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Soil pH, available P of an ultisol and castor performance as influenced by contrasting tillage methods and wood ash

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The effect of tillage methods and rates of wood ash on soil chemical properties and castor bean plant performance was studied in field trial at Abakaliki in three planting seasons. The experiment was a split plot in randomized complete block design with three tillage methods (mound, ridge, flat) and four rates of wood ash (0, 2t, 4 and 6 tha^{-1}) replicated three times. Crop start version 7.2 was used to analyze data collected and mean separation was done using least significant difference (LSD) at 5% alpha level. The results of soil pH and available P showed that tillage method (TM) increased the values of the nutrients in 2nd year, but decreased in the 3rd year planting. The values of these parameters observed in Ridge method was found to be higher when compared to the values of Mound and Flat except for the result of available P in 1st and 3rd year planting periods. The wood ash (WA) amendment was found to change the soil from slightly acidic in 1st year to alkaline in 2nd year to slightly acidic in 3rd year. The control soil remained acidic throughout the three years of study. The available P obtained from Rd6 consistently gave the highest values among the TM and rates of WA. Tillage methods had no effect on leaf area index (LAI) at 50 days after planting (DAP) and 100 DAP in 1st and 2nd year planting periods, but had significant effect on the parameters in 3rd year planting season. Flat showed highest plant height in 1st and 2nd years but decreased in the 3rd year. While the least value in plant height for the 3 years' of study was recorded in Mound. The findings from this study has clearly shown that soil application of wood ash and tillage practices has the potential to cause positive and useful changes in the fertility and productivity status of the soil by improving the soil properties and yield component of castor.

Key words: Ash, available P, castor plant, leaf area, plant height, soil reaction, tillage.

INTRODUCTION

A stepwise increase in agricultural production across the globe is necessary in order to ensure the food supply for an increasing world population. As a result fallow periods are often reduced, shifting cultivation in the tropics

leading to irreversible soil degradation and increased destruction of remaining natural forest due to cultivation of new area after slash and burn (Sanders et al, 1996; Woodruff, 2009). In most tropical environment, sustainable agriculture faces large constraints due to low nutrient content and accelerated mineralization of soil organic matter as a result of temperature and rainfall (Nweke, 2015). Soil fertility decline can as well occur through leaching, soil erosion and crop harvesting (Donova and Cassey, 1998). This trend that is fertility decline may be continuously experienced in tropical soil like Nigeria, unless the soil fertility status are replenished through the organic wastes, mineral fertilizer or through crop residues or rebuilt more comprehensively through traditional fallow systems that allow restoration of soil nutrients and reconstruction of soil organic matter, though this is not fully in practice due to increasing demand for land as a result of population increase (Akanbi et al., 2010; Nweke and Nnabude, 2014). Attempt have been made to improve soil properties of tropical soils of Nigeria through soil management practices such as tillage and incorporation of organic wastes, though the effectiveness of these wastes depend on the soil characteristic on which the waste will be applied.

Wood ash when used in agricultural soils has the potential to counteract the natural loss and loss of nutrients from crop harvesting. Its activities have been found to improve soil characteristics and crop performance. Agricultural fields need to be maintained as near as possible to neutral pH during cultivation and manure amendments applied to the top soil for immediate effect over short and long term periods. Wood ash has this capability as it has good acid neutralizing capacity and ability to supply the soil with basic cations; an ideal for tropical soils that are highly weathered and often classified as acidic or leached soils. Wood ash according to Eriksson (1998) contains in addition various concentrations of readily soluble neutral salts, such as sulphate and chlorides of Na and K. All these combined will create positive impact on the soil productivity and crop performance. Decreased acidity and increased base saturation and microbial activity have also been reported following wood ash application on agricultural soils (Bramryd and Fransman, 1995; Eriksson, 1998).

Soil structural modification through tillage is aimed at optimizing soil condition for seed germination seedling emergence and growth. Hence any good tillage method should therefore provide soil tilt, improve soil water infiltration and retention, reduce weed competition, minimize soil erosion, control infestation of pests, and encourage biological activities of soil micro-organism and recycle soil organic matter. Soil chemical indicators such as soil pH, available P, organic matter (OM), total nitrogen (TN), organic carbon (OC) etc are influenced by soil management practices such as tillage, organic waste application and cropping. In many ecological zones and on different soil types, crop response to tillage and indeed the economic viability of tillage systems are still subject of investigation (Aluko and Lasisi, 2009; Agbede, 2010). Thus the essence of this study was to evaluate the effect of contrasting tillage methods and wood ash on soil pH, available P and castor bean plant performance.

MATERIALS AND METHODS

Location of experiment

This study was carried out in three years cropping seasons at Teaching and Research Farm of Faculty of Agriculture and National Resources Management (FARM), Ebonyi State University, Abakaliki. The area of the study is located within latitude $06^{o}19^{1}$N and Longitude $08^{o}06^{1}$E of the southeast in the derived savannah 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 annual rainfall range of 1700 to 1800 mm. The temperature of the area ranges from 27 to 31°C. The relative humidity of the study area is between 60 and 80%. The soil is Ultisol and classified as Typic Haplustult by FDALR (1985).

Land preparation and treatment application

A land area measuring 41 m × 15 m (0.0615 ha) 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 treatments are mound (Md), ridge (Rd) and flat (Ft), wood ash of different levels 0, 2, 4 and 6 t/ha was spread uniformly on the soil surface and buried in their respective plots immediately after cultivation. The details of treatments used are as follows:

1. Mound without wood ash (Md0)
2. Ridge without wood ash (Rd0)
3. Flat without wood ash (Ft0)
4. Md + 2 t/ha of wood ash (Md2)
5. Md + 4 t/ha of wood ash (Md4)
6. Md + 6t/ha of wood ash (Md6)
7. Rd + 2t/ha of wood ash (Rd2)
8. Rd + 4t/ha of wood ash (Rd4)
9. Rd + 6t/ha of wood ash (Rd6)
10. Ft + 2t/ha of wood ash (Ft2)
11. Ft + 4t/ha of wood ash (Ft4)
12. Ft + 6t/ha of wood ash (Ft6)

Two castor seeds per hole were planted at a spacing of 0.9 m between rows and 0.45 m within rows at a depth of 8 cm. 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. The same procedure was repeated in

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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 41 m × 15 m (0.0615 ha). 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 plot measuring 3 m × 4 m (12 m^2). A plot was separated by 0.5 m alley and each replicate was 1m apart. Four (4) rates of wood ash viz., control (0t/ha); wood ash (WA) at the rate of 2 t/ha equivalent to 2.4 kg/plot, WA at 4t/ha equivalent to 4.8kg/plot and WA at 6t/ha equivalent to 7.2 kg/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:

Md0 = Mound without wood ash
Rd0 = Ridge without wood ash
Ft0 = Flat without wood ash
Md = Mound
Rd = Ridge
Ft = Flat

Soil sample collection

Auger soil samples were randomly taken from ten (10) observational points in the experimental area at the depth of 0 to 20 cm prior to planting. The Auger soil samples were mixed thoroughly to form a composite soil sample and used for pre-planting soil analysis. Also the wood ash treatment used was analyzed for determination of its nutrient values. At the end of each cropping season 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.

Laboratory methods

Chemical properties

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

Soil pH

The soil pH was measured in extract of soil solution in water at ratio of 1:2.5. After stirring for 30 min, the pH value was read using glass electrode pH meter.

Available phosphorous

This was determined by the procedure described by Bray and Kurtz (1945), Bray II method. The available phosphorous was read off from the standard curve after obtaining the optical density from colorimeter.

Agronomic parameters

The fertility status and productivity of any soil environment is physically observed or monitored and directly measured or quantified by measuring the agronomic parameters or properties of a crop growing on the soil. The measurement of which ranges from seed germination test to crop yield or seed yield depending on the desired parameter to be measured. For this particular study the following agronomic parameters were studied and measured.

Leaf area index (LAI)

Ten plants from each plot were randomly sampled and the LAI for each sampled plant was calculated as length × width × 0.75 summed over all leaves and divided by land area per plant.

Plant growth (m)

Ten castor plants per plot were sampled for plant height. This was taken at the end of the study with a tape. The measurement was taken from the plant base to the tip of the tallest leaf.

Data analysis

The data generated were subjected to an analysis of variance test based on RCBD using Crop Stat software version of 7.0, while statistically significant difference among treatment means was estimated using the least significant difference (LSD < 0.05).

RESULTS

Chemical contents of the study site and ash before treatment application

The initial soil properties presented in Table 1 show that the soil is acidic and the available phosphorous (P) value was relatively high with a value of 17.20 $mgkg^{-1}$. The properties of wood ash before application show higher concentrations of nutrients in the ash (Table 2). The pH of the ash is strongly alkaline (11.60) and very high in available P (261.10 $mgkg^{-1}$). Thus the ash is relatively rich in the plant chemical elements.

Effect of tillage and wood ash on soil pH and available P

The effect of tillage methods (TM) in Table 3 showed that the result of soil pH tested increased in the 2nd year planting, but decreased in the 3rd year planting. The change in soil pH for the 3 years' study in mound was from moderately acidic (1st year) to neutral (2nd year) and acidic (3rd year). In Ridge the change was moderately acidic (1st year) near neutral (2nd year) to moderately acidic (3rd year). While soil pH in flat showed moderately acidic for all the years under study. The soil pH values in 1st and 2nd year planting results showed a variation of mound > ridge > flat, while the 3rd year presented a contrary result order of flat > ridge > mound. The result variation of 1st year planting, however, showed that the values of soil pH obtained from mound, ridge and flat were relatively alike. This also applies to the 2nd year values of mound and ridge. The soil pH was non-

Table 1. Initial soil parameters before treatment application.

Test parameter	Value
pH (H_2O)	5.5
Available phosphorous (P)	17.20 $mgkg^{-1}$

Table 2. Chemical composition of the wood ash before application.

Test parameter	Value
pH (H_2O)	11.60
Available phosphorous (P)	261.10 $mgkg^{-1}$

significant ($P < 0.05$) during the TM in all the 3 years of study.

For the available P, the TM showed statistical significant effect in 1st and 2nd year planting with non-significant effect in the residual year. The result obtained from mound method showed that the value of available P decreased in the 2nd year planting, but increased in the 3rd year planting period. Hence the nature of the result was 1st year > 3rd year > 2nd year planting periods. The result variation in ridge was 2nd > 1st > 3rd year planting period, indicating that the highest value of available P in ridge method was obtained from the 2nd year planting as against the 1st year planting in mound. For the case of flat method, the result variation showed that highest value of available P was obtained from the 2nd year, while the least value of available P was observed in the 1st planting. In comparison of the TM in reference to the years' under study, 1st year result presented a variation of mound > ridge > flat; 2nd year ridge > flat > mound, while 3rd year showed mound > flat > ridge. The lowest value of available P among the TM in reference to the years under study was observed in flat in the 1st year planting period.

The effect of the wood ash result presented in Table 3 showed statistical significant difference among the rates of WA applied for the two tested parameters (pH and available P) and for the three years studied. The pH of the soil changed from slightly acidic in 1st year to slightly alkaline in 2nd year to moderately acidic in the 3rd year planting period. However, the control soil remained acidic throughout the period under study. The rates of WA ash apply in all the TM studied showed inconsistence in values obtained, which simply signify that the values are independent of the rates of WA applied. The rates of WA on mound showed that in 1st year planting, Md4 gave higher value of pH and the nature of result variation was Md4 > Md2 > Md6 > Md0. The Md2 and Md6 values were almost the same in fact; the 2nd year result showed that Md2 and Md6 yield the same value of soil pH; the 3rd year result showed a variation of Md6 > Md4 > Md2 > Md0. The rates of WA on ridge for the 1st year planting showed that the value of soil pH increased as the rates of WA applied increased. This scenario was equally true for the 3rd year result, but for the 2nd year result, the value of pH increased as the rates of WA increased, but decreased at Rd6.

Critical observation of the soil pH values for the 3 years study showed that the values of 2nd year > 1st year > 3rd year planting periods. The rates of WA on flat for the 1st year result showed that the values of soil pH increased as the rate of WA applied increased, but it decreased in Ft6. The 2nd and 3rd year results, however presented a perfect picture, that showed that the values of soil pH was dependent on the rate of WA applied because the values increased as the rate of WA applied increased. Hence the result order for the 2nd and 3rd year planting period was Ft0< Ft2< Ft4< Ft6. The 1st year result of available P in mound (Table 3) showed that Md4 had higher value compared to the other rates, Md4 > Md2 > Md6 > Md0. The 2nd year result showed a decrease in value among the rates relative to 1st and 3rd year values. From the residual year result, it was observed that the highest value of available P was obtained in Md2 and the least value from Md0.

For the 3 years study the lowest value of available P (14.8 $mgkg^{-1}$) was obtained from Md6 in the 2nd year planting period. The result of WA on Ridge for the 1st year planting indicated that the values of available P was dependent on the rates of WA applied as the values increased with an increasing rate of WA. The result of the 2nd and 3rd showed that the values of available P were independent of rates of WA applied. However, Rd6 in the 2nd year planting gave the highest available P values compared to the other rates the next in rank was Rd4. While in the 3rd year planting, Rd2 presented a highest value and next in rank was Rd6 among all the other rates. For 1st year result of WA on Flat, it was observed that Ft0 gave the highest value of available P and this value decreased as the rate of WA application increased, though an increased value was observed in Ft6 but not in comparison to the value obtained in Ft0. The 2nd year result presents a perfect order, indicating dependency of available P on the rates of WA applied. The value of available P increased with the attendant increase in the rates of WA, hence the order Ft6 > Ft4 > Ft2 > Ft0. The residual year result indicated a decrease in value of available P in Ft2, but later increased in response to the quantity of rates of WA applied.

The effect of tillage and wood ash on the two parameters was very effective, as it showed statistical significant different on the tested nutrients. In most results it was observed that the values obtained increased as the rate of WA application increased. The value recorded for available P showed that Ridge method and WA at the rate of 6 tha^{-1} (Rd_6) consistently gave the highest values among the tillage methods and rates of WA, though the value decreased in the residual year, but still greater than its value in Md6. The percentage decrease in the residual year relative to 2nd year planting

Table 3. Effect of tillage and wood ash on Soil pH and available P.

Treatment	1st Year		2nd Year		3rd Year	
	pH (H_2O)	P ($mgkg^{-1}$)	pH (H_2O)	P ($mgkg^{-1}$)	pH (H_2O)	P ($mgkg^{-1}$)
Md0	5.600	16.400	5.400	15.600	5.200	17.800
Md2	6.700	37.500	7.300	18.700	5.900	27.500
Md4	7.400	71.900	7.200	25.000	6.300	25.100
Md6	6.600	27.300	7.300	14.800	6.500	21.000
Mean	6.515	38.275	6.800	18.525	5.975	22.850
Rd0	5.800	14.800	5.700	14.800	5.400	18.600
Rd2	6.100	20.300	6.400	14.000	6.000	23.000
Rd4	6.800	25.000	7.400	36.700	6.100	22.000
Rd6	7.000	31.200	7.300	60.900	6.500	25.100
Mean	6.425	22.825	6.700	31.600	6.000	22.175
Ft0	5.700	16.600	5.500	13.200	5.500	16.600
Ft2	6.000	16.400	6.100	23.400	6.100	13.300
Ft4	7.000	14.000	6.500	27.300	6.400	22.600
Ft6	6.300	15.600	7.700	38.300	7.000	29.100
Mean	6.250	15.650	6.450	25.550	6.250	20.400
Tillage method	NS	10.99	NS	10.82	NS	NS
Wood ash	0.35	14.17	0.37	10.14	0.39	3.57
TM x WA	0.48	4.06	0.25	1.11	0.73	0.86

LSD0.05; Md0 = Mound without wood ash (WA); Md2 = Mound +2 t/ha WA; Md4 = Mound + 4 t/ha WA; Md6 = Mound + 6 t/ha WA; Rd0 = Ridge without WA ; Rd2 = Ridge +2 t/ha WA; Rd4 = Ridge + 4 t/ha WA; Rd6 = Ridge + 6 t/ha WA; Ft0 = Flat without WA; Ft2 = Flat + 2 t/ha WA; Ft4 = Flat + 4 t/ha WA; Ft6 = Flat + 6 t/ha WA.

was 142.635%. The available P content of the soil was greatly influenced by the application of wood ash as higher values were obtained in WA amended soils relative to the control soils

Effect of tillage and wood ash on leaf area index at 50 DAP and 100 DAP

The leaf area index (LAI) at 50 DAP and 100 DAP recorded in Table 4 showed that tillage methods had no effect on the leaf area index in 1st and 2nd years planting period and at 50 DAP in the 3rd year. But there was significant effect at 100 DAP at the 3rd year planting, the 1st year planting result of Mound showed that the value of LAI at 50 decreased as the year of planting increased, hence 1st year result > 2nd year result > 3rd year result. For the 3 years' of study the residual showed lowest value compared to 1st and 2nd year result. The percentage decrease in value of LAI at 50 DAP in residual year relative to 1st year result was 42.77%. The result of LAI at 100 DAP also indicated decreased value as the year of planting increased. The order of result variation was 1st year result > 2nd year result > 3rd year result. However, the result obtained from 1st and 2nd year planting were relatively the same as the percentage difference of the two results were merely 8.1%. But the LAI value decreased much in the residual to the tune of 47.16% relative to the 1st years planting result.

The result of the ridge also took the result line of the mound in the sense that for both 50 DAP and 100 DAP, the leaf area value showed 1st year result to be greater in value compared to 2nd and 3rd year values. The lowest value of LAI for 50 DAP and 100 DAP was observed in the residual year. The reduction in value for LAI at 50 and 100 DAP relative to the 1st year values were 45.1 and 34.92%, respectively; the result of LAI at 50 and 100 DAP obtained from flat method indicated decreased value as the year of planting increased, with the highest and lowest value observed in 1st and residual year result respectively. When the three tillage methods (mound, ridge, and flat) were compared, the LAI result at 50 DAP obtained in 1st, 2nd and 3rd year showed that mound was higher and the least was obtained from flat. The order of result variation for the 3 years' of study was mound > ridge > flat. The 100 DAP result present a contrary result order to 50 DAP as the result showed least value in ridge, hence the order mound > flat > ridge. The same order was observed in the 2nd year planting result, though the value of mound and flat are relatively the same as their percentage difference in value was merely 3.8%. The residual year (3rd) result indicated higher value in ridge and the least value in flat, variation of result showed order of ridge > mound > flat. The rates of wood ash were significant ($P<0.05$) for the leaf area index measured at 50 and 100 days after planting (DAP) for the 3 years planting period (Table 4).

The rates of WA application effect on mound for the

Table 4. Effect of tillage and rates of wood ash on leaf area index at 50 and 100 DAP.

Treatment	1st Year		2nd Year		3rd Year	
	50 DAP	100 DAP	50 DAP	100 DAP	50 DAP	100 DAP
Md0	7.655	21.608	7.606	21.558	3.756	10.553
Md2	9.997	27.565	9.740	27.390	6.072	13.366
Md4	14.313	29.799	14.264	29.749	8.086	16.673
Md6	12.309	27.668	12.259	27.620	7.421	15.755
Mean	11.069	26.660	10.967	26.579	6.334	14.087
Rd0	7.368	20.640	7.110	20.590	4.574	12.973
Rd2	10.186	17.063	10.136	17.041	5.463	17.644
Rd4	12.636	27.085	12.586	27.023	5.939	14.702
Rd6	13.009	27.689	12.959	27.514	7.707	14.859
Mean	10.799	23.119	10.698	23.042	5.921	15.045
Ft0	8.414	20.819	8.364	20.769	4.092	8.357
Ft2	13.704	28.148	13.653	28.098	5.703	10.630
Ft4	16.673	29.688	16..623	29.638	5.927	11.541
Ft6	15.554	27.707	15.504	27.658	7.804	12.994
Tillage method	NS	NS	NS	NS	NS	3.03
Wood ash	6.68	4.87	6.58	4.80	1.27	3.65
TM x WA	NS	8.20	NS	8.18	2.31	6.0
Mean	13.586	26.591	13.536	26.541	5.881	10.881

LSD0.05. Md0 = Mound without wood ash (WA); Md2 = Mound + 2 t/ha WA; Md4 = Mound + 4 t/ha WA; Md6 = Mound + 6 t/ha WA; Rd0 = Ridge without WA; Rd2 = Ridge + 2 t/ha WA; Rd4 = Ridge + 4 t/ha WA; Rd6 = Ridge + 6 t/ha WA; Ft0 = Flat without WA; Ft2 = Flat + 2 t/ha WA; Ft4 = Flat + 4 t/ha WA; Ft6 = Flat + 6 t/ha WA.

result of LAI at 50 DAP showed that for the 3 years' study, the result order for 1st, 2nd and 3rd year was Md4 > Md6 > Md2 > Md0. The result order was also true for LAI at 100 DAP, which indicated that for the 3 years' study the Md4 consistently gave the highest value of LAI at 50 DAP and 100 DAP. The WA application on ridge showed a contrary result order to that of mound as the highest value of LAI at 50 and 100 DAP was observed in Rd6 for the 3 years' of the study except the residual year result of 100 DAP. The result order for 1st, 2nd and 3rd result of LAI at 50 DAP was Rd6 > Rd4 > Rd2 > Rd0. The 100 DAP result did not follow any particular order the 1st year result indicated lower value in Rd2 and highest value in Rd6 among all the other rates.

The 2nd year result showed the same order of result like the 1st year because the order was Rd6 > Rd4 > Rd0 > Rd2. But then, the residual year (3rd year) result, the Rd2 which consistently recorded lowest value of LAI among all other rates of WA turned out to record the highest value of LAI at 100 DAP relative to the other rates. The value of this particular rate (Rd2) was 36.01 and 18.74% higher respectively to Rd0 and Rd6 which are rates that recorded the lowest and next in rank to Rd0 value. The application of WA on flat indicated a result order of Ft4 > Ft6 > Ft2 > Ft0. This order was true for 1st year and 2nd year result of LAI at 50 DAP. While that of 100 DAP showed an order of Ft4 > Ft2 > Ft6 > Ft0 for the 1st and 2nd year planting results. A contrary result order was observed in the residual year for the values of LAI at 50 and 100 DAP. The result variation for the two rates was Ft6 > Ft4 > Ft2 > Ft0.

The result presented in Table 4 showed that the tillage methods (TM) and wood ash was non- significant for leaf area index at 50 DAP in 1st and 2nd planting year, but significantly affected the leaf areas index at 100 DAP and 50 and 100 DAP of the 3rd year planting. There was a decrease in value as the planting period increased. The value of leaf area index obtained from the plots that received 4 tha $^{-1}$ (Md4, Rd4 and Ft4) WA was highest in 50 and 100 DAP among the values of the other rates in 1st and 2nd year planting periods while the rate that gave the highest LAI value at 50 and 100 DAP in the residual year (3rd) was the plots that received 6 tha^{-1}WA (Md6, Rd6 and Ft6). This indicates that 6 tha^{-1} rate have strong residual effect on the LAI more than the other rates. The 3rd year result in both 50 DAP and 100 DAP showed that LAI value was dependent on the quantity of WA applied as the result showed increased value as the rate of WA application increased.

The result of the leaf area index at 50 and 100 DAP generally show that the values decreased gradually from 1st to 2nd year planting and drastically at the 3rd year planting period. The influence of WA was much on the amended soils compared to the control soils as higher values were observed on the amended soil relative to the control soils.

Table 5. Effect of tillage and wood ash on plant height (m).

Treatment	1st Year	2nd Year	3rd Year
Md0	1.465	1.385	0.822
Md2	1.943	1.830	1.004
Md4	2.353	2.273	1.287
Md6	1.985	1.905	1.298
Mean	1.936	1.848	1.103
Rd0	1.584	1.504	1.049
Rd2	2.244	2.164	1.295
Rd4	2.454	2.374	1.345
Rd6	2.417	2.336	1.422
Mean	2.174	2.095	1.278
Ft0	1.897	1.817	0.965
Ft2	2.419	2.338	1.089
Ft4	2.610	2.530	1.274
Ft6	2.661	2.581	1.492
Mean	2.396	2.316	1.205
Tillage method	0.34	0.33	NS
Wood ash	0.30	0.29	0.24
TM x WA	0.44	0.43	0.46

LSD0.05. Md0 = Mound without wood ash (WA); Md2 = Mound + 2 t/ha WA; Md4 = Mound + 4 t/ha WA; Md6 = Mound + 6 t/ha WA; Rd0 = Ridge without WA ; Rd2 = Ridge +2 t/ha WA; Rd4 = Ridge + 4 t/ha WA; Rd6 = Ridge + 6 t/ha WA; Ft0 = Flat without WA; Ft2 = Flat + 2 t/ha WA; Ft4 = Flat + 4 t/ha WA; Ft6 = Flat + 6 t/ha WA.

Effect of tillage and wood ash on plant height (m)

The effect of tillage methods on plant height (PH) was significant (P<0.05) in 1st and 2nd year planting and non-significant in the 3rd year (Table 5). The result from mound indicated 1st year result > 2nd year result > 3rd year result, there was much decrease in value of PH of the residual year relative to the 1st year result of which the percentage decreased value was 43.03%. The result of PH obtained from ridge showed decrease in value as the planting year increased though the 1st and 2nd year value were relatively the same as the percentage difference of the two results was merely 7.8%. The 3rd year result showed decrease in value relative to both 1st and 2nd year result. The flat result showed a result order of 1st > 2nd > 3rd year. The percentage decrease in value of PH at 3rd year relative to the 1st year result was 49.71%. When the TM are compared, the 1st year planting result showed an order of flat > ridge > mound (Table 5). The decreased value in mound relative to the flat value was 19.20%. The 1st year result order was also observed in the 2nd year planting result, but the 3rd year result presented a contrary result order of ridge > flat > mound though the value of flat and mound did not vary much as the difference in their value was just 0.07 m.

The result of the rates of WA on the tillage methods significantly (P<0.05) affected the plant height for the 3 years studied. The rates of WA on mound showed a result order of Md4 > Md6 > Md2 > Md0 in 1st and 2nd year planting result, but the 3rd year result showed a contrary order of Md4 > Md6 > Md2 > Md0. The results just indicated that higher PH was observed in Md4 for 1st and 2nd year result, but in residual year higher value of PH was observed in Md6. The same scenario of WA result on mound was observed in ridge results, whereby Rd4 consistently recorded higher values of PH relative to other rates in 1st and 2nd year planting, while the 3rd year result indicated higher value of PH in Rd6 among all the other rates. The result order for ridge were Rd4 > Rd6 > Rd2 > Rd0 (1st and 2nd year result), and Rd6 > Rd4 > Rd2 > Rd0 (3rd year result). However, the result of WA application on flat presented a contrary order of result to that of mound and ridge in the sense that for 3 years' of study, the Ft6 rate consistently recorded the highest value of PH. The result order was Ft6 > Ft4 > Ft2 > Ft0 (Table 5).

Tillage method and wood ash effect on plant height showed statistical significant effect for the 3 years study. The values decreased as the year of planting increased. Also the values obtained were not dependent on the quantity of ash applied. Flat was observed to have recorded the highest PH in the 1st and 2nd year planting (Table 5), but decreased in the 3rd year where the Ridge recorded the highest plant height, while the least value in PH for the years under study was recorded in Mound. The wood ash application was found to influence the value of PH as higher values of PH were observed in ash amended soils compared to the control soils. The plots

that received 4 tha^{-1} WA (Md4 and Rd4) gave the highest PH value in 1st and 2nd year planting periods while the plot that received 6 tha^{-1} (Md6, Rd6 and Ft6) rates of WA gave the highest PH value in 3rd year planting period indicating strong residual effect of 6 tha^{-1} on the PH compared to the other rates. The values decreased as the planting year increased. The data recorded equally showed that Flat and WA at the rate of 6 tha^{-1} (Ft6) consistently recorded the highest value of PH for the 3 years of study among all other rates studied on tillage methods. The rates of WA on Flat also showed the dependency of the PH value on the quantity of ash applied.

DISCUSSION

Properties of the soil and ash at beginning of the study

The soil analysis of the experimental site before the initiation of the study indicates that the pH of the soil was 5.5 which indicate acidity according to the ratings of USDA-SCS (1974) and Chude et al. (2005). This implies that the studied soil is well leached and strongly weathered. The available phosphorous (P) content of the soil was relatively rich with a value of 17.20$mgkg^{-1}$, the value observed is above the critical level for soils of south eastern, Nigeria according to the ratings of FMANR (1990). This high P observed in the studied soil may have arisen from P fertilization over the years in the study site, without regard to P mobility and nutrient reaction in the soil. Table 2 shows the nutrient composition of wood ash used as soil amendment. The nutrient content shows that the wood ash was very rich in available phosphorus (P) 261.10 $mgkg^{-1}$ and the pH of the ash were alkaline with a value of 11.60.

Soil chemical properties

The soil chemical parameters assessed indicated that tillage methods had effect on the chemical properties of the soil. Although after 3 years of study the parameters measured were found to be non- significant at $P<0.05$. The non- statistical significant differences observed among the tillage methods on the parameters studied and the cropping years observed may be that the 3 years study was not enough time for detecting changes in soil properties. Gomez et al. (2001) in their studies hypothesised that 5 years was enough time for detecting changes in soil properties. The result of soil pH and available P recorded showed that TM varied in their effect. The recorded value showed that mound gave higher values of soil pH and available P in 1st and 2nd years of planting and available P in 3rd year planting compared to ridge and flat. The flat showed least values in these two parameters.

This probable may be due to less soil inversion caused by manual hoeing in Flat compared with the mound and ridge. The pH of soil is important for a variety of reasons such as the solubility of aluminium which is toxic to many plants and organism, the weathering of minerals and the distribution of cation on the exchange complex. The potential differences in production between the three tillage methods (mound, ridge, flat) and differences in waste distribution in the soil also might have influenced the result of chemical parameters. Soil pH and nutrient availability are influenced by cropping systems and soil management practices like tillage methods, soil organic matter and biological activity. This scenario might have influenced greatly the result of the third year planting season.

The nature of the result of the tillage methods with regard to the chemical nutrients obtained may be linked 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.

The WA effect showed that irrespective of the TM the ash was applied the pH of the soil changed from slightly acidic to alkaline in the 2nd year planting while the control soils remained acidic throughout the 3 years of the study.

The recorded values of pH when WA was applied in mound, ridge and flat were relatively alike. The available P content of the soil was found to be influenced by the application of WA. However, its value decreased irrespective of TM the WA was applied in 2nd year and 3rd year planting period. Though the decrease in value with regard to the aforementioned parameter in the 3rd year were inconsistent as the value of available P order was 1st year < 3rd year < 2nd year result. For the 3 years of the study the plots that received 6 tha^{-1} rate of WA had higher values of the tested parameters irrespective of the TM compared to the other rates studied in most cases except for WA on mound for the value of available P where plots that received 4 tha^{-1} showed higher value against 6 tha^{-1} rate for the 3 years study. 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 higher pH values in amended soils relative to control could be attributed to the calcium supplied to the soil by the WA, and the level of soil available P might have being influenced by the changes in soil pH brought about by the application of WA. The solubility of mineral

nutrients is greatly affected by soil pH. Phosphorus is never readily soluble in the soil but is most available in soil pH range that centred around 6.5. A soil pH range of approximately 6 to 7 promotes the most readily available chemical nutrients (Miller and Donahue, 1992; Tisdale et al., 1993). At pH below 6.0 there will be less nitrate production. Mbah and Oweremadu (2009) reported significant increase in the soil available P levels of the soils amended with organic wastes relative to the control plots. The liming effect of wood ash creates a more favourable pH in studies by Awodon et al. (2007), which showed increased soil nutrient content following plant derived ash application.

The effect of tillage and wood ash result showed that higher nutrient values were obtained more on WA treated plots compared to where WA were not applied. This observation was in line with the findings of Nweke et al. (2014) and Nnabude et al. (2015). Nweke et al. (2014) further reported that interaction between various levels of plant spacing and rates of poultry manure has positive effect on soil pH and ON, but non-significant for exchangeable bases, CEC and available P. For the parameters assessed it was observed that values obtained increased as the rate of WA application increased. The value recorded for available P showed that ridge method and WA at the rate of 6 tha^{-1} (Rd6) consistently gave the highest value among the TM and rates of WA though this value decreased in 3rd year planting and the percentage decrease relative to the 2nd year planting was 142.63%. Generally, the result showed that interaction between tillage methods and rates of WA can affect chemical properties of the soil.

Agronomic parameters of castor plant

The effect of tillage methods on the agronomic parameters of castor showed that the values of leaf area index (LAI) measured at two different dates decreased in the entire TM studied as the planting year increased. Higher values of LAI measured at 100 days after planting (DAP) was recorded in mound in 1st and 2nd year planting and next in rank was the value of Flat compared to the value of ridge. However the 3rd year result showed the ridge as the highest recorded value of LAI compared to mound and flat. The result of plant height (PH) indicated flat among the entire TM to have recorded the highest PH in the 1st and 2nd year planting season but decreased in the 3rd year where the ridge recorded the highest PH while the least value in PH for the 3 years of study was recorded in mound.

The seed yield result showed that the highest seed yield for the 3 years of study among the TM was recorded in mound and the least in ridge except the 3rd year result whereby the seed yield of ridge was higher than the flat value. Bessam and Marbet (2003) observed that conventional tillage promotes greater aeration of the soil which increases the breakdown of OM that releases a large quantity of nutrients to support plant growth. No wonder the much variation in the yield result of flat compared to the mound and ridge as rate of soil inversion during tillage is much in mound and ridge compared to flat.

The nature of the yield result obtained might be dependent on the type of test crop and TM studied because the best TM of one crop can adversely affect the productivity of another crop and soil properties. Hence indicating that crops may not always respond to a given tillage method in the same manner and degree. Kurshid et al. (2006) reported that among the crop production factors tillage contribute up to 20%, as it affects the sustainable use of soil resources through its influence on soil properties. Tillage system effects on yield according to Griffith et al. (1993) are highly dependent on upon soil type, drainage and climate. Singh et al. (2003) found out that the tillage method studied significantly influenced the grain yield of wheat over that obtained from zero tillage in the first and second year, however the effect of tillage in the third year were not significant. While Kombiok et al. (2005) assessed the effect of tillage systems (mounding, ridging, ploughing harrowing) and no-tillage (flat field) on cowpea growth and yield components under ferric luvisol in the northern guinea savannah zone of Ghana. They found that disc ploughing followed by disc harrowing resulted in the growth and yield of cowpea plant compared with that under no tillage (flat).

The WA effect on the agronomic parameters generally show that the values obtained decreased gradually from 1st to 2nd year planting and drastically at the 3rd year planting period. The values of LAI and PH recorded in 4 tha^{-1} WA gave the highest values of these parameters among the values obtained from the other rates in the 1st and 2nd year planting periods. While the rate that gave the highest value of these parameters in the 3rd year planting period was the plots that received 6 tha^{-1} WA showing strong residual effect on the assessed parameters compared to other rates of WA applied. The drastic reduction in the value of leaf area index in the 3rd year probable may be due to reduction in nutrient availability for the plant uptake. Significant effect in leaf area index following organic waste application has been reported in Nweke et al. (2013).

The recorded values of these parameters irrespective of the TM the ash was applied were relatively similar. The differences in values of the parameters tested could be attributed to the differences in plant nutrients in the rates of wood ash applied. Increases in plant height following addition of organic amendments have been reported by Nweke and Nsoanya (2013). The data recorded from the combined effect of TM and WA on the agronomic parameters of castor show that mound and WA at the rate of 4tha^{-1} consistently gave the highest PH values in 1st and 2nd year planting but decreased in the 3rd year planting. The highest value in pH was recorded in flat

with 6 tha^{-1} rate of WA. The data recorded also show that TM and WA were much effective as the quantity of ash applied and planting period increased.

Conclusion

The effect of tillage methods and rates of wood ash on the tested parameters were significant. The values decreased as the cropping years increased. TM and WA effect were found to be effective on the assessed soil chemical parameters and higher nutrient values were more obtained in WA amended soils than in non-amended soils. Soil application of wood ash at the rates of 2, 4 and 6 tha^{-1} significantly increased castor growth relative to control plots. Also increasing the rate of wood ash application was found to have led to an increase in the growth and in the soil parameters. From the value recorded for the parameters tested in first and second year planting period, there was not much difference observed in 4 and 6 tha^{-1} rates of wood ash, but the residual year, the 3rd year planting period remarkable differences were observed in the results of the two rates (4 and 6 tha^{-1}), which shows that beyond 2 years, wood ash application at the rate of 6 tha^{-1} has strong residual effect on the parameters assessed. That is for 2 years cropping the optimum for wood ash application should be 4 tha^{-1} for cost effectiveness on the side of the farmer; but beyond 2 years the maximum should be 6 tha^{-1}. The values of the tested parameters varied among the tillage methods and planting periods observed. Tillage methods and wood ash effect was found to have significant effect on the parameters studied of which their values decreased as the cropping years increased. Wood ash can easily be sourced and it is cheap in the study area and its integration with tillage improved soil productivity and castor yield as was revealed in this study. The findings from this study has clearly shown that soil application of wood ash and tillage practices has the potential to cause positive and useful changes in the fertility and productivity status of the soil by improving the soil properties and growth of castor.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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