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Acidic Soil Remediation Applied with Coffea Lignum Carbo as Soil Amendment

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ABTRACT

The study was conducted at Cagayan State University, Sta. Maria Lal-lo Cagayan from March 28, to April 18, 2024. Generally, the study was conducted to determine the remediation mechanism of coffea lignum carbo (CLC) in acidic soils. Specifically, the study aimed to assess the effects of coffea lignum carbo (CLC) application on the physical (bulk density, color, and soil texture) and chemical (potential hydrogen, organic matter, phosphorus, potassium, zinc, copper, manganese, and iron) properties of acidic soil and to determine the chemical properties of the coffea lignum carbo. The Completely Randomized Design (CRD) was used in the study. Ninety-six (96) polyethylene bags weighing 1 kg of soil were used in the four (4) treatments with three (3) replications. Soil media packed in the polyethylene bags correspond to one (1) replicate. The treatments used in the study were as follows: Treatment 1 (Lime), Treatment 2 (30grams of CLC), Treatment 3 (50grams of CLC), and Treatment 4 (70grams of CLC). Result revealed that T4 (70 grams of CLC) is the most effective application rate of coffea lignum carbo, therefore, it is recommended as an effective soil amendment to improve physical and chemical properties of soil. Likewise, the result of the study will be useful to the following; a) to researchers, use as baseline data to the improvement of future studiesrelated to coffea lignum carbo and create new technology to address soil acidity with the use of coffea lignum carbo; b) to students, use as their basis in conducting another set of research to study other parameters that are not included in the current study; c) to organic practitioners, the CLC will be used as additional/alternative substrate in making organic fertilizer; and d) to farmers, the use of coffea lignum carbo will address their problem on soil acidity to improve their crops' agronomic characteristics.

Keywords: *Coffea Lignum Carbo, Remedation, Acidic soil, Bulk density, Color, Soil texture.*

INTRODUCTION

Soil acidity poses a potential significant threat to soil quality. Excessive soil acidity can lead to reduction in essential nutrient availability, intensify the effects of toxic elements, diminish plant yield and water consumption, disrupt crucial soil biological functions such as nitrogen fixation, and render soil more susceptible to structural degradation and erosion. Without proper treatment, soil acidification can significantly impact agricultural productivity and the sustainability of farming systems. Acidity itself does not directly impede plant growth. Instead, it can negatively impact biological processes crucial for plant development. Acidic conditions affect soil by reducing the availability of vital plant nutrients like phosphorus and molybdenum, elevating the levels of certain elements to toxic concentrations, particularly aluminum and manganese and leaching of essential nutrients beyond the root zone (Agriculture Victoria, 2023).

Several technologies have been used to address soil acidity such as the use of lime. However, one of the problems faced in using lime is its availability in other communities. Thus, resorts have been made to create alternative for lime and this include the use of biochar.

Biochar can increase soil moisture and pH. By increasing the pH, biochar can cause a liming effect. Evidence shows that this can improve soil fertility by increasing microbial activity, nutrient availability, and reducing aluminum ($Al3+$) toxicity. While biochar is not a fertilizer, research indicates that it can help retain nutrients in the soil due to its charged surface and high surface area which allow it to adsorb nutrients like nitrogen, phosphorus, and carbon. Biochar has high potential as a sustainable product for increasing soil health and fertility in agricultural soils. Biochar production and its effects on soils can reduce the need for commercial fertilizers (O'Neal et al., 2020).

Hence, this study was conducted to determine the remediation mechanism of coffea lignum carbo in acidic soils.

MATERIALS AND METHODS

A. Materials

The materials used in the study are coffee wood water, a lighter, a bolo, improvised mini coffea lignum carbo retort, straight-edge clear jar, permanent marker, ruler, watch, tablespoon of powdered dishwashing detergent, and mesh sieve or colander.

B. Experimental Design and Treatments

The acidic soil was collected from the arable layer (0–30 cm). One-kilogram soil was placed in eight polyethylene bags per treatment replicated. The treatments were kept in room temperature and watered every three (3) days. The pots were incubated for 21 days. The treatments used in the study are the following;

T1- Control – 1 gram lime per 1kg of soil (agricultural lime)

T2-30 grams CLC per 1kg of soil (coffee wood)

T3-50 grams CLC per 1kg of soil (coffee wood)

T4 -70 grams CLC per 1kg of soil (coffee wood)

C. Methods

C.1. Production of Coffea Lignum Carbo

Coffea lignum carbo was produced via pyrolysis using coffee wood. Two half-kilogram samples of each of the CLC products were taken to the University of the Philippines, Los Baňos - Agricultural Systems Institute, for analysis of pH, organic matter content, available phosphorus, and exchangeable potassium.

C.2. Soil Sample Collection and Analysis

An acidic soil was collected in Cambong, Lal-lo, Cagayan. A composite sample of the soil was taken to the Regional Soil Analytical Laboratory in Tuguegarao City for analysis.

C.3. Soil Texture Analysis using Jar method

Using a mesh sieve or an old colander, sift the soil to eliminate any debris, rocks, and large organic matter such as leaves, sticks, and roots. Fill one-third of the jar with the soil to be tested. Then, fill the rest of the jar with clean water, leaving some space at the top. Add one tablespoon of powdered dishwashing detergent. Secure the jar with its cap and shake vigorously until the soil transforms into a uniform slurry. Place the jar on a level surface and allow it to settle for one minute. Afterward, mark the outside of the jar to indicate the coarse sand layer settled at the bottom. Let the jar remain undisturbed on a level surface for 2 hours. Mark the top of the next settled layer with a permanent marker; this layer represents the silt. After 48 hours, mark the top of the next settled layer with the permanent marker; this layer represents the clay settled on top of the silt layer. Using a ruler, measure and record the height of each layer as well as the total height of all three layers.

C.4. Room incubation of soil with Coffea lignum carbo

The effects of different levels of Coffea lignum carbo materials produced from coffee wood were examined through a room incubation experiment. One-kilogram air-dried soil was weighed and placed in polyethylene bags, and lime (finely powdered) and each CLC rate were added at 30, 50, and 70 grams per kilogram of soil and thoroughly homogenized. The moisture content of the soil-CLC mixture was maintained at 70% field capacity throughout the incubation period. All major holes were covered, and small holes were made to allow gaseous exchange but to minimize moisture loss upon incubation. The polyethylene bags were weighed every three days, and water was added to maintain constant moisture content throughout the experiment (Malo et al., 2013). The soils were sub-sampled at 0, 7, 14, and 21 days until the initiation of incubation. Three replicates of each treatment were prepared, randomly placed, and incubated in the political science room at room temperature for 21 days. The 1-kilogram soil samples were removed and air-dried from all the treatments and analyzed for nutrients, and the other parameters were also analyzed as per the standard methods.

Data gathered

1. Soil Chemical Properties. The chemical properties of the soil were recorded before and after the conduct of the study, including soil pH, nutrient content such as available phosphorus, exchangeable potassium, organic matter content, and micronutrients.

2. Soil Physical Properties. The physical properties of the soil were recorded before and after the conduct of the study, including soil color, soil texture and soil bulk density.
   - Soil Texture. These were taken by computing the percent of every soil particles of the soil sample using the formula:

$$\text{Soil Texture} = \frac{\textit{Height of soil particle}}{\textit{Total height}} \times 100$$

   - Bulk Density. These were taken by computing the ratio of oven dried soil to the

$$\text{Bulk Density} = \frac{\textit{Mass of oven-dried soil}}{\textit{Volume of the soil}}$$

3. Coffea lignum carbo properties. A sample of the biochar product was brought to the University of the Philippines, Los Baños-Agricultural Systems Institute for analysis of pH, available phosphorus, exchangeable potassium, nitrogen, and organic matter content.

Statistical Analysis

All the data gathered were collated, tabulated and analyzed following the Analysis of Variance (ANOVA) for Completely Randomized Design (CRD). The means were compared using the Least Significant Difference (LSD) test if the result of any parameter is significant (Gomez et al, 1998).

RESULTS AND DISCUSSION

1. Chemical properties

a. Coffea lignum carbo properties

Table 1 shows the chemical properties of coffea lignum carbo. Result revealed that coffea lignum carbo is composed of 3.51% of organic matter, 0.1 of phosphorus, 0.5 of potassium, and 9.4 of potential hydrogen.

The high organic matter content (3.51%) indicates that coffea lignum carbo could be used as soil amendment or organic fertilizer, enhancing soil structure and fertility. The presence of phosphorus (0.1%) and potassium (0.5%) suggests that coffea lignum carbo could be used to supplement these essential plant nutrients, promoting plant growth and development. The relatively high potential hydrogen (pH 9.4) implies that coffea lignum carbo may have liming properties, which could be beneficial for acidic soils by neutralizing their acidity and improving soil pH (Portilo et al., 2022)

Table 1. Result of Analysis for Coffea lignum carbo properties

Sample code	OM%	P_2O_5	K_2O	pH
Coffea Lignum Carbo	3.51	0.1	0.5	9.4

b. Potential Hydrogen (pH) level

Table 2 shows the pH level at 7, 14, and 21 days of incubation. Result revealed that the highest liming potential among all treatments is Treatment 4 (70 grams of CLC), followed by Treatment 3 (50 grams of CLC), Treatment 2 (30 grams of CLC) and Treatment 1 (Lime) The Analysis of Variance (ANOVA) shows that all treatments are significantly different with each other. This means that a higher application rate of CLC can increase the pH level of acidic soil. Higher biochar application rates can increase the soil pH. Studies have consistently shown that the application of biochar can significantly increase soil pH, particularly in acidic soils (Sigh et al., 2022).

Table 2. pH level at 7, 14, 21 days incubation

Treatment	7 days of incubation	14 days of incubation	21 days of incubation
T1 (Lime)	5.7 d	5.71 d	5.43 d
T2 (30g of CLC)	6.12 c	6.16 c	6.05 c
T3 (50g of CLC)	6.57 b	6.68 b	6.73 b
T4 (70g of CLC)	6.59 a	6.99 a	7.14 a
Statistical Inference	** at 0.01 level	** at 0.01 level	** at 0.01 level
CV (%)	1.41	1.07	1.29

c. Percent of organic matter

Table 3 shows the percent organic matter content at 7, 14 and 21 days of incubation.

Analysis of variance shows that there was no significant difference among all treatments. This means that whatever treatments used had the same effect in terms of percent in organic matter content.

In the study conducted by Kang et al., (2022), they concluded that biochar, when added to soil can increase the pH by attracting and holding nutrients, which can lead to increased decomposition rate and a decrease in soil organic matter content.

Table 3. OM% at 7, 14, 21 days of incubation

Treatment	7 days of incubation	14 days of incubation	21 days of incubation
T1 (Lime)	2.75	2.75	2.96
T2 (30g of CLC)	2.81	2.94	2.69
T3 (50g of CLC)	2.96	2.93	2.89
T4 (70g of CLC)	2.93	2.99	2.97
Statistical Inference	ns	ns	Ns
CV (%)	4.87	6.81	4.36

d. Phosphorus level

Table 4 shows the phosphorus level at 7, 14, and 21 days of incubation. Result revealed that the highest phosphorus level among all treatments is Treatment 4 (70 grams of CLC) with a mean of 6.91 at 7 days, 7.41 at 14 days, and 5.49 at 21 days of incubation, followed by Treatment 3 (50 grams of CLC), Treatment 2 (30 grams of CLC) and Treatment 1 (lime).

The analysis of variance indicated that Treatment 4 is highly significant from all other treatments in 7, 14, and 21 days incubation. Treatment 3 and 2 showed comparable effects and were significantly different from Treatment 1 under 7 days of incubation. On the other hand, at 21 days of incubation, Treatments 4 and 3 exhibited comparable effects and were significantly different from Treatment 2 and Treatment 1.

A study on the effect of biochar application on macronutrient retention and leaching in coconut-growing soils found that phosphorus (P) retention outperformed all other nutrients, indicating that biochar can bind to phosphorus, making it less accessible to plants over time. (Dissanayake et al., 2023). Similarly, another study reported that biochar can increase potassium (K) availability in the short term but may not significantly affect its availability over a longer incubation period.

Table 4. Phosphorus at 7, 14, 21 days incubation (ppm)

Treatment	7 days of incubation	14 days of incubation	21 days of incubation
T1 (Lime)	2.58 c	2.61 d	2.34 c
T2 (30g of CLC)	4.97 b	4.68 c	3.70 b
T3 (50g of CLC)	5.84 b	5.87 b	4.88 a
T4 (70g of CLC)	6.91 a	7.41 a	5.49 a
Statistical Inference	** at 0.01 level	** at 0.01 level	** at 0.01 level
CV (%)	10.9	11.03	4.41

Note: Means with the same letter are not significantly different.

e. Potassium level

Table 5 shows the potassium level at 7, 14, and 21 days of incubation. Result revealed that Treatment 4 (70 grams of CLC) has the highest potassium level among all treatments, followed by Treatment 3 (50 grams of CLC), Treatment 2 (30 grams of CLC) and Treatment 1 (lime).

The analysis of variance indicates that at 14 days of incubation, Treatment 4 showed significant difference among all treatments, while Treatments 3 and 2 exhibited comparable effects but were significantly different from Treatment 1. On the other hand, at 21 days of incubation, Treatments 4 and 3 yielded comparable effects and were significantly different from Treatment 2 and Treatment 1.

A study on the effects of biochar and compost on soil macronutrients found that the pH values of leachates decreased with increasing incubation periods for both biochar and compost,

indicating a reduction in macronutrient availability over time (Khalilet et al, 2017).

Table 5. Potassium at 7, 14, 21 days incubation (ppm)

Treatment	7 days of incubation	14 days of incubation	21 days of incubation
T1 (Lime)	52.56 d	62.54 c	44.9 c
T2 (30g of CLC)	282.10 c	319.36 b	279.95 b
T3 (50g of CLC)	368.27 b	439.45 b	413.65 a
T4 (70g of CLC)	446.77 a	626.19 a	501.13 a
Statistical Inference	** at 0.01 level	** at 0.01 level	** at 0.01 level
CV (%)	10.45	18.04	17.42

Note: Means with the same letter are not significantly different.

f. Available Zinc

Table 6 shows the zinc level in 7, 14, and 21 days of incubation. Result revealed that among all treatments, Treatment 4 (70 grams of CLC) has the highest zinc level, followed by Treatment 3 (50 grams of CLC), Treatment 2 (30 grams of CLC), and Treatment 1 (lime). The analysis of variance indicates that Treatment 4 exhibits a significant difference among all Treatments. However, under 7 days of incubation, Treatments 3, 2, and 1 demonstrated comparable effects. At 14 days of incubation, Treatments 4 and 3 showed comparable effects and were significantly different from treatments 2 and 1. However, upon reaching 21 days of incubation, all treatments are significantly different with each other. The results suggest that soil texture and incubation period can affect the dissolution and leaching of zinc in the soil (Umar et al, 2023).

Table 6. Zinc at 7, 14, 21 days incubation (ppm)

Treatment	7 days of incubation	14 days of incubation	21 days of incubation
T1 (Lime)	0.33 b	0.33 b	0.27 d
T2 (30g of CLC)	1.69 b	1.94 b	1.31 c
T3 (50g of CLC)	6.89 ab	7.11 a	4.40 b
T4 (70g of CLC)	9.78 a	11.33 a	10.27 a
Statistical Inference	* at 0.05 level	** at 0.01 level	** at 0.01 level
CV (%)	81.29	45.77	9.18

Note: Means with the same letter are not significantly different.

g. Available Copper

Table 6 below presents the copper levels at 7, 14, and 21 days of incubation. The results revealed that Treatment 1 (lime) exhibited the highest level of copper, followed by Treatment 2 (30 grams of CLC), Treatment 3 (50 grams of CLC), and Treatment 4 (70 grams of CLC).

The analysis of variance indicates that at 21 days, only Treatment 1 achieved the highest copper level, although it showed comparable effects to Treatment 2. Treatment 2, in turn, exhibited comparable effects to Treatment 3, and similarly, Treatment 3 showed comparable effects to Treatment 2 and 4.

Copper availability in the soil is directly related to pH levels. At higher pH levels, copper becomes less available to plants due to the formation of insoluble copper compounds (Rosa et al, 2020).

Table 7. Copper at 7, 14, 21 days incubation (ppm)

Treatment	7 days of incubation	14 days of incubation	21 days of incubation
T1 (Lime)	0.70	0.63	0.69 a
T2 (30g of CLC)	0.69	0.65	0.59 ab
T3 (50g of CLC)	0.49	0.53	0.44 bc
T4 (70g of CLC)	0.56	0.45	0.43 c
Statistical Inference	ns	ns	* at 0.05 level
CV (%)	14.59	21.99	15.54

Note: Means with the same letter are not significantly different.

h. Available Manganese

The results for the levels of available manganese at 7, 14, and 21 days of incubation are presented in Table 7. The findings indicate that Treatment 1 (lime) exhibited the highest level of manganese, followed by Treatment 2 (30g of CLC), Treatment 3 (50g of CLC), and the lowest manganese level was observed in Treatment 4 (70g of CLC).

The analysis of variance indicates that at 7, 14 days of incubation had no significant result among all. However, under 21 days of incubation, there was an insignificant effect on the manganese levels.

Soil with pH values lower than 5.5 may contain a large amount of manganese in watersoluble or exchangeable form, making it more available to plant (Mulder et al)

Table 8. Manganese at 7, 14, 21 days incubation (ppm)

Treatment	7 days of incubation	14 days of incubation	21 days of incubation
T1 (Lime)	34.20 a	36.00 a	84
T2 (30g of CLC)	30.87 a	29.87 ab	70
T3 (50g of CLC)	21.93 b	21.87 bc	74
T4 (70g of CLC)	19.80 b	15.20 c	61.33
Statistical Inference	** at 0.01 level	** at 0.01 level	ns
CV (%)	11.88	21.08	11.17

Note: Means with the same letter are not significantly different.

i. Available Iron

Table 9 shows the iron level at 7, 14, and 21 days of incubation. Result revealed that Treatment 1 (lime) has the highest iron level, followed by Treatment 2 (30 grams of CLC), Treatment 3 (50 grams of CLC), and Treatment 4 (70 grams of CLC).

The analysis of variance shows that Treatment 1 and Treatment 2 had comparable effects, as did Treatment 3 and Treatment 4, at 7 days of incubation. At 14 days, Treatment 1 exhibited significant differences among all Treatments, while Treatment 2 and Treatment 3 showed comparable effects, as did Treatment 3 and Treatment 4. However, at 21 days, Treatment 1 showed significant differences among all Treatments, while Treatment 2 and 3 exhibite d comparable effects, as did Treatment 3 and Treatment 4.

At higher pH levels, ferric iron becomes less soluble and tends to precipitate out of solution as hydroxides, reducing the amount of dissolved iron (Sulaiman et al, 2017).

Table 9. Iron at 7, 14, 21 days incubation (ppm)

Treatment	7 days of incubation	14 days of incubation	21 days of incubation
T1 (Lime)	20.37 a	20.9 a	29.67 a
T2 (30g of CLC)	18.00 a	18.1 ab	21.67 b
T3 (50g of CLC)	11.03 b	11.7 bc	15.67 bc
T4 (70g of CLC)	10.30 b	8.50 c	11.00 c
Statistical Inference	** at 0.01 level	** at 0.01 level	** at 0.01 level
CV(%)	13.88	24.11	21.14

Note: Means with the same letter are not significantly different.

2. Physical Properties

a. Soil texture

The soil texture at 7, 14, and 21 days of incubation is presented in table 10. Result revealed that all Treatments did not changed in soil texture in 7, 14, and 21 days of incubation.

Table 10. Soil Texture Analysis

Treatments	7 days	14 days	21 days
Treatment 1 (Lime)	loamy sand	loamy sand	loamy sand
Treatment 2 (30 grams of CLC)	loamy sand	loamy sand	loamy sand
Treatment 3 (50 grams of CLC)	loamy sand	loamy sand	loamy sand
Treatment 4(70 grams of CLC)	loamy sand	loamy sand	loamy sand

b. Bulk Density

The bulk density results at 7, 14, and 21 days (Table 11) showed Treatment 1 (Lime) had the highest density at 1.29, followed by Treatment 2 (1.26 with 30g CLC), Treatment 3 (1.23 with 50g CLC), and Treatment 4 (1.12 with 70g CLC).

The results indicate that higher application rates of biochar lead to greater reductions in soil bulk density (Singh et al, 2022). Lower bulk density allows for better soil aeration, water movement, and root growth, making it more suitable for plant growth.

Table 11. Soil Bulk Density

Treatments	Baseline Data	Computed Bulk Density
Treatment 1 (Lime)	1.4 g/cm^3	1.29 g/cm^3
Treatment 2 (30 grams of CLC)	1.4 g/cm^3	1.26 g/cm^3
Treatment 3 (50 grams of CLC)	1.4 g/cm^3	1.23 g/cm^3
Treatment 4 (70 grams of CLC)	1.4 g/cm^3	1.12 g/cm^3

c. Soil Color

Table 12 shows the soil color at 21 days of incubation. Result revealed that the color of Treatment 1 (lime) is reddish brown, Treatment 2 (30g of CLC) is weak red, Treatment 3 (50g of CLC) is reddish gray and Treatment 4 (70g of CLC) is dark reddish gray.

Similarly, research has found that biochar application can increase the soil's organic carbon levels, which can lead to a darker color (Singh et al, 2022). Darker soils are often associated with rich, fertile soil that support a wide range of plant growth.

Table 12. Soil Color at 21 days of incubation

Treatments	21 days incubation			
	Hue	Value	Chroma	Color
T1 (lime)	2.5YR	5	4	Reddish brown
T2 (30g of CLC)	2.5YR	4	2	Weak red
T3 (50g of CLC)	2.5YR	6	1	Reddish gray
T4 (70g of CLC	2.5YR	4	1	Dark reddish gray

CONCLUSION

Based on the results of this study, it proved the effectiveness of Coffea Lignum Carbo application in ameliorating acidity which increase the soil pH and macronutrients, and decreased the micronutrients of the soil except zinc. Among all the treatments, Treatment 4 (70 grams of CLC) was found to have significantly better liming potential than other treatments. However, in the Organic Matter content, 7 and 14 days of incubation in copper, and 21 days of incubation in manganese is found not significant.

RECOMMENDATIONS

Based on the result of the study T4 (70 grams of CLC) is the most effective application rate of coffea lignum carbo, therefore, it is recommended as an effective soil amendment to improve physical and chemical properties of soil. Likewise, the result of the study will be useful to the following;

To **researchers**, it can be used as baseline data to the improvement of a future study related to coffea lignum carbo and create new technology to address soil acidity with the use of coffea lignum carbo;

To **students**, it can be used as their basis in conducting the same research while including some parameters that are not included in the study;

To **organic practitioners**, the coffea lignum carbo will be used as additional/alternative substrate in making organic fertilizer; and

To **farmers**, the use of coffea lignum carbo can address their problem on soil acidity to improve agronomic characteristics of crops.

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