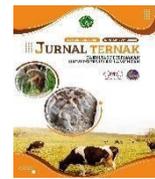




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Synergistic Effects of Water Hyacinth Compost on Vegetative Development of Forage Corn in Degraded Soils

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ABSTRACT

Post-mining lands in Indonesia are characterized by severely degraded soils with low fertility, high acidity, and poor water retention, posing major challenges for agricultural rehabilitation. This study investigates the effect of water hyacinth (*Eichhornia crassipes*) compost at varying dosages (0%, 25%, and 50%) on early vegetative growth parameters of forage maize over a 30-day period. A randomized complete block design was used with six replications per treatment. Key growth indicators—plant height, stem diameter, and their respective growth rates—were measured and statistically analyzed. Results showed that the 50% compost treatment significantly increased plant height (51.87 cm) and height growth rate (1.73 cm/day) compared to lower dosages. Stem diameter parameters, while numerically improved, did not yield statistically significant differences. The improved growth is attributed to enhanced nutrient availability, microbial activity, and water retention due to compost application. These findings confirm that compost from invasive biomass can effectively improve degraded soils and initiate early crop development. The study contributes to sustainable land reclamation strategies and emphasizes that there must be long-term assessments of compost

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INTRODUCTION

Milk is classified as an animal food that cannot be stored for a long time and is easily Widespread coal mining operations in Indonesia have resulted in the degradation of extensive land areas, leaving behind soils characterized by disrupted structure, elevated acidity, diminished nutrient

content, and severely depleted organic matter [1], [2]. These post-mining substrates, predominantly sandy with insufficient clay fractions, exhibit poor water retention and limited cation exchange capacity, rendering them unsuitable for sustainable agricultural production [3], [4], [5]. In light of the pivotal role of agriculture in ensuring food security and supporting rural livelihoods, the ecological restoration of such degraded landscapes represents a national priority. Among the array of strategies explored for post-mining land rehabilitation, the utilization of organic soil amendments has emerged as a promising, sustainable solution for restoring soil fertility and physical structure.

One such organic amendment of interest is compost derived from *Eichhornia crassipes* (water hyacinth), an invasive aquatic macrophyte widely regarded as an ecological nuisance. When processed through aerobic decomposition, water hyacinth compost has demonstrated the capacity to enhance microbial biomass, promote nutrient mineralization, and improve soil moisture retention—factors integral to root establishment and early plant development [6], [7]. In addition to its agricultural benefits, turning water hyacinth into compost serves two ecological purposes: it helps stop the spread of invasive species and helps restore land. [9], [10].

The compost treatment has been extensively documented in the literature, particularly in their ability to enhance nutrient availability, biomass accumulation, and plant tolerance to abiotic stressors [8], [11], [12]. These have been shown to promote nitrogen uptake efficiency and increase soil microbial diversity, both of which are critical indicators of functional soil health [13], [14]. Nonetheless, early-stage growth of maize (*Zea mays*), a crop of dual importance for forage and staple consumption, often remains suboptimal on post-mining substrates, particularly during the initial 30-day establishment phase—a period essential for root proliferation and above-ground biomass development.

Recent research has suggested that water hyacinth compost, could be a good way to get around these problems. Empirical findings suggest that compost application enhances nutrient solubility and microbial function, soil moisture retention and structural integrity [9], [15], [16]. However, despite their theoretical promise, empirical investigations addressing the short-term impacts of specific compost dosages under post-mining soil conditions remain limited. Moreover, few studies have examined these dynamics within the context of tropical environments, where soil degradation challenges are both acute and complex. This paucity of data represents a critical research gap, particularly for the development of site-specific and crop-targeted soil rehabilitation protocols.

The present study aims to address this gap by evaluating the effects of water hyacinth compost at varying volumetric proportions (0%, 25%, and 50%) on the early vegetative growth performance of forage maize cultivated in post-mining soil. The research specifically focuses on key growth metrics—plant height, stem diameter, and their respective growth rates—during the critical 30-day establishment phase. By employing compost derived from invasive biomass, the study contributes to sustainable land management practices and aligns with circular economy principles. The outcomes of this research are anticipated to inform future soil management strategies and offer practical advice regarding the restoration of degraded ecosystems using locally available organic resources.

METHOD

This study was designed to evaluate the effects of different dosages of water hyacinth (*Eichhornia crassipes*) compost on the early vegetative growth dynamics of forage maize cultivated in post-mining soil. A 30-day experimental period was implemented under controlled field conditions to observe plant height, stem diameter, and their respective growth rates.

Study Site and Soil Characteristics

The experiment was conducted from 30 September to 31 October 2025 at the Field Laboratory of the Animal Feed Technology Program, Department of Agricultural Industrial Technology, Politeknik Negeri Tanah Laut. The soil utilized in this study was sourced from a rehabilitated coal mining site operated by PT Arutmin Indonesia in Satui, Tanah Bumbu Regency, South Kalimantan. This substrate, representative of typical post-mining conditions in tropical regions, is characterized by poor fertility, compacted texture, low organic matter, and limited water-holding capacity, thus offering a pertinent environment for evaluating soil amelioration strategies in degraded systems.

Data collection

Field data were collected in 5 smallholder oil palm plantations younger than 10 years. At each site, twenty square plots were randomly established using 1 × 1 m quadrats. Within every quadrat, all understory plant species were identified and the number of individuals of each species was recorded, following standard quadrat-based vegetation survey procedures commonly applied in oil palm plantations. To evaluate their potential use as forage and estimate biomass production, selected understory species were first offered to cattle to confirm palatability, then harvested by cutting at ground level and weighed to obtain fresh biomass yield, in line with destructive sampling approaches used to estimate forage production under oil palm. Each plant species sample was subsequently oven-dried to constant weight following FAO guidelines for feed sampling and dry matter determination, providing standardized data for further nutritional evaluation [17].

Experimental Design

A Randomized Complete Block Design (RCBD) was employed to control for experimental variability and ensure equal representation of treatments across replicates. This design is widely acknowledged for its statistical robustness in agronomic research, particularly in soil amendment trials [18], [19]. Three treatments were implemented, each with six replications, culminating in a total of 18 experimental units. All treatments were established in polybags to ensure uniform soil volume and root zone constraints. The treatments were defined based on volumetric ratios of compost to post-mining soil:

E0 (Control): 0% compost + 100% post-mining soil

E1: 25% compost + 75% post-mining soil

E2: 50% compost + 50% post-mining soil

Media Preparation and Plant Cultivation

Water hyacinth compost was produced via aerobic decomposition and subjected to a one-week incubation under moist, covered conditions to initiate microbial mineralization processes. Although longer composting durations are often advised for complete stabilization [20], recent findings suggest that even short-term composting can enhance microbial activity and nutrient bioavailability during early plant development [21], [22], [23], [24].

Forage maize seeds (cultivar BISI 18) were pre-soaked in water to break dormancy and then directly sown into the prepared media. During the initial seven days, seedlings were shaded to mitigate environmental stress and promote uniform germination. Subsequently, the plants were exposed to full sunlight for the remainder of the experimental period. No additional fertilizers were applied, ensuring that observed plant responses could be attributed solely to the compost treatment. Watering was conducted daily and uniformly across all treatments to maintain optimal moisture conditions.

Measurement of Vegetative Growth Parameters

At the conclusion of the 30-day growth period, key indicators of early vegetative development were assessed. Plant height was measured using a standard measuring tape from the soil surface to the apical meristem of the tallest shoot. Stem diameter was determined using a digital caliper at the second internode above the soil surface, in accordance with established agronomic protocols for maize morphology [12].

To quantify growth dynamics, the Plant Height Growth Rate (PHGR) and Stem Diameter Growth Rate (SDGR) were calculated using the following equations:

$$\text{PHGR} = (H_2 - H_1) / (t_2 - t_1)$$

$$\text{SDGR} = (D_2 - D_1) / (t_2 - t_1)$$

where H_2 and D_2 represent final plant height and stem diameter, H_1 and D_1 are initial values at planting, and $(t_2 - t_1)$ corresponds to the 30-day growth period. These metrics provide nuanced insights into the temporal effects of compost application on maize growth under suboptimal soil conditions [13].

Statistical Analysis

All data were statistically analyzed using SPSS software version 22.0. A one-way Analysis of Variance (ANOVA) was employed to test for statistically significant differences ($p < 0.05$) among treatment means. Where significant effects were detected, Duncan's Multiple Range Test (DMRT) was utilized for post-hoc comparisons. This combination of ANOVA and DMRT is a conventional and reliable approach in plant science research for identifying treatment-specific impacts.

RESULTS AND DISCUSSION

The application of water hyacinth compost exerted a significant influence on early vegetative growth parameters of forage maize cultivated in post-mining soil over a 30-day period (Table 1). Among the three treatments, statistical analysis using ANOVA and DMRT at a 5% significance level indicated that the 50% compost dosage (EG2) significantly enhanced plant height (51.87 cm) and height growth rate (1.73 cm/day) compared to EG0 (43.00 cm; 1.43 cm/day) and EG1 (43.53 cm; 1.45 cm/day), likely due to improved nutrient availability and microbial activation in the amended soils [14], [25]. While stem diameter (7.83 mm) and stem growth rate (0.26 mm/day) in EG2 showed numerical increases over the lower treatments, these differences were statistically non-significant, potentially reflecting the influence of residual environmental stressors typical of post-mining substrates or the limited experimental duration. Nevertheless, the observed trends suggest potential longer-term benefits [26], [27], indicating that organic amendments, particularly at higher dosages, may progressively restore soil function and plant structural development under degraded tropical soil conditions.

Table 1. Early Vegetative Growth of Maize (0–30 Days After Planting) under Different Compost Dosages

Parameters	Treatment			SEM	p-Value
	EG0	EG1	EG2		
Plant Height, cm	43.00a	43.53a	51.87b	1.619	0.031
Height Growth Rate, cm/day	1.43a	1.45a	1.73b	0.054	0.032
Stem Diameter, mm	6.45	6.37	7.83	0.332	0.126
Stem Growth Rate, mm/day	0.22	0.21	0.26	0.011	0.134

Note: ^{a,b}Mean values with different superscripts within the same row are different at $p < 0.05$; EG0 (Control): 0% compost + 100% post-mining soil; EG1: 25% compost + 75% post-mining soil; EG2: 50% compost + 50% post-mining soil. SEM: *standard error mean*.

The findings of this study indicate that the application of water hyacinth compost at a 50% dosage (EG2) significantly enhanced the early vegetative growth performance of forage maize cultivated on post-mining soil. The EG2 treatment exhibited the highest plant height and growth rate, reflecting the efficacy of organic amendments in stimulating initial biomass accumulation under conditions of soil nutrient deficiency. This enhancement can be attributed to improved nutrient bioavailability, enhanced soil moisture retention, and increased microbial activity [14], [25], [28], [29], [30]. These results also point to the prospect of valorizing invasive aquatic biomass, such as *Eichhornia crassipes*, as a sustainable input within land rehabilitation frameworks, thereby aligning with the principles of circular economy and ecological intensification [31], [32].

In contrast, stem diameter and its corresponding growth rate did not exhibit statistically significant differences across treatments, despite numerical increases under the 50% compost application. This outcome may reflect the delayed responsiveness of structural growth traits to organic inputs, or alternatively, the limitations imposed by the relatively short 30-day observation period, as noted by [33]. Additionally, residual stressors prevalent in post-mining soils, including trace metal toxicity and

microbial community imbalances, may have inhibited stem development [26], [27]. It is plausible that early elongation of the shoot system represents an adaptive response to environmental stressors, prioritizing vertical growth for light capture over structural reinforcement during the initial vegetative phase [34]. Therefore, long-term investigations encompassing full-season growth cycles are warranted to elucidate the cumulative effects of compost on structural biomass allocation, reproductive development, and overall soil recovery. Taken together, these findings support the strategic use of 50% water hyacinth compost as an ecologically viable and economically feasible intervention for enhancing early-stage crop performance in rehabilitated tropical soils.

Conclusion

Application of 50% water hyacinth compost significantly enhanced early vegetative growth of forage maize on post-mining soil, as indicated by increased plant height and growth rate within 30 days. While stem diameter showed no significant changes, upward trends suggest possible long-term effects. Utilizing invasive biomass as organic input presents a sustainable land rehabilitation strategy. These findings draw attention to the importance of low-cost amendments in restoring degraded soils and call for extended studies on compost across diverse conditions and full crop cycles.

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