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Impact of Integrating Biochar and Straw Along with Chemical Fertilizers on Soil Health

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Abstract

This research set out to compare the short-term impacts of biochar, straw, and chemical fertilizers to the impacts of chemical fertilization alone on the chemical and microbiological parameters of paddy soil. The following five soil fertilization methods were assessed. Bamboo biochar plus regular fertilizers (BCRF),Straw plus Regular Fertilizers (SRF),Straw Biochar plus Regular Fertilizers (SCRF), Regular Chemical Fertilizers (RF), and Straw Biochar plus 70% Regular Chemical Fertilizers (RCF). After around 1.5 years, their impacts were studied. The pH and Cation Exchange Capacity (CEC) of soils treated with biochar were both noticeably higher. After applying biochar, the soil's phosphorus and potassium concentrations rose. Moreover, with straw biochar to the SCRF and SC plus seventy percent RF treatments, the soil Colwell P concentration was dramatically raised.When bamboo biochar was taken out of the ground, the oxygen-to-carbon ratio quadrupled. This suggested that the soil-borne oxidation of BC was considerable. The microbial communities' fingerprints created by Denaturing Gradient Gel Electrophoresis (DGGE) varied depending on the treatments. The Shannon diversity and species richness indexes were greater in soils with additional biochar than in soils without it. According to the findings, biochar may increase soil fertility.

Keywords: Biochar, Impact, chemical fertilizers, straw amendment, soil health

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1. Introduction

"Soil health Management is crucial for the conservation of biodiversity and the protection of agricultural production that is ecologically responsible." Hence, maintaining and protecting the health of the soil is of the utmost significance for the survival of the ecosystem. The qualities of the soil, including physicochemical and biological features [1]. Healthy food and nutrient supply are becoming more vital in the face of difficulties like the expanding human population and the impacts of climate change. Soil carbon sequestration is one way in which the agriculture industry may help mitigate climate change by lowering GHG emissions and atmospheric CO_2. Moreover, new synergies between agriculture and energy production may have mitigation potentials by supplying agricultural leftovers for bioenergy production to replace fossil fuels. Bioenergy may be effectively generated by thermal gasification from a wide variety of agricultural portions, with biochar as a useful by-product owing to its high level of carbon [2].

Biochar has recently gained popularity as a desirable soil conditioner, a method of carbon sequestration, and a possible boost to crop yield. A solid substance known as biochar is created by heating agricultural waste in an oxygen-limited environment. It has high carbon content, a lacunose structure, a sizable surface area, and an aromatic nature. As biochar is resistant to microbial deterioration, adding it to the soil offers great potential for sequestering carbon [3]. Moreover, straw biochar has been shown to have beneficial impacts on soil cation exchange capacity, soil water retention, and root growth in addition to a liming effect and fertilizer value. Hence, using straw biochar as a soil improvement and carbon sequestration agent is a viable strategy for fusing the production of bioenergy with the preservation of soil quality, although the idea has not yet been extensively tested on the ground [4].

The use of chemical fertilizer is an extremely important step in increasing crop yield and improving the fertility of the soil. Chemical fertilizers are available in several forms, including those rich in potassium, nitrogen, andphosphorus. The use of fertilizers not only leads to an improvement in crop yield but also leads to changes in the physicochemical and biological features of the soil. Yet, the continuous use of chemical fertilizers is to blame for the falling levels of decomposed organisms in the soil and the accompanying deterioration in the health of farmingsoil.The misuse of chemical fertilizers causes the soil to become more compacted, decreases pollutes the environment, soil fertility, soil, and water, and diminishes the number of essential nutrients and nutrients in the soil, which in turn creates an environmental dangers [5].

The research [6] investigated the impact of lowering the use of mineral fertilizer and partly replacing in a vegetable garden's effect of organic enhancement on Heavy metals and soil fertility concentration had been grown consistently for 10 years between 2009 and 2012.The study [7] explored the effects of three different rates of straw application paired with the same inorganic fertilizer on the yield of maize, the water-use efficiency, and the characteristics of the soil.Thepaper [8] discussedthe meaning of soil health as well as its history. After which it is contrasted with many other soil-related ideas. They present an overview of the ecosystem services that soils provide, the indicators that are utilized to quantify soil functioning, and their incorporation into useful soil quality indices.Thestudy [9] focused on the external variables that affect the number of rhizosphere bacteria, as well as the effect that crop management methods have on the health of the soil and the role that these factors play in the production of crops sustainably.The article [10] discussed the many different impacts that pesticides and fertilizers have on the environmental composition and structure of the soil, as well as the many different alternatives to using inorganic fertilizers and pesticides. This will allow for preventative measures to be taken to preserve the natural world.

The purpose of the study was to determine how biodegradable plastic mulches affect soil quality.That was accomplished by analyzing the effects of these mulches on a variety of soil properties and estimating the functions that these properties and functions are estimated to perform [11].The brief article was an assessment of the effect that human actions have had on the biodiversity and succession of microorganisms [12]. The study [13]examined the effects of direct drill and shallow non-inversion two conventional tillage techniques that are used in place of conventional mouldboard plowing. five years following their introduction from 2013 to 2018 within the River Wensum DTC.The study [14] used next-generation sequencing of the 16S ribosomal RNA gene to evaluate soil microbial community structure, diversity, and richness and found that conservative and organic agricultural systems had substantial effects on soil microbial heterogeneity and community composition, while the consequences of soil health treatments were more modest in both farming systems. The [15] study investigated the relationship between cover crops, crop rotation, and other long-term tillage practices and the yields of maize as well as the health of the soil.

The goal of this research was to assess the microbiological and chemical characteristics of agricultural soil before and after exposure to biochar, straw, and chemical fertilizers.

2. Materials and methods

2.1. Experimental location and configuration

An outdoor study was carried out at a rice field in Uttaraandhra, which is located in Andhra Pradesh Province, India. The region experiences an average subtropical climate with an annual rainfall of 1,552 millimeters, nearly 40% occurs between March and early July, and about 15% falls between the months of late July and November. Rice is grown during the summer months (June to September), and rapeseed is grown during the fall months. According to the Organization of Soil Science and CAS 2001, the soil that is used for paddy has roughly 30 percent clay. Five fertilization treatments were applied: (1) RF, (2) SRF, (3) SCRF, (4) BCRF, and (5) straw biochar+seventy percent of the SC seventy percent RF. Every therapy was carried out in triplets with aregion of ninety-four meters square in a randomized block strategy. For a growth season, normal fertilization usage rates for Nitrogen (N), Phosphorous (P), and potassium (K) were eighty, sixty, and seventy kg ha-1, correspondingly. The Nitrogen fertilizer was administered at a 3:4:3 ratio both as a base fertilization and throughout the tillering and ear differentiating phases.

Superphosphate and potassium chloride, accordingly, were utilized as the basis for the fertilization of the soil. A gradual pyrolysis process lasting 8 hours at about 600°C produced the biochar utilized in the experiments. A computerized temperature regulator (detection accuracy: 5°C) was installed in the muffle furnace where the biochar was created. Biochar has a 25% production yield, on average. Bamboo biochar (BC, size < 3 mm) and straw biochar (SB, < 2 mm) were applied at rates of 7.5 t ha-1 each.A rate of thirty 〖ha〗^(-1)of rice straw chips was implemented. Table 1 displays the biochar's characteristics.

Table 1: characteristics of the biochars made from bamboo and straw that were utilized in the study

Type	Bamboo biochar	Straw biochar
Density (g cm^{-3})	0.56	0.14
Fixed carbon (%)[1)]	69.01	51.81
pH(1:20 H_2O)	8.61	9.01
Ash contents (%)	11.91	24.00

Fixed carbon is the carbon that remains after burning biochar at a high temperature without additional biochar or straw. The test plots were maintained using conventional farming methods in the area. Following the harvest of the rice in October 2012, three replicate soil samples were taken at 0–20 cm depth for every treatment. To separate the fresh soil for DNA extraction and chemical research, it was passed through a 5 mm mesh screen. The part that was utilized to extract the DNA was kept at -76°C till 2 weeks later when it was evaluated. The part utilized for chemical analysis was pulverized, sieved through a 2-mm mesh, air-dried at room temperature, and then kept in sealed plastic bags until it was examined. Utilizing a “scanning electron microscope (SEM) paired with an energy-dispersive X-ray spectrometer(EDX)”, bamboo biochar fragments are easily separated from the soil for analysis.

2.2. Study of biochar, Soil, and soil microbial diversity

The accessible potassiumis evaluated utilizing atomic absorption spectrophotometry, Colwell P was determined utilizing the Colwell technique, and soil pH was assessed in a 1:2.5 soil extract. The subsample was further ground for it to be able to fit through a sieve with a millimeter size of 1 for the CEC, which was evaluated using a compulsive exchange.

The subset was collected and dried even more finely so that it could get past the 0.149-mm screening that was used for the average nutritional analysis. The Kjeldahl method was used to calculate the total amount of N. Utilizing NaOH melting and UV-vis spectrophotometer technique and the atomic absorption spectrophotometry technique, correspondingly, the total soil phosphorous and Potassium were established.The updated ASTM D1762-84 was used to determine the biochar's characteristics. SEM with EDX was used to analyze the morphologies of biochar.

2.3. PCR magnification of the 16S rDNA and complete microbial DNA extraction

Triplicate samples from each therapy were combined to form a homogenous mixture from which total DNA was extracted. The "Ezup Column Genomic DNA Extraction Kit," which was altered under the manufacturer's recommendations, was used to extract about 0.3 g of frozen materials.For a higher level of accuracy, the samples and the solutions both were placed inside a fresh Eppendorf tube and then vibrated. The supernatants were poured into a new tube as directed in the first stage of the instructions that came with the kit.At -20°C, the finishing DNA was frozen after being diluted with 52 L of TE.Ethidium bromide (5 g mL-1) was used to stain the gel, and gel imaging equipment was used to digitize the image.To ensure reproducibility and reduce PCR bias, 35 amplification cycles were performed after the starting denaturation phase. A constant voltage of 1% agarose gel electrophoresis was used to measure the diameters of the PCR goods.

2.4. Research on the denaturing gradients gel electrophoresis technique (DGGE)

Every therapy was subjected to DGGE analysis utilizing a DCode Mutation Detection Mechanism.Every figure or its legend included an indication of the acrylamide/bis concentration (37.5:1), denaturant gradient, and electrophoresis.The gels underwent a 2-hour polymerization process. The gels were run in a 1 TAE buffer at 60 V and 60 °C. After electrophoresis, the gels are stained with deionized water containing ethidium bromide at a concentration of 0.75 g mL-1, and photographs under UV trans illuminating were made. The software Bio-Quantity one 4.4.0 was used to evaluate "DGGE fingerprint profiles" that were created from the "16S rDNA gene banding patterns on the DGGE gels".After background removal,the lanes were normalized. By adding the intensities of all the bands, the comparative abundance of every bacterial group in every sample was calculated. Unweight pair group approach (UPGMA)with arithmetic mean was used to determine how related the profiles were to one another and to establish how each treatment should be clustered.

2.5. Statistic evaluation

The SPSS 17.0 programme was used to examine the data. The therapies were compared using Fisher's LSD test as well as the one-way analysis of variance (ANOVA).The variations are significant at P 0.05 unless otherwise noted**.**

3. Results and Discussions

3.1. Features of bamboo biochar

Due to the SB's small size and weak physical properties, we were unable to recover it from the soil after 1.5 years. As an outcome, we are only able to present the BC modifications that occurred after 1.5 yrs.Further magnification revealed smooth surfaces formed when cellular pores melted and fused, and some attachments developed in the holes, which was consistent with prior observations.

When seen under a microscope, it appears like root hairs clung to the surface of the biochar or entered macropores. This makes interactions between soil and plants that use biochar more complex, including those involving redox reactions, connections with soil biota, and dissolution-precipitation reactions.The research concluded that old BC had lower quantities of carbon and magnesium than fresh BC, however, the oxygen content was not affected in any way by the aging process. Among all the elements, Potassium showed the most variance. Compared to fresh BC, aged BC had a potassium content that was nine times higher.Aged BC had an O: C ratio of around three times that of fresh BC (0.3). Results demonstrated that soil-infused biochar suffered considerable oxidation and the formation of the organo-mineral difficult on the biochar surface.Repeated studies of biochar as a function of period and place are therefore required. Biochar also has the potential to lower greenhouse gas emissions while enhancing crop growth. Long-term estimates of its cost-effectiveness are required.

3.2. Variations in soil features

Agriculture in subtropical locations faces considerable challenges because of small soil acidity, low organic Carbon, and high fertilizer use.The pH of the soil was dramatically raised in this research by both bamboo and straw biochar. While the pH increase in treatments using biochar was higher, the pH rise in the SRF treatment was lower, going from 4.68 to 4.86. The BCRF therapy increased soil pH to 5.96 while the SCRF increased soil pH to 5.98 as shown in table 3.

Table 2: Characteristics of the soil 1.5 years after adding biochar

Treatments[1)]	Colwell P (mg kg^{-1})	Potassium	Average of Nitrogen	Total Potassium	TOC	CEC	Total P (g kg^{-1})	pH (1:2.5 H_2O)
SRF	21.4±1.3 b	78.5±3.6 c	2.62±0.2 a	39.4±0.99 b	35.5±2.1 ab	11.3±0.10 c	0.45±0.06 a	4.87±0.07 b
BCRF	20.2±1.5 b	106.6±2.3 b	2.51±0.09 a	42.5±0.14 a	36.3±1.3 ab	13.2±0.35 b	0.41±0.05 a	4.96±0.05 ab
RF	20.8±1.1 b	68.9±1.6 d	2.50±0.1 a	40.4±0.87 b	30.4±1.2 c	11.2±0.79 c	0.44±0.02 a	4.69±0.04 d
SCRF	28.8±0.9 a	137.6±3.7 a	2.52±0.1 a	40.8±1.66 ab	38.3±1.4 a	14.3±0.09 a	0.49±0.01 a	4.99±0.05 a
SC+70%RF	27.9±1.6 a	86.6±1.0 c	2.51±0.09 a	40.3±0.78 b	36.9±0.6 ab	11.2±0.41 c	0.48±0.04 a	4.84±0.10 c

Table 3: Component analyses of fresh bamboo charcoal (BC) and soil-extracted bamboo charcoal (aged BC)

	Aged Bamboo charcoal		Fresh Bamboo charcoal	
Components	**Component (wt %)**	**Atom (%)**	**Element (wt %)**	**Atom (%)**
Oxygen	22.59±0.6	18.40±1.1	8.80±0.2	6.92±0.13
Potassium	0.34±0.06	0.12±0.01	3.08±0.1	100.00±0.03
Carbon	73.87±2.1	80.16±2.3	87.58±2.4	91.86±1.6
Magnesium	0.12±0.01	0.07±0.00	0.26±0.03	0.14±0.02

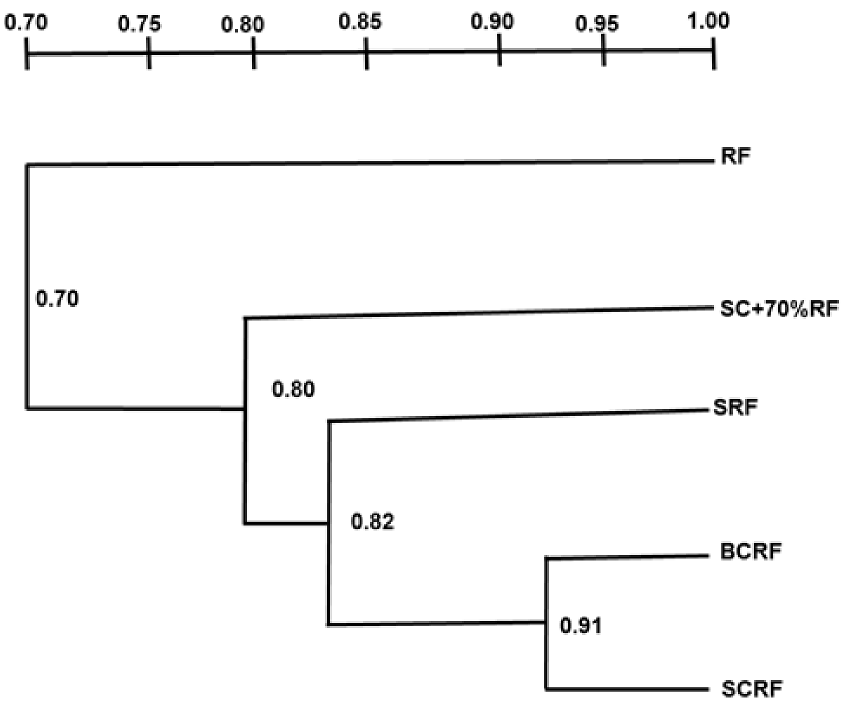

Figure 1: Analysis of cluster dependent on Person's correlation index and UPGMA

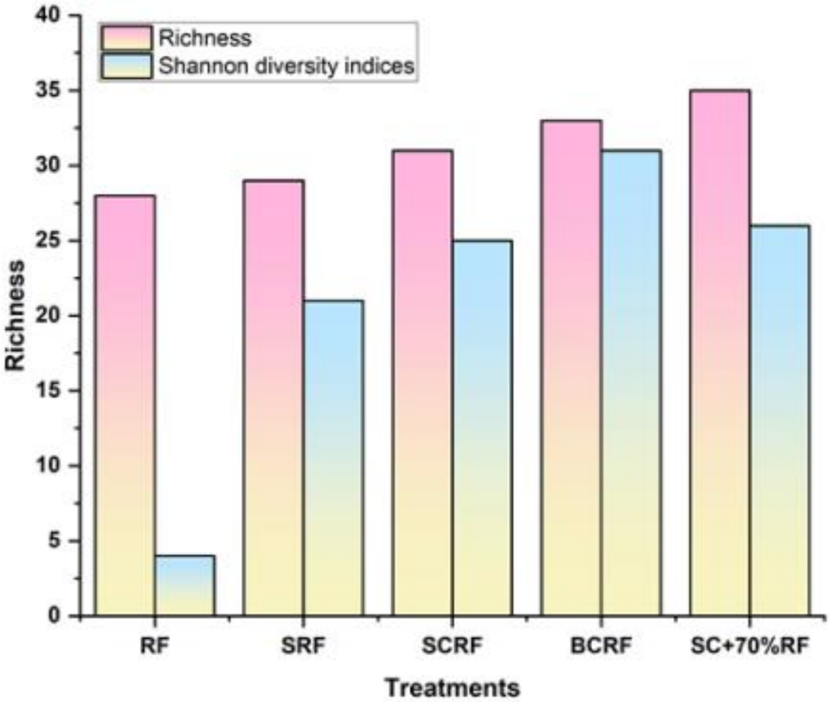

Figure 2: Microbial species diversity and Shannon's H at various conditions

Nutrients including Ca, Mg, K, and Na are present in plant straws. Crops in the field were used to make straws. When it comes to biochar, the process of pyrolysis is what causes the accretion of alkaline elements on the surface of the biochar, which in turn raises the pH of the soil. The increased CEC might have been brought on by biotic or abiotic oxidizing on the interface, which produces carboxylic groups. Generally, biochars with a higher CEC had a superior capacity to retain nutrients. According to the findings of this study, the CEC of the SCRF and SC+70%RF therapies were very different from one another. A decrease in the pace of chemical fertilizer delivery may have an impact on the surface oxidation of biochar by altering pH, the oxidative state, or the makeup of the microbial population.As a result, biochar application rates affect the effect on soil and need to be further studied.After adding charcoal for 1.5 years, treatments with biochar had no discernible impact on the overall Nitrogen or Potassium content. N is the most heat-sensitive macronutrient out of all of them and begins to volatilize at temperatures above 200°C.

At about 600°C, the biochar utilized in the current investigation underwent pyrolysis. It follows that a significant amount of N was probably lost during combustion. Thus, biochar couldn't enrich soils with nitrogen. The total organic carbon (TOC) was considerably higher with the count of bamboo and straw biochar compared to RF. The greater and stubborn Carbon content of the biochar was most likely to blame for this. On soil TOC, SRF had a considerable impact. Because straw was an element of it, it served as an organic substance that instantly raised the quantity of organic carbon and boosted a soil's physical qualities, so enhancing the biomass of both microorganisms and plant roots.There was consensus that the biochar therapy considerably raised the total and accessible potassium content.As a result, adding biochar to the soil immediately boosted some nutrient concentrations.Moreover, the rise in soil pH resulted in greater availability of phosphorous. In this investigation, rice straw biochar considerably boosted the soils' Colwell P concentration as compared to RF.

3.3. DGGE outlines the 16S rDNA gene segments amplified by PCR

Around 230 bp of PCR, goods were produced after the 16S rDNA gene's V3 region was amplified. There were more than 20 electrophoretic bands visible in the DGGE fingerprints of the microbial populations, which changed between treatments.These bands demonstrated that fertilizer treatments had an effect, although a slight one, on the composition of the bacterial community.In all treatments, the majority of bands were present, however, signal intensities differed.29 and 31 bands from RF and SRF, correspondingly, were found in this investigation. The number of bands formed raised with the count of biochar.3 biochar therapy had a higher band number than RF. This demonstrated that the use of biochar increased the diversity of the microbial population.Higher levels of biochar, phosphorous, and Ca, as well as greater soil pH, were the causes of the greater microbial diversity in those anthrosols.

Yet biochar contains some labile carbon that can serve as a carbon source and encourages the development of heterotrophic microorganisms.Biochar's enormous surface area and high porosity shielded bacteria from predators and boosted the soil's ability to store water, both of which are necessary for microbial growth.

3.4. Study of the diversity and organization of bacterial communities

In comparison to BCRF, the five treatments had bacterial communities that were more comparable than 68.7% of the time. The most resemblance (90.9%) was found between SCRF and BCRF, accompanied by SRF and SC seventy percent of RF when related to BCRF.The UPGMA revealed that soils treated with biochar had considerably different community structures from other types of soil. Communities from SCRF and BCRF were gathered together with a parallel of 0.91 as shown in figure 1. The results revealed that the development of bacterial communities was significantly influenced by biochar. For SRF, SCRE, BCRF, and SC seventy percent RF, correspondingly, the species richness of the therapy was thirty, thirty-four, thirty-five, and thirty-six, which was greater than that for RF as shown in figure 2. According to statistical research, there is an r=0.794, P=0.033 positive association between the “Shannon diversity indices and species richness”. This was in line with the findings, which found that the species richness of human-made terra preta was almost 25 percent higher than that of pristine forest soil.

4. Conclusions

The outcomes of this research indicate that the combination of biochar and chemical fertilizers has beneficial impacts on the physical characteristics of the soil as well as the composition of the microbial community. The addition of biochar resulted in a large rise in soil pH, soil CEC, and soil total organic carbon, which are the parameters that limit the fertility of acidic soils.Utilizing an SEM revealed that the cellular microstructure of BC had undergone many shifts after it had been incorporated into the soil for 1.5 years. To be more exact, the surfaces of the gaps were not smooth, and minute mineral and organic materials had formed in the channels that formed up the pores.The carbon and magnesium levels of old BC were found to be lower than those of fresh BC, according to the results of elemental analysis; however, the oxygen content remained the same. There was convincing molecular evidence that biochar has a strong stimulating effect on the activity of microbes. Both the Shannon diversity index and the species richness of the therapies that included biochar was found to be greater than those of the therapies that did not include biochar. As a result, the application of biochar therapies helped to preserve soil nutrients and the transfer of energy required for productive soil.

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