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EFFECTS OF BANANA PSEUDOSTEM COMPOST RATES IN GROWING MEDIA ON GROWTH OF BLACK PEPPER (Piper nigrum L.) SEEDLINGS

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Abstract

This study aimed to identify the most effective dosage of banana stem compost as a growing medium for black pepper seedlings (Piper nigrum L.). The experiment was arranged using a single-factor Randomized Block Design (RBD) consisting of five compost dosages: R0 (soil without compost), R1 (100 g compost/kg soil), R2 (200 g compost/kg soil), R3 (300 g compost/kg soil), and R4 (400 g compost/kg soil). Each treatment was replicated five times, resulting in 25 experimental units, with each unit consisting of five pepper seedlings. The observed variables included shoot length, number of leaves, root length, fresh weight, and dry weight of seedlings at 12 weeks after transplanting. Data were analyzed using analysis of variance (ANOVA), followed by Bartlett's test for homogeneity and Tukey's test to examine data additivity. When the F-test indicated significant effects, orthogonal polynomial analysis at the 5% and 1% significance levels was conducted.The results showed that banana stem compost significantly influenced shoot length, number of leaves, and root length, but did not significantly affect fresh and dry biomass. The optimal dosage was 300 g compost/kg soil, which supported balanced growth above and below the ground. Overall, banana stem compost demonstrated strong potential as a locally available organic material for pepper seedling production.

Keywords: Banana Pseudostem compost, pepper seedlings, compost dosage, growing medium

INTRODUCTION

Black pepper (Piper nigrum L.) is a strategically important spice commodity in global trade and is widely used not only as a culinary ingredient but also as a raw material for the food and beverage, pharmaceutical, cosmetic, and health-product industries due to its bioactive metabolites (Ashokkumar et al., 2021; Takooree et al., 2019; Zou et al., 2024). Alongside expanding downstream utilization, analytical studies have also documented variability in pepper chemical profiles associated with product origin, highlighting the importance of reliable supply and robust cultivation systems (Liang et al., 2020). Nevertheless, the success of pepper cultivation is strongly determined by the quality of planting material from the nursery stage. Healthy and vigorous seedlings generally develop stronger root systems, achieve better nutrient uptake efficiency, and exhibit greater early tolerance to biotic and abiotic stresses after transplanting (Indu et al., 2022; Nysanth et al., 2022). At the same time, soil-borne diseases remain a major constraint; quick wilt/foot rot caused by Phytophthora capsici has been reported as one of the most destructive pathogens, capable of attacking plants from the seedling stage through maturity. Therefore, the availability of healthy and uniform seedlings is a key prerequisite for successful cultivation (Indu et al., 2022; Nysanth et al., 2022).

During nursery production, the growing medium directly influences aeration, water retention, nutrient availability, and root development. Media with low organic matter typically have reduced porosity and cation exchange capacity, more limited water- and nutrient-holding capacity, and lower soil microbial activity that otherwise supports decomposition and nutrient mineralization. For this reason, adding organic matter through compost is a relevant and sustainable approach. Meta-analytical evidence indicates that organic amendments increase soil microbial diversity, strengthen microbial functions, and in many cases improve plant growth and yield (Shu et al., 2022). In addition, the quality of organic amendments influences microbiome structure and functional bacterial groups involved in nitrogen cycling, thereby affecting nutrient availability dynamics in the growing medium (Ouyang et al., 2022). Medium-term studies also show that sustained compost inputs can maintain soil structure and carbon storage by increasing carbon availability for microbes and enhancing microbial biomass (Wang et al., 2022). More specifically, compost can reinforce phosphorus cycling by stimulating phosphatase-producing microbial groups and increasing soil P availability (Jiang et al., 2025), and it can promote functional genes associated with microbial P cycling in amended soils (Wu et al., 2025). From a physical standpoint, compost can improve media quality by reducing bulk density, increasing porosity, and enhancing water retention. These responses are often governed by application rate and material characteristics, so the effect may be optimal at specific doses (Ammar et al., 2018). Recent findings further show that compost particle size and the use of additives can modify soil physical parameters that are directly related to water availability—an important factor for balanced shoot and root growth during the seedling stage (Wu et al., 2025). Thus, dose determination is critical: too little compost may be insufficient to improve the medium, while excessive doses may disrupt aeration–moisture balance or alter mineralization/immobilization dynamics. In the context of local resource utilization, banana stems/pseudostems are abundant agricultural residues with high potential as compost feedstock.

Co-composting based on banana pseudostem biomass has been reported to produce compost with improved chemical properties during the composting process (Awasthi et al., 2021). Banana pseudostem derivatives (compost and/or sap/extract applications) have also been reported to support nutrient acquisition and crop performance in tropical soils (Islam et al., 2024; Sulok et al., 2024). As interest in sustainable growing media increases, compost has also been widely studied as a component of peat-free seedling substrates; combinations of compost with porous materials such as biochar have been reported as promising for developing more environmentally friendly nursery substrates, although composition and dose still require optimization (Fan et al., 2024; Martins et al., 2023; Yu et al., 2023). These findings strengthen the scientific rationale for testing banana stem compost as a growing medium for pepper seedlings, with an emphasis on identifying an optimal dose that supports balanced shoot and root development. Accordingly, research on banana stem compost dosage as a growing medium for pepper seedlings has dual relevance: (1) improving nursery media quality by enhancing physical, chemical, and biological properties, and (2) supporting sustainable agriculture by converting locally available organic waste into a value-added input, thereby reducing dependence on non-renewable growing-media materials. Within the broader effort to strengthen sustainable pepper production systems, improving nursery quality is also aligned with the development of more adaptive and efficient cultivation strategies (Singh et al., 2026).

RESEARCH METHODS

Time and Study Site

This study was conducted on a plantation field in Tiuh Balak Village, Baradatu Subdistrict, Way Kanan Regency, Lampung Province, Indonesia. The site was selected because it represents the typical agroecosystem conditions of smallholder land commonly used for black pepper nursery production; therefore, the results are expected to be applicable at the farmer level. The study was carried out from March 2024 to June 2025, covering the entire seedling growth period as well as environmental variation during the rainy season and the transitional season.

Experimental Design

The experiment was arranged in a single-factor Randomized Block Design (RBD) to account for field variability. The factor tested was the dosage of kepok banana stem compost with five treatment levels: R0 = no compost (control); R1 = 100 g compost/kg soil; R2 = 200 g compost/kg soil; R3 = 300 g compost/kg soil; and R4 = 400 g compost/kg soil Each treatment was replicated five times, resulting in 25 experimental units. Each experimental unit consisted of five pepper seedlings, so a total of 125 seedlings were used.

Materials and Equipment

Materials used included topsoil as the base medium, kepok banana stem compost, black pepper seedlings of the Natar 1 variety aged 30 days after cutting propagation, rice bran, rice husk charcoal, EM4 as a composting activator, palm sugar as an energy carbon source, and water. Equipment included polybags measuring 15 × 25 cm and 20 × 25 cm, a machete, knife, measuring tape, watering can, hoe, bucket, and shade net (paranet).

Preparation of Banana Stem Compost

Compost was prepared using a standardized procedure to obtain relatively uniform compost quality between batches. Kepok banana stems were chopped into small pieces to increase surface area and accelerate decomposition. A total of 45 kg of chopped banana stem was mixed with 3 kg of rice bran and 5 kg of rice husk charcoal. The mixture was then inoculated with 100 mL of EM4, previously diluted in 5 L of water and supplemented with 0.5 kg of palm sugar. All materials were thoroughly mixed until homogeneous, then piled and covered with a tarpaulin for fermentation for approximately 30 days. During composting, the pile was turned every 7 days to maintain aeration and promote decomposition. The compost was considered mature when it turned dark/blackish, had no strong odor, showed a crumbly texture, and its temperature approached ambient temperature. These criteria follow the recommendations of Martínez et al. (2022) regarding mature compost indicators.

Growing Medium Preparation and Planting

Topsoil was sieved to remove stones and foreign materials, then mixed with compost according to each treatment dosage. The prepared medium was filled into polybags and arranged under a shade net to reduce excessive light intensity and minimize seedling stress during early adaptation. Pepper seedlings were then planted in each polybag and labeled according to treatment and replication to ensure traceability of observations.

Seedling Maintenance

All seedlings were maintained uniformly to minimize the influence of external factors. Maintenance included watering 1–2 times per day depending on weather conditions, weekly weeding, and mechanical control of pests and diseases without pesticide application to avoid confounding effects on compost treatments. Additional fertilizers beyond the treatments were deliberately not applied to ensure that all growth responses could be attributed to kepok banana stem compost.

Observed Variables

The observed variables were:

1. Shoot (vine) length (cm): measured from the root collar to the latest growth point weekly until 12 weeks after planting (WAP).
2. Number of leaves (leaves): counted as fully expanded leaves.
3. Root length (cm): measured at the end of the study after carefully uprooting the seedlings.
4. Fresh weight (g): weighed immediately after uprooting and cleaning the growing medium from the plant.
5. Dry weight (g): determined after oven-drying at 80°C until constant weight was achieved.

Data Analysis

Data were analyzed using analysis of variance (ANOVA) to test treatment effects on all observed variables. Prior to ANOVA, statistical assumptions were evaluated. Normality was tested using the Shapiro–Wilk test, which is appropriate for small to moderate sample sizes and has good sensitivity for detecting non-normal distributions (Ghasemi & Zahediasl, 2012). Homogeneity of variance was tested using Bartlett's test, while additivity was assessed using Tukey's test. When the ANOVA F-test indicated significant effects, the analysis was continued using orthogonal polynomial regression to determine the response pattern of compost dosage on growth variables. The response forms evaluated included linear, quadratic, cubic, and quartic patterns following the analytical guidance of Gomez and Gomez (1984). All statistical analyses were performed using Excel and SPSS software. This stepwise and rigorous statistical approach was applied to ensure that the conclusions drawn accurately reflect the biological responses of pepper seedlings to kepok banana stem compost and are scientifically defensible.

RESULTS AND DISCUSSION

Results

Overall, banana stem compost application had a highly significant effect on shoot (vine) length, number of leaves, and root length, but showed no significant effect on fresh and dry biomass of black pepper seedlings (Table 1).

Table 1. Summary of ANOVA: effect of banana stem compost dosage on black pepper seedling growth

Growth variable	F-calculated	F-table		Remark
		(0.05)	(0.01)	
Shoot (vine) length	6.61	4.49	8.53	**
Number of leaves	5.02	4.49	8.53	**
Root length	7.41	4.49	8.53	**
Fresh biomass weight	0.96	4.49	8.53	ns
Dry biomass weight	0.33	4.49	8.53	ns

Notes: ** = highly significant at 1% level; ns = not significant at 5% level.

1) Shoot (vine) length

Shoot length was highly significantly affected by compost dosage (Table 1). The 300 g compost/kg soil (R3) treatment produced the highest mean shoot length, approximately 29.90 cm (Figure 1).

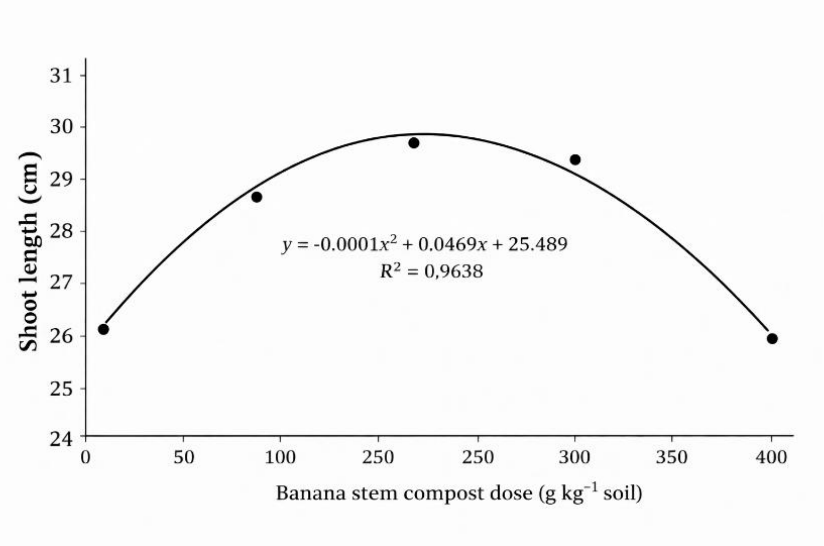

Figure 1. Effect of banana stem compost dosage on shoot (vine) length of black pepper seedlings

2) Number of leaves

The number of leaves was also highly significantly influenced by compost dosage (Table 1). The R3 (300 g/kg soil) treatment resulted in the highest mean number of leaves, about 10.36 leaves per seedling (Figure 2).

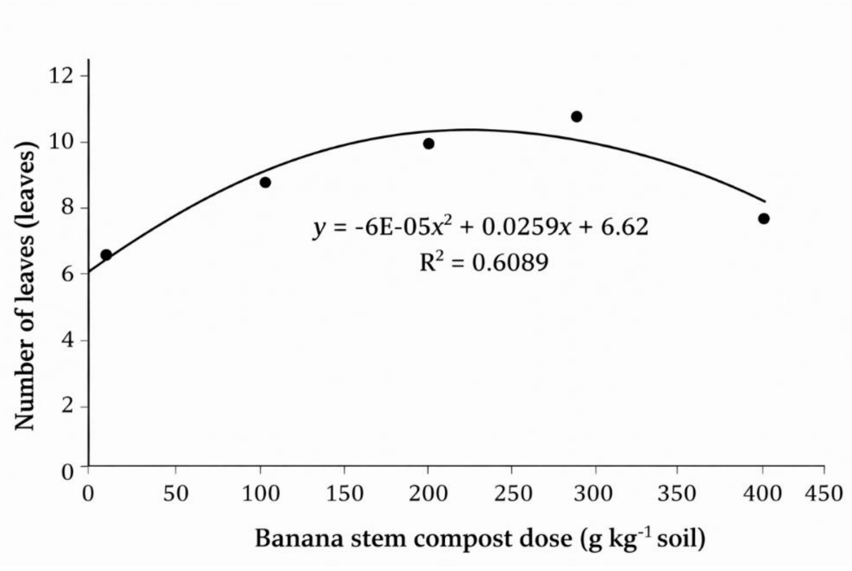

Figure 2. Effect of banana stem compost dosage on number of leaves of black pepper seedlings.

3) Root length

Root length was highly significantly affected by compost dosage (Table 1). Increasing compost dosage generally increased root length, with the highest mean observed in R4 (400 g/kg soil) at approximately 8.52 cm (Figure 3).

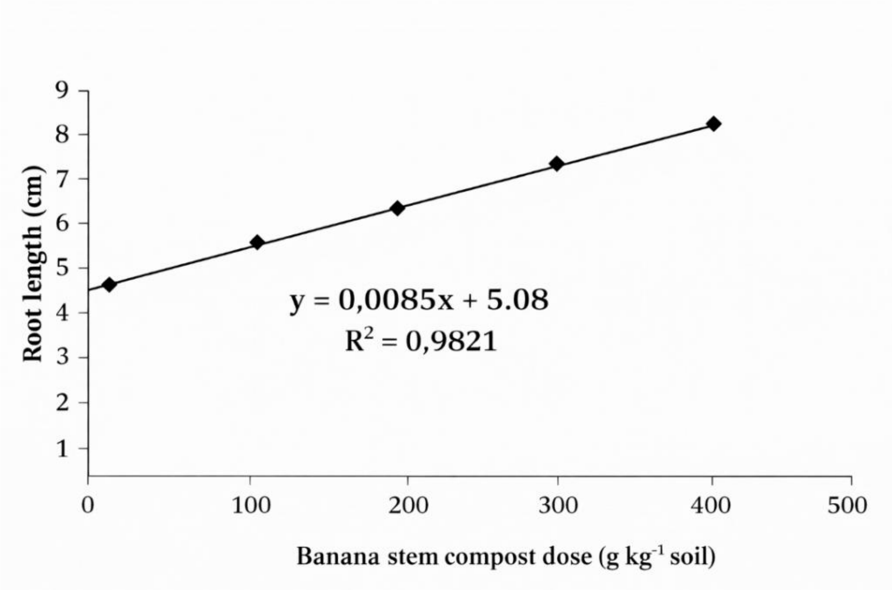

Figure 3. Effect of banana stem compost dosage on root length of black pepper seedlings.

4) Fresh biomass weight

Compost application had no significant effect on fresh biomass weight (Table 1). Orthogonal polynomial analysis showed that all components (linear–quartic) were not significant (Table 2).

Table 2. Orthogonal polynomial analysis for fresh biomass weight of black pepper seedlings

Component	Contrast coefficients					SS	F-calculated	Remark
	R0	R1	R2	R3	R4			
Linear	-2	-1	0	1	2	3.13	0.73	ns
Quadratic	2	-1	-2	-1	2	7.10	1.65	ns
Cubic	-1	2	0	-1	1	5.78	1.35	ns
Quartic	1	-4	6	-4	1	0.53	0.12	ns

Notes: ns = not significant at 5% level.

5) Dry biomass weight

Similarly, compost application had no significant effect on dry biomass weight (Table 1). Orthogonal polynomial analysis indicated that all components were not significant (Table 3).

Table 3. Orthogonal polynomial analysis for dry biomass weight of black pepper seedlings

Component	Contrast coefficients					SS	F-calculated	Remark
	R0	R1	R2	R3	R4			
Linear	-2	-1	0	1	2	0.00	0.00	ns
Quadratic	2	-1	-2	-1	2	0.20	0.75	ns
Cubic	-1	2	0	-1	1	0.15	0.56	ns
Quartic	1	-4	6	-4	1	0.00	0.00	ns

Notes: ns = not significant at 5% level.

Discussion

Shoot length and number of leaves peaked at R3 (300 g/kg soil). Physiologically, shoot growth and leaf formation are strongly influenced by nitrogen availability and overall macronutrient balance (N–P–K), which support cell division, chlorophyll formation, and leaf expansion. Organic amendments such as compost can enhance nutrient availability gradually via mineralization, while also improving nutrient retention capacity and microbial activity that supports soil functioning (Liu et al., 2023). Meta-analyses further indicate that organic amendments generally improve soil microbial functions and often promote plant growth and yield, although responses depend on amendment type, dose, and environmental context (Shu et al., 2022). The slight decline in shoot length at the highest dosage (R4) is biologically plausible because high compost rates may increase soluble salts (electrical conductivity) or alter the C:N balance, potentially causing temporary nitrogen immobilization and limiting shoot growth (Gondek et al., 2020). Therefore, a mid-range optimum such as R3 is commonly observed in compost-amended growing media. The highest root length at R4 (400 g/kg soil) suggests that compost contributed strongly to improving the physical properties of the growing medium, especially porosity and reduced mechanical resistance, thereby facilitating root penetration and elongation. Compost can reduce bulk density and increase pore space, improving aeration and water availability in the root zone. Recent evidence also shows that compost particle size and additives can modify key soil physical parameters linked to water availability—critical for root development in seedlings (Głąb et al., 2025). In banana-based materials, co-composting has been reported to improve chemical characteristics during composting, producing a more mature and plant-safe compost product (Islam et al., 2021). Moreover, banana pseudostem-derived compost and associated products have been shown to support nutrient acquisition and crop performance in tropical soils, reinforcing the potential agronomic value of banana biomass as an organic input (Sulok et al., 2024).

The absence of significant differences in fresh and dry biomass—despite significant changes in morphological traits—can occur during early seedling stages because biomass accumulation is highly dynamic and often shows substantial variability among individuals. Fresh weight is also strongly affected by tissue water content, which can fluctuate with micro-variation in watering and evapotranspiration. In many cases, compost effects are first expressed in morphological parameters (shoot, leaves, roots) before translating into consistent biomass differences. In addition, the impact of organic amendments on biomass/yield is context-dependent and influenced by compost quality, dose, and observation duration (Liu et al., 2023; Wang et al., 2022). Nutrient cycling processes—particularly phosphorus dynamics—may also require longer periods before producing stable biomass differences (Jiang et al., 2025; Wu et al., 2025). This supports the interpretation that, at 12 weeks after planting, compost dosage primarily affected growth traits rather than total biomass accumulation. From an applied perspective, 300 g compost/kg soil (R3) can be considered the most efficient dosage to enhance aboveground growth (shoot length and leaf number) while maintaining good root development, resulting in a more balanced seedling profile for transplanting. Meanwhile, 400 g/kg soil (R4) promoted stronger root elongation but did not further increase shoot growth, indicating an upper threshold for improving aboveground vegetative performance (Gondek et al., 2020; Shu et al., 2022).

CONCLUSION

Based on the results of this study, banana stem compost was shown to have a significant effect on black pepper seedling growth, particularly on shoot (vine) length, number of leaves, and root length, whereas fresh and dry biomass weights did not show significant differences at the observed sampling time. Among the five dosages tested, the application of 300 g compost per kg of soil produced the most optimal and well-balanced growth response, supporting both aboveground growth (shoots and leaves) and belowground growth (roots). These findings indicate that banana stem compost has strong potential as a cost-effective, readily available, and environmentally friendly local organic material to improve the quality of growing media for black pepper seedlings, especially in smallholder nursery systems.

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