



# Influence of Tillage and Wood Ash on Zn and Fe Content of Soil, Castor Shoot and Seed

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## Abstract

The effect of tillage methods (Mound, Ridge, Flat) and rates of wood ash on soil properties and yield of castor bean plant were studied in field trial at Abakaliki for 3 years cropping seasons. The experiment was a split plot in randomized complete block design with three tillage methods and four rates of wood ash (0 t·ha<sup>-1</sup>, 2 t·ha<sup>-1</sup>, 4 t·ha<sup>-1</sup> and 6 t·ha<sup>-1</sup>), replicated three times. CropStat Version 7.2 computer software for data management developed primarily for the analysis of data from agricultural field trials was used to analyze data collected from the study and mean separation was done using least significant difference (LSD) at 5% alpha level. The findings from the study showed for soil heavy metal contents, it was observed that tillage methods had no effect on the heavy metals except for 1<sup>st</sup> year cropping result of Zn and 2<sup>nd</sup> year cropping result of Fe. The effect of tillage methods on heavy metal contents of castor shoot showed a significant difference  $P < 0.05$  except for 3<sup>rd</sup> year result of Fe. The values obtained from Ridge and Flat were higher when compared with the value of Mound with regard to soil and castor shoot; heavy metal content with higher values was more observed in Flat method. The result of heavy metal content of seed indicated that tillage method had no effect on the heavy metal contents of the castor seed; the results of Fe, Zn in 1<sup>st</sup> and 2<sup>nd</sup> year planting season were not significant among the rates of wood ash applied. The effect of tillage and wood ash on heavy metal content of soil, castor shoot and seed was found to be significant ( $P < 0.05$ ). The values obtained decreased as the planting season increased, and the amount was found to increase as the rates of wood ash application increased. The effect of Ridge and wood ash at the rates of 2 t·ha<sup>-1</sup> (Rd<sub>2</sub>), 4 t·ha<sup>-1</sup> (Rd<sub>4</sub>) and 6 t·ha<sup>-1</sup> (Rd<sub>6</sub>) on Fe 2<sup>nd</sup> year planting result of castor seed was statistically similar, while the result from Mound method was found to increase the seed uptake of the tested parameters. The observed values of the tested parameters (Fe, Zn) in wood ash amended plots in the three years' study were beyond acceptable limits; hence reservation in the use of wood ash

on continuous bases as soil amendment especially at higher rates. The findings also indicated that the use of wood ash as soil amendment on continuous basis on the same piece of land especially at higher rates might constitute pollution problems on the near future.

### Subject Areas

Agricultural Science

### Keywords

Castor, Iron, Tillage, Wood Ash, Zinc

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## 1. Introduction

Zinc (Zn) and Iron (Fe) are heavy metals, otherwise known as trace metals or minor essential elements. They are micro-nutrients required by the growing plants in a small amount for proper physiological development and optimum crop performance. For instance, Zn functions are as the activator of enzymes and a component of growth regulators. According to Marschner [1], the element is required for the maintenance of the integrity of bio membranes. Fe in its own case is important in chlorophyll synthesis and it is involved in oxidation-reduction reactions. Iron also interacts with molybdenum, phosphorous, manganese and copper and therefore, needs to be in proper balance with these elements in plant. It is also an important element in haemoglobin, the oxygen carrier in humans. Nonetheless their actions in plants depend on their bioavailability which according to Norvel *et al.* [2], will depend on the concentration form of the metals, organic matter (OM), clay content, soil pH, presence of other cations and fertilization practices.

The relevance of these metals to plants and humans, notwithstanding, adversely becomes toxic in excess quantities or toxicant at an elevated concentration. The range between the adequacy of these metals and their toxicity levels is always small. Soils with high concentration of heavy metals can present physiological problems to the plants and health risk to humans by exposing them to the contaminants that do rest in its different layers. Body *et al.* [3] reported chronic ill health effects on man particularly children as being caused by heavy metals. While Okoronkwo *et al.* [4] and Islam *et al.* [5] reiterated that once an environment was polluted with zinc, for example it began its journey to man's body by being readily absorbed by plants [6] which were subsequently consumed directly by animals and indirectly by human. Heavy metals which are inorganic pollutant particles/elements that are in excess quantities accumulate in soils in various forms. According to He *et al.* [7], heavy metals can accumulate in soils in form of water soluble, carbonate associated, exchangeable, oxide associated, organic associated and residual. They also differ in their mobility [8] and their activities influence the properties of soil. Plant uptake of heavy metals or their leaching to the

ground water is partially or wholly dependent on the factors that may enhance the mobility of the heavy metals in the soil; such as the properties and concentration of the metal, type and quality of soil binding agents, soil pH, species of the plant, the concentration of the complexions and competing cations in solution. The plant uptake of trace metals differs depending on the species of the plant and organic waste applied. Larega and Evans [9] observed increase in Cu, Ni, and Zn concentrations in soils amended two (2) years with bio solids. When metals are added to the soil through wastes or soluble salts a linear response is expected. This then means that as the concentration of metal increases in the soil, there will be an attendant increase in the metal concentration in the plants. Metals are known to be present in the soil solid phase and in solution in free ions or adsorbed to soil colloidal particles. The work of Fresco [10] showed that heavy metals solubility in soil is controlled by adsorption, precipitation, dissolution and complex ions reactions. These interactions influence the partition of the metals in the solid and liquid phases of the soil and are responsible for their mobility and bioavailability in the system. The hydrous oxide of Al, Fe, Mn and OM is the main soil constituents involved in adsorption of trace elements being in this way similar in properties to hydroxyl groups on oxides surfaces.

Tillage and organic waste are important cultural practices that can improve soil productivity and crop yield. Strudley *et al.* [11], observed that tillage methods and intensity have various effects on the soil physical and chemical properties that affect plant growth and crop yield. Also wood ash have been reported by Vuorinen and Kurkala [12] and Jacobson [13] to have positive effect on Ca, K, content of soil as well as an increase of K, Mg, S, B, Fe and Zn in tissue of the Scots Pine. While Saarsalmi *et al.* [14] observed an increase in concentration of almost all nutrients except N in soil amended with wood ash. Though wood ash amendment in mineral soils was found not to have any positive growth response in plants growing on such soils [13] [15]. Enriching the soil with wood ash would cause some changes in the metabolism and physiological activity of plants [14] [16] and soil properties. The capacity of the soils to retain and release heavy metals can be an important factor to predict environmental impact of the use of wastes or residues containing these metals. Thus the essence of this study is to evaluate the effect of three tillage systems and four different rates of wood ash on Zn and Fe content of soil, castor shoot and seed.

## **2. Materials and Methods**

### **2.1. Location of Experiment**

This study was carried out in three different cropping seasons at Teaching and Research Farm of Faculty of Agriculture and National Resources Management Ebonyi State University, Abakaliki. The area of the study is located within latitude 06° 19'N and Longitude 08° 06' 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 average annual rainfall range of 1700 - 1800 mm. The temperature of the area ranges from

27°C - 31°C. The relative humidity of the study area is between 60% - 80% and the soil is ultisol and classified as TypicHaplustult by FDALR [17].

## 2.2. 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 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. The details of treatments used are as follows:

1. Md0 – Mound without wood ash (Md0)
2. Rd0 – Ridge without wood ash (Rd0)
3. Ft0 – 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 + 6 t/ha of wood ash (Md6)
7. Rd + 2 t/ha of wood ash (Rd2)
8. Rd + 4 t/ha of wood ash (Rd4)
9. Rd + 6 t/ha of wood ash (Rd6)
10. Ft + 2 t/ha of wood ash (Ft2)
11. Ft + 4 t/ha of wood ash (Ft4)
12. Ft + 6 t/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 0.4 kg NPK fertilizer to all plots two weeks after planting. 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 were dried in the sun 2 - 3 days and then threshed to release the seeds used for heavy metal content determination. The shoot was also harvested for heavy metal studies. The same procedure was repeated in the 2<sup>nd</sup> and 3<sup>rd</sup> year of the experiment but without application of wood ash in the 3<sup>rd</sup> year to test the residual effect.

## 2.3. Experimental Design

The total land area used for the study was 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 measuring 3 m × 4 m (12 m<sup>2</sup>). A plot was separated by 0.5 m alley and each replicate was 1 m apart. Four (4) rates of wood ash viz control (0 t·ha<sup>-1</sup>); wood ash (WA) at the rate of 2 t·ha<sup>-1</sup> equivalent to 2.4 kg/plot, WA at 4 t·ha<sup>-1</sup> equivalent to 4.8 kg/plot and WA at 6 t·ha<sup>-1</sup> equivalent to 7.2 kg/plot was used for the study. Each treatment was replicated 3 times along with the three tillage methods (Mound, Ridge and Flat) used for the study.

## 2.4. Soil Sample Collection

Auger soil samples were randomly taken from ten (10) observational points in the experimental area at the depth of 0 - 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 for heavy metals of which the result is shown in **Table 1**. Also the wood ash treatment used was analyzed for determination of its heavy metal values. The result is presented in **Table 2**. 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 the determination of soil heavy metal content.

## 2.5. Laboratory Method

### 2.5.1. Determination of Soil Heavy Metals

The determination of heavy metals (Fe, Zn) was by using the method outlined by Miller *et al.* [18].

### 2.5.2. Determination of Heavy Metals Content of Castor Shoot and Seed

The castor shoot and seed were dried at 65°C for four (4) days to constant weight. They were then ground independently in food processor with a stainless steel grinder. 1 g of each sample independently was digested using a mixture of 1 ml HNO<sub>3</sub> and 3 ml of HCl (Aqua Regia) and the content heated in a hot plate in a fume cupboard to dryness at 100°C, allowed to cool and leached with 0.5 m HCC before analysis using Perkin Elmer Atomic Absorption Spectrometer (AAS).

## 2.6. Data Analysis

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

## 3. Results

### 3.1. Heavy Metal Contents of the Study Site and Ash before Treatment Application

The initial soil properties presented in **Table 1** indicated that the soil show higher values in iron (Fe) and zinc (Zn) The order of their increase in the soil was Fe > Zn. The properties of wood ash before application (**Table 2**) showed higher values in the tested heavy metal contents, the order of their increase in the ash were

**Table 1.** Initial soil parameters before treatment application.

Test Parameter	Value
Zinc (Zn)	136.94 mg·kg <sup>-1</sup>
Iron (Fe)	238.60 mg·kg <sup>-1</sup>

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

Test Parameter	Value
Iron (Fe)	246.30 mg·kg <sup>-1</sup>
Zinc (Zn)	225.00 mg·kg <sup>-1</sup>

Fe > Zn. The heavy metal content of ash showed higher values compared to their values obtained from soil.

### 3.2. Effect of Tillage and Wood Ash on Fe and Zn Content of Soil (mg·kg<sup>-1</sup>)

The result presented in **Table 3** showed the effect of tillage method on soil heavy metals Fe and Zn. The result obtained showed that tillage methods (Mound, Ridge and Flat) had no effect on the two parameters for the 3 years of study. Though significant differences ( $P < 0.05$ ) were observed in the values of Zn in 1<sup>st</sup> planting and Fe in 2<sup>nd</sup> planting periods. The result of Fe and Zn from Mound indicated decrease in value as the planting year increased lowest result for the two parameters were observed in residual (3<sup>rd</sup>) year. The 1<sup>st</sup> and 2<sup>nd</sup> year showed much increased value for Fe and Zn though the result order for the two metals for the 3 years' study were 1<sup>st</sup> year > 2<sup>nd</sup> year > 3<sup>rd</sup> year result. In the Ridge the same result scenario of Mound was observed that is 1<sup>st</sup> year result > 2<sup>nd</sup> year result > 3<sup>rd</sup> year result for the two parameters (Fe and Zn). An increased value for the parameters was observed in 1<sup>st</sup> and 2<sup>nd</sup> year result, but these values decreased drastically in the residual year to the extent that their decrease value in 3<sup>rd</sup> year planting relative to 1<sup>st</sup> and 2<sup>nd</sup> year result in Ridge method were 98.05% (1<sup>st</sup> year), 98.28% (2<sup>nd</sup> year) for Fe and 89.57% (1<sup>st</sup> year), 81.49% (2<sup>nd</sup> year) for Zn. These decreased values attest to the extent of Fe and Zn reduction in Ridge method in the 3<sup>rd</sup> year planting period. The result of Fe and Zn in the Flat method showed result order of 1<sup>st</sup> year > 2<sup>nd</sup> year > 3<sup>rd</sup> year result. The 3 years' study showed drastic reduction in the values of Fe and Zn in the residual year period. When the tillage methods are compared on the basis of values obtained from 3 years of study, the 1<sup>st</sup> year planting result indicated that highest value of Fe was observed in Ridge, next in rank was Flat while least value was obtained in Mound. The result of Zn for 1<sup>st</sup> year planting present an order of Flat > Ridge > Mound, the 2<sup>nd</sup> year planting result still show that the leading value obtained for Fe was still from Ridge, which was very much higher in value compared to the value obtained from Flat, the next in rank and Mound value that was the least.

The decreased value (Fe) in Mound relative to the Ridge value was 41.43%. The Zn result for the 2<sup>nd</sup> year however, showed a result variation of Mound > Flat > Ridge. Though the value of Zn in Flat and Ridge are relatively alike as the difference in their values was merely 0.74 mg·kg<sup>-1</sup> the residual year result for Fe and Zn, show that there was no much variations in their values obtained from the tillage method especially for the case of Zn values. Although Fe showed result order of Mound > Ridge > Flat, while Zn present an order of Ridge > Mound > Flat.

The soil heavy metal contents (Fe and Zn) were significantly different among the rates of the wood ash applied, except for Zn in 1<sup>st</sup> year planting (**Table 3**). The rates of WA on Mound showed that the values of Fe and Zn obtained for 3 years' of study was independent of quantity of ash applied. Though result of Zn in 2<sup>nd</sup> year showed dependency on the rates of ash the 1<sup>st</sup> year planting showed an order of Md6 > Md4 > Md0 > Md2 (Fe) and Md4 > Md6 > Md2 > Md0 (Zn). The 2<sup>nd</sup> year result also indicated higher values of Fe and Zn on Md6 respectively, the next in rank for Fe result was obtained from Md2 and its decrease in Md0 was 94.21% which indicated that there was much reduction of Fe in Md0 plots. The next in rank to Md6 for the case of Zn was Md<sub>4</sub> and the Zn value decreased much in Md0 to the tune of 81.92% relative to the Md6 value. The 3<sup>rd</sup> year result present result variation for Fe as Md4 > Md6 > Md2 > Md0 and for the 3 years study the lowest value 8.8 mg·kg<sup>-1</sup> of Fe was observed in the residual year. The value was greatly reduced compared to its value of 1178.90 mg·kg<sup>-1</sup> in the 1<sup>st</sup> year planting. The Zn result in the residual year showed an order of Md6 > Md4 > Md0 > Md2. The 3 years' result showed lowest value to be observed in Md2 of residual year of which the percentage reduction in value relative to 1<sup>st</sup> year planting was 92.98%. The rates of WA on Ridge for the 1<sup>st</sup> year result showed that Fe value in Rd6 increased much when compared to its value in the other rates. The next in rank was Rd2 while least value was obtained in Rd0. The Zn result showed increased value as the rate of WA applied increased, though its value decreased in Rd6, but still higher than the value recorded in Rd0. The 2<sup>nd</sup> year planting result for Fe indicated increase in value with attendant increase in the rates of ash applied. However the value from Rd4 and Rd2 are relatively alike though the result order was Rd6 > Rd4 > Rd2 > Rd0. A different scenario of result was observed in 2<sup>nd</sup> year for the case of Zn. The Rd4 showed highest value and closely followed was the value recorded in Rd6 while the least value was recorded in Rd2. The 3<sup>rd</sup> year result present an order of Rd6 > Rd2 > Rd4 > Rd0 (Fe) and Zn, Rd6 > Rd4 > Rd2 > Rd0, the result of Zn showed dependent of value on the quantity of ash applied. The 3 years' result showed that lowest value of Fe and Zn were recorded in their Rd0 respectively. The result of ash on Flat in 1<sup>st</sup> year showed an increased value of Fe in Ft2 and the least value in Ft0 compared to the other rates. The value recorded in Ft4 and Ft6 are almost the same though Ft<sub>6</sub> show higher value compared to Ft4 rate. The Zn result for 1<sup>st</sup> year was Ft6 > Ft4 > Ft0 > Ft2. The 2<sup>nd</sup> year result of Fe still show higher value in Ft2 and least value in Ft0 relative to the other rates of Ft4 and Ft6. While the value of Zn showed dependent on the rate of WA applied hence the order Ft6 > Ft4 > Ft2 > Ft0. Also the residual year result for Fe and Zn indicated that the values were dependent on the rates of ash applied hence the order of result for the two parameters in 3<sup>rd</sup> year was Ft6 > Ft4 > Ft2 > Ft0.

The effect of tillage and wood ash result (**Table 3**) indicated that the combination of tillage and wood ash has great effect on the values of soil heavy metal contents tested. The result showed that their values increased as the rates of ash applied increased in all the tillage methods. The value of the rates recorded in Ridge

**Table 3.** Effect of Tillage and wood ash on Fe and Zn soil heavy metals (mg·kg<sup>-1</sup>).

Treatment	1 <sup>st</sup> Year		2 <sup>nd</sup> Year		3 <sup>rd</sup> Year	
	Fe	Zn	Fe	Zn	Fe	Zn
Md0	1178.90	163.460	104.50	39.800	8.800	14.500
Md2	97.800	177.457	847.60	94.350	28.400	12.450
Md4	1205.74	181.490	546.50	106.800	33.100	22.900
Md6	1285.50	179.000	1804.20	220.150	32.600	25.780
Mean	941.985	175.352	825.700	115.275	25.725	18.908
Rd0	126.200	185.800	1120.40	57.800	8.740	8.900
Rd2	1441.30	180.050	1346.00	44.500	28.600	17.000
Rd4	1404.20	217.700	1348.30	178.300	19.567	26.650
Rd6	2014.00	189.700	1824.45	155.200	40.200	28.100
Mean	1246.43	193.312	1409.79	108.950	24.277	20.163
Ft0	152.60	100.900	193.40	84.250	11.200	10.480
Ft2	1578.40	99.250	1402.00	88.900	20.400	14.950
Ft4	1264.00	111.250	1216.80	120.200	21.100	22.020
Ft6	1296.60	177.500	1126.03	145.400	38.500	25.660
Mean	1072.90	122.225	984.558	109.689	22.800	18.278

LSD 0.05

Tillage method	NS	18.05	412.52	NS	NSNS	
Wood ash	458.16	NS	363.08	27.39	4.60	1.93
TM × WA	0.84	0.49	84.27	0.31	4.47	0.28

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.

and Flat for the 3 years' study were similar but higher in value to that of Mound. The ash application increased the values of the parameters as higher values were observed in ash amended soils compared to the control soils. Significantly higher values of Fe and Zn were observed in 1<sup>st</sup> and 2<sup>nd</sup> year planting though these values decreased very much in 3<sup>rd</sup> year planting result. The values of Zn (1<sup>st</sup> year), Fe (2<sup>nd</sup> year) and Fe (3<sup>rd</sup> year) obtained from 2 t·ha<sup>-1</sup> and 4 t·ha<sup>-1</sup> WA respectively were statistically similar but significantly better than the values of control soils.

### 3.3. Effect of Tillage and Wood Ash on Fe and Zn Content of Castor Shoot (mg·kg<sup>-1</sup>)

The effect of the tillage methods on the two elements (Table 4) showed significant differences among the tillage methods studied, however, the result of Fe in the 3<sup>rd</sup> year planting showed non-significant difference among the tillage methods. The values obtained in each of the tillage method decreased as the planting period increased hence the order 1<sup>st</sup> year > 2<sup>nd</sup> year > 3<sup>rd</sup> year for each of the tillage method result for Fe and Zn. When the tillage methods are compared, it was Flat that yields the highest value of Fe and Zn from Mound for the 1<sup>st</sup> year planting result, which gave a result variation of Flat > Ridge > Mound (Fe), for Zn, Mound > Ridge > Flat. The result scenario of the Fe and Zn in the 2<sup>nd</sup> year planting was just a mirror of their value variation in 1<sup>st</sup> year planting, only that 2<sup>nd</sup> year result showed decreased value relative to their values recorded in 1<sup>st</sup> year planting. The residual

**Table 4.** Effect of Tillage and wood ash on Fe and Zn content of castor shoot ( $\text{mg}\cdot\text{kg}^{-1}$ ).

Treatment	1 <sup>st</sup> Year		2 <sup>nd</sup> Year		3 <sup>rd</sup> Year	
	Fe	Zn	Fe	Zn	Fe	Zn
Md0	194.450	690.250	193.500	689.300	15.900	2.500
Md2	151.610	586.450	150.660	585.500	17.600	3.100
Md4	157.350	547.950	156.400	547.100	14.220	2.800
Md6	118.050	516.650	117.100	515.700	15.700	2.200
Mean	155.365	585.325	154.415	584.375	15.855	2.650
Rd0	230.943	570.950	230.000	970.00	14.000	3.300
Rd2	314.350	367.450	313.600	366.500	25.100	5.000
Rd4	304.150	707.250	303.200	706.300	15.600	4.400
Rd6	249.050	214.850	248.100	213.900	16.740	3.600
Mean	274.623	465.125	273.675	464.175	17.860	4.075
Ft0	209.450	105.250	208.500	104.300	9.500	3.800
Ft2	456.950	280.710	456.000	282.760	19.550	1.600
Ft4	506.950	452.950	506.100	452.000	16.700	1.800
Ft6	938.850	754.350	937.900	753.367	18.200	2.500
Mean	528.050	399.065	527.125	398.107	15.988	2.425

LSD 0.05

Tillage method	133.39	155.96	133.37	155.89	NS	0.57
Wood ash	207.44	NS	207.40	NS	2.24	NS
TM $\times$ WA	0.29	0.38	1.06	0.34	0.20	0.14

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.

year result for the Fe and Zn however, presented a contrary order whereby Ridge recorded higher values of Fe and Zn respectively, hence the order Ridge > Flat > Mound (Fe) and Zn, Ridge > Mound > Flat.

The effect of wood ash on the Fe content of the castor shoot (**Table 4**) were statistically significant among the rates of WA applied however, the values of Zn observed throughout the 3 years' period of study were not significantly different among the rates of WA. Rates of WA on the tillage methods showed an increased value in all the rates of WA applied especially in the 1<sup>st</sup> and 2<sup>nd</sup> year planting period. The rate of WA on Mound showed that higher values of Fe and Zn were observed in Md0 in 1<sup>st</sup> and 2<sup>nd</sup> year planting and their values decreased with attendant increase in rates of WA, especially for Zn result. The result order for Fe in 1<sup>st</sup> and 2<sup>nd</sup> year was Md0 > Md4 > Md2 > Md6. The 3<sup>rd</sup> year result of Fe showed Md2 to record the highest value, the value obtained from Rd0 and Rd6 were relatively the same as their difference in value was merely 0.2  $\text{mg}\cdot\text{kg}^{-1}$ . The result of Zn in the 3<sup>rd</sup> year showed a variation of Md2 > Md4 > Md0 > Md6. The result of ash application on Ridge generally showed non dependent of the values on the rates of WA applied, though an increased values in all the rates were observed of which decreased sharply in the 3<sup>rd</sup> year planting. The result of Fe and Zn in 1<sup>st</sup> year showed that Rd2 and Rd4 gave the highest value respectively. The decrease in the value of Zn in Rd6 rate the least value among all the rates was 69.62%. This value indicated that there was much reduction in value of Zn in Rd6 plots. The 2<sup>nd</sup> year result of Fe and Zn showed a result variation of Rd2 > Rd4 > Rd6 > Rd0 (Fe) and Zn Rd0 >

Rd4 > Rd2 > Rd6. The Zn content of Rd0 showed a rapid increase when compared to its value in 1<sup>st</sup> year planting. The increased value was found to be 41.14%. The 3<sup>rd</sup> year result of Fe still present Rd2 as the highest recorded Fe content among all the other rates, next in value was obtained in Rd6 and the least from Rd0. Zn also show higher value in Rd2 relative to the other rates the next rank in value was obtained in Rd4 while Rd0 recorded the least value. The rates of ash on Flat method indicated that the values of Fe and Zn, 1<sup>st</sup> and 2<sup>nd</sup> year planting was dependent on the quantity of ash applied, hence the result order of Ft6 > Ft4 > Ft2 > Ft0. The 3<sup>rd</sup> year result for Fe indicated increased value in Ft2 relative to the values in the other rates, the closest value in rank was obtained from Ft6 while the Zn result in the 3<sup>rd</sup> year present an order of Ft0 > Ft6 > Ft4 > Ft2. That is the value increased as the rate of ash applied decreased.

The effect of tillage and wood ash on the parameters was found to be significantly different. The values of the Fe and Zn decreased as the years of planting period increased with sharp reduction in the residual year. The values of Fe and Zn obtained from 4 t·ha<sup>-1</sup> and 6 t·ha<sup>-1</sup> rates of WA among the tillage methods were found to be relatively higher than the values obtained from 0 t·ha<sup>-1</sup> and 2 t·ha<sup>-1</sup> rates. The yield values of elements obtained from Ridge and Flat were relatively higher than the values obtained from Mound. Also the values of Fe and Zn for the 3 years study showed a trend of Zn > Fe. The trend of change observed was Zn > Fe. The implication of the trend was that the ash increased the uptake of Zn by the castor compared to plant uptake of Fe.

### 3.4. Effect of Tillage and Wood Ash on Fe and Zn Content of Castor Seed (mg·kg<sup>-1</sup>)

The result of the Fe and Zn content of castor seed presented in **Table 5** showed that the effect of tillage on Zn for the 3 years of study and Fe for the 3<sup>rd</sup> year planting was not significant among the tillage methods. The result generally showed decreased value as the planting years increased. The result obtained from the Mound, Ridge and Flat for the two parameters (Fe and Zn) for the 3 years' of study showed a result variation of 1<sup>st</sup> year > 2<sup>nd</sup> year > 3<sup>rd</sup> year. The 3<sup>rd</sup> year result showed much decrease in value when compared to 1<sup>st</sup> and 2<sup>nd</sup> year results. In comparing the TM, higher content of Fe and Zn in the 1<sup>st</sup> year were observed in Mound and Ridge respectively and least values in Ridge and Flat respectively while the 2<sup>nd</sup> year showed a similar result order to that of 1<sup>st</sup> year result in that for Fe, Mound > Flat > Ridge and Zn, Ridge > Mound > Flat. The 3<sup>rd</sup> year result for Fe present a contrary result order whereby values from Flat > Ridge > Mound and Zn, Ridge > Flat > Mound. From the tillage method results, it was observed that the TM increased the uptake of Fe and Zn metals by the castor seed. Statistically similar results were obtained from Ridge and Flat for Fe in 2<sup>nd</sup> year planting periods. However, among the tillage methods, Ridge was found out to increase the uptake, Zn and Mound the uptake of Fe by the castor seeds. Tillage is an integral part of the crop production system that influences plant nutrients and heavy metal uptake by plants.

The effect of wood ash on Fe and Zn content of castor seed (**Table 5**) in 1<sup>st</sup> and 2<sup>nd</sup> year planting were not significantly different ( $P < 0.05$ ) among the rates of WA applied. The rates of WA on Mound showed higher value to be observed in Md2 for Fe in 1<sup>st</sup> year planting, this value decreased as rates of ash increased, though lowest value of Fe was obtained in Md0. The Zn result in 1<sup>st</sup> year showed that the highest value of Zn was obtained in Md6 and this decreased so much in Md2 with a value of 80.42%. The 2<sup>nd</sup> year result was similar to that of 1<sup>st</sup> year result variation only that there was a decrease in value of Fe and Zn content of the rates. The 3<sup>rd</sup> year result for Fe showed higher value in Md2, but the Fe content of the Md2 did not vary much with the value obtained in Md6 as their difference in value was 1.2 mg·kg<sup>-1</sup>. The least value of Fe was observed in Md4. The Zn result showed higher value in Md6, but decreased in Md0 with a value of 25.67% relative to the value of Md6. The result of the ash on Ridge showed that values of Fe 1<sup>st</sup> and 2<sup>nd</sup> year planting were independent on the quantity of ash applied. Hence, the result variation of the parameter for 1<sup>st</sup> and 2<sup>nd</sup> year planting was Rd0 > Rd4 > Rd2 > Rd6. While Zn content showed dependent on the rate of ash applied as the value decreased with an increase in the rate of WA applied in 1<sup>st</sup> and 2<sup>nd</sup> year planting. Hence the result variation order was Rd0 > Rd2 > Rd4 > Rd6. The residual year result for Fe showed an increased value in Rd6 of which decreased much in Rd4 by 61% - 86%. Also Zn showed an increased value in Rd6 and next in rank was obtained in Rd2, however the value of Rd0 showed greater reduction by 88.03% when compared with the value from Rd6. The result of the Flat showed that the values of the tested parameters are independent of the rate of WA applied. The Fe result in 1<sup>st</sup> year indicated higher value in Ft0 of which apart from the value from Ft6, its value was double the value of Fe obtained in Ft2 and Ft4 respectively. While Zn result showed higher value in Ft2 which was closely followed by the value from Ft4 and the lowest value obtained in Ft6. The 2<sup>nd</sup> year result of Fe showed a variation of Ft0 > Ft2 > Ft6 > Ft4, while Zn showed an order of Ft2 > Ft4 > Ft0 > Ft6. The 3<sup>rd</sup> year result of Fe indicated lowest value in Ft0 of the percentage decrease in value was 70.71% relative to the value obtained in Ft6 that was the highest value of Fe among all the rates studied. Zn showed lowest result in Ft0 and closely followed by the value obtained from Ft6, while the highest value of Zn was observed in Ft4 of which the increased value relative to Ft0 value was 126.80%. From the wood ash result, it was observed that the application of ash increased the uptake of the tested parameters by the castor seeds. It was equally noted that the values of Fe and Zn content of seeds in each rate of WA applied decreased as the year of planting increased.

The effect of tillage and wood ash on the tested parameters (**Table 5**) were statistically significant,  $P < 0.05$  however, the effect of Ridge and WA at the rates of 2 t·ha<sup>-1</sup> (Rd2), 4 t·ha<sup>-1</sup> (Rd4) and 6 t·ha<sup>-1</sup> (Rd6) on Fe in 2<sup>nd</sup> year planting were statistically similar. From the obtained values it was observed that the effect of tillage and WA increased the seed uptake of heavy metals Fe and Zn (**Table 5**). The variation change can be Fe > Zn. However, these obtained values decreased as the year of planting increased with greatest reduction in the residual year.

**Table 5.** Effect of Tillage and wood ash on Fe and Zn content of castor seed ( $\text{mg}\cdot\text{kg}^{-1}$ ).

Treatment	1 <sup>st</sup> Year		2 <sup>nd</sup> Year		3 <sup>rd</sup> Year	
	Fe	Zn	Fe	Zn	Fe	Zn
Md0	604.950	470.050	604.00	469.100	135.800	95.000
Md2	1023.150	164.350	1022.201	163.400	151.200	120.700
Md4	997.550	511.950	996.600	511.000	128.500	115.000
Md6	983.950	839.450	983.000	838.500	150.000	127.800
Mean	902.400	496.450	901.450	495.500	141.375	114.625
Rd0	334.050	507.950	333.100	507.000	102.600	30.520
Rd2	300.830	505.960	299.880	505.010	164.500	168.800
Rd4	309.350	500.950	304.400	500.000	96.500	130.500
Rd6	283.650	497.920	282.700	496.976	253.000	255.000
Mean	306.970	503.195	306.020	502.245	154.150	146.205
Ft0	734.050	399.350	566.433	398.400	75.000	77.250
Ft2	320.850	561.350	512.900	560.400	152.100	108.000
Ft4	237.650	469.950	236.700	469.000	110.767	175.200
Ft6	461.350	241.650	460.400	240.700	256.100	110.600
Mean	438.475	418.075	394.108	417.125	155.992	117.763

LSD 0.05

Tillage methods	128.21	NS	122.96	NS	NSNS	
Wood ash	NS	NS	NS	N	29.84	40.17
TM $\times$ WA	0.73	0.71	140.43	1.62	1.59	1.31

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.

## 4. Discussion

### 4.1. Soil Heavy Metals

The result of Fe and Zn, soil heavy metals after 3 years of study showed that higher values are observed in 1<sup>st</sup> and 2<sup>nd</sup> year planting compared to the 3<sup>rd</sup> year planting values in all the tillage methods studied. The values of these parameters observed in the Ridge and Flat for the 3 years planting were relatively similar and higher in value when compared to their values obtained from Mound. The yield of these parameters could be dependent on the soil type, climate and drainage. Griffith *et al.*, [19] noted that effect of tillage systems on yield and soil parameters are highly dependent upon soil type, drainage and climate.

The wood ash application for the 3 years study showed that the result of Zn (1<sup>st</sup> year) in 4 t $\cdot$ ha<sup>-1</sup> (Md4, Rd4, Ft4) and 6 t $\cdot$ ha<sup>-1</sup> (Md6, Rd6, Ft6) were statistically similar but significantly different with control plot. Also the values of Zn (1<sup>st</sup> year), Fe (2<sup>nd</sup> year) and Fe (3<sup>rd</sup> year) obtained from 2 t $\cdot$ ha<sup>-1</sup> (Md2, Rd2, Ft2) and 4 t $\cdot$ ha<sup>-1</sup> WA respectively were statistically similar but significantly better than the control plots. The values of Zn decreased as planting years increased and the soil heavy metals tested Zn and Fe was found to have decreased most in value in the 3<sup>rd</sup> year planting season. Trace elements are hazardous to human health, although according to ICRCL [20], some of them are phyto toxic, such as B, Cu, Ni and Zn, especially when they build up to critical level which can result to reduce plant growth and yield. The values of soil heavy metals increased as the rate of WA increased.

Significantly higher values of Fe > Zn were observed in 1<sup>st</sup> and 2<sup>nd</sup> years cropping season. However, these values decreased much at 3<sup>rd</sup> year planting season. The result of the 3 years' study also shows that the soil heavy metals vary with the rate of WA application. The value of Fe and Zn obtained from 0 t·ha<sup>-1</sup> significantly were small when compared with the values obtained from the other rates of WA applied. Zn has been found to be absorbed reversibly by cation exchange at low pH, but irreversibly by lattice penetration into clay particles [21]. While Zn hydroxide captured on clay surfaces may produce strong pH dependent retention of Zn with retention greatest at alkaline pH [22]. Also the widespread knowledge of Zn with P and Fe antagonism in soils show that high P values in soils result to lowered Zn values, which are largely related to activity in the root rhizosphere. These scenarios might have contributed to the nature of results obtained. In fact Alloway [21] considers that the biologically active fraction of Zn is most soluble at low pH values, therefore, that the addition to low pH soils would result in the maximum soil adsorption of the mineral. Alloway [23] put the normal range of Zn in soil to be 1 - 900 mg·kg<sup>-1</sup> the value obtained for this element (Zn) however is within the acceptable range. Anthropogenic activities such as amendment of soils with agricultural wastes increased soil heavy metals concentration. The following authors: Asadu *et al.*, [24], Nwite *et al.*, [25], LASEPA [26] and WHO [27] reported significant increases in these soil heavy metals in organic waste amended soils compared to the control plots. Hence, continuous application of organic waste on soil could impose the risk of heavy metal pollution on the soil with its health implications such as ecto-toxicology. Thus, the absorption of the metals in the plant tissue by the plants growing in such soils according to Smith *et al.*, [28] are considered to be harmful to the health of humans that consume it. The values obtained for these heavy metals differed greatly with that of the results of Mba *et al.*, [29], [30] and [31] which could be associated with the type of organic waste applied, test crop used, planting period observed and the state of climate and precipitation at the time of study. The result also differed with the observations of Gallardo-lara *et al.*, [32] who observed increased residual extractable Zn following increased application of waste. Also, the works of Islam *et al.*, [5], Okoronkwo *et al.*, [4] and Kos *et al.*, [6] showed that when an environment becomes polluted with Zn, it begins its journey to man's body by being readily absorbed by plants which are subsequently consumed by man.

The tillage and WA effect showed that the values of the soil heavy metals (Fe and Zn) increased as the rate of WA applied increased irrespective of the tillage method the ash was applied. The effect on the values were observed to be higher in the 1<sup>st</sup> and 2<sup>nd</sup> years planting and decreased in the 3<sup>rd</sup> year planting season. Also their values obtained from 4 t·ha<sup>-1</sup> and 6 t·ha<sup>-1</sup> irrespective of the TM the WA was applied were found to be relatively similar, but higher in value compared to their values obtained from 2 t·ha<sup>-1</sup> and 0 t·ha<sup>-1</sup> rate of WA. The result obtained could be associated with the type of tillage method, waste applied and water content and infiltration rate of the soil. Soil water content is affected by tillage because of changes produced in infiltration, surface run-off and evaporation. These factors are capable

of influencing the Fe and Zn contents, as they can be soluble and transformed in the soil into their carbonate or hydroxyl content which might be of help to soil nutrient distribution and plant growth, while in water stress situation they can become insoluble and adsorbed by soil particles. Tillage methods influenced soil water storage more than the degree of canopy formed by the different crop varieties, according to Fabrizzi *et al.*, [33] and this invariable will have great impact on soil heavy metal content.

#### 4.2. Heavy Metal Content of Shoot of Castor

The effect of tillage methods on the heavy metal contents of castor shoot showed significant difference at  $P < 0.05$  among the TM studied (Table 4). However, the result of Fe in the 3<sup>rd</sup> year planting showed non-significant difference among the tillage method the values obtained in each of the TM decreased as the planting years increased. Their recorded values in Ridge and Flat were relatively higher than the values obtained from the Mound. The parameter Zn (3<sup>rd</sup> year) its value in Ridge and Flat were statistically similar. The same statistical similarity applies to the values obtained from Mound and Ridge with regard to the values of Fe, Zn (1<sup>st</sup> and 2<sup>nd</sup>) years planting periods. The result obtained for the parameters could be attributed to some factors such as tillage method used, waste applied, root development and soil aggregation. For instance, when soil is annually cultivated, roots develop more extensively below 10 cm than with no-till systems while intermediate root distribution occurs with minimum tillage system and when residues are removed, there is greater root growth in the 15 cm soil surface [34]. Also the work of Mandal *et al.*, [35] reported that OM, pH, soil moisture status, microbial activity in the root rhizosphere and concentration of other trace elements influence zinc availability of crops. This affected the yield contents of these parameters much on the 3<sup>rd</sup> year planting period where their values decreased remarkably, probably due to non-application of WA. Also, the ability of Ridge and Mounds to conserve limited soil moisture might have influenced the statistical similarity in values of the parameters observed. Rowland [36] observed that the traditional system of Ridge and Mound cultivation improve aeration for roots and facilitates the growth and development of crops. Continuous cultivation reduces aggregate size, because small aggregates are less stable than large ones [37] [38] and soils with small aggregates are more prone to compaction, crusting, soil erosion and reduced yield. All these invariably may have influenced the uptake of heavy metals by the castor plant.

The values of Fe and Zn obtained from the rates of WA applied irrespective of the tillage method it was applied were observed to be high throughout the three years planting period studied. However the trend of changes in these parameters was observed to be inconsistent irrespective of the TM. For example the value of Fe in 1<sup>st</sup> and 2<sup>nd</sup> years planting were found to increase as the rates of WA applied increased. While the value of Zn decreased as the rates of WA increased to 2 t·ha<sup>-1</sup> and then increased in 4 t·ha<sup>-1</sup> and decreased again in 6 t·ha<sup>-1</sup> rates of WA. Even the values obtained for Zn were beyond the range given by Brown [39] and

Alloway [23] in the years studied for tolerable limits and, therefore, may cause toxicity problems to the crop and injury to humans. The values of Zn observed throughout the 3 years' periods of study were not significantly different among the rates of WA. Increasing the heavy metal contents of soil may not only be deleterious to soil productivity but harmful to humans and animals that invariably will depend on soil for their livelihood. Naidu *et al.*, [40] stressed that continuous application of organic waste amendment were the greatest threat to the environment as a result of surface input to soil system of heavy metals.

The effect of TM and WA showed that the observed values of Fe and Zn for the periods under study showed that combination of tillage and WA has the potentials of increasing the uptake of the elements by the crop. The values obtained for these parameters (Fe, Zn) from 4 t·ha<sup>-1</sup> and 6 t·ha<sup>-1</sup> rates WA among the tillage methods were found to be relatively higher than the values obtained from 0 t·ha<sup>-1</sup> and 2 t·ha<sup>-1</sup> rates. Soil disturbance and subsequent changes in soil organic matter strongly affect the stability of soil aggregates and other soil properties [41] [42]. These changes in turn will have feedback effect on the uptake ability of the heavy metals by the castor plant.

### 4.3. Heavy Metal Contents of Seed

Tillage methods were observed to have increased the uptake of Fe and Zn metals by the castor seed. Statistically similar results were obtained from Ridge and Flat for Fe in 2<sup>nd</sup> year planting. Among the TM Mound was found out to increase the uptake of the tested parameters followed by the Ridge method. Tillage is an integral part of the crop production system that influences plant nutrients and heavy metal uptake by plants. According to Arshad *et al.*, [43], tillage is crucial for optimising productivity by alleviating physico-chemical and biological constraints of soil. Hence, nature of the result obtained from the three tillage methods collaborated with the findings of Dick *et al.*, [44] and Okpoku *et al.*, [45] who postulated that yield reduction have often been observed in no-tillage compared to other methods, especially when used in poorly drained fine textured soils. Also, it should be noted that crop responses to tillage methods depend upon the number of years a tillage system has been established, amendment used and the history of the field.

The values Fe and Zn obtained from 4 t·ha<sup>-1</sup> and 6 t·ha<sup>-1</sup> rates of WA and the TM applied were found to be statistically similar but significantly different from the control plots. Heavy metal contents of seed in each rate of WA applied decreased as the year of planting increased. The observed remarkable decrease in the uptake of these heavy metals in third year planting by the castor seed could be due to non-application of WA, which tend to portray that organic waste application on agricultural soils can be one of the common sources of soil contamination as the crops source out the nutrients from the soil. Thus, Jones *et al.*, [46] reported that heavy metals were absorbed at particle surface, bound to carbonates or occluded in iron or manganese hydroxides, organic matter and sul-

phide. The values obtained for Fe and Zn for the three years period of study were high and beyond the range stipulated by Widdowson [47] and Granick [48] for normal human requirement. Increasing the rate of WA application increased the uptake of these heavy metals. The values of rates of WA on Mound were observed to be relatively higher compared to the values of rate of WA on Ridge and Flat. Therefore, continuous application of WA with regard to these two elements can constitute potential dangers to humans.

From the obtained values it was equally observed that the combined effect of tillage methods and rates of WA increased the uptake of Fe and Zn. Though these obtained values of the heavy metal content of seeds decreased as the years of planting increased. The observed variations in the tested parameters among the tillage methods and rates of WA and the three years of study collaborated with the findings of Vousta and Samara [49] who reported that harvested crops show large variations in heavy metal concentration from year to year in the same field. This they attributed to plant uptake, variable emission rates, deposition process and atmospheric transport. The increases in Fe uptake by the crop observed from the result of the study is very crucial, as excess Fe reduces the haemoglobin content which is oxygen carrying pigment of red blood cells causing siderosis [50].

## 5. Conclusion

The findings from this study have revealed that the rates of wood ash and tillage methods studied influence greatly the heavy metals studied. Increasing the rate of wood ash application was found to lead to an increase in Fe and Zn studied. From the value recorded for the parameters in first-and-second year planting period, there was not many differences observed in 4 t·ha<sup>-1</sup> rates and 6 t·ha<sup>-1</sup> rates of wood ash, but in the residual year, the 3<sup>rd</sup> year planting period, remarkable differences were observed in the results of the two rates (4 t·ha<sup>-1</sup> and 6 t·ha<sup>-1</sup>), which showed that beyond 2 years, wood ash application at the rate of 6 t·ha<sup>-1</sup> had strong residual effects on the parameters assessed. The observed values of these heavy metals in wood ash amended plots in the three years planting periods were within the acceptable limits, but the uptakes of Fe and Zn by the seed of castor were beyond the normal range. Tillage methods and wood ash effect were found to have significant effects on the parameters studied, which their values decreased as the cropping years increased. Based on the results obtained from this study, it may be appropriate to recommend that the use of wood ash as soil amendment on continuous basis at higher rates on the same piece of land, no matter the tillage method practiced may cause pollution problems in the near future.

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