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Reduction of Lead Bioavailability and Phytotoxicity in Pb-Slag Contaminated Soil Using Soil Mixing and Compost-Modified Biochar

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Abstract

Food security and human safety are being threatened by heavy metal contamination of agricultural lands. Several physical and biological methods have been employed separately for soil remediation. In this study, effects of combining soil mixing with compost (C) and cow-dung (CD) for reduction and immobilization of Pb in the soil as well as growth, Pb uptake and biochemical responses of maize grown on contaminated soil were investigated. Lead contaminated soil mixed with uncontaminated soil at different ratios to give 0%, 25%, 50%, 75% and 100% levels of contamination were further mixed with C and CD at four different levels (0, 10 20 and 30 t/ha) before planting of maize. Data were collected on maize growth and yield, Photosynthetic Pigments (PP), stress indicators (proline and glycine betaine) contents as well as Pb uptake by maize crop and post-cropping soil Pb concentrations. Pb concentration was reduced by 29-85% in soil mixtures while, C and CD further reduced Pb by 69-77% and 42-66%, respectively. Combined treatments reduced Pb uptake, enhanced maize tolerance and growth as no germination was recorded in 100% Pb contaminated soil. Dry matter accumulation and PP were more in maize crop grown on compost treated soils compared with those grown on soil mixtures only. Proline and glycine betaine contents in maize leaf were reduced in treated plants than untreated plants. Combination of soil mixing with organic amendments could be a better approach for reducing Pb uptake by maize crop and enhanced maize growth on contaminated soil.

Keywords: Heavy metal: Maize: Organic amendment: Osmolytes: Oxidative stress: Restoration

Introduction

Crop production is reduced by both biotic and abiotic stress factors. Abiotic factors such as poor soil fertility, drought and soil contamination with heavy metals pose serious challenges to crop production (Liu et al., 2012; Feng et al., 2013). Among these, the most worrisome is soil contamination with heavy metals. It reduces soil fertility, causes yield reduction and food poisoning through food chain (John et al., 2007; Kozhevnikova et al., 2009; Adejumo et al., 2011). Heavy metals find their way into the soil, air and water bodies through natural and anthropogenic sources (Paz-Alberto et al., 2007). They are capable of bio-accumulating in living systems thereby causing metabolic disruption and death (Minaii et al., 2008; Pant et al., 2011; Krzesłowska, et al., *2010;* Kaur et al., 2013).

Lead (Pb), for instance, has negative effects on crop growth and development (Eun et al., 2000; Islam et al., 2007; Kopittke et al., 2007). Hossain et al. (2012) reported that Pb affects plant metabolic activities in various ways. It hinders photosynthetic pigments formation, competes with the essential elements in the plant and induces excessive production of Reactive Oxygen Species (ROS), thereby causing phyto-toxicity (Liu et al., 2010; Liu et al., 2012; Feng et al., 2013). The over-production of ROS in plants destroys cell's bio-molecules like protein, lipid, and carbohydrate molecules, interrupts with the DNA synthesis in plant and causes oxidative stress (Malecka et al., 2009; Schützendübel and Polle, 2002; Shah et al., 2011; Kaur et al., 2012). Pb contamination of agricultural land has also been reported to cause reduction in the growth and yield of maize (Adejumo et al., 2014). With the increase in human population and the demand for food, agricultural production must be increased so as to feed the ever-increasing population. Meanwhile, available land resources for agricultural production are reducing daily due to contamination with toxic metals from anthropogenic sources. To achieve increase in food production the abandoned contaminated lands must be brought under cultivation. Strategies must be developed to enhance crop production on contaminated sites and reduce toxic metal uptake.

The use of organic amendment like compost and cow-dung has been reported to reduce metal bioavailability (Kham et al., 2000 and Adejumo et al., 2010) and re-vegetate Pb contaminated site (Adejumo et al., 2012; Amos et al., 2015). Compost addition has also been reported to supply the nutrients needed for plant growth and at the same time help in immobilizing heavy metal in contaminated soil thereby minimizing uptake by plant (Bolan et al., 2003; Rennevan et al., 2007; Adejumo et al., 2014). Physical methods like soil washing and soil mixing have also been employed to reduce the level of contaminants in soil (Adejumo et al., 2015). Though, there was reduction in Pb concentration, but none of these could give total restoration of contaminated sites for crop production when used separately (McGrath et al., 2002; Mangkoedihardjo and Surahmaida, 2008). Hence, it was hypothesized in this study that using sustainable methods of diluting contaminated soil with uncontaminated soil and further addition of organic amendments might reduce the Pb concentration or immobilize Pb and enhance crop production on contaminated soil. Combination of two or more different strategies could be more effective and was therefore investigated in this study. The goals were to enhance plant establishment, growth, yield and reduce crop contamination by heavy metals. The use of soil mixture and organic amendments for reducing bioavailability and phytotoxicity of Pb in contaminated soil could be a better approach. Meanwhile, there is dearth of information regarding the use of organic amendments in combination with soil mixing for crop production on contaminated soil. Therefore, this research was carried out to compare the sole and combined effects of soil mixing with uncontaminated soil (Physical method) and organic amendments (Biological method) in enhancing crop production on Pb contaminated soil and reduce Pb uptake.

Maize (Zea mays L.) which is one of the most widely cultivated cereal crops especially in Sub-Sahara Africa was used for this study. It is a multipurpose crop which provides food for human being, feed for livestock and raw materials for industries. Its production is reduced by both biotic and abiotic stress factors. The growth, yield and tolerance levels of two maize varieties grown on the contaminated and treated soils were assessed in this study. Plants have also been reported to survive stress through production of different antioxidants and osmolytes like phenolics, proline and glycine betaine (Mishra et al., 2006; Jiang and Liu, 2007; Gupta et al., 2009; Handique and Handique, 2009; Gohari et al., 2012; Hayat et al., 2013; Adejumo et al., 2015). The roles of these combined strategies on the production of these osmolytes in stressed maize plants and the biochemical mechanisms induced for growth and survival of the two maize varieties were also investigated.

Materials and Methods

Soil Collection and Pretreatment

The study was carried out at the Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Oyo state, Nigeria. The geographical location is 7^0 24'N3^0 54'E, 234 above sea level. The contaminated soil used for the study was collected from the dumpsite of a defunct lead-acid battery manufacturing company at Lalupon in Lagelu Local Government Area of Ibadan, Oyo State, Nigeria. The topsoil was collected randomly from different points on the site at a depth of 0-20 cm. It was then mixed, air-dried, broken up, homogenized, and sieved through a 2-mm mesh screen. Following the same procedure, the uncontaminated soil was collected from the fallow land of the crop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria. It was also collected at the surface layer (0-20 cm), air dried, broken up, homogenized and sieved through a 2-mm mesh screen. Composite samples were taken from contaminated and uncontaminated soils for pre-cropping soil analysis following standard procedures. The results of the analysis showed that uncontaminated soil was close to neutral (6.56) while, the contaminated soil was acidic (4.60). Lead concentration was 175 times more in contaminated soil than uncontaminated soil with contaminated and uncontaminated soils having 63006.0 and 360.2 mg/kg Pb, respectively. The micronutrient contents were also more in contaminated soil than uncontaminated soil. The uncontaminated soil however, contained more of organic carbon, total nitrogen and available phosphorus compared to their values in contaminated soil.

Experimental Procedure

Soil mixing

The physical remediation method was carried out by mixing contaminated soil with uncontaminated soil at different ratios. One (1) kg of these soils was filled into each pot. After mixing the soil, the Pb concentrations in each soil mixture was analysed and were; 360.2mg/kg, 9,367mg/kg, 21,553mg/kg, 44,625mg/kg and 63,006mg/kg, respectively, in different soil mixtures to give five different levels of soil contamination having different Pb concentrations and denoted as 0%: 360.2 mg/kg Pb, 25%: 9,367 mg/kg Pb, 50%: 21,553 mg/kg Pb, 75%: 44,625 mg/kg Pb and 100%: 63,006 mg/kg Pb. The normal soil containing background level of Pb was used as control. This soil was not mixed with contaminated soil, but, since heavy metal is said to be present in every soil at a background level as they are naturally occurring metals in the soil. This is why there is a permissible background level that is recognized globally for each metal in the soil. In this study, the normal soil that was used as control also contained small concentration of Pb. Though, relatively higher than the background level recommended by European Union (2002, 2006) for Pb, the level was within the permissible level in soils. The Pb concentration in the normal soil is therefore classified as 0% Pb contamination for the purpose of this experiment because, it was not mixed with contaminated soil like other soil mixtures used. Similarly, in comparison with the Pb concentration in the 100% Pb contaminated soil, these are also equivalent to 0.5, 14.9, 34.2 and 70.8% Pb, in control soil 1, containing 0 g of contaminated soil + 1000 g of normal soil, soil 2 containing 250 g of normal soil + 750 g of contaminated soil), soil 3 containing 500g of normal soil + 500g of contaminated soil and soil 4 containing 750g of normal soil + 250 g of contaminated soil, respectively {i.e. soil 1 (0% Pb contaminated soil = 0.5% Pb), soil 2 (25% Pb contaminated soil = 14.9% Pb), soil 3 (50% Pb contaminated soil =34.2% Pb), soil 4 (75% Pb contaminated soil = 70.85% Pb) and soil 5(100% Pb contaminated soil)}. The control soil had 360.2 mg/kg Pb, while the concentration of Pb in other soil mixtures containing contaminated soil was abnormally high due to high concentration of Pb in this battery slag. The soil mixtures are as shown below:

$\text{Soil 1} = \text{0\% contaminated soil (360.2 mg/kg Pb)} = \text{0g contaminated soil} + \text{1000g uncontaminated soil}$

$\text{Soil 2} = \text{25\% contaminated soil (9,367 mg/kg Pb)} = \text{250g contaminated soil} + \text{750g uncontaminated soil}$

$\text{Soil 3} = \text{50\% contaminated soil (21,553 mg/kg Pb)} = \text{500g contaminated soil} + \text{500g uncontaminated soil}$

$\text{Soil 4} = \text{75\% contaminated soil (44,625 mg/kg Pb)} = \text{750g contaminated soil} + \text{250g uncontaminated soil}$

$\text{Soil 5} = \text{100\% contaminated soil (63,006 mg/kg Pb)} = \text{1000g contaminated soil} + \text{0g uncontaminated soil}$

Organic amendments

This was carried out with the use of two types of organic amendments (Mexican sunflower compost; MSC and cow-dung; CD) at four different levels (0, 10, 20 and 30 t/ha). The compost was prepared from Mexican sunflower and poultry manure while cured cow-dung was obtained from the Teaching and Research Farm cattle section of the University of Ibadan. The chemical compositions of each of the fertilisers were determined following standard procedure. For the nutrient compositions of the organic manure, the total nitrogen in compost and cow-dung were almost the same (2.802% and 2.94%, respectively), whereas, micronutrients were more in cow-dung than compost. Phosphorus, calcium, magnesium, potassium and sodium were more in compost than cow-dung.

Experimental Design and Planting Procedure

The experiment was laid out in a Completely Randomized Design with three replicates making a total of 240 pots (i.e. 5 different Pb contamination levels (0%, 25%, 50%, 75% and 100%), 2 types of organic amendments (Compost and cow-dung) at 4 rates (0, 30, 20 and 10 t/ha) and 2 maize varieties (DTMA and OBA SUPER 1) to give 5x2x4x2 factorial]. Organic amendments were applied to each pot receiving the amendment (except the control of 0 t/ha) and were left for a week before sowing maize seeds. The organic amendment treatments were designated as:

Control – No compost, no cow-dung, COM 1 – compost at 30 t/ha, COM 2 – compost at 20 t/ha, COM 3 –

compost at 10 t/ha, CWD 1 –cow-dung at 30 t/ha, CWD 2 –cow-dung at 20 t/ha and CWD 3 – cow-dung at 10 t/ha.

Data collection

Data were collected on the growth and yield parameters, physiological and biochemical analyses, pre and post planting soil Pb concentrations and Pb uptake by maize plants. The growth and yield parameters include, leaf area, plant height and biomass accumulation. Photosynthetic pigments (Chlorophyll and carotenoid) were determined following the procedure of Sarropoulou and Dimassi-Theriou, (2012). Biochemical data were also collected on phenolics, proline and glycine betaine. Proline was determined following the method described by Bate et al. (1973). Known sample weight of 0.5g of fresh leaf from each treatment was homogenised in 5ml of 3% aqueous sulpho-salicylic acid and centrifuged at 2,000 x g for 5 minutes. The supernatant was filtered and 2ml of the filtrate was added to 2ml of glacial acetic acid and 2ml acid ninhydrin which was prepared by warming 1.25 g of ninhydrin in 30 ml glacial acetic acid and 20 ml of 6 N phosphoric acid. The mixture was heated in boiling water bath for 1 hour. Thereafter, the tubes were placed in the ice bath to terminate the reaction and 4ml of Toluene was added to the mixture and stirred for 20-30 seconds. The toluene layer was separated and the red colour intensity was measured using UV spectrophotometer at 520 nm.

The glycine betaine content in the leaf tissues was determined following the method of Grieve and Grattan (1983). Fresh leaf material (1.0 g) from each treatment was shaken in 10 ml of 0.5% toluene solution and filtered. After filtration, 1 ml of the extract was mixed with 1 ml of 2N H_2SO_4 and 0.5 ml of the mixture was taken in glass tube and 0.2ml of Potassium tri-iodide (KI3) solution was added. Then 2.8 ml ice cooled distilled water and 6ml of 1,2-dichloroethane (cooled at 4^oC) were added to the mixture. The upper aqueous layer was discarded and optical density of the lower layer was measured at 365 nm using UV spectrophotometer. The phenolics was determined following the method described by Julkeenen-Titto (1985). Leaf sample of 0.5 g from each treatment was weighed accurately and dissolved in 10ml of distilled water. Thereafter, 1 ml of this solution was transferred to a test tube and 0.5 ml 2N of the Folin Ciocalteu reagent and 1.5 ml 20% sodium carbonate solution was added and the volume was made up to 8ml with distilled water followed by vigorous shaking and finally allowed to stand for 2 hours after which the absorbance was taken at 765 nm. These data were used to estimate the total phenolic content using a standard calibration curve obtained from various diluted concentrations of Gallic acid.

Post Planting Soil and Plant Tissue Pb Concentration

Determination of post cropping soil Pb concentration and Pb uptake by maize crop was carried out following the method described by Ogundiran (2007). Briefly, for soil analysis, 1 g of soil sample was heated in 10 ml of 2 M HNO_3 for 1 hr. Allowed to cool, filtered into standard flask and made up to 50 ml with distilled water. For plant analysis, 0.5g of plant samples was ashed at 450-500^{0}C for 6-12 hours until the sample was totally burnt to ashes. Ten (10) ml of 2 M Nitric acids was added and filtered into 50 ml standard flask and made up to the mark with distilled water. They were read for Pb concentration using Atomic Absorption Spectrophotometer (VGP210 BUCK Scientific Model).

Results and Discussion

Vegetative Growth of Maize on Pb Contaminated Soil

In this study, maize seeds grown on 100% Pb contaminated soil did not germinate irrespective of maize variety and addition of organic amendments. However, mixing of the soil with uncontaminated soil coupled with addition of organic amendments supported seed germination and enhanced maize growth in the treated soils compared to untreated 100% Pb contaminated soil. Though, in comparison with 100% Pb contaminated soil, mixing of Pb contaminated soil with normal soil (containing Pb at the background level) also enhanced growth and development of maize in the different soil mixtures, but addition of compost and cow-dung was more effective than soil mixture only. The performance of organic amendments used for this study, however, varied based on the type of amendment, maize variety, soil Pb level, and rate of application. On the growth parameters for instance, cow dung was generally, more effective than compost but varied based on maize variety. DTMA maize variety performed better than OBA SUPER 1 across all the soil levels. For plant height and leaf area of DTMA under different soil levels, cow-dung was better than compost, while compost performed better for Oba super 1. The plant height of DTMA variety grown in soil 1 amended with cow-dung at 30 t/ha performed better than all other treatments including control whereas Oba Super grown on uncontaminated soil without amendment (0t/ha) had the highest value. This was followed by the ones grown on soil 1 amended with cow-dung at 20 t/ha. In soil 2 (25% Pb soil), the trend was the same for DTMA with cow-dung applied at 30 t/ha being superior. In the case of Oba Super, addition of compost at 30 t/ha increased plant height, though not significantly different from other amendments.

Plant height generally reduced in soil 3 compared to soils 1 and 2 but compost at 30 t/ha gave the highest plant height (18.73 cm) for DTMA, while cow-dung at 10 t/ha gave the lowest (5.38 cm). The lowest rate of compost (10 t/ha), however, performed better than other treatments for Oba Super, while control plant grown on un-amended soil 3 did not germinate. Surprisingly, in soils 3 and 4, the control plants grown on contaminated soil mixtures without amendment performed better than those with amendments for DTMA, but, for Oba super variety, compost at 10 t/ha and cow-dung at 20 t/ha gave the highest plant height in soil 3 and 4, respectively but could not germinate in the control soils 3 and 4 without amendments. There was also no germination in both varieties grown on soil 5 (100% Pb contaminated soil) (Table 1).

On the leaf area, there was a decrease as the Pb concentration increased. Cow-dung at 30 t/ha gave the highest values for leaf area in both varieties that were grown on soil 1 (uncontaminated soil), while, the lowest leaf area values were recorded for DTMA and Oba super treated with compost at 30 and 20 t/ha, respectively. In soil 2, there was a general increase in the maize leaf area under different amendments and rates compared to the un-amended contaminated soil (Control). However, unlike what was observed in soil 1, compost at 30 t/ha gave the highest leaf area for DTMA (69.44 cm^2) and Oba super (54.69 cm^2), while the control had the lowest value of 15.26 cm^2 for DTMA and Oba super did not germinate in control treatment. For DTMA in soil 3, Cow-dung at 30 t/ha gave the highest leaf area value (16.93 cm^2), followed by compost at 30 t/ha (14.05 cm^2) and the least leaf area value was recorded in cow-dung treatment at 20 t/ha.

In this soil mixture, Oba super generally had smaller leaf area compared to DTMA and Compost at the rate of 10 t/ha was the best. However, in soil 4 (75% Pb soil), for DTMA, control plant without amendment surprisingly had the highest leaf area value (14.12 cm^2) as observed for the plant height and was significantly different from those grown on treated soils. This was followed by cow-dung treatment at 30 t/ha and the lowest was recorded in compost treatment at 10 t/ha. Meanwhile, these were reversed for OBA SUPER. Compost at 10 t/ha that gave the lowest leaf area in DTMA now produced plant with the highest leaf area, and the lowest leaf area was recorded in compost treatment at 20 t/ha (Table 1).

Table 1 Effects of compost and cow dung on the plant growth parameters and biomass of the two maize varieties across all the soil levels

Soil type	Organic manure	DMRT			Oba super		
		Plant height (cm)	Leaf Area (cm^2)	Biomass (g)	Plant height (cm)	Leaf Area (cm^2)	Biomass (g)
1	COR1	45.50c	65.10d	3.54c	39.20c	34.30e	0.80c
	R2	51.50ab	77.80c	5.45ab	26.00e	22.70f	0.01d
	R3	48.20b	84.50b	6.03a	33.70d	64.40c	2.64b
	CDR1	54.20a	102.00a	6.40a	44.60b	86.80a	4.25a
	R2	49.90b	71.20d	5.55a	46.80b	60.60d	2.77b
	R3	43.50c	69.60d	4.70ab	42.50c	77.30b	2.32b
	Control	43.70c	77.90c	4.20b	55.40a	82.10ab	5.15a
2	COR1	44.80a	69.40a	1.89c	34.60a	54.70a	1.52b
	R2	44.70a	56.80b	2.81bc	33.30ab	42.20c	1.47bc
	R3	42.50b	50.40bc	3.82b	31.40b	43.50c	1.72b
	CDR1	46.50a	52.60bc	3.04b	32.90b	44.10c	2.62a
	R2	33.80c	38.50e	2.92bc	33.20ab	52.10b	3.01a

	R3	35.00c	45.20d	4.31a	25.30c	33.60d	1.99b
	Control	19.60d	15.30f	2.21c	0.00	0.00	0.00
3	COR1	18.70a	14.10b	0.34a	9.63c	5.11c	0.16c
	R2	15.40c	11.90c	0.19b	11.30b	7.06b	0.02d
	R3	16.20bc	11.50c	0.40a	18.40a	19.20a	0.98a
	CDR1	17.70b	16.90a	0.46a	13.90b	8.71b	0.27b
	R2	5.38d	3.38d	0.01c	9.99c	7.64b	0.00
	R3	0.00	0.00	0.00	0.00	0.00	0.00
	Control	17.20b	10.40c	0.53a	0.00	0.00	0.00
4	COR1	8.77b	5.47c	0.10c	3.85b	0.00	0.00
	R2	6.23c	4.22c	0.00	16.10a	2.82c	0.29a
	R3	7.05bc	4.13c	0.00	4.25b	13.90a	0.00
	CDR1	19.00a	12.20b	0.35b	0.00	3.04c	0.00
	R2	0.00	0.00	0.00	16.90a	0.00	0.00
	R3	0.00	0.00	0.12c	0.00	6.63b	0.00
	Control	20.30a	14.10a	0.63a	0.00	0.00	0.00
5	COR1	0.00	0.00	0.00	0.00	0.00	0.00
	R2	0.00	0.00	0.00	0.00	0.00	0.00
	R3	0.00	0.00	0.00	0.00	0.00	0.00
	CDR1	0.00	0.00	0.00	0.00	0.00	0.00
	R2	0.00	0.00	0.00	0.00	0.00	0.00
	R3	0.00	0.00	0.00	0.00	0.00	0.00
	Control	0.00	0.00	0.00	0.00	0.00	0.00

NB: Means in the same column followed by the same letters for each maize variety and each soil type are not significantly different according to Duncan Multiple Range Test ($P<0.05$). NB. All the columns showing zero value did not germinate or could not survive.

COR1= Compost at 30t/ha, COR2 = Compost at 20 t/ha, COR3 = Compost at 10t/ha, CDR1= Cow-dung at 30t/ha, CDR2 = Cow-dung at 20 t/ha, CDR3 = Cow-dung at 10t/ha.

Biomass Accumulation in Maize

Biomass accumulation in maize exposed to Pb was generally reduced, especially in untreated soils. However, as observed for growth parameters, mixing of soil with uncontaminated soil and addition of organic amendments diluted the Pb concentration in the soil mixtures and increased the soil nutrient status. The biomass accumulation in the maize grown on the amended soil mixtures was therefore better than that of the maize grown on untreated contaminated soil. The biomass accumulation in response to treatments as observed for the growth parameters also varied based on plant variety and organic amendment treatments. DTMR generally performed better than Oba super with regards to biomass accumulation and the performance varied based on the different treatments. DTMA grown on soil 1 (uncontaminated soil) amended with cow-dung at 30 t/ha had the highest biomass followed by those treated with compost at 10 t/ha. Oba super, however, had the highest biomass in control soil and was followed by that of cow-dung at 30 t/ha. In soil 2, cow-dung also performed better than compost and cow-dung treatment gave the highest biomass for both maize varieties. Cow-dung at 10 t/ha gave the highest biomass for DTMA, while biomass accumulation was enhanced in Oba super treated with cow-dung at 20 t/ha and this was not significantly different from that of 30 t/ha. The dry matter yield of maize in soil 3 and 4 was significantly reduced due to high Pb concentration. In soil 3, control plants without any amendment had the highest value for DTMA. This was followed by those grown on soil treated with cow-dung at 30 t/ha, while the least was recorded in those treated with lower rate of cow-dung. For Oba super, compost at 10 t/ha gave the highest biomass in this soil mixture. The trend was almost similar in soil 4 where the highest value for DTMA was recorded in the control and was also followed by that of cow-dung treatment at 30 t/ha and there was no value recorded for the compost treatments except in higher rate of compost. Oba super also had the highest biomass accumulation in compost treatment at 20 t/ha. Unlike DTMA, in Oba super, there was no plant in the control treatments for soils 2, 3 and 4 (Table 1).

Chlorophyll and Carotenoid Contents of Maize Leaf

Photosynthetic pigment production also decreased as Pb concentration increased. The total chlorophyll content was more in soil 1 (uncontaminated control) compared to other soil mixtures. Addition of organic amendments, however, enhanced chlorophyll synthesis in all the soil mixtures. In soil 1, compost at 30 t/ha gave the highest chlorophyll content compared to control and other treatments (Fig 1A). Chlorophyll production was found to respond positively to compost more than cow-dung. In soil 2, compost at rates 10 and 20 t/ha also enhanced chlorophyll formation in the maize plants grown in this soil compared to control and these treatments were superior to other treatments (Fig 1B). In soil 3, the highest rate of compost performed better than other organic treatments and control (Fig 1C). In terms of chlorophyll content, compost was more effective in soil 3 and 4 with higher Pb concentration while cow-dung was effective in soil mixtures with lower Pb concentration. Conversely, chlorophyll content in maize grown on soil 4 was the highest (Fig 1D). Although, all treated soils increased the carotenoid content more than the control treatment, but different amendments behaved differently in different soil mixtures and at different rates. In soil 1, the carotenoid content was high in maize grown on soil amended with cow-dung at 30 t/ha, while the lowest carotenoid content was obtained in maize treated with compost at 20 t/ha (Fig 1A). In soil 2 however, compost at 30 t/ha gave the highest carotenoid content while compost and cow-dung at 10 t/ha had no significant difference ($p \leq 0.05$) (Fig 1B). In soils 3 and 4, compost gave the highest carotenoid contents in DTMA (Figs 1C and 1D). Carotenoid content was also more in Pb contaminated soil mixtures compared to the uncontaminated control soil. For example, control plants from normal soil (soil 1) had 159.01 μg/g FW, while soil 3, had 198.31 and soil 4 had 189.94 μg/g FW. Across all the soil levels, soil treated with compost performed better than those with cow-dung in photosynthetic pigment production. On the interaction, the higher rate of organic amendments performed better than lower rates on soil 1 and other soil mixtures for chlorophyll and carotenoids except in soil 2 where chlorophyll was more in leaf grown on soil amended with lower rate of compost and cow dung (Table 2).

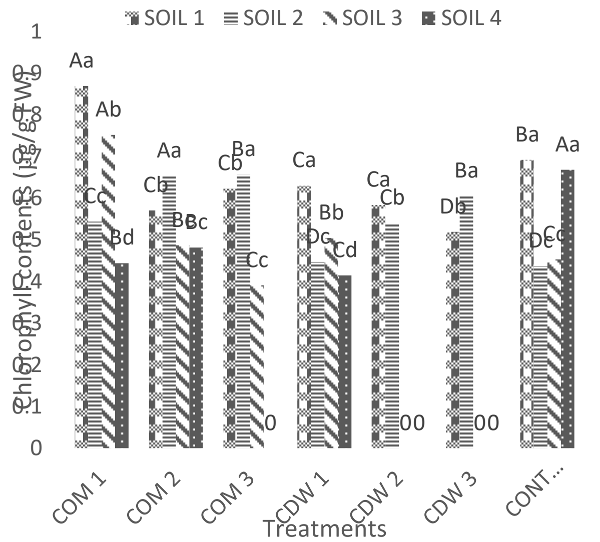

Fig. 1A Chlorophyll contents of maize leaf in different soil levels in response to different rates of compost and cow dung

NB: CHL = Chlorophyll, CAR = Carotenoid, COM 1= Compost at 30t/ha, COM 2 = Compost at 20 t/ha, COM 3 = Compost at 10t/ha, CDW 1= Cow-dung at 30t/ha, CDW 2 = Cow-dung at 20 t/ha, CDW 3 = Cow-dung at 10t/ha.Means are separated using DMRT. The capital letters (A, B, C) indicate the difference based on different organic amendments. The small letters (a, b, c) indicate the difference based on the different soil mixtures under each amendment.

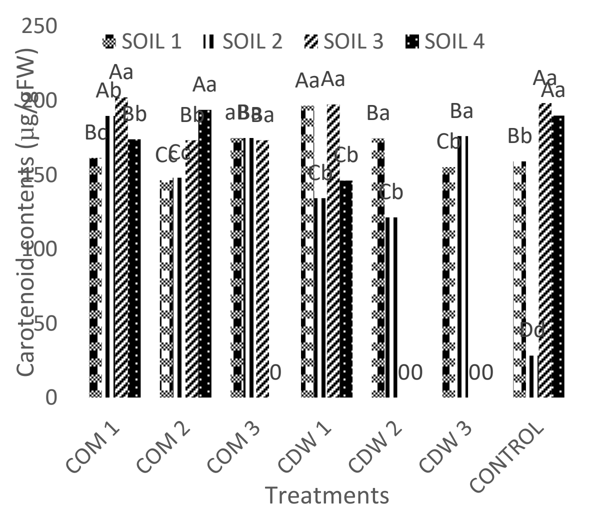

Fig. 1B Carotenoid contents of maize leaf in different soil levels in response to different rates of compost and cow dung

NB: CHL = Chlorophyll, CAR = Carotenoid, COM 1= Compost at 30t/ha, COM 2 = Compost at 20 t/ha, COM 3 =

Compost at 10t/ha, CDW 1= Cow-dung at 30t/ha, CDW 2 = Cow-dung at 20 t/ha, CDW 3 = Cow-dung at 10t/ha.Means are separated using DMRT. The capital letters (A, B, C, D) indicate the difference based on different organic amendments. The small letters (a, b, c) indicate the difference based on the different soil mixtures under each amendment.

Table 2 Interactive effects of treatments on the Photosynthetic pigments and biochemical parameters of DMRT

Treatment	Chlorophyll (µg/gFW)	Carotenoid (µg/gFW)	Porphyrin (µg/gFW)	Glycine betaine (µg/gFW)	Phenolics (µg/gFW)	Proline (µg/gFW)
S1T1V2R1	0.87a	161.36c	4142.00a	0.19a	1.10a	0.10b
S1T1V2R2	0.57c	146.30d	2693.00d	0.18a	0.92b	0.09b
S1T1V2R3	0.62c	174.84b	3144.00c	0.18a	0.93b	0.10b
S1T2V2R1	0.63c	196.45a	3506.00b	0.19a	1.10a	0.14a
S1T2V2R2	0.58c	174.49b	3560.00b	0.16b	1.21a	0.06c
S1T2V2R3	0.52cd	155.25cd	2522.00d	0.17ab	0.72c	0.09b
Control	0.69b	159.01c	3668.00b	0.18a	0.80bc	0.09b
S2T1V2R1	0.54b	189.61a	2743.00b	0.17b	0.61c	0.09c
S2T1V2R2	0.65a	147.97c	3108.00a	0.17b	1.21a	0.09c
S2T1V2R3	0.66a	174.88b	2931.00b	0.17b	1.09a	0.25a
S2T2V2R1	0.45c	134.28c	2035.00bc	0.16b	0.82b	0.08c
S2T2V2R2	0.54b	121.43c	2387.00b	0.19b	0.71b	0.13b
S2T2V2R3	0.61a	176.01b	2579.00b	0.33a	0.74b	0.15b
Control	0.44c	28.29d	1702.00c	0.21b	0.98a	0.14b
S3T1V2R1	0.75a	202.14a	1547.00c	0.17b	0.93a	0.11c
S3T1V2R2	0.49b	173.29b	2802.00a	0.31a	0.74b	0.10c
S3T1V2R3	0.39b	173.30b	2036.00b	0.17b	0.77b	0.16b
S3T2V2R1	0.51b	197.31a	2729.00a	0.34a	0.61b	0.16b
S3T2V2R2	0.00	0.00	0.00	0.00	0.00	0.00
S3T2V2R3	0.00	0.00	0.00	0.00	0.00	0.00
Control	0.46b	198.27a	1434.00c	0.35a	1.24a	0.62a
S4T1V2R1	0.44a	173.96a	2134.00b	0.28b	0.55c	0.16b
S4T1V2R2	0.48a	193.79a	2454.00a	0.13c	1.03b	0.19b
S4T1V2R3	0.00	0.00	0.00	0.00	0.00	0.00
S4T2V2R1	0.04b	146.17b	2037.00b	0.33a	0.83c	0.19b
S4T2V2R2	0.00	0.00	0.00	0.00	0.00	0.00
S4T2V2R3	0.00	0.00	0.00	0.00	0.00	0.00
Control	0.07b	189.94a	1399.00c	0.42a	2.02a	0.27a

NB: Means in the same column followed by the same letters for each maize variety and each soil type are not significantly different according to Duncan Multiple Range Test ($P<0.05$).

S means the soil level, T means treatment i.e T1= Compost and T2 = Cow dung, V2- DTMA, R means rate of application of compost and cow-dung. R1, R2, R3 = 30 t/ha, 20 t/ha, 10 t/ha, respectively.

Proline, Glycine Betaine and Phenolic Contents of Maize Leaf.

Proline and Glycine Betaine contents were high in maize grown on Pb contaminated soil without amendment (control plants) compared to the normal soil and treated Pb contaminated soil mixtures. Proline content in maize plants grown in soil mixtures treated with organic amendments decreased compared to control.

The concentration was also reduced in compost treatments more than cow-dung treatments.

The behavior of compost and cow dung varied based on their rate of application and soil Pb concentration. In soil 1, endogenous proline content was highest in maize treated with cow-dung at 30 t/ha and lowest in the plant treated with cow-dung at 20 t/ha, while in soil 2, compost at 10 t/ha gave the highest proline content which was higher than the control.

However, in soil 3 and 4, that contained higher concentration of Pb, the roles of organic amendments in stress amelioration were very clear with regards to proline production.

Proline content was more in maize plant grown on un-amended soil mixture (control) compared to treated soil mixtures.

The maize plant grown on soil amended with compost had reduced amount of proline compared to control plants grown on 50 and 75% Pb contamination levels without any amendment (Fig 2A).

For the GB content of maize leaf in different soil levels, the response was similar to that of proline. In soil 1, there was no significant difference between all the treatments including control except in cow-dung treatment at 20 t/ha.

In soil 2, apart from cow-dung at 10 t/ha, the GB in the control plant was significantly higher than all other treatments. In Soils 3 and 4, it was also observed that the GB in control plant was significantly higher than all other treatments.

However, among the organic amendment treatments, cow-dung at 30 t/ha, surprisingly gave the highest GB content in both soils 3 and 4 (Fig 2B).

In soil 1, the phenolic content on its own was high in plant grown in soil treated with cow-dung at 20 t/ha. The lowest was recorded in maize plant grown in soil 1 amended with cow-dung at 10 t/ha.

In soil 2, compost at 20 t/ha gave the highest phenolic content in maize, while compost at 30 t/ha gave the lowest. However, as observed for proline and GB, the control had the highest phenolic content compared to all other treatments both in soil 3 and soil 4 (Fig 2C).

On the general interactions of maize variety DTMA, soil Pb level and amendments, Proline, GB and phenolics were more in maize leaf treated with lower rate of organic amendments and higher soil Pb level compared to higher rate of organic amendment (Table 2).

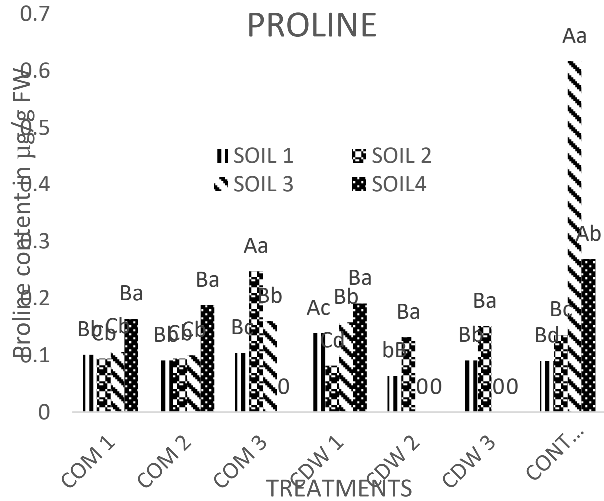

Fig. 2A Proline content in the leaf of maize plant grown on different soil levels in response to different rates of compost and cow dung

NB. COM 1= Compost at 30t/ha, COM 2 = Compost at 20 t/ha, COM 3 = Compost at 10t/ha, CDW 1= Cow-dung at 30t/ha, CDW 2 = Cow-dung at 20 t/ha, CDW 3 = Cow-dung at 10t/ha. Means are separated using DMRT. The capital letters (A, B, C) indicate the difference based on different organic amendments. The small letters (a, b, c, d) indicate the difference based on the different soil mixtures under each amendment.

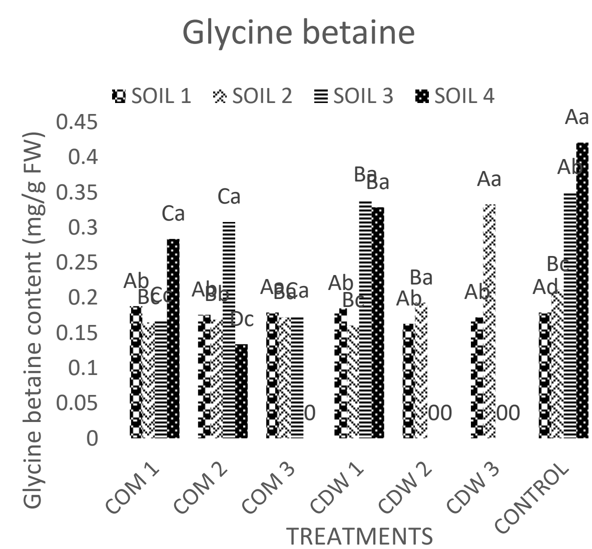

Fig. 2B Glycine betaine content in the leaf of maize plant grown on different soil levels in response to different rates of compost and cow dung

NB. COM 1= Compost at 30t/ha, COM 2 = Compost at 20 t/ha, COM 3 = Compost at 10t/ha, CDW 1= Cow-dung at 30t/ha, CDW 2 = Cow-dung at 20 t/ha, CDW 3 = Cow-dung at 10t/ha. Means are separated using DMRT. The capital letters (A, B, C, D) indicate the difference based on different organic amendments. The small letters (a, b, c) indicate the difference based on the different soil mixtures under each amendment.

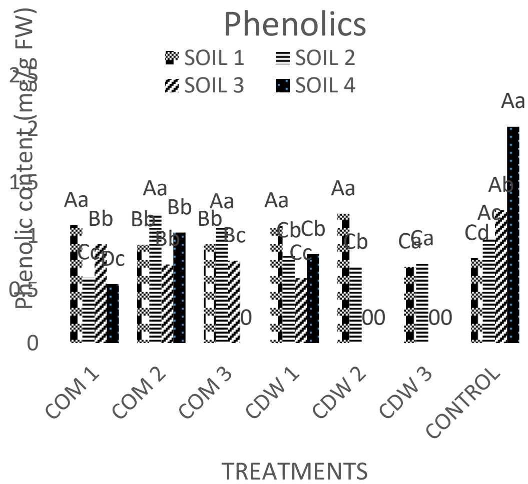

Fig. 2C Phenolic content in the leaf of maize plant grown on different soil levels in response to different rates of compost and cow dung

NB. COM 1= Compost at 30t/ha, COM 2 = Compost at 20 t/ha, COM 3 = Compost at 10t/ha, CDW 1= Cow-dung at 30t/ha, CDW 2 = Cow-dung at 20 t/ha, CDW 3 = Cow-dung at 10t/ha. Means are separated using DMRT. The capital letters (A, B, C, D) indicate the difference based on different organic amendments. The small letters (a, b, c, d) indicate the difference based on the different soil mixtures under each amendment.

Shoot and Root Pb Uptake by Maize and Post Cropping Soil Pb Concentration

Lead concentration increased in both shoot, root and soil as the soil Pb concentration in the soil mixtures increased. It was generally observed that Pb concentration in the root was higher than that of the shoot in most treatments. Both maize varieties however, accumulated Pb primarily in their roots in higher concentrations and transport it to their shoot. Lead accumulation in the shoot however, varied based on amendment, soil Pb level and variety. Pb concentration in the shoot and root of maize was found to be concentration and biomass dependent. DTMA, accumulated more Pb in the shoot than Oba Super 1. As Pb concentration increased in the soil, accumulation also increased. Except compost rate at 20 t/ha, all other amendments increased Pb accumulation in the shoot under soil 1 compared to un-amended control. In soil 2, however, the highest value was recorded for control shoot. In soil 3, organic amendment also increased Pb accumulation in the shoot compared to the control (Table 3). The root Pb concentration varied with the addition of organic amendment and the level was based on the type of amendment, rate, soil Pb level and the maize variety. Surprisingly, in soil 1 (0.5% Pb contamination. i.e. Control with background level of Pb), maize grown in organic amended soils also had higher Pb concentration in their root compared to the un-amended soil 1 and the highest value was recorded in the root of maize plant treated with compost at 30 t/ha. The accumulation was also more in DTMA than Oba Super. However, under soil 2, DTMA control plant had the highest Pb concentration in the root and the lowest value was recorded for maize root grown on soil 2 amended with highest compost rate.

In Oba Super, the highest Pb accumulation in the root was found in the maize grown on soil amended with lowest rate of cow-dung. In soil 3, compared to the un-amended control, compost at 20 t/ha gave the lowest value of Pb in DTMA. The trend was similar in Oba Super. In soil 4, control plant also had the lowest value (Table 3). Meanwhile, it was observed that more Pb was also accumulated in the shoots of the treated plants than control. On post-cropping soil Pb concentration, both the sole and combined methods reduced the Pb concentration in the soil compared to the original level. Under sole/physical remediation, before planting, Pb concentration was reduced by 85%, 65% and 29% in 25 (Soil 2), 50 (Soil 3) and 75% (Soil 4) soil mixtures, respectively. With the addition of organic amendments to the soil mixtures and after planting, in compost amended soil, Pb concentration was further reduced by 69%, 74% and 77% while, in cow-dung treated soil, it was reduced by 57%, 42% and 66%, using 30, 20 and 10 t/ha rates, respectively in soil 2 compared to 100% contaminated soil. Compared to untreated control for soil 2, compost addition generally gave the lowest Pb concentration in post-cropping soil, probably due to uptake by the plant. Under soil 3 and soil 4, cow-dung applied at the rate of 10 t/ha gave considerable reduction in post-cropping Pb concentration compared to their respective control soils (Table 3). The interactions between the organic amendments, rates of application and soil mixture showed that as the rate of organic amendment and soil Pb level increased, the Pb uptake in the shoot and root also increased (Table 3).

Table 3 Interactive effects of treatments and soil mixtures on Pb uptake by maize and post-cropping soil Pb concentration(mg/kg)

Soil type	Organic manure	DMRT			Oba super		
		Shoot	Root	Soil	Shoot	Root	Soil
1	COR1	67.20c	56.25b	281.00a	100.10b	269.50a	221.00a
	R2	0.00	0.00	47.00d	9.27e	223.40b	149.00c
	R3	115.20a	0.28c	62.30c	116.00a	120.10c	97.00d
	CDR1	78.60b	82.20a	128.60b	83.20c	128.30c	229.00a
	R2	32.10d	0.42c	103.50b	73.50c	133.40c	161.00b
	R3	23.40d	81.70a	65.20c	83.20c	170.40c	169.00b
	Control	10.10e	52.20b	0.00	64.20d	42.50d	28.00e
2	COR1	153.80a	1589.23e	13563.20b	133.20c	2145.83b	19312.00b
	R2	52.30b	2197.14d	17946.80a	256.20b	2726.50b	16058.00c
	R3	61.00b	2867.50d	16337.60a	266.30b	2589.00b	14457.00c
	CDR1	58.30b	3581.00c	16403.50a	258.70b	2778.00b	26534.00a
	R2	55.60b	4157.00b	17526.90a	258.90b	2439.50b	20234.00b
	R3	153.80a	6497.83a	10172.60c	86.70d	3606.50a	21236.00b
	Control	0.00	0.00	0.00	308.00a	3835.00a	20902.00b
3	COR1	0.00	0.00	29052.30a	862.61a	1271.43d	39214.00a
	R2	0.00	0.00	23580.20b	684.17b	477.23b	32104.00b
	R3	646.60a	4070.00a	27011.20a	479.40b	1745.83d	29057.00b
	CDR1	0.00	0.00	27240.10a	600.95b	3313.89c	31158.00b
	R2	0.00	0.00	28280.10a	0.00	0.00	28057.00b
	R3	0.00	0.00	21660.30b	0.00	0.00	26457.00bc
	Control	0.00	0.00	0.00	170.00	12390.00a	33859.00b
4	COR1	0.00	0.00	29460.10b	938.00b	582.50a	43675.20a
	R2	977.19a	0.00	35552.40a	0.00	0.00	44562.50a
	R3	0.00	0.00	32845.20b	0.00	0.00	43675.40a
	CDR1	0.00	0.00	26015.20c	0.00	0.00	30482.30b
	R2	0.00	0.00	32120.10b	0.00	0.00	26285.50c
	R3	0.00	0.00	28050.10b	0.00	0.00	15663.10d
	Control	0.00	0.00	0.00	1510.00a	29.24b	42827.00a
5	COR1	0.00	0.00	29835.40c	0.00	0.00	29835.40b
	R2	0.00	0.00	29640.10c	0.00	0.00	29640.10b
	R3	0.00	0.00	35820.30b	0.00	0.00	35820.30b
	CDR1	0.00	0.00	23590.40d	0.00	0.00	23590.40c
	R2	0.00	0.00	35430.20b	0.00	0.00	35430.20b
	R3	0.00	0.00	39725.80b	0.00	0.00	39725.80b
	Control	0.00	0.00	63005.70a	0.00	0.00	63005.70a

NB: Means in the same column followed by the same letters for each maize variety and each soil type are not significantly different according to Duncan Multiple Range Test (P<0.05).
COR1= Compost at 30t/ha, COR2 = Compost at 20 t/ha, COR3 = Compost at 10t/ha, CDR1= Cow-dung at 30t/ha, CDR2 = Cow-dung at 20 t/ha, CDR3 = Cow-dung at 10t/ha.

Discussion

Lead is detrimental to crop growth at every growth stage as observed from this study. It has been reported that there is a possibility of disrupting metabolic activities in plants, inhibiting seed germination and reducing crop growth and development (Harris et al. 2002; Azad et al., 2011). The high Pb concentration in this soil could have inhibited seed germination. It causes oxidative stress that could result in the destruction of cell's biomolecules (Schützendübel and Polle, 2002; Malecka, et al., 2009; Kaur et al., 2012). The inability of the seeds to germinate can also be blamed on the increase in the osmotic potential of the soil because of Pb contamination thereby causing seed plasmolysis and eventual death. From this study, however, mixing contaminated soil with uncontaminated soil was also not effective in remediating the contaminated soil. The mixing of contaminated soil with uncontaminated soil alone partially improved seed germination, but with the addition of organic amendments to the soil mixtures, there was a significant difference between the germination on amended soils compared to un-amended soil mixtures only. It means that physical remediation of heavy metal contaminated soil alone could not support plant's survival, growth and development on heavily contaminated soil like our experimental soil. This is because soil mixture only diluted the Pb concentration in the soil but, addition of organic amendments apart from binding to the metals, improves soil health thereby enhancing seed germination and plant's growth on contaminated soil mixtures (Amlinger et al., 2007; Rennevan et al., 2007; Adejumo et al., 2010). The availability of the essential nutrients in the organic amended soil mixture (contaminated and uncontaminated), therefore puts it at an advantage over soil mixtures only.

The level of tolerance also varied for DTMA and Oba Super 1. Except in soil 1 (uncontaminated control soil), Oba Super 1, did not germinate in all the soil mixtures without amendment (0 t/ha) whereas, DTMA germinated in all the soil types except in soil 5. The growth and development of Oba Super 1 was generally impaired by Pb compared to DTMA. The variation in their tolerance level might be linked to the differences in their genetic compositions. DTMA is a drought tolerant maize variety, and it has been reported that any crop that has been bred to confer resistance or tolerance to a particular stress factor is likely to be tolerant to other stress factors. Meanwhile, the general tolerance of the two maize varieties to Pb contamination (amended or unamended) might also be due to the ability of maize to endure and tolerate harsh conditions and this is common to carbon four (C4) plants like maize due to their high-water use and photosynthetic efficiencies.

On the growth parameter, soil amendment with compost also caused significant difference compared to soil mixture only. This supports the previous reports that addition of organic amendments to contaminated soil helps in ameliorating heavy metal stress on crops (Rennevan et al., 2007; Adejumo et al., 2010). Organic amendment has been reported to supply the nutrients needed for plant growth and at the same time help in immobilizing heavy metal in contaminated soil thereby minimizing uptake by plant (Bolan et al., 2003; Rennevan et al., 2007; Adejumo et al., 2014). Variations were, however, observed in the behavior of organic amendments and their rates of application. This might be connected with their nutrient compositions. Compost is made from plant and animal manure (poultry manure), while cow-dung is made up of only ruminant animal manure. This was reflected in the results of their nutrient analysis, the macro-nutrient contents in compost were also more than that of cow-dung, while micronutrients were more in cow-dung (Data not shown). The phytotoxicity induced by Pb could have caused the general reduction observed in the biomass of the stressed maize plants compared with control. This reduction in maize biomass could be due to destruction of cell biomolecules and oxidative stress induced by over-production of ROS in Pb-stressed plants (Malecka, et al., 2009; Kaur et al., 2012). Interruption of the DNA synthesis coupled with the destruction of protein, lipid, and carbohydrate molecules have been blamed for reduction in the final dry matter yield of the stressed plants (Schützendübel and Polle, 2002; Shah et al., 2011).

Chlorophyll content is an indicator of heavy metal toxicity. This was because Pb has been reported to compete with magnesium ion (the element responsible for Chlorophyll production) thus inhibiting its production (Seregin and Ivanov, 2001; Chaffei et al., 2004; Sing et al., 2010). Lead in the soil has therefore been reported to inhibit growth and phototsynthetic activity in crop through chlorophyll degradation and induction of oxidative stress (Flora et al., 2008; Gichner et al., 2008; Hanc et al., 2009; Kaur et al, 2012). Conversely, the high chlorophyll content observed in the control leaf on soil 4 (Pb contaminated soil mixture without amendment) confirms the report of Hossain et al. (2012) that photosynthetic pigments can also serve as antioxidants under stress as their production is sometimes increased under environmental stress. The chlorophyll production was, however, found to respond positively to compost more than cow-dung. As reiterated earlier, the availability of more nutrients in compost than that of cow-dung could have contributed to the compost performance.

Similarly, carotenoid has been reported to act as a non-enzymatic antioxidant mechanism induced to

protect the cell against ROS under environmental stress (Hon et al., 2007; Hossain et al., 2012). This was confirmed in this study and carotenoid content was more in Pb contaminated soil mixtures compared to the uncontaminated control soil. This could therefore be attributed to stress induced increase in carotenoid production (Tewari et al., 2002; Chanda et al., 2009). This might also relate to the ability of compost in reducing metal bioavailability in the soil (Adejumo et al., 2010) which probably might have enhanced photosynthetic pigments production.
In this study also, proline and glycine betaine contents that have been reported as osmo-protectants under abiotic stress (Theriappan et al., 2011; Shahid et al., 2014; Adejumo et al., 2015) were found to be high in maize grown on Pb contaminated soil without amendment (control plants) compared to the normal soil and treated Pb contaminated soil mixtures. This indicates that those without amendment were more stressed than those with amendment and this was confirmed by the lower proline content in maize plants grown in soil treated with organic amendments compared to untreated control. This probably could be adduced to the ameliorative roles of amendments on the metal stressed maize crop which could have resulted in reduction in osmolyte contents. The binding of heavy metals with the organic functional groups in organic amendments as suggested by Shahid et al. (2012) has been attributed to the reduction in the Pb phytotoxicity in the amended soil. As observed for the photosynthetic pigments, the interactions between the organic amendment, rate and soil mixture also followed the same trend for the osmolytes. However, differences were also observed in the behavior of each amendment and their rates with regards to different osmolytes and under different soil mixtures. Compost was also found to be more effective than cowdung as the proline concentration was lower in compost than cow-dung treatments. This according to previous reports, might be due to variation in their nutrient contents. The nutrient availability might have provided enough strength for the plant, thereby reducing the osmolyte production because of reduction in plant stress (Rennevan et al., 2007; Adejumo et al., 2014).

The Pb uptake was found to be positively correlated with soil Pb concentration and the concentration in maize plant was increasing as soil Pb concentration in the soil mixtures was increasing. The Pb concentration in the root was also higher than that of the shoot. All these observations were in accordance with the previous findings that root accumulate 90% of the total Pb in plant because of the mass flow mechanism or the poor Pb mobility (Patra et al., 2004; Sinha et al., 2006). The poor mobility attributed to the ability of the plant to restrict the upward movement of Pb into the shoot where most metabolic activities take place for plant growth and development (Fahr et al., 2013). More importantly, the uptake was generally reduced in amended soil, probably due to immobilization of Pb (Bolan et al., 2003; Salati et al., 2010; Auguy et al., 2013). Park and Lamb, (2012) also reported that soil amendment changes the chemistry of the soil thus, causing transformation and changes in mobility and bioavailability of Pb in the soil. The transformation taking place at the root zone, however, is said to be the major determinant responsible for the uptake and upward movement of Pb in plant (Lin et al., 2004; Adejumo et al., 2018). All these confirmed the results obtained in this study. However, more Pb was unexpectedly accumulated in the shoots of the treated plants than untreated control plants. This was probably due to variation in their biomass as accumulation of heavy metal is reported to be biomass dependent (Patra et al., 2004; Sinha et al., 2006; Tangahu et al., 2011; Adejumo et al., 2019). The root architecture and volume also determine the amount of Pb that is taken up by plant (Strubi´nska and Hanaka, 2011). The tolerant variety DTMA with more biomass also took up more Pb in the shoot than susceptible variety (Oba super), which shows that uptake was biomass dependent. Tolerance was also dependent more on detoxification than selective absorption as the variety with more Pb grew better than the variety with lower Pb uptake.

The performance of compost and cow-dung in reducing the post-cropping Pb concentration in this study has also been previously reported (Rennevan et al., 2007: Adejumo et al., 2010; Salati et al., 2010; Auguy et al., 2013). This was attributed to the ability of the dissolved organic matter, humic and fulvic materials in organic amendments to bind with heavy metals (Adejumo et al., 2011; Auguy et al., 2013). Phosphorus in organic amendment has also been reported to play a key role in the complexation of metals in the soil (Ogundiran, 2007). Combined strategies of soil mixing and organic amendments, however, resulted in considerable reduction in post cropping soil Pb concentration.

Conclusions

Pb contaminated soil has detrimental effects on plant growth and survival as observed in this study. However, the addition of compost and cow-dung as organic amendments improved plant's survival, growth and development. Effectiveness was, however found to depend on the soil mixing ratio, type of organic manure and their application rates. Compost was more effective than cow dung and out of all the soil levels (25%, 50%, 75% and 100% Pb soil), soil 2 (75% Pb reduction) was the best, as it competes with the normal soil favourably. The photosynthetic pigment formation and maize tolerance was enhanced under the different soil mixtures in combination with soil amendment. In reducing the toxic effect of Pb contaminated soil on crop, physical method plus the addition of organic amendment can be employed as they both enhanced the growth of maize in Pb contaminated soil. In addition, it could be concluded that Proline and Glycine Betaine production was the maize tolerance mechanism being employed by maize in contaminated soil.

Statements and Declarations

Authors' contributions

All authors contributed meaningfully to the study from inception to completion. Study design, laboratory and greenhouse studies, data collection and analysis were carried out by E. Ogundipe in conjunction and under the supervision of S.A. Adejumo, James A. Adediran and A.O.Togun. The manuscript was written by S.A. Adejumo and all authors read and approved of the final manuscript.

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