrient content and optimal microbiological activity, demonstrated the greatest effectiveness at specific concentrations. These findings indicate that the success of liquid organic fertilizer is determined not only by the composition of the raw materials but also by the interaction between nutrient content, microbial activity, and the correct application dosage. Thus, the combination of banana stems and coconut fiber with the MA-11 bioactivator has great potential as an effective and sustainable liquid organic fertilizer. This formulation not only utilizes local organic waste but is also able to significantly increase plant growth when applied at optimal concentrations.

Conclusion

This study demonstrated that the K3 formulation (125 g banana pseudostem, 375 g coconut fiber, MA-11 bioactivator, 1 L coconut water, and 125 g molasses) applied at a 15% concentration was the most effective treatment for promoting marigold growth under greenhouse conditions. The findings provide scientific evidence that combining banana pseudostem, coconut fiber, and MA-11 enhances the production of liquid organic fertilizer via microbial fermentation and supports the valorization of agricultural waste into value-added products. This formulation represents a promising approach for sustainable organic fertilizer development and circular bioeconomy practices. Future research should focus on micronutrient enrichment, evaluation of microbial dynamics during fermentation, and field validation across different crop species to improve fertilizer quality and agronomic performance.

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Author Contributions

Conceptualization: I.A.P.S; Methodology and conduct of experiment: I.A.P.S and I.M.P.A.S; Data analysis and data visualization: I.A.P.S and I.M.P.A.S.

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Conflicts of Interest

The authors declare no conflict of interest.

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