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Application of Prosopis Wood Biochar on Soil and its Effect on Soil Nutrient and Carbon content

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ABSTRACT: In the current study, prosopis wood material was pyrolyzed at high temperatures to create biochar, which was then characterised. A laboratory closed incubation experiment was used to investigate how biochar affects soil properties. The prosopis biochar that was created had an exchangeable acidity of 49 mmol kg-1 and a pH that was neutral. A 16 cmol kg^{-1} cation exchange capacity was present. In comparison to nitrogen and phosphorus, it included a considerably higher amount of potassium (K). (940 g kg^{-1}) of carbon was present, which was unusually high. The high porosity structure of biochar, which has the ability to improve water retention and increase soil surface area, is one of the main qualities that make it appealing as a soil amendment. While a soil's pH dropped as low as 7.92 after being added at various rates of biochar during incubation, the soil's cation exchange capacity (CEC) was shown to have dramatically risen as a result of the biochar addition. With an increase in the rate of biochar application, the soil organic carbon (SOC) significantly rose, and it continued to rise during the 90 days of incubation.

Keywords: Biochar, CEC, Soil fertility, Enzyme activity, Microbes.

INTRODUCTION

Mulches, composts, and manures all boost soil fertility; but, under tropical circumstances, the increase is temporary as the additional organic matter and bases are quickly oxidised and leached. Long-lasting increases in soil fertility have been observed when biochar (charcoal made by the pyrolysis of biomass feedstock) is applied to infertile Oxisols (Steiner et al., 2007). Biochar with a large surface area per unit mass and a high charge density (Lehmann, 2007) is primarily made of single and condensed ring aromatic C. These characteristics make biochar more refractory in tropical soils and contribute to biogenic soil organic matter's lower capacity to sorb cations per unit mass (Liang *et al*., 2006).

Application of biochar to soils is not a novel idea (Mann, 2005). For instance, in the Amazon basin, anthropogenic dark earth soils (known as Terra Preta) have a significant amount of charred materials that were probably added by pre-Columbian farmers who engaged in a type of slash-and-burn agriculture and disposed of charcoal waste from hearths (Sombroeket *et al.*, 2003). The biochar functions as a soil conditioner in these soils, enhancing the physical characteristics and nutrient usage efficiency of the soil to promote plant growth. The Terra Preta soils are highly prized for agricultural and horticultural usage in the Amazon basin today, 500 years after the practises that produced these soils came to an end (Glaser *et al*., 2002; Lehmann and Rondon 2006).

Knowing the organic structural makeup of the biochar is crucial for predicting its stability and reactivity when added to soil. The biogeochemistry of the biomass feedstock and the pyrolysis conditions have an impact on the structural shape of carbon in biochar (Kramer *et al.*, 2004; Lehmann, 2007). While biochars with higher concentrations of single-ring aromatic and aliphatic C will mineralize more quickly, biochars made predominantly of condensed aromatic C are known to survive in soil conditions for millennia (Lehmann, 2007: Novotny *et al.*, 2007). Because of this, a laboratory closed incubation experiment was carried out as part of the study to investigate the effect of biochar on soil properties.

MATERIAL AND METHODS

Various biological materials, including paddy straw, maize stover, groundnut shell, coconut shell, coir waste, and prosopis, were pyrolyzed to create biochar samples.

Collection of Materials: The Department of Farm Management provided the paddy straw and the maize stovers that were collected. Groundnut shells were gathered from the TNAU Coimbatore Department of Oil Seeds. We gathered coconut shells from a farm near Vadavalli, Coimbatore. In the Vedappatti hamlet of the Coimbatore District, coir dust samples were gathered from the coir industry. From a private company in Ramanathapuram, Coimbatore, prosophis was obtained.

Fabrication of pyrolysis stove: The cylindrical zinc alloy sheet drum that makes up the pyrolysis stove was built by the Safire Scientific Company in Coimbatore. Combustion chamber, ventilation cone, outside tin, and lid make up this apparatus. The cylinder's height was 38 cm, while the combustion chamber and outer chamber had corresponding diameters of 15 cm and 28 cm. The combustion chamber and outer chamber have respective volumes of 6726 cm3 and 16,682 cm3. 13 centimetres separated the combustion area from the outside chamber. The ventilation cone stood 10 cm tall.

Process of pyrolysis: Fuel items (wood pellets, dried twigs, etc.) used for lighting were placed inside the combustion chamber. The gasifier space (the area between the combustion chamber and the outer chamber) was filled with the biological waste source material. Kerosene-soaked rags were employed as fire starters. When the fire first began to burn, the stove's lid was put on it. The waste biomass in the outer chamber started to burn after 30 minutes, while the fuel material burned hotter after 10 to 15 minutes, causing the flame to appear yellow. It began to emit gases at that point, turning the flame blue and producing minimal smoke. This suggested that the gasoline had been completely burned. This process took two hours to complete, and after one hour the stove had cooled down. All of the biomass was converted to char at the end of the procedure. Biochar characterization: Samples of biochar were taken from the pyrolysis burner and sieved (0.25 mm), after which their key features were examined.

Characterization of Biochar: Samples of biochar were taken from the pyrolysis stove, sieved (0.25 mm), and their key attributes were examined.

RESULTS

Table 1 lists several significant traits of biochar samples made from the pyrolysis of prosopis, rice straw, maize stover, coconut shell, and groundnut shells. The EC ranged from 0.39 to 4.18 dSm^{-1}, while the pHs ranged from 7.57 to 9.68. Paddy straw, maize stover, coconut shell, groundnut shell, and coir waste all had biochar samples with higher pHs (> 9.0) than prosopis. The biochar made from groundnut shells had the lowest EC of all the samples (0.39 dSm^{-1}). A higher EC of biochar was produced from maize stover, then coir waste.

A significant range of variance in CEC, from 3.2 to 16.0 cmol (+) kg^{-1}, was seen in biochars made from various types of biomass. The CEC of the prosopis Biochar was higher than that of the other samples. The CEC was lower in the biochar made from coir waste (3.2 cmol (+) kg $^{-1}$). The range of the exchangeable acidity was 9.5 to 49 mmol kg^{-1}. The groundnut shell produced substantially less exchangeable acidity (9.5 mmol kg $^{-1}$), but prosopis produced larger exchangeable acidity (49 mmol kg^{-1}).

Biochar's C content ranged greatly, from 540 to 940 g kg^{-1}. The prosopis - Biochar and coconut shell - Biochar both had the most. Paddy straw was determined to contain the least amount of Biochar. Similar to this, the C/N ratio showed a wide range between 51.4 and 96.8. Paddy straw-derived biochar had the lowest C/N ratio (51.4) and coconut shell-derived biochar had the highest C/N ratio (96.8)

8.5 to 1.12 g kg^{-1}, 0.6 to 3.2 g kg^{-1}, and 2.4 to 29 g kg^{-1}, respectively, were the ranges for the NPK contents of biochars. The biochar made from coconut shells had the highest P content, followed by that made from maize stover. Additionally, there were significant variations in the amounts of Na, Ca, and Mg in various Biochar samples. Ca concentrations ranged from 1.8 to 11 g k^{-1}, while Na concentrations ranged from 5.2 to 38 g kg^{-1}. Na and Ca concentrations were relatively greater in the prosopis-Biochar. Only 0.36 to 6.2 g kg-1 of Mg were discovered in the samples of biochar, with prosopis biochar having the lowest Mg level. Paddy straw biochar had the highest Mg content.

Prosopis – Biochar. Prosopis is commonly planted throughout Tamil Nadu, especially in arid regions and wastelands. It's widely accessible and in large supply. Table 1 lists the physical, chemical, and biological properties of the biochar created by pyrolyzing prosopis. With a porespace of roughly 48%, the Biochar had a bulk density and particle density of 0.45 Mg m^{-3} and 0.54 Mg m^{-3}, respectively. It showed a high water retention capacity (131%) despite having a very low moisture content (1.21%). The analysis revealed that Biochar's pH was almost neutral (7.57). It had a CEC of 16 cmol (+) kg^{-1} and an EC of 1.3dSm^{-1}. The association between CEC and Total Organic Carbon Content in Biochar was significant (Fig. 1). (49 mmol kg-1) The sample has a high exchangeable acidity). Although the total N content was modest (1.12 g kg^{-1}), the C content was relatively high (940 g kg^{-1}). Only small levels of total P (1.06 g kg^{-1}) were present in the biochar. However, the Biochar had a comparatively larger level of total K (29 g kg^{-1}). Figs. 2 and 3 show the major and trace nutritional contents of several biochars made from various wastes. Na was present in substantially larger concentrations in the biochar (38 g kg^{-1}) than Ca (11 g kg^{-1}). There was just a trace amount of magnesium (0.36 g kg^{-1}) in the biochar.

DISCUSSION

Pyrolysis is the chemical breakdown of an organic material through burning without oxygen. The high temperatures employed in pyrolysis can cause some feedstock components to thermally decompose into smaller molecules as well as stimulate polymerization of the molecules within the feedstocks, whereby larger molecules are also created (including both aromatic and aliphatic chemicals).

Biochar from biological wastes. A range of biological resources, including paddy straw, maize stover, coconut shells, groundnut shells, coir waste, and prosopis wood, were pyrolyzed to create biochar. The qualities of the Biochars varied greatly. The pH ranged from 7.57 to 9.68 when measured in a 1:5 solid: water suspension. Paddy straw-Biochar had the highest pH, and prosopis-Biochar had the lowest pH. A significant range in EC was also seen, with values ranging from 0.39 to 4.18 dSm^{-1}. The highest EC was obtained in maize stover-biochar, followed by coir waste-biochar.

The CEC of Biochar ranged from 3.2 to 16 cmol (+) kg^{-1}, with prosopis-Biochar having the highest CEC. The

CEC was lower in the coirwaste-Biochar. These values are significantly lower than those that Liang *et al.* (2006); Lehmann (2007) reported. The prosopis-Biochar had the highest exchangeable acidity, which varied from 9.5 to 49 mmol kg^{-1}. The value provided by Cheng *et al.* (2006) is comparable.

The prosopis-Biochar had the lowest nitrogen content, ranging from 1.1 to 10.5 g kg^{-1} in the Biochars. Paddy straw-Biochar and groundnut shell-Biochar were both relatively higher in N content. Following maize stover, coconut shell-Biochar had greater levels of total P and K. Between the Biochar samples, there were substantial differences in the amounts of Na, Ca, and Mg. The carbon (C) content of biochar, which determines its agricultural and environmental advantages, is one of its key properties. The range of total organic carbon (TOC) was 540 to 940 g kg^{-1}. According to Novak *et al.* (2009); Rondon *et al.* (2007), such variation was frequently noted for a variety of Biochar made from various feedstocks. Prosopis-Biochar had the highest C content (940 g kg^{-1}), followed by coconut shell-Biochar (910 g kg^{-1}) and maize stover-Biochar (830 g kg^{-1}). These Biochar samples had higher C/N ratios, which ranged from 51.4 to 96.8 due to the higher C content. The biochar made from coconut shells was discovered to have the highest C/N ratio. The prosopis-Biochar has an 83.9 C/N ratio. These values are remarkably similar to those found in other carbonised Biochar, as reported by Novak *et al.* (2009); Rondon *et al.* (2007); Cheng *et al.* (2006).

Characteristics of Prosopis-Biochar. The bulk density of the prosopis - Biochar was 0.45 Mg m^{-3}, whereas the particle density was 0.54 Mg m^{-3}. It could contain 131% more water than it could hold. Although the pH (7.57) was neutral, the exchangeable acidity (49 mmol kg^{-1}) was considerable. The Biochar had a very low salt content, according to the EC, an indication of salt loading.

K > N > P was the order of the nutrients in the biochar, and sodium was considerably more abundant than calcium and magnesium. The chemical components of Biochar are directly influenced by the temperature, the length of time a material is held at a certain temperature, and the heating rate during pyrolysis (Lima and Marshall 2005). During the heating process, specific elements could be released as soluble oxides, fixed into resistant forms, or lost to the atmosphere. For instance, when wood-based biochar is produced naturally, C starts to volatilize at a temperature of about 1000°C, N at about 2000°C, S at about 3750°C, and K and P at about 700–8000°C (Neary *et al.*, 1999).

Heating causes some nutrients to volatilize, mainly near the surface of the material, while other nutrients become concentrated in the leftover Biochar during the pyrolysis or oxidation process that creates Biochar. Of all the macronutrients, nitrogen is the most susceptible to the N content is low as a result of heating (Tyron, 1948). Because of this, biochar is probably more crucial as a soil conditioner and a catalyst for nutrient conversions than it is as a source of nutrients in and of itself (Glasser *et al*., 2002; Lehmann *et al*., 2003).

As was already indicated, the prosopis-Biochar had a C/N ratio of 83.9 and a very high C content (940 g kg^{-1}). According to biochemical research, cellulose had a substantially larger content (36%) than hemicelluloses (31%) and lignin (22%). In addition to more easily degradable aliphatic and oxidised C structures, charred biomass also contains resistant aromatic ring structures (Schmidt and Noack 2000). Fig. 4 displays the prosopis biochar SEM picture. Depending on the C characteristics, a biochar particle's range of C forms may vary (Lehmann, 2007). When Novak *et al.* (2009) examined the 13C NMR spectrum pattern of pecan-Biochar, they discovered that the majority of the C in that material was located in aromatic structures (58%), with smaller amounts of C present in carboxyl (13%) and single bonds to O (29%) and carbohydrate (0%) groups. Generally speaking, the yield of biochar is inversely related to its C concentration. The yield of Biochar reduced from 67 to 26% with an increase in pyrolysis temperature from 300 to 8000C, although the C content increased from 56 to 93% (Sohi *et al.,* 2009).

Table 1: Characteristics of Biochar from different Biomass.

Sr. No.	Characters	Paddy straw	Maize stover	Coconut shell	Groundnut shell	Coir waste	Prosopis wood
1.	pH (1: 5 solid water suspension)	9.68	9.42	9.18	9.30	9.40	7.57
2.	EC (dSm^{-1}) (1: 5 soil water extract)	2.41	4.18	0.73	0.39	3.25	1.3
3.	Cation Exchange Capacity (cmol(+) kg^{-1})	8.2	6.5	12.5	5.4	3.2	16
4.	Exchangeable Acidity (mmol kg^{-1})	22	27	32	14	9.5	49
5.	Total organic carbon (g kg^{-1})	540	830	910	770	760	940
6.	Total Nitrogen (g kg^{-1})	10.5	9.2	9.4	11	8.5	1.12
7.	C:N Ratio	51.4	90.2	96.8	70	89.4	83.9
8.	Total Phosphorus (g kg^{-1})	1.2	2.9	3.2	0.6	1.5	1.06
9.	Total Potassium (g kg^{-1})	2.4	6.7	10.4	6.2	5.3	29
10.	Sodium (g kg^{-1})	14	21.5	16.8	5.2	9.6	38
11.	Calcium(g kg^{-1})	4.5	5.6	8.5	3.2	1.8	11
12.	Magnesium (g kg^{-1})	6.2	4.3	5.8	2.1	1.4	0.36

Values are mean of triplicate sample

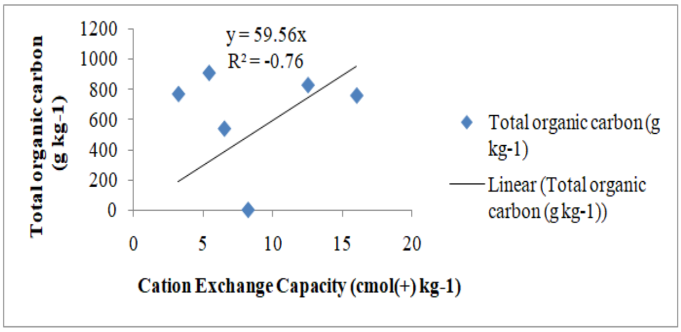

Fig. 1. Relationship between Total Organic Carbon and Cation Exchange Capacity.

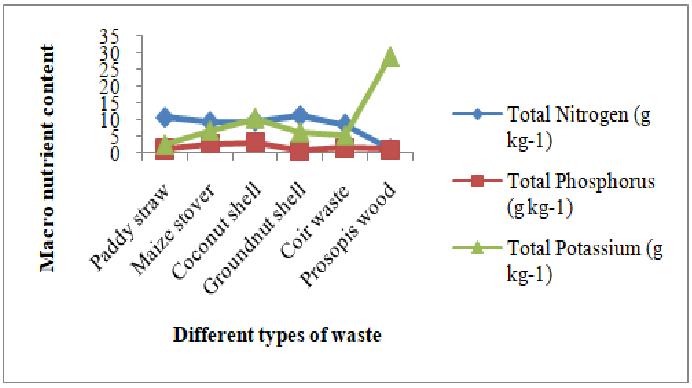

Fig. 2. Macronutrient content of various biochar from different waste.

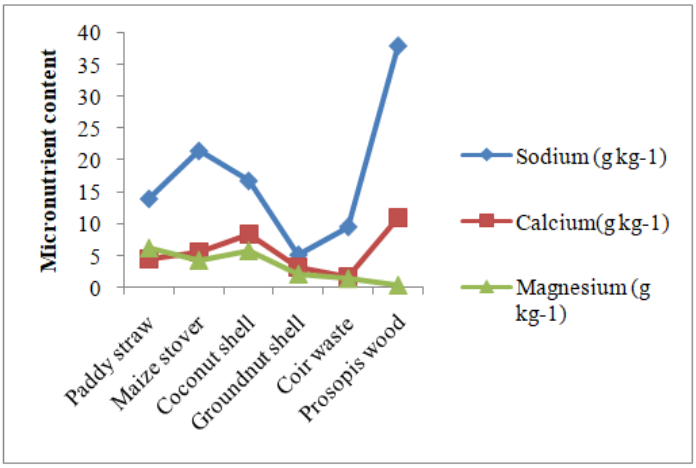

Fig. 3. Micronutrient content of various biochar from different waste.

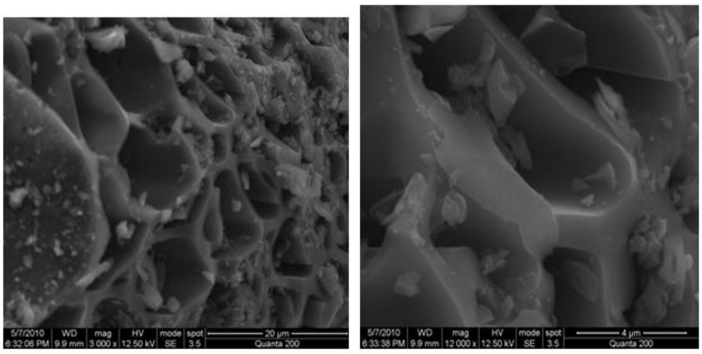

Fig. 4. Scanning Electron Microscope (SEM) images of Biochar.

CONCLUSIONS

The properties of biochar specified by chemical and physical processes reveal the infrastructure of biochar. Biochar defined by its useful application to soil, is expected to enhance an advantage from enduring chemical and physical properties. For large surface area and porosity of biochar, they can raise the capacity of water holding of soil and the absorption of nutrients with a view to decrease loss and an augment soil structure, so biochar might progress fertility of soil and raise crop yields in future if it is applied to soil with a suitable application rates.

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Conflict of interest. None.

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