

Original Research Article

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## Climate Change Impact on Yield, Quality and Soil Fertility of Maize in Sandy Clay Loam as Influenced By Biochar and Inorganic Nutrients in Typic Haplustalf

B. Gokila\*

Long Term Fertilizer Experiment, Department of Soil Science and Agricultural Chemistry,  
Tamil Nadu Agricultural University, Coimbatore – 641 003, Tamil Nadu, India

\*Corresponding author

### ABSTRACT

To increase the accumulation of atmospheric carbon dioxide is due to the anthropogenic activity, natural fire and industrialization induced climate change. To increase the pressure regarding reduce the concentration of CO<sub>2</sub> in the environment, sequestration of carbon is the trend to improve the carbon sink and environmental health in soil. The maintenance of a threshold level of organic matter in the soil is crucial for maintaining physical, chemical and biological integrity of the soil and also for the soil to perform its agricultural production and environmental functions. The application of biochar to the soil is proposed as a novel approach to establish a significant long term sink for atmospheric carbon dioxide in terrestrial ecosystems. For rising interest regarding carbon sequestration and soil sustainability field experiment was conducted to determine the influence of biochar and fertiliser with biofertiliser for yield, quality and soil fertility of maize in Typic Haplustalf of Tamirabharani tracts. The experiment was imposed with randomized block design with fifteen treatments (two levels of biochar and two levels of recommended dose of fertiliser with biofertiliser (Azophos 4 pockets ha<sup>-1</sup>) and two replications. Application of biochar with inorganic fertilisers and biofertiliser increased the yield components of maize viz., hundred grain weight (38.9g), cob length (23.5cm), cob weight (310g), grain yield (8100 kg ha<sup>-1</sup>) and stover yield (12,150 kg ha<sup>-1</sup>) and also quality trait such as crude protein content. Higher yield and quality was obtained from the combination of 5 t ha<sup>-1</sup> plus 100 per cent recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O plus biofertiliser on maize. The combined application of biochar with 100 per cent recommended dose of fertiliser and biofertiliser increased the yield, quality and soil fertility in maize growing soil.

#### Keywords

Engineered char,  
Pyrolysis, Biochar,  
Carbon sequestration,  
Soil fertility, Climate  
change.

#### Article Info

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### Introduction

Greenhouse gases (e.g., CO<sub>2</sub>, CH<sub>4</sub>) from anthropogenic and biogenic sources are accumulating in the atmosphere. The concentration of atmospheric CO<sub>2</sub> alone is projected to double from pre- industrial levels by the mid to late 21<sup>st</sup> century. According to general circulation models of climate change, infrared radiation trapped by the additional

greenhouse gases in the troposphere could cause the earth's surface temperature to increase 1.5 to 4.5°C and influence frequency and distribution of regional precipitation. To evaluate a possible means for offsetting part of the increase of atmospheric CO<sub>2</sub>, an assessment began in late 1990 to evaluate the potential to enhance C sequestration in global

terrestrial ecosystems through forest and agroforest management. 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 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 as 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 (Glaser *et al.*, 2002). Modern pyrolysis techniques, which are currently undergoing a rapid technical development (Laird *et al.*, 2010) allow energy production from syngas (mainly CO, H<sub>2</sub> and CH<sub>4</sub> 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 (Amonette and Joseph, 2009; Downie *et al.*, 2009). Experimental evidence so far shows that biochar is quite stable and hence principally suitable for C sequestration (Major *et al.*, 2010) and addition often promotes plant growth, in particular combined with N-fertilizer addition in poor soils (Blackwell *et al.*, 2009), and followed by it reduces nutrient leaching (Chan *et al.*, 2008). Additionally it could be shown that the

cation exchange capacity (CEC) of soils increases with biochar addition (Liang *et al.*, 2006) in particular over time as the functional groups are oxidized (Cheng *et al.*, 2008). 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. The present study was undertaken to study the effect of yield, quality and soil fertility in sandy clay loam as influenced by biochar in Typic Haplustalf.

## **Materials and Methods**

### **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 stabilizes the remaining carbon into a black, highly aromatic solid.

### **Characterization of *Prosopis juliflora* L. biochar**

The Biochar samples were collected from the pyrolysis stove sieved (< 0.25 mm) and their important characteristics were analyzed (Table 2). 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 (Fig. 1). The degree of ashing, mobile or labile matter and resident matter or recalcitrant matter was analyzed and followed by characterizing biochar (Hugh McLaughlin, 2010).

### **Biochar application**

Biochar was applied in different levels viz. 5.0 and 7.5 t ha<sup>-1</sup> as soil application with two

levels of NPK fertilization for maize. The biochar was applied uniformly in the respective plots at 5 cm depth of the soil prior to sowing.

### Study site description

A field experiment was conducted in farmer's field at Sivasubramaniapuram village near to the Agricultural College and Research Institute, Killikulam of Thoothukudi district with test crop of maize during 2011-2012 to evaluate the impact of soil applied *Prosopis* biochar on yield and quality of maize in Alfisol.

The experimental site located at 8° 46'N latitude and 77°42' longitude at an elevation of 40 meters above mean sea level. The soil of the experimental site belonged to Sivasubramaniapuram series and according to USDA soil taxonomy it could be classified as Sandy clay loam, fine non arid Kaolinticisomegathemic family of TypicHaplustalfs. The characteristics of the experiment soil, determined by standard methods are presented in Table 1. Crude protein was analyzed by using this formula N (%) content × conversion factor 6.25. The method as suggested by Merrill and Watt (1973).

### Experimental description

A field experiment for yield, quality and soil fertility of maize hybrid (Pioneer 30R77) was investigated with different levels of biochar, fertilizers 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<sup>-1</sup>, 16 c mol (p+) kg<sup>-1</sup> and 0.43 per cent respectively. The soil was low in KMnO<sub>4</sub> - N (223.4 kg ha<sup>-1</sup>), medium in Olsen - P (11.32 kg ha<sup>-1</sup>) and low in NH<sub>4</sub>OAc - K (270.7 kg ha<sup>-1</sup>). The recommended dose of

nutrients for maize as 135: 62.5: 50 kg N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O hectare<sup>-1</sup>. The treatment combinations comprises two levels of recommended dose of fertilizer and two levels of biochar and biofertiliser in 15 treatments viz., T<sub>1</sub> - (control), T<sub>2</sub> - (5 t ha<sup>-1</sup> biochar), T<sub>3</sub> - (7.5 t ha<sup>-1</sup> biochar), T<sub>4</sub> - (75 % RDF), T<sub>5</sub> - (100 % RDF), T<sub>6</sub> - (75 % RDF + biofertiliser), T<sub>7</sub> - (100 % RDF + biofertiliser), T<sub>8</sub> - (5 t ha<sup>-1</sup> biochar + 75 % RDF), T<sub>9</sub> - (5 t ha<sup>-1</sup> biochar + 100 % RDF), T<sub>10</sub> - (7.5 t ha<sup>-1</sup> biochar + 75 % RDF), T<sub>11</sub> - (7.5 t ha<sup>-1</sup> biochar + 100 % RDF), T<sub>12</sub> - (5 t ha<sup>-1</sup> biochar + 75% RDF + biofertiliser), T<sub>13</sub> - (5 t ha<sup>-1</sup> biochar + 100 % RDF+ biofertiliser), T<sub>14</sub> - (7.5 t ha<sup>-1</sup> biochar + 75% RDF+ biofertiliser), T<sub>15</sub> - (7.5 t ha<sup>-1</sup> biochar + 100 % RDF + biofertiliser) with two replications were statistically analyzed with randomized block design.

## Results and Discussion

### Properties of *Prosopis* 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 2. The *Prosopis* biochar had a very little moisture (1.52 %) and 1.4 w w<sup>-1</sup> of ash.

Mobile and resident matter of the biochar was 38 g kg<sup>-1</sup> and 31 g kg<sup>-1</sup> respectively. In respect of pH and EC was obtained at 8.1 and 1.45 dSm<sup>-1</sup> of *Prosopis* biochar. The organic carbon content and cation exchange capacity of the biochar was 720 g kg<sup>-1</sup> and 17.2 c mol (p+) kg<sup>-1</sup>. With respect to total nutrient content, *Prosopis* biochar had high amount of carbon and low amount of total nitrogen (1.82 g kg<sup>-1</sup>). It had low amount of total phosphorus (2.02 g kg<sup>-1</sup>) and total potassium (25.3 g kg<sup>-1</sup>) and also contained the exchangeable cations like calcium (12.2 g kg<sup>-1</sup>) and magnesium (0.47 g kg<sup>-1</sup>).

## **Effect of biochar with fertiliser on growth, yield parameters and yield of maize in alfisols**

### **Growth parameters**

Combination of biochar and recommended dose of fertilisers had significantly increased the plant height from vegetative to harvest stage. The plant height ranged from 83 to 136 cm and 177 to 245 cm at vegetative and harvest stages respectively. Among the treatment T<sub>13</sub> (biochar @ 5 t ha<sup>-1</sup> +100 % recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O + biofertiliser) was significantly superior in improving the plant height by recording 136 cm and 245 cm followed by T<sub>12</sub> (biochar @ 5 t ha<sup>-1</sup> + 75 % recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O + biofertiliser) registered 126 and 237 cm at vegetative and harvest stages respectively. This might be attributed due to application of biochar could retain soil moisture and nutrients because of their porous xylem structure. These would adsorb the cation and exchange the nutrients because of their net negative charges of biochar and clay component. This was augmented with the findings of Peng *et al.*, (2011) who revealed the increase in growth and biomass by biochar was recorded in maize with rice straw derived biochar amendment could be attributed with dry matter production.

### **Yield components of maize**

Significant influence of biochar with fertilizers on the yield components of maize *viz.*, hundred grain weight, cob length, cob weight was presented (Table 3). The hundred grain weight, cob length and cob weight were ranged from 17.2 to 38.9 g, 15.0 to 23.5 cm and 155 to 310 g respectively. Among treatments, application of biochar @ 5 t ha<sup>-1</sup> plus 100 per cent recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O plus biofertiliser (T<sub>13</sub>) recorded the highest hundred grain weight (38.9 g), cob

length (23.5 cm) and cob weight (310 g) over other treatments and control. While comparing other treatment combinations, it was observed that the treatment received biochar @ 5 t ha<sup>-1</sup> plus 75 per cent recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O biofertiliser (T<sub>12</sub>) recorded next best levels of hundred grain weight, cob length and cob weight of 35.0 g, 23.0 cm and 306 g respectively. The lowest hundred grain weight, cob length and cob weight of 17.2 g, 15.0 cm and 155 g was recorded in T<sub>1</sub> (control). This was ascribed due to application of fertiliser and biochar would increase the availability of assimilates (source) and storage (sink) exert an important regulative function on the complex process of yield formation. The present findings is accordance with Chan *et al.*, (2008) also recorded that the lowest application of biochar @ 10 t ha<sup>-1</sup> increases 42 per cent yield compared with the unamended control in radish.

### **Grain and stover yield of maize**

Application of biochar with NPK fertilisation significantly increased the grain and stover yield (Table 4) of maize which ranged from 2,538 to 8,100 kg ha<sup>-1</sup> and 4,061 to 12,150 kg ha<sup>-1</sup> respectively. While comparing the biochar treatments, it was evident that application of biochar to maize crop was significantly higher with combination of different levels of fertilisers and biofertiliser. In the treatment combinations, the treatment received biochar @ 5 t ha<sup>-1</sup> plus 75 per cent recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O plus biofertiliser (T<sub>13</sub>) recorded the highest grain and stover yield of 8100 and 12150 kg ha<sup>-1</sup> respectively and followed by T<sub>12</sub> (biochar @ 5 t ha<sup>-1</sup> + 75 % recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O + Biofertiliser) recorded higher grain (7700 kg ha<sup>-1</sup>) and stover yield (11,550 kg ha<sup>-1</sup>). The control (T<sub>1</sub>) recorded the lowest grain and stover yield of 2538 and 4061 kg ha<sup>-1</sup> respectively.

**Table.1** Physico - chemical properties of the soil

Sl. No.	Soil Parameters	Experimental Result
<b>A.</b>	<b>Particle size distribution</b>	
1.	Coarse sand (%)	21.2
2.	Fine sand (%)	12.4
3.	Silt (%)	32.1
4.	Clay (%)	33.8
5.	Textural class	<b>Sandy clay loam</b>
<b>B.</b>	<b>Physical properties</b>	
1.	Bulk density ( $Mg\ m^{-3}$ )	1.30
2.	Particle density ( $Mg\ m^{-3}$ )	2.34
3.	Water holding capacity (%)	41.4
4.	Pore space (%)	36.4
<b>C.</b>	<b>Physico- chemical properties</b>	
1.	Soil reaction (pH)	7.70
2.	EC ( $dSm^{-1}$ )	0.43
3.	CEC ( $c\ mol\ (p^+)\ kg^{-1}$ )	12.3
<b>D.</b>	<b>Chemical properties</b>	
1.	Organic carbon ( $g\ kg^{-1}$ )	5.43
2.	Total nitrogen (%)	0.052
3.	Total phosphorus (%)	0.017
4.	Total potassium (%)	0.283
5.	Alk - $KMnO_4 - N$ ( $kg\ ha^{-1}$ )	232
6.	Olsen - P ( $kg\ ha^{-1}$ )	24.8
7.	$NH_4Oac - K$ ( $kg\ ha^{-1}$ )	214
8.	Exchangeable Ca ( $c\ mol\ (p^+)\ kg^{-1}$ )	3.80
9.	Exchangeable Mg ( $c\ mol\ (p^+)\ kg^{-1}$ )	1.83
10.	DTPA extractable Zn ( $mg\ kg^{-1}$ )	0.39
11.	DTPA extractable Fe ( $mg\ kg^{-1}$ )	2.99
12.	DTPA extractable Cu ( $mg\ kg^{-1}$ )	1.61
13.	DTPA extractable Mn ( $mg\ kg^{-1}$ )	0.89

**Table.2** General characteristics of *Prosopis juliflora* L. Biochar

Sl. No.	Characters	<i>Prosopis</i> 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

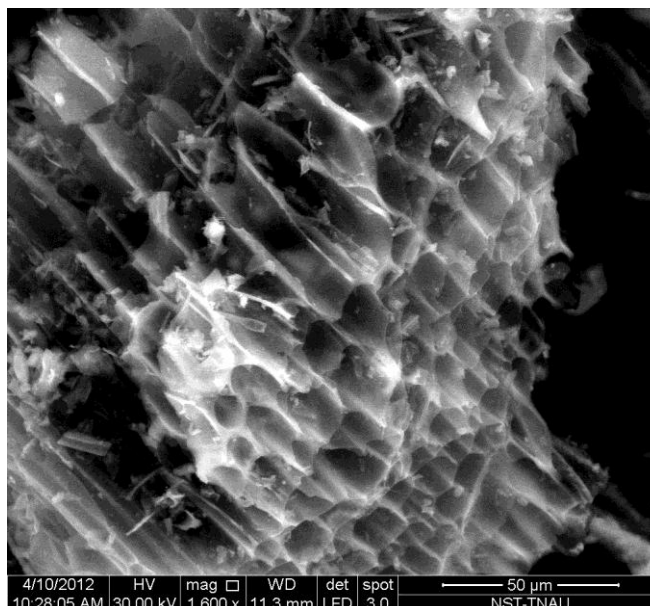
**Table.3** Effect of biochar with fertiliser on growth, yield parameters and yield of maize in Typic Haplustalf

Treatments	Parameters				
	Plant Height (cm)		Hundred grain weight (g)	Cob length (cm)	Cob weight (g)
	Vegetative	Harvest			
Absolute control	83	177	17.2	15.0	155
5 t ha <sup>-1</sup> Biochar alone	93	188	24.8	16.9	173
7.5 t ha <sup>-1</sup> Biochar alone	83	184	22.8	16.4	164
75 % RDF	97	193	24.9	17.2	172
100 % RDF	108	220	28.8	18.4	210
75 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	97	211	27.1	17.8	208
100 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	109	221	32.0	18.7	216
5 t ha <sup>-1</sup> Biochar + 75 % RDF	123	232	34.8	22.0	280
5 t ha <sup>-1</sup> Biochar + 100 % RDF	125	234	34.9	22.4	304
7.5 t ha <sup>-1</sup> Biochar+ 75 % RDF	122	229	34.1	20.5	266
7.5 t ha <sup>-1</sup> Biochar + 100 % RDF	116	227	34.2	20.1	246
5 t ha <sup>-1</sup> Biochar + 75 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	126	237	35.0	23.0	306
5 t ha <sup>-1</sup> Biochar + 100 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	136	245	38.9	23.5	310
7.5 t ha <sup>-1</sup> Biochar + 75 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	113	222	33.9	19.2	229
7.5 t ha <sup>-1</sup> Biochar + 100 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	123	229	34.6	21.6	276
Mean	110	217	30.5	19.5	234
SEd	2.09	2.95	2.1	2.3	4.8
CD (p=0.05)	4.50	5.77	4.5	4.1	6.1

**Table.4** Effect of biochar with fertilisers in grain, straw yield (kg ha<sup>-1</sup>) and crude protein (%) of maize in Typic Haplustalf

Treatment	Grain yield (kg ha <sup>-1</sup> )	Stover yield (kg ha <sup>-1</sup> )	Crude Protein (%)
Absolute control	2538	4061	5.0
5 t ha <sup>-1</sup> Biochar alone	4600	7360	5.6
7.5 t ha <sup>-1</sup> Biochar alone	4850	7760	5.2
75 % RDF	4850	6790	5.6
100 % RDF	5075	7105	6.4
75 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	5000	7000	5.9
100 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	5125	7175	6.2
5 t ha <sup>-1</sup> Biochar + 75 % RDF	7150	10725	8.3
5 t ha <sup>-1</sup> Biochar + 100 % RDF	7275	10913	8.5
7.5 t ha <sup>-1</sup> Biochar+ 75 % RDF	7450	11175	7.4
7.5 t ha <sup>-1</sup> Biochar + 100 % RDF	7625	11438	6.9
5 t ha <sup>-1</sup> Biochar + 75 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	7700	11550	9.3
5 t ha <sup>-1</sup> Biochar + 100 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	8100	12150	9.9
7.5 t ha <sup>-1</sup> Biochar + 75 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	7600	11400	6.6
7.5 t ha <sup>-1</sup> Biochar + 100 % RDF + Biofertiliser (Azophos @ 10 packets ha <sup>-1</sup> )	7725	11588	7.7
Mean	6178	9213	7.0
SEd	26	35	0.15
CD (p=0.05)	55	65	0.31

**Fig.1** Structure of *Prosopis* biochar by using scanning electron microscope



This may be attributed that application of biochar with N would increase nitrogen availability its regulating nitrate reductase by high negative charged biochar particles increased the grain and stover yield of maize. And also the pattern of nutrient release to the environment was slower when compared to control. This was in agreement with the findings of Baronti *et al.*, (2010) reported that application of biochar @ 10 t ha<sup>-1</sup> recorded higher grain production in maize, wheat and also in ryegrass.

## Quality

### Crude protein content

The crude protein content of maize varied from 5.0 to 9.9 per cent showing the significant influence of biochar and fertilisers (Table 4). Among the treatments, biochar @ 5 t ha<sup>-1</sup> plus 100 per cent recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O plus biofertilisers (T<sub>13</sub>) recorded significantly the highest crude protein content (9.9 %) in maize followed by biochar @ 5 t ha<sup>-1</sup> plus 75 per cent recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O +

biofertiliser (T<sub>12</sub>) recorded higher (9.3 %) crude protein content in maize as compared over to other treatments and control. This might be due to increase the available of nitrogen and its uptake and storage in grain. Potassium uptake by maize has also marked due to biochar with fertiliser application. Rondon *et al.*, (2007) who reported that different types of biochar applied in soil influencing high K uptake by maize. Usherwood (1985) who reported that potassium can play a role in quality development of maize, when supplement K fertilisation was applied to maize, it produced on increase in grain protein content and amino acid content and Yang *et al.*, (2004) also supporting this high protein concept.

It could be concluded that application of biochar along with fertiliser and biofertiliser would increase the maize growth and yield. This may be due biochar had porous medium and the graphite sheet could be adsorbed higher moisture and nutrient. The oxidation of functional groups of biochar would adsorb more cation and exchange with root hairs (H<sup>+</sup>) leads to higher nutrient assimilation by plants.



Also biochar leads to increase the organic carbon in soil by way of less oxidation of organic matter in to CO<sub>2</sub> leads to sequester carbon in soil. These can applicable when soils are contaminated with heavy metals, biochar could act like an organic matter by adsorb the heavy metal through ligand exchange mechanism to less availability of heavy metal into ground water and phyto toxicity. Less CO<sub>2</sub> emissions also leads to reduce the climate change effect on environment.

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