Improvement of Quality of Biocatalytic Fertilizer Through Incorporation of Biomass-Based Nutrients

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***Abstract*—Biochar, harnessed as a biocatalyst, offers a transformative opportunity to revolutionize the production of biochar fertilizer, achieving both higher quality and cost-effectiveness. This study aimed to develop an exceptional organic fertilizer by harnessing the catalytic potential of rice husk biochar. The biochar was activated by formulating aqueous biocatalysts in separate aerobic reactors. Five aerobic reactors were constructed using 10 L plastic containers and 3 mm diameter transparent flexible tubes. The process involved blending a mixture of shredded organic (*Gliricidia sepium* leaves, *Tithonia diversifolia* leaves, and *Micropiper pellucidum*, with five different ratios) with a precisely measured amount of water. 10 g of Eppawala rock phosphate (ERP) was added to each solution. These prepared slurries were then transferred into the custom-made reactors, and continuous aeration was maintained throughout the experimental period. Size-reduced biochar was added intermittently to each reactor. Treatment 4 ((*Gliricidia* (500g) + *Thithoniya* (500g) + *Micropiper pellucidum* (500g) + Biochar (453g) + ERP (10g)) consistently displayed higher nutrient levels on day 01 and day 7 (N = 1540 mg/Kg, P =72 mg/Kg, K = 3028 mg/Kg), and also consistently exhibited high pH (7.36±0.21) levels throughout the study. Due to its ability to retain and gradually release nutrients, treatment 4 presents itself as a compelling subject for further exploration and utilization. The composition of treatment 4 is well-suited for the creation of organic fertilizers enriched with biochar biocatalysts, compost, ERP, and other components, resulting in a nutrient-rich end product.**

***Keywords*—Biochar, biochar-biocatalyst, gliricidia green leaves, macropiper pellucidum, tithonia diversifolia**

I. Introduction

Intensive agricultural activities have long been recognized as a driving force behind the depletion of soil carbon storage, effectively diminishing their capacity to function as vital carbon sinks[1]. To address this pressing concern, numerous strategies have been explored to bolster soil carbon sequestration, including conservation practices, the incorporation of biosolids and organic waste into soil amendments, and an emphasis on diversified crop rotations [2]. Organic residues, when applied to agricultural soils, hold the promise of not only enhancing soil carbon storage but also mitigating greenhouse gas emissions[3]. However, a persistent challenge associated with the utilization of organic waste materials, such as green manures and composts, lies in their relatively swift decomposition rate, rendering them a source of carbon emissions rather than an effective carbon sink [4]. In stark contrast, organic waste possesses the potential to transform into biochar, a substance characterized by its notably slow decomposition rate. Biochar has emerged as a stable and enduring alternative to compost, making it a promising tool for improving soil carbon sequestration [5]. Various physical and chemical attributes of biochar, including surface area, degree of condensation, and particle size, play pivotal roles in determining its stability within soils [6].

This paper delves into the compelling rationale for the co-application of biochar and compost as organic soil amendments. Composting, a widely employed organic soil supplement, is celebrated for its contributions to enhancing soil quality and sequestering carbon post-application [7]. Yet, the aerobic microbial degradation inherent to composting processes carries an unfortunate side effect: the avoidable loss of essential nutrients, particularly nitrogen. Studies reveal that the total nitrogen loss during composting can span an alarming range, from 16% to 76% [8]. This substantial nitrogen loss not only diminishes the nutritional value of the final compost products but also raises concerns about its environmental impact. Recognizing the shared objective of enhancing soil quality and nutrient retention, this paper underscores the potential synergy between biochar and compost when utilized together [9]. Research by Hardy Schulz (2014) demonstrated that co-composted biochar significantly promoted plant growth, particularly in sandy soils, making it an attractive prospect for augmenting soil fertility. Additionally, biochar, known for its nutrient-absorbing properties, can be employed during composting to curtail nutrient losses, particularly nitrogen, thus yielding nutrient-dense green manure[10]. However, further enhancements can be achieved by introducing biochar to a biocatalyst [6, 11], a material facilitating biochemical reactions in living organisms. Such biocatalysts can occur either chemically or biologically, with the latter offering unique agricultural advantages. By catalyzing biochar with natural enzymes that exhibit microbial activity, it is possible to forge a path towards entirely organic fertilizers enriched with nutrients derived from biocatalysts, compost, and Eppawala Rock Phosphate (ERP). This study aimed to develop bio-catalyzed organic fertilizer utilizing biochar, laden with essential elements for both short-term and perennial crops.

II. METHODOLOGY

A. Addition of Ingredients and Pre-processing

Collection of Raw Materials and Preprocessing

2 kg of *Tithonia diversifolia* leaves, 2 kg of *Gliricidia sepium* leaves 3 kg, 1.5 kg of *Micropiper pellucidum* [12, 13], 2 kg of Rice husk biochar, and 50 g of Eppawala Rock Phosphate (ERP) were collected. The collected *Tithonia diversifolia*, Glydrisyria sepium leaves, and *Micropiper pellucidum* were cut into small particles separately using a separate grinder and each mixture was taken to prepare a fertilizer solution. The added ingredients can be analyzed to determine the initial composition. Rice husk biochar was obtained from a fertilizer producing company and *Thithoniya diversifolia*, *Gliricidia sepium* leaves, and *Micropiper pellucidum* were collected from the Sri Lanka Technological Campus Padukka premises. The biochar was produced under pyrolytic conditions, using a temperature range of 450 °C for a period of 2.5 hours. Particle size of selected biochar was reduced and particles <4 mm was used for the experiment [6]. Preprocessed *Thithonia diversifolia* leaves and size-reduced (<2 mm) *Gliricidia sepium* green leaves were analyzed separately for moisture content (MC), ash content, total solids (TS), and volatile solids (VS) concentration using APHA Method 2540-G. Statistical analysis was carried out employing Analysis of Variance (ANOVA).

Reactor Fabrication, Biocatalysts Preparation, and Analysis

Five aerobic reactors were constructed using 10 L plastic containers and 3 mm diameter transparent flexible tubes. The plastic containers remained unaltered, and their lids were intentionally left open to facilitate gas exchange and promote aeration, specifically to accommodate the insertion of an aerator tube. Continuous aeration was maintained using an aerator pump (SDA-2800). The process involved blending a mixture of shredded organic with a precisely measured amount of water to create a homogenous solution. Similarly, the chopping and blending procedure was applied to prepare separate solutions from 2 kg of *Gliricidia sepium* leaves, 2 kg of *Tithonia diversifolia* leaves, and 1.5 kg of *Micropiper pellucidum* leaves. In each case, 100 mL of the resulting solution was set aside for characterization. The remaining slurries were diluted with water to achieve a consistent organic matter-to-water ratio of 1:4. During this dilution process, 10 g of ERP was added to each solution as P source. *Micropiper pellucidum* leaves were incorporated as a rich source of K. For these five treatments were applied as given in Tab. 1.

TABLE 1: TREATMENTS USED FOR THE EXPERIMENT

Treatment	**Composition of the biochar biocatalyst mixture**
Treatment 1	*Gliricidia* (1Kg) + Biochar (302 g) + ERP (10g) + Water (4L)
Treatment 2	*Thithoniya*(1Kg) + Biochar (302g) + ERP(10g) + Water (4L)
Treatment 3	*Gliricidia* (500g) + Biochar (402g) + *Micropiper pellucidum* (500g) + ERP (10g) + Water (4L)
Treatment 4	*Gliricidia* (500g) + *Thithoniya* (500g) + *Micropiper pellucidum* (500g) + Biochar (453g) + ERP (10g) + Water (4L)
Treatment 5	*Thithoniya* (500g) + *Micropiper pellucidum* (500g) + Biochar (302g) + ERP (10g) + Water (4L)

These prepared slurries were then transferred into the custom-made reactors, and continuous aeration was maintained throughout the experimental period. To adjust the pH of the reactors to a neutral value of 7, size-reduced biochar was added intermittently to each reactor. The quantity of added biochar was carefully measured and recorded as outlined in Tab. 2.

TABLE 2: QUANTITIES OF BIOCHAR ADDED TO EACH BIOCATALYTIC REACTOR

Treatment	**Quantity of biochar added (g)**
01	Day 01 – 302g
02	Day 01 – 302g
03	Day 01 – 302g, Day 03 – 100g
04	Day 01 – 453g
05	Day 01 – 302g

Representative samples were collected from each reactor and analyzed daily for 07 days. This analysis included pH measurements using a pH meter (Thermo Scientific, model Orion 2 star), as well as assessments of EC, salinity, and TDS (Total Dissolved Solids) concentration obtained using a conductivity meter (Thermo Orient Model 145 A). Additionally, TS (Total Solids) and TSS (Total suspended solids) were determined following the APHA Method 2540-G. Furthermore, total nitrogen (N) content was determined using the Kjeldahl method, total potassium (K) was analyzed through the Exchangeable Base method with a flame photometer, and total phosphorus (P) was measured using the Olsen P method.

III. RESULTS AND DISCUSSION

In the study of biocatalytic fertilizers enriched with biomass-based nutrients, various treatments were explored, each constituted by a unique combination of *Gliricidia sepium*, *Tithonia diversifolia* (wild sunflower), *Micropiper pellucidum*, biochar, and ERP as raw materials. The research aimed to comprehend the implications of these treatments on nutrient dynamics, soil health, and their potential applications in sustainable agriculture. A pivotal aspect of these biocatalytic fertilizers was their pH levels, which played a significant role in nutrient availability. The pH ranged from mildly alkaline (pH 7) to moderately alkaline (pH 10) [6]. Interestingly, the pH varied across treatments, showcasing the influence of raw materials on the biocatalytic mixture's pH. Notably, Treatment 4, which contained all the mentioned components, consistently exhibited higher pH levels throughout the study, highlighting its potential alkaline effect.

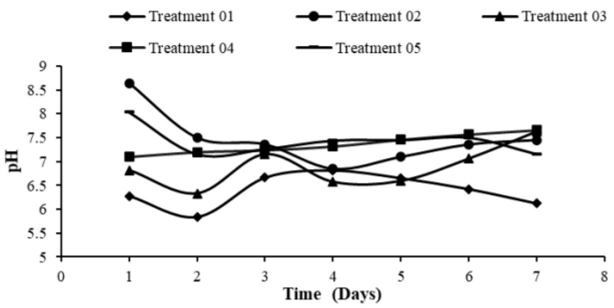

Fig. 1. pH variations with time

This was crucial as a higher pH (5.5 to 7) could enhance nutrient availability in the soil, making essential elements more accessible for plant uptake. Furthermore, the study delved into TDS and EC as vital parameters for assessing nutrient concentration and soil salinity. Treatments 4 and 5 consistently showed higher TDS and EC levels, indicating a potentially increased nutrient solubility, but the need for managing potential soil salinity concerns. Moreover, TSS measurements reflected the nutrient retention capabilities of the treatments, with Treatment 1 consistently demonstrating an upward trend, suggesting effective nutrient retention, especially in the presence of ERP. On the other hand, Treatment 3 displayed fluctuations, potentially due to the influence of *Micropiper pellucidum*, warranting further analysis. TS measurement emphasized the complex nature of these mixtures, with Treatment 4 showing substantial variations in TS values, suggesting intricate compositional dynamics.

TABLE 3: CHARACTERISTICS OF THE TREATMENT MIXTURES DURING THE STUDY PERIOD

Treatment	pH	TDS (mg/L)	EC (mS/cm)	TSS (mg/L)	TS (mg/L)
Treatment 01	6.40 ±0.34	3925.14 ±1313.195	6439.43 ±1823.63	55571.43 ±26893.97	72142.86 ±105550
Treatment 02	7.47 ±0.57	2969.57 ±503.54	5939.14 ±1007.08	77285.71 ±43942.06	429285.7 ±355568
Treatment 03	6.88 ±0.44	3106.86 ±139.29	6215.43 ±276.08	32714.29 ±105550	175571.4 ±47240.02
Treatment 04	7.36 ±0.21	3108.86 ±179.13	5962.43 + - 682.54	41857.14 ±12088.96	161285.7 ±57438.99
Treatment 05	7.43 ±0.31	2598.71 + - 331.70	5196.29 ±662.40	22428.57 ±2699.206	25587.1 ±164975.2

In conclusion, the variations in nutrient content, including Total Nitrogen (N), Total Phosphorus (P), and Total Potassium (K), showcased the potential of these biocatalytic fertilizers for sustainable agriculture.

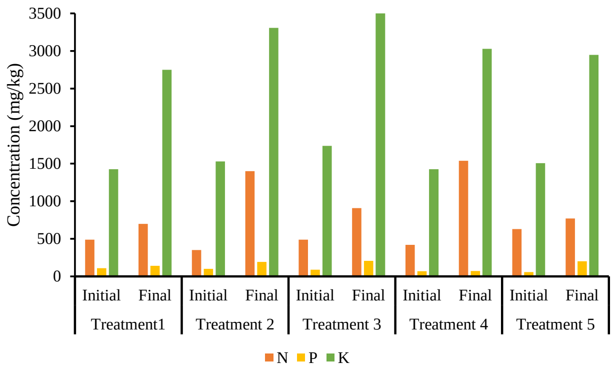

Fig. 2. Total N, P, K contents variation of catalysts

Treatment 3 exhibited a significant increase in nitrogen content from an initial level of 490 mg/kg to a final level of 910 mg/kg. Similarly, phosphorus levels increased notably from 88 mg/kg to 208 mg/kg, and potassium levels rose from 1,737 mg/kg to 3,625 mg/kg. In contrast, treatment 4 displayed a lower initial nitrogen content of 420 mg/kg, which increased substantially to 1,540 mg/kg. However, phosphorus levels saw a minimal change, starting at 68 mg/kg and reaching 72 mg/kg. Potassium levels showed an increase from 1,426 mg/kg to 3,028 mg/kg. Treatment 4 consistently displayed higher nutrient levels on day 01 and day 07 (N= 1540 mg/Kg, P=72 mg/Kg, K=3028 mg/Kg) reflecting its superior nutrient retention and release capabilities, making it a promising candidate for further investigation and application. The composition of treatment 4 is suitable for developing organic fertilizer with biochar biocatalyst, compost, and ERP, etc. which will be rich in nutrients. Continuous monitoring and customization of nutrient management strategies are recommended to maximize their effectiveness in developing fertilizers to achieve sustainable agriculture goals.

IV. CONCLUSION

The study of biocatalytic mixtures enriched with biomass-based nutrients has unveiled the intricate interplay between raw materials, pH, nutrient dynamics, and their implications for sustainable agriculture. The research encompassed five distinct treatments, each comprising a unique combination of *Gliricidia sepium*, *Tithonia diversifolia* (wild sunflower), *Micropiper pellucidum*, biochar, and ERP as the raw materials. The findings have several key implications. First, the pH variations in the biocatalytic mixtures have highlighted the importance of raw materials in modulating soil pH. Treatment 4 consistently exhibited higher pH levels, indicating its potential to impart alkalinity to soils. This effect can significantly influence nutrient solubility and availability, especially for crops favoring alkaline conditions, thus holding promise for tailored nutrient management. The analysis of TDS and EC emphasized the need for balanced nutrient solubility and the management of potential soil salinity concerns. Treatments 4 and 5 consistently showed elevated TDS and EC levels, suggesting an increased nutrient solubility, while Treatment 2 consistently displayed lower TDS and EC values. The careful selection of treatments is crucial to cater to crop and soil requirements and to minimize adverse effects on soil salinity. Treatment

4, composed of *Gliricidia*, *Thithonia diversifolia*, *Micropiper pellucidum*, biochar, and ERP, consistently exhibited higher nutrient levels and retention across various parameters, suggesting its efficacy in nutrient management. This outcome offers significant promise for advancing environmentally friendly and high-yield agriculture, emphasizing the need for further research to understand the mechanisms underlying its superior performance.

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