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Optimizing Seedling Media for Tomato (*Lycopersicum esculentum* Mill.) Cultivation

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ABSTRACT

This study evaluates the growth performance and cost-effectiveness of six different seedling media for tomato (Lycopersicum esculentum Mill) cultivation: sand (M1), rice husk charcoal (M2), clay (M3), organic fertilizer (M4), clay-organic fertilizer (M5), and sand-organic fertilizer (M6). The experiment assessed plant height, number of leaves, and number of branches from 7 to 35 days after sowing (DAS). Results showed that media containing organic fertilizer (M4, M5, M6) significantly enhanced all growth parameters compared to non-organic treatments. Among these, M5 (clay-organic fertilizer) achieved the highest values for plant height (34.9 cm), number of leaves (15.5), and number of branches (5.5) at 35 DAS, indicating superior performance. However, cost analysis revealed that M5 also incurred the highest production cost. In contrast, M6 (sand-organic fertilizer) offered a more cost-effective option by providing strong growth performance at a lower cost. These findings highlight the importance of incorporating organic fertilizers into seedling media to improve early growth stages of tomato plants. The use of organic blends, particularly M6, presents a practical and sustainable solution for smallholder farmers aiming to maximize seedling vigor without incurring high input costs, ultimately supporting more efficient and eco-friendly agricultural practices.

1. Introduction

Tomato (*Lycopersicum esculentum Mill*) is a widely recognized and consumed plant worldwide. Its presence is essential in various culinary dishes, both as fresh fruit and processed products. Tomatoes are also popular as beverages, thus playing a significant role in the agricultural product trade market.

With the rapid population growth, the demand for tomato consumption continues to increase. Not only does the growing number of consumers drive this demand, but also losses in tomato processing contribute to the robust market. Apart from small-scale household consumers, large-scale tomato processors, such as sauce manufacturers, require substantial quantities of tomato paste. Additionally, advancements in transportation have significantly supported the widespread distribution of tomatoes (Kartika, Yusuf and Syakur, 2015).

One of the major challenges in meeting the demands of supermarkets and export markets is the discrepancy between the quality required by the market and the quantity produced (Lisanty *et al*., 2021). This quality gap often limits tomato producers, leading to the return of large quantities of tomatoes from the market due to substandard quality. To meet these quality standards, knowledge of cultivation practices, post-harvest processes, and marketing intricacies is crucial (Hamidi, 2017).

To support the successful cultivation of tomato plants, selecting an appropriate growing medium is vital, as it influences water availability, temperature, and the mechanisms of nutrient uptake (Indrawati, Indradewa and Utami, 2012). The ability of the growing medium to support good root development depends on the distribution of soil pore sizes and soil microorganism activity (Widiatmaka, Ardiansyah and Ambarwulan, 2012). Previous researches, including studies by Bui *et al*. (2015) and Junaidi & Moeljanto (2019), have primarily focused on the growing medium throughout the entire cultivation process but have often overlooked the critical role of the seedling medium. As the initial growth medium for tomato plants, the seedling medium is the first determinant of successful tomato cultivation. The addition of organic materials such as manure, rice husk charcoal, and sawdust can decrease particle density while increasing porosity, water availability, and drainage capacity (Kolo and Raharjo, 2016).

Therefore, research on seedling media is essential to understand the effects of different seedling media on the growth of tomato plants. The results of this study aim to provide valuable insights for tomato farmers in selecting the most appropriate seedling medium or the best composition of several media types for optimal results, cost-efficiency, and increased income. Good tomato cultivation practices, beginning with the selection of the best seedling medium, can lead to improvements not only in the quantity but also in the quality of the tomatoes produced.

Finally, the objective of this research is to evaluate the growth performance and cost-effectiveness of various seedling media on tomato plants, focusing on parameters such as plant height, number of leaves, and number of branches. This study aims to offer insights that are useful for tomato farmers and producers to enhance the quantity and quality of their tomato crops, thereby increasing their overall profitability.

Population growth in Bengkulu City has also resulted in agricultural land shrinking, which has decreased rice fields because landowners are building houses or buying and selling them. Narrow rice fields also result in poverty for rice farming workers. Workers such as rice farmers require large areas of rice fields, and large land areas will affect the income of rice farming workers in Bengkulu City.

The income of farm workers itself is a complex problem of poverty. The cause of poverty for farm workers is the uncertain income of farm workers, where it is known that working as a farm worker is a calling job. When agricultural workers do not receive a summons from the landowner on that day, the farm laborer does not get any income. Therefore, working as a summons worker causes the agricultural laborer's income to be uncertain, so they are said to be in the category of poor people.

Although numerous studies have examined poverty in the agricultural sector, most have focused on a monetary approach (Susilowati & Maulana, 2012; Angraini, 2023). However, research utilizing a multidimensional perspective to assess poverty among rice farm laborers remains limited. Additionally, the contributing factors to multidimensional poverty among rice farming households have not been fully explored within the local context, particularly in Bengkulu City. Given that Bengkulu Province is the second poorest province on Sumatra Island, rice farm laborer households in Bengkulu City are suspected to experience significant multidimensional poverty. Therefore, this study seeks to bridge this gap by employing MPI as the primary analytical method and identifying the determinants of multidimensional poverty among rice farming households in Bengkulu City.

This research is essential as it provides a more comprehensive insight into the factors contributing to multidimensional poverty in the agricultural sector. The findings of this study serve as a foundation for more effective policymaking to address poverty, not only by increasing income but also by improving access to education, healthcare, and decent living conditions. Furthermore, the results of this study are expected to serve as a reference for local governments and other stakeholders in designing evidence-based intervention strategies to reduce poverty among rice farm laborers. This study aims to (1) analyze the multidimensional poverty status of rice farm laborer households in Bengkulu City using the Multidimensional Poverty Index (MPI) and (2) identify the factors influencing multidimensional poverty, including work experience, land ownership, working days, education level, and household size.

2. Methodology

This study was conducted in the greenhouse of the Faculty of Agriculture, Universitas Kadiri, Kediri. The equipment used in the study included seedling boxes, sand sieves, sprayers, and 6 x 8 cm polybags. The materials involved hybrid tomato seeds (Permata F1 variety), organic fertilizer, sand, rice husk charcoal, clay, NPK Yaramila fertilizer, and white KNO3 fertilizer.

High-quality tomato seeds with a minimum germination rate of 80% were selected. Before sowing, the seeds underwent a priming process by soaking them in water for 10 minutes, followed by wrapping in newspaper or priming paper and exposure to lamp light for 24 hours. After priming, the seeds were transferred into polybags filled with seedling media. In contrast to Supriati & Siregar (2015), which recommends maintaining seedlings for approximately three weeks or until they develop three fully developed leaves before transplanting, tomato plants in this study were nurtured for 35 days after sowing (DAS) before transplanting.

The seedling media included sand (M1), rice husk charcoal (M2), clay (M3), organic fertilizer (M4), clay-organic fertilizer (M5), and sand-organic fertilizer (M6). Each medium underwent specific preparation steps to ensure sterility and suitability for seedling growth. Sand was sieved and washed to remove impurities like dirt, wood fragments, glass shards, and dried leaves. Rice husk charcoal was prepared by burning dry husks to charcoal, dousing it with water to extinguish, and then sieving to remove ash. Clay was dried, sieved to break clumps, and cleaned. Organic fertilizer, derived from fermented goat and chicken manure, was sieved to remove clumps and foreign materials.

Consistent care protocols were applied across all media types, including regular watering to maintain moisture without waterlogging, weed removal to prevent nutrient competition, and pest and disease management using safe practices. Additional liquid fertilization with solution of NPK and KNO3 supported seedling growth as needed. Temperature was controlled, with a maximum of 27°C, and humidity maintained at 60-70%. The seeding area, within a greenhouse, was shaded with netting reducing sunlight up to 80%. Nevertheless, plants received 5-6 hours of shaded sunlight daily: in the morning from 07:00-12:00 and in the afternoon from 14:00-15:00. This standardized care approach ensured that differences in seedling growth could be attributed to media types rather than care practice variations.

A Completely Randomized Design (CRD) was employed with a single factor (seedling media) comprising six treatments. Each treatment was replicated three times with ten plants per replicate, totaling 180 plants (6 x 3 x 10). Measurements of plant height (cm), leaf number, and branch count began at 7 DAS and were recorded at 7-day intervals, totaling five observations. Data were subjected to ANOVA (F-test) for variance analysis at significance levels of 5% and 1%. Significant F-test results (F-calculated ≥ F-table) prompted further pairwise mean comparisons using the Tukey post-hoc analysis at a 5% error rate.

3. Results and Discussion

The growth parameters of tomato plants from day 7 to day 35 after sowing (DAS) across various seedling media were presented in Table 1, 2, and 3 subsequently for plant height, number of leaves, and number of branches.

Table 1. Average Plant Height of Tomato Plants from 7 to 35 DAS

Seedling media	O1	O2	O3	O4	O5
M1	5.8[a]	12.4[a,b]	18.5[b]	23.2[b]	28.5[b]
M2	6.5[b]	13.5[b,c]	20.0[c]	25.0[c]	31.2[c]
M3	5.5[a]	11.5[a]	16.8[a]	22.0[a]	27.8[a]
M4	7.0[c]	14.5[b,c]	21.0[d]	27.5[e]	33.6[e]
M5	7.5[d]	15.0[c]	22.5[e]	29.5[f]	34.9[f]
M6	6.8[b,c]	14.0[b,c]	20.5[c,d]	26.0[d]	32.4[d]

Notes: M1 (sand); M2 (rice husk charcoal); M3 (clay); M4 (organic fertilizer); M5 (clay-organic fertilizer); M6 (sand-organic fertilizer). O1 (7 DAS); O2 (14 DAS); O3 (21 DAS); O4 (28 DAS); O5 (35 DAS). The notations (letters a-f) beside the numbers indicate the results of a Tukey post-hoc analysis, where the same letter within each column (DAS) signifies no significant difference in plant height between those media, while different letters indicate significant differences

Throughout the observation period, significant differences were observed in plant height among different seedling media. The highest plant heights were consistently recorded in media enriched with organic fertilizer, particularly in M5 (Clay-Organic Fertilizer) and M4 (Organic Fertilizer), reaching 34.9 cm and 33.6 cm respectively by day 35. Media with less organic content, such as M1 (Sand) and M3 (Clay), showed comparatively lower plant heights, indicating slower growth rates. Similarly, a Tukey post-hoc analysis indicates that M5 consistently shows the highest plant heights at each interval, with significant differences compared to other media, especially M3, which consistently shows the lowest heights. The notations indicate that the choice of seedling media significantly affects tomato plant height throughout the growing period. This aligns with existing agricultural studies that emphasize the role of organic nutrients in promoting robust plant growth (Gao *et al*., 2020; Ye *et al*., 2020). These studies indicate that organic fertilizers enhance soil fertility, improve nutrient uptake efficiency, and stimulate overall plant development, contributing to taller and healthier plants.

Table 2. Average Number of Leaves of Tomato Plants from 7 to 35 DAS

Seedling media	O1	O2	O3	O4	O5
M1	2.5^{b}	5.8^{b}	9.2^{b}	11.5^{b}	12.3^{b}
M2	2.8^{c}	6.5^{c}	10.5^{c}	12.8^{c}	13.5^{c}
M3	2.3^{a}	5.5^{a}	8.8^{a}	11.0^{a}	11.8^{a}
M4	3.0^{d}	7.0^{e}	11.0^{d}	13.8^{e}	14.2^{d}
M5	3.2^{e}	7.5^{f}	12.0^{f}	14.8^{f}	15.5^{f}
M6	$2.9^{c,d}$	6.8^{d}	10.8^{d}	13.5^{d}	14.8^{e}

Notes: M1 (sand); M2 (rice husk charcoal); M3 (clay); M4 (organic fertilizer); M5 (clay-organic fertilizer); M6 (sand-organic fertilizer). O1 (7 DAS); O2 (14 DAS); O3 (21 DAS); O4 (28 DAS); O5 (35 DAS).

Similar trends were noted in the number of leaves and branches as presented in Table 2 above and Table 3 below. Media supplemented with organic fertilizer consistently supported higher leaf and branch proliferation. A Tukey post-hoc analysis on the number of leaves indicates significant differences between media choices at various growth stages. M5 consistently shows the highest number of leaves, while M3 consistently shows the lowest. Similar notations (letters a-f) denote no significant differences between those media; different letters indicate significant differences. Meanwhile, a Tukey post-hoc analysis on the number of branches by 35 DAS, M3 remains the lowest, while M1 and M5 have the highest branch counts. The consistent pattern indicates that M5 generally results in the highest number of branches, whereas M3 results in the lowest, demonstrating a significant effect of seedling media on branch development over time.

Therefore, the choice of seedling media significantly affects the number of leaves throughout the growing period, with M5 performing best and M3 the least favorable. This phenomenon can be attributed to the balanced nutrient composition and microbial activity fostered by organic fertilizers, which facilitate enhanced photosynthesis and biomass accumulation (Shah and Wu, 2019; Barsha *et al*., 2021; Sani and Yong, 2022).

Table 3. Average Number of Branches of Tomato Plants from 7 to 35 DAS

Seedling media	O1	O2	O3	O4	O5
M1	1.8^{b}	3.2^{b}	4.5^{b}	5.0^{b}	5.5^{d}
M2	$2.0^{b,c}$	3.5^{c}	5.0^{c}	5.5^{c}	4.8^{b}
M3	1.5^{a}	2.8^{a}	3.8^{a}	4.0^{a}	3.9^{a}
M4	$2.2^{c,d}$	4.0^{d}	5.5^{d}	6.0^{d}	5.1^{c}
M5	2.5^{e}	4.5^{e}	6.0^{e}	6.5^{e}	5.5^{d}
M6	$2.3^{d,e}$	4.2^{d}	5.8^{e}	$6.2^{d,e}$	$5.0^{b,c}$

Notes: M1 (sand); M2 (rice husk charcoal); M3 (clay); M4 (organic fertilizer); M5 (clay-organic fertilizer); M6 (sand-organic fertilizer). O1 (7 DAS); O2 (14 DAS); O3 (21 DAS); O4 (28 DAS); O5 (35 DAS).

Based on these findings, M5 (Clay-Organic Fertilizer) demonstrated superior performance in promoting tomato plant growth, including height, leaf number, and branch development. This is likely due to the combined benefits of clay's water retention and organic fertilizer's nutrient supply, supporting robust vegetative growth (Widjajanto, Rahman and Zainuddin, 2021; Alhassan *et al.*, 2023). Studies by Bonanomi *et al*. (2020); Celestina *et al*. (2019); and Thomas *et al*. (2019) have consistently report superior growth outcomes and yield increases in crops treated with organic amendments compared to conventional methods.

While M5 showed the best growth results, its production cost should be considered against the expected yield increase.

To evaluate the economic viability of each seedling medium, production costs were considered, encompassing seed procurement, polybag expenses, and medium preparation costs. The cost comparison, presented in Table 4, underscores the higher initial investment associated with organic-based media (M4, M5, M6) compared to mineral-based alternatives (M1, M2, M3). Despite these higher costs, the improved growth metrics observed in organic-based media justify the expenditure, potentially leading to higher yields and profitability over the crop cycle.

Table 4. Cost Comparison (in IDR) per plant of Different Seedling Media

Seedling media	Cost	Notes
M1	300	Low cost, includes seed cost, polybag, sand
M2	500	Moderate cost, includes seed cost, polybag, charcoal
M3	400	Low to moderate cost, includes seed cost, polybag, clay
M4	800	Higher cost, includes seed cost, polybag, organic fertilizer
M5	1000	Higher cost, includes seed cost, polybag, clay, organic fertilizer
M6	600	Moderate cost, includes seed cost, polybag, sand, organic fertilizer

Notes: Cost per plant includes expenses for tomato seeds, polybags, and the respective seedling media. Seed cost is standardized across all treatments. Polybag cost is uniform for all media types. Maintenance cost not included explicitly in this table, but typically involves ongoing expenses such as water, nutrients, labor, and pest control.

The cost comparison reveals M1 (Sand) and M3 (Clay) are the least expensive options, suitable for growers aiming to minimize initial investment. M4 (Organic Fertilizer) and M5 (Clay-Organic Fertilizer) incur higher costs due to the procurement and preparation of organic materials, with M5 being the most expensive but also showing superior growth results. Based on the growth parameters and cost comparison, media containing organic fertilizer (M4, M5, M6) consistently showed superior growth performance in terms of height, number of leaves, and number of branches. Despite the higher production costs associated with organic fertilizer, the enhanced growth metrics justify the investment, potentially leading to higher yields and overall profitability. The findings from Khairi *et al*. (2023) and Verma *et al*. (2020) validate the higher initial costs of organic-based media by demonstrating enhanced nutrient availability, soil structure improvement, and pest resistance, all of which contribute to sustainable agricultural practices and long-term profitability.

For farmers seeking a balance between cost-effectiveness and optimal growth, M6 (Sand-Organic Fertilizer) emerges as a viable option. It offers a moderate production cost compared to M5 (Clay-Organic Fertilizer), while still providing satisfactory growth results. By using a blend of sand and organic fertilizer, growers can benefit from improved nutrient availability and root development without significantly increasing production expenses. Growers may consider factors such as growth performance, resource availability, and long-term benefits when selecting the optimal seedling medium for tomato cultivation. The recommendation aligns with studies advocating for integrated nutrient management strategies that combine organic and inorganic inputs to maximize resource efficiency and crop productivity (Selim, 2020; Kushwah *et al.*, 2023).

4. Conclusion

This study aimed to evaluate the growth performance and cost-effectiveness of various seedling media for tomato cultivation, focusing on plant height, number of leaves, and number of branches. Six different seedling media were tested: sand (M1), rice husk charcoal (M2), clay (M3), organic fertilizer (M4), clay-organic fertilizer (M5), and sand-organic fertilizer (M6). The experiment monitored the growth parameters from day 7 to day 35 after sowing, revealing that organic fertilizer-enriched media (M4, M5, M6) consistently outperformed others in promoting robust plant growth. M5 (Clay-Organic Fertilizer) showed the highest growth metrics, but at a higher production cost. Cost analysis highlighted that M6 (Sand-Organic Fertilizer) offers a balanced approach, combining moderate cost with satisfactory growth outcomes, making it a viable option for farmers seeking both cost-efficiency and optimal plant development. These findings suggest that integrating organic fertilizers, especially in blends like M6, can enhance tomato seedling growth while managing production costs, aligning with sustainable agricultural practices.

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