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Biochar Amendments for Reducing Nitrate Leaching from Soils of Different Textural Classes in the Nigerian Savanna[#]

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A R T I C L E I N F O

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A B S T R A C T

This study was carried out with the aim of assessing the effectiveness of four biochar materials; in reducing nitrate leaching from soils of three different textural classes in the Nigerian Savanna region. Soil samples (0-20 cm depth) were collected from three different soil types and three different locations each in the Nigerian Savanna using stratified random sampling. Two hundred and fifty (250) g of soil samples were amended with 0, 2.5, 5, 7.5 and 10 $tonha^{-1}$ of Maize cob biochar (MCB), rice husk biochar (RHB), cow dung biochar (CDB) and poultry litter biochar (PLB) and were subjected to laboratory leaching experiment. Sixty (60) ml of nutrient solutions containing 300 mgl^{-1} nitrate using ammonium nitrate (NH_4NO_3) was applied to each of the laboratory biochar-incubated soil columns to study biochar effect on nutrients retention and transport. The experiment was laid in a Randomize Complete Block Design (RCBD) replicated three times. Leachates were collected and nitrate concentration was determined using a dual beam UV/VIS spectrophotometer. The data collected were analysed using the Generalized Linear Model (GLM) procedure and the means were separated using Tukey's honest significant difference (SAS version 9.4). Results obtained revealed that there were no significant differences among the biochar treatments on nitrate leaching from Clay loam. However, highest nitrate leaching from Loamy soil of 30.53% was recorded by the application of 2.5 $tonha^{-1}$ PLB and was significantly different from the application of 2.5 and 5-ton ha^{-1} RHB and 5-ton ha^{-1} MCB. Similarly, highest nitrate leaching from Sandy loam of 32.18 % was recorded by the application of 5-ton ha^{-1} MCB and was significantly higher than 5.94, 2.40 and 7.12 % recorded by the application of 2.5 and 5-ton ha^{-1} RHB and 7.5 $tonha^{-1}$ CDB respectively. Therefore, application of 2.5, 5-ton ha^{-1} RHB and 7.5 $tonha^{-1}$ CDB can effectively reduce nitrate leaching from Sandy loam. While 2.5, 5, 7.5 $tonha^{-1}$ CDB and 2. 5 and 5 $tonha^{-1}$ RHB reduced nitrate leaching from Loamy soils.

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Introduction

Nitrogen (N) is an essential element that is required for plant growth and development. Farmers, particularly, in developing countries, often apply N fertilizer in excessive amounts in an attempt to maximize yields (Liu et al., 2017). Although, application of inorganic fertilizer to agricultural soil is an effective method for improving crop productivity (Li et al., 2018). Continuous inorganic fertilizer application has been the leading cause of nutrient release from agricultural fields to groundwater and aquatic systems through runoff and leaching of the nutrients (Yao, et al., 2012; Adegoke et al., 2013). These have led to the accumulation of high nutrient concentrations in surface and/or groundwater that promote eutrophication (Karaca et al., 2004). Nitrate leaching has also caused significant declines in soil productivity through the depletion of soil fertility, accelerate soil acidification as a result of leaching of basic cations along with nitrate ion, increase fertilizer costs for the farmers, reduce crop yields, and is a major threat to environmental health (Laird et al., 2010; Ozacar, 2003).

Nitrate is highly soluble in water hence, it is the primary form through which N is lost from agricultural soils. Masarik et al. (2014) and Mahmud et al. (2021) reported soil permeability, pore size distribution, soil depth, artificial drainage and the distribution of precipitation over the year to be the major factors affecting the extent of nitrate leaching in soils (Mahmud et al., 2021). In order to reduce the high cost of fertilizer application for the farmers, improve nutrients retention in soils and reduce ground and surface water contamination (Teutscherova et al., 2018), measures that would improve nutrient retention in soil and prevent losses has to be adopted.

Clough and Condron (2010); Steiner et al. (2008) reported that biochar is effective at retaining nitrate and other nutrients in soils. Several studies have also shown that biochar enhances nitrogen retention in compost, reducing emissions of ammonia and increasing total nitrogen retention by as much as 65 % (Borchard et al., 2019; Li et al., 2018; Kumar et al., 2016; Troy et al., 2014; Knowles et al., 2011; Steiner et al., 2008). Similarly, Lehmann (2007) claimed that biochar can retain nutrients for plant uptake and limits the infiltration of harmful quantities of nutrients and pesticides into ground water, soil erosion and run off into surface waters thereby, reducing nutrients pollution into water bodies. Lehmann and Chroth (2003) in a related study observed that biochar amendment in soil recycles most of the nutrients that are lost due to the harvest and linked it to the high surface area and high surface charge density. Zhang et al. (2015) observed that biochar increases the capacity of soils to hold nutrients and plant available water and lessen the leaching of nutrients and agricultural chemicals. By retaining nutrients in the root zone, leaching through the soil profile and into water bodies would be limited thereby improving soil fertility and crop productivity.

Therefore, assessment of different biochar materials for their effectiveness in mitigating nitrate leaching with special reference to the soil textural class is a prerequisite for reducing the cost of fertilizer application for the farmers, improving nutrients retention in soils and reducing pollution of aquatic environments.

Materials and Methods

Soil Sampling, Preparation, and Analysis

Bulk soil surface samples (0-20 cm depth) were collected from three different soil textural classes from three different locations each in the Nigerian Savannah using stratified random sampling. Clayloam were collected from Numan, Shelleng and Guyuk Local government areas of Adamawa State. While Sandy loam were collected from Modibbo Adama University (MAU) Yola teaching and research farm in Adamawa State, Federal College of Land Resources Technology (FECOLART) Kuru, Jos in Plateau State and Institute for Agricultural Research (IAR) Research Farm, Samaru, Zaria in Kaduna State. Similarly, Loamy soils were collected from Akko Local Government Area of Gombe State, Farmers' fields behind Area F Residential Quarters, ABU Zaria (Bawa, 1997) and Barkin Ladi in Plateau State (Table 1) and were analyzed using standard laboratory procedure. Similarly, 250 g of the soil samples were kept for leaching studies at the soil chemistry laboratory of the Departmental of Soil Science, Faculty of Agriculture, Ahmadu bello University, Zaria.

The soil pH (soil reaction) was measured using a glass electrode pH meter in a 1: 2.5 soil to water ratio and in 0.01M $CaCl_2$ as described by Jaiswal (2003). The organic carbon was determined by Chromic acid wet oxidation method of Walkley and Black as described by Jaiswal (2003). Total soil nitrogen was determined by wet digestion using the macro Kjeldahl digestion and distillation procedure as described by Jaiswal (2003). The available phosphorus was determined using Bray 1 method (Bray and Kurtz, 1945).

The exchangeable bases were extracted in neutral 1N ammonium acetate (NH_40Ac). Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrophotometer while, K^+ and Na^+ were determined with a flame photometer (Jaiswal, 2003). Electrical Conductivity (EC) was determined in a 1: 2.5 (soil: water) suspension as described by Jaiswal (2003). Effective cation exchange capacity (ECEC) was determined by the summation method (Juo, 1978). The soil nitrate was determined using spectrophotometry by nitration of salicylic acid. The zero points of charge (ZPC) was determined using the pH drift method as described by Calvete et al. (2009).

Biochar Preparation and Analysis

Biochar materials were prepared from two plant materials (Maize cob and rice husk) and two animal wastes (cow dung and poultry litter). In each case, the feedstock was placed in an air tied stainless steel container separately before putting it into the furnace. The oven was heated to 600°C (to obtain high surface area) at heating rate of 20°C per minute and kept at that temperature for 45 min. The biochar mass was then ground and sieved through a 2 mm mesh sieve in order to obtain a powder consistency that would mix uniformly with the soils.

The ground biochar materials were characterized for pH, total C, nitrate, specific surface area, volatile matter, biochar yield, and morphology. The pH of the char was measured in 1: 10 char/water suspensions with a compound glass electrode. Similarly, the Langmuir surface equation was used to calculated the specific surface area using the methylene blue adsorption onto the biochar (Itodo et al., 2010). While total carbon was determined by dry combustion method, the volatile matter was determined by measuring the weight loss that follows the combustion of about 1 g of char in a crucible at 950℃. The percentage biochar yield was estimated as the ratio of the weight of the pyrolysis product to original materials and multiply by 100. To determine the structure of the different biochar, their morphologies were studied through scanning electron microscopy (SEM) Pheno Prox model manufactured by Phenoworld Eindhoven, the Netherlands at the Department of Chemical Engineering, ABU, Zaria.

Table 1. Location, State, Soil Type and Geographical Positioning System (GPS) Coordinates of the Sampling Locations

Location	State	STC	Coordinate
Barkin Ladi	Plateau	Loam	9°33'55.868"N - 09º34'0.73" N, 8°55'6.209"E - 08º58'7.87" E
Akko	Gombe	Loam	10°6'13.530"N- 10º 4'40.53" N, 11°1'22.999"E - 11º 6'30.81" E
Area F	Kaduna	Loam	11º 10'20.33" N - 11º 10'17.80" N, 07º 37'33.44" E-07º 37'34.30" E
Numan	Adamawa	Clay loam	9°27'14.081"N - 9°27'56.011"N, 12°0'35.188"E'- 12°0'55.168"E
Guyuk	Adamawa	Clay loam	9°49'26.483"N - 9 º38'59" N, 11°55'48.953"E -11º54'57" E
Shelleng	Adamawa	Clay loam	9°53'42.520"N 09º - 09º 56'32.71" N, 12°0'37.615"E - 12º 3'15.96" E
MAU, Yola, TRF	Adamawa	Sandy loam	9°20'26.708"N -09º 51'49.26" N, 12°30'6.006"E - 12º 4'12.82" E
IAR Farm	Kaduna	Sandy loam	11º 10'37.26" N- 11º 10'38.18" N, 7º 36'38.51.38" E-7º 37'38.0.20" E
FECOLART, Farm	Plateau	Sandy loam	9º44'30.74"-9º44'45.56" N, 8º48'55.36"-8º49'3.28" E

STC: Soil Textural class

Leaching Studies

To monitor nitrate leaching, soil columns were used. Soil samples were packed into the columns. The columns were made of polyvinyl chloride (PVC) pipes measuring 16.5 cm in height and 10.0 cm in diameter, using 250 g of soil sample mixed with the different rates of biochar and were gently tapped to simulate the field bulk density of the soils. The control was handled in the same manner, without any biochar application. The bottom of the soil columns was covered with mesh and filter paper to prevent soil loss. The soil-biochar mixture was allowed to incubate for four weeks by adding water to the experimental columns daily during the incubation period to maintain the moisture content of 80% of the maximum water holding capacity (WHC) of the soil. Two sets of these columns were established. One set of soil-biochar mixture was terminated after 4 weeks incubation and the soil samples were analyzed for pH_{ZPC}. The remaining columns (the other set) were saturated with 0.01 M $CaCl_2$ solution for 24 hours then flushed with 10 pore-volumes of deionize water as described by (Mahmood-Ul-Hassan et al., 2010) with slight modification to pre-condition the column. Sixty (60ml) of nutrient solutions containing 300 mgl^{-1} nitrate using ammonium nitrate (NH_4NO_3), as the sources of nitrate. These solutions were applied to these laboratory biochar-incubated soil columns to study biochar effect on nutrients retention and transport. The columns were then flushed with one pore-volume deionize water each day for one week. Leachates were collected and the concentrations of nitrate in the leachate was determined using a dual beam UV/VIS spectrophotometer.

Treatments and Experimental Design

To determine the treatments effects on nitrate leaching, the data were analysed using the Randomize Complete Block Design (RCBD) replicated three times. The treatments were no biochar, 2.5 ton ha^{-1} RHB, 5 ton ha^{-1} RHB, 7.5 ton ha^{-1} RHB, 10 ton ha^{-1}RHB, 2.5 ton ha^{-1} MCB, 5 ton ha^{-1} MCB, 7.5 ton ha^{-1} MCB, 10 ton ha^{-1} MCB, 2.5 ton ha^{-1} CDB, 5 ton ha^{-1} CDB, 7.5 ton ha^{-1} CDB, 10 ton ha^{-1} CDB, 2.5 ton ha^{-1} PLB, 5 ton ha^{-1} PLB, 7.5 ton ha^{-1} PLB, and 10 ton ha^{-1}PLB for each soil type while the three locations from where each soil type was collected served as the three replications (blocks).

Data Analysis

The data collected were analyzed using the Generalized Linear Model (GLM) procedure and the means were separated using Tukey's honest significant difference using Statistical Analysis Software (SAS version 9.4).

Results and Discussion

Physical and chemical properties of soils of the study area are presented in Table 2. Results of some biochar characterization and morphology are presented in Table 3 and Figure 1 respectively.

Effect of Biochar on Nitrate Leaching from Clay Loam

The effect of biochar on ZPC, leachate pH, nitrate leaching from Clay loam are presented on Table 4. There were significant ($P<0.05$) differences on ZPC among the biochar treatments in Clay loam (Table 4). Highest ZPC of 7.73 was recorded by 7.5-ton ha^{-1} RHB and was significantly different from 4.10, 4.23 and 4.33 recorded by the application of 5, 7.5 and 10-ton ha^{-1} MCB. No significant differences were observed among the biochar treatments in Clay loam with respect to leachates pH (Table 4). Although, MCB recorded high initial pH value, significantly lower pH and ZPC recorded by the application of 5, 7.5 and 10 ton ha^{-1} MCB application indicated low ability of the biochar to resist abrupt change in pH. Dai et al. (2014) obtained low pH values in soils amended with reed straw biochar and linked the results to low buffering capacity of the biochar materials.

There were no significant differences among the biochar treatments on nitrate leaching in Clay loamy soil. However, lowest nitrate leaching of 1.27 % was recorded by soil amended with 5-ton ha^{-1} CDB but was not significantly different from the rest of the treatments. Lack significant effect of biochar treatments on nitrate leaching in this soil, may be due to the higher clay content of this soil. Gaines and Gaines (1994) reported that soils with high clay and organic matter contents retain more nitrate compared to their coarse texture counterpart.

Effect of Biochar on Nitrate Leaching from Loamy Soil

Highest ZPC of 5.37 was recorded by the application of 10 $tonha^{-1}$ PLB and was significantly ($P<0.05$) higher than those recorded by 7.5ton ha^{-1} MCB, all rates of RHB and treatments without biochar application. However, it was not significantly different from the rest of the treatments. Based on leachates pH, significant ($P<0.05$) differences were observed among the biochar treatments (Table 4). Highest leachates pH of 6.67 was recorded by the application of 7.5-ton ha^{-1} MCB and was significantly ($P<0.05$) different from 5.0, 5.17. 4.73, 4.97, 4.77 and 5.10 recorded by the application of 10 and 2.5 $tonha^{-1}$ PLB, 2.5 $tonha^{-1}$ CDB, 10 and 2.5 $tonha^{-1}$ MCB as well as 10 $tonha^{-1}$ RHB respectively. However, it was not significantly different from the rest of the treatments (Table 4). Significantly lower ZPC recorded by all rates of RHB and treatments without biochar application may be attributed to the inability of RHB to increase the pH of this soil type due to its low pH value. It may also be due to the low ZPC of the soil and RHB as well as the low buffering capacity of the biochar samples. Dai et al. (2014) reported lower pH values in Plinthudult and Paleudalf amended with reed straw biochar and soils with no biochar amendments and linked the results to low acid buffering capacity of this biochar as a result of its low carbonates content compared to the rest of the biochar materials. Higher leachates pH recorded by 7.5 ton ha^{-1} MCB application may not be unconnected to the high pH of the biochar material. Nyambo et al. (2018) obtained significant increase in pH of acidic soils with the application of maize residue biochar and attributed it to the liming ability of the biochar sample due to its high ash content. Similar result was reported by Chintala et al. (2014).

Table 2. Some Physical and Chemical Properties of Soils of the Study Locations

Textural class	Sand	Silt	Clay	Bulk D	Porosity	pH	EC	OC	TN
		(g kg^{-1})		(Mg m^{-3})	(%)	(Soil:H_2O)	(dS m^{-1})	gkg^{-1}	
Loam	427.8	353.5	218.7	1.4	47.22	5.87	0.083	5.99	0.35
Clay loam	381.11	285.56	333.33	1.25	49.44	6.71	0.089	9.21	0.81
Sandy loam	602.21	288.9	108.9	1.54	41.78	6.29	0.085	8.81	0.56
Textural class	Nitrate	AvP	Ca^{2+}	Mg^{2+}	K^+	Na^+	H +Al^{3+}	ECEC	ZPC
	$mgkg^{-1}$					cmol(+)kg^{-1}			
Loam	8.11	4.52	5.05	0.71	0.22	0.16	0.73	6.87	5.43
Clay loam	18.67	9.1	10.25	1.41	0.63	0.82	0.58	13.69	5.28
Sandy loam	12.89	17.23	8.8	1.36	0.33	0.58	0.51	11.58	5.94

Table 3. Some Properties of Biochar Materials used in the Study

Parameters	Maize cob biochar (MCB)	Rice husk biochar (RHB)	Cow dung biochar (CDB)	Poultry litter biochar (PLB)
pH (1:10 Biochar: H_2O)	10.3	7.9	7.6	7.8
pH (1:10 Biochar: 0.01M $CaCl_2$)	9.5	7.2	7.1	7.5
EC (dS m^{-1})	3.5	2.7	2.6	3.1
Bulk density (Mg m^{-3})	0.413	0.405	0.345	0.58
Moisture content (%)	1.9	1.32	1.67	1.66
Biochar yield (%)	23.6	30.1	33.8	31.4
pH_{ZPC} (NaCl)	8	6.9	6.7	6.9
pH_{ZPC} (KCl)	8	6.9	6.8	6.9
Total ash (g kg^{-1})	690	490	589	480
Total C (g kg^{-1})	292	395	300	400
Volatile matter (%)	0.655	0.645	1.45	1.362
Nitrate (mg kg^{-1})	16.55	7.98	8.21	6.19
Specific surface area (cm^2 g^{-1}) (Langmuir)	2.735×10^3	3.107×10^3	2.955×10^3	2.896×10^3

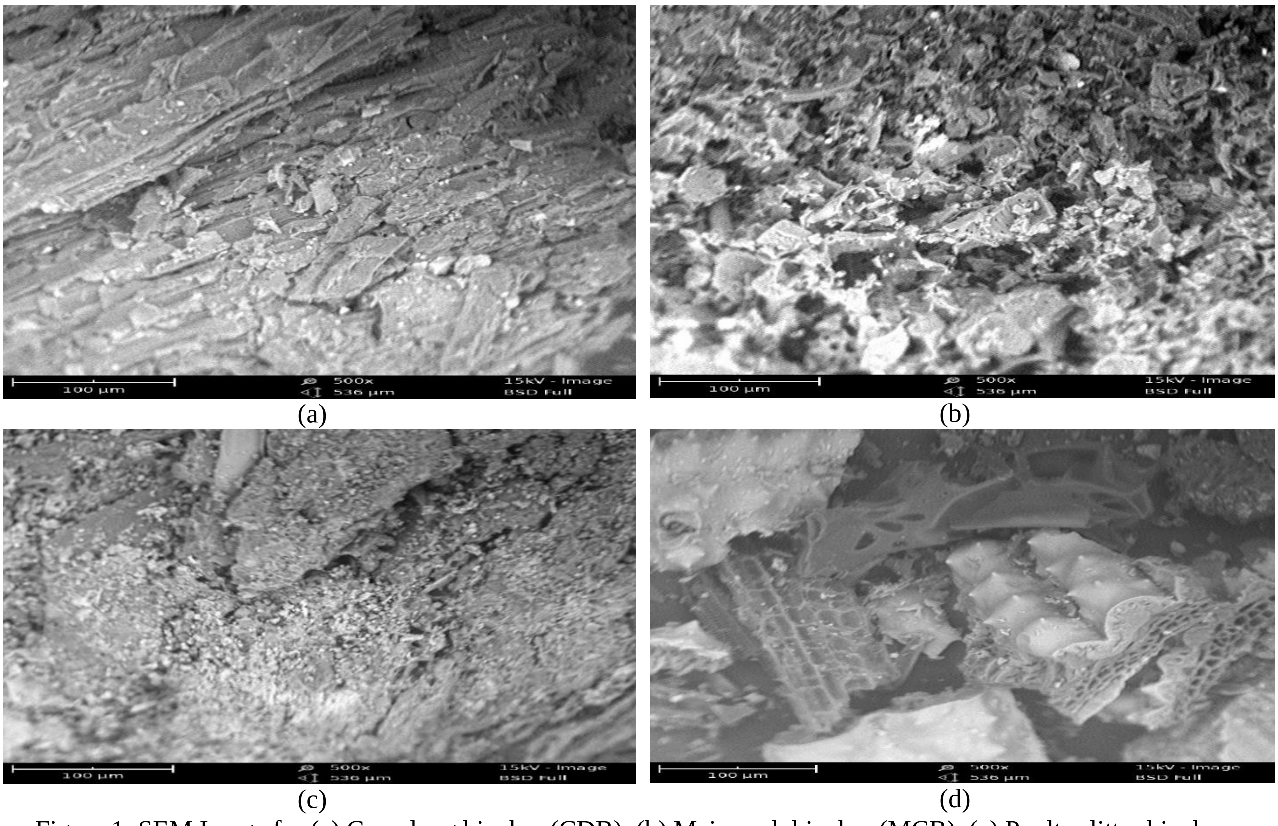

Figure 1. SEM Image for (a) Cow dung biochar (CDB), (b) Maize cob biochar (MCB), (c) Poultry litter biochar (PLB) and (d) Rice husk (RHB) Biochar

Table 4. Effect of Biochar on ZPC, Leachate pH and Nitrate Leaching from Soils of Different Textural Classes

Biochar	Clay loam			Loamy			Sandy loam		
	ZPC	lpH	NL	ZPC	lpH	NL	ZPC	lpH	NL
No biochar	5.30[ab]	5.73	11.10	4.40[ab]	5.67[abc]	15.72[abcd]	4.50[bc]	4.80[b]	12.47[abcd]
2.5 tonha^{-1} RHB	6.27[ab]	5.50	6.81	4.37[b]	5.77[abc]	6.12[bcd]	5.13[abc]	5.00[ab]	5.94[cd]
5 tonha^{-1} RHB	5.50[ab]	5.77	10.02	4.03[b]	5.87[abc]	6.83[bcd]	5.43[abc]	5.33[ab]	2.40[d]
7.5 tonha^{-1} RHB	7.73[a]	6.23	21.5	4.23[b]	6.03[abc]	21.42[abc]	5.27[abc]	4.90[ab]	19.61[abcd]
10 tonha^{-1} RHB	6.13[ab]	6.27	11.83	4.33[b]	5.10b[c]	20.00[abcd]	5.23[abc]	5.30[ab]	20.00[abcd]
2.5 tonha^{-1} MCB	4.73[ab]	5.03	8.08	4.40[ab]	4.77[c]	15.85[abcd]	4.20[c]	4.80[b]	13.80[abcd]
5 tonha^{-1} MCB	4.10[b]	4.93	14.46	4.93[ab]	6.00[abc]	13.28[bcd]	4.17[c]	4.90[ab]	32.18[a]
7.5 tonha^{-1} MCB	4.23[b]	6.47	16.32	4.37[b]	6.67[a]	16.83[abcd]	4.43[bc]	4.83[b]	27.53[ab]
10 tonha^{-1} MCB	4.33[b]	6.6	14.48	4.67[ab]	4.97[bc]	15.05[abcd]	4.10[c]	5.23[ab]	15.60[abcd]
2.5 tonha^{-1} CDB	6.27[ab]	6.77	2.31	4.43[ab]	4.73[c]	4.95[cd]	5.33[abc]	4.97[ab]	16.71[abcd]
5 tonha^{-1} CDB	7.28[ab]	6.91	1.27	4.43[ab]	5.40[abc]	10.82[bcd]	6.00[ab]	5.30[ab]	23.74[abcd]
7.5 tonha^{-1} CDB	7.28[ab]	6.08	5.89	4.60[ab]	6.40[ab]	4.48[d]	6.13[a]	6.03[a]	7.12[bcd]
10 tonha^{-1} CDB	6.50[ab]	6.53	3.91	4.40[ab]	5.80[abc]	16.25[abcd]	5.37[abc]	4.93[ab]	19.77[abcd]
2.5 tonha^{-1} PLB	4.83[ab]	5.23	4.84	4.80[ab]	5.17[bc]	30.53[a]	4.30[c]	5.23[ab]	13.61[abcd]
5 tonha^{-1} PLB	5.57[ab]	5.53	3.31	4.90[ab]	5.23[abc]	15.19[abcd]	4.53[abc]	5.27[ab]	26.04[abc]
7.5 tonha^{-1} PLB	4.30[b]	5.9	2.15	4.90[ab]	6.00[abc]	22.19[ab]	4.47[bc]	5.67[ab]	18.45[abcd]
10 tonha^{-1} PLB	5.13[ab]	5.17	15.5	5.37[a]	5.00[bc]	17.75[abcd]	4.40[bc]	4.87[b]	22.42[abcd]
MSD	3.250	2.505	21.789	0.9882	1.4965	16.932	1.6065	1.1571	21.503

lpH: leachate pH; NL: Nitrate leached(%); MSD= Minimum significant difference, means with different letters in the same column are significantly different at 5 %level of probability

Highest nitrate leaching of 30.53 % was recorded by the application of 2.5 tonha^{-1} PLB and was significantly ($P<0.05$) different from the application of 2.5 and 5-ton ha^{-1} RHB, 5-ton ha^{-1} MCB and 2.5-, 5- and 7.5-ton ha^{-1} CDB with 6.12,6.83, 13.28, 4.95,10.82 and 4.48 % respectively. Significantly lower nitrate leaching recorded by these treatments may be due to improved water holding capacity of this soil as a result of their larger surface area (RHB, MCB and CDB). It may also be due to lower bulk density of these biochar materials compared to that of PLB thereby, providing more sites for nitrate adsorption resulting in reduced leaching. Similar results were reported by Kowanga et al. (2016) and Jindo et al. (2014) who obtained higher nitrate retention in biochar with large surface area and associated it to greater adsorption.

Effect of Biochar On Nitrate Leaching from Sandy Loam

There were significant ($P<0.05$) differences among the biochar treatments on ZPC and leachate pH. Highest leachates pH of 6.03 was recorded by the application of 7.5-ton ha^{-1} CDB and was significantly ($P<0.05$) different from 4.80, 4.83, 4.87 and 4.80, recorded by the application of 2.5 and 7.5-ton ha^{-1} MCB, 10-ton ha^{-1} PLB and treatments with no biochar application respectively. However, it was not significantly different from the rest of the treatments (Table 4). Similar to that of leachate pH, significant ($P<0.05$) differences were observed on ZPC among the biochar treatments. Highest ZPC of 6.13 was recorded by the application of 7.5-ton ha^{-1} CDB and was significantly ($P<0.05$) different from the application of all rates of MCB and PLB. However, it was not significantly different from the rest of the treatments.

Significantly higher pH and ZPC recorded by the application of RHB and CDB may be attributed to the high buffering capacity of the biochar samples. This result is in conformity with the findings of Sakurai et al. (1989) who reported a high positive correlation between ZPC and specific surface area. Also, Whalen et al. (2000) reported increased pH of acid soil amended with cattle manure biochar and linked it to buffering from bicarbonates and organic acids from the biochar.

There were ($P<0.05$) significant differences among the biochar treatments on Sandy loam based on nitrate leaching (Table 4). Highest nitrate leaching of 32.18 % was recorded by the application of 5-ton ha^{-1} MCB and was significantly ($P<0.05$) higher than 5.94, 2.40 and 7.12 % recorded by the application of 2.5 and 5-ton ha^{-1} RHB and 7.5 tonha^{-1} CDB respectively. Significantly lower nitrate leaching recorded by these treatments may be attributed to improved nitrate retention due to larger surface area of these biochar materials. Similar results were reported by Kowanga et al. (2016) and Jindo et al. (2014).

Conclusion

Although, no significant differences were observed among the biochar treatments on nitrate leaching from Clay loam, lowest nitrate leaching were observed irrespective of the rate and source of biochar material compared to those of Sandy loam and Loamy soil. Nitrate leaching in soil without biochar application was in the order Loamy > Sandy loam > Clay loam. Application of 2.5, 5-ton ha^{-1} RHB and 7.5 tonha^{-1} CDB can effectively reduce nitrate leaching from Sandy loam. While 2.5, 5, 7.5 tonha^{-1} CDB and 2. 5 and 5 tonha^{-1} RHB reduced nitrate leaching from Loamy soils. Sandy loam should be amended with CDB and RHB to effectively reduce nitrate leaching. While PLB should be avoided to minimize nitrate leaching from Loamy soils.

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