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Effects of Biochar on Some Soil Fertility Parameters in Malumfashi Local Government Area, Katsina State, Nigeria

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ABSTRACT

Soil fertility can be improved using sustainable soil management such as application of biochar which enhanced soil moisture and sequester soil organic carbon. The study assessed the effect of biochar on soil fertility and organic carbon stock. The study area was divided in to experimental and control plots, thereby biochar made from sugarcane stalk was incorporated in to experimental plots. The OC, TN, available P, pH, E.C, exchangeable bases and CEC from thirty soil samples and raw biochar were determined in laboratory. The results were subjected to descriptive statistics and student t-test at α value of 0.05. The results revealed that biochar contain high values of pH (9.38), EC (2.63), OC (0.54), TN (0.42) Avl. P (3.84), CEC (7.50), Ca (3.84), Na (0.21), K (0.34) and Mg (0.87) than soil. This entails that these nutrients easily release for crop utilization when biochar incorporated the soil. It was learned that the mean value of these soil fertility parameters and soil carbon stock are higher in the experimental plots. This implies that biochar is protagonist in improving soil fertility and retaining soil carbon. It was concluded that biochar application increased soil fertility and also have the capacity to sequester soil carbon.

Keywords: Biochar, soil fertility, soil organic carbon stock, carbon sequestration

INTRODUCTION

The application of soil organic amendment play a significant role in improving fertility of soil which modify the physical, chemical and biological properties of soil and consequently enhance soil health and plant growth with cumulative crop yield (Awad *et al.*, 2018). The biochar is produced by pyrolysis process between 350 to 700 °C temperature without oxygen (Varma *et al.*, 2018). Biochar adsorbed soil nutrients and releases gradually to crops thereby reducing nutrients (Oni *et al.*, 2019). Some researches such as Sedlak (2018) explained that use of biochar decrease the production of some green house gases by 83%, consequently increases carbon sequestration, soil nutrient, microbial activities, water holding capacity, soil contamination and recycling of plant nutrients. Yilangai *et al.* (2014) reported that indigenous people have used charcoal in the previous time as a soil amendment for enhancing soil fertility The water holding and nutrient adsorption capacity of soil can be improved by the addition of biochar particularly in tropical soils where the nutrient are exhausted (Bakewell-Stone, 2011). The headstrong nature of biochar makes it to decompose gradually thereby releasing the required nutrient progressively over a long duration, this differentiates it from other organic materials that can easily decompose and releases the nutrient within short period (Chan *et al.*, 2008).

Nutrient depletion via leaching can be reduce by application of biochar because of its water retention capacity, nutrients adsorption and yield capacity of soil enhanced (Gunarathne *et al.*, 2017). The effects of biochar on fertility parameters and SOC stock are very important factors for sustainable soil managements, enhancing the productivity and soil carbon sequestrations. This study aims at assessing the impacts of biochars on soil fertility parameters and soil carbon stock.

MATERIALS AND METHODS

Description of Study area

The work was carried out work at Malumfashi local government area, situated between latitude 11° 65' 34.340 N to 11° 97' 43.7" N and longitude 7° 42' 0.27" E to 7° 89' 3.69" E (Fig. 1). The area situated in tropical climatic zone with total annual rainfall of about 1000mm. Generally, the climate varies considerably according to months and seasons (Katsina State Ministry of Environment, 2010).

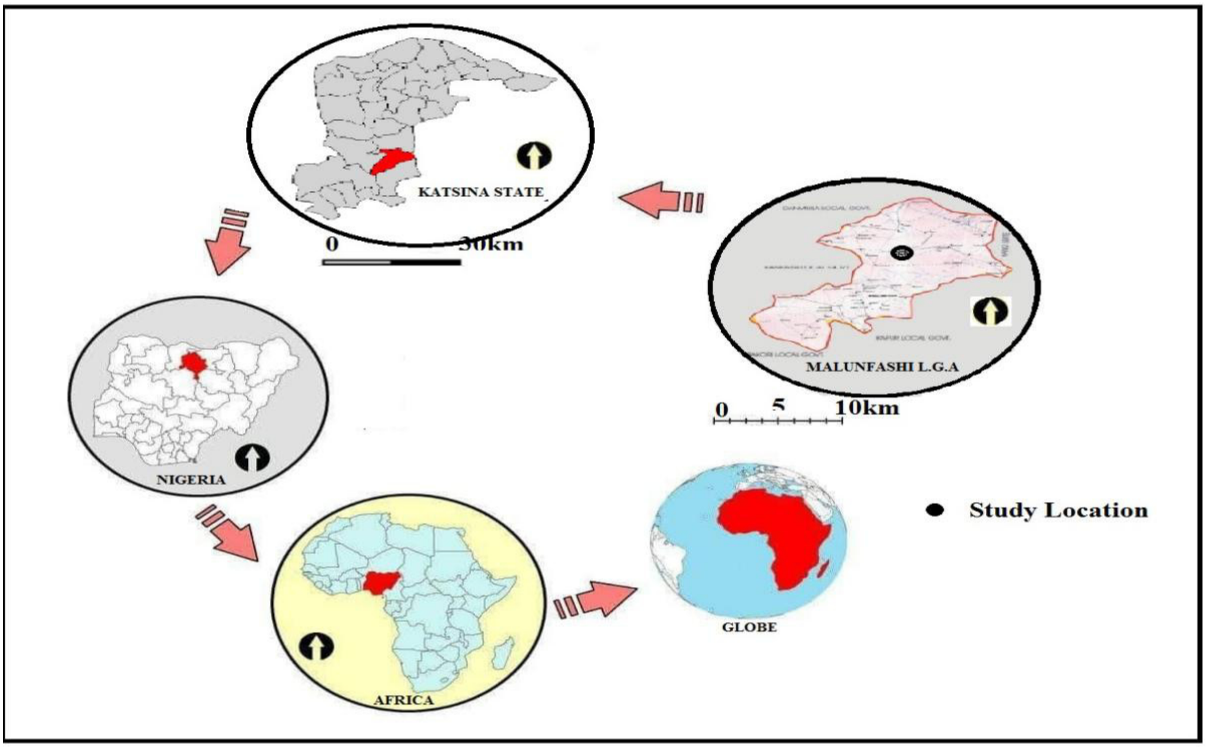

Fig. 1: Malunfashi Local Government Area Showing Study Location

Biochar Production

The biomass of sugarcane stalks was used for biochar production at high temperature which crumpled and sieve through 2 mm prior to chemical categorization.

Research Design

Experimental design (figure 2) was used whereby the study location was alienated in to experimental and control plots. The biochar was incorporated in to the soil at experimental plots and then allowed for three months. The experimental site was be clearly demarcated from control site by 50m interval. Three ridges were made measuring 250m x 150m within which 15 plot (50x50m) were demarcated and thus, served as soil sampling points. This was carried out in experimental and control plot making thirty samples for the analysis.

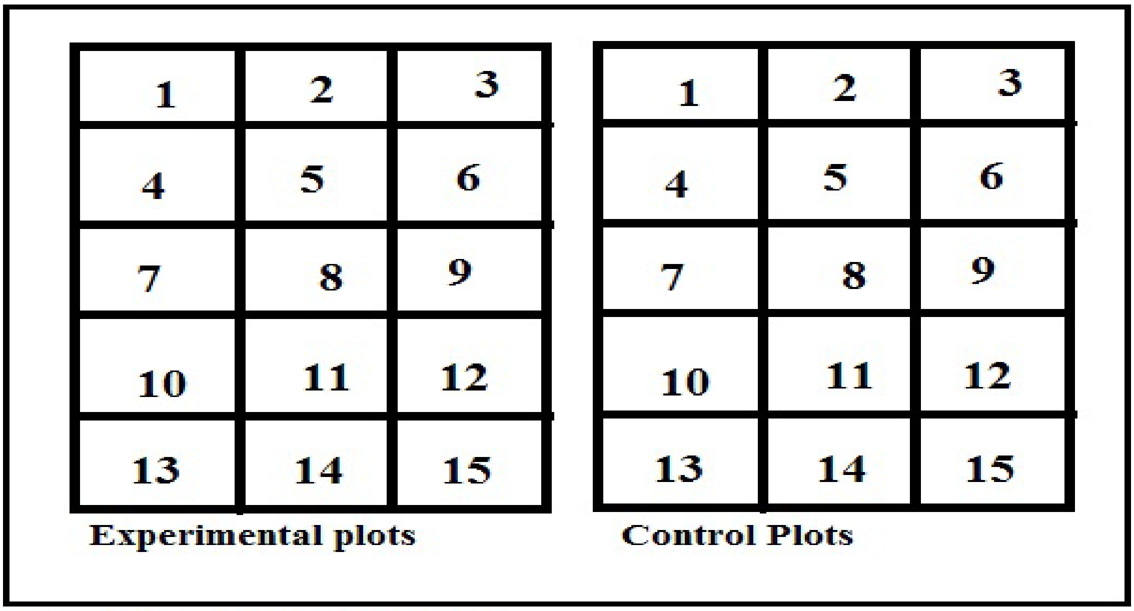

Fig. 2: Experimental Design

Soil Sampling and Laboratory Analysis

In each of the plots at both experimental and control site, fifteen soil samples were collected and kept in sterilized polyethylene bags, leveled appropriate, taken to laboratory for the analysis of selected properties. Adequate care was taken to avoid contamination of sample and all equipment used in the field and laboratory were cleaned with sterilizer to avoid sample contamination and to ensure quality assurance. However, the raw biochar and soil samples collected were analysed by appropriate laboratory procedures.

The pH meter was used for detecting soil reaction as described by Sarkar and Haldar (2005), while, oxidation techniques was used for determine organic carbon (Nelson and Sommers, 1982). Micro Kjeldahl digestion procedure was adopted for total nitrogen was determination. Bray-1 techniques was used for the analysis of available phosphorus (Dipak and Abhijit, 2005) and Exchangeable EDTA titration techniques was adopted for the analysis of exchangeable cations (Ca and Mg), while flame photometer was used to read the extract for K and Na. The normal neutral ammonium acetate was used to determine the cation exchange capacity (Sarkar and Haldar, 2005). The laboratory results from raw biochar and soil samples were analyzed using descriptive statistics. Student t-test was also carried out in determine differences in soil fertility parameters between experimental and control site at α values of 0.05.

The soil carbon stock can be calculated using the formula 1 as described by Mohammed, (2015).

$$C_{soc} = C_{soc\ sample} \text{ x } D_b \text{ x } Dep_{sample} \text{ x } 100 \qquad 1$$

Where C_{soc} = C stock in SOC in the sample, $C_{soc\ sample}$ =

SOC, D_b= bulk density, Dep_{sample}= soil

RESULTS AND DISCUSSION

Soil Fertility Parameters and Biochar

Soil fertility parameters considered for this study: pH, EC, OC, CEC, TN, Avl. P and exchangeable cation (Ca, Mg, Na and K) were analyzed (Table 1). The results reveals that raw biochar recorded high values of all soil fertility parameter than the values obtained in the soil samples.

Table 1: Fertility parameters in soil and Biochar

Soil fertility parameters	Soil Sample	Raw Biochar
pH (H2O)	5.66	9.38
EC (dsm3)	0.9	2.63
OC (%)	0.1	0.54
T N (%)	0.04	0.42
Avl. P (PPM)	0.84	3.84
CEC (Cmol/kg)	5.68	7.5
Ca (Cmol/kg)	2.32	3.99
Mg (Cmol/kg)	0.23	0.87
Na (Cmol/kg)	0.12	0.21
K (Cmol/kg)	0.18	0.34

The mean values of pH in soil is acidic and is ideal for most crops (Brady and Weil, 2017), while the pH values in the biochar is slightly alkaline (Table 1). Low pH values in soil is probably attributed to low base cation in the soil, conversely, high values cation in raw biochar is due to its high pH values. Brady and Weill (2017) buttressed that low and high pH in soil is due to low and high concentration of base cation respectively. This implies that addition biochar can improve the soil pH. The soil acidity nature is a typical characteristic of the Nigerian soils and is endorsed by the geology, heavy rainfall which influence downward movement of cations into subsoil. The findings corroborate with the results reported by Yusif *et al.* (2020a) who reported that application of biochar modify soil pH.
The electrical conductivity is higher in raw biochar than in soil (Fig. 3), this signifies that biochar contain more soluble salt than the soil of the area. The mean values of OC in soil and biochar are low (Figure 3) based on the ranking of London (1991). High concentration of OC in biochar indicates high organic materials that decomposed to produce some soil nutrient and subsequently improve soil moisture and soil microbial activities (Mohammed and Yusuf, 2021). Consequently, biochar application may enhance soil nutrient, soil moisture and other soil quality.

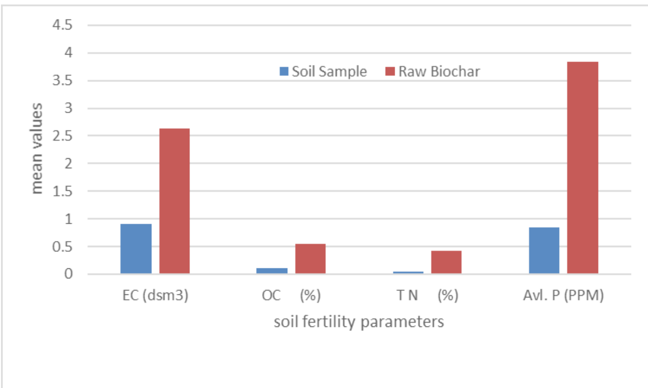

Fig.3: Mean values of EC, OC, TN & Avl. P

The mean values of N in soil and biochar is considered low based on the ranking of (Chude *et al.*, 2011), yet the nitrogen values is higher in biochar than in soil, thereby its application to soil may raise the N contentment of the soil. Low N in soil is due to the crops mining, drainage system, runoff and erosion, and leaching. It is contended that gaseous emission, run-off and crops uptake are the major ways through which N is losses from in the tropical (Brady and Weil, 2017).

Available phosphorus in the soil and raw biochar is low as classified according to soil fertility ranking (Chude *et al.*, 2011). Avl. P values was found to be lower than the findings of Muhammed (2017) who reported that the Avl. P in soils of semi arids zones of Nigeria are general very low which ranges from 65.00ppm-280ppm. This indicates that there is steady decrease in the available phosphorus which is probably attributed to crops absorption and percolation. This is reported that the prime ways through which phosphorus is loss from soil are plant removal and erosion of phosphorus taking soil particles which dissolve the phosphorus and then taken away as runoff (Brady and Weill, 2017).

Figure 4 shows the mean values of Exchangeable cation in the area. The CEC of the soil is higher in biochar than in soil which indicates that biochar has the ability and capability to adsorb exchangeable cation and therefore addition of biochar has the propensity to enhance soil CEC.

The exchangeable cation (Figure 4) shows that Ca, Mg, K and Na in soil and biochar were ranked low according soil fertility index (Chude *et al.*, 2011).

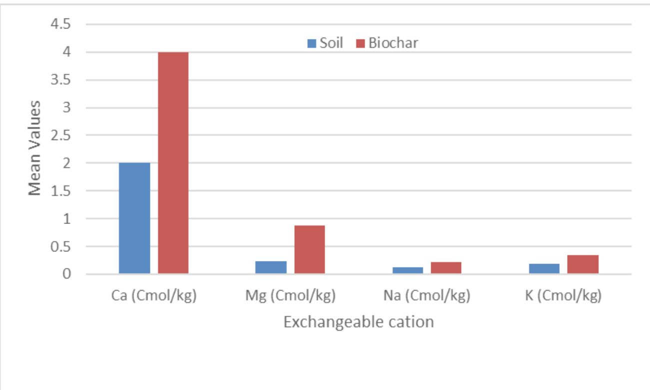

Fig. 4: Mean values of Exchangeable cation

Effect of Biochar on Fertility Parameters of Soil

The raw biochar was incorporated into the experimental plots and then allowed for three months before taking the soil samples for laboratory analyses. The results in table 2 below show the analysed mean value of soil fertility parameters of experimental and its control plots.

Table 2: Soil fertility parameter in the area

Parameters	Plots	
	Control	Experimental
pH (H2O)	5.75	8.56
EC (dsm3)	6.06	7.72
OC (%)	0.73	0.82
T N (%)	0.37	0.72
Avl. P (PPM)	0.13	0.53
CEC (Cmol/kg)	7.95	24.29
Ca (Cmol/kg)	2.02	4.15
Mg (Cmol/kg)	0.38	1.14
Na (Cmol/kg)	0.09	0.23
K (Cmol/kg)	0.09	0.24

The results revealed that the mean values of soil fertility parameters considered in this work were higher in the experimental plots where biochar was integrated than control plots. This implies that biochar applied in experimental plots assimilated into the soil and improve the fertility parameters therefore, it has the substantial influence in augmenting soil fertility in the area. The results obtained are similar to the finding of Yusif *et al.* (2020a) who postulated remarkable enhancement of some soil fertility parameter after mixing the soil with biochar. This is expounded that bochar enhanced soil fertility parameters and improve fertilizer-use efficiency (Yusif *et al.,* 2020b). Figure 5 shows significant values of soil pH values in experimental plot compared to its control plot. The high pH values in experimental plots is because of high alkalinity in ash contained in biochar. However, addition of biochar can alter the soil pH. Subsequently, biochar can be used as liming material which is purely organic and eco-friendly other than use chemical material for liming.

High level of CEC in experimental plot is due to intrinsic physiognomies of biochar such as high surface area, highly porous variable charge organic material that has the potential to increase soil cation exchange capacity (CEC), surface sorption capacity and base saturation when added to soil. An increase in CEC in soil amended with biochar was reported by Hardy *et a*l. (2017). Consequently, application of biochar increases the exchangeable cation which influence the exchange soil nutrient in soil solution, improve soil microbial condition, this conversely, may reduce the use of inorganic fertilizer which is costly and may affect the ecosystem.

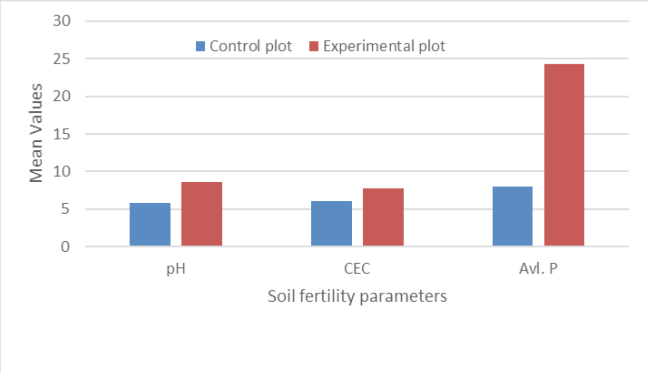

Fig. 5: Soil fertility parameters in the area

The high values of electrical conductivity (Figure 6) in the plot with biochar is attributed to high concentration of ash residues which is subjugated by alkaline carbonate. This implies that application of biochar can neutralize the acidity or alkalinity of the soil and this help in reducing the use of chemicals for liming which is costly and may affect the soil microbes. The finding is in line with result conveyed by Arocena and Opio (2003) who described the capability of biochar to deactivate the acidic soil due to ashes content.

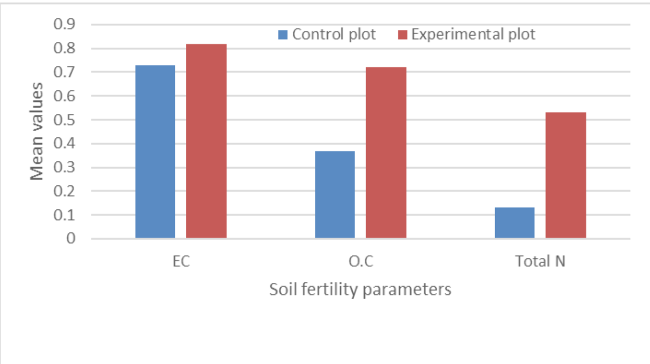

Fig.6: Mean values of EC, OC & TN

OC= The high mean values of OC in biochar amended soil is due the inherent characteristic of biochar of high concentration of organic material which transformed into organic carbon.

The total N content in the experimental plots revealed that biochar is one of the sources of soil organic N. It is elucidated that biochar is the major source of N, S and P in soil (Brady and Weil, 2017). This is further supported by Liang *et al.* (2006) that N rises with the continual augmentation in the rate of biochar in the soil. Consequently, the challenges posed by low accessibility and high cost of inorganic fertilizer such as urea can be minimized by application of biochar to supplement the N required by the crops in the area

Figure 7 revealed that addition of biochar in experimental plot results in high values of exchangeable cations. This implies that application of biochar enhance the level of exchangeable cation which can be replaced in soil solution for crop use. This is contended by Niemeyer *et al.* (2005) who reported that ash present in biochar facilitated the production and releases of the corked materials like Ca, K and N in to soil. Thus, It was comprehended that application of biochar enhances soil fertility and it can be used to abate the encounters pretense by low availability and high cost of inorganic fertilizer. Subsequently, the environmental impact of inorganic fertilizer such as emission of green house gases, soil and water contamination can be minimized by the use of biochar in place of inorganic fertilizer.

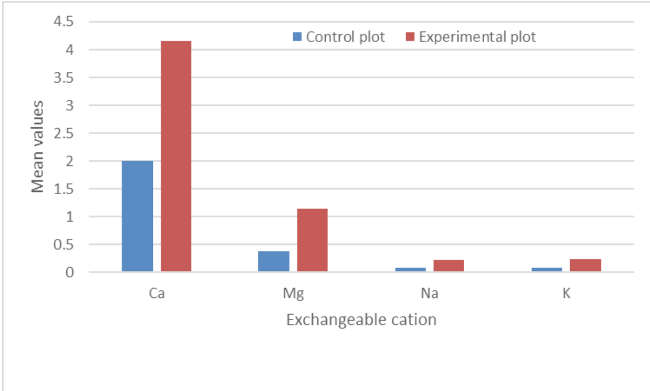

Fig. 7: Mean values of exchangeable cation in the area

However, the difference in soil fertility parameters among the study locations were determined by student t-test (Table 3) which indicates that there is significant difference in the mean value of pH, EC, OC, TN, Avl. P, CEC, Ca, K and Na between the experimental and control plots at α values of 0.05. However, no significant difference was observed in the mean value of Mg between the experiment and control plots.

Table 3: Statistical difference in fertility parameter between experimental and control plot

Parameters	std err	t-stat	Df	p-value	S i g . level	effect r
pH (H2O)	0.17	16.35	3.47	0	Yes	0.99
EC (dsm3)	0.06	32.02	3.83	0	Yes	1
OC (%)	0.04	8.33	5.82	0	Yes	0.96
T N (%)	0.08	5.17	5.93	0	Yes	0.9
Avl. P (PPM)	3.52	4.87	3.03	0.02	Yes	0.94
CEC (Cmol/kg)	0.15	11.12	4.97	0	Yes	0.98
Ca (Cmol/kg)	0.14	13.28	4.59	0	Yes	0.99
Mg (Cmol/kg)	0.27	2.69	3.81	0.06	No	0.81
Na (Cmol/kg)	0.01	12.15	4.87	0	Yes	0.98
K (Cmol/kg)	0.02	7.7	3.78	0	Yes	0.97

Effects of Biochar on Soil organic Carbon Stock (SOC)

The effect of biochar on mean values of soil carbon stock was evaluated (Table 4) which reveals higher values of SOC stock in experimental plots (1140c/100g) than the control plot (489 c/100g), this is due to high amount of organic material in the biochar and their ability to be released into the soil for crop use. This buttressed by Ndor *et al.* (2015) who discovered high values SOC stock in the plot incorporated with biochar than their control counter part. This is further adduced by Mohammed (2015); Kutsch *et al.* (2009) who explained the rate of SOC production in soil influenced by rate of a addition through the accumulation of organic materials and loss via erosion.

Table 4: Mean values of Soil carbon stock in the area

Study location	SOC (%)	D_b	Dep $_{\text{of soil}}$	C_{soc} stock
Experimental plot	0.76	1	15	1140
Control plot	0.29	0.94	15	489

High amount of SOC stock in experimental plots indicates the potential of carbon storage by biochar incorporated in experimental plots and therefore, amending soil with biochar has significant impact in mitigating GHGs emission. This is adduced by Rondon *et al.* (2005) who reported that leguminous crop (soybean) reduced N_2O emission from soil mixed with biochar at the rate of 20 t ha^{-1}. Convincingly, biochar can be used for soil carbon sequestration and is considered a means of soil carbon mitigation strategy.

CONCLUSION

The findings revealed significant improvement among the experimental plot compared to control plot. Therefore, application of biochar is imperative in order to increase soil fertility. Biochar have the capacity to store more carbon in the soil, consequently can be used for soil carbon sequestration in the area as a result of the innate characteristics of biochar.

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