CONTRASTING TILLAGE SYSTEMS AND WOOD ASH EFFECT ON SOIL CHEMICAL PROPERTIES

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ABSTRACT: *The assessment of the impact of tillage and wood ash on soil chemical properties are needed to identify those with the potential to improve soil nutrients. A field trial was conducted in three different cropping years to evaluate the effect of three tillage methods (mound, ridge, flat) and four rates of wood ash (0t/ha, 2t/ha, 4t/ha, 6t/ha) on the soil exchangeable bases, base saturation (BS) and exchangeable acidity (EA). Results from the study showed that the effect of tillage methods (TM) in all the parameters were significant ($P<0.05$) in the 1st year planting season, virtually all were non-significant in the 3rd year planting season. The values obtained from the TM increased in the 2nd year but decreased in the 3rd year cropping season. The values recorded from ridge method was higher compared to mound and flat for all the parameters tested. Wood ash application influenced the exchangeable bases of the soil but the values did not change much throughout the planting period. On the average, exchangeable (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) nutrient output per year varies among the rates and highest was observed in 6t/ha rate of wood ash (WA). WA increased the values of effectivecation exchange capacity (ECEC), base saturation (BS) and decreased the exchangeable acidity (EA) values in treated plots relative to control. The interactionresult of TM and WA were very effective on the tested parameters, values increased as the rates of WA increased. Generally, higher nutrient values were observed more in amended plots than the control plots. From the findings of the present study, it is evident that tillage and wood ash when properly managed with appropriate rates improves the soil nutrient status, decrease soil acidity and optimise soil condition for good crop production.*

KEYWORDS: Base saturation, effective caution exchange capacity,exchangeable acidity, soil exchangeable properties, soil chemical properties

INTRODUCTION

The quality of soil stemmed from the ability of that soil to provide nutrients and promote the growth and yield of crops grown on it. The productivity of a soil is reduced through such soil degradation processes such as erosion and desertification and increased destruction of natural forest due to cultivation of new areas after slash and burn. According to Williams et al. (1990), Nweke (2015), the reduction may manifest as soil constraints such as loss of plant nutrients, loss of storage capacity for plant available water, degradation of soil structure and decreased uniformity of soil conditions within a field. Non-sustainable land use in developing countries, like Nigeria, was the course of low yield

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and widespread poverty. This came as a result of low nutrient contents and accelerated mineralisation of soil organic matter due to intense temperature and rainfall. As consequence, the cation exchange capacity of the soils, which is often low due to their clay mineralogy decreases further. Under such situation the efficiency of applied mineral fertilization is very low when the loss of mobile nutrients such as NO_3 or K from the top soil is enhanced by high rainfall. Additionally, many farmers cannot afford the cost of regular application of mineral fertilizer especially in the case of Nigeria and it has not been sustainable at the farmer's level. In the tropics, the most common form of land use is the shifting cultivation using slash and burn techniques. During burning of the above ground biomass the nutrients are rapidly released into the soil. These nutrients addition have positive effect on soil fertility only for a short period. Application of mulches, composts, organic matter is usually mineralised very rapidly and only a small portion of the soil in the long term but successive released to the atmosphere as CO_2 (Fearnside et al., 1993). Thus, an alternative is the use of more stable compounds that will ensure high level of soil organic matter and available nutrients.

Investigation has shown that wood ash/charcoalcan be used to counteract natural and anthropogenic acidification of soil and loss of nutrients resulting from tree and crop harvesting (Abyhammar et al., 1994; Nweke 2017), so nutrients could be turned into soil by wood ash fertilization. Wood ash and wood charcoal generally has a good acid neutralising capacity and ability to supply the soil with base cations (Na^+, K^+, $Ca^{2+}$and Mg^{2+}). However, the acid neutralising capacity of wood ash or charcoal mainly depends on the content of oxides, hydroxides and carbonates of Ca, Mg and K content of the plant species from which the ash or charcoal were derived. Wood ash also contains various concentrations of readily soluble neutral salts, such as sulphates and chlorides of K and Na (Eriksson, 1998). Decreased acidity and increased nutrients availability and base saturation have equally been reported following wood ash/charcoal application in agricultural soils (Abyhammar et al., 1994; Branryd and Fransman 1995; Eriksson 1998; Nweke 2017). Wood ash is an important soil amendment that often increases pH and the availability of K, P,Ca and Mg depending on the ash composition. As pH is raised by addition of wood ash, the net negative charge on soil surface is increased and the ratio of negative to positive charges also increases. Soils in south-eastern Nigeria are poor in their native availability of nutrients as the application may help in coping with low nutrient levels in the soil (Nwite et al., 2011). Nutrient management should be offered greater attention in order to obtain appreciable returns. Tillage systems have also been found to influence the exchangeable properties. Researchers have shown increases in CEC in the surface soils of no-till systems compared with conventional tillage due to increased soil organic carbon (Jaiyoba, 2003; Ciotta et al., 2003).Therefore, the essence of this research is to evaluate the effect of tillage and wood ash on the chemical properties of the soil.

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MATERIALS AND METHODS

Location of experiment

This study was carried out in three different cropping seasons at Teaching and Research Farm of Soil Science and Environmental Management, Ebonyi State University, Abakaliki. The area of the study is located within latitude 06^o19^1 N and Longitude 08^o06^1 of the southeast agro-ecological zone of Nigeria. The rainfall distribution is bimodal with wet season from April to July and peak in June and September to November. It has an average annual rainfall range of 1700 – 1800mm. The temperature of the area ranges from 27^oC – 31^oC. The relative humidity of the area is between 60 – 80% and the soil is ultisol, classified as TypicHaplustult by FDALR (1985). The vegetation of the area is dominated by *Andropogongayamus, Panicum maximum, Pennisetumpurpurem,* shrubs and some other weed species.

Land preparation and treatment application

A land area measuring 41m x 15m (0.0615ha) was mapped out and used for the study. The experimental site was cleared of the natural vegetation using cutlass and the debris removed. Tillage operation was done manually using hoe. The tillage treatments are mound (Md), Ridge (Rd) and Flat (Ft). Wood ash of different levels was spread uniformly on the soil surface and buried in their respective plots immediately after cultivation.

Two castor seeds per hole were planted at a spacing of 0.9m between rows and 0.45m within rows at a depth of 8cm. There was basal application of NPK fertilizer to all plots two weeks after plant. The seedlings were thinned down to one plant per stand two weeks after germination. Weeding was done manually with hoe at 3-week intervals till harvest. Harvesting was done when the capsules containing the seed turn brown. The harvested spikes was dried in the sun 2-3 days and then threshed to release the seeds. The same procedure was repeated in the second and third year of the experiment but without application of wood ash in the third year to test the residual effect.

Experimental Design

The total land area used for the study was 41m x 15m (0.0615ha). The experiment was laid out as split plot in a randomized complete block design (RCBD), with 12 treatments replicated 3 times to give a total of 36 plots each measuring 3m x 4m ($12m^2$). A plot was separated by 0.5m alley and each replicate was 1m apart. Four (4) rates of wood ash viz., control (Ot/ha); wood ash (WA) at the rate of 2t/ha equivalent to 2.4kg/plot, WA at 4t/ha equivalent to 4.8kg/plot and WA at 6t/ha equivalent to 7.2kg/plot were used for the study. Each treatment was replicated 3 times along with the three tillage methods (Mound, Ridge and Flat) used for the study.

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Soil Sample Collection

Auger soil samples were randomly taken from ten (10) observational points in the experimental area at the depth of 0 – 20cm prior to planting. The Auger soil samples were mixed thoroughly to form a composite soil sample and used for pre-planting soil analysis of which the result is shown in Table I. Also the wood ash treatment used was analyzed for determination of its nutrient values, quantity and chemical composition. The result is presented in Table 2. At the end of each cropping year that is after crop harvest auger soil samples were collected from three observational points in each plot, the soil samples were air dried, sieved and used for chemical analysis

Laboratorymethods

Chemical properties

The soil sample collected for chemical analysis was air dried and sieved with 2mm sieve and used for chemical properties determination

Exchangeable bases: Cations were determined by the method described by Thomas (1982).

Exchangeable acidity (EA): The EA was determined by the titrimetric method of Mclean (1982).

Effective cationexchange capacity (ECEC)

The humid tropical soils are predominantly variable charges, which simple means pH dependent charge, which indicate that there cation exchange capacity (CEC) vary with soil pH and the soil variable colloids are necessitated by the presence of iron (Fe) and aluminum (Al) oxides. The reason is that for soils dominating in variable charges the ECEC measured will give more realistic CEC values of such soils especially with the strongly weathered soils like the utilisol.

ECEC was determined by the summation method

ie ECEC = TEB + TEA

Where ECEC = Effective cation exchange capacity

TEB = Total exchangeable bases (CEC or Ca, Mg, k,Na)

TEA = Total exchangeable acidity (H^{+}+ Al^{3+})

Base saturation

Base saturation was estimated from the values of exchangeable base (TEB) and cation exchange capacity value.

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$$\% \text{ Base saturation (BS)} = \frac{TEB}{ECEC} \times \frac{100}{1}$$

Data Analysis

The data generated were subjected to an analysis of variance test based on RCBD using Crop Stat software version of 7.2, while statistically significant difference among treatment means was estimated using the least significant difference (LSD = 0.05).

Results

Properties of soil and wood ash before the beginning of the study

The soil contains low level of major nutrient elements (Table 1). Hence the soil of the experimental site is considered poor in these essential plant nutrient elements. The properties of wood ash before application show higher concentrations of nutrients in the ash (Table 2). The recorded values of exchangeable bases (Ca, Mg, K and Na) were 48.80cmolkg^{-1} (Ca), 9.60cmolkg^{-1} (Mg), 0.286cmolkg^{-1} (K) and 0378cmolkg^{-1} for Na respectively. Thus the ash is very rich in most of the major plant chemical elements.The high content of Ca and Mg is a good attribute as Ca is a component of calcium pectate that give plant cell wall stiffness and it influence the assimilation of phosphorous and some major micronutrients. Therefore it is expected that the studied soil will benefit immensely from ash application

Table 1: Initial soil parameters before treatment application

Test Parameter	Value
Ca^{2+}	2.80cmolkg^{-1}
Ng^{2+}	1.60cmolkg^{-1}
K^{+}	0.072cmolkg^{-1}
Na^{+}	0.127cmolkg^{-1}
EA	0.56cmolkg^{-1}
ECEC	5.159cmolkg^{-1}
Base saturation (BS)	89%

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Table 2: Chemical composition of the wood ash before application

Test Parameter	Value
Ca^{2+}	48.80cmolkg^{-1}
Mg^{2+}	9.60cmolkg^{-1}
K^{+}	0.286cmolkg^{-1}
Na^{+}	0.378cmolkg^{-1}

Effect of Tillage and Wood ash on Soil Exchangeable Bases (Ca, Mg, K and Na)

The result of the exchangeable bases in Table 3 indicated significant differences among the tillage methods for the parameters except for Mg in 2nd year and Ca in 3rd year planting periods. The result of the Mound showed that Ca increased as the year of planting increased that is 1st year value < 2nd year value < 3rd year values. In Ridge for this particular parameter the result showed 2nd year value > 3rd year value > 1st year value, while the values of Ca obtained from Flat indicated an increased value as the years of planting period increased, hence 1st year value < 2nd year value < 3rd year value. The Mg result of the Mound showed that highest value was obtained from 2nd year planting period and the decrease in value of the parameter in residual year relative to the 2nd year planting was 7.58%. The Ridge result of Mg indicated an increase in value as the year of planting increased to 2 years but decreased in the 3rd year planting period of which the percentage decrease in value relative to 1st and 2nd year results were 15.38% and 21.43%. The Flat result showed increased value with order 3rd year > 2nd year > 1st year. In comparison of the TM and years of the study with regard to the values of Ca and Mg the 1st year result presented a scenario of Mound > Ridge > Flat (for Ca and Mg). The scenario was the same for Mg result in 2nd year, but for the Ca result a different order was obtained whereby Ridge > Mound > Flat. The 3rd year result for Ca showed Ridge > Flat > Mound, while Mg result of 3rd year indicated Flat > Mound > Ridge.

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Table 3 Effect of Tillage and Wood ash on Soil Exchangeable Bases (Ca, Mg, K, and Na)

Treatment	1st Year				2nd Year				3rd Year			
	Ca	Mg cmolkg^{-1}	K	Na	Ca	Mg cmolkg^{-1}	K	Na	Ca	Mg cmolkg^{-1}	K	Na
Mdo	3.200	1.600	0.102	0.277	2.800	0.800	0.094	0.193	7.600	2.200	0.065	0.262
Md2	6.000	3.600	0.251	0.356	9.200	2.000	0.143	0.308	8.000	2.800	0.085	0.240
Md4	8.000	3.200	0.228	0.347	8.000	5.600	0.107	0.387	10.000	5.600	0.088	0.258
Md6	12.400	4.400	0.540	0.255	12.400	4.800	0.260	0.286	7.200	1.600	0.083	0.256
Mean	7.400	3.200	0.280	0.309	8.100	3.300	0.151	0.294	8.200	3.050	0.083	0.253
Rdo	4.000	1.600	0.097	0.281	2.800	2.000	0.130	0.246	8.000	2.400	0.053	0.227
Rd2	3.600	2.000	0.094	0.228	4.000	1.600	0.163	0.335	6.000	2.000	0.083	0.253
Rd4	9.600	4.800	0.256	0.268	12.000	4.000	0.163	0.440	8.000	2.400	0.070	0.262
Rd6	11.200	2.000	0.251	0.286	16.200	3.600	0.284	0.482	12.000	2.000	0.108	0.245
Mean	7.100	2.600	0.175	0.266	8.750	2.800	0.185	0.376	8.500	2.200	0.079	0.247
Fto	2.800	0.800	0.028	0.290	2.000	0.800	0.110	0.277	8.000	2.000	0.250	0.270
Ft2	4.000	3.200	0.148	0.320	5.200	2.000	0.153	0.294	6.800	2.000	0.078	0.245
Ft4	4.000	2.400	0.163	0.264	5.600	2.800	0.161	0.281	8.400	4.600	0.088	0.249
Ft6	5.600	1.600	0.161	0.237	16.030	4.800	0.256	0.325	10.000	4.400	0.098	0.262
Mean	4.100	2.000	0.150	0.279	7.208	2.600	0.170	0.294	8.300	3.250	0.129	0.257

LSD 0.05

TM 2.47 0.94 0.09 0.03 0.22 NS NS 0.06 NS 1.0 0 0.04 0.01

WA 2.10 0.90 0.09 0.04 2.0 0.77 0.02 0.06 1.36 0.96 0.05 0.01

TM x WA 1.16 0.11 0.01 0.01 0.54 0.53 0.01 0.004 1.38 0.23 0.01 0.01

Mdo = Mound without wood ash (WA); Md2 =Mound +2t/ha WA; Md4 = Mound + 4t/ha WA; Md6 = Mound + 6t/ha WA; Rdo = Ridge without WA ; Rd2 = Ridge +2t/ha WA; Rd4 = Ridge + 4t/ha WA; Rd6 = Ridge + 6t/ha WA; Fto = Flat without WA; Ft2 = Flat + 2t/ha WA; Ft4 = Flat +4t/ha WA; Ft6 = Flat + 6t/ha WA

The result of K and Na obtained from Mound method indicated decrease in value as the year of planting period increased to 3years. The result indicated that the lowest value of K and Na was observed in residual year, that is 1st year values > 2nd year value > 3rd year values. The result of the Ridge showed that the lowest value of K and Na was obtained from 3rd year planting result. The

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decrease in value of the two parameters in 3rd year planting relative to the 2nd year planting result that was of the highest value were 57.297% and 34.31% respectively for K and Na. The value of K and Na for Flat increased in the 2nd year planting, but decreased in value in the residual year. When the values of K and Na obtained are compared among the tillage methods and years of study it showed that the 1st year planting result for K, Mound > Ridge > Flat, for Na Mound > Flat > Ridge the 2nd year result indicated that Ridge > Flat > Mound with respect to K value while Mound and Flat yield the same value of Na with an increased value in Ridge.The 3rd year result presented an order of Ridge < Mound < Flat for the value of K, while Na result showed that the value of Flat > Mound > Ridge.

The result of the rates of WA (Table 3) showed statistical significant difference on the parameters assessed. The rates of WA on Mound showed that the value of Ca increased with an increase in the quantity of ash applied in the 1st year planting result. The 2nd year result showed that highest value of Ca was obtained from Md6 and the least from Md0. The 1st and 2nd year result showed that Md6 constantly gave the highest Ca value. In the residual year the order of result was Md4> Md2> Md0>Md6. The result of Mg did not follow any particular order of increase. The 1st year result showed an increased value in Md6 with attendant decrease in Md0, while the 2nd year result showed that the highest value of Mg was obtained in Md4 of which its percentage decrease in Md0 was 85.71%. The 3rd year result indicated an increased value in Md4 with least value in Md6. The result of the values of K and Na in 1st year planting showed an order of Md6> Md2> Md4> Md0 and Md2> Md4 > Md0 > Md6 respectively. The 2nd year result showed that the least values of K and Na was observed in Md0 with higher values recorded in Md6 (K) and Md4 (Na). The 3rd year result showed that K value increased as the rate of WA applied increased, but decreased value was observed in Md6. The decreased value was however, significantly different from the value of K obtained from Md0. While the result of Na indicated higher value in Md0 with least value in Md2.

The rates of WA on Ridge for the 1st planting year result showed that the value of Ca is dependent on the quantity of ash applied this were equally true for the 2nd year result. The 3rd year however showed a contrary result, though the Rd6 constantly showed higher values for the Ca result. The result of Mg in the years studied did not present any particular order. It showed non-dependency of the value obtained on the quantity of ash applied. The 1st year presents an order whereby Rd6 and Rd2 are of the same value. 2nd year result showed Rd4 > Rd6> Rd0 > Rd2 and 3rd year, the Rd6 and Rd2 as well as Rd4 and Rd0 gave the same value of Mg respectively. The result of K in 1st planting indicated decrease in value as the rate of WA increased, while Rd6 showed higher value of Na, with least value obtained from Rd2. The 2nd year result showed that the value of K increased as the rate of WA increased, with Rd4 and Rd2 given the same value of K while Na result showed an order of Rd6> Rd4> Rd2> Rd0 indicating that the value of Na is dependent on the quantity of WA applied. The residual year result for K and Na showed decreased value in all the rates of WA relative to the 1st and 2nd year results. The order of the result for 3rd year were Rd6> Rd2> Rd4> Rd0 for K and Rd4> Rd2> Rd6> Rd0 for Na respectively. The rates of WA on Flat for the 1st year result indicated that Ft2 and Ft4 yield the same value of Ca with highest value from Ft6. For the 2nd and 3rd years result the value of Ca was dependent on the quantity of WA applied as the result indicated increase in value as the rates of WA increased. The Ft6 for the 3 years study constantly gave the highest Ca value. The result of Mg in 1^{st} year did not show any particular order, but higher value was obtained in Ft2. However, in 2^{nd} year result, the value of Mg showed dependent on the rates of WA application as the order was Ft6> Ft4> Ft2> Ft0. The 3^{rd} year indicated that higher value of Mg was obtained from Ft4, while Ft2 and Ft0 gave the same value of Mg. The result of K showed an increased value with attendant increase in rates of WA, though decreased value was observed in Ft6 that was statistically significant different from the value in Ft0. While Na showed higher value in Ft2 next in rank was Ft0 compared to the other rates. The 2^{nd} year result present an order of Ft6> Ft4> Ft2>Ft0 for K indicating dependence on the quantity of ash applied and Na an order of Ft6> Ft2> Ft4> Ft0. The 3^{rd} year result showed a decreased value in all the rates except for Ft0 compared to the values obtained from the rates of 1^{st} and 2^{nd} year results. However, the value of K presents an order of Ft2< Ft4< Ft6< Ft0 and Na Ft2< Ft4< Ft6< Ft0.

The effect of tillage and wood ash was very much effective as the results showed significant differences on the parameters tested. In most of the results the value obtained increased as the rate of WA application increased. The exchangeable bases of the amended soil were highly influenced by the WA application and were found not to have changed much throughout the planting periods (Table 3).

Effect of Tillage and Wood ash on Soil Exchangeable Acidity (EA), Effective Cation Exchange Capacity (ECEC) and Base Saturation (BS)

The effect of tillage methods was not effective on the parameters tested except for the 1^{st} year result (Table 4). The exchangeable acidity (EA) result obtained from the Mound indicated decrease in value as the years of planting increased to 3 years hence 1^{st} year value > 2^{nd} year value > 3^{rd} year value. The percentage decrease in the value of EA in 3^{rd} year relative to the 1^{st} year value was 28.57%. The result of ECEC showed that the 2^{nd} year result was of the highest value when compared to the result of 1^{st} year and 3^{rd} years. The next in rank was the result from 3^{rd} year planting of which the percentage difference from 1^{st} year planting result was 31.6%. The percentage base saturation (BS) result of Mound indicated increased value in the 3^{rd} year planting result compared to the 1^{st} and 2^{nd} year planting results, hence the order 3^{rd} year value > 1^{st} year value > 2^{nd} year value. The result variation showed that the least value of BS was obtained from the 2^{nd} year, though the percentage difference from 3^{rd} year result was merely 1.5%.The result obtained from the Ridge for EA indicated an increase in value in the 2^{nd}year planting result, hence the order 2^{nd} year value > 3^{rd} year value > 1^{st} year value. The ECEC result showed an increased value in the 2^{nd} year result but decreased in the 3^{rd} year result, though the decreased value was greater than the value of ECEC obtained from the 1^{st} year result. The BS result of the Ridge in 2^{nd} year showed decrease in value relative to 1^{st} and 3^{rd} year result, while the 1^{st} and 3^{rd} year planting gave the same value of BS. The result of the exchangeable properties from Flat indicated a decrease in value of EA as the years of planting increased though the 2^{nd} and 3^{rd} year

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planting gave the same value of EA. The ECEC result indicated the value increased with attendant increase in the years of planting hence the order 1st year < 2ndyear < 3rd year result. The same scenario of result variation applies to the result of BS % with an order of 1st year < 2nd< 3rd year result. In comparison of the TM and years of planting with regard to each of the parameter showed that for EA, in 1st year result, the value of EA obtained from Flat was highest compared to Mound and Ridge, while the next in rank was Mound. The value from Ridge was low as its percentage decrease in value relative to the value from Flat was 56.25%. The 2nd year result presented a contrary result of Mound > Ridge > Flat, this order was equally the same for 3rd year result. This simply means that for the 3 years' study that for EA result Mound maintained the highest value of EA in 2nd and 3rd year planting period. The result of ECEC showed that in 1st year planting, the highest value was obtained from Mound relative to that of Ridge which is next in rank and Flat value that was the least. The percentage decrease in value of Flat relative to the Mound value was 40.28%. The Table 4 indicated that 2nd year result showed an order of Ridge > Mound > Flat, while the 3rd year result indicated an increased value in Flat > Mound > Ridge. The 1st year result of BS showed an order of Ridge > Mound > Flat. The 2nd year result showed that Mound and Flat gave the same value of BS with the value from Ridge being the highest (97.25%). In 3rd year planting result, it was observed that the same value of BS was obtained from Mound and Ridge, with the Flat value being the highest though the percentage difference from Mound and Ridge value was merely 0.25%.

The effect of wood ash application was very much effective as the result indicated statistical significant differences on the parameters and the years of study (Table 4). Its effect on Mound for the result of EA showed that in 1st year planting, higher value was obtained from Md0, next in rank was Md2, while the least value was obtained in Md4. The 2nd year result still present the Md0 as the highest value, but with an order of Md0> Md6> Md4 > Md2. The 3rd year result indicated that Md0 and Md6 as well as Md2 and Md4 gave the same value of EA respectively. The result of ECEC in 1st year and 2nd year planting indicated increase in value as the rate of WA application increased. The Md6 constantly gave the highest value of ECEC in the 1st and 2nd year result with the least value obtained from Md0. The result of the 3rd year showed an increased value in the Md4, the next in rank was Md2. The Md6 value indicated decrease in value of which the percentage decrease relative to Md4 value was 41.79%. The BS result in 1st year planting showed an increased value with attendant increase in the quantity of ash applied, though the value obtained in Md4 and Md6 are the same. The 2nd and 3rd year results present the same scenario as the values increased with increase in amount of ash applied, though it was observed that for the 2nd and 3rd year result, Md4 and Md2 gave the same value of BS.

The ash application on Ridge showed that Rd0 and Rd4 rates gave the same value of EA in 1st year result with the highest value in Rd6. The 2nd year result indicated highest value in Rd0 with least value in Rd2, while the value in Rd4 and Rd6 are the same. The EA value of Rd0 in 2nd and 3rd year results are the same (0.320 cmolkg^{-1}), this value in 3rd year result was the highest when compared with the same values of the other rates. The Rd2 and Rd6 gave the same value of EA. The ECEC result showed increased values in Rd4 and Rd6 for the 1st, 2nd and 3rd years results compared to the results obtained from Rd2 and Rd0 rates. The Rd4 showed the highest value of ECEC in 1st year result but Rd6 constantly maintained the highest value of ECEC in 2nd and 3rd results. The result of BS for the 3 years study did not practically change much except for the Rd0 values.

The effect of WA on Flat showed that the result variation of EA for the 3 years study are virtually the same except for a kind of alternation in value in rates and year of study. For example, the 2nd and 3rd year result showed that Ft2 and Ft6 (2nd year) and Ft2 and Ft4 as well as Ft0 and Ft6 (3rd year) respectively gave the same value of EA. While in the 1st year result the EA value showed decrease in value as rates of ash applied increased. The ECEC showed an order of Ft2> Ft6> Ft4> Ft0 in 1st year planting result while the 2nd year result was dependent on the rates of WA applied as the result value increased with attendant increase in the rates of WA. The 3rd year result of ECEC showed an order of Ft6 > Ft4> Ft0> Ft2. This indicated that higher value was obtained in Ft6 and least value in Ft2. For the 3 years' of study, the Ft6 constantly gave the highest value of ECEC relative to the other rates of WA studied. The result of WA on Flat for the BS value for the 3 years of the study did not change much on the rates. For example, the Ft2 value in 2nd and 3rd year results are the same. The 1st year planting result depicted Ft4 with highest value of BS next in rank was Ft6 and least value was obtained in Ft0. The 2nd year result showed an increased value in Ft2 and Ft6 which of course were the highest value compared to Ft4 and Ft0 rates. The 3rd year result showed that the value of BS in Ft2 and Ft4, Ft0 and Ft6 are of the same value respectively.

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Table 4 Effect of Tillage and Wood ash on Soil EA, ECEC and BS
LSD 0.05

Treatment	**1st Year**			**2nd Year**			**3rd Year**		
	EA cmolkg^{1}	**ECEC cmolkg^{1}**	**BS %**	**EA cmolkg^{1}**	**ECEC cmolkg^{1}**	**BS %**	**EA cmolkg^{1}**	**ECEC cmolkg^{1}**	**BS %**
Mdo	0.400	5.579	93.00	0.500	4.287	91.00	0.240	10.372	98.00
Md2	0.320	10.527	97.00	0.080	11.731	99.00	0.160	11.285	99.00
Md4	0.160	11.935	99.00	0.160	14.254	99.00	0.160	16.106	99.00
Md6	0.240	17.835	99.00	0.320	18.066	98.00	0.240	9.376	97.00
Mean	0.280	11.469	97.00	0.265	12.085	96.75	0.200	11.785	98.25
Rdo	0.080	6.058	99.00	0.320	5.496	94.00	0.320	11.000	97.00
Rd2	0.160	4.082	97.00	0.160	6.257	97.00	0.160	8.496	98.00
Rd4	0.080	15.004	99.00	0.240	16.843	99.00	0.080	10.812	99.00
Rd6	0.240	13.977	98.00	0.240	20.806	99.00	0.160	14.513	99.00
Mean	0.140	10.280	98.25	0.240	12.351	97.25	0.180	11.205	98.25
Fto	0.800	4.818	83.00	0.320	3.507	91.00	0.240	10.760	98.00
Ft2	0.240	7.913		0.080	7.727		0.080	9.203	
Ft4	0.080	6.907		0.160	9.002		0.080	13.417	

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Ft6	0.160	7.758	97.00 99.00 98.00	0.080	21.461	99.00 98.00 99.00	0.240	15.000	99.00 99.00 98.00
Mean	0.320	6.849	94.25	0.160	10.424	96.75	0.160	12.095	98.50
TM	0.15	3.11	3.64	NS	NS	NS	NS	NS	NS
WA	0.16	2.88	3.54	0.09	2.21	1.13	0.04	1.84	0.87
TM x WA	0.07	0.01	2.18	0.13	0.01	1.29	0.02	0.69	1.38

Mdo = Mound without wood ash (WA); Md2 =Mound +2t/ha WA; Md4 = Mound + 4t/ha WA; Md6 = Mound + 6t/ha WA; Rdo = Ridge without WA ; Rd2 = Ridge +2t/ha WA; Rd4 = Ridge + 4t/ha WA; Rd6 = Ridge + 6t/ha WA; Fto = Flat without WA; Ft2 = Flat + 2t/ha WA; Ft4 = Flat + 4t/ha WA; Ft6 = Flat + 6t/ha WA

The effect of tillage methods and wood ash (TM x WA) on the soil exchangeable properties indicated significant ($P<0.05$) differences among the parameters assessed which showed that effect of tillage and wood ash were very effective on the nutrients tested. Their values increased as the rate of WA applied increased and as the planting years increased in some parameters. The amended soils were found to be higher in values compared to control soils except for EA values. The values of the rates of WA on Mound were found to be higher compared to its values on Ridge and Flat of which the order can relatively be put as Mound > Ridge > Flat. This result however, is basically true for some parameters especially the ECEC result.

DISCUSSION

Initial properties of soil and wood ash before the study

The values of exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) were generally low, indicating that the soils of experimental site are poor and deficient in the essential plant nutrient elements. The low values might probably be due to agricultural activities taken place in the study area over the years or leaching activities. The soil exchange complex was dominated by calcium (2.8cmolkg^{-1}) and magnesium (1.60cmolkg^{-1}). The exchangeable acidity (EA) and effective cation exchange capacity (ECEC) was 0.56cmolkg^{-1} and 5.159cmolkg^{-1} respectively and they are rated low according to Landon (1991). The percentage base saturation (BS) of the soil was high with a value of 89% (FDALR 1990), the high

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base saturation suggested their dominance in the absorption complex. The low levels of exchangeable bases indicated that the soil of the study area is of low base status and suggest soil amendment to provide the deficit between the inherent basic nutrient status and the amount removed by the crops and leaching losses for good crop performance and yield. Since most of the parameters are at their lowest levels it is expected that both the soil and test crop will benefit from wood ash application in the long term. Since manure is known to influence soil parameters positively. Tillage improved soil productivity and crop yield with time especially when tillage is combined with soil amendments (Klaji and Hoogmoed 1993). The implication of Table 1 results therefore is that appropriate soil amendment should be practised to realise optimum production capacity of the soil.

Soil ChemicalProperties

Significant differences in soil exchangeable bases (Ca, Mg K and Na) assessed in this 3 years' study were observed among the tillage methods. Their values increased in the entire TM as the year of planting increased. Mound was observed to show higher values in these parameters in the 1st planting while Ridge took the lead in the 2nd year planting. Their 3rd year result indicated Ridge to be only higher in Ca,while Mound show higher values in all other parameters. Flat however showed least results compared with Mound and Flat in all these parameters. The result of the exchangeable properties (EA, ECEC and BS) indicated non-significant ($P<0.05$) differences among the tillage methods except for their 1st year planting result. The parameters varied for the 3 years of study as follows; EA lowest in Mound, ECEC highest in Mound and BS highest in Ridge for the 1st year study. The 2nd year study showed EA to be lowest in Flat, Ridge was highest in ECEC and BS. The 3rd year result however showed Flat to be highest in ECEC and lowest in EA values, while BS values showed non-variation among the tillage methods except for Flat result. Jaiyeoba (2003) and Ciotta*et al*. (2003) observed increases in CEC in the surface soils of no-till systems compared with conventional tillage due to increase in soil OC. While Bouman*et al*. (1995) reported decrease in exchangeable bases (Ca, Mg, K, Na) in soil not receiving treatment as a result of acidification. This often according to Singer and Mums (1999) is due to removal of exchangeable bases from the exchange sites on clay and organic matter by H and Al. Hence, differences in acidification (EA) between the tillage methods can also result in differences in exchangeable bases as was obtained from the study. The change in the values of EA and to some extent other chemical properties among the tillage methods may probable be linked to wood ash application. The nature of the result of the tillage methods with regard to the chemical nutrients obtained may be associated to the environmental condition, type of soil and intensity of the tillage system that might have been done on the soil previously and those acting together with the type of crop species, soil properties and their complex interactions, according to Ishaq*et al*. (2002), might have influenced the nature of results obtained. Strudley*et al*. (2008) observed that the depth and intensity of tillage methods affect the soil chemical properties that affect plant growth and yield. This probable may be the reason why the results of the soil chemical properties obtained from Mound and Ridge differed much from that of Flat.

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The exchangeable bases of the amended soil were highly influenced by the WA application and were found not to have changed much throughout the planting periods irrespective of the TM the WA was applied. The obtained values of the parameters (Table 3 and 4) across the rates and TM the ash was applied were relatively similar except for WA on Ridge were Rd4 and Rd6 show much higher values in Ca and ECEC compared to the other rates on Mound and Flat.The observed improvement in these tested parameters in amended soil could be attributed to the higher content of the nutrients in the WA applied as well as the synergistic relationship between the parameters and soil pH. The liming effect of wood ash creates a more favourable pH in that studies by the following authors: Owolabi*et al*. (2003), Odedina*et al*. (2003) and Awodon*et al*. (2007), showed increased soil nutrient content following plant derived ash application. Mbah*et al*. (2010) reported that applied wood ash reduced soil acidity to levels required by the maize production. The result of EA, ECEC and BS presented in Table 4 showed that WA significantly ($P<0.05$) increased the values of ECEC, BS and decreased EA in treated plots relative to control plots thus indicating much acidity level in control plots than the treated plots. The result is a good attribute for nutrient release and absorption for crop plant and the result obtained was in line with the findings of Adeleye*et al*. (2010). Also, the work of Nottidge*et al*. (2006) reported high ECEC value in wood ash amended soil compared to non-amended soil.

The effect of tillage and wood ash result also showed that higher nutrient values were obtained more on WA treated plots compared to where WA were not applied. In most of the parameters assessed it was observed that values obtained increased as the rate of WA application increased.Chemical properties provide an adequate environment and sufficient nutrients to the organism for optimal biological activity which in turn improves the soil chemical properties through improved soil structure and nutrient cycling that invariably transformed to increased yield observed in the study.

CONCLUSION

Results of this study show that soil optimisation through tillage and wood ash application together could improve soil nutrient status. The exchangeable nutrients output per season varied among the rates and there was increase in the values of ECEC, BS and a decrease in EA of the amended plots relative to control plots. The interaction of TM and WA was found to be effective, which portray that the combination of tillage and wood ash amendment in crop production experiments will perform better than either when used alone. Thus wood ash at the rates and tillage methods studied could be used as soil amendment to improve soil nutrient status.

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