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EFFECTS OF ORGANIC SOIL AMENDMENTS ON THE PHYSICOCHEMICAL PROPERTIES OF REDDISH-BROWN EARTH SOILS (ALFISOLS) IN SRI LANKA

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ABSTRACT--
Application of soil organic amendments changes soil characteristics. Hence, a study was carried out to assess the effect of different organic amendments on soil pH, electrical conductivity (EC), organic carbon retention and the moisture absorption of Reddish Brown Earth (RBE) soils. A pot experiment was conducted using three organic amendments: compost, acacia leaf litter, and rice biochar, along with an unamended control. The amendments were applied at three rates (5, 10, and 15 t ha^{-1}) and incubated at room temperature for eight weeks in a Completely Randomized Design (CRD) with four replicates. Soil moisture content in each pot was maintained at 75% of field capacity throughout the study period. Soil pH, EC, organic carbon and water drop penetration were measured at the beginning (initial), 2nd, 4^{th,} and 8th weeks during incubation period. The results demonstrated that both the type and application rate of organic amendments influenced the selected soil properties. Rice biochar produced the greatest increase in soil pH, particularly at the higher application rates, whereas compost and acacia leaf litter had comparatively limited effects on soil pH. Soil EC generally increased during the initial four weeks, reflecting the release of soluble ions from the amendments, and subsequently stabilized. Soil organic carbon declined during incubation, with greater reductions observed in compost and acacia leaf litter amended treatments, indicating greater decomposition and mineralization of relatively labile carbon. In contrast, rice biochar treatments showed comparatively greater carbon retention, which can be attributed to the recalcitrant nature of biochar carbon. Water drop penetration time generally decreased with incubation, suggesting a reduction in water repellency over time and indicating that amendment induced changes in soil wettability were largely transient. Overall, rice biochar showed greater potential for improving soil pH and retaining organic carbon while maintaining relatively stable soil properties. Rice biochar therefore appears to be a promising organic amendment for improving selected properties and supporting the long-term sustainability of RBE soils.
KEYWORDS: *Compost, Microbial Decomposition, Mineralization, Soil Carbon*---

INTRODUCTION

The application of organic amendments to agricultural soils can substantially modify their chemical, physical, and biological properties. However, the magnitude and direction of these changes vary considerably depending on the type, quality, application rate, and decomposition characteristics of the amendment, as well as the inherent properties of the soil and prevailing climatic conditions. Organic amendments can influence soil pH, electrical conductivity (EC), organic carbon, nutrient availability, aggregate stability, bulk density, water-holding capacity, and microbial activity. Therefore, the selection of an appropriate organic amendment is an important component of sustainable soil management (Agegnehu et al., 2017; Brichi et al., 2023).

The Reddish Brown Earth (RBE) soils, classified mainly as Alfisols in the USDA Soil Taxonomy, are among the most extensive and agriculturally important soils of Sri Lanka. They are particularly widespread in the dry zone and also occur in the drier parts of the intermediate zone. RBE soils are important for the cultivation of a range of food and other agricultural crops under both rainfed and irrigated conditions. However, many agricultural soils in the dry zone are characterized by relatively low soil organic carbon and nutrient availability, and their productivity can be constrained by limitations associated with soil structure, water availability, and soil fertility (Sanjeevani et al., 2013; Mapa et al., 2020). For example, characterization of an RBE soil from the dry zone reported relatively low organic carbon content, demonstrating the importance of maintaining and increasing soil organic matter in these soils (Sanjeevani et al., 2013).

Compost and fresh plant residues generally contain relatively labile organic compounds that can be rapidly decomposed by soil microorganisms. In contrast, biochar contains a relatively stable carbon fraction and can persist in soil for longer periods. Organic amendments can also influence soil pH and electrical conductivity through the release of soluble organic compounds, nutrients, and basic cations during decomposition. Biochar, in particular, may increase soil pH because of its alkaline components and liming effect, although the response depends on the characteristics of the biochar and the initial properties of the soil (Zhang et al., 2021). Similarly, the decomposition of compost and plant residues can temporarily increase EC because of the release of soluble salts and mineral nutrients. Therefore, different organic amendments may produce substantially different temporal patterns of soil pH and EC.

Despite the growing body of international research on organic amendments, the effectiveness of different amendment materials is highly site and soil specific. A substantial proportion of published studies have been conducted under temperate or non-tropical conditions, while relatively fewer studies have systematically compared locally available organic amendments under the specific climatic and soil conditions of Sri Lanka. This represents an important research gap because the decomposition rate of organic materials, nutrient release, soil–amendment interactions, and persistence of amendment-derived carbon can vary considerably under tropical climatic conditions. Although farmers commonly have access to materials such as compost, crop residues, and biochar-producing agricultural wastes, scientifically validated information regarding the comparative effectiveness of these materials under local soil and climatic conditions remains limited. Consequently, the development of locally relevant recommendations is necessary to support the effective utilization of organic resources and promote sustainable soil management. In the present study, compost, acacia leaf residues, and rice biochar were selected as organic amendment materials because of their potential availability and relevance to local agricultural systems. Compost can be produced from agricultural and household organic wastes and provides a source of relatively decomposable organic matter and nutrients. Acacia leaf residues represent a readily available plant derived organic resource in many dry zone landscapes and can contribute organic matter and nutrients through decomposition. Rice biochar, produced from rice derived biomass such as rice husk, represents a more stable carbon amendment and has considerable potential for improving soil physical and chemical properties. The contrasting characteristics of these materials provide an opportunity to evaluate whether different types of organic amendments produce different responses in RBE soils. Therefore, this study was undertaken to evaluate the influence of different organic soil amendments compost, acacia leaf residues, and rice biochar—on selected soil chemical, physical parameters of Reddish Brown Earth (Alfisols) soils under Sri Lankan conditions.

MATERIALS AND METHODS

The experiment was conducted at the Faculty of Agriculture, Rajarata University of Sri Lanka, Puliyankulama, Anuradhapura, Sri Lanka. The study site represents the typical climatic conditions and Reddish Brown Earth (Alfisols) soils of Sri Lanka's dry zone. Surface soil samples (0–15 cm depth) were collected using a systematic random sampling method. The collected soil was air dried under shade for 1–2 days. Stones, plant residues, and other foreign materials were removed manually. The soil was subsequently passed through a 2-mm sieve to obtain a uniform particle size and remove coarse fragments. A total of 40 plastic pots were filled with 1 kg of sieved soil for the incubation experiment.

Three organic amendments were selected based on their local availability. Well-decomposed compost was obtained from the composting facility of the Faculty of Agriculture, Rajarata University of Sri Lanka. The compost exhibited the typical characteristics of mature compost, including a dark brown colour, earthy smell, and stable structure. Fresh leaf litter of *Acacia auriculiformis* was collected from trees growing within the university premises. The leaves were oven-dried for 12 hours and ground to a particle size of 2–5 mm to facilitate uniform mixing with the soil. Rice biochar was produced from rice husks obtained from a local rice mill. The required quantities of each amendment were thoroughly mixed with the soil according to the designated treatment. Soil moisture content was maintained at 75% of field capacity throughout the incubation period by adding distilled water whenever necessary.

The experiment was arranged in a Completely Randomized Design (CRD) comprising ten treatments with four replications, resulting in a total of 40 experimental units. Three application rates (5, 10, and 15 t ha^{-1}) were evaluated for each amendment, together with an unamended control. The treatments were as follows:

Table 01 – Treatments

No	Treatment	Description
1	T1	Soil + Compost (5 t ha^{-1})
2	T2	Soil + Compost (10 t ha^{-1})
3	T3	Soil + Compost (15 t ha^{-1})
4	T4	Soil + *Acacia* leaf residues (5 t ha^{-1})
5	T5	Soil + *Acacia* leaf residues (10 t ha^{-1})
6	T6	Soil + *Acacia* leaf residues (15 t ha^{-1})
7	T7	Soil + Rice biochar (5 t ha^{-1})
8	T8	Soil + Rice biochar (10 t ha^{-1})
9	T9	Soil + Rice biochar (15 t ha^{-1})
10	T10	Control (Soil only)

Soil pH, electrical conductivity (EC), organic carbon (OC), and water drop penetration time (WDPT) were determined at the beginning of the incubation experiment (Week 0) and after 2, 4, and 8 weeks of incubation. Soil pH was measured potentiometrically in a 1:2.5 soil to distilled water suspension, while EC was determined using a 1:5 soil to distilled water suspension with a conductivity meter (Rayment & Lyons, 2011). Soil organic carbon was determined using the loss on ignition (LOI) method (Ball, 1964). For the determination of water drop penetration time, distilled water droplets were placed on the surface of the soil sample, and the time required for complete penetration of the water droplet into the soil was recorded as the WDPT. The WDPT method is a commonly used measure of the persistence of soil water repellency, with longer penetration times indicating greater persistence of water repellency (Dekker et al., 2009).

RESULTS AND DISCUSSION

No significant changes in soil pH were observed throughout the incubation period in most treatments, except for the rice biochar-amended treatments (T7, T8 and T9) (Table 2). Among all treatments, the highest pH value of 6.6 was recorded in T9, which received the highest rate of rice biochar, at the end of the incubation period. The gradual increase in pH with increasing biochar application rate suggests that rice biochar had a greater capacity to modify soil acidity than compost and acacia leaf residue. The increase in soil pH following biochar application can be associated with the presence of alkaline ash components, particularly carbonates, hydroxides and oxides of basic cations such as Ca, Mg and K, which can neutralize soil acidity. Biochar also contains oxygen-containing functional groups that can interact with H^+ and Al^{3+} in the soil solution, thereby reducing proton activity and contributing to an increase in soil pH. These mechanisms are widely recognized as important pathways through which biochar ameliorates soil acidity (Li et al., 2017; Xu et al., 2019; Bolan et al., 2023). The greater pH response observed at the higher biochar rate in T9 may be attributed to the greater quantity of alkaline constituents introduced into the soil. Previous studies have reported that the magnitude of pH increase following biochar application is strongly influenced by the application rate, feedstock characteristics and alkalinity of the biochar (Xu et al., 2019).

In contrast, the compost and acacia leaf residue amended treatments did not show significant changes in pH throughout the incubation period. This relatively stable pH may be associated with the buffering capacity of the organic materials and the gradual decomposition of their readily decomposable constituents. Unlike biochar, which contains relatively stable alkaline mineral components and recalcitrant carbon, compost and fresh plant residues contain larger proportions of labile organic compounds that undergo microbial decomposition and produce organic acids, CO_2 and other products during mineralization. These processes may offset changes in soil pH and result in comparatively small net changes during the incubation period. The absence of significant pH changes in these treatments therefore suggests that their influence on soil acidity was relatively limited under the experimental conditions.

Table 02 - Soil pH variation

	Initial	**Week 2**	**Week 4**	**Week 8**
T1	5.4^a	5.8^a	5.4^a	5.5^a
T2	5.5^a	5.1^a	5.5^a	5.7^a
T3	5.7^a	5.2^a	5.7^a	5.9^a
T4	5.6^a	5.1^a	5.3^a	5.4^a
T5	5.7^a	5.2^a	5.6^a	5.1^a
T6	5.8^a	5.9^a	5.4^a	5.2^a
T7	5.6^b	5.7^b	5.8^b	6.2^a
T8	5.5^b	5.5^b	6.3^a	6.4^a
T9	5.7^b	5.8^b	6.3^a	6.6^a
T10	5.6^a	5.9^a	5.7^a	5.6^a

Means within a row followed by the same superscript letter are not significantly different at $p > 0.05$.

The soil electrical conductivity (EC) values showed a clear treatment dependent and time dependent pattern over the 8 weeks incubation period. Overall, EC increased progressively with incubation time in T1–T9, whereas T10 remained statistically unchanged throughout the experiment. At the beginning of the experiment, soil EC ranged from 86 to 252 $\mu S\ cm^{-1}$**,** indicating considerable variation among treatments. Treatments T3, T6 and T9 where highest rate was added showed higher EC levels at the beginning. to During the first two weeks, EC changes were relatively small in most treatments. Compost amended treatments (T1, T2, T3) and acacia residue amended treatments (T5, T6, T7) showed statistically similar EC values up to 2nd week, suggesting that the release of soluble ions was relatively limited during the initial stage (Danielle et al. 2008). However, T8 and T9 showed significant increases from the beginning to week 2, indicating relatively rapid release of soluble constituents from these treatments. A substantial increase in EC was observed by week 4 in almost all treatments. This was particularly evident in compost amended treatments (T2 and T3), where EC increased from 201 to 450 $\mu S\ cm^{-1}$ and from 286 to 625 $\mu S\ cm^{-1}$, respectively. The marked increase suggests that these treatments released considerably greater amounts of soluble ions into the soil solution. Similar, although less pronounced, increases were observed in acacia leaf and biochar amended treatments (T4, T5, T6, T7, T8 and T9). This increase in EC may be attributed to the dissolution of readily soluble compounds and the release of mineral nutrients during decomposition or mineralization of applied materials**.** Depending on the nature of the amendments, ions such as K^+, Ca^{2+}, Mg^{2+}, NH_4^+ and other soluble ions may contribute to the increased EC (Rizwan et al., 2023).

The most important feature of the results is that EC generally stabilized after week 4**.** There were no significant differences between weeks 4 and 8 in T1–T9. Similar stabilization occurred in the other treatments. This suggests that the major release of readily soluble ions occurred during the first four weeks, after which the soil-amendment system approached a relatively stable condition. The small increases or decreases observed between weeks 4 and 8 were not statistically significant.

Table 03 - Soil EC variation (µS cm^{-1})

	Initial	Week 2	Week 4	Week 8
T1	163^{b}	172^{b}	250^{a}	262^{a}
T2	199^{b}	201^{b}	450^{a}	445^{a}
T3	252^{b}	286^{b}	625^{a}	629^{a}
T4	86^{b}	133^{ab}	205^{a}	211^{a}
T5	87^{b}	110^{b}	215^{a}	219^{a}
T6	134^{b}	140^{b}	278^{a}	272^{a}
T7	106^{b}	108^{b}	243^{a}	248^{a}
T8	103^{c}	157^{b}	278^{a}	281^{a}
T9	117^{c}	154^{b}	345^{a}	338^{a}
T10	88^{a}	97^{a}	89^{a}	94^{a}

Means within a row followed by the same superscript letter are not significantly different at $p > 0.05$.

The organic carbon content varied among the treatments over the 8 weeks incubation period. Overall, most treatments showed a decreasing trend in organic carbon during the incubation period, although the magnitude of decline differed considerably among treatments. T1, T2, T4, T5 and T10 showed clear reductions**,** whereas T7, T8 and T9 maintained relatively stable organic carbon levels**.** T3 and T6 showed an initial decline followed by a slight recovery at week 8. Treatment T10 had the lowest organic carbon content and declined from 1.1% to 0.4% over the 8 weeks. Overall, the reduction in organic carbon in most treatments indicates progressive decomposition and mineralization of organic materials during incubation.

The rice biochar amended treatments (T7, T8 and T9) showed a relatively lower rate of organic matter decomposition compared with the compost and acacia leaf residue amended treatments. This may be attributed mainly to the recalcitrant nature and chemical stability of biochar carbon, which contains relatively stable aromatic and condensed carbon structures that are more resistant to microbial decomposition. Studies have demonstrated that biochar generally decomposes much more slowly than fresh organic residues, thereby contributing to the longer-term stabilization of carbon in soil (Kuzyakov et al., 2009; Santos et al., 2012). In contrast, plant residues contain relatively more labile and readily decomposable compounds, including soluble compounds, cellulose and hemicellulose, which can be utilized by soil microorganisms during decomposition. The chemical quality of the organic substrate is an important factor controlling decomposition rates (Prescott, 2010; Cotrufo et al., 2013). Therefore, compost and acacia leaf residue may have undergone more rapid decomposition and mineralization during the incubation period, resulting in a greater reduction in measured organic carbon compared with the biochar-amended treatments. The relatively slow decomposition of biochar makes it potentially important for long-term carbon stabilization and retention in soil**.**

Table 04 - Soil organic carbon (mg kg^{-1})

	Initial	Week 2	Week 4	Week 8
T1	2.4^{a}	2.2^{a}	1.4^{b}	1.4^{b}
T2	2.5^{a}	2.2^{a}	1.7^{b}	1.6^{b}
T3	3.2^{a}	2.8^{ab}	2.2^{b}	2.4^{b}
T4	2.4^{a}	2.2^{a}	1.9^{b}	1.4^{c}
T5	2.6^{a}	2.3^{a}	1.8^{ab}	1.5^{b}
T6	2.9^{a}	2.7^{a}	2.2^{b}	2.4^{ab}
T7	2.3^{a}	2.0^{a}	1.8^{a}	1.9^{a}
T8	2.7^{a}	2.6^{a}	2.6^{a}	2.4^{a}
T9	3.1^{a}	3.0^{a}	2.8^{a}	2.8^{a}
T10	1.1^{a}	0.9^{a}	0.7^{ab}	0.4^{b}

Means within a row followed by the same superscript letter are not significantly different at $p > 0.05$.

Water drop penetration time (WDPT), an indicator of soil water repellency, generally decreased with increasing incubation period in most treatments (Table 05). The compost-amended treatments (T1–T3) initially recorded WDPT values ranging from 1.2 to 1.8 s, which generally declined during incubation. Although no significant differences were observed among the incubation periods for T1 and T2, T3 showed a significant reduction in WDPT from 1.8 s at the beginning of the incubation to 0.7 s at week 8. Similarly, the acacia leaf residue-amended treatments (T4–T6) showed a gradual decline in WDPT. Treatment T6 recorded the highest initial WDPT (2.4 s) and maintained relatively higher values during the first four weeks, but its WDPT significantly decreased to 1.8 s at week 8. Treatment T4 also showed a significant reduction from 1.7 s to 1.1 s, whereas the variation in T5 was not statistically significant. The rice biochar-amended treatments (T7–T9) exhibited a similar temporal pattern, with WDPT generally declining during incubation. In particular, T7, T8 and T9 showed significant reductions by week 8, reaching 0.7, 0.9 and 0.8 s, respectively.

In contrast, the control treatment (T10) maintained a relatively low WDPT throughout the incubation period, with values ranging from 0.7 to 1.1 s, and no significant temporal variation was observed.

The relatively higher WDPT observed in some amended treatments during the early stages of incubation may be associated with the presence of hydrophobic organic compounds introduced with the organic amendments. The magnitude of water repellency, however, depends not only on the quantity of organic matter but also on its chemical composition, degree of decomposition and interaction with soil minerals. Organic amendments can therefore produce different responses in WDPT despite increasing soil organic matter content (Doerr et al., 2000; De Bano, 2000).

The progressive reduction in WDPT observed during incubation may be attributed to the decomposition and transformation of relatively labile organic compounds and the gradual alteration of hydrophobic surfaces. Microbial decomposition can break down readily decomposable hydrophobic compounds, while incorporation and redistribution of organic materials within soil aggregates can reduce their direct influence on soil wettability. Consequently, the relatively short WDPT values recorded at the end of the eight-week incubation indicate that the amendments did not cause persistent or severe soil water repellency under the experimental conditions.

Among the amendments, acacia leaf residue treatments tended to maintain comparatively higher WDPT values during the early incubation period, particularly T6, while compost and biochar treatments generally showed lower WDPT values by the end of incubation. This difference may be related to the contrasting chemical characteristics and decomposition rates of the amendments. Biochar, containing relatively stable carbon and potentially hydrophobic surfaces, can exhibit variable effects on water repellency depending on feedstock and pyrolysis conditions (Mekuria and Noble, 2013). Therefore, the observed decline in WDPT with incubation suggests that the water-repellent effects of the amendments were relatively transient and were progressively reduced as the amended organic materials interacted with the soil and underwent decomposition and transformation.

Table - 05 Water drop penetration (seconds)

	Initial	**Week 2**	**Week 4**	**Week 8**
T1	1.2^{a}	0.9^{a}	0.7^{a}	0.8^{a}
T2	1.6^{a}	1.2^{a}	0.8^{a}	0.5^{a}
T3	1.8^{a}	1.6^{a}	1.8^{a}	0.7^{b}
T4	1.7^{a}	1.4^{a}	1.2^{ab}	1.1^{b}
T5	1.5^{a}	1.8^{a}	1.5^{a}	1.2^{a}
T6	2.4^{a}	2.2^{a}	2.1^{a}	1.8^{b}
T7	1.6^{a}	1.4^{a}	1.1^{a}	0.7^{b}
T8	1.7^{a}	1.8^{a}	1.6^{a}	0.9^{b}
T9	1.8^{a}	2.0^{a}	1.2^{ab}	0.8^{b}
T10	0.8^{a}	0.8^{a}	1.1^{a}	0.7^{a}

Means within a row followed by the same superscript letter are not significantly different at $p > 0.05$.

CONCLUSION

Overall, the 8-week incubation study demonstrated that the type and application rate of organic amendment strongly influenced the chemical and physical characteristics of Reddish Brown Earth soils. Rice biochar showed the greatest potential for improving soil pH, particularly at higher application rates, while compost and acacia leaf residue had comparatively limited effects on soil pH. Soil EC increased mainly during the first four weeks, indicating the initial release of soluble ions from the amendments, and subsequently stabilized. Organic carbon generally declined during incubation due to decomposition and mineralization, with greater reductions observed in compost- and acacia leaf residue-amended treatments, whereas rice biochar maintained relatively stable organic carbon due to its recalcitrant carbon. Water repellency also generally decreased with incubation time, indicating that the effects of the amendments on soil wettability were mainly transient and did not result in persistent water repellency. Overall, rice biochar demonstrated greater potential for improving soil pH and promoting carbon stabilization, while maintaining relatively stable soil properties during incubation. Therefore, rice biochar appears to be a promising amendment for improving selected soil properties and supporting the long-term sustainability of Reddish Brown Earth soils (Alfisols) in Sri Lanka.

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