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Research article

CHARACTERIZATION OF *PROSOPIS JULIFLORA*.L BIOCHAR AND ITS INFLUENCE OF SOIL FERTILITY ON MAIZE IN ALFISOLS

B.Gokila[1] and K.Baskar[2]

Department of Soils and Environment, Agriculture college & Research Institute, Tamil Nadu Agricultural Unversity, Madurai -625 104, TamilNadu, India.
Email: singh_gokila@rediffmail.com

ABSTRACT : Biochar is a stable carbon (C) compound created when biomass (feedstock) is heated to temperatures between 300 and 1000ºC, under low (preferably zero) oxygen concentrations. Biochar, due to its aromatic structure and long mean residence time in soil (more than 100 years) has the potential for long-term carbon sequestration in the soil. Biochar can be produced from a variety of biomass feed stocks, but is generally designated as biochar only if it produces a useable co-product for soil improvement. The efficiency and effectiveness of the process of its creation and use can vary and the specific biomass sources used can affect the characterization and stability of the biochar. A study was conducted to determine the prosopis biochar characterisation and soil fertility of maize in Alfisols of Thoothukudi district. A randomized block design was employed with fifteen treatments (two levels of biochar and two levels of recommended dose of fertiliser with biofertiliser (Azophos 4 pockets ha^{-1})) and two replications. Application of biochar with inorganic fertilisers and biofertiliser increased the soil fertility of maize in Alfisols. The combined application of biochar with 100% recommended dose of fertiliser and biofertiliser increased the nutrient use efficiency and soil fertility status of the soil.
Keywords: Biochar, Pyrolysis, Carbon sequestration

INTRODUCTION

Climate change and fossil fuel shortage is a main concern for using renewable feedstock for energy. For replacing fossil fuel, agricultural wastes, crop residues and woods are subjected to conversion of energy through biological or thermal conversion. Pyrolysis of this biomass which is produces the char, oil and gases. Biochar and char which is produced through pyrolysis technique (thermal conversion). Agricultural waste and wood have the cellulose, hemicelluloses and lignin us a building unit. Through the thermal conversion process, these building units are produced the volatile products. Biochar is a product of thermal decomposition of biomass produced by a process termed pyrolysis. In recent years, application of black, charred carbon (‘biochar’) has been increasingly discussed as a mitigation strategy for sequestering recalcitrant carbon into agricultural soils, which can, at the same time, improve soil fertility [6]. Modern pyrolysis techniques, which are currently undergoing a rapid technical development [8] allow energy production from syngas (mainly CO, H_2 and CH_4 and other hydrocarbons) and/or liquid–fuel production while simultaneously generating different types of biochar. The resulting biochars can greatly differ in their material properties (CHO-concentrations, aromaticity, cation exchange capacity, pH, nutrient contents, porosity, energy density etc.), depending on feedstock and pyrolysis conditions [1] [5]. Experimental evidence so far shows that biochar is quite stable and hence principally suitable for C sequestration [13], and addition often promotes plant growth, in particular combined with N-fertilizer addition in poor soils [2], and followed by it reduces nutrient leaching [3]. Additionally it could be shown that the cation exchange capacity (CEC) of soils increases with biochar addition [9] in particular over time as the functional groups are oxidized [4]. Significant improvement in the available N, P, K and DTPA- extractable Zn, Fe, Cu and Mn status at different growth stages of maize was evidenced with the conjoint application of biochar with fertilisers and biofertilisers.

MATERIALS AND METHODS

Biochar sample were collected from the pyrolysis of *Prosopis juliflora*.L by *SCAD* engineering college, soil fertility unit, cherenmadevi.

Preparation of *Prosopis* Biochar

Prosopis biochar is made by heating biomass under oxygen-limited conditions ˜ 450 ° C (e.g. slow pyrolysis).

The thermo-chemical conversion drives off the volatile components of the biomass and stabilises the remaining carbon into a black, highly aromatic solid. The materials (*Prosopis* Biochar) procured from SCAD Engineering College at Cheranmahadevi, Tirunelveli, Tamil Nadu.

Characterisation of *Prosopis juliflora* L. Biochar

The Biochar samples were collected from the pyrolysis stove sieved (< 0.25 mm) and their important characteristics were analysed. The biochar sample was subjected to structural analysis for xylem structure and surface properties by using Scanning Electron Microscope at Tamil Nadu Agricultural University – Nano technology laboratory. The degree of ashing, mobile or labile matter and resident matter or recalcitrant matter was analysed and followed by characterizing biochar [7].

A study was conducted for characterisation of biochar and soil fertility of maize was investigated with different levels of biochar, fertilisers and biofertilisers during September 2011 – January 2012. the experimental soil was sandy clay loam in texture with the pH, EC, CEC and organic carbon content of 6.2, 0.45 ds m^{-1},16 c mol (p+) kg^{-1} and 0.43 % respectively. The soil was low in $KMnO_4$ – N (223.4 kg ha^{-1}), medium in Olsen – P (11.32 kg ha^{-1}) and low in NH_4OAc- K (270.7 kg ha^{-1}). The recommended dose of nutrients for maize as 135: 62.5: 50 kg N, P_2O_5 and K_2O hectare $^{-1}$. The treatment combinations comprises two levels of recommended dose of fertiliser and two levels of biochar and biofertiliser in 15 treatments *viz.*, T_1 - (control), T_2 - (5 t ha^{-1} biochar), T_3- (7.5 t ha^{-1} biochar) , T_4- (75 % RDF), T_5- (100 % RDF), T_6- (75 % RDF + biofertiliser), T_7- (100 % RDF + biofertiliser), T_8 - (5 t ha^{-1} biochar + 75 % RDF), T_9 - (5 t ha^{-1} biochar + 100 % RDF), T_{10} - (7.5 t ha^{-1} biochar + 75 % RDF), T_{11} - (7.5 t ha^{-1} biochar + 100 % RDF), T_{12} - (5 t ha^{-1} biochar + 75% RDF + biofertiliser), T_{13} - (5 t ha^{-1} biochar + 100 % RDF+ biofertiliser), T_{14} - (7.5 t ha^{-1} biochar + 75% RDF+ biofertiliser), T_{15} - (7.5 t ha^{-1} biochar + 100 % RDF + biofertiliser) with two replications were statistically analysed with randomized block design.

RESULTS

The result of the yield and quality of maize and their correlation status was presented in Table 1 to Table 3.

Properties of biochar

Prosopis is widely grown in many parts of Tamil Nadu and it is available in large quantities particularly in dry tracts and wastelands. The data obtained from the prosopis biochar was presented in the table 1. The prosopis biochar had a very little moisture (1.52 %) and 1.4 w w^{-1} of ash. Mobile and resident matter of the biochar was 38 g kg^{-1} and 31 g kg^{-1} respectively. In respect of pH and EC was obtained at 8.1 and 1.45 dSm^{-1} of prosopis biochar**.**

Structure of biochar by using Scanning Electron Microscope

Structure and surface characteristics of the biochar was analysed by using Scanning electron microscope at Department of Nano Sceince and Technology, Tamil Nadu Agricultural University, Coimbatore. The xylem structure and the porosity character of prosopis biochar were presented in fig.1. A notable characteristic of biochar is its high porosity. In general biochar retains the cell wall structure of the biomass feedstock as observed in Scanning electron microscope. Some smaller scale biochar consists largely of amorphous graphene sheets, which give rise to large amounts of reactive surfaces where a wide variety of organic (both polar and non-polar) molecules and inorganic ions can sorb. The xylem structure was taken by using large field detector (LFD) and 3.0 probe current or spot. The working distance of this image is 11.3 mm and 30 KV high voltages. Magnification in a Scanning electron microscope can be controlled over a range of up to 6 orders of magnitude from about 10 to 500,000 times and the resolution of the image is 30 μm.

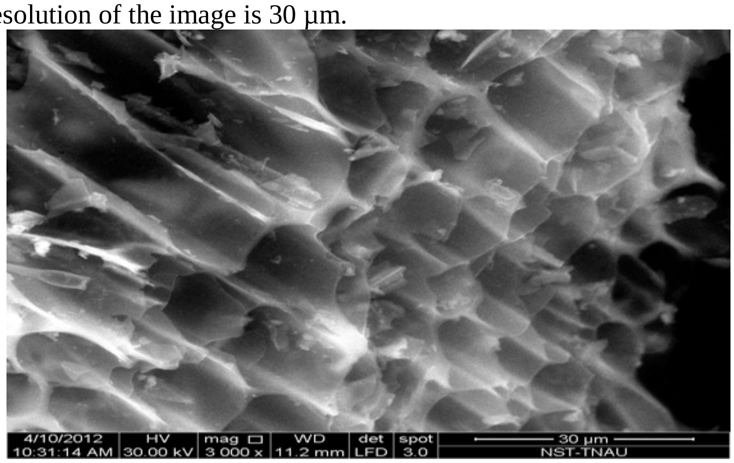

Fig.1 structure of prosopis biochar through SEM

Soil fertility

Results of the effect of biochar on nutrient availability are present in table 2. Biochar has an impact on soil nutrient availability in two general ways *viz.,* nutrient addition and nutrient retention. The ash in biochar contains plant nutrient, mostly bases such as Ca, Mg and K but also P and micronutrients including zinc, manganese.

Among the treatments, biochar @ 5 t ha^{-1} plus 100 per cent recommended dose of N, P_2O_5 and K_2O (T_9) enhanced the availability of major ($KMnO_4$ – N, Olsen – P, NH_4 OAc- K) in soil. Similar results for potassium were obtained by [11] reported that the potassium availability was increased by biochar application in the year following its application, and this likely results directly from the considerable amounts of K that were added along with the biochar from which it is readily leached. The biochar had the most significant effects on the availability of Ca and Mg, as well as Sr that was applied with fertiliser.

CEC and Organic carbon

Results of the effect of biochar on nutrient availability are present in table 3. The cation exchange capacity of the soil is the main factor governing the nutrient supplying power of the soil and hence all the factors influencing cation exchange capacity will influence the nutrient supplying power of the soil. The changes of organic carbon would influence the soil fertility. Hence, it is quite relevant to study the influence of biochar on organic carbon content of soil. Combined application of biochar @ 5 t ha^{-1} plus 100 per cent recommended dose of NPK fertilisers significantly enhanced the organic carbon content in the post harvest soil of maize.

Table 1. General characteristics of *Prosopis juliflora* L. biochar

S. No.	Characters	Prosopis Wood Biochar
1.	Moisture %	1.52
2.	Ash w w^{-1}	1.40
3.	Mobile matter g kg-1	38.0
4.	Resident matter g kg-1	31.0
5.	pH (1:10 solid water suspension)	8.10
6.	EC (dSm^{-1}) (1:10 soil water extract)	1.45
7.	Cation exchange capacity (c mol (p+) kg^{-1})	17.2
8.	Organic carbon (g kg^{-1})	720
9.	Total Nitrogen g kg^{-1}	1.82
10.	C:N ratio	395
11.	Total Phosphorus (g kg^{-1})	2.02
12.	Total Potassium (g kg^{-1})	25.3
13.	Calcium (g kg^{-1})	12.2
14.	Magnesium (g kg^{-1})	0.47

(Values are mean of triplicate sample)

Table 2. Post harvest Soil available $KMnO_4$-N (kg ha^{-1}), Olsen -P (kg ha^{-1}) and NH_4OAc – K (kg ha^{-1}) of maize in Alfisols

Treatment	$KMnO_4$-N (kg ha^{-1})	Olsen -P (kg ha^{-1})	NH_4OAc – K (kg ha^{-1})
T_1	212	21	171
T_2	216	45	225
T_3	215	43	218
T_4	223	45	227
T_5	225	48	230
T_6	224	46	229
T_7	226	48	232
T_8	260	51	232
T_9	266	55	238
T_{10}	245	50	217
T_{11}	238	49	216
T_{12}	227	52	219
T_{13}	239	52	232
T_{14}	237	49	224
T_{15}	239	50	217
Mean	233	46	223
SEd	4.1	2.2	3.8
CD (p=0.05)	7.8	4.8	7.5

(Values are mean of triplicate sample)

Table 3. Post harvest soil cation exchange capacity (c mol (p+) kg^{-1}) and organic carbon (g kg^{-1}) of maize in Alfisols

Treatment	Cation exchange capacity	Organic carbon
T_1	13.7	4.2
T_2	16.0	5.4
T_3	17.0	5.8
T_4	17.3	6.7
T_5	17.2	8.1
T_6	17.7	7.5
T_7	17.7	7.4
T_8	19.2	8.0
T_9	19.0	8.2
T_{10}	17.0	5.8
T_{11}	17.1	6.8
T_{12}	17.2	5.6
T_{13}	18.3	6.7
T_{14}	17.1	6.6
T_{15}	17.1	6.7
Mean	17.1	6.6
SEd	1.2	0.5
CD (p=0.05)	2.3	0.9

(Values are mean of triplicate sample)

DISCUSSION

The Biochar had a very poor nutrients content, which followed: K > N > P. sodium content was relatively higher in the Biochar than Ca and Mg. The temperature, the time a material is held at a given temperature and the heating rate during pyrolysis directly influence the chemical constituents of Biochar [10]. Individual elements are potentially lost to the atmosphere, fixed into recalcitrant forms or liberated as soluble oxides during the heating process. For example, in the case of wood based Biochar formed under natural conditions, C begins to volatize around 1000C, N above 2000C, S above 3750C, and K and P between 700 to 8000C [14]. The organic carbon content and cation exchange capacity of the biochar was 720 g kg^{-1} and 17.2 c mol (p +) kg^{-1}. With respect to total nutrient content, prosopis biochar had high amount of carbon and low amount of total nitrogen (1.82 g kg^{-1}). It had low amount of total phosphorus (2.02 g kg^{-1}) and total potassium (25.3 g kg^{-1}). It also contained the exchangeable cations like calcium (12.2 g kg^{-1}) and magnesium (0.47 g kg^{-1}). The result was corroborating with findings of [17]. [15] found that most of the Biochar– C was distributed in aromatic structures (58%), with less amounts of C having single bonds to O (29%) and in carboxyl (13%) groups, but little carbohydrate – C. In general, the C content of Biochar is inversely related to Biochar yield. Increasing pyrolysis temperature from 300 to 800^0C decreased the yield of Biochar from 67 to 26%, but increased the C content from 56 to 93 % [18].

Soil fertility

The treatment combination biochar @ 5 t ha^{-1} plus 100 per cent recommended dose of NPK fertilisers had highly influenced the native soil fertility. The result is in line with the findings of [16] who made that the greater contribution of N derived from the atmosphere with biochar mostly to greater availability of Boron and Molybdenum in biochar amended soils. Soil applied Prosopis biochar had high mobile and resident matter this sequester the long term carbon stock so the native fertility of soil would be improved. Because of high organic matter and cation exchange capacity of carbon sequester soils.

CEC and Organic carbon

And also the cation exchange capacity & organic carbon status of the soil is improved when the application of biochar and inorganic fertilizers. Because the prosopis biochar have the hallow tube porous media, this led to have high effective surface. This high surface have high chemical reactive surface can sorbs nutrients this improve the soil water holding, nutrient holding capacity. Similarly [12] confirmed that conversion of biomass carbon leads to sequestration of about 50 per cent of the initial carbon compared to the low amounts retained after burning (3 %) and biological decomposition (< 10 – 20 % after 5 – 10 years), therefore yielding more stable soil carbon than burning (or) direct land application of biomass.

CONCLUSIONS

It could be concluded that, the prosopis biochar had chemical structure of charcoal is characterized with polycondensed aromatic groups, providing prolonged biological and chemical stability that sustains the fight against microbial degradation, it also provides, after partial oxidation, the highest nutrients retention. The combined application of biochar with fertiliser and biofertiliser increased soil fertility of maize in Alfisols of Thoothukudi District.

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