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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
The use of biochar as soil amendment is being promoted due to its ability to improve fertility and confiscate soil 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 are 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

Biochar, being used as soil improvement have substantial role on soil fertility by mutable the physical, chemical and biological properties of soil. Its impact as soil amendment improves soil quality and plant growth with increasing crop yield (Awad *et al*., 2018). The biochar is produced by pyrolysis from thermochemical technology for transforming biomass into biochar between 350 to 700°C temperature by the absence of oxygen (Varma *et al*., 2018). Biochar affects nutrient availability positively, which makes it a great prospect as a slow-release fertilizer in the soil, therefore when nutrient are released from the biochar, it is solely influenced by its desorption characteristics (Oni *et al*., 2019).

Biochar is the carbon-rich product obtained from the biomass when heated in a closed container with little or no available oxygen. Some researches such as Sedlak (2018) explained that application of biochar reduce the emission 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 charcoal application has been used by indigenous people in the past as a soil improvement, to increase the fertility of the soil. Biochar has the potential characteristic of increasing water retention capacity and nutrient especially in depleted tropical soils **(**Bakewell-Stone**,** 2011). Unlike most conventional soil organic materials, which are readily decomposed, the recalcitrant nature of biochar increases its potential value as a soil amending material for the longer duration (Chan *et al*., 2008).

Nutrient depletion via leaching can be reduce by application of biochar because of its water retention capacity thereby, improving soil nutrients retention ability and productivity (Gunarathne *et al*., 2017). Growth stimulating effects are generally attributed to the biochar's capacity to supply nutrients, improve soil fertility such as increase soil pH (in acidic soils) and -use efficiency, stemming from its high surface area and high cation-exchange capacity (van Zwieten *et al*., 2010). The soil organic carbon (SOC) is very important component of global carbon cycle because of it ability to store carbon inform of SOC,

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this consequently reduce the quantity of carbon present in the atmosphere and therefore help to mitigate the problem of global warming and climate change (Hobley and Willgoose, 2010).

MATERIALS AND METHODS

Study area

The study was conducted at Malumfashi local government area, located 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 at 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).

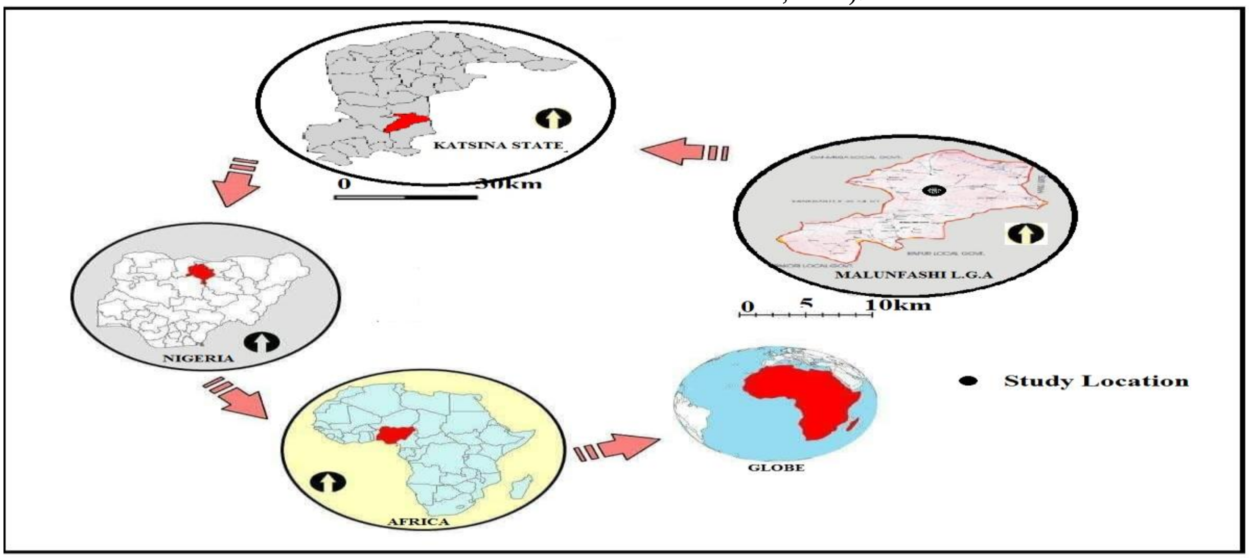

Fig. 1: Malunfashi Local Government Area Showing Study Location

Biochar Production

The biochar was produced from sugarcane stalks as the feedstock by pyrolysis for hours at temperature range of about 300°C to 500°C. Biochar was crushed and passed through a 2 mm sieve before chemical characterization.

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 experiment 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.

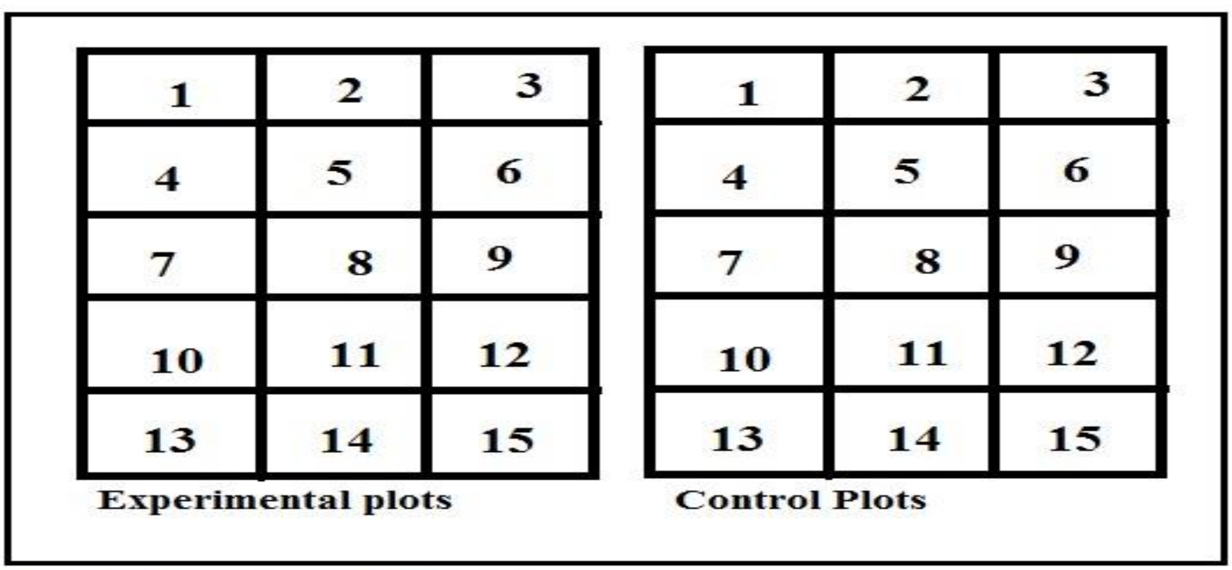

Fig. 2: Experimental Design

Soil Sampling and Laboratory Analysis

In each of the plots at both experimental and control site, fifteen soil samples were collected using composite sampling techniques from 0 – 15 cm depth and the samples collected were kept in sterilized polyethylene bags, leveled appropriate and then taking to the laboratory for the analysis of some selected soil fertility parameters. Adequate care was taken to avoid contamination sample and all equipment used in the field and laboratory were clean with sterilizer to avoid sample contamination to ensure quality assurance. However, the raw biochar and soil samples collected were determined using standard laboratory procedures.

The soil pH was determined using glass electrode pH meter as described by Sarkar and Haldar (2005), while, soil organic carbon was determined using oxidation method as described by Nelson and Sommers (1982). Total nitrogen was determined by Micro Kjeldahl digestion method. Available phosphorus was determined using bray-1 method (Dipak and Abhijit, 2005) and Exchangeable Calcium (Ca) and magnesium (Mg) were determined using EDTA titration method while potassium (K) and sodium (Na), in the extract were read using flame photometer. Normal neutral ammonium acetate was used in the determination of cation exchange capacity (CEC) of the soil as described by Sarkar and Haldar (2005).

The laboratory results from raw boichar and soil samples were analyzed using descriptive statistics such as the mean, standard deviation. Student t-test was also carried out to determine the 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).

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

1.

Where C_{soc} = carbon stock in SOC in the sample, $C_{soc\ sample}$ = soil organic carbon determines, D_b= bulk density, Dep_{sample}= depth of soil sample collected

RESULTS AND DISCUSSION

Fertility Parameters of Soil and Biochar

The soil fertility parameters considered for this study: pH, EC, OC, CEC, TN, Avl. P and exchangeable cation (Ca, Mg, Na and K) were analyzed and presented in the table 1. The results shows that raw biochar have the highest mean 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 base cation in the raw biochar attributes to the high values of pH in the biochar. Brady & Weill (2017) supports this by explaining that, low and high pH in soil is due to low and high concentration of base cation respectively. This implies that pH of the soil can be adjusted positively by application of the biochar. The acidity nature of soil is a typical characteristic of the Nigeria soils and is endorsed by the parent materials, excessive precipitation which leads to leaching of cations into subsoil. This is in line with the findings reported by Yusif *et al*. (2020) who discovered that soil pH was 5.02 and was rated as strongly acidic where biochar was found to be high.

The electrical conductivity is high 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) according to 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, 2018). Consequently, biochar application may enhance soil nutrient, soil moisture and other soil quality.

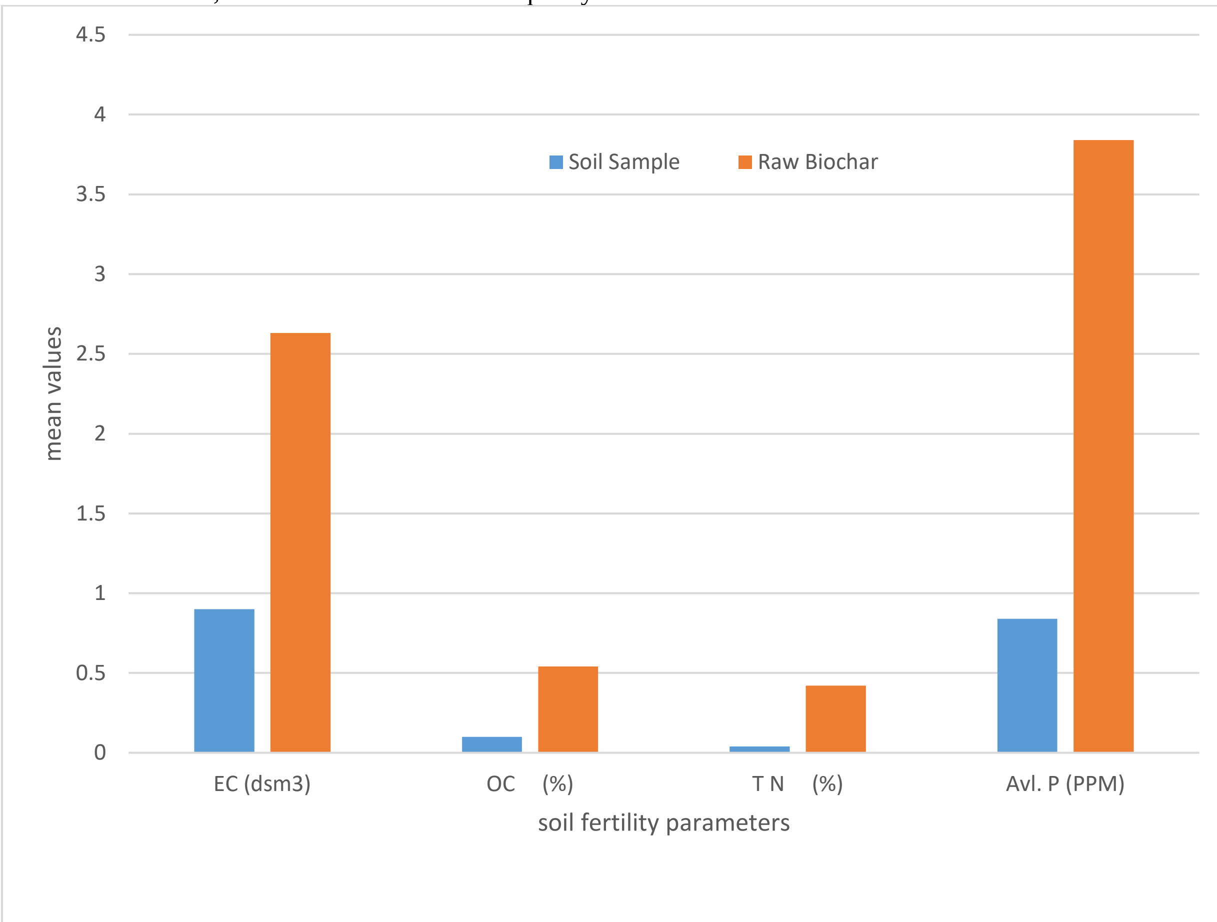

Fig.3: Mean values of EC, OC, TN & Avl. P

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. This is contended by Brady and Weil (2017) who explained that gaseous emission, erosion, run-off and crops uptake are the major ways through which N is losses from in the tropical.

Available phosphorus The available phosphorus (mg/kg) content in the soil and raw biochar is low as classified based on soil fertility ranking manual which ranked mean phosphorus value of < 10 mg/kg as low for Nigerian soils (Chude *et al.*, 2011). The value of Avl. P this study was found to below 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 implies that, there is gradual reduction in the available phosphorus in the soil which is attributed to crops uptake, leaching and runoff which are major sources of phosphorus losses in the soil. This is adduced by Brady and Weill (2017) who reported that, the principal pathways through which phosphorus is reduced or loosed from soil are plant removal, erosion of phosphorus taking soil particles and runoff water which dissolve the phosphorus and then taken away as runoff.

The cation exchange capacity of the soil is higher in biochar than in soil which indicates that biochar have the ability and capability to adsorbed exchangeable cation and therefore application of biochar to soil have the propensity to enhance the CEC of the soil.

The exchangeable cation (Figure 4) shows that exchangeable cation in soil and biochar were ranked low base on soil fertility assessment manual which ranked mean value of exchangeable cations of < 0.15 cmol/kg as low for Nigerian soils (Chude *et al.*, 2011).

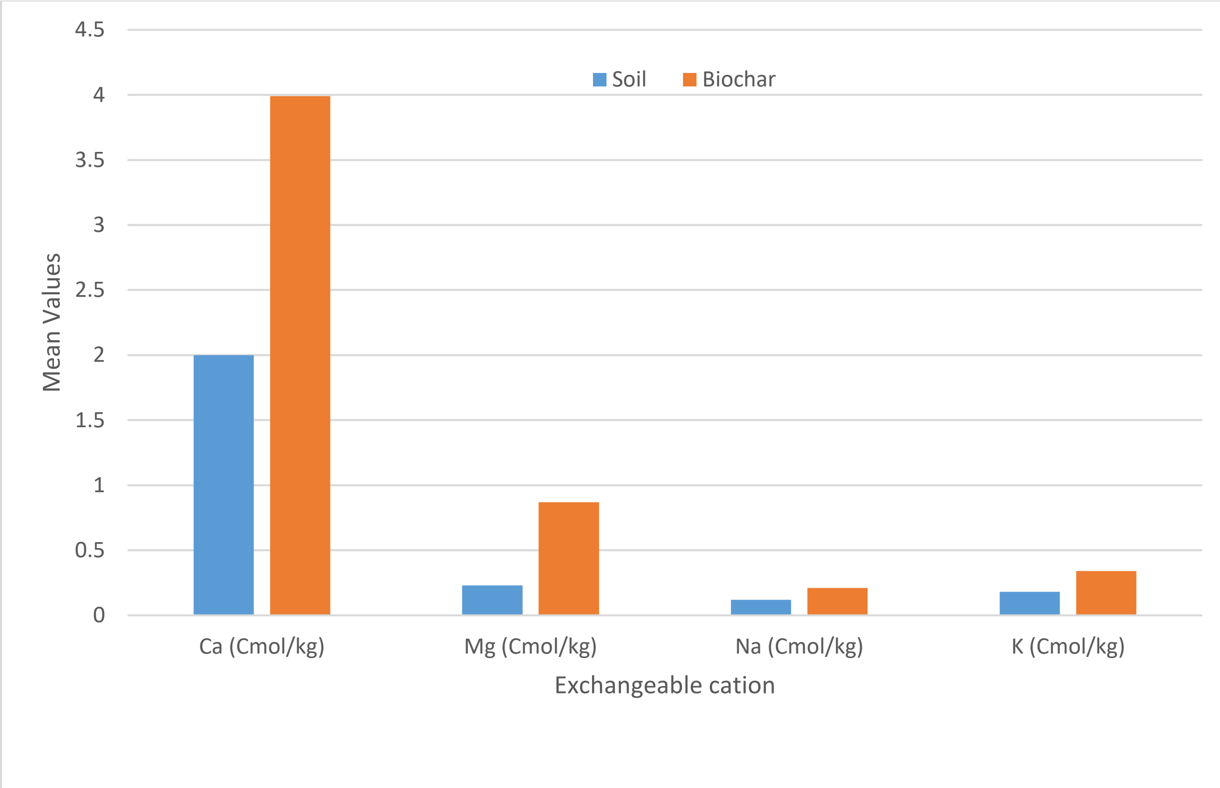

Fig. 4: Mean values of Exchangeable cation

Effect of Biochar on Fertility Parameters of Soil

The raw biochar was incorporated into the experimental plots and allowed for three month thereby samples was collected and analysed. The results shows that the mean value of soil fertility parameters between control and experimental plots were analysed and presented in table 2.

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 in the fertility parameters therefore, it has the substantial influence in augmenting soil fertility in the area. The results obtained corroborate with finding of Yusif *et al*. (2020a) who reported significant improvement of some soil fertility parameter after mixing the soil with biochar. This is further supported by Yusif *et al.* (2020b) who reported that, biochar have the ability to improve soil properties, enhancing soil fertility level and improve fertilizer-use efficiency.

Figure 5 shows significant values of soil pH in the experimental plots than control plots. The high pH in soil amended with biochar is due to high alkalinity in the ash contained in the biochar. However, application of biochar to soil can alter the soil pH. The results obtained corroborate with finding reported by Glaser *et al*. (2002) who stated that, biochar serves as a liming agent resulting in increases pH of the soil. Subsequently, biochar can be used for liming material which is purely organic and eco-friendly than use of chemical material for liming.

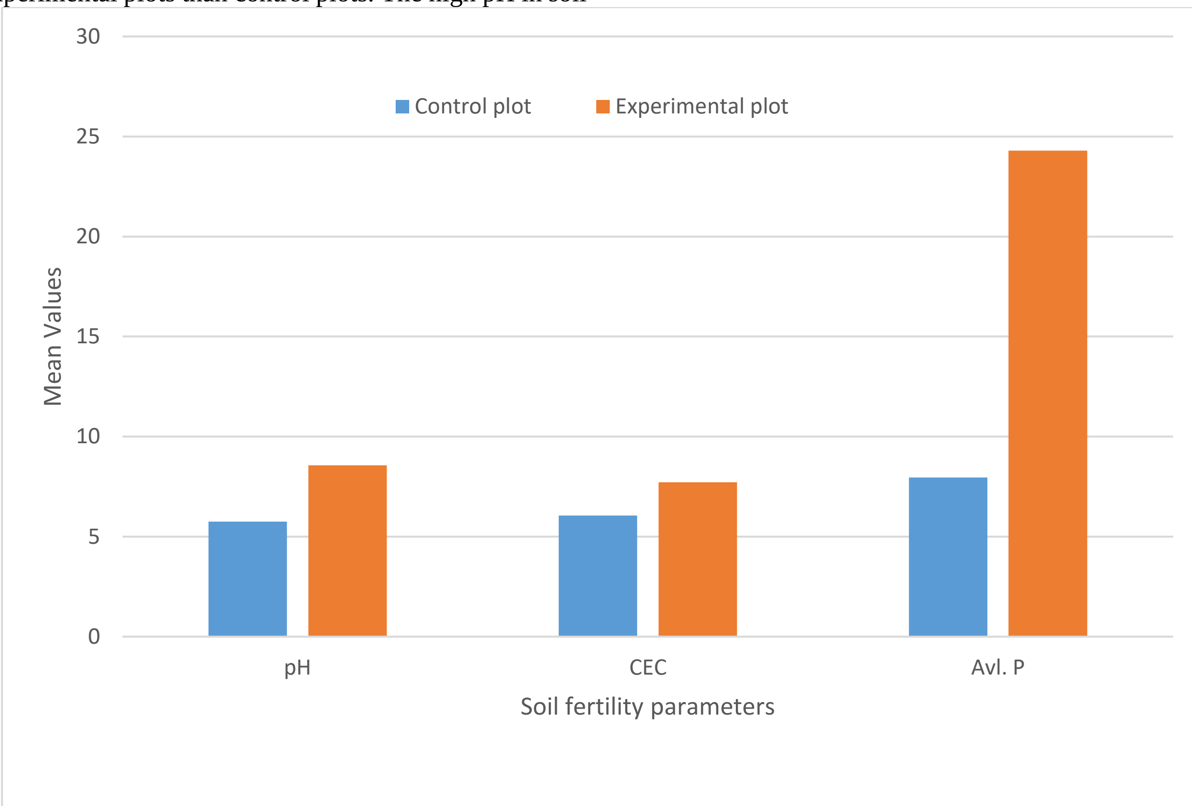

Fig. 5: Soil fertility parameters in the area

High level of CEC in experimental plot is due to inherent characteristics 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. This result is in line with some researches such as Yusif *et al.* (2016) who testified that, biochar application have the potential to improve soil chemical properties. This is supported by Hardy *et al*. (2017) who reported an increase in CEC of soil amended with biochar. Consequently, application of biochar increases the exchangeable cation which influence the exchange of soil nutrients in soil solution, improve soil microbial condition, this conversely, may reduce the use of inorganic fertilizer which is costly and may affect the ecosystem.

High level of available P in experiments plots indicates the ability of biochar to break the complexes of Al and Fe in soil and thereby releasing more phosphorus. This is further adduced by Brady and Weill (2017) who elucidates that, soil available P increased significantly under liming due to lowering P fixation by other elements (such as Al, Mn, and Fe). The high values of electrical conductivity (Figure 6) in the plot with biochar is attributed to high concentration of ash residues which is generally dominated by carbonates of alkali and alkaline. This implies that application of biochar can neutralize the acidity or alkalinity of the i.e. it can alter the soil pH of the soil to avoid used of chemical for liming activities 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 capacity of biochar to neutralize the acidic soil due to the ashes content.

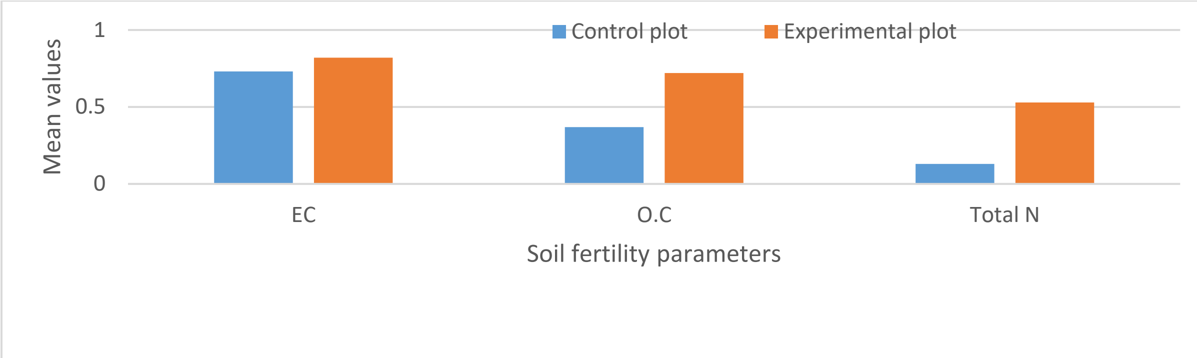

Fig.6: Mean values of EC, OC & TN

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 organic N in to the soil. This is contended by Brady and Weil (2017) who clarified that biochar is the major source of organic N, S and P in soil. This is further supported by Liang *et al*. (2006) who stated that, N increases 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 exchange in soil solution for crop use. High exchangeable cation in soil amended with biochar might be attributed to the presence of ash in the biochar, which release occluded mineral nutrients in the soil. This is contended by Niemeyer *et al.* (2005) who explained that the ash present in the biochar facilitated the production and releases of the corked materials like Ca, K and N in to the soil. It was comprehended that application of biochar to soil 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.

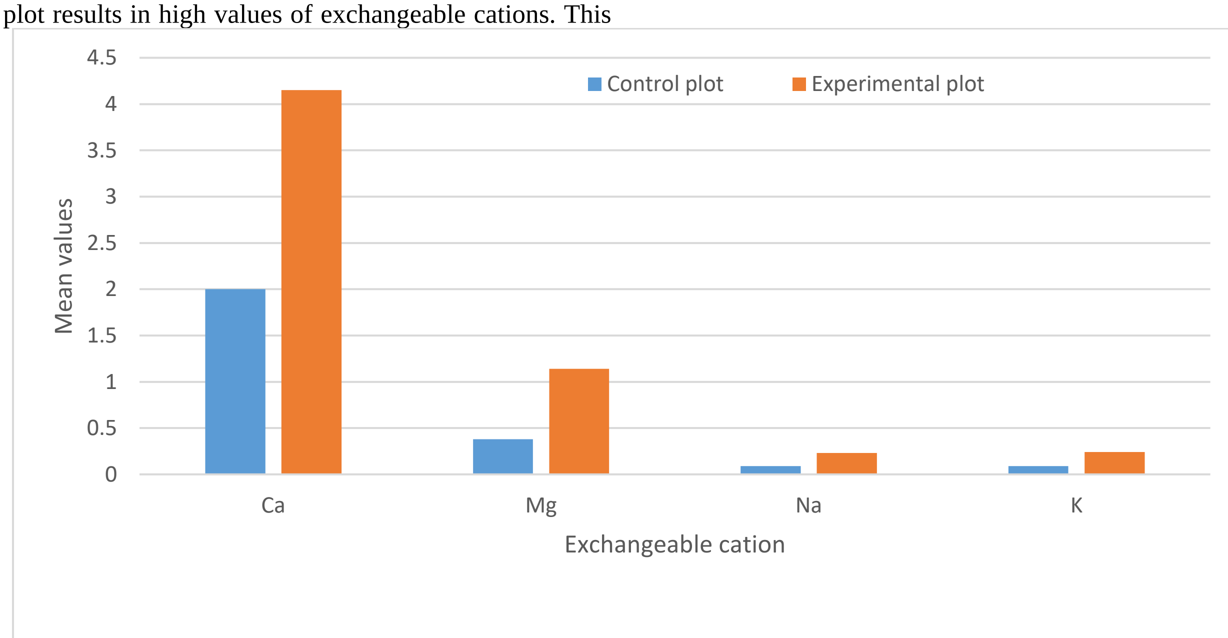

Fig. 7: Mean values of exchangeable cation in the area

However, the difference in the mean values of soil fertility parameters between experimental and control plots were determined using student t-test (Table 3) which revealed 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	Sig. 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 the mean values of soil carbon stock was evaluated and presented in table 4 which shows that the mean values of SOC stock is higher 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 release into the soil for crop use. This supported by Ndor *et al*. (2015) who reported high values of SOC stock in the plot incorporated with biochar than control counter part. This is further adduced by Mohammed (2015); Kutsch *et al*. (2009) who explained that, the rate of SOC production in the soil is controlled by the rate of a gain through the addition of organic materials and loss through 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 experiment 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 the soil incorporated with biochar at the rate of 20 t ha^{-1}. Convincingly, biochar can be used for soil carbon sequestration and therefore consider biochar application to soil as a means of carbon mitigation.

CONCLUSION

Generally, the research revealed that, biochar application increases the fertility of the soil and invariably improves soil health and productivity. The studied showed significant improvement among the experiment plots when compared to control plots. Therefore, application of biochar is imperative in increasing soil fertility. Therefore, biochar have the capacity to store more carbon in the soil, consequently can be used in as soil carbon sequestration in the area as a result of the inherent characteristics of biochar.

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