ORIGINAL RESEARCH PAPER

Volume - 14 | Issue - 11 | November - 2025 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

COMPREHENSIVE ASSESSMENT OF NUTRIENT ENRICHMENT IN VERMICOMPOST DERIVED SOLELY FROM BANANA PSEUDO STEM WASTE

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ABSTRACT

Sustainable management of agricultural waste, particularly Banana Pseudostem (BP), is a major environmental and economic goal. This study evaluated the potential of BP as a premium substrate for vermicomposting, focusing on the final nutrient quality. Three treatments were processed by Eisenia fetida: 100% BP (Sample 1), 50% BP mixed with 50% Garden Waste (GW) (Sample 2), and 100% GW (Sample 3). Analysis of the resulting vermicomposts revealed that the 100% BP substrate (Sample 1) consistently yielded the highest concentrations of all three major plant macronutrients—Nitrogen (N), Phosphorus (P), and Potassium (K). Sample 1 recorded the highest calculated Total N, Available P, and Available K. Furthermore, its physicochemical profile, characterized by a near-neutral pH and the lowest electrical conductivity, indicated superior stability and maturity. This research demonstrates that pure Banana Pseudostem waste is an exceptionally effective, standalone feedstock for producing high-quality, nutrient-concentrated organic fertilizer.

KEYWORDS

Banana Pseudostem; Vermicompost; Nutrient Concentration; Total Nitrogen; Available Phosphorus; Available Potassium; Organic Fertilizer.

1. INTRODUCTION AND LITERATURE REVIEW

1.1 The Imperative For Waste Valorization

Global agricultural practices, particularly in fruit cultivation, generate enormous volumes of biomass waste. The banana industry, one of the largest fruit sectors globally, produces an estimated tonnes of residue per hectare annually, predominantly in the form of the **pseudostem** [1, 2]. The traditional practice of leaving this bulky, fibrous waste to decompose slowly in the field is inefficient, contributing to pathogen buildup and nutrient loss.

Vermicomposting represents a highly effective, eco-friendly biotechnology for waste valorization. It utilizes detritivorous earthworms, such as Eisenia fetida, to rapidly transform organic residues into **vermicompost**—a stable, humified product rich in plant-available nutrients and beneficial microorganisms [3, 4]. The final quality of the vermicompost is intrinsically linked to the chemical composition of the initial feedstock.

1.2 Banana Pseudostem: A Nutrient-Rich Substrate

The **Banana Pseudostem (BP)** possesses distinct chemical advantages as a vermicomposting substrate. It is characterized by high moisture content and a significant concentration of **Potassium (K)**, an essential macronutrient, due to the banana plant's high uptake requirements for its rapid growth [5]. Previous research often recommends co-composting BP with animal manures (like cow dung) to improve the initial ratio and manage moisture levels [6]. However, this dilution reduces the unique, high-nutrient signature contributed by the BP itself. Limited studies have precisely quantified the final nutrient difference when utilizing BP against substrates containing non-specialized wastes like garden waste (GW).

1.3 Research Hypothesis And Objectives

Based on the known high content and high organic matter of banana pseudostem, we hypothesized that the vermicompost produced from **BP (Sample 1)** would exhibit superior concentrations of N, P, and K compared to substrates diluted with GW (Sample 2) or composed entirely of GW (Sample 3).

The Primary Objectives Were:

1. To evaluate and compare the maturity and stability of vermicomposts through analysis of **pH and Electrical Conductivity (EC)**.
2. To quantify and compare the final concentrations of **Organic Carbon (OC), Total Nitrogen (N), Available Phosphorus (P), and Available Potassium (K)** across the three treatments.
3. To confirm the optimal feedstock ratio for maximizing nutrient enrichment in the final vermicompost product.

2. MATERIALS AND METHODS

2.1 Substrate Collection And Preparation

Feedstock Materials: Freshly harvested **Banana Pseudostem (BP)** was collected, shredded to particle size, and mixed with chopped **Garden Waste (GW)** (dried leaves, grass) according to the treatment plan.

Pre-Composting: All raw materials underwent a **two-week pre-composting phase**. This step involved stacking, maintaining moisture, and turning every three days. Pre-composting is essential to reduce volatile organic acids, stabilize the material, and lower the initial ratio, thereby ensuring earthworm survival and optimal feeding conditions [7].

2.2 Experimental Setup

The experiment employed a **Completely Randomized Design (CRD)** with three treatments, each replicated four times. The three feedstock treatments were:

- **Sample 1 (T1):** Pre-composted Banana Pseudostem (BP).
- **Sample 2 (T2):** Pre-composted BP Pre-composted Garden Waste (GW) (w/w).
- **Sample 3 (T3):** Pre-composted Garden Waste (GW).

Each plastic vermibed contained of the respective substrate.

2.3 Vermicomposting Process And Maintenance

Earthworm Inoculation: Each vermibed was inoculated with of adult Eisenia fetida (Red Wiggler) earthworms.

Environmental Control: The vermicomposting process lasted **days**. The moisture content was rigidly maintained between by periodic watering.

Temperature was monitored daily and controlled at an average of throughout the duration to optimize earthworm metabolic activity. Gentle mixing was performed weekly to ensure adequate aeration and prevent anaerobic pockets.

2.4 Physicochemical And Nutrient Analysis

Upon completion of the -day period, the mature vermicompost was harvested, air-dried, and sieved. All analyses were performed on four replicates per treatment using standard laboratory methods:

- **pH and EC:** Determined in a (w/v) slurry using digital meters [8].
- **Organic Carbon (OC):** Measured using the **Walkley-Black wet oxidation method** [9].
- **Total Nitrogen (N):** Calculated from the OC content, assuming a stable **ratio of** for mature vermicompost, a widely accepted proxy for stable, humified organic matter: [10].
- **Available Phosphorus (P):** Extracted using the **Olsen's method** and quantified via spectrophotometry [11].
- **Available Potassium (K):** Extracted with ammonium acetate and quantified using **Flame Photometry** [8].

3. RESULTS AND DISCUSSION

The statistical analysis confirmed significant differences () among all treatments for every parameter measured, as summarized in Table 1.

Table 1: Physicochemical And Macronutrient Characteristics Of Final Vermicompost

Parameter	Unit	Sample 3 (100% GW)	Sample 2 (50% BP + 50% GW)	Sample 1 (100% BP)	Statistical Significance (P value)
pH	-	6.3	6.6	7.1	P<0.001
Electrical Conductivity (EC)	dS/m	0.6	0.4	0.2	P<0.001
Organic Carbon (OC)	%	4.58	5.5	6.21	P<0.001
Calculated Total Nitrogen (N)	%	0.458	0.55	0.621	P<0.001
Available Phosphorus (P)	kg/Ha	198	248	298	P<0.001
Available Potassium (K)	kg/Ha	886	984	1025	P<0.001

3.1 Physicochemical Properties And Product Maturity

3.1.1 pH And EC

The **profile** indicated that Sample 1 was the most favorable, achieving a near-neutral value that optimizes nutrient availability [13]. Sample 3 () was the most acidic, likely due to slower decomposition and residual organic acid accumulation in the high-lignocellulose Garden Waste (GW) [14].

The **Electrical Conductivity** demonstrated superior stability in the Banana Pseudostem (BP) product, with Sample 1 recording the lowest. Low values in mature vermicompost are desirable, confirming non-phytotoxic salt levels safe for direct application [15]. The higher in Sample 3 suggests greater residual salinity or incomplete stabilization of mineralized components in the GW substrate.

3.1.2 Organic Carbon (OC) and Total Nitrogen (N)

Organic Carbon (OC): The BP vermicompost (Sample 1) exhibited the highest final content . This indicates that the BP substrate, despite the volume reduction inherent in vermicomposting, resulted in the highest concentration of stable, humified organic matter. This humic content is vital for improving soil structure, water-holding capacity, and cation exchange capacity (CEC) [16].

Total Nitrogen (N): The calculated Total content directly followed the trend, with **Sample 1 achieving the maximum** . This calculation relies on the widely recognized principle that mature vermicompost stabilizes to a ratio close to [10]. The higher content in the BP treatments confirms that the pseudostem provided a more -rich starting material compared to the lignocellulosic Garden Waste, which typically has a high initial ratio that takes longer to narrow. Earthworm activity, through mucus secretion and microbial enhancement, also significantly contributes to the final concentration .

3.2 Enhanced Macronutrient Profile (P and K)

3.2.1 Available Phosphorus (P)

Available was significantly highest in the BP treatment, marking a increase over the-only control (Sample 3). Vermicomposting enhances availability via-solubilizing microorganisms amplified in the earthworm gut. The BP matrix's chemical structure appeared highly favorable for this bio-mineralization, enabling superior conversion of organic into plant-available orthophosphates compared to the more recalcitrant Garden Waste.

3.2.2 Available Potassium (K)

The most notable difference was in Available . The BP vermicompost (Sample 1) yielded an outstanding of available . This confirms the strong hypothesis based on the banana plant's physiology as a accumulator [5]. The concentration effect was clear: Sample 1 produced more than Sample 3 and more than the blend (Sample 2). Given potassium's critical role in plant osmotic regulation, disease resistance, and fruit quality, co-composting BP with lower-nutrient materials like demonstrably results in the dilution of this critical nutrient asset.

4. Conclusion And Future Research

4.1 Synthesis And Recommendations

The results of this study definitively establish the superior quality of vermicompost derived exclusively from **Banana Pseudostem (BP)**. The BP substrate (Sample 1) consistently outperformed the blend and the Garden Waste control across all measured metrics. Its minimal and near-neutral values confirm optimal maturity and safety for agricultural use.

This study strongly advocates for the adoption of **Banana Pseudostem** as a primary, specialized feedstock for commercial vermicomposting. This approach provides a sustainable, high-NPK organic fertilizer source while simultaneously managing a major agricultural waste stream.

4.2 Future Directions

To Further Capitalize On These Findings, Future Research Should Focus On:

1. **Field Efficacy Trials:** Quantifying the direct impact of the high-K, BP vermicompost on crop yield, quality, and soil health across various agricultural systems.
2. **Nutrient Speciation:** Detailed analysis of the various forms of (e.g., nitrate and ammonium) and to better understand their release kinetics and plant availability.
3. **Process Optimization:** Investigating the ideal pre-composting duration and potential inoculation strategies to further accelerate the conversion of the highly fibrous BP waste.

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