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Original Research Article

Reclamation of Former Brick Mining Lands: Enhancing Oil Palm Growth Using Goat Manure and Rice Husk Charcoal

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Abstract

This study focuses on the impact of goat manure and rice husk charcoal distribution on oil palm cultivation in former mining lands. The objective is to determine the optimal combination of goat manure and rice husk charcoal that enhances the growth of oil palm plants on these lands. Conducted in Pijoan Village, Muaro Jambi District, Jambi Province in 2021, the research utilized a completely randomized block design with 8 treatments and 3 repetitions, yielding 24 experimental units. The eight treatments consisted of varying ratios of goat manure to rice husk charcoal: (P1) 150 g goat manure + 325 g rice husk charcoal per planting hole, through (P8) 325 g goat manure + 150 g rice husk charcoal per planting hole. Results indicated that the combination of 325 g goat manure + 150 g rice husk charcoal (P8) provided the best outcomes in plant height, stem diameter, leaf balance at the third frond, and total frond count on reclaimed land.

Keywords: Rice husk charcoal; coal mining; environment; goat manure; organic fertilizer; reclamation; oil palm

1. Introduction

Indonesia, endowed with abundant mineral resources, has long capitalized on extractive industries to support national economic development. However, mining activities—particularly those involving brick clay extraction—have resulted in severe environmental degradation. Former brick mining sites are typically left with severely altered soil profiles, characterized by the removal of topsoil, diminished organic matter, and depletion of essential nutrients, which collectively render the land compacted, infertile, and difficult to rehabilitate (Feng et al., 2019; Gabarrón et al., 2019). Unlike coal mining, which has been the subject of numerous rehabilitation studies, brick mining specifically targets clay and leaves behind shallow pits with high compaction and poor drainage, making natural vegetation regrowth and land reclamation especially challenging.

Restoring the ecological functionality and agricultural potential of such degraded lands requires the implementation of effective reclamation strategies. Among these, the application of organic soil amendments has gained attention for their ability to enhance the physical, chemical, and biological properties of damaged soils (Dhaliwal et al., 2019). Organic inputs such as goat manure and rice husk charcoal have demonstrated promising effects on soil structure improvement, nutrient cycling, and stimulation of beneficial microbial activity. These materials not only alleviate soil compaction but also

enhance water retention capacity, buffer pH levels, and contribute essential macronutrients that are vital for plant growth (Wang et al., 2023).

Despite increasing awareness of sustainable land rehabilitation methods, there remains a paucity of research focused specifically on the reclamation of former brick mining sites. Existing literature tends to extrapolate findings from coal mining rehabilitation, often overlooking the unique characteristics of clay-extracted landscapes, which typically exhibit more acidic conditions and greater soil density (Pratiwi et al., 2021). This gap underscores the need for site-specific investigations that consider the distinct limitations and potential of brick mining areas.

This study aims to address that gap by evaluating the synergistic use of goat manure and rice husk charcoal as low-cost, locally available amendments for improving soil health and supporting oil palm (Elaeis guineensis) cultivation on former brick mining lands. The specific objectives are: (1) to determine the optimal combination of goat manure and rice husk charcoal that maximizes oil palm growth, (2) to assess the impact of these amendments on plant growth parameters such as height, stem diameter, and frond development, and (3) to evaluate their contribution to improving soil fertility and promoting sustainable agricultural practices. The outcomes of this study are expected to offer practical, scalable insights into organic-based reclamation approaches for underutilized post-mining lands in tropical regions.

2. Methods

2.1. Materials

This study was conducted in Pijoan Village, Muaro Jambi District, Jambi Province, in 2021. The materials used included oil palm plants, goat manure, rice husk charcoal, water, and soil from a former coal mining site. Tools employed in the research were shovels, measuring instruments, callipers, writing equipment, cameras, paper, and a measuring tape. The soil nutrient content before the experiment (four weeks prior to planting) was as follows: pH H_2O (5.41; acidic), organic C (0.16%; very low), N (0.36%; medium), and C/N ratio (0.44; very low). The nutrient content of goat manure was: organic C (40.0%), total N (9.09%), C/N ratio (4.4), P (0.014%), and K (0.223%).

2.2. Data Collection and Data Analysis

The research was structured using a completely randomized block design (RCBD) with 8 treatments and 3 replications, resulting in 24 experimental units. Each experimental unit (plot) was planted with 3 oil palm seedlings, totalling 72 plants. Plants were spaced 9 m x 9 m apart in a triangular pattern, covering an area of 121.5 m^2. The treatments consisted of combinations of goat manure and rice husk charcoal, as follows:

P1: 150 g goat manure + 325 g rice husk charcoal per planting hole;
P2: 175 g goat manure + 300 g rice husk charcoal per planting hole;
P3: 200 g goat manure + 275 g rice husk charcoal per planting hole;
P4: 225 g goat manure + 250 g rice husk charcoal per planting hole;
P5: 250 g goat manure + 225 g rice husk charcoal per planting hole;
P6: 275 g goat manure + 200 g rice husk charcoal per planting hole;
P7: 300 g goat manure + 175 g rice husk charcoal per planting hole;
P8: 325 g goat manure + 150 g rice husk charcoal per planting hole.

Planting holes measured 30 cm x 30 cm x 30 cm (length x width x height). A basic fertilizer mix (20 g of NPK Phonska) was initially mixed with the topsoil in each planting hole. One week later, goat manure and rice husk charcoal were applied to the planting holes according to the treatment dosages. Seedlings, sourced from Marihat, North Sumatra Province were planted one week after treatment application. The variables observed included plant height, stem diameter leaf balance on the third frond, and total number of fronds. Observations were made when the plants were 6, 7, 8, and 9 months after

planting (MAP). Data collected were tabulated and analyzed for variance using the F-test, and significant differences were further analyzed using Tukey's HSD at the 5% level.

3. Result and Discussion

3.1. Plant Height

The application of goat manure and rice husk charcoal at varying doses had a significant impact on oil palm plant height. The data presented in Table 1 indicate that different treatment combinations influenced plant growth, with higher proportions of goat manure generally contributing to greater plant height. Among the eight treatments, P8 (325 g goat manure + 150 g rice husk charcoal per planting hole) yielded the highest mean plant height of 282.83 cm at 9 MAP. This result was significantly different from treatments P1 through P5, indicating a clear trend where increased goat manure application improved plant growth.

The incremental growth pattern over time is visually represented in Figure 1, which illustrates plant height measurements recorded at 6, 7, 8, and 9 MAP. The data reveal a progressive increase in height across all treatments, with P8 consistently outperforming other combinations throughout the observation period. In contrast, P1 (150 g goat manure + 325 g rice husk charcoal) exhibited the lowest growth, suggesting that excessive rice husk charcoal without sufficient goat manure may limit nutrient availability for optimal plant development.

The enhanced plant height in P8 can be attributed to the higher nitrogen, phosphorus, and potassium contentprovided by goat manure, which supports robust vegetative growth. Additionally, the presence of rice husk charcoal in the appropriate proportion likely improved soil aeration and water retention, creating favorable conditions for root expansion and nutrient uptake. These findings align with previous studies that emphasize the role of organic amendments in enhancing soil fertility and plant performance in degraded soils

Table 1. Oil palm plant height after application of goat manure and rice husk charcoal at various doses at 9 MAP

Treatment	Plant Height
P1	150 g goat manure + 325 g rice husk charcoal per planting hole
P2	175 g goat manure + 300 g rice husk charcoal per planting hole
P3	200 g goat manure + 275 g rice husk charcoal per planting hole
P4	225 g goat manure + 250 g rice husk charcoal per planting hole
P5	250 g goat manure + 225 g rice husk charcoal per planting hole
P6	275 g goat manure + 200 g rice husk charcoal per planting hole
P7	300 g goat manure + 175 g rice husk charcoal per planting hole
P8	325 g goat manure + 150 g rice husk charcoal per planting hole

The observed increase in plant height over time, as shown in Figure 1, suggests that a balanced ratio of organic fertilizers can effectively improve plant vigor in reclaimed post-mining soils. Notably, the trend observed in this study highlights the importance of optimizing amendment combinations rather than relying solely on one organic input. Excessive application of rice husk charcoal, as seen in P1, may negatively impact plant growth due to its high carbon content, which can induce nitrogen immobilization, thereby limiting nutrient availability

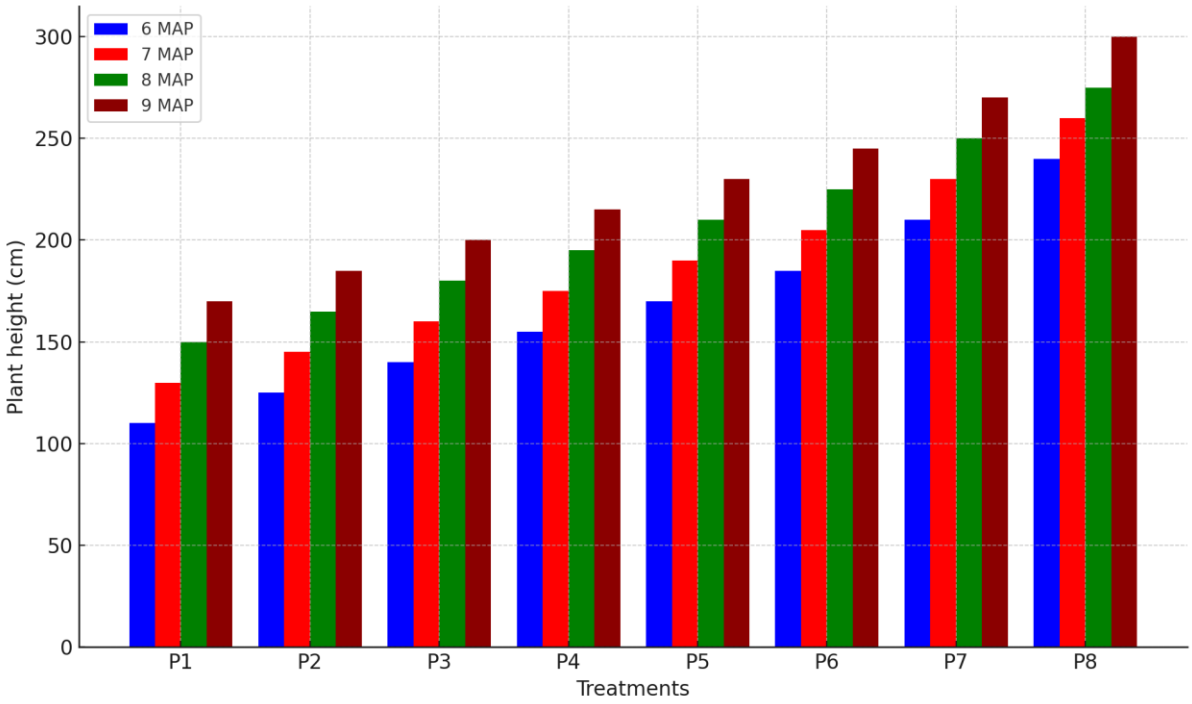

Figure 1. Influence of goat manure and rice husk charcoal dosage combinations on the height of oil palm plants at 6, 7, 8, and 9 months after planting (MAP)

3.2. Stem Diameter

The application of goat manure and rice husk charcoal at varying doses significantly influenced the stem diameter of oil palm plants. The data presented in Table 2 indicate that different treatment combinations impacted stem thickening, with higher proportions of goat manure contributing to increased stem diameter. Among the eight treatments, P8 (325 g goat manure + 150 g rice husk charcoal per planting hole) exhibited the greatest stem diameter, averaging 97.83 cm at 9 MAP. This value was significantly different from treatments P1 through P4, while treatments P5, P6, and P7 showed no statistically significant differences from P8.

The progressive increase in stem diameter across all treatments over time is visually represented in Figure 2, which illustrates the measurements recorded at 6, 7, 8, and 9 MAP. The data reveal a steady increase in stem girth with increasing goat manure application, with P8 consistently showing the highest values throughout the observation period. Conversely, P1 (150 g goat manure + 325 g rice husk charcoal per planting hole) exhibited the smallest stem diameter, highlighting the limited contribution of excessive rice husk charcoal without sufficient nutrient-rich manure.

The enhanced stem development observed in P8 is likely attributed to the nutrient-dense composition of goat manure, which provides essential macronutrients such as nitrogen, phosphorus, and potassium—critical for cell division, vascular tissue formation, and overall structural integrity. Additionally, rice husk charcoal contributed to improving soil porosity and aeration, facilitating root expansion and nutrient uptake, which are vital for supporting robust stem growth

Table 2. Stem diameter of oil palm plants after application of goat manure and rice husk charcoal at various doses at 9 MAP

Treatment	Stem Diameter
P1	47.67a
P2	48.00a
P3	59.00b

P4	69.67b
P5	78.33b
P6	78.33b
P7	88.67c
P8	97.83d

As depicted in Figure 2, the trend of progressive stem thickening highlights the role of organic amendments in improving plant structure and resilience. The increasing stem diameter observed in treatments with higher goat manure proportions suggests that nitrogen and phosphorus availability played a pivotal role in enhancing vascular tissue development and carbohydrate translocation. This aligns with previous findings that organic amendments contribute to the strengthening of plant stems by promoting robust nutrient circulation and mechanical stability

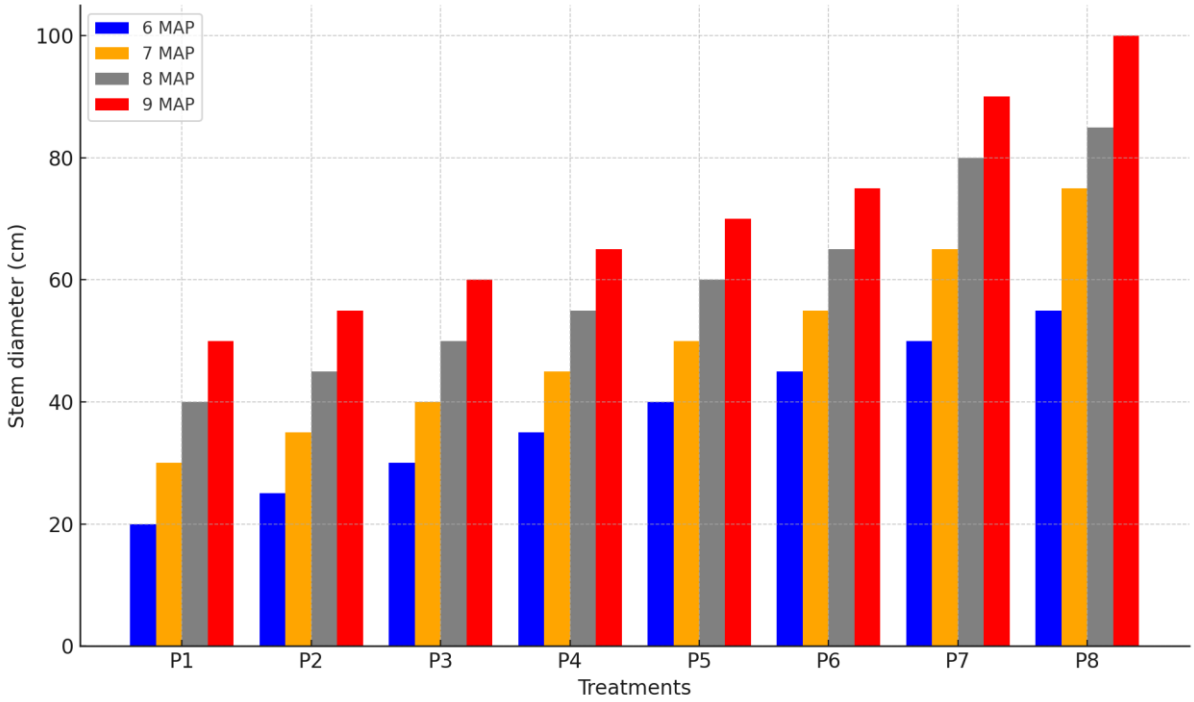

Figure 2. Effect of goat manure and rice husk charcoal dosage combinations on the stem diameter of oil palm plants at 6, 7, 8, and 9 months after planting (MAP).

3.4. Total Number of Fronds

The application of goat manure and rice husk charcoal at different doses significantly influenced the total number of fronds in oil palm plants. Table 4 presents the frond count across the eight treatment combinations, revealing that higher proportions of goat manure generally promoted greater frond production. Among the treatments, P8 (325 g goat manure + 150 g rice husk charcoal per planting hole) recorded the highest frond count at 13.17, which was significantly greater than all other treatments.

The incremental frond growth trend over time is depicted in Figure 3, which illustrates frond production at 6, 7, 8, and 9 MAP. The data demonstrate a steady increase in the number of fronds across all treatments, with P8 consistently outperforming the other treatment combinations throughout the experimental period. In contrast, P2 (7.50 fronds) and P3 (7.67 fronds) showed the lowest numbers, suggesting that insufficient goat manure application limits vegetative expansion.

The enhanced frond production in P8 can be attributed to the high nitrogen content in goat manure, which plays a crucial role in chlorophyll synthesis and photosynthetic efficiency—key factors influencing leaf development. Additionally, the improved soil aeration and moisture retention provided by rice husk charcoal likely contributed to optimal root development and nutrient uptake, further supporting increased frond production

Table 4. Total number of fronds after application of goat manure and rice husk charcoal at various doses at 9 MAP.

Treatment	Number of Fronds
P1	8.00a
P2	7.50a
P3	7.67a
P4	8.67ab
P5	8.67ab
P6	8.83ab
P7	10.33b
P8	13.17c

As depicted in Figure 3, the steady increase in frond count across all treatments reinforces the positive role of organic amendments in improving plant vigor. Notably, the trend suggests that an excessive proportion of rice husk charcoal (e.g., P1 and P2) may hinder optimal nitrogen availability, potentially due to nitrogen immobilization caused by high carbon content (Pratiwi et al., 2021). Conversely, the balanced ratio in P8 provided the most favorable conditions for sustained frond growth. These findings emphasize the importance of an optimized ratio of goat manure to rice husk charcoal in enhancing oil palm frond development in reclaimed brick mining soils. The increased frond production observed in P8 highlights the potential of organic amendments in improving biomass accumulation, which is essential for long-term productivity and carbon sequestration in rehabilitated post-mining landscapes.

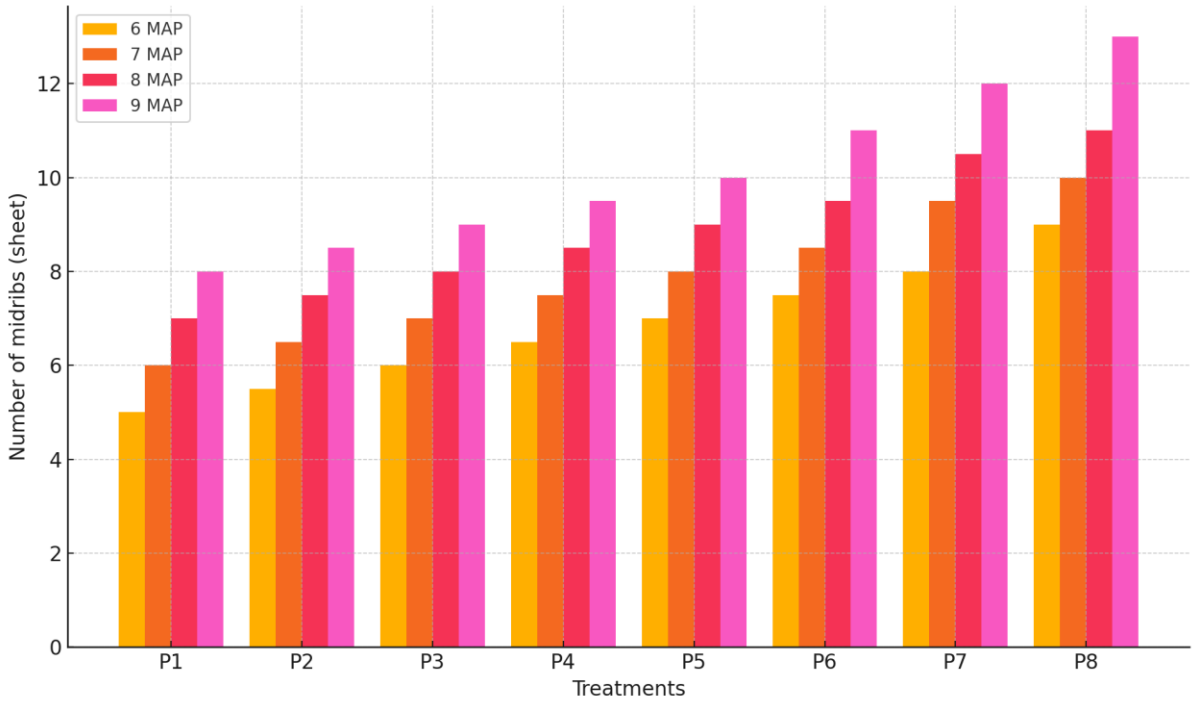

Figure 3. Impact of goat manure and rice husk charcoal dosage combinations on the number of fronds (leaves) of oil palm plants at 6, 7, 8, and 9 months after planting (MAP).

4. Discussion

The application of organic amendments, particularly goat manure and rice husk charcoal, has proven to be a highly effective strategy for rehabilitating degraded soils. These soils, especially those impacted by open-pit mining, often suffer from severe physical disruption, nutrient depletion, and chemical imbalances that make them unfit for sustained plant growth. Open-pit mining exposes subsoil

layers that are generally low in organic matter, have poor water retention, and are prone to compaction, all of which hinder the establishment of vegetation. The combined use of goat manure and rice husk charcoal represents an environmentally sustainable and efficient approach to address these challenges.

In the study, the application of goat manure and rice husk charcoal significantly enhanced plant growth parameters, including plant height, stem diameter, and total number of fronds. These parameters are critical indicators of plant health and productivity. Treatment P8, which achieved the highest plant height of 282.83 cm, demonstrated the optimal balance of nutrients and improved soil conditions resulting from the amendments (Haryuni et al., 2022).

Plant height, as a key measure of vegetative growth, is directly influenced by nutrient availability and soil structure. Goat manure, a rich source of nitrogen, phosphorus, and potassium, contributes essential nutrients for chlorophyll synthesis and photosynthesis, which drive vertical growth. The rice husk charcoal complements this by enhancing the soil's water-holding capacity, ensuring that plants receive consistent moisture levels critical for cell elongation and metabolic processes (Rahmaniah and Azwana, 2023). This synergy highlights the importance of integrating organic amendments to achieve sustainable soil fertility and plant growth.

Similarly, the observed improvements in stem diameter under Treatment P8 underscore the structural benefits provided by these amendments. A robust stem ensures the development of a strong vascular system for nutrient and water translocation. Phosphorus, supplied abundantly by goat manure, supports energy transfer and structural integrity, while potassium helps regulate water uptake and maintain turgor pressure. These nutrients are crucial for developing thicker and more resilient stems capable of withstanding environmental stressors (Kharisun et al., 2019).

The total number of fronds, indicative of the plant's photosynthetic capacity, also increased significantly with the application of these amendments. The production of additional fronds is directly related to the plant's ability to synthesize chlorophyll, a process heavily reliant on nitrogen and magnesium. These nutrients, supplied by goat manure and facilitated by the enhanced aeration provided by rice husk charcoal, enable efficient nutrient absorption and root expansion (Mishra et al., 2017). Together, these factors promote vigorous foliage growth, improving the plant's photosynthetic efficiency and productivity.

The transformative effects of goat manure and rice husk charcoal on soil properties are pivotal to understanding their role in restoring degraded soils. Goat manure is a nutrient-rich organic amendment containing macronutrients (N, P, K) and organic carbon that enhances soil fertility. It provides a steady nutrient supply while promoting microbial activity, essential for organic matter decomposition and the conversion of nutrients into plant-available forms. The microorganisms involved in this process also produce compounds that improve soil structure by enhancing soil aggregation and porosity (Suyanto et al., 2023).

Rice husk charcoal, on the other hand, acts as a physical and chemical enhancer for soils. It improves porosity, which facilitates better air and water movement, and increases the cation exchange capacity, allowing the soil to retain and supply nutrients more effectively. The biochar-like properties of rice husk charcoal make it an excellent agent for long-term soil improvement, as it remains stable and resistant to decomposition over time. This stability ensures that nutrients remain available to plants, reducing the need for frequent fertilization and contributing to the sustainability of agricultural systems (Supriyadi et al., 2022).

The combination of goat manure and rice husk charcoal also addresses soil acidity, a common problem in degraded soils. Organic amendments help buffer soil pH, mitigating the effects of acidity or alkalinity, and thereby increasing the availability of essential nutrients such as phosphorus and potassium (Fitriana et al., 2020). This buffering capacity, coupled with improved soil aggregation and water retention, creates an environment conducive to root development and plant growth.

The implications of these findings extend beyond individual plant growth parameters to the broader field of land restoration. Post-mining soils are often characterized by poor fertility, low organic matter content,

and compacted structures that impede root penetration. The application of organic amendments such as goat manure and rice husk charcoal provide a holistic solution to these challenges. By improving both the chemical and physical properties of the soil, these amendments create a favourable environment for vegetation establishment and growth, an essential step in ecosystem restoration (Steiner et al., 2007).
These amendments also enhance soil resilience to environmental stressors such as drought and nutrient leaching. The water-holding capacity provided by rice husk charcoal ensures that plants have access to moisture even during dry periods, reducing the risk of water stress. Moreover, the nutrient retention capabilities of goat manure and rice husk charcoal minimize losses due to leaching, ensuring that nutrients remain available to plants over extended periods (Koyama and Hayashi, 2017).

The use of goat manure and rice husk charcoal also aligns with the principles of sustainable agriculture and a circular economy. By recycling agricultural waste into valuable soil conditioners, these practices reduce reliance on synthetic fertilizers, which are energy-intensive to produce and contribute to greenhouse gas emissions. Improved soil fertility reduces the need for external inputs, lowering the environmental footprint of agricultural practices. Additionally, the long-term benefits of these amendments, such as increased organic carbon levels and enhanced microbial activity, support the natural nutrient cycling processes critical for sustainable land management (Kharisun et al., 2019).
Economically, the use of locally available organic materials such as goat manure and rice husk charcoal can significantly reduce input costs for farmers, particularly in resource-constrained settings. These amendments not only improve crop yields but also enhance soil health, providing long-term benefits that outweigh the initial investment. This makes them an attractive option for smallholder farmers and large-scale agricultural operations alike.

While the benefits of goat manure and rice husk charcoal are well-documented, certain limitations warrant further investigation. For instance, the long-term effects of these amendments on soil health and productivity need to be evaluated to establish their sustainability. Additionally, potential environmental impacts, such as greenhouse gas emissions during the decomposition of organic materials, should be carefully monitored. Future research could explore the integration of these amendments with other soil restoration strategies, such as the use of cover crops, compost, or advanced biochars, to further enhance their efficacy (Haryuni et al., 2022). Moreover, site-specific conditions such as soil type, climate, and cropping systems must be considered to optimize the application rates and combinations of these amendments. Tailoring these practices to local contexts will maximize their benefits and ensure their successful adoption.

5. Conclusion

The application of goat manure in combination with rice husk charcoal has markedly influenced plant growth parameters, including stem diameter, leaf arrangement on the third frond, and the overall frond count. Specifically, the treatment involving 325 grams of goat manure mixed with 150 grams of rice husk charcoal (P8) demonstrated substantial improvements in plant height, stem robustness, and foliar development in areas previously subjected to mining. These findings underscore the transformative impact of this organic mixture on vegetation rehabilitation in degraded lands. Given the positive outcomes observed, it is imperative that further research be conducted to explore the long-term effects and sustainability of using goat manure and rice husk charcoal on oil palm plants. Future studies should aim to expand the experimental scope to multiple growth cycles and varying environmental conditions to validate and potentially optimize the restorative benefits of these treatments. Thus, this research highlights the promising potential of integrating goat manure and rice husk charcoal into land rehabilitation strategies, particularly in post-mining landscapes. Continued investigation will be crucial in establishing robust, scalable methods for ecological restoration and enhancing agricultural productivity in compromised soils.

References

Agus, C., Primananda, E., Faridah, E., Wulandari, D., dan Lestari, T. 2019. Role of arbuscular mycorrhizal fungi and Pongamia pinnata for revegetation of tropical open-pit coal mining soils. International Journal of Environmental Science and Technology, 16, 3365–3374.

Feng, Y., Wang, J., Bai, Z., dan Reading, L. 2019. Effects of surface coal mining and land reclamation on soil properties: a review. Earth-Science Reviews, 191, 12–25.

Fitriana, M., Sodikin, E., dan Sulaiman, F. 2020. The use of oil palm empty fruit bunches compost, rice husk charcoal and chicken manure to reduce npk fertilizer doses on the growth and yield of cauliflower (brassica oleraceae var. botrytis l.). RJOAS, 98, 161–165.

Wibowo, Y. G., Safitri, H., Khairurrijal, K., Taher, T., Ode Arham, L., Jarwinda, J., Akbari Danasla, M., Fadhilah, R., Kharisma Army, E., Zul Hakim, H., Tawfiequrahman Yuliansyah, A., dan Tri Bayu Murti Petrus, H. 2024. Recent advances in acid mine drainage treatment through hybrid technology: comprehensive review of scientific literature. Environmental Nanotechnology, Monitoring & Management, 21, 100945.

Haryuni, H., Amin, M., Suprapti, E., Dewi, T. S. K., dan Hartoyo, E. 2022. Proline reduction and increasing growth of vanilla plants induced by BNR fungus with dose of goat manure and husk charcoal. Jurnal Bioedukasi, 14, 82–89.

Kharisun, Fadillah, Mujiono, dan Suciati. 2019. Composition of planting media and biological agents to improve physical and chemical properties of soil. IOP Conference Series: Earth and Environmental Science, 250, 012099.

Koyama, S., dan Hayashi, H. 2017. Rice yield and soil carbon dynamics over three years of applying rice husk charcoal to an Andosol paddy field. Plant Production Science, 20, 176–182.

Mishra, A., Taing, K., Hall, M. W., dan Shinogi, Y. 2017. Effects of rice husk and rice husk charcoal on soil physicochemical properties, rice growth and yield. Agricultural Science, 8, 1014–1032.

Pratiwi, Narendra, B. H., Siregar, C. A., Turjaman, M., Hidayat, A., Rachmat, H. H., Mulyanto, B., Suwardi, Iskandar, Maharani, R., Rayadin, Y., Prayudyaningsih, R., Yuwati, T. W., Prematuri, R., dan Susilowati, A. 2021. Managing and reforesting degraded post-mining landscape in Indonesia: a review. Land, 10, 658.

Rahmaniah, R., dan Azwana, A. 2023. The effects of rice husk ash and goat manure application on the growth of mustard plants (brassica juncea l.) varieties tosakan. CJMS, 3, 304–312.

Ramadan, B. S., Wulandari, M., Wibowo, Y. G., Ikhlas, N., dan Nurseta, D. Y. 2021. Removing ionic and nonionic pollutants from soil, sludge, and sediment using ultrasound-assisted electrokinetic treatment. Dalam Ribeiro, A. B., dan Vara Prasad, M. N. (Eds.), Electrokinetic Remediation for Environmental Security and Sustainability. Wiley, halaman 653–677.

Setiawan, A. 2022. Potensi cadangan mineral dan batubara di Indonesia dan dunia. Jurusan Teknik Pertambangan Program Studi S1 Teknik Pertambangan Universitas Papua, 1, 20–31.

Singhal, R. K. 2022. Geotechnical stability in surface mining: proceedings of the International Symposium on Geotechnical Stability in Surface Mining, Calgary, 6-7 November 1986. CRC Press, Leiden, Netherlands.

Steiner, C., Teixeira, W. G., Lehmann, J., Nehls, T., De Macêdo, J. L. V., Blum, W. E. H., dan Zech, W. 2007. Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. Plant and Soil, 291, 275–290.

Supriyadi, S., Widjajani, B. W., dan Murniyanto, E. 2022. The effect of rice husk biochar and cow manure on some soil characteristics, N and P uptake and plant growth of soybean in Alfisol. Jurnal Tanah Tropika, 27, 59.

Suyanto, A., Rahayu, S., Irianti, A. T. P., dan Suryani, R. 2023. The use of rice harvest residue as soil amendment for growth and yield of rice (oryza sativa l.) on acid sulfate soil. Jurnal Teknologi Lingkungan Lahan Basah, 12, 968.

Wibowo, Y. G., Imron, M. F., Kurniawan, S. B., Ramadan, B. S., Taher, T., Sudibya, A. H., Syarifuddin, H., Khairurrijal, K., dan Jarwinda, J. 2023a. Emerging strategies for mitigating acid mine drainage formation and environmental impacts: a comprehensive review of recent advances. Science and Technology Indonesia, 8, 516–541.

Wibowo, Y. G., Lululangin, B. R. G., Safitri, H., Rohman, A., Sudibyo, Priyanto, S., Syarifuddin, H., Tatik Maryani, A., Tawfiqurahman Yuliansyah, A., Kurniawan, A., Nur'ani, H., Tsabitah, N., Taher, T., dan Petrus, H. T. B. M. 2023b. Rapid and highly efficient adsorption of dye and heavy metal on low-cost adsorbent derived from human feces and Chlorella vulgaris. Environmental Nanotechnology, Monitoring & Management, 20, 100905.

Wibowo, Y. G., Safitri, H., Malik, I. B. I., Sudibyo, dan Priyanto, S. 2022a. Alternative low-cost treatment for real acid mine drainage: performance, bioaccumulation, translocation, economic, post-harvest, and bibliometric analyses. Sustainability, 14, 15404.

Wibowo, Y. G., Sudibyo, Naswir, M., dan Ramadan, B. S. 2022b. Performance of a novel biochar-clamshell composite for real acid mine drainage treatment. Bioresource Technology Reports, 17, 100993.

Wibowo, Y. G., Taher, T., Khairurrijal, K., Ramadan, B. S., Safitri, H., Sudibyo, S., Yuliansyah, A. T., dan Petrus, H. T. B. M. 2024. Recent advances in the adsorptive removal of heavy metals from acid mine drainage by conventional and novel materials: a review. Bioresource Technology Reports, 25, 101797.

Yang, W., Mu, Y., Zhang, W., Wang, W., Liu, J., Peng, J., Liu, X., dan He, T. 2022. Assessment of ecological cumulative effect due to mining disturbance using Google Earth Engine. Remote Sensing, 14, 4381.