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Research Article

Liming and Compost Amendment of Heavy Metal Contaminated Soil Reduced Pb Accumulation in *Ocimum gratissimum L*, Enhanced Secondary Metabolism and Chlorophyll Formation

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ABSTRACT

Soil contamination by heavy metals limits plant metabolic processes and development. Technique that immobilizes metal in the soil and reduced uptake by crop is preferred. Effects of liming and compost amendment on Pb immobilization and secondary metabolism of *Osmium gratissimum L.* planted on lead-acid battery wastes contaminated soil were studied. Four levels of lime (0 ton/ha, 2 ton/ha, 4 ton/ha and 8 ton/ha) and compost (0 ton/ha, 10 ton/ha, 20 ton/ha and 30 ton/ha) were used while uncontaminated and contaminated soil without amendments served as checks. Data were collected on growth and yield parameters, nutrient uptake, leaf chlorophyll and secondary metabolites (Total phenols, Terpenoids and Flavonoids) contents. Addition of compost (30 t/ha) and in combination with lime (2 t/ha) reduced post-cropping soil Pb concentration and accumulation in plant. Biomass accumulation was reduced in *Ocimum gratissimum* grown on contaminated soil by 85.23% compared to uncontaminated control. Liming and compost addition however enhanced the growth and yield of Occimum spp on contaminated soil and there was increase in the phenolic and terpenoids production by 78.53% in the plant grown on contaminated soil compared to uncontaminated control. Sole application of lime however inhibited phenolic production except in combination with compost whereas flavonoid production was enhanced by liming. Similarly, there was 56.21% increase in chlorophyll content of Occimum spp grown on contaminated soil amended with 30 t/ha compost in combination with lime at 8 t/ha. Highest rate of compost (30 t/ha) in combination with 2 t/ha lime was more effective in improving the chlorophyll content, growth and yield of *Ocimum gratissimum* on Pb contaminated soil.

Keywords: Lime; Compost lead; Soil; Secondary metabolites; Chlorophyll

INTRODUCTION

Various toxic pollutants have been introduced into the environment though indiscriminate disposal of wastes most especially industrial wastes. These pollutants consist of different organic and inorganic compounds which have detrimental effects on human health and ecosystem in general. Among the inorganic pollutants are the heavy metals such as Cu, Zn, Pb, Hg, Cd and Cr which are of major concern because of their persistence in the environment. Soil contamination with heavy metals is one of the most important environmental factors that disrupts the metabolism of the plants and reduces crop productivity. Primary and secondary metabolism in plant is affected either directly or indirectly by metal contamination through disruption of the metabolic pathways.

Pb in particular is grouped among the most toxic and dangerous elements. It is not an essential element for plants, but can be easily absorbed and accumulated in plants. It induces chlorosis in leaf and blackening of the root system thereby reducing plant growth and productivity. In addition, Pb induces the production of excessive reactive oxygen species which are capable of degrading cell biomolecules and disturbs the uptake and translocation of nutrient elements thereby causing nutrient

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imbalance. To reduce the effect of lead on crop growth and prevent human contamination through food chain, different methods are being proposed.

Since metals are not degradable and their uptake depends on their concentrations in the bioavailable form, immobilization of heavy metals in contaminated media could be an ecologically acceptable method for remediation of contaminated soil for healthy crop production. Immobilization strategies through addition of different organic and inorganic materials have been report. Addition of organic amendment has been reported to decrease the concentration of Pb in metal contaminated soil. It increases soil pH thereby decreasing heavy metal solubility.

As metal solubility is pH dependent, increasing soil pH through liming is also a common practice in agriculture aimed at enhancing field productivity and reducing metal solubility. It reduces soil acidity and increases the availability of some important nutrients such as calcium, magnesium, phosphorus and sulfured. Liming also alters the electrochemical behavior of colloids as a consequence of chemical modifications. Hence, altering the chemical and physical properties of the heavy metal contaminated soil through the use of organic amendments in combination with lime could be a sustainable approach.

Agricultural research on medicinal plants is very few compared to the research on food crops despite the fact that medicinal plants are well endowed with secondary metabolites which make them the integral parts of drug manufacturing companies. They are used as sources of raw materials for drug formulation. However, to avoid drug contamination, there is need for proper monitoring of the source of medicinal plants used for drug formulation. This is very important as the cases of contamination of some medicinal plants and some plant-based drugs by heavy metals have been reported. The danger is compounded with the fact that most medicinal plants because of their inbuilt natural anti-oxidative defense mechanisms are able to survive and grow naturally on contaminated soil and protect themselves from phytotoxicity. This could predispose ignorant/innocent animals and humans relying on these plants for their food and medication to heavy metal contamination.

Study of the response of different medicinal plants to heavy metal contamination with regards to their antioxidant defense system, metal accumulation and secondary metabolism will guide in understanding the behaviour of medicinal plants that are naturally growing or mistakenly cultivated on contaminated soil. More importantly, the biosynthesis of the secondary metabolites in plants depends on genetic, physiological and environmental factor. In this regard, secondary metabolites and photosynthetic pigment production in medicinal plant grown on Pb contaminated soil needs to be investigated. The effect of liming and compost amendments on the metal accumulation, physiological and secondary metabolism of medicinal plants growing on heavy metal contaminated soil must also be determined. This work was carried out to assess the effects of liming and compost amendments of lead-acid battery wastes contaminated soil on soil remediation, growth, Pb and nutrient uptake of *Ocimum gratissimum* grown on lead contaminated soil.

Ocimum gratissimum is a highly valued plant, distributed in many countries of the tropics and subtropics. It has impressive range of medicinal uses with high nutritional value. *Ocimum gratissimum* is extensively used throughout West Africa as a febrifuge, anti- malarial and anti-convulsant. The crushed leaf juice is used in the treatment of convulsion, stomach pain and catarrh. It is rich in amino acids, phenolics, alkaloid, tannins, phytates, terpenoids and flavonoids. This study would help in determining the ability of compost and lime in increasing Pb immobilization in soil and decreasing uptake by *Occimum* plant. On the metal uptake the study would help in investigating the suitability of *Occimum spps* for possible phytoremediation as well as secondary metabolite production in response to contaminated environment.

MATERIALS AND METHODS

Soil sampling and analysis

The experimental soil (Contaminated soil) was collected from Pb contaminated site in Kumapayi, Ibadan, Oyo State, Nigeria. The uncontaminated soil (Normal soil) that was used as control was collected from the crop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria. Composite samples from both soils were taken to the laboratory for the determination of initial soil physicochemical properties. Soil pH in water was determined using a 1:1 soil water ratio with a glass electrode pH meter. Total nitrogen was determined by macrokjedahl, available Phosphorus was determined by Bray P1 method, soil Organic Carbon was determined by Walkley-Black method and exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were determined in 1.0 N ammonium acetate (NH_4OAc) extract. Potassium and sodium were determined using flame photometer while heavy metal (Pb), calcium and magnesium were determined with the atomic absorption spectrophotometer VGP 210 Chicago after wet digestion with 2M HNO_3. The chemical and the physical properties of the soil used for the experiment showed that the soil was slightly acidic (6.37). The organic matter, total nitrogen and available phosphorus were 1.50 g/kg, 0.36 g/kg and 22.46 g/kg respectively. The soil used was low in Nitrogen and organic carbon. The contaminated soil had lead concentration of 11172.5 mg/kg while the normal soil had a lead concentration of 23.45 mg/kg (Table 1).

Table 1: Physical and chemical properties of the Soil and Compost used for the experiment.

Parameters	Contaminated Soil	Normal Soil	Dry Compost
pH (H_2O)	5.93	6.37	

Org C (%)	1.90	3.50	16.72
Total N (g/kg)	0.46	1.36	1.92
Exchangeable base (cmol/kg)			
K	0.13	0.27	6.80
Ca	0.02	0.01	0.43
Mg	0.03	0.68	30.75
Na	3.25	33.50	14.08
Extractable Micronutrients (mg/kg)			
Mn	116.50	88.50	16.00
Fe	52.00	2.30	9.78
Zn	70.00	88.00	2.05
Cu	617.00	44.50	75.00
Particle size distribution (g/kg)			
Sand	64.6	84.6	
Silt	23.4	7.4	
Clay	12.0	8.0	
Heavy metal (mg/kg) Pb (Lead)	11,172.5	23.45	

Experimental procedure and treatments

The treatments were: agricultural lime (Calcium Hydroxide; Ca (OH)$_2$) and Compost. Compost was prepared from Thitonia diversifolia and poultry manure in ratio 3:1. The Phosphorus, Potassium, Calcium and Sodium as well as the Organic Carbon contents of the matured compost were 7.84, 6.80, 0.43, 14.80 and 16.7 cmol/kg respectively while available Nitrogen was 1.92 g/kg (Table 1). Each of the treatments (Lime and Compost) was applied at four levels to give a total of twenty treatments altogether with their various combinations and they were arranged in a Completely Randomized Design (CRD) with three replicates. Uncontaminated and contaminated soil without lime or compost served as control It was a factorial experiment fitted in Completely Randomized Design with 2 factors i.e. Agricultural lime at four levels; 0 t/ha, 2 t/ha, 4 t/ha and 8 t/ha and compost at four levels; 0 t/ha, 10 t/ha, 20 t/ha, and 30 t/ha. Lime at 2, 4 and 8 t/ha means 4, 8 and 16 g of lime per 4 kg soil while compost at 10, 20 and 30 ton/ha means 20, 40 and 60 g of compost per 4 kg soil in the pot respectively. The treatment combinations were; Compost 0 ton/ha+Lime 2 ton/ha (0 g C+4g L per pot), Compost 0 ton/ha+Lime 4 ton/ha (0 g C+8g L per pot), Compost 0 ton/ha+Lime 8 ton/ha (0 g C+16g L per pot), Compost 10 ton/ha+Lime 0 ton/ha (40 g C+0g L per pot), Compost 10 ton/ha+Lime 2 ton/ha (20g C+4g L per pot), Compost 10 ton/ha+Lime 4 ton/ha (20 g C+8 g L per pot), Compos t 10 ton/ha+Lime 8 ton/ha (20 g C+16 g L per pot), Compost 20 ton/ha+Lime 0 ton/ha (40 g C+0 g L per pot), Compost 20 t/ha+Lime 2 t/ha (40 g C+4 g L per pot), Compost 20 ton/ha+Lime 4 ton/ha (40 g C+8 g L per pot), Compost 20 ton/ha+Lime 8 t/ha (40 g C+16 g L per pot), Compost 30 ton/ha+Lime 0 ton/ha (60 g C+0 g L per pot), Compost 30 t/ha + Lime 2 ton/ha (60 g C+4 g L per pot), Compost 30 ton/ha+Lime 4 ton/ha (60 g C+8 g L per pot), Compost 30 ton/ha+Lime 8 ton/ha (60 g C+16 g L per pot). Treatments were applied to the soil one week before planting and the seeds of *Ocimum gratissimum* were sown directly into the pots and monitored for 12 weeks before harvesting. The experiment was repeated for residual trial. Data were collected on the vegetative parameters and at harvesting; the dry matter yield was obtained after air drying to constant weight for 48 hours at 70°C in the Gallenkamp oven. Post-cropping soil analysis was carried out at harvesting following the procedure described above.

Plant nutrient analysis, secondary metabolites and photosynthetic pigment determination.

Dried plant samples were ground and the samples were taken for nutrient determination. Total nitrogen was determined by the

Kjeldahl method, Phosphorus was determined in plant ash using the Vanado-Molybdenum method while macro and micronutrients were determined using atomic absorption spectrometer. For secondary metabolites determination, phenolics was determined by weighing 0.5g of air dried leaf sample into a beaker and was extracted with 5 mls of 80:20 water: acetone: and 0.2% Formic acid. This was filtered and 2mls of the extract was pipetted into a test tube and 0.2 ml Folin-Ciocalteau reagent was added and allowed to stand for 20 mins for colour development. Absorbance was read at 765 nm and concentration for a standard graph was obtained. For flavonoids, 6 mls of 80% methanol was added to 0.5 g of air dried leaf sample and it was left to stand for 2 hours. The extract was filtered into a weighed petri dishes and left to dry in the oven at 400°C. The petri dishes were then reweighed until they reached constant weight. Terpenoid was determined by weighing 0.5 g of air dried leaf sample and 6 mls of petroleum ether was added and the mixture was allowed to stand for 15 minutes. The mixture was filtered and absorbance was read at the wavelength of 420 nm. Chlorophyll content was determined by taking two grammes of fresh leaf samples, crushed (using mortar and pestle) in 10mls of 80% acetone. The extract was later filtered and the filtrate was made up to volume (100 mls) with 80% acetone. 5mls was then taken out of the solution and it was made up to volume (50 mls) with 80% acetone. Absorbance was measured at 652 nm. The total amounts of chlorophyll in the leaves were calculated based on the formula of Mackinney (1941). Total chlorophyll (c)=D652/34.5 (mg per litre)=d652 x 1000/34.5 (grammes per litre).

DATA ANALYSIS

Data were analyzed using ANOVA of the GLM Procedure of SAS package (1999). Means were separated using Least Significant Difference (LSD) and Duncan Multiple Range Test (DMRT) at P<0.05

RESULTS

Effect of Compost and Lime on vegetative parameters of *Ocimum gratissimum* planted on Pb contaminated soil The plant height of *Occimum* was generally reduced in contaminated soil compared to uncontaminated control. The reduction was more pronounced in contaminated soil treated with lime alone at different rates. For instance, sole application of lime to Pb contaminated soil reduced the plant height of *Ocimum gratissimum L* at 12 WAS by 81.92, 74.99 and 84.27% in contaminated soil amended with 2,4 and 8 t/ha of lime respectively more than contaminated control. However, compost application alone at 30 t/ha or in combination with lower rate of lime was able to increase the plant height more than contaminated control. It only reduced the plant height by 38.50% compared to uncontaminated control. Among the treatment combinations (i.e., compost+lime), compost at 30 t/ha in combination with lime at 2 t/ha had the highest mean value (5.43) compared to other treatments ($p \leq 0.05$) including contaminated control (Table 2). Compost amendment of Pb contaminated soil either as sole application or in combination with lime also enhanced leaf formation in *Ocimum gratissimum* more than lime alone. The 10 t/ha of compost with 0 ton/ha of lime had the highest mean number of leaves (7.00). Amendment with 20 t/ha and 30 t/ha compost alone and in combination with 2 t/ha of lime also increased the number of leaves more than that of contaminated control Among all the treatments, the lowest number of leaves was recorded from the plant grown on the contaminated soil treated with 8 t/ha of lime either as sole application or in combination with compost. The effect of compost and lime treatment on leaf area of *Ocimum gratissimum* showed that compost application at 30 t/ha alone and in combination with lime at 2 t/ha gave the highest mean values at each sampling period and differed ($P \leq 0.05$) significantly from control.. Lime alone at 8 t/ha gave the lowest mean leaf area in Ocimum plant (1/98 cm^2) compared with control (4.70 cm^2) (Table 2).

Table 2: Effect of Compost and Lime on *Ocimum gratissimum* vegetative parameters.

Treatments	NOL	LA(cm^2)	PH(cm)
Control (Contaminated soil)	8.33 ± 1.20	4.09 ± 1.13	8.53 ± 2.50
Control (Normal soil)	20.33 ± 7.33	15.01 ± 4.37	29.87 ± 4.79
0 tons/ha compost+2 tons/ha lime	5.33 ± 2.66	2.82 ± 1.98	5.40 ± 3.37
0 tons/ha compost+4 tons/ha lime	6.00 ± 3.46	4.32 ± 2.17	7.47 ± 3.47
0 tons/ha compost+8 tons/ha lime	5.00 ± 2.52	1.98 ± 0.99	4.70 ± 2.35
10 tons/ha compost+0 tons/ha lime	9.33 ± 4.70	6.94 ± 4.57	10.20 ± 5.69
10 tons/ha compost+2 tons/ha lime	12.00 ± 1.15	5.36 ± 0.79	11.07 ± 1.83

10 tons/ha compost+4 tons/ha lime	9.00 ± 2.65	7.61 ± 3.96	13.33 ± 2.82
10 tons/ha compost+8 tons/ha lime	6.33 ± 3.76	6.62 ± 4.18	10.07 ± 5.56
20 tons/ha compost+0 tons/ha lime	16.67 ± 0.67	8.14 ± 7.34	15.40 ± 6.69
20 tons/ha compost+2 tons/ha lime	15.00 ± 3.00	5.42 ± 0.45	11.67 ± 0.38
20 tons/ha compost+4 tons/ha lime	7.67 ± 3.93	5.87 ± 3.02	9.50 ± 5.24
20 tons/ha compost+8 tons/ha lime	5.00 ± 5.00	8.65 ± 8.64	10.40 ± 10.40
30 tons/ha compost+0 tons/ha lime	13.00 ± 2.08	11.07 ± 4.02	18.37 ± 5.73
30 tons /ha compost+2 tons/ha lime	8.67 ± 0.67	10.72 ± 6.22	17.70 ± 3.18
30 tons/ha compost+4 tons/ha lime	7.67 ± 3.84	7.54 ± 5.32	8.93 ± 4.71
30 tons/ha compost+8 tons/ha lime	9.67 ± 1.20	11.54 ± 5.71	17.00 ± 6.03
L.S.D (p≤0.05)	9.80	14.61	16.19

Effect of Lime and compost on the Fresh and dry Weight of Ogratissimum (g/pot) on Pb contaminated soil.

As was observed for the growth parameters, similar effect of compost and lime was also observed on fresh and dry matter yield. There was reduction in the shoot fresh weight of Ocimum grown on Pb contaminated soil compared with uncontaminated soil. Ocimum grown on Pb contaminated soil amended with compost at 10, 20 and 30 t/ha alone or in combination with lime at the rates of 2 and 4 t/ha increased shoot fresh weight compared to contaminated control and sole application of lime. Among these treatment combinations, compost at 30 t/ha alone and in combination with lime at 2 t/ha also gave the highest shoot fresh weight value of 15.13 and 11.99 g respectively and were significantly ($p \leq 0.05$) different from contaminated control (4.13 g). Application of compost at 20 t/ha in combination with lime at 8 t/ha also increased the shoot fresh weight (12.26 g/plant) compared to control. Sole application of lime at 8 t/ha gave the lowest shoot fresh weight (1.73 g/pot) compared to control. There was 85.23% reduction in the air dried shoot weight of *Ocimum gratissimum* grown on contaminated control when compared with uncontaminated control. Application of compost at 30 t/ha and in combination with lime at 2 t/ha gave the highest shoot dry weight of 2.78 and 2.63 g/plant respectively. Sole lime application also gave the lowest shoot dry weight. There was no significant difference between sole compost application at 10 and 30 t/ha compost with lime at 8 t/ha, even though compost at10 t/ha had the highest shoot dry weight (2.28 g/pot) but they were all significantly different from control. Among all the treatments, compost at 30 t/ha in combination with lime 0 t/ha influenced the root fresh weight giving the highest root fresh weight of 4.06 g/pot. It was significantly different from all other treatments and control. There was also an increase in root fresh weight of *Ocimum* grown on Pb contaminated soil treated with compost at 20 t/ha in combination with lime at 8 t/ha, and sole application of compost at 30 t/ha and in combination with 8 t/ha of lime. Compost at 20 t/ha with lime at 4 t/ha gave the highest root fresh weight (2.00) compared to control. On the root dry weight, compost at 30 t/ha combined with lime at 2 t/ha had the highest root dry weight of 0.91 g/pot (Table 3).

Table 3: Effect of compost and lime on *O.gratissimum* Shoot fresh and air-dried weight on Pb contaminated soil.

Treatments	Shoot fresh weight	Shoot Dry weight	Root fresh weight	Root Dry weight
Control (Contaminated soil)	4.13 ± 0.74	1.14 ± 0.33	1.58 ± 0.20	0.26 ± 0.14

Control (Normal soil)	21.90 ± 3.01	7.72 ± 2.24	6.11 ± 2.52	4.04 ± 1.32
0 tons/ha compost+2 tons/ha lime	2.77 ± 0.07	0.58 ± 0.21	0.64 ± 0.01	0.17 ± 0.06
0 tons/ha compost+4 tons/ha lime	5.37 ± 0.32	0.94 ± 0.34	1.76 ± 0.07	0.25 ± 0.04
0 tons/ha compost+8 tons/ha lime	1.73 ± 0.08	0.21 ± 0.09	0.49 ± 0.02	0.11 ± 0.01
10 tons/ha compost+0 tons/ha lime	10.89 ± 1.48	2.28 ± 0.49	2.76 ± 0.45	0.57 ± 0.06
10 tons/ha compost+2 tons/ha lime	8.33 ± 2.75	1.24 ± 0.54	1.87 ± 0.06	0.27 ± 0.05
10 tons/ha compost+4 tons/ha lime	9.31 ± 0.20	1.75 ± 0.68	2.89 ± 0.04	0.53 ± 0.10
10 tons/ha compost+8 tons/ha lime	5.87 ±1.59	1.17±0.77	1.69 ± 0.04	0.25 ± 0.06
20 tons/ha compost+0 tons/ha lime	7.45 ± 1.23	1.89 ± 1.89	1.96 ± 0.09	0.45 ± 0.11
20 tons/ha compost+2 tons/ha lime	8.23 ± 0.24	1.40 ± 0.31	1.82 ± 0.01	0.41 ± 0.17
20 tons/ha compost+4 tons/ha lime	9.25 ± 2.49	1.63 ± 0.38	2.00 ± 0.05	0.35 ± 0.09
20 tons/ha compost+8 tons/ha lime	12.26 ± 2.69	2.78 ± 0.64	3.10 ± 1.19	0.73 ± 0.04
30 tons/ha compost+0 tons/ha lime	15.13 ± 3.40	2.77 ± 2.77	3.06 ± 1.18	0.73 ± 0.09
30tons /ha compost +2tons/ha lime	11.99 ± 2.49	2.63 ± 0.19	4.06 ± 1.42	0.91±0.11
30 tons/ha compost+4 tons/ha lime	5.07 ± 0.04	1.01 ± 0.34	1.66 ± 0.02	0.36±0.08
30 tons/ha compost+8 tons/ha lime	10.32 ± 0.36	2.11 ± 0.56	3.06 ± 0.33	0.62±0.05
L.S.D (p ≤ 0.05)	5.14	1.49	1.71	0.28

Secondary metabolite concentrations in *Ocimum gratissimum* planted on Pb contaminated soil as influenced by Compost and Lime.

An increase of about 78.53% was recorded in terpenoids concentration produced by *Ocimum gratissimum* planted in Pb contaminated soil when compared with that of normal soil. The effect of compost and lime on terpenoids showed that soil amendment with compost and lime generally increased the terpenoids concentration in the plant more than unmended soil. Except in soil treated with compost alone at 30 t/ha with 94 (mg/100 g) terpenoids, amendment with 30 t/ha in combination with lime at 8 t/ha produced the highest concentration of terpenoids (154 mg/100 g) compared to contaminated control which had 118 mg/100 g of terpenoids. The plants that were treated with lime alone at 8 t/ha, compost at 10 t/ha in combination with lime at 8 t/ha and compost at 30 t/ha in combination with lime at 2 t/ha had the same terpenoids concentration of 152 (mg/100 g) each which was significantly higher and different from that of contaminated control. Flavonoid however, was not detected in *Ocimum gratissimum* planted on Pb contaminated soil amended with compost alone and in contaminated control. It was only found in *Ocimum* plants grown on soil treated with lime alone at rates 2, 4 and 8 t/ha as well as their combinations with compost except in the plant grown on soil amended with 20 t/ha compost in combination with different rates of lime. Unlike terpenoids however, flavonoid concentration in the plant from uncontaminated control (Normal soil) was more, though not significantly different from other treatments with flavonoid. The trend of Phenolics production in *Ocimum spp* planted on Pb contaminated soil amended with lime and compost showed that lime addition to contaminated soil inhibited phenolic production except in combination with compost and the higher the lime rate even in the presence of compost, the lower the amount of phenolics produced. It was also found in contaminated and uncontaminated control but was more in the plants from unmended contaminated soil than normal soil with 74.07% increase. *Ocimum* from soil amended with lowest rate of compost (10 t/ha) combined with lowest rate of lime (2 t/ha) produced the highest phenolic concentration of 64 (GAE/100 g). This was followed by those of contaminated control and soil amended with compost at 10t/ha combined with 4 t/ha lime. About 89.06% increase in the phenolics was recorded with compost addition at 10 t/ha in combination with lime at 2 t/ha compared with uncontaminated control (Figure 1).

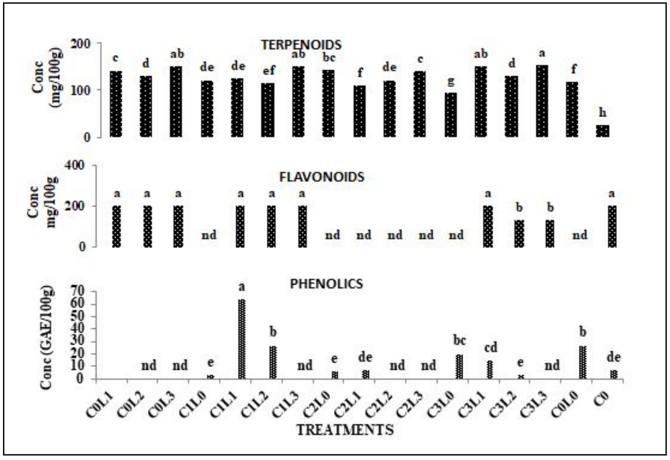

Figure 1: Effect of Compost and Lime on Terpenoids, Flavonoids and Phenolics concentration in *Ocimum gratissimum* on Pb contaminated soil.

Bars carrying the same alphabet are not significantly different from each other at P<0.05

C0L0: Contaminated soil (control); C0: Normal soil (control); C0L1: 0 ton/ha compost+2 tons/ha lime; C0L2: 0 ton/ha compost+4 tons/ha lime; C0L3: 0 ton/ha compost+8 tons/ha lime; C1L0: 10 ton/ha compost+0 ton/ha lime; C1L1:10 ton/ha compost+2 ton/ha lime; C1L2:10 ton/ha compost+4 ton/ha lime; C1L3:10 ton/ha compost+8 ton/ha lime; C2L0: 20 ton/ha compost+0 ton/ha lime;C2L1:20 ton/ha compost+2 ton/ha lime:C2L2: 20 ton/ha compost+4 ton/ha lime; C2L3:20 ton/ha compost+8 ton/ha lime; C3L0: 30 ton/ha compost+0 ton/ha lime; C3L1:30 tons/hacompost+2 ton/ha lime; C3L2:30 ton/ha compost+4 ton/ha lime;C3L3:30 ton/ha compost+8 ton/ha lime. nd=not detected.

Effect of Compost and Lime on Photosynthetic pigment (PP) concentration in *Ocimum gratissimum* planted on Pb contaminated soil.

Conversely, chlorophyll contents of Ocimum planted on contaminated soil was more than that of normal soil (uncontaminated control) both in the treated and untreated soil. The effect of compost and lime on the chlorophyll content showed that higher application rate of compost at 30 t/ha in combination with higher lime rate at 8 t/ha increased its chlorophyll content compared to other treatments. It gave the highest chlorophyll concentration of 4.75 µg/g FW when compared to contaminated and uncontaminated control which had concentration of 2.08 µg/g FW and 0.78 µg/g FW respectively. Sole application of lime amendment to Pb contaminated soil at rates of 2 t/ha and 8t/ha however, reduced the chlorophyll concentrations in Ocimum by 37.5 and 84.62% respectively compared to contaminated control. Similarly, the chlorophyll concentrations in Ocimum grown in contaminated soil treated with compost at rates 20 t/ha combined with 2 t/ha and 4 t/ha were reduced by 65.38 and 59.62% respectively when compared with contaminated control (Figure 2).

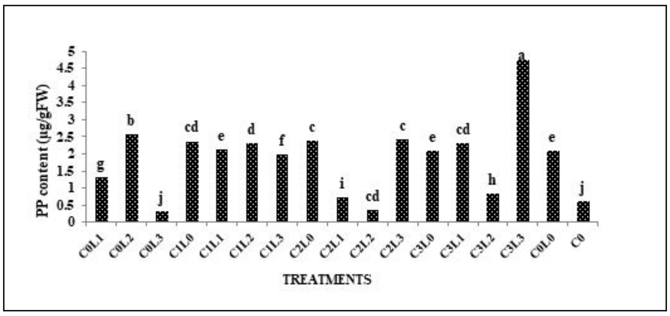

Figure 2: Effect of Compost and Lime on Photosynthetic Pigment (PP) concentration of Ocimum gratissimum.

Bars carrying the same alphabet are not significantly different from each other at P<0.05 C0L0: 0 ton/ha compost+0tons/ha lime (Contaminated soil control); C0: Normal soil control; C0L1: 0 ton/ha compost+2 tons/ha lime; C0L2: 0 ton/ha compost+4 tons/ha lime;

C0L3: 0 ton/ha compost+8 tons/ha lime; C1L0: 10 ton/ha compost+0 ton/ha lime;

C1L1:10 ton/ha compost+2ton/ha lime; C1L2:10 ton/ha compost+4ton/ha lime;

C1L3:10 ton/ha compost+8ton/ha lime; C2L0: 20 ton/ha compost+0ton/ha lime;

C2L1:20 ton/ha compost+2 ton/ha lime:C2L2: 20 ton/ha compost+4 ton/ha lime;

C2L3:20 ton/ha compost+8 ton/ha lime; C3L0: 30 ton/ha compost+0 ton/ha lime;

C3L1: 30 tons/hacompost+2 ton/ha lime; C3L2:30 ton/ha compost+4 ton/ha lime;

C3L3:30 ton/ha compost+8 ton/ha lime.

Effect of compost and lime treatments on post-cropping soil nutrients and Pb concentration on lead contaminated soil.

After harvesting, significant reduction in lead concentration was recorded in response to liming and compost amendment except in soil treated with 8 t/ha lime. Compost at 20 t/ha in combination with lime at 2 t/ha gave the lowest Pb concentration (4142.00 mg/kg). Other amendments that reduced lead concentration were the sole application of lime at 4 t/ha giving mean value of 4428.00 mg/kg Pb. Compost10 t/ha in combination with lime at 2 t/ha gave 4985.00 mg/kg and higher rate of compost (30 t/ha) in combination with higher rates of lime at 4 and 8 t/ha gave 4188 and 4885.00 mg/kg respectively compared to control (9166 mg/kg) (Figure 3). It was observed that application of lime and compost generally increased the nutrient contents of contaminated soil compared to the control (unmended contaminated soil). Organic carbon content and other nutrients (Ca, Mg, P and K) responded positively to the treatments. The Nitrogen content of Pb contaminated soil reduced from 0.46% which was the pre-cropping value to 0.17% after planting. Among all the treatment combinations, addition of 8 t/ha improved the N, OC and P contents more than other treatments giving mean values of 0.53%, 2.15% and 9.25 mg/kg respectively. In the case of Potassium, sole application of Compost at 30 t/ha and in combination with lime at 2 t/ha increased the K-content when compared to control and the pre-cropping value of 0.13% giving the mean values of 2.55 and 2.44% respectively. The value of sodium also increased when compared with the pre-cropping value but sole application of lime at 2 t/ha and compost 20 t/ha in combination with 8 t/ha lime decreased the concentration of sodium when compared with control and the pre-cropping value. Similar to Sodium, there was an increase in Magnesium concentration when compared to the pre-cropping value and control with addition of compost alone at 30 t/ha having significant effect on the concentration of Magnesium. Sole application of lime at 8 t/ha however increased considerably the availability of Phosphorus. Concentrations of micronutrients like Zn and Cu were also increased in response to liming and compost amendments (Table 4).

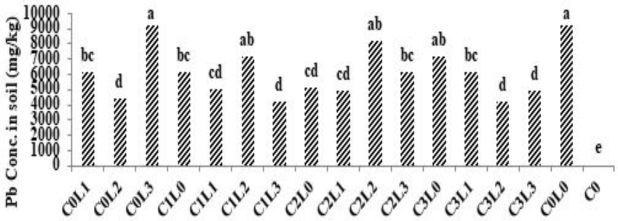

Figure 3: Effect of Compost and Lime on Lead Concentration of Pb contaminated soil

Bars carrying the same alphabet are not significantly different from each other at P<0.05 (LSD).

C0L0: 0 ton/ha compost+0tons/ha lime (Contaminated soil control)

C0: 0 ton/ha compost (Normal soil control); C0L1: 0 ton/ha compost+2 tons/ha lime

C0L2: 0 ton/ha compost+4 tons/ha lime; C0L3: 0 ton/ha compost+8 tons/ha lime

C1L0: 10 ton/ha compost+0 ton/ha lime; C1L1: 10 ton/ha compost+2 ton/ha lime

C1L2: 10 ton/ha compost+4 ton/ha lime; C1L3: 10 ton/ha compost+8 ton/ha lime

C2L0: 20 ton/ha compost+0 ton/ha lime; C2L1: 20 ton/ha compost+2 ton/ha lime

C2L2: 20 ton/ha compost+4 ton/ha lime; C2L3: 20 ton/ha compost+8ton/ha lime

C3L0: 30 ton/ha compost+0 ton/ha lime; C3L1: 30 tons/ha compost+2 ton/ha lime

C3L2: 30 ton/ha compost+4 ton/ha lime; C3L3: 30 ton/ha compost+8 ton/ha lime

Table 4. Effect of compost and lime on post-cropping soil nutrients concentration.

				Exchangeable base				Extractable Micronutrients			
Treatments	ORG C (%)	Total N (%)	AVAIL P	K	Ca	Mg	Na	Mn	Fe	Zn	Cu
			mg/kg								
Control (Contaminated soil)	0.69^{c}	0.17^{c}	3.79^{b}	0.31^{c}	2.85^{e}	0.95^{c}	0.87^{d}	181.00^{a}	232.00^{ab}	25.00^{d}	4.89^{e}
Control (Normal soil)	1.48^{ab}	0.36^{ab}	241.57	1.22^{c}	8.08^{d}	0.97^{c}	4.39^{b}	175.00^{ab}	305.00^{ab}	68.00^{ab}	10.50^{bc}
0 tons/ha compost +2 tons/ha lime	1.22^{b}	0.29^{b}	1.08^{c}	2.13^{ab}	4.92^{e}	1.36^{ab}	2.19^{c}	166.00^{ab}	464.00^{a}	52.00^{abc}	14.20^{b}

0 tons/ha compost +4 tons/ha lime	1.40^{b}	0.34^{ab}	2.42^{ab}	1.26^{c}	13.60^{a}	0.90^{c}	4.49^{b}	175.00^{ab}	268.00^{ab}	56.00^{abc}	11.50^{bc}
0 tons/ha compost +8 tons/ha lime	2.15^{a}	0.53^{a}	9.25^{a}	$1.42b^{c}$	13.15^{a}	0.81^{c}	$3.09b^{c}$	155.00^{ab}	188.00^{bc}	48.00^{c}	10.80^{bc}
10 tons/ha compost +0 tons/ha lime	1.14^{b}	0.28^{b}	1.42^{c}	1.52^{bc}	9.88^{c}	1.28^{ab}	6.89^{a}	95.00^{b}	285.00^{ab}	68.00^{ab}	6.20^{d}
10 tons/ha compost +2 tons/ha lime	1.52^{ab}	0.36^{ab}	3.04^{b}	1.54^{bc}	9.43^{c}	0.81^{c}	3.84^{bc}	30.7^{c}	286.00^{ab}	55.00^{abc}	18.80^{ab}
10 tons/ha compost +4 tons/ha lime	1.93^{a}	0.46^{a}	2.29^{bc}	1.6^{bc}	14.77^{a}	1.25^{ab}	6.83^{a}	166.00^{ab}	266.00^{ab}	71.00^{a}	9.70^{c}
10 tons/ha compost +8 tons/ha lime	1.30^{abc}	0.32^{ab}	1.87^{bc}	1.62^{bc}	14.55^{a}	1.09^{bc}	6.53^{ab}	182.00^{a}	242.00^{ab}	68.00^{ab}	10.60^{bc}
20 tons/ha compost +0 tons/ha lime	1.52^{ab}	0.36ab	3.5^{b}	1.93^{b}	8.53^{cd}	1.32^{ab}	4.52^{b}	166.00^{ab}	258.00^{ab}	64.00^{ab}	10.80^{bc}
20 tons/ha compost +2 tons/ha lime	1.13^{bc}	0.28^{b}	0.26^{d}	1.83^{b}	10.56^{b}	1.11^{b}	5.09^{b}	98.00^{b}	337.97^{b}	58.00^{abc}	13.10^{ab}
20 tons/ha compost +4	1.22^{b}	0.29^{b}	0.54^{d}	1.99^{b}	12.23^{ab}	1.14^{b}	3.97^{bc}	178.00^{ab}	184.00^{bc}	44.00^{c}	13.10^{ab}

tons/ha lime											
20 tons/ha compost +8 tons/ha lime	0.77^{c}	0.19^{c}	1.36^{bc}	1.3^{c}	11.03^{ab}	0.81^{c}	2.91^{c}	120.67^{bc}	130.00^{c}	31.33^{d}	5.20^{d}
30 tons/ha compost +0 tons/ha lime	1.46^{b}	0.35^{ab}	2.75^{b}	2.55^{a}	10.83^{b}	1.63^{a}	6.83^{a}	192.00^{a}	166.00^{bc}	68.00^{ab}	7.00^{d}
30 tons /ha compost +2 tons/ha lime	1.24^{bc}	0.29^{b}	1.92^{bc}	2.44^{a}	12.10^{ab}	1.28^{ab}	6.70^{a}	182.00^{a}	207.00^{bc}	46.00^{c}	12.20^{bc}
30 tons/ha compost +4 tons/ha lime	0.33^{c}	0.16^{c}	1.00^{c}	1.74^{b}	9.60^{c}	1.03^{b}	3.11^{bc}	20.00^{c}	174.67^{bc}	32.00^{d}	10.80^{bc}
30 tons/ha compost +8 tons/ha lime	1.36^{abc}	0.32^{ab}	2.21^{b}	2.50^{a}	10.50^{b}	1.56^{a}	4.36^{b}	12.20^{c}	244.00^{ab}	45.00^{c}	20.2^{a}
LSD	0.65	1.02	1.02	1.23	8.25	0.83	2.28	82.97	136.87	23.95	6.07

Effect of Compost and Lime treatment on nutrient and Pb uptake by *Ocimum gratissimum* grown on Pb Contaminated soil.

There was no significant effect of amendment on the nutrient uptake by *Ocimum*. However, for potassium content of *Ocimum*, amendment with compost at 30 t/ha alone increasing the potassium content with mean value of 6.34% as against contaminated control which gave a mean value of 3.72%. It was also observed that the application of 20 t/ha in combination with 2 t/ha lime increased the calcium content of *Ocimum* planted on Pb contaminated soil. Only amendment with 20 t/ha compost alone and in combination with 2 t/ha lime increased the nitrogen content of *Ocimum* when compared with control (Table 5). Results of the effect of compost and lime addition on Pb concentration in *Ocimum gratissimum* showed that all the treatments significantly decreased the accumulation of Pb in plant tissue compared to unamended contaminated control with sole application of higher rate of lime (8 t/ha) and in combination with highest rate of compost (C3L3) being more effective (Figure 4). The lowest concentration was however recorded in uncontaminated control treatment.

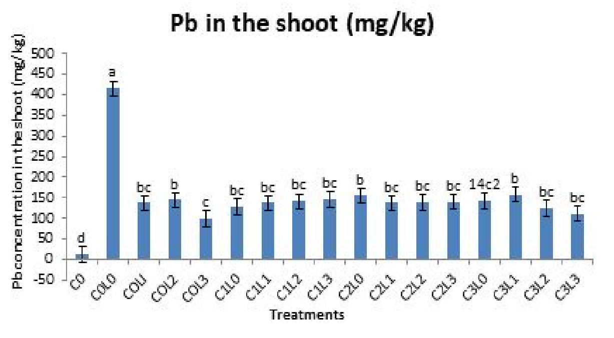

Figure 4: Effect of Compost and Lime on Lead Concentration in the shoot of *Ocimum gratissimum*.

C0L0: 0 ton/ha compost+0tons/ha lime (Contaminated soil control)

C0: 0 ton/ha compost (Normal soil control); C0L1: 0 ton/ha compost+2 tons/ha lime

C0L2: 0 ton/ha compost+4 tons/ha C0L3: 0 ton/ha lime; compost+8 tons/ha lime

C1L0: 10 ton/ha compost+0 ton/ha lime; C1L1: 10 ton/ha compost+2 ton/ha lime

C1L2: 10 ton/ha compost+4 ton/ha lime; 10ton/ha C1L3: compost+8 ton/ha lime

C2L0: 20 ton/ha compost+0 ton/ha lime; 20ton/ha C2L1: compost+2 ton/ha lime

C2L2: 20 ton/ha compost+4 ton/ha C2L3: 20ton/ha lime; compost+8 ton/ha lime

C3L0: 30 ton/ha compost+0 ton/ha lime; C3L1: 30 tons/ha compost+2 ton/ha lime

C3L2: 30 ton/ha compost+4 ton/ha lime; C3L3:

Table 5: Effect of Compost and Lime on nutrient uptake by *Ocimum gratissimum* grown on Pb contaminated soil.

				Exchangeable base			Extractable Micronutrients	
Treatments	**Total N**	**AVAIL P**	**K**	**Ca**	**Mg**	**Na**	**Mn**	**Fe**
Control (Contaminated soil)	1.22^{ab}	0.56^{a}	3.72^{abc}	1.17^{bc}	0.49^{ab}	1.62^{a}	0.21^{a}	0.11^{a}
Control (Normal soil)	1.63^{a}	0.82^{a}	5.21^{ab}	2.96^{a}	0.65^{a}	0.12^{c}	0.13^{ab}	0.06^{b}
0 tons/ha compost+2 tons/ha lime	0.95^{b}	0.31^{a}	1.96^{abc}	0.48^{c}	0.15^{bc}	0.27^{b}	0.13^{ab}	0.07^{ab}
0 tons/ha compost+4 tons/ha lime	0.97^{b}	0.27^{a}	1.98^{abc}	0.49^{c}	0.15^{bc}	0.49^{b}	0.08^{abc}	0.03^{b}
0 tons/ha compost+8 tons/ha lime	0.95^{b}	0.33^{a}	0.86^{c}	0.17^{c}	0.08^{c}	0.21^{b}	0.05^{c}	0.02^{b}
10 tons/ha compost+0 tons/ha lime	0.69^{b}	0.43^{a}	4.17^{ab}	1.96^{ab}	0.40^{ab}	0.28^{b}	0.09^{abc}	0.02^{b}
10 tons/ha compost+2 tons/ha lime	1.04^{b}	0.43^{a}	6.15^{a}	2.48^{ab}	0.63^{a}	0.70^{ab}	0.11^{abc}	0.11^{a}
10 tons/ha compost+4 tons/ha lime	1.04^{b}	0.54^{a}	5.92^{a}	2.27^{ab}	0.59^{ab}	0.63^{ab}	0.08^{abc}	0.09^{a}
10 tons/ha compost+8 tons/ha lime	0.94^{b}	0.33^{a}	2.97^{abc}	0.91^{c}	0.25^{c}	0.27^{b}	0.03^{c}	0.03^{b}
20 tons/ha compost+0 tons/ha lime	1.61^{a}	0.52^{a}	5.83^{a}	2.67^{a}	0.64^{a}	0.62^{ab}	0.15^{ab}	0.03^{b}
20 tons/ha compost+2 tons/ha lime	1.61^{a}	0.46^{a}	6.20^{a}	2.74^{a}	0.61^{a}	0.61^{ab}	0.19^{a}	0.02^{b}
20 tons/ha compost+4 tons/ha lime	1.06^{b}	0.42^{a}	4.14^{ab}	0.35^{abc}	0.44^{ab}	0.35^{b}	0.10^{abc}	0.01^{b}
20 tons/ha compost+8 tons/ha lime	0.67^{b}	0.16^{a}	2.03^{abc}	0.87^{c}	0.18^{c}	0.07^{c}	0.05^{c}	0.01^{b}
30 tons/ha compost+0 tons/ha lime	1.47^{ab}	0.49^{a}	6.34^{a}	2.26^{ab}	0.62^{a}	0.42^{b}	0.14^{ab}	0.05^{b}

30 tons /ha compost+2 tons/ha lime	1.48^{ab}	0.52^{a}	6.00^{a}	2.44^{ab}	0.65^{a}	0.87^{ab}	0.13^{ab}	0.03^{b}
30 tons/ha compost+4 tons/ha lime	1.34^{ab}	0.39^{a}	3.88^{abc}	1.41^{ab}	0.41^{ab}	0.54^{ab}	0.08^{abc}	0.01^{b}
30 tons/ha compost+8 tons/ha lime	1.49^{ab}	0.53^{a}	5.27^{ab}	1.95^{ab}	0.54^{ab}	0.72^{ab}	0.14^{ab}	0.02^{b}
LSD	1.02	0.45	3.81	1.69	0.42	0.63	0.13	0.05

DISCUSSION

Although growth reduction is a well-known effect of the toxic impact of heavy metals, it was observed in this study that the sole application of compost at 30 t/ha and in combination with lime at 2 t/ha positively improved the growth and yield of *Ocimum gratissimum* in lead contaminated soil. This can be correlated with the findings of that application of manure to either uncontaminated or contaminated soils improves yield. The major benefits of manure addition to soil are related to the increase in organic matter content and biological activity. Organic matter from manure acts as a nutrient pool, improves nutrient cycling, increases CEC and buffer capacity, reduces compaction, improves soil physical properties, and reduces metal phytotoxicity. Organic amendment like compost has also been reported to contain a high proportion of humified Organic Matter (OM) which is capable of decreasing the bioavailability of heavy metals in the soil. Several studies have shown that application of OM (farmyard manure, compost, peat soil) reduced heavy metal accumulation in crop plants (corn, wheat and radish). The OM forms strong complexes with heavy metals which results in their immobilization in the soil.

Conversely, application of higher rate of lime at 8 t/ha (which was expected to increase crop yield on contaminated soil) was found to reduce the growth of *Ocimum gratissimum*. This was similar to the study of Ingemarsson, who found that higher concentrations of slaked lime at 6 ton/ha and 9 ton/ha inhibited plant growth and gave an extremely low plant yield. The high dose of lime (8 ton/ha) could result in nutrient stress and nutrient imbalance for *O.gratissimum* during growth due to unavailability of some essential nutrients most especially the micronutrients. Solubity of some important macronutrients like P and N also varies and are pH dependent. For instance, P is soluble under slightly acidic medium. Increase in pH might have reduced P solubility and hence P deficiency in the plant. Another reason as was suggested by) could be due to increase in the transformation and solubility of PbS (Galena) under high liming condition. This could have been responsible for the stunted growth and general growth reduction observed under 8 t/ha liming.

It has also been reported that heavy metal stress causes an increase in the synthesis of secondary metabolites. This was seen in the case of terpenoids and phenolics which were more in the plant grown on contaminated soil compared to that of uncontaminated soil. The effect of metal contamination on secondary metabolite production was also confirmed by where an increase in eugenol concentration was reported in an occimum plant exposed to Cr. Application of compost at the rate of 10 t/ha with lime at 2 t /ha gave 89.06% increase in the concentration of phenolics while terpenoids concentration was increased by 74.07% in plant grown on contaminated control compared to uncontaminated control. An enhancement of the amount of secondary metabolites has been observed under different environmental factors and stress conditions. An increase in phenolics and terpenoids could be due to the increase in the activity of the enzymes involved in their metabolism as was reported by suggesting their synthesis under heavy metal stress. Occimum naturally is identified with high terpenoid content but it was clear from this study that terpenoid production in Occimum is a function of prevailing environmental conditions. Under stressful condition its production could be enhanced to be able to play its protective roles. This might be one of the strategies being employed by Occimum gratissimum for protection against oxidative stress. Cellular antioxidants have been reported to play an important role in inducing resistance in plants exposed to various abiotic stresses by maintaining the internal homeostasis and protecting the plants against attack by free radicals which could lead to oxidative stress. The flavonoid synthesis varies and is also induced by some ecological factors but liming seems to enhance flavonoid synthesis more than other treatments. It was found that compost application alone did not favor flavonoid production except in the presence of lime at any rate except in combination with 20 t/ha compost. It was also not discovered in the plant grown on unmended Pb contaminated soil which further confirms the fact that its production was induced by liming. It is believed that heavy metal pollution probably inhibited some necessary enzymes for flavonoid synthesis whereas liming activated them due to change in pH. This was confirmed by who carried out some studies on some fluoride polluted legume species which showed changing in amount and number, appearance or disappearance of leaf flavonoids in comparison with control. In this study, it is clear that variation in flavonoid concentration in Pb contaminated soil is a response to Pb contamination and they may have a protective defensive role against heavy metal contamination.

Previous studies had indicated that heavy metals interfere with chlorophyll synthesis either through direct inhibition of an enzymatic step or by inducing deficiency of an essential nutrient.

Most plants have been shown to exhibit some deleterious consequences of metal toxicity on chlorophyll at higher levels. In this study however, there was 56.21% increase in the chlorophyll content of *Ocimum gratissimum* grown on contaminated soil most especially in soil amended with compost at 30 t/ha in combination with lime at 8 t/ha. The increase in the chlorophyll content confirmed the involvement of photosynthetic pigments in antioxidative system under abiotic stress. The production was in turn enhanced with the availability of nutrients which were supplied by the organic amendments compared to unamended and uncontaminated soil. There was however a decrease in the leaf chlorophyll content of *Ocimum gratissimum* grown on soil treated with 8 t/ha lime alone which further confirmed the positive role of organic amendment in photosynthetic pigments production.

Liming, though increased the concentrations of some important elements in the post-cropping soil analysis most especially at the rate of 8 t/ha but there was considerable reduction in the concentrations of these elements in the plant tissues. For example, phosphorus content was improved by higher liming rates compared to other treatments but its concentration in plant tissue was low reported that liming of acid soils caused a moderate not high pH increase which enhance phosphorus availability. The highest values of plant nutrients were mostly recorded in plants grown on contaminated soil amended with compost in combination with lower rates of lime. Ca was also found to increase under liming probably due to increase in calcium hydrite in response to liming

From the result of the Standard Measured and Testing program, it was also reported that liming was effective on immobilization of other heavy metals except Pb most especially at higher concentration. Pb solubility was said to be enhanced in pH values that range between 6 and 8 due to dissolution of Pb-organo complex at high pH and oxidation of PbS. This was confirmed in this study with the higher Pb concentration in the post cropping soil analysis of contaminated soil that received sole application of lime at 8 t/ha, (though lower than that of unamended soil) but could be associated with the ineffective immobilization of Pb by lime except in combination with compost. Higher rate of lime ironically was in turn found to reduce Pb content in the plant tissue compared to other treatments most especially as sole treatment and in combination with the highest rate of compost. The plant tissue Pb content was found to be significantly reduced in response to all the amendments both at sole or combined applications compared to the unamended contaminated control treatment.). This was because, lime addition to soil most especially in combination with organic manure at the right quantity has been reported to moderately increase pH and induce pozzolanic reaction to form C-S-H and C-A-H which enhances metal immobilization in soil. This in turn decreases metal uptake by plant as rightly observed from this study.

CONCLUSION

Addition of lime and compost reduced the post cropping Pb concentration in soil compared to unmended soil and consequently reduced the uptake by plant. Heavy metal stress was found to increase terpenoid production in Occimum compared to uncontaminated soil. Sole application of lime to contaminated soil inhibited phenolic production except in combination with compost and the higher the lime rate, the lower the amount of phenolics produced whereas flavonoid production was enhanced in the presence of lime. Chlorophyll contents of Ocimum planted on contaminated soil was also found to be more than that of normal soil (uncontaminated control) both in the treated and untreated soil. The study also showed that compost applied at 30tons/ha aided the growth, yield and chlorophyll content of *Ocimum gratissimum* on lead contaminated soil which gave the indication that compost made from Thitonia diversifolia can ameliorate the effect of contamination and it is also a good source of nutrient. High dose of lime 8 ton/ha usage should not be encouraged as it had a limiting effect on growth, yield and chlorophyll content of *Ocimum gratissimum*.

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