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Comparative Effect of Composts, Animal Manures and Biochar on Pb Uptake in Two Maize Varieties Grown on Pb Contaminated Alfisol in South Western Nigeria

Morakinyo-Fasipe OlutoyeTemitope[1] and Ayeni Leye Samuel[2*]

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[1]Department of Crop Science, College of Agricultural Sciences, Joseph Ayo Babalola University,Arakeji – Ikeji, Osun State, Nigeria.
[2]Department of agricultural sciences, Adeyemi College of Education, Ondo, Ondo State, Nigeria.

ABSTRACT

Screen-house experiments were conducted to determine the effect of poultry manure composted Mexican sunflower (*Tithonia diversifolia* (CPM), poultry manure alone (UNPM), Composted poultry manure (CMPM), cattle dung composted with Mexican sunflower (Tithonia *diversifolia)* (CMCD), cow dung alone (UNCD) and biochar (BIO) on soil Pb content and nutrient uptake of maize grown in a soil contaminated with Pb in Ibadan, southwestern Nigeria. Both contaminated (Control L) and uncontaminated (Control N) soils with Pb were used as control. The three levels for all the treatments used except the control experiments were (20, 30 and 40 t/ha). There were twenty-three treatments replicated three times arranged in Completely Randomized Design (CRD) with three replications. The two maize varieties used were DTMA -Y -STR and DTMA –W- STR. This experiment showed that DTMA – Y - STR absorbed less amount of Pb than DTMA W STR. UNCD2 to DTMA –Y- STR compared favourably with DTMA –Y- STR that served as a control in the contaminated soil. The experiment showed that composted organic manure could help in alleviating metal stress in maize crop grown on Pb contaminated soil and immobilize Pb in the soil. Application of CMP at 20, 30, CMCD 20, 30 and 40 t/ha and BIO 20, 30 and 40 t/ha significantly reduced Pb concentration compared with DTMA –Y- SR grown in contaminated soil. The Pb content in the soil was still high after harvest of the maize. Caution must be exercised when applying organic manures as fertilizers to avoid Pb toxicity in food and pollution in agricultural soils.

Key word: Heavy metal, Sunflower, Poultry manure, Cattle dung, Composted poultry manure, Composted cattle dung.

*Corresponding author. E-mail: leyesam@gmail.com

INTRODUCTION

Heavy metals are conventionally defined as elements with metallic properties (ductility, conductivity, stability as cations, ligand specificity, etc.) and an atomic number >20. They are chemical elements with a specific gravity that is at least 5 times the specific gravity of water. For example, the specific gravity of Cd is 8.65, Fe 7.9, Pb 11.34 and Hg 13.5. About 53 of the 90 naturally occurring elements are heavy metals (Schutzendubel and Polle, 2002), but not all of them are agriculturally important. The most common heavy metal contaminants are cadmium, chromium, copper, Pb, molybdenum and zinc (Zenk, 1996). The effects of heavy metals on plant development vary according to different soil characteristics, type of plant and metal. The main sources of heavy metal contaminants in soils include metal mining and smelting, agricultural and horticultural materials, such as fertilizer and pesticide application, sewage sludges, fossil fuel combustion, metallurgical industries, electroplating, chemical and other industrial sources (energy and fuel production), and waste disposal. Large areas of cultivated land in many countries have been contaminated by As and Cd

due to agricultural and industrial practices such as application of pesticides and chemical fertilizers, wastewater irrigation and smelter wastes and residues from metal mining (Papazoglou et al., 2005).

Elevated levels of heavy metals in soils may Pb to their uptake by plants, which depends not only on heavy metal contents in soils but is also determined by soil pH value, organic matter and clay contents, and influenced by the fertilization (Papazoglou et al., 2005). Composting is considered as a viable and environmentally sound method of waste management that hastens the decomposition of the organic waste under controlled conditions, thereby reducing its volume (Eneji et al., 2001). Currently, contamination of soil and water by heavy metals also represents a major environmental hazard to human health. Accumulation of Pb in human body may cause renal failure, brain and liver damage (Lucky and Kenugopal, 1997). High concentrations of certain heavy metals in maize show the level of food insecurity and these calls for public concern (Malomo et al., 2013). Pb has no known essential function in human and is a well-known metal that damages liver, kidneys, brain central nervous and reproductive system of man. For human safety, there is need to take caution in the amount of Pb released to the soil that is absorbed by maize since maize is a crop consumed by many people in southwestern Nigeria. Attention should be on growing maize varieties that do not take or have significance uptake of Pb. Therefore, the objectives of this study were to determine the effect of different rates of compost manure, poultry manure and biochar on soil chemical properties and nutrient concentration of two maize varieties to Pb toxicity.

MATERIALS AND METHODS

Experimental Design and Treatments Application

The materials used in treatments formulation in this experiment were sunflower, poultry manure, cow dung and biochar. The treatments were Control (Contaminated soil, control (Normal soil), composted poultry manure with Mexican flower, composted cow dung, uncomposted poultry manure, uncomposted cow dung, composted cow dung and Poultry manure (2:1) and Rice husk Biochar. The treatments were applied at 20, 30 and 40 t/ha. There were twenty-three treatments and the treatments were arranged in CRD with three replicates. Compost used was made from Mexican sunflower *(Tithonia diversifolia)* and poultry manure. The materials were laid out in ratio 3:1 of plant materials to poultry manure (on dry weight basis) after sorting and chopping using Partially Aerated Composting Technique (PACT-2) proposed by Akande et al. (2005) and Morakinyo- Fasipe et al. (2018).The heap was left to decompose for a period of three months (September to December). Continuous turning and watering were done fortnightly to quicken the decomposition rate, after which the matured composts were removed from the heap, air- dried, shredded and samples were collected for micronutrients analysis. The composted cow dung and poultry manure were laid out in ratio 2:1 of cow dung to poultry manure on dry weight basis using the Partially Aerated Composting Technique (PACT-2) inside a composting bin.

The compost mixture was watered moderately and thoroughly mixed to allow for even distribution of moisture. Bin was covered and turning was done weekly to hasten decomposition rate. Matured compost was evacuated from the composting bin after a month and was air-dried, ground, sieved and stored in polythene bags Composted poultry manure and Composted cow dung followed the same composting process. Rice husk biochar was collected from Crop Physiology Unit of the Department of Crop Protection and Environmental Biology. Soil contaminated with Pb and uncontaminated soil weighing 1.5 kilograms was individually weighed into different pots and the pots were labelled according to the treatment. The treatments were applied according to the rate by mixing them with soil two weeks before sowing. Two maize (*Zea mays)* varieties were planted. The two varieties used were DTMA -Y -STR and DTMA –W-STR. Three seeds per pot were planted and later thinned to two plants per pot a week after germination. The experiment was terminated at four weeks.

Plant Analysis

Dried plant samples were ground and the samples were taken for nutrient determination. Maize roots and shoots were separated from each other, washed with distilled water, air dried in oven at a temperature of 65°C for 24 h, grind into powder with pestle and mortar. The powder was digested with $HCl/HClO_3$ for the determination of Fe, Cu, Zn and Mn. For Pb determination, the remaining grounded powder was later ached in the furnace at 550°C and finally digested in acid. Both micronutrients and Pb were read with Atomic Absorption Spectrophotometer.

Data Analysis

The mean data were presented in a bar chart using IBM Procedure of SPSS package (2010).

RESULTS

The Pb present in compost, cow dung and poultry manure were generally low. Cow dung had the highest Pb content (Table 1). The Pb present in un-contaminated soil was below 50 mg/kg recommended by Umoru (2014) as the critical level for crop production while the contaminated soil had Pb (Pb) concentration far above the critical level and thus might pose problem to soil fertility. The Pb present in un-contaminated soil

Table 1. Chemical properties of organic amendments used for the experiment.

Parameters	Compost	Cowdung	Poultry Manure
Extractable Micronutrient(mg/kg)			
Mn	16.00	167.50	32.50
Fe	9.78	1.95	0.94
Zu	2.05	52.50	57.95
Cu	75.00	14.30	6.95
Pb	0.42	1.07	0.89

Table 2. Micronutrients content of the soil and organic amendments used for the experiment.

Parameters	Uncontaminated Soil	Contaminted Soil
pH (H_2O)	6.9	5.5
OM (%)	3.50	1.84
	Extractable Micronutrient (mg/kg)	
Mn	13.00	33.40
Fe	138.00	378.00
Cu	4.95	39.40
Zn	1.64	4.21
	Heavy Meta l(mg/kg)	
Pb (Pb mg/kg)	38.75	66376.75

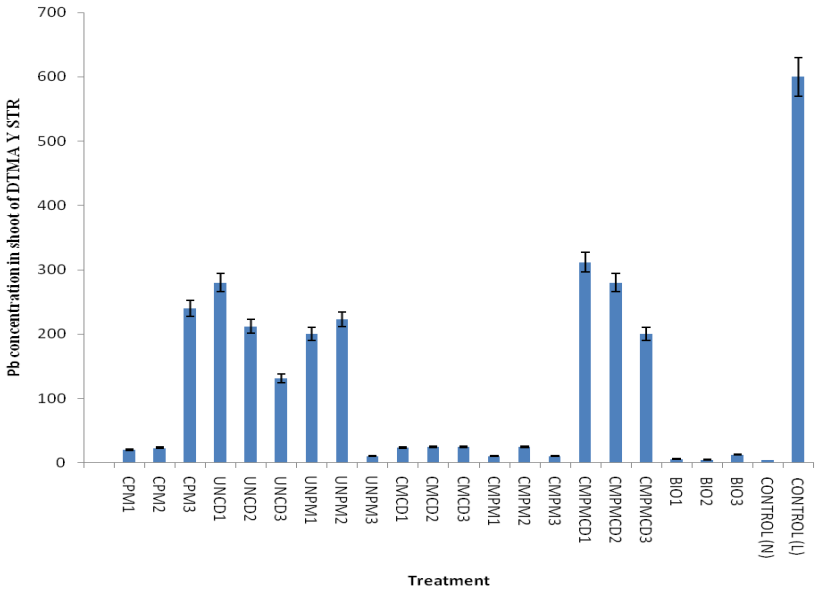

Figure 1. Effect of composted, uncomposted organic amendments, Biochar on Pb concentration in the shoo t of MA YSTR maize variety contaminated with Pb.
COMP1(Compost at 20t/ha), Comp 2-Compost at 30t/ha,Comp 3- Compost at 40t/ha, UNCD(Cowdung alone)1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, Poultry manure alone)- 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CMCD(Composted Cowdung) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CMPM(Composted Poultry manure) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CPMCD(Composted poultry manure+cowdung 1- at 20t/ha, 2- at 30t/ha,3- at 40t/ha, Bio(Biochar) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, Control N(Normal soil), Control L(Pb contaminated soil).

was below 50 mg/kg recommended by Umoru (2014) as the critical level for crop production while the contaminated soil had Pb (Pb) concentration far above the critical level and thus might pose a problem to soil fertility (Table 2). The pH of the soil that was not contaminated with Pb was higher than the contaminated soil. Soil pH might have strong effect on Pb uptake by maize. Effect of Composted and Uncomposted Organic amendments and Biochar on Pb concentration in shoot of DTMA Y STR and DTMA W STR Maize variety Shoot planted in Pb Contaminated Soil are presented in Figures 1 and 2. Compared with the DTMA –Y- SR has

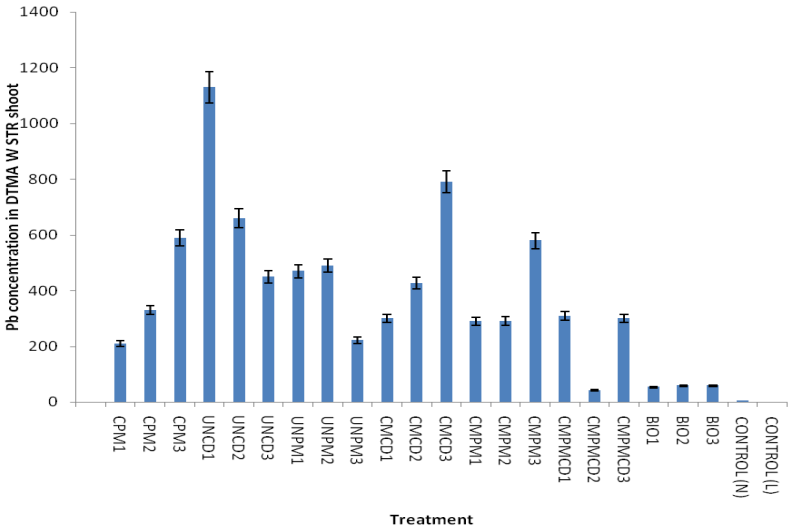

Figure 2. Effect of composted, uncomposted organic amendments, Biochar on Pb concentration in the shoot DTMA W STR maize variety contaminated with Pb. COMP1(Compost at 20t/ha), Comp 2-Compost at 30t/ha,Comp 3- Compost at 40t/ha,UNCD(Uncomposted Cowdung)1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha,UNPM(Uncomposted Poultry manure)- 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CMCD(Composted Cowdung) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CMPM(Composted Poultry manure) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CPMCD(Composted poultry manure+cowdung 1- at 20t/ha, 2- at 30t/ha,3- at 40t/ha, Bio(Biochar) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, Control N(Normal soil), Control L(Pb contaminated soil).

grown in uncontaminated soil, all the DTMA –Y- SR grown with uncomposted cattle dungs (UNCD) and combined composted cattle dung and poultry manure (CMPMCD) had higher increase in Pb uptake. All the DTMA –Y- SR grown in contaminated soil did not germinate; hence, number '0' was recorded for them. It was of our opinion that the high concentration of Pb in the soil inhibited their germination. The data in Figure 1 shows that uncomposted cattle dung applied at 20 t/ha (UNCD2) compared favourably with DTMA –Y- SR that served as control in the contaminated soil. Composted poultry manure (CMP1, 2 and 3) at all rates, composted cattle dung at all rates (CMCD1, 2 and 3) and biochar (BIO 1, 2 and 3) at all rates were significantly reduced in Pb concentration compared with DTMA –Y- SR grown in contaminated soil. It was observed that DTMA –Y – SR planted in contaminated soil showed the highest Pb content. By visual counting, it was observed that the maize in contaminated soil exhibited stunted growth although not reported in this research.

In Figure 2, the Pb content in all the treatments in the shoot of DTMA –W - SR were very high when compared with the DTMA –Y – SR and control. The DTMA –W – SR treated with UNCD1 recorded highest Pb content followed by CMCD3 while the DTMA –W – SR treated with BIO 1, 2 and 3 recorded the lowest Pb apart from the control. The Pb by the DTMA –W – SR grown in uncontaminated control experiment was negligible while there was no Pb recorded for DTMA –W – SR grown in contaminated soil because they did not germinate. Generally, DTMA –W – SR absorbed more Pb than DTMA –Y – SR work in this research. Figures 3 and 4 showed the effect of the amendments on Pb uptake by the roots of DTMA –Y – SR and DTMA –W – SR, respectively. It was observed that biochar 1,2 and 3 recorded the lowest Pb in the roots of DTMA –Y – SR and DTMA –W – SR. All the treatments were significantly higher than the control experiment. The DTMA –W – SR fertilized with treatments UNPM3, CMCD1, 2, and 3 were all low in Pb compared with the rest treatments. It was observed the Pb content in the roots of all the maize irrespective of the varieties they belong were higher than the Pb content in their shoots.

The roots of DTMA –Y – SR retained more Pb its roots than DTMA –W – SR showing that DTMA –Y – SR had affinity to translocate Pb than DTMA –W – SR in this experiment. Effect of composted and uncomposted organic amendments and biochar on Pb concentration in Pb contaminated soil planted with DTMA Y STR and DTMA W STR maize varieties are shown in Figures 5 and 6. After the harvest of DTMA Y STR maize variety grown on Pb contaminated soil, reduction in Pb concentration was observed in the soil amended with compost at 30 t/ha with Pb concentration of 37300 mg/kg. Other amendments that reduced Pb concentration were compost at 20 t/ha and composted poultry manure at 30t/ha with a concentration of 42450 and 42950 mg/kg. Biochar at 20 and 30 t/ha recorded

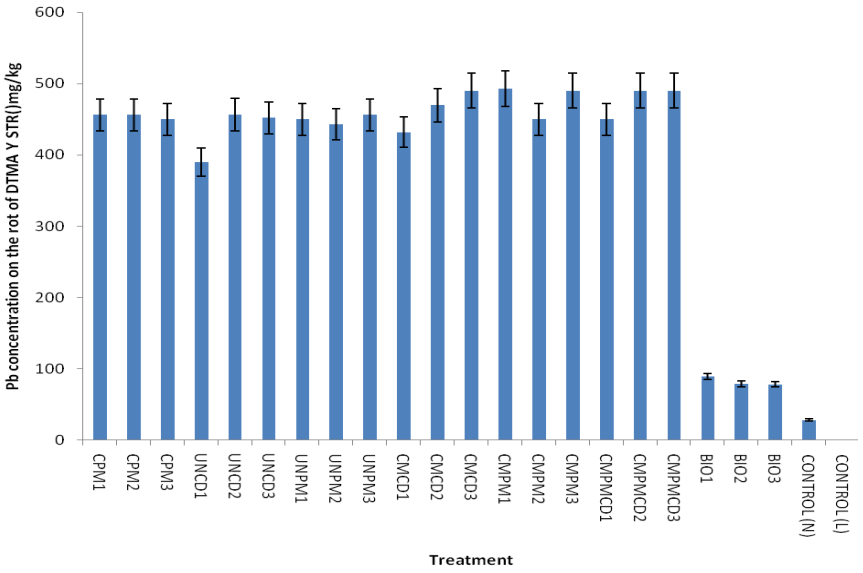

Figure 3. Effect of composted, uncomposted organic amendments, Biochar on Pb concentration in the root of DTMA Y STR maize variety contaminated with Pb. COMP1(Compost at 20t/ha), Comp 2-Compost at 30t/ha,Comp 3- Compost at 40t/ha, UNCD(Uncomposted Cowdung)1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, UNPM(Uncomposted Poultry manure)- 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha,CMCD(Composted Cowdung) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha,CMPM(Composted Poultry manure) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha,CPMCD(Composted poultry manure+cowdung 1- at 20t/ha, 2- at 30t/ha,3- at 40t/ha,Bio(Biochar) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha,Control N(Normal soil), Control L(Pb contaminated soils).

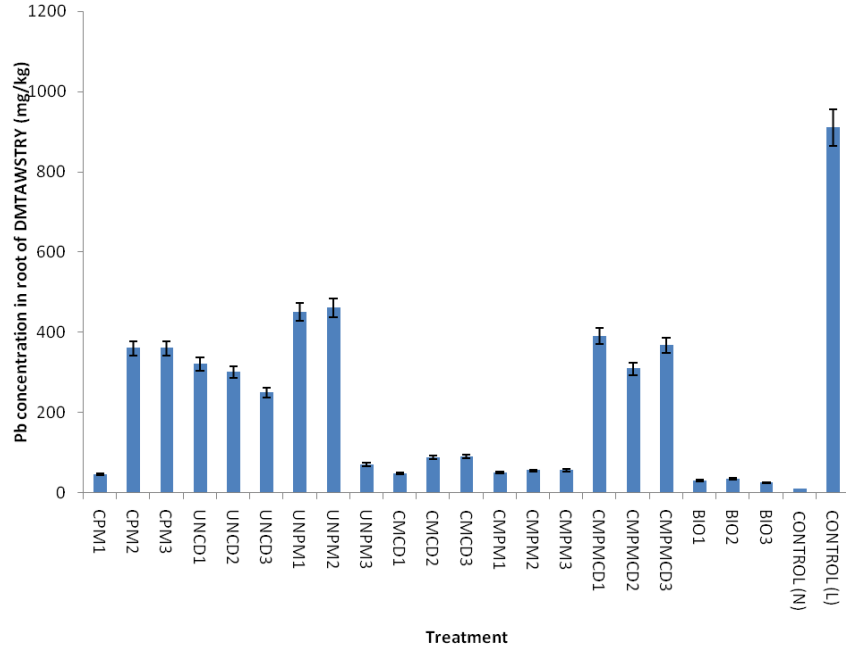

Figure 4. Effect of composted, uncomposted organic amendments, Biochar on Pb concentration in the root DTMA W STR maize variety contaminated with Pb.
COMP1(Compost at 20t/ha), Comp 2-Compost at 30t/ha,Comp 3- Compost at 40t/ha, UNCD(Uncomposted Cowdung)1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, UNPM(Uncomposted Poultry manure)- 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CMCD(Composted Cowdung) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CMPM(Composted Poultry manure) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CPMCD(Composted poultry manure+cowdung 1- at 20t/ha, 2- at 30t/ha,3- at 40t/ha, Bio(Biochar) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, Control N(Normal soil), Control L(Pb contaminated soil).

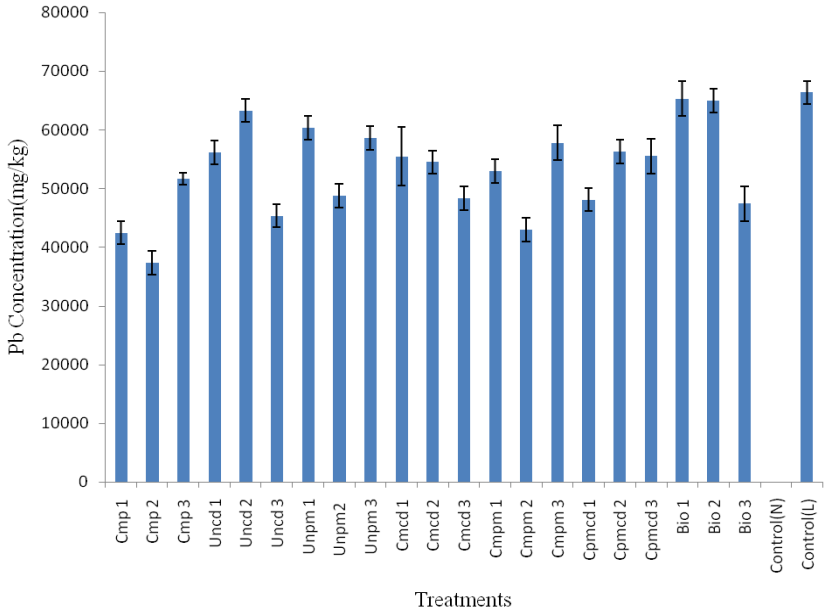

Figure 5. Effect of Composted and Uncomposted Organic amendments and Biochar on Pb concentration in Pb Contaminated Soil planted with DTMA Y STR variety.
COMP1(Compost at 20t/ha), Comp 2-Compost at 30t/ha,Comp 3- Compost at 40t/ha, UNCD(Uncomposted Cowdung)1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, UNPM(Uncomposted Poultry manure)- 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CMCD(Composted Cowdung) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CMPM(Composted Poultry manure) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CPMCD(Composted poultry manure+cowdung 1- at 20t/ha, 2- at 30t/ha,3- at 40t/ha, Bio(Biochar) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, Control N(Normal soil), Control L(Pb contaminated soil).

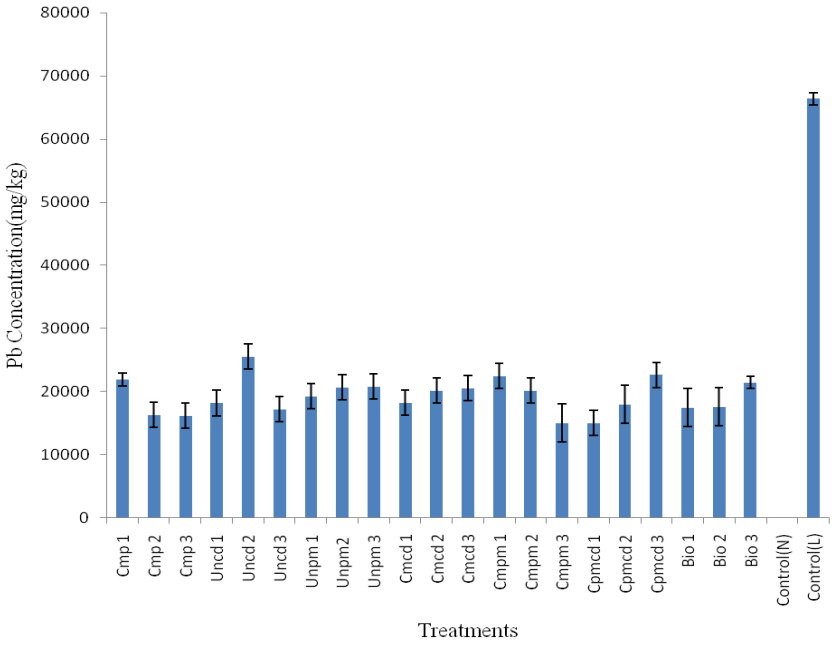

Figure 6. Effect of Composted and Uncomposted Organic amendments and Biochar on Pb concentration in Pb Contaminated Soil planted with DTMA W STR maize variety.
COMP1(Compost at 20t/ha), Comp 2-Compost at 30t/ha,Comp 3- Compost at 40t/ha, UNCD(Uncomposted Cowdung)1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, UNPM(Uncomposted Poultry manure)- 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CMCD(Composted Cowdung) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CMPM(Composted Poultry manure) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, CPMCD(Composted poultry manure+cowdung 1- at 20t/ha, 2- at 30t/ha,3- at 40t/ha, Bio(Biochar) 1- at 20t/ha, 2- at 30t/ha, 3- at 40t/ha, Control N(Normal soil), Control L(Pb contaminated soil).

the highest Pb concentrations of 66500 and 66000 mg/kg, respectively (Figure 5). With Pb cotaminated soil planted with DTMA W STR maize variety, it was observed that the reduction in the Pb concentration in the soil came from the amendment with composted poultry manure at 40 t/ha with Pb concentration of 15027 mg/kg. Other amendments that reduced Pb concentration were compost at 30 t/ha and 40 t/ha with concentrations of 16300 and 16203 mg/kg, composted poultry manure and cow dung at 20t/ha having Pb concentration of 16063 mg/kg. Uncomposted cow dung at 30t/ha had the highest Pb concentration of 25563 mg/kg. Comparing all the treatments with control (contaminated), there was significant reduction in the Pb concentration of Pb soil treated with organic amendments and biochar (Figure 6). The lower Pb content in the soil-grown with DTMA W STR maize variety after the experiment showed that it tapped more Pb than DTMA Y STR maize variety

DISCUSSION

It was observed from the result that, all the treatments reduced the uptake of Pb in the shoot of DTMA-Y-STR and DTMA-W-STR when compared with maize planted in the soil treated with high amount of Pb (Control L). This shows that composted cow dung, poultry manure and their natural forms, as well as biochar, had the ability to reduce Pb uptake in maize. The inability of the maize to grow in contaminated soil showed that it was the treatments applied that reduced the Pb uptake by the maize. This assertion buttressed the findings of Scialdon et al. (1980) Wong and Lau (1985) and Ye et al. (1999) that cow waste, poultry manure, compost, sewage sludge and pig manure could reduce Pb availability to plant. The high amount of organic matter with high pH was expected to reduce Pb intake as the soil contaminated with Pb recorded lower pH that the uncontaminated soil. The presence of high amount of Fe, Cu, Zn, Mn and Pb might have increased soil acidity. DTMA-Y-STR and DTMA-W-STR exhibited different characteristic in absorbing Pb in this experiment. Abdul et al. (2010) showed that different maize varieties absorbed Pb at different rates in an experiment conducted to show the effect of Pb toxicity on growth, chlorophyll and Pb contents of two varieties of maize. This was also supported by Zoubu (2008) who stated that the concentrations of heavy metals such as Pb in plants depend on the application rate, soil reactions and plant species. Organic matter in uncontaminated soil was higher than the soil contaminated with Pb in this experiment. Ye et al. (1999) stated that addition of organic matter can improve soil properties and nutrient status of contaminated soils.

It was observed that the roots of the maize accumulated more Pb than the shoots in this experiment. This finding was in the line with the work of Patra et al. (2004) in the experiment that compared mercury, Pb and arsenic with respect to the genotoxic effect of plant systems and the development of genetic tolerance. The death of maize planted in contaminated soil without any treatment might be as a result of toxic effect of the high amount of Pb in the soil. This was buttressed by Nkansah et al. (2010) assertion that metals like mercury, Pb, cadmium and arsenic are toxic at very low concentrations. Umoru (2014) recommended 50 mg/kg of Pb as the critical level for maize uptake. Going by this assertion, the maize planted in the contaminated soil in this experiment exhibited tolerance to Pb. DTMA Y STR tolerated Pb more than DTMA W STR. This experiment also shows that farmers must be sure of the nutrient composition of the manures they apply to their crops as cattle dung and poultry manure used in this experiment contained Pb.

CONCLUSION

Screen-house experiments were conducted to determine the effect of poultry manure composted Mexican sunflower (*Tithonia diversifolia*, poultry manure alone, Composted poultry manure, cattle dung composted with Mexican sunflower (*Tithonia diversifolia)*, cow dung alone and biochar on soil Pb content and nutrient uptake of maize grown in a soil contaminated with Pb in Ibadan, southwestern Nigeria. This experiment showed that DTMA – Y - STR absorbed less amount of Pb than DTMA W STR. The experiment showed that composted organic manure could help in alleviating metal stress in maize crop grown on Pb contaminated soil and immobilize Pb in the soil. Application of composted poultry manure, composted cow dung and biochar applied at 20, 30 and 40 t/ha reduced in Pb concentration maize grown in contaminated soil. This experiment showed that DTMA Y STR absorbed less amount of Pb than DTMA W STR.

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