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Effect of Cow Dung and Urban Waste Compost in Reducing the Accumulation of Cadmium (Cd) and Lead (Pb) in Amaranth Grown in Contaminated Soil

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Authors' contributions

This work was carried out in collaboration among all authors. Author ZRM designed the study, performed statistical analysis, wrote the protocol, and first draft of the manuscript. Author SWP supervised the study, drafted the manuscript, performed study protocol, designed and processed the data, and actively participated in the study. Author S/ITC and NRWA participated in the study, collected the data and wrote of the manuscript. Author SA followed on-station experiments and laboratory analysis and managed the literature searches. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: The effect of cow dung and urban waste compost on the capacity of amaranth to absorb cadmium and lead was studied in contaminated soil.

Study Design: Amaranth was cultivated in pot trials randomized blocks with five treatments and four replications for each treatment: control; contaminated soil; contaminated soil with cow dung; contaminated soil with compost and contaminated soil with cow dung and compost.

Place and Duration of Study: The trial was carried out in laboratory conditions in the Research Institute for Applied Sciences and Technologies in Ouagadougou from march to April 2022.

Methodology: Lead and cadmium concentrations in amaranth leaves and stems was determined using atomic emission spectrometry (MP-AES) after acid digestion.

Results: The results showed that contaminated soil with 5 mg kg^{-1} of lead and 0.2 mg kg^{-1} of cadmium had no significant effect on amaranth growth. In the dried leaves, mean cadmium levels were 93.5 mg kg^{-1} in the absence of cow dung and 4.14 mg kg^{-1} in the presence of cow dung. Mean cadmium levels in dry stems were 64 mg kg^{-1} and 2.1 mg kg^{-1} respectively in the absence and presence of cow dung. Lead uptake did not vary significantly in the presence of amendments (0.44 mg kg^{-1}) or in absence of amendments (0.75 mg kg^{-1}) in the stems. The cow dung treatment was more effective than the compost treatment. However, our results showed that the two amendments reduced cadmium transfer by 90% and lead transfer by 70% to amaranth.

Keywords: Amaranth; amendment; Lead; cadmium; contaminated soil; urban agriculture.

1. INTRODUCTION

Generally, in sub-Saharan Africa urban area and particularly in Ouagadougou (Burkina Faso), agricultural activities are increasingly important [1]. Urban agriculture helps to clean the environment because urban waste is used to fertilize soil [2] and for irrigation. However, urban waste use has some environmental consequences because it can contain trace metal elements such as lead and nickel in varying concentrations [3]. Their use can lead to an accumulation of trace metal elements in the soil [4]. On the Kossodo market garden, site irrigated by treated wastewater, [5] found lead in soil samples with average levels of 193 mg kg^{-1}. In the soil, depending on the soil constituents and the physicochemical conditions of soil, trace metals may be phytoavailable and contaminate the food chain [6]. Amaranth an metallophyte vegetable species [7] grown on most market garden sites in Burkina Faso. Even when metals are trace in the soil, amaranth can accumulate them. Lead and cadmium are highly neurotoxic and are strict contaminants for humans and plants [8]. Although naturally present in the soil, these elements are brought into the soil by agricultural soil improvers, solid and liquid urban waste, industrial waste and pesticides. Most market garden sites in Burkina Faso use urban waste to improve soil fertility or to irrigate soil [9]. In Niger, the presence of cadmium, lead and other trace metal was revealed in the leaves of amaranth grown on polluted soil [7]. The average of cadmium and lead in amaranth leaves were 0.49 and 5.18 mg kg^{-1} respectively. In Burkina Faso, cadmium with concentrations various from 1.27 to 2.93 mg kg^{-1} and lead from 1.32 to 1.69 mg kg^{-1} were found in lettuce grown on Paspanga and Tanghin sites in Ouagadougou [10]. These values are higher than the standards required in plants, that are 0.2 mg kg^{-1} for cadmium and 0.5 mg kg^{-1} for lead [11]. The consumption of market garden products, which has the capacity to adsorb and accumulate trace metals in its various organs (roots, stems, and leaves), exposes humans to diseases [12]. Organic amendments are used to complex or precipitate metal ions to reduce the mobility and availability of trace metal elements in the soil [12]. In market garden sites, organics amendments are used such us cow dung, manure, urban waste compost or crop residue compost [13]. In China, 1% of organic manure decreased the shoot of Cd and Pb concentrations in maize root [14]. In Burkina Faso, studies on the phytoextraction of heavy metals in soil have been carried out by [15,16].

These authors showed that vetiver was adsorbing and accumulating large quantities of cadmium, lead, copper, and zinc. Assess the effects of organic soil improvers on the availability of heavy metals for plants could minimize the transfer of heavy metals to crops and humans. Rich in nutrients, organic amendments can fertilize, improve soil structure, and fix metal ions by complexation or chemisorption with a high degree of selectivity [17]. This study aimed to assess the efficiency of cow dung and an urban waste-based compost in reducing cadmium and lead accumulation in amaranth grown in contaminated soil.

2. MATERIALS AND METHODS

2.1 Study Area and Experimental Material

The study was conducted in 2022 at the experimental station of the Natural Substances Department (X: 664392 UTM; Y: 1373955 UTM; Z: 300 m) of the Research Institute of Applied Science and Technologies in Ouagadougou. The trial was conducted on the soil was taken from uncontaminated land in Gampela village (X: 679391 UTM; Y: 1376148 UTM; Z: 289 m), located east of Ouagadougou on national road number 4. A composite sample was formed with auger by taking six samples at six points at the diagonals, in 0-20 cm horizon. This soil is a brown ferruginous leached soil with a silty-sandy texture and poor at organic matter (0.97%).

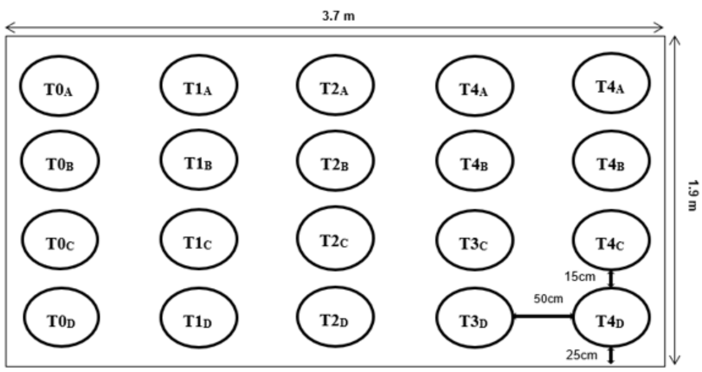
Soil was contaminated with cadmium and lead. The cadmium used was hydrated sulfate cadmium powder ($3CdSO_4$ $8H_2O$) with a molar mass M= 769.51 g mol^{-1}. The lead used was a 1000 mg l^{-1} AR solution. A solution containing 100 mg l^{-1} of lead and 2 mg l^{-1} of cadmium was prepared with distilled water to contaminate the soil.

Cow dung and urban waste compost were applied in the contaminated soil to reduce the transfer of trace metals to plants. The compost was made from manure, urban waste, and Burkina phosphate (mineral fertilizer). The composting process took 90 days. The amendments were mixed with contaminated soil and put in plastic pots. The amendments were applied to the soil at 10% of the soil mass.

The *Amaranthus hybridus L.* species was used for the experiment. Seeds were purchased from a sales outlet. The amaranth plant reached maturity at 45 days.

2.2 Experimental Design and Process

The experiment was conducted using a completely randomized design with five treatments and four replications [18]. Amaranth was seeded in plastic pots each containing 2 kg of soil sample with 200 g of cow dung and urban waste compost using five treatments (Fig.1). Each treatment was replicated 4 times (Fig. 1). To contaminate soil, one hundred (100) ml of a solution containing 100 mg l^{-1} of lead and 2 mg/l of cadmium was added at soil. Each pot was moistened with 100 ml water twice a day. Hoeing was carried out once every 15 days. Three (3) vigorous plants per pot were kept. The plants were allowed to grow for 52 days. Plant size, number of leaves and weight were measured at harvest. The parts of the plants (roots, stems, leaves) were washed separately with tap water and then rinsed with distilled water. The fresh weight of leaves and stems was recorded before



T0: Control; T1: Contaminated soil not amended; T2: Contaminated soil amended with 200 g of cow dung; T3: Contaminated soil amended with 200 g of compost; T4: Contaminated soil amended with 100 g of cow dung and 100 g of compost. The letter A, B, C, D indicate the replicates of each treatment. 50cm: inter-treatment distance; 15cm: intra-treatment distance; 25cm: distance between pot and system limit.

Fig. 1. Experimental set-up for evaluating the effect of amendment on the availability of cadmium and lead for amaranth.

they were dried in the shade at room temperature (30 to 35°C) for 10 days.

2.3 Analysis of Soil Samples, Plants, and Soil Improvers

The pH of the water was measured electrometrically using the potentiometric method. Potassium phosphorus and nitrogen (NPK) were measured using the Kjeldhal method with acid etching [19]. Cation exchange capacity (CEC) and total organic carbon (TOC) were determined respectively by the soil saturation method using a silver thiourea solution and the Walkley and Black [20] method modified for soil. The loss on ignition method was used to determine the total organic carbon (TOC) of amendments. The granulometry of three soil fractions was determined by hydrometry.

Pseudo-total cadmium and lead levels in plants, soil and soil improvers were measured using the Microwave plasma atomic emission spectrometer (MP-AES 4210). Samples were dissolved in a mixture of nitric acid and hydrochloric acid in a 1/3 ratio and to mineralized using the microwave. The method used corresponds to EPA Method 3051A with microwave-assisted *aqua-regia* digestion.

2.4 Data Analysis

Statistical analyses were carried out using XLSTAT 2014 software. An analysis of variance (ANOVA) was performed to assess the effect of the amendments on the presence of cadmium and lead in the leaves and stem of amaranth. Correlation tests were carried out to determine the differences between the means at a significance level of 0.05.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Physical and chemical characteristics of the soil and amendments

Table 1 shows the physical and chemical characteristics of soil. Granulometric analysis of the soil shows that the soil texture was silty-sandy according to the FAO textural triangle. The soil was moderately acidic with a pH of 5.97. The organic matter was low in soil (Table 1). Cadmium and lead concentrations in the soil were very low and below the limit of detection (Table 1).

Table 2 shows the physical and chemical characteristics of the compost and cow dung. The compost has a slightly basic pH. The cow dung has a neutral pH (Table 2). The quantity of organic matter contained in the cow dung is greater than that contained in the compost which is richer in nitrogen (Table 2). The average pseudo-total cadmium content of the soil improvers was below the detection limit (LD=1 mg kg $^{-1}$). The pseudo-total average lead content in compost was 36.4 mg.kg^{-1} and in cattle manure 11 mg kg^{-1}.

Table 1. Physical and chemical properties of experimental soil (0-20 cm).

Properties	Value
Clay (%)	15.69 ± 0.84
Silt (%)	15.68 ± 1.02
Sand (%)	68.63 ± 0.86
Organic matter (%)	0.97 ± 0.01
pH (1: 2.5/ soil: water)	5.97 ± 0.03
CEC (meq/100g)	3.34 ± 0.02
Cd_pt (mg kg $^{-1}$)	< LD
Pb_pt (mg kg $^{-1}$)	< LD

The value in the table has the mean of three measures ± the standard deviation CEC: cationic exchange capacity; Cd_pt: pseudo total cadmium; Pb_pt: pseudo total lead; LD: limit of detection.

Table 2. Physical and chemical properties of the amendments used in the experiment.

Parameters	Cow dung	Compost
Organic matter (%)	38.95 ± 1.89	30.48 ± 1.57
Nitrogen (%)	01.03 ± 0.32	01.16 ± 0.26
pH $_{water}$	07.46 ± 0.35	08.21 ± 0.12
Cd_pt (mg kg $^{-1}$)	< LD	< LD
Pb_pt (mg kg $^{-1}$)	11 ± 1.58	36.4 ± 2.37

The value in the table has the mean of three measures ± the standard deviation; Cd_pt: pseudo-total cadmium; Pb_pt: pseudo-total lead; LD: limit of detection.

3.1.2 Effect of cadmium and lead on amaranth growth

The results of the parameters measured during amaranth cultivation are given in Table 3. The effect of heavy metals on amaranth growth was assessed by observing treatments T0 (uncontaminated soil) and T1 (contaminated soil). The result showed that amaranth grown on T0 (uncontaminated soil) had slightly higher growth than the one grown on T1 (contaminated soil). However, this difference was not significant (Table 3). The dose of 5 mg kg^{-1} of lead and 0.2 mg kg^{-1} of cadmium in the soil did not have a significant effect on amaranth growth. In the presence of the amendments, amaranth showed better growth with a significant difference between the parameters observed compared with amaranth planted in unamended pots.

Table 3. Average parameters observed and measured 52 days after sowing of amaranth in pots.

Amaranth	Size (cm)	Number of Sheets	Fresh leaf weight (g)	Fresh stem weight (g)
T0	$07.92^{a} \pm 1.95$	$10^{b} \pm 1$	$02.13^{b} \pm 0.31$	$01.05^{c} \pm 0.32$
T1	$07.08^{a} \pm 1.73$	$09^{b} \pm 1$	$01.16^{b} \pm 0.38$	$0.56^{c} \pm 0.25$
T2	$38.5^{b} \pm 4.31$	$18^{a} \pm 1$	$17.78^{ab} \pm 8.41$	$42.05^{b} \pm 3.59$
T3	$34.58^{b} \pm 6.36$	$16^{a} \pm 1$	$35.28^{a} \pm 6.02$	$51.38^{a} \pm 4.48$
T4	$38.33^{b} \pm 6.37$	$19^{a} \pm 2$	$29.44^{a} \pm 15.97$	$45.64^{ab} \pm 1.95$

The value in the table has the mean of 4 replicas ± the standard deviation; T0: Uncontaminated soil not amended; T1: Contaminated soil not amended; T2: Contaminated soil amended with 200 g of cow dung; T3: Contaminated soil amended with 200 g of compost; T4: Contaminated soil amended with 100 g of cow dung and 100 g of compost. The letters a, b and c indicate the significant differences between the means according to the Tukey test with a confidence level of 95% and a significance level of 0.05.

T0 : Control ; T1 : contaminated soil not amended. Each treatment is repeated in four pots. The letter A, B, C, D indicate the replicates of each treatment.

Fig.2. Amaranth growth 50 days after sowing.

3.1.3 Effect of the cow dung and urban waste compost on cadmium and lead content in amaranth stems and leaves

The average of pseudo-total cadmium and lead levels measured in amaranth leaves and stems are shown in Table 4. Cadmium and lead levels in amaranth stems and leaves fell sharply in the presence of the amendments (Table 4). The analysis of variance showed a significant difference between cadmium and lead levels in the leaves and stems of amaranth grown on unamended contaminated soil and on amended contaminated soil. However, there was no significant difference between cadmium and lead levels in the stems and leaves of amaranth grown on unamended, uncontaminated soil and amended, contaminated soil. The cow dung meant a reduction of cadmium and lead levels in leaves and stems by more than 90%. In the presence of 10% of amendments, the amaranth absorbed the metals less. The mixture of cow dung and compost is more effective in reducing the accumulation of heavy metals in amaranth plants than compost alone. The amendments had a positive effect because they considerably reduced the absorption of cadmium and lead by the amaranth.

Table 4. Mean pseudo-total cadmium and lead content in leaves and stems of amaranth growing in contaminated and amended soils.

Amaranth	Cd pseudo-total µg g^{-1}		Pb pseudo-total µg g^{-1}	
	Stems	**Leaves**	**Stems**	**Leaves**
T0	0.78^{b}±0.59	0.35^{b}±0.17	0.7^{b}±0.42	< LD
T1	64^{a}± 4.95	93.5^{a}±3.53	1.52^{a}±0.18	< LD
T2	2.1^{b}±0.53	4.14^{b}±1.23	0.44^{b}±0.07	0.76^{a}±0.27
T3	5.48^{b}±2,59	6.58^{b}±1,59	0.41^{b}±0.27	0.57^{a}±0.08
T4	3.17^{b}±1.18	5.09^{b}±1.44	0.38^{b}±0.24	< LD
P value	<.0001	<.0001	.001	.109
Significance	S	S	S	NS

The values in the table are the mean of 4 replicas± the standard deviation; LD: limit of detection 0.5 µg. g^{-1}; Cd: cadmium; Pb: lead; T0: uncontaminated unamended soil; T1: contaminated unamended soil; T2: contaminated soil amended with 200 g of cow dung; T3: contaminated soil amended with 200 g of compost; T4: contaminated soil amended with 100 g of cow dung and 100 g of compost. In a column, values followed by the same letter are not significantly different at the 5% threshold probability. S: significant, NS: non-significant.

Table 5. Pearson correlation matrix between biomass and cadmium and lead levels in amaranth leaves and stems.

Variables	Cd_stems	Cd_leaves	Pb_stems	Pb_leaves
Fresh weight of leaves	-0,493	**-0,503**	**-0,639**	0,170
Dry weight of leaves	**-0,600**	**-0,606**	**-0,729**	0,448
Fresh weight of stems	**-0,618**	**-0,621**	**-0,721**	**0,613**
Dry weight of stems	**-0,630**	**-0,632**	**-0,741**	**0,610**

Values in bold are different from 0 at significance level alpha=0.05; Cd: cadmium; Pb: lead.

3.1.4 Effect of cadmium and lead concentrations on amaranth biomass

The Pearson correlation matrix shows a significant correlation between cadmium and lead levels and amaranth biomass. There was a significant negative correlation between biomass and cadmium levels in leaves and stems (Table 5), and lead levels in stems. The greater the biomass, the lower the cadmium content in the leaves and stems. Similarly, the greater the stem biomass, the lower the lead content. In fact, the dry biomass of leaves in contaminated soil without amendment was 0.22 g and contained 93.5 µg g^{-1} of cadmium. The dry leaf biomass of the amended contaminated soil was 4.99 g and contained 4.17 µg g^{-1} of cadmium. However, the greater the leaf biomass, the greater the lead concentration in the leaves (Table 5).

3.2 Discussion

The experiment was carried out to assess the effect of cow dung and urban waste compost on lead and cadmium accumulation in amaranth grown in contaminated soil. Fifty-two (52) days after sowing, amaranth grown on T1 (contaminated, unamended soil) showed stunted growth in height and weight, compared with amaranth grown on T0 (uncontaminated, unamended soil). This shows that the presence of cadmium and lead in the soil had a negative but not significant impact on amaranth growth. The presence of heavy metals in the soil is toxic for plants, which accumulate heavy metals in their tissues, modifying their morphology, anatomy and physiology [21]. This toxicity depends on the dose of heavy metals in the soil, the exposure time of the plant and the level of heavy metal concentration in the plant [22]. Studies by Haller et al. [23] showed that plants of *Amaranthus hypochondriacus* grown for 180 days on soil containing 20 mg kg^{-1} of Cd did not reach maturity. In addition, the results show that amaranth is capable of accumulating high quantities of cadmium and lead. This accumulation is regulated by the soil amendments. Average cadmium levels of 64 mg kg^{-1} and 93 mg kg^{-1} were found in leaves and stems of amaranth growing on contaminated soil without amendments. These concentrations could be justified by the availability of cadmium and lead that have been accumulated in the leaves and stems of the plant. This result shows that even if the soil is only slightly contaminated, amaranth can accumulate large quantities of cadmium and lead in its leaves and stems. *Amaranthus hypochondriacus* plants grown for 180 days on soil containing 2 mg kg^{-1} Cd accumulated 113 to 176 mg kg^{-1} of Cd in the stems and 64 to 94 mg kg^{-1} of Cd in the leaves [23]. Also, the work of Gado and al. (2018) [7] on unamended soil polluted to 1.52 mg Cd kg^{-1} and 89.35 mg Pb kg^{-1} in the Gounti Yéna valley in Niamey, Niger, showed that the leaves of amaranth and sorrel absorbed significant concentrations of cadmium (0.49 mg kg^{-1} and 0.67 mg kg^{-1}) and lead (5.18 mg kg^{-1} and 0.69 mg kg^{-1}) respectively. These concentrations are higher than the CSHPF [11] standard set at 0.2 mg kg^{-1} of cadmium and 0.5 mg kg^{-1} of lead in plants. In the presence of cow dung and compost, average cadmium and lead levels in leaves and stems were reduced by 90%. The addition of organic matter to the soil considerably reduced the concentration of cadmium and lead in the plant. Indeed, authors have shown that soil organic matter can effectively chemisorb metal ions and form strong ionic or covalent bonds [24,25]. Wang and al. (2020) [12] showed that 1% of organic manure decreased cadmium and lead concentration in maize roots. Ferruginous soils alone, poor in organic matter, were unable to retain cadmium and lead, as can be seen from the high concentrations of these metals in amaranth. Ferruginous soils amended with compost or cow dung reduce the uptake of cadmium and lead by amaranth.

4. CONCLUSION

The study was carried out to assess the effect of compost and cow dung on cadmium and lead accumulation by amaranth plant. The results showed that the use of cow dung and compost reduced the availability of cadmium and lead in the soil for plant. Ten per cent (10%) of cow dung and urban waste compost reduced cadmium accumulation by over 90% in the leaves and stems of amaranth grown on T2, T3 and T4. Cadmium concentrations in amaranth leaves and stems were reduced by 96% and 98% respectively in the presence of cow dung (T2). Compost (T3) reduced cadmium concentration in stems (91%) and leaves (93%). The cow dung and compost treatment (T4) reduced cadmium concentration in leaves and stems by 95%. Cow dung (T2) was more efficient than compost (T3) in reducing cadmium accumulation in amaranth leaves and stems. T4 was more efficient than compost alone (T3) in reducing cadmium accumulation in amaranth leaves and stems. Lead accumulation in amaranth leaves and stems was reduced by 71% in T2, 73% in T3 and 75% in T4. the treatment with cow dung and compost (T4) was more efficient in reducing lead in amaranth leaves and stems. Urban waste compost enriched with phosphate and cow dung can be used as an amendment to increase cadmium and lead retention in contaminated soils to limit amaranth contamination. For future research, the reduction of cadmium and lead accumulation with cow dung and compost can be carried out in the field with amaranth and/or other plant species. The effectiveness of cow dung and compost can be tested on other heavy metals.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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