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Comparative Effects of Chicken and Cattle Manure Biochar on Soil Physical Properties and Mustard Yield in Acidic Tropical Soil

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Abstract. Soil degradation characterized by high bulk density and strong acidity remains a major constraint in intensive vegetable production, particularly in tropical agricultural systems. Although biochar has been widely studied as a soil amendment, comparative evaluations of different manure-derived biochar types under field conditions remain limited. This study aimed to assess the effects of biochar derived from chicken and cattle manure on soil pH, soil bulk density, and mustard greens (*Brassica juncea* L.) yield. We experimented using a completely randomized design with three treatments: control (without biochar), chicken manure biochar, and cattle manure biochar. Both types of biochar significantly improved soil properties compared to the control. Chicken manure biochar increased soil pH from 4.75 to 6.31 and reduced bulk density from 1.36 g cm⁻³ to 0.81 g cm⁻³. In comparison, cattle manure biochar also improved soil pH (5.68) and reduced bulk density (0.88 g cm⁻³). These improvements translated into enhanced crop performance. Chicken manure biochar produced the highest fresh biomass and marketable yield, followed by cattle manure biochar, indicating a clear advantage of manure-derived biochar application in improving soil conditions and crop productivity. The findings demonstrate that converting livestock waste into biochar provides an effective soil amelioration strategy, particularly in acidic soils. This approach not only enhances soil quality and crop yields but also supports sustainable agricultural practices by valorizing organic waste within a circular economy framework.

1. Introduction

Agricultural soils worldwide are increasingly degraded by long-term monocropping, excessive use of chemical fertilizers and pesticides, and continuous tillage practices that reduce soil organic matter and disturb soil biological processes [1][2]. These conditions often result in soil compaction, declining soil organic carbon (SOC), and increased soil acidity, which limit nutrient availability, suppress microbial activity, and ultimately reduce crop productivity [3][4]. Maintaining soil health has therefore become a central principle in sustainable agriculture, particularly within the framework of Good Agricultural Practice (GAP), which emphasizes the long-term functionality of soil as a living system [5][6].



In recent years, biochar has gained attention as a promising soil amendment capable of improving both physical and chemical soil properties. Produced by pyrolysis of biomass under limited-oxygen conditions, biochar is characterized by a stable carbon structure, high porosity, and a considerable cation exchange capacity (CEC), which contribute to enhanced water retention, nutrient availability, and soil pH buffering [7][8]. These properties support better soil aggregation, improve microbial habitats, and contribute to long-term carbon sequestration in agricultural soils [9][10]. In addition, the use of biochar aligns with climate mitigation strategies due to its resistance to decomposition and its role in reducing greenhouse gas emissions [11][12].

From a circular economy perspective, converting agricultural and livestock residues into biochar offers an effective way to manage organic waste while simultaneously improving soil quality [13][14]. In tropical agricultural systems, where soil degradation and acidity are often more pronounced, biochar application has been recognized as a practical strategy to restore soil functionality and support sustainable crop production [15]. In particular, livestock manure, such as chicken and cattle waste, represents an abundant and underutilized resource that can be transformed into value-added soil amendments.

However, despite the increasing number of studies on biochar application, most research has focused on general biochar effects or single-source biochar, with limited attention to how different biochar feedstocks influence soil physical properties and crop performance under field conditions. Comparative studies between livestock manure-derived biochar types remain relatively scarce, especially in tropical acidic soils. Furthermore, the relationship between soil physical improvement and crop yield response is often described in a general manner, without sufficient explanation of the underlying mechanisms.

Therefore, this study aims to evaluate and compare the effects of biochar derived from chicken and cattle manure on soil pH, soil bulk density, and mustard greens (*Brassica juncea* L.) yield. This study also seeks to provide a clearer understanding of how changes in soil physical properties affect crop performance, thereby offering more targeted insights for sustainable soil management in tropical agricultural systems.

2. Materials and Methods

2.1 Research Location

We conducted this study at an experimental field located in Karo Regency, North Sumatra Province, Indonesia. The site is a typical agricultural area used for vegetable cultivation and is characterized by acidic soil. The experiment was conducted during the growing season of mustard greens (*Brassica juncea* L.) under open-field conditions.

2.2 Tools and Research Materials

We used mustard green seeds (*Brassica juncea* L.), chicken manure biochar, cattle manure biochar, and field soil as the main materials in this study. We produced both types of biochar via pyrolysis under limited-oxygen conditions. We applied biochar as a soil amendment before planting. We thoroughly mixed the biochar into the topsoil layer to improve soil properties.

We used standard field and laboratory equipment, including soil sampling tools, weighing scales, planting tools, and laboratory instruments to measure soil pH and bulk density. We also used standard agricultural tools to manage crop cultivation and to measure plant growth and yield.

2.3 Research Methods

We arranged the experiment using a completely randomized design (CRD) with three treatments:

T0: Control (without biochar application)

T1: Chicken manure biochar

T2: Cattle manure biochar

We replicated each treatment to ensure data reliability and experimental accuracy. We analyzed the collected data using analysis of variance (ANOVA) to determine the effect of treatments. When significant differences were detected, we performed mean comparisons using Duncan's Multiple Range Test (DMRT) at the $p < 0.05$ significance level.

2.4 Research Implementation

We applied biochar evenly to each designated plot before planting. We incorporated it into the topsoil at a rate of 25 t ha^{-1} . Each experimental plot measured $2 \times 2 \text{ m}$.

Mustard green seeds were then planted following standard cultivation practices. All treatments were maintained under uniform conditions, including irrigation, weed control, and general crop management, to minimize external variability.

During the experimental period, soil pH and bulk density were measured using standard analytical methods. At harvest, crop yield was assessed based on fresh biomass and marketable yield. Soil samples were collected after biochar application to evaluate changes in soil physical properties and assess its effectiveness.

3. Results and Discussion

3.1 Soil pH

Soil pH was significantly influenced by the application of manure-derived biochar (Table 1). Both chicken and cattle manure biochar increased soil pH compared to the control, with chicken manure biochar showing the most pronounced effect. The increase from strongly acidic conditions (pH 4.75) to near-neutral levels (pH 6.31) indicates a substantial improvement in soil chemical balance.

Table 1. Effect of manure-derived biochar on soil pH.

Treatment	Soil pH
Control (without biochar)	4,75 ^c
Chicken manure biochar	6,31 ^a
Cattle manure biochar	5,68 ^b

Values followed by different superscript letters are significantly different at $p < 0.05$

The stronger effect observed in chicken manure biochar is likely related to its higher ash content and greater concentrations of basic cations such as Ca, Mg, and K, which contribute to more effective neutralization of soil acidity. Compared to cattle manure biochar, which generally

contains higher lignocellulosic residues, chicken manure biochar tends to exhibit a more immediate liming effect.

From an agronomic perspective, the shift toward near-neutral pH is particularly important in tropical acidic soils, where nutrient availability is often constrained by aluminum toxicity and low base saturation. The improvement in soil pH observed in this study, therefore, provides a critical foundation for enhancing nutrient uptake and plant growth. Similar trends have been reported in previous studies, confirming that manure-based biochar, particularly from poultry sources, is more effective in increasing soil pH [16][1].

3.2 Soil Bulk Density

The application of manure-derived biochar significantly reduced soil bulk density (Table 2), indicating improved soil physical structure. The decrease from 1.36 g cm^{-3} in the control to 0.81 g cm^{-3} in the chicken manure treatment suggests a substantial reduction in soil compaction.

This effect can be explained by the inherently porous structure and low density of biochar, which contribute to increased soil aggregation and pore space. The incorporation of biochar particles into the soil matrix likely improved soil aeration and water movement, creating more favorable conditions for root development.

Table 2. Effect of manure-derived biochar on soil bulk density.

Treatment	Bulk density (g cm^{-3})
Control (without biochar)	1,36 ^a
Chicken manure biochar	0,81 ^c
Cattle manure biochar	0,88 ^b

Values followed by different superscript letters are significantly different at $p < 0.05$.

The slightly greater reduction observed in chicken manure biochar may reflect differences in its composition, particularly in mineral content and particle characteristics. These results are consistent with previous findings that biochar amendment reduces soil bulk density and improves soil physical properties [17-19].

Improved soil structure is particularly important in intensively cultivated systems, where repeated tillage and chemical inputs often lead to soil compaction. By reducing bulk density, biochar application enhances root penetration and water infiltration, which are essential for optimal plant growth.

3.3 Crop Yield Response

Crop yield responded positively to manure-derived biochar application (Table 3). Both chicken and cattle manure biochar produced significantly higher yields than the control treatment, with chicken manure biochar showing the greatest yield response. The control treatment yielded 184.87 g of fresh biomass. In contrast, chicken manure biochar increased yield to 244.40 g , followed by cattle manure biochar at 216.50 g , indicating a clear agronomic advantage of biochar application.

Table 3. Effect of manure-derived biochar on mustard green yield.

Treatment	Crop yield (g)
Control (without biochar)	184,87 ^c
Chicken manure biochar	244,40 ^a
Cattle manure biochar	216,50 ^b

Values followed by different superscript letters are significantly different at $p < 0.05$.

The observed yield enhancement was closely associated with improvements in soil pH and reductions in bulk density, which collectively created more favorable conditions for root development and nutrient uptake. Improved soil structure and chemical balance likely enhanced plant growth and biomass accumulation. Similar positive yield responses following manure-based biochar application have been widely reported in recent studies [20-22].

These improvements can be further explained through their direct influence on soil-plant interactions. Increasing soil pH reduces aluminum toxicity. It enhances the availability of essential nutrients such as phosphorus, calcium, and magnesium, which are often limited under acidic conditions. At the same time, the reduction in soil bulk density improves soil porosity and aeration, allowing better root penetration and expansion. This improved root development enhances water and nutrient uptake efficiency, ultimately supporting higher biomass accumulation and yield.

3.4 Marketable Yield

Marketable yield followed a similar trend to total biomass (Table 4), indicating that biochar application not only increased plant growth but also improved the economic value of the crop. The highest marketable yield observed in the chicken manure biochar treatment suggests that this type of biochar is particularly effective in enhancing both yield quantity and quality [20-21].

Table 4. Effect of manure-derived biochar on marketable yield on mustard greens.

Treatment	Marketable Yield (g)
Control (without biochar)	170,83 ^c
Chicken manure biochar	279,07 ^a
Cattle manure biochar	247,76 ^b

Values followed by different superscript letters are significantly different at $p < 0.05$.

This improvement reflects the combined effect of better soil structure and enhanced nutrient availability, which support more uniform and healthy plant development [22][23]. From a practical perspective, marketable yield is a critical parameter, as it directly influences farmers' income and production efficiency.

In addition, the use of manure-derived biochar aligns with circular economy principles by converting livestock waste into valuable agricultural inputs [13][14]. While chicken manure biochar showed the highest effectiveness, cattle manure biochar also provided significant improvements compared to the control, indicating its potential as an alternative resource in areas where poultry waste is less available.

Nevertheless, the findings of this study are based on short-term observations, and the long-term stability of these improvements requires further investigation under different environmental and management conditions.

4. Conclusion

This study shows that applying manure-derived biochar improves soil physical properties and enhances mustard green productivity under acidic soil conditions. Biochar application increased soil pH and decreased soil bulk density, thereby improving growing conditions and increasing yields compared to the control treatment.

Among the treatments, chicken manure biochar demonstrated a stronger effect in improving soil properties and crop yield. However, cattle manure biochar also produced significant improvements, indicating that both types of livestock waste can serve as effective soil amendments.

These findings suggest that manure-derived biochar can be applied as a practical strategy to improve soil quality in intensively cultivated agricultural systems. In addition, using livestock waste as biochar supports more sustainable agricultural practices by reducing organic waste and promoting resource efficiency.

Further studies are recommended to evaluate long-term effects, optimal application rates, and performance under different soil and environmental conditions to strengthen its applicability at a broader scale.

References

- [1] Ighalo, J. O., Adeniyi, A. G., Marques, G., & Onifade, D. V. (2024). Biochar for ameliorating soil fertility and microbial diversity: From production to action of the black gold. *iScience*, 27(4), 111524. <https://doi.org/10.1016/j.isci.2024.111524>
- [2] Zhang, N., Xing, J., Wei, L., Liu, C., Zhao, W., Liu, Z., ... & Zhang, P. (2025). The potential of biochar to mitigate soil acidification: a global meta-analysis. *Biochar*, 7(1), 49. <https://doi.org/10.1007/s42773-025-00451-5>
- [3] Warke, A. T., & Wakgari, T. (2024). A Review on the Impact of Soil Acidification on Plant Nutrient Availability, Crop Productivity, and Management Options in the Ethiopian Highlands. *Agriculture, Forestry and Fisheries* 2024, 9, 31. <https://doi.org/10.11648/j.aff.20241302.13>
- [4] Tang, K. H. D. (2025). Biochar amendments for soil restoration: impacts on nutrient dynamics and microbial activity. *Environments*, 12(11), 425. <https://doi.org/10.3390/environments12110425>
- [5] Telo da Gama, J. (2023). The role of soils in sustainability, climate change, and Ecosystem services: Challenges and opportunities. *Ecologies*, 4(3), 552-567. <https://doi.org/10.3390/ecologies4030036>
- [6] Kumar, A., Singh, H. S., Kumar, A., Singh, M. P., Singh, A., Maurya, N. K., Sudha Darbha and Kumar, R. (2025). A Comprehensive Review on Plant-Soil Interactions: Microbial Dynamics, Nutrient Cycling and Sustainable Crop Production. *Asian Journal of Soil Science and Plant Nutrition*, 11(2), 44-62. <https://doi.org/10.9734/ajsspn/2025/v11i2509>
- [7] Ali, A., Jabeen, N., Chachar, Z., Chachar, S., Ahmed, S., Ahmed, N., Farruhbek, R., and Yang, Z. (2025). The role of biochar in enhancing soil health & interactions with rhizosphere properties and enzyme activities in organic fertilizer substitution. *Frontiers in Plant Science*, 16, 1595208. <https://doi.org/10.3389/fpls.2025.1595208>
- [8] Fakhar, A., Canatoy, R. C., Galgo, S. J. C., Rafique, M., & Sarfraz, R. (2025). Advancements in modified biochar production techniques and soil application: a critical review. *Fuel*, 400, 135745. <https://doi.org/10.1016/j.fuel.2025.135745>

- [9] Shyam, S., Ahmed, S., Joshi, S. J., & Sarma, H. (2025). Biochar as a Soil amendment: implications for soil health, carbon sequestration, and climate resilience. *Discover Soil*, 2(1), 18. <https://doi.org/10.1007/s44378-025-00041-8>
- [10] Xu, L., Wu, K. C., Deng, Z. N., Huang, C. M., Verma, K. K., Pang, T., & Huang, H. R. (2024). Biochar and its impact on soil profile and plant development. *Journal of Plant Interactions*, 19(1), 2401356. <https://doi.org/10.1080/17429145.2024.2401356>
- [11] Song, K., Jiang, S., Liu, Z., Cai, Y., Liu, W., Bian, R., Zheng, J., and Li, L. (2024). Biochar improves soil organic carbon sequestration potential in the topsoil and subsoil of a paddy field. *Current Research in Environmental Sustainability*, 8, 100267. <https://doi.org/10.1016/j.crsust.2024.100267>
- [12] Ashraf, S. K., Ripta, S. K., Rana, M. T., & Islam, K. K. (2025). Biochar enhanced agroforestry systems for carbon sequestration, soil health and climate resilience. *Discover Forests*, 1(1), 53. <https://doi.org/10.1007/s44415-025-00057-6>
- [13] Shazileh, S. A. H. S., & Benis, K. Z. (2026). Valorization of livestock manure for bioenergy recovery. In *Next-Generation Biofuels* (pp. 19-39). Elsevier. <https://doi.org/10.1016/B978-0-443-27564-7.00008-9>
- [14] de OLIVEIRA, J. S., de OLIVEIRA, J. P., de OLIVEIRA, C. P., & Veloso, C. M. (2025). Circular economy as a tool for the valorization of agro-industrial residues and the development of biodegradable and sustainable packaging: a bibliometric review from 2015 to 2024. *Cleaner and Circular Bioeconomy*, 100188. <https://doi.org/10.1016/j.clcb.2025.100188>
- [15] Charloq, C., Thoha, A. S., Yazid, A., Sidiq, A. M., & Lubis, O. A. (2024). Estimating oil palm (*Elaeis guineensis*) production potential using Unmanned Aerial Vehicle. *Biodiversitas Journal of Biological Diversity*, 25(9). <https://doi.org/10.13057/biodiv/d250919>
- [16] Drózd, D., Malińska, K., Wystalska, K., Meers, E., & Robles-Aguilar, A. (2023). The influence of poultry manure-derived biochar and compost on soil properties and plant biomass growth. *Materials*, 16(18), 6314. <https://doi.org/10.3390/ma16186314>
- [17] Walters, R. D., & White, J. G. (2018). Biochar in situ decreased bulk density and improved soil-water relations and indicators in Southeastern US Coastal Plain Ultisols. *Soil Science*, 183(3), 99-111.
- [18] Amalina, F., Abd Razak, A. S., Krishnan, S., Sulaiman, H., Zularisam, A. W., & Nasrullah, M. (2022). Biochar production techniques utilizing biomass waste-derived materials and environmental applications—A review. *Journal of Hazardous Materials Advances*, 7, 100134. <https://doi.org/10.1016/j.hazadv.2022.100134>
- [19] Zhu, Z., Zhang, Y., Tao, W., Zhang, X., Xu, Z., & Xu, C. (2025). The biological effects of biochar on soil's physical and chemical characteristics: A review. *Sustainability*, 17(5), 2214. <https://doi.org/10.3390/su17052214>
- [20] Ali, N., Jiang, Q., Akhtar, K., Luo, R., Jiang, M., He, B., & Wen, R. (2025). Biochar and manure co-application improves soil health and rice productivity through microbial modulation. *BMC Plant Biology*, 25(1), 914. <https://doi.org/10.1186/s12870-025-06834-x>
- [21] Kabir, E., Kim, K. H., & Kwon, E. E. (2023). Biochar as a tool for the improvement of soil and environment. *Frontiers in Environmental Science*, 11, 1324533. <https://doi.org/10.3389/fenvs.2023.1324533>
- [22] Wijitkosum, S., Sriburi, T., & Chutivisut, P. (2025). Biochar amendment improves soil properties and augments soil bacteria on continuous maize cultivation over two years. *International Journal of Environmental Science and Technology*, 1-14. <https://doi.org/10.1007/s13762-025-06484-4>
- [23] Toková, L., Igaz, D., Horák, J., & Aydin, E. (2020). Effect of biochar application and re-application on soil bulk density, porosity, saturated hydraulic conductivity, water content and soil water availability in a silty loam Haplic Luvisol. *Agronomy*, 10(7), 1005. <https://doi.org/10.3390/agronomy10071005>
- [24] Edeh, I. G., & Mašek, O. (2022). The role of biochar particle size and hydrophobicity in improving soil hydraulic properties. *European Journal of Soil Science*, 73(1), e13138. <https://doi.org/10.1111/ejss.13138>
- [25] Adekiya, A. O., Alori, E. T., Ogunbode, T. O., Sangoyomi, T., & Oriade, O. A. (2023). Enhancing organic carbon content in tropical soils: strategies for sustainable agriculture and climate change mitigation. *The Open Agriculture Journal*, 17(1). <https://doi.org/10.2174/0118743315282476231124074206>
- [26] J Medhekar, A. (2024). Circular economy in agriculture and sustainable development. *Circular economy and manufacturing*, 15-31. <https://doi.org/10.1016/B978-0-443-14028-0.00007-4>