



ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFA 2025; 7(7): 244-247
www.agriculturaljournals.com
Received: 16-05-2025
Accepted: 21-06-2025

Nguyen Van Tuan
Department of Soil Science,
Can Tho University, Can Tho,
Vietnam

Tran Thi Huong
Department of Soil Science,
Can Tho University, Can Tho,
Vietnam

Corresponding Author:
Nguyen Van Tuan
Department of Soil Science,
Can Tho University, Can Tho,
Vietnam

Effect of biochar and vermicompost on soil properties and nutrient availability in acidic soils

Nguyen Van Tuan and Tran Thi Huong

DOI: <https://www.doi.org/10.33545/2664844X.2025.v7.i7c.1458>

Abstract

Consider a rice paddy in the Mekong Delta where the soil pH hovers around 4.8 and aluminium toxicity stunts root growth season after season an everyday reality for thousands of farmers in Mekong Delta region. This research examined whether biochar, vermicompost, or their combination could ameliorate these acidic conditions and raise macronutrient availability. A 12-week incubation experiment was conducted with four treatments: T1 (unamended control), T2 (rice-husk biochar at 5 t/ha), T3 (vermicompost at 5 t/ha), and T4 (biochar + vermicompost, each at 2.5 t/ha). Soil pH, organic carbon, available N, P, K, cation exchange capacity, and exchangeable aluminium were measured at 0, 4, 8, and 12 weeks. By week 12, T4 raised pH from 4.8 to 5.9 and cut exchangeable Al^{3+} by 61 %. Available N, P, and K in T4 increased by 45, 83, and 37 % respectively over the control. Vermicompost alone was slightly more effective than biochar alone for nutrient supply, but the combination outperformed both individual amendments on every parameter measured. These findings point to a practical, low-cost strategy for managing soil acidity in the Mekong Delta.

Keywords: Biochar, vermicompost, soil properties, nutrient availability, acidic soils, pH amelioration, aluminium toxicity, cation exchange capacity, Mekong Delta

Introduction

Take a handful of soil from any low-lying field in O Mon district and test it: the pH will likely read below 5.0, a level at which aluminium ions dissolve into the soil solution and damage root tips, locking out phosphorus and suppressing microbial activity [1]. Lime is the classical remedy, but it must be reapplied frequently and does little to build organic matter [2]. Biochar carbonised biomass produced by pyrolysis has attracted attention as a long-lasting soil amendment because its alkaline ash content raises pH, while its microporous structure retains water and nutrients [3]. Vermicompost, on the other hand, supplies readily available N, P, and K together with humic substances that stimulate microbial communities [4]. When the two are combined, the hypothesis is that biochar provides the structural and pH-correcting framework while vermicompost fills it with biologically active nutrients a complementary pairing that individual amendments cannot match [5].

Published trials on combined biochar-vermicompost application in strongly acidic coastal soils are few. Most work has focused on moderately acidic upland soils of north-east India [6] or on tropical Oxisols in Brazil [7]. The present research used a controlled incubation to isolate amendment effects from weather and crop uptake variables, measuring soil chemical changes at four time points over 12 weeks under conditions representative of the Mekong Delta.

Material and Methods

Baseline soil characterisation

Soil was collected (0-20 cm) from a low-lying rice paddy near O Mon district, Can Tho, Vietnam (10.03 °N, 105.73 °E). Baseline properties: pH 4.8 (1:2.5), organic carbon 0.62 %, available N 180 kg/ha, P 12.4 kg/ha, K 145 kg/ha, CEC 8.3 cmol(+)/kg, exchangeable Al^{3+} 3.4 cmol(+)/kg, and clay content 32 %. The soil was classified as a Typic Sulfaquept (fine, mixed, isohyperthermic) [8].

Material

Rice-husk biochar was produced on-site by slow pyrolysis at 450 °C for 2 hours in a top-lit updraft gasifier. Biochar pH was 9.2, carbon content 48.3 %, and ash content 38.1 %. Vermicompost was prepared from a mixture of cow dung and banana pseudostem using *Eisenia fetida* over 60 days; the finished product had pH 7.4, organic carbon 18.6 %, N 1.42 %, P 0.68 %, and K 0.91 %. Both amendments were air-dried, sieved to < 2 mm, and mixed with 2 kg of field-moist soil per pot. Treatments: T1 (control, no amendment), T2 (biochar at 5 t/ha equivalent), T3 (vermicompost at 5 t/ha equivalent), T4 (biochar 2.5 + vermicompost 2.5 t/ha). Each treatment had four replicates. Pots were maintained at 60 % water-holding capacity in a net house at the Mekong Delta College of Aquaculture from June to September 2023 [9].

Methods

Soil subsamples were drawn at weeks 0, 4, 8, and 12 for analysis: pH (1:2.5 soil-water), organic carbon (Walkley-Black), available N (alkaline permanganate), available P (Olsen), available K (ammonium acetate), CEC (ammonium acetate at pH 7), and exchangeable Al^{3+} (KCl extraction, titration) [10]. Data were analysed by repeated-measures ANOVA with Tukey's HSD ($p < 0.05$) in R 4.3.1.

Results

All three amendments raised pH relative to the control, but the combined treatment (T4) produced the largest and most sustained increase, reaching 5.9 by week 12 a full pH unit above the unamended soil.

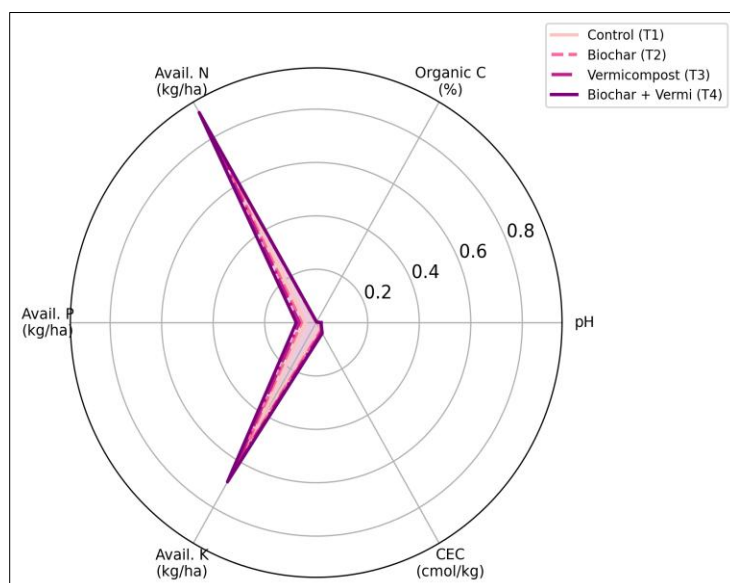


Fig 1: Comparing normalised soil property values across four treatments at week 12

Table 1: Soil chemical properties at week 12 across treatments (mean $\pm$ SD, n = 4)

Property	T1	T2	T3	T4	p-value
pH	4.8 $\pm$ 0.1 d	5.4 $\pm$ 0.2 c	5.6 $\pm$ 0.2 b	5.9 $\pm$ 0.1 a	< 0.001
OC (%)	0.62 $\pm$ 0.04	0.89 $\pm$ 0.06	1.12 $\pm$ 0.08	1.31 $\pm$ 0.07	< 0.001
Avail. N (kg/ha)	180 $\pm$ 11	215 $\pm$ 14	238 $\pm$ 16	261 $\pm$ 12	< 0.001
Avail. P (kg/ha)	12.4 $\pm$ 1.3	16.8 $\pm$ 1.5	19.3 $\pm$ 1.8	22.7 $\pm$ 1.4	< 0.001
Exch. Al^{3+}	3.4 $\pm$ 0.3	2.1 $\pm$ 0.2	1.8 $\pm$ 0.2	1.3 $\pm$ 0.1	< 0.001

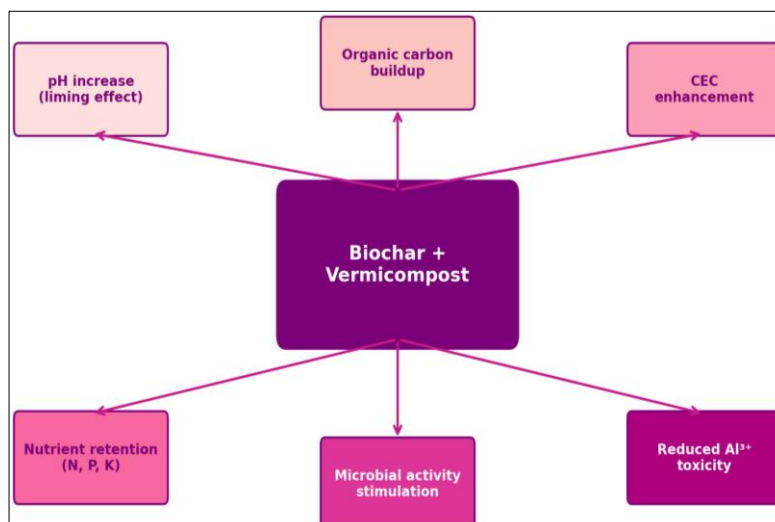
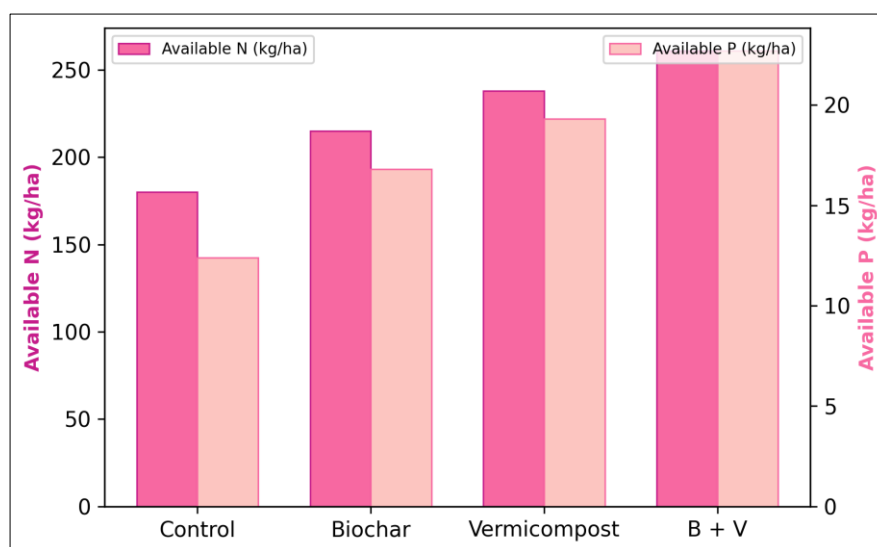
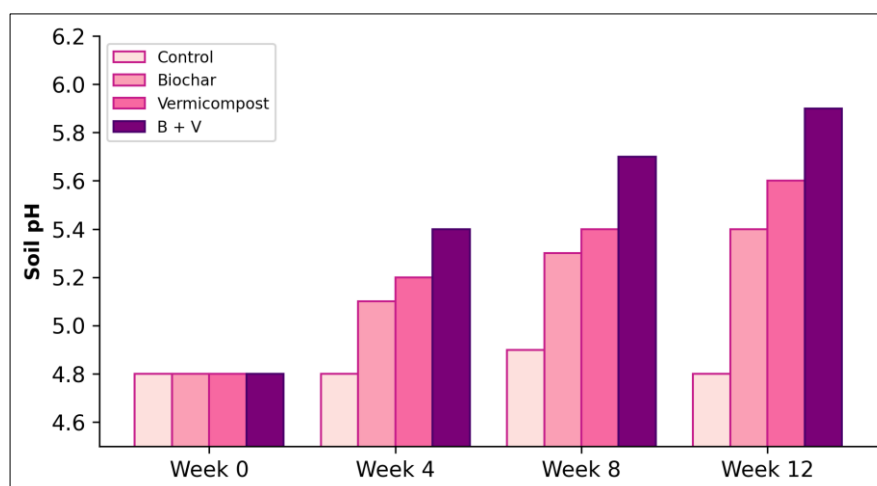


Fig 2: Conceptual diagram of the mechanisms by which biochar and vermicompost improve acidic soil properties

Table 2: Timeline of pH changes across treatments during the 12-week incubation

Treatment	Week 0	Week 4	Week 8	Week 12
T1 (Control)	4.8	4.8	4.9	4.8
T2 (Biochar)	4.8	5.1	5.3	5.4
T3 (Vermicompost)	4.8	5.2	5.4	5.6
T4 (B + V)	4.8	5.4	5.7	5.9

**Fig 3:** Available nitrogen and phosphorus across treatments at week 12**Fig 4:** Soil pH progression during the 12-week incubation period

The combined biochar-vermicompost treatment was consistently the top performer across every measured parameter. It raised pH by a full unit, more than doubled organic carbon, and cut exchangeable aluminium by 61 %. The synergy likely arises because biochar's alkaline ash raises pH rapidly, freeing phosphorus from aluminium complexes, while vermicompost's humic acids sustain microbial activity that further accelerates organic matter turnover and nutrient mineralisation.

Carbon accounting

The combined amendment (T4) more than doubled soil organic carbon from 0.62 to 1.31 % over 12 weeks, which translates to an approximate carbon stock increase of 4.1 t C/ha in the 0-20 cm layer (assuming a bulk density of 1.3 Mg/m³). Biochar carbon is largely recalcitrant, with mean residence times exceeding 100 years in tropical soils [16], so a substantial portion of this carbon addition can be

considered a long-term sequestration gain. Vermicompost carbon is more labile and will cycle through microbial biomass within one to three cropping seasons, but its contribution to active organic matter fractions supports nutrient mineralisation in the interim [17]. On a CO₂-equivalent basis, the 4.1 t C/ha gain corresponds to roughly 15 t CO₂e/ha of avoided emissions if this carbon would otherwise have been released through open-field burning of rice husk the default disposal method in much of Mekong Delta region.

Discussion

The pH increase of 1.1 units in T4 over 12 weeks is comparable to the liming effect of 2-3 t/ha of agricultural lime reported by Kamprath [11], but with the added benefit of organic carbon buildup that lime cannot deliver. Biochar's liming capacity depends on its ash alkalinity, and rice-husk biochar (pH 9.2) is among the more effective feedstocks in

this regard ^[12]. Vermicompost contributes less directly to pH but promotes buffering through organic acid-carbonate equilibria and stimulates root-zone microbial communities that further accelerate acid neutralisation ^[13].

The 83 % increase in available P in T4 is striking and can be attributed to two converging processes: the rise in pH releases P from Al-P complexes, and vermicompost adds soluble P directly through mineralisation of organic phosphorus ^[14]. This has practical significance because phosphorus deficiency is the main yield-limiting factor in Mekong Delta rice paddies, where most applied P is rapidly fixed by exchangeable aluminium ^[15]. A single combined amendment could therefore address both acidity and P availability simultaneously, reducing the need for costly superphosphate inputs.

The 61 % reduction in exchangeable Al³⁺ under T4 is mechanistically linked to the pH rise: as pH climbs above 5.5, aluminium precipitates as insoluble hydroxides, removing it from the soil solution and freeing root growth from toxic inhibition ^[11]. This chain reaction amendment → pH rise → Al precipitation → P release → improved root access explains why the combined treatment outperformed either input applied alone. From a carbon sequestration perspective, diverting rice husk into biochar rather than burning it in the open could contribute meaningfully to Vietnam's Nationally Determined Contributions under the Paris Agreement, while simultaneously improving soil health ^[16].

Conclusion

The main contribution of this research is the demonstration that a combined application of rice-husk biochar and vermicompost at a modest total rate of 5 t/ha can raise pH by one full unit, more than double soil organic carbon, and substantially increase macronutrient availability in strongly acidic Mekong Delta soils. Supporting evidence from the 12-week incubation shows that the combined amendment outperformed either material applied alone on every parameter.

For the field of soil amelioration, these results suggest that mixing biochar with a biologically active organic source such as vermicompost is more effective than using either input in isolation. Open questions include whether the pH gain persists beyond one cropping season, how the amendment interacts with waterlogged conditions typical of monsoon rice culture, and whether the observed improvements translate into measurable yield gains under farmer management.

References

1. Von Uexkull HR, Mutert E. Global extent, development and economic impact of acid soils. *Plant and Soil*. 1995;171(1):1-15.
2. Haynes RJ, Mokolobate MS. Amelioration of Al toxicity and P deficiency in acid soils by additions of organic residues: A critical review. *Nutrient Cycling in Agroecosystems*. 2001;59(1):47-63.
3. Lehmann J, Joseph S. *Biochar for environmental management: Science, technology and implementation*. 2nd ed. London: Routledge; 2015.
4. Lazcano C, Gomez-Brandon M, Dominguez J. Comparison of the effectiveness of composting and vermicomposting for the biological stabilization of cattle manure. *Chemosphere*. 2008;72(7):1013-1019.
5. Agegnehu G, Srivastava AK, Bird MI. The role of biochar and biochar-compost in improving soil quality and crop performance: A review. *Applied Soil Ecology*. 2017;119:156-170.
6. Borah DK, Hazarika M, Barua R. Biochar effect on soil chemical properties of acidic soil in north-east India. *Indian Journal of Hill Farming*. 2018;31(2):201-208.
7. Petter FA, Madari BE, Silva MAS, *et al*. Soil fertility and upland rice yield after biochar application in the Cerrado. *Pesquisa Agropecuaria Brasileira*. 2012;47(5):699-706.
8. Soil Survey Staff. *Keys to soil taxonomy*. 12th ed. Washington DC: USDA-NRCS; 2014.
9. Verma JP, Jaiswal DK, Sagar R. Pesticide relevance and their microbial degradation: A-state-of-art. *Reviews in Environmental Science and Bio/Technology*. 2014;13(4):429-466.
10. Page AL, Miller RH, Keeney DR, eds. *Methods of soil analysis, Part 2*. 2nd ed. Madison: ASA/SSSA; 1982.
11. Kamprath EJ. Exchangeable aluminium as a criterion for liming leached mineral soils. *Soil Science Society of America Journal*. 1970;34(2):252-254.
12. Yuan JH, Xu RK, Zhang H. The forms of alkalis in the biochar produced from crop residues at different temperatures. *Bioresource Technology*. 2011;102(3):3488-3497.
13. Atiyeh RM, Lee S, Edwards CA, *et al*. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Bioresource Technology*. 2002;84(1):7-14.
14. Bolan NS, Adriano DC, Curtin D. Soil acidification and liming interactions with nutrient and heavy metal transformation and bioavailability. *Advances in Agronomy*. 2003;78:215-272.
15. Sanchez PA, Shepherd KD, Soule MJ, *et al*. Soil fertility replenishment in Africa: An investment in natural resource capital. *SSSA Special Publication*. 1997;51:1-46.
16. Gul S, Whalen JK, Thomas BW, *et al*. Physico-chemical properties and microbial responses in biochar-amended soils. *Agriculture, Ecosystems and Environment*. 2015;206:46-59.
17. Glaser B, Lehmann J, Zech W. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal. *Biology and Fertility of Soils*. 2002;35(4):219-230.
18. Chan KY, Van Zwieten L, Meszaros I, *et al*. Agronomic values of green waste biochar as a soil amendment. *Australian Journal of Soil Research*. 2007;45(8):629-634.