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Effect of Vermicompost and Rice Husk Ash as an Organic Amendments Media on Rice Seedling and Mat Quality in Tray Nursery

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ABSTRACT

Background: Efficient mechanized rice transplanting depends on both the structural integrity of seedling mats and the physiological quality of the seedlings. To address this need, enhancing seedling and mat through organic growing media is essential for optimizing mechanized rice transplanting.

Aims & Methods: This study aimed to evaluate the effects of organic amendments on seedling quality (seedling height, biomass, and plant population) and mat characteristics (thickness, weight, rolling score and diameter) in tray nursery. A randomized complete block design with three replications was employed, testing four treatments: alluvial soil without organic amendment (CO), with vermicompost (V), with rice husk ash (R), and with vermicompost and rice husk ash (RV).

Results: The results showed that the rice seedling nursery using a mixture of soil and organic growing media (R, RV, and V) produced better seedling quality compared to CO including seedling height, biomass, and plant population. Regarding mat performance, RV produced the thickest (1.77 cm) and lightest (3.27 kg) mats, aligning with ideal conditions for mechanical transplanting. In contrast, CO mats were the heaviest (4.40 kg), and V produced the thinnest mats (1.40 cm). Rolling quality was highest in CO (score 10), while RV mats showed lower rolling integrity (score 6.7). V treatment achieved the smallest roll diameter (13.87 cm), facilitating better handling and transport. Overall, the results demonstrate that organic amendment selection significantly affects both physiological seedling traits and the physical integrity of seedling mats. The RV treatment offered the most balanced improvement in mat structure and seedling growth, making it a promising option for mechanized rice production.

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1. Introduction

Rice is a staple food widely consumed by more than 60% of the world's population (Sen *et al.,* 2020). Its production is critical for global food security and economic stability, especially in Asia, where rice serves as the main source of calories and the countries most produced up to 90% and consumed of rice are China, India, Indonesia, Thailand, and Vietnam (Yuan *et al.,* 2022). To overcome this issue, increasing rice productivity must be supported by good nurseries, superior varieties, maintenance to harvest and post-harvest (Purbiati *et al.,* 2024). Substituting or amending soil with alternative growing media by considering the type and dosage of soil amendments suitable for seedling growth and production can be an option to support seedling growth and quality (Choudhary *et al.,* 2023; Zaki *et al.,* 2020).

Soil organic amendments have re-emerged as a cornerstone of sustainable rice cultivation, offering simultaneous improvements in soil physical properties, paddy seedling vigor, and the functional architecture of the root system—all of which determine whether modern "mat paddy" and tray nursery technologies can deliver their promised gains in mechanized rice planting (He *et al.,* 2023). Organic amendments, when optimized, reconcile this trade-off. Vermicompost has a benefits for improving soil physico-chemical properties such as porosity, bulk density, pH and CEC which contribute to better root development, promoting nutrient availability (Das *et al.,* 2022) and plant establishment (Blouin *et al.,* 2019).

In addition, rice husk ash, rich in silica, potassium, and carbon, which is enhances both soil structure and fertility, which improves soil porosity and soil water content by reduced bulk density, making it especially beneficial for degraded soils (Lu *et al.,* 2014). It also enhances nutrient availability, particularly phosphorus and potassium, and supports microbial activity, promoting better plant growth and yield (Gu *et al.,* 2024). In addition, the integrating organic amendments such as vermicompost in the paddy cultivation increases yield up to 35.3% (Wu *et al.,* 2019) and mat quality (Hossen *et al.,* 2018). Based on above, shows that mixing soil with organic amendments has advantages for rice seedling nurseries in tray plastics which supported to improved soil structure, aggregation.

Nevertheless, an understanding type and proportion combination of organic amendments as growing media in tray nursery is still lack. In particular, using vermicompost, rice husk ash, and Alluvial soils. Therefore, this study aims to analyze various and proportion combinations of alluvial soils and organic amendment on rice seedling quality and mat characteristics during seedling tray nursery.

2. Material and Methods

2.1. Study site and microclimate condition

The study was conducted at the greenhouse and Soil and Water Engineering Laboratory, Universitas Gadjah Mada, Yogyakarta, Indonesia. The experiment was conducted started from July to September 2024 with the altitude (115 m asl) and average temperature 25 – 27 ^{o}C. In this study, the alluvial soils and *Rojolele Srinuk* (indica rice) cultivars as the soil and variety test.

2.2. Experimental design and parameters analysis

Plastic seedling trays (58 cm×28 cm×3 cm) were employed for cultivating rice seedlings and the seedling density up to 270-300 grams per tray which can produce sprouts of up to 375 grams. A randomized complete block design (RCBD) with three replications. The four treatments are Alluvial soils and without organic amendments as a control (CO), Alluvial soils + vermicompost (V), Alluvial soils + Rice Husk Ash (R), and), Alluvial soils + Rice Husk Ash +Vermicompost (RV). The type and proportion combinations used this study was modified based on previous study (Dwibedi *et al.,* 2023; Hossen *et al.,* 2018) with details as shown in Table 1.

Table 1. The proportion of treatment used in this study

Treatment	Percentage compositions			
	Soil	Rice husk ash	Manure	Vermicompost
CO	100%			
V	60%		40%	
R	75%	25%		
RV	40%	25%		35%

In tray-based rice seedling cultivation systems, seedling quality plays a pivotal role as it directly influences subsequent plant growth performance and final yield. The assessment of seedling quality observed during 15 up to 20 days after sowing is based on several critical parameters, including germination rate, seedling height, biomass production, and plant population was observed around 15 - 20 days after sowing (DAS), a period considered optimal for transplanting. The germination parameters reflects the percentage of seeds that successfully sprout and establish into viable seedlings, which is the germination rate was used in this study up to 83%. A high germination percentage indicates not only superior genetic and physiological seed quality but also favorable nursery conditions (Ling *et al.,* 2024). Seedling height was analyzed and measured from 7, 14, 20 DAS, serves as a proxy for early growth potential; uniform and optimal height suggests healthy cell elongation, hormonal balance, and adequate nutrient availability (Zhu *et al.,* 2023). Biomass production was observed 20 DAS and typically measured as the total fresh weight such as stems and leaves, serves as an indicator of carbon assimilation and vegetative strength (Han *et al.,* 2022).

In this study, three strips of mats was cut with a size of 3 cm x 3 cm which is represent 1m x 1m area and for analyzing of treatment proportion combinations, whereby, the thickness and weight of the mats were analysed using meter scales and precision scales with expressed in kilogram per unit area. Furthermore, the diameter parameters and quality score of the mat rolls were analysed using a scale of 1-10 as shown in Table 2.

Table 2. The characteristics of mat quality using Rolling score (Hossen *et al.,* 2018).

Characteristics	Score
No cracking	10
Minor cracking (single)	8
One crack, or more but possible to rolled up (medium)	6
Large site of crack, but possible to rolled up	4
Large site crack, difficult to rolled up	2
Not possible to rolled up	1

2.3. Statistical analysis

The Data analysis in this study used Analyze of varience (ANOVA) using SPSS Software, where the least significant difference (LSD) and standard error (SE) as the post hoc tests used to see the significance ($p < 0.05$) of the effect of the treatments. The data collected were analysed to evaluate the effect of different types and combinations of proportions of soil organic amendments media on quality of rice seed and mat performances.

3. Results and Discussion

3.1. Rice seedling quality analysis

The application of soil organic amendments during the rice seedling stage is a critical practice, particularly when evaluated against several standard seedling quality parameters. As shown in Figure 1, the results revealed that seedling height, biomass, and plant population for each treatment were as follows: CO (17.77 cm; 0.55 kg; 4.3 seedlings/cm^2), V (18.43 cm; 0.59 kg; 5.8 seedlings/cm^2), R (19.22 cm; 0.58 kg; 5.4 seedlings/cm^2), and RV (18.40

cm; 0.63 kg; 4.7 seedlings/cm²). Based on above seedlings height and plant population under organic amendments media (V, R, and RV) were significantly higher than CO. These findings indicate that the proportion and type of organic amendments media significantly influence seedling height and plant population, likely through enhanced nutrient availability and improved substrate structure (Eshetie *et al.,* 2025), with an optimal transplanting height for mechanization being close to 20 cm at 16–21 DAS (Hossen *et al.,* 2019).

In addition, the V treatment showed the highest plant population, suggesting that vermicompost positively influences seedling emergence and early establishment. This supports previous findings indicating that vermicompost enhances soil fertility and improves seedling vigor (Ding *et al.,* 2021). Vermicompost is rich in essential nutrients and bioactive compounds that significantly promote root growth—including increased root length, surface area, and branching (Patnaik *et al.,* 2020)—also has been shown to enhance antioxidant enzyme activity in rice seedlings (Ruan *et al.,* 2021). However, the biomass showed no significant difference for each treatments but has a different values which the highest is RV followed by V, R, and CO, which is align with previous study that the incorporation of organic amendments can stimulate root development related on nutrient and water uptake, which impacts both morphological characteristics and physiological activity, ultimately contributing to better growth (Pan *et al.,* 2016), biomass accumulation (Ruan *et al.,* 2021), and improved plant population, enhances early nutrition enhances seedling vigor (Zhao *et al.,* 2024).

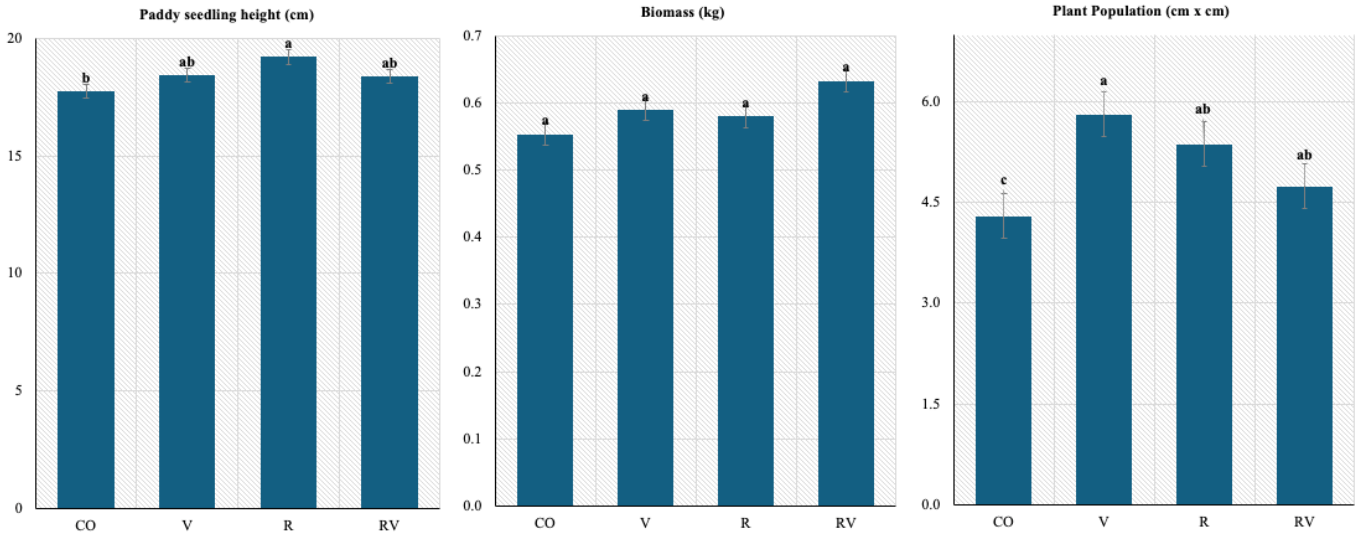

Figure 1. The effect of treatments on paddy seedling quality

3.2. Mat weight and thickness analysis in the transplantation stages

Mat thickness plays a critical role in seedling uprooting and transplanting efficiency. The optimal mat thickness for producing high-quality rice seedlings has been reported to be approximately 2.0 cm (Choudhary *et al.,* 2023; Hossen *et al.,* 2018; Huang *et al.,* 2013). In this study, the RV treatment produced the thickest mats (1.77 ± 0.058 cm) greater than those observed in the R and CO treatments, as shown in Figure 2. These results are consistent with previous findings that organic amendments rich in carbon and silica, such as rice husk ash, enhance the structural integrity and porosity of the growing media, thereby promoting improved mat formation and cohesion (Dwibedi *et al.,* 2023).

Conversely, the vermicompost (V) treatment exhibited the thinnest mats (1.40 ± 0.265 cm), likely due to its finer particle size and rapid decomposition rate, which can reduce compaction and structural stability (Patel *et al.,* 2024). In addition, overly thin mats are prone to falling down when put in the box of a mechanical transplanter, which may lead to an increased number of floating seedlings and inadequate rooting contact. However, thinner mats can also reduce the force required for uprooting, potentially easing transplanting operations.

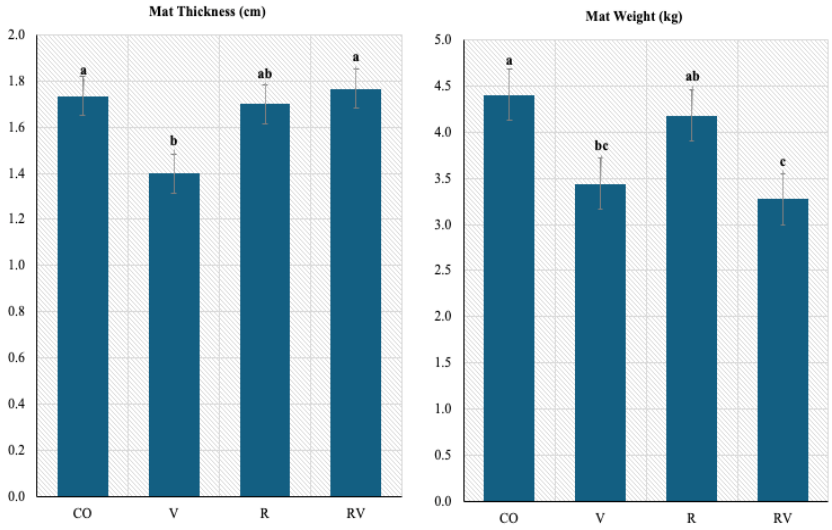

Figure 2. The effect of treatments on mat thickness and mat weight

Another important parameter for assessing mat quality in mechanized rice production is mat weight. The results showed that the control treatment without organic amendment (CO) produced the heaviest mats (4.40 ± 0.549 kg), compared to V (3.44 ± 0.381 kg), R (4.18 ± 0.886 kg), and RV (3.27 ± 0.445 kg). This is likely due to the denser and less porous soil structure in CO, which, although heavier, can be disadvantageous in mechanized systems due to difficulties in handling, cutting, and transportation (He *et al.,* 2023). In contrast, lighter mats are advantageous for mechanical transplanting as they reduce operator effort and mechanical resistance during lifting and placement (Huang *et al.,* 2013).In addition, the proportion of the combination in the RV treatment appears well-suited to mechanical transplanting due to the fact that mixing rice husk ash + vermicompost in alluvial soils increases organic matter content, enriches nutrients, and improves soil structure and aggregation resulting in mat thickness close to 2 cm but has a light weight (Choudhary and Machavaram, 2023).

3.3. Rolling quality analysis in the transplantation stages

In rice nurseries, the rolling quality of the mats is a parameter in agricultural mechanisation especially in the efficient transport of the mats and proper placement in the seedling tray of transplanter.. Based on the results, the smallest roll diameter was observed in the V treatment (13.87 ± 1.097 cm), followed by CO (13.90 ± 0.173 cm), RV (13.97 ± 1.305 cm), and R (14.67 ± 0.577 cm) as shown in Figure 3. A smaller roll diameter facilitates easier handling, improves spatial efficiency during transport, and allows more seedling mats to be carried in a single trip (Haytham *et al.,* 2010). For mechanical transplanting systems, seedling mats must have a cohesive root structure that enables them to maintain integrity during rolling and unrolling.

The growing media plays a significant role in determining this rolling capacity. As reported by (Hossen *et al.,* 2018), the type of media affects not only the structural quality of the mat but also its suitability for being loaded into and fed through the seedling tray of a mechanized transplanter. As shown in Figure 4. the highest rolling quality—characterized by minimal cracking and full integrity—was achieved in the CO treatment, with a rolling score of 10, followed by V (9.3), R (8.0), and RV (6.7). These results emphasize that media composition directly influences mat flexibility, cohesion, and mechanical resilience.

The physical performance of the seedling mat—including its rollability, uniformity, and structural durability—is crucial for the efficiency of mechanized transplanting. A well-formed, high-quality mat minimizes seedling breakage and ensures uniform depth and spacing during transplanting. As mechanization becomes increasingly adopted in rice production systems, optimizing mat characteristics through precise soil mixture formulations becomes essential (Choudhary *et al.,* 2023).

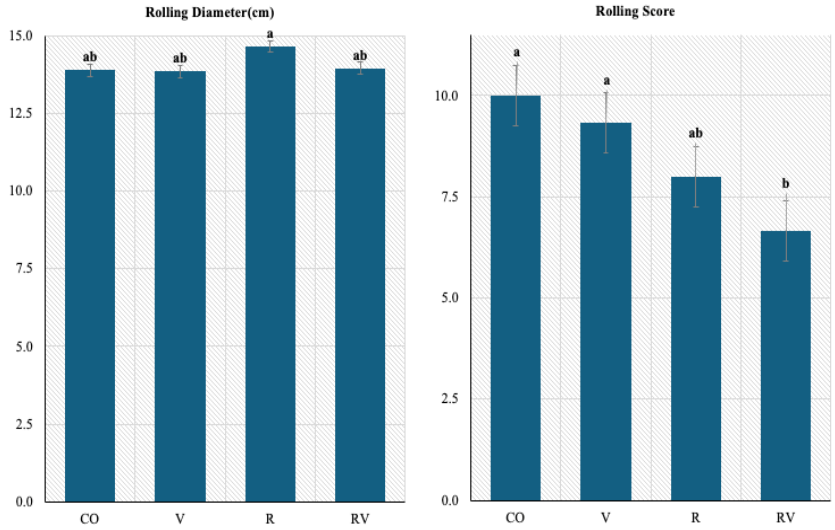

Figure 3. The effect of treatments on diameter and score of rolling mat

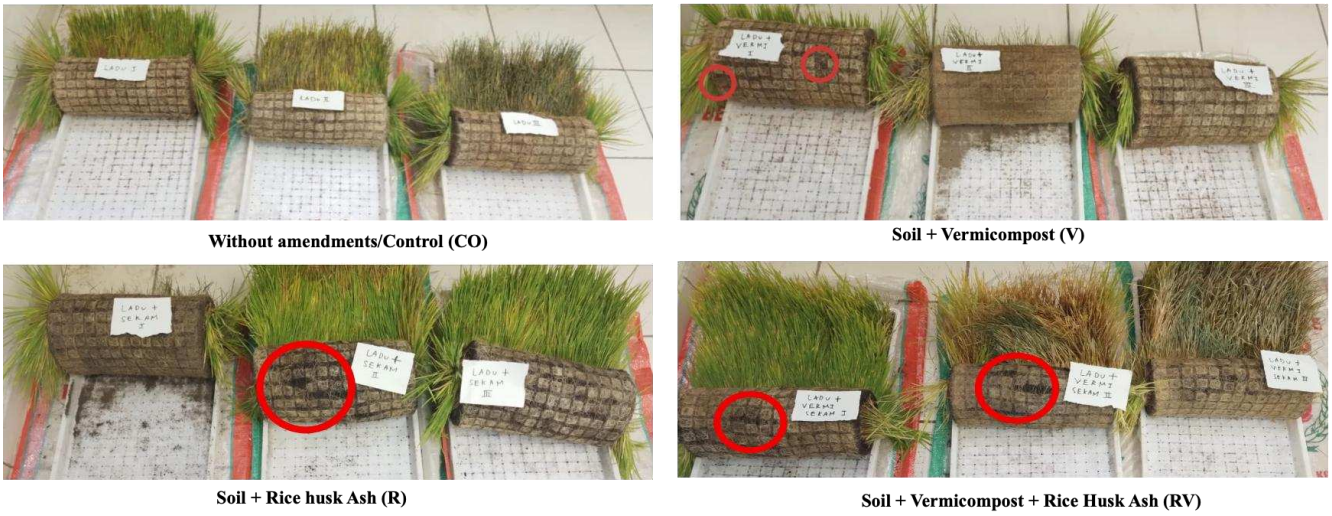

Figure 4. The measurement of rolling quality in the tray nursery

However, variability in mat consistency due to different organic amendments may require fine-tuning of transplanter settings such as tray pressure, feeder speed, and cutting mechanisms. Organic amendments such as rice husk ash, farmyard manure, and vermicompost have shown promise in improving mat structure, water retention, and root binding (Choudhary *et al.,* 2023; Patel *et al.,* 2024). These benefits contribute to enhanced transplanting efficiency, more sustainable nursery practices, and ultimately, increased crop establishment and yield potential.

4. Conclusion & Recommendations

This study demonstrates that rice seedling quality and the physical and structural properties of seedling mats are significantly influenced by the type of organic growing media applied during the nursery phase. These factors play a crucial role in the success of mechanized rice transplanting, which is increasingly being adopted in modern rice farming systems. The findings indicate that the use of organic growing media strongly affects both seedling and mat quality. For example, the RV treatment produced optimal growth up to 2 cm dan optimal thickness and lighter weight of mats, making them highly suitable for mechanical transplanting. This is attributed to rice husk ash enhancing structural rigidity and aeration, while vermicompost enriches the substrate with nutrients and microbial activity. However, when these amendments are applied individually, the results are less optimal—some treatments may improve seedling quality but not mat quality. Moreover, without organic amendments results in heavier mats and lower seedling quality, despite achieving high rolling scores. Overall, the findings highlight the

importance of balancing mechanical suitability with agronomic performance. The careful selection and combination of organic amendments can enhance seedling mat characteristics, support efficient mechanization, and promote sustainable nursery practices. The future research of this study will be focused on soil bio-chemical properties, growth and yield after transplanting in the paddy field.

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