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Response of *Amaranthus Cruentus* to Some Amendments on a Sandy-Loam Alfisol Contaminated by Heavy Metals

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ABSTRACT— ***Indiscriminate dumping of industrial wastes often leads to heavy metal accumulation in soils but organic matter amendments may ameliorate the resulting toxicity in crop production. This study evaluated the effectiveness of eight fertilizer treatments (Control; Urea, U; Organic Fertilizer, OF; Single Superphosphate, SSP; SSP+U; OF+U and OF+SSP; OF +SSP+U) in reducing heavy metal uptake by Amaranthus cruentus (L) on contaminated alfisols .Treatments were replicated three times in completely randomized design. Sole and combined treatments (organic and/or inorganic) significantly (p<0.05) enhanced crop performance while heavy metal tissue concentration and uptake by plants were low compared to Control. Plants treated with OF+U gave the least concentration of tissue Pb (647.00 mg/kg), Zn (198.50 mg/kg) and Cu (16.50 mg/kg) while control plants had the highest corresponding values of 2562.50 mg/kg, 695.00 mg/kg and 66.00 mg/kg. Mineral fertilizer-fortified organic manures have great potential in the production of amaranth plants devoid of heavy metal poisoning.***

Keywords— Contamination, Heavy metals, Amaranth, Industrial waste, Metal uptake, Fertilizers

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1. INTRODUCTION

The level of dangerous wastes in the environment has continued due to indiscriminate dumping. With the industrialization of most countries of the world, toxic waste products are being released into the ecosystems at increasing rate with consequent devastating effects on plants, animals and human lives. The common sources of these toxic wastes stem from by-products of manufacturing plants, farming, city septic systems, construction, automotive garages, laboratories and hospitals, while some other wastes are components of computers, electronic devices, batteries, hazardous chemicals.

Individuals often throw out wastes without realizing its impacts on the immediate environment and where they might be transported to, while corporate bodies also usually engage in improper dumping to avoid the costs associated with environmentally acceptable procedure. No matter the location of dumping there is always a chance that the wastes get into the ground and eventually into our bodies through food chain.

Heavy metals are elements which occur naturally in the earth's crust. They are therefore found naturally in soils and rocks with a subsequent range of natural background concentrations in soils, sediments, waters and organisms. Heavy metals are dangerous to the environment because they can be toxic, persistent and not broken down over a long period of time. Unlike many organic pollutants which eventually degrade, heavy metals tend to accumulate in the environment. Heavy metals accumulate in organisms as a result of direct uptake from the surroundings across the body wall, from respiration and from food. Uptake via food is most important in terrestrial organisms (Kachenko and Singh, 2006; Singh and Kumar, 2006).

In Africa, majority of vegetables consumed are planted on dump sites containing toxic heavy metals. In many cities in the developing world, lack of access to land compels some farmers to convert dumpsites to vegetable gardens. Little information is available on the health hazards associated with such practices. Currently, efforts are being made to remediate heavy metal contaminated-environment with conventional remediation technologies (Palmer and Moy, 1991). Other ways of remediating are also being looked at; with increased concern about climate change. Efforts are increasingly being geared toward protecting and amending soils to reduce adverse effects on the environment and the health of human beings. This study sought to investigate the comparative effects of different fertilizer types (single superphosphate, urea and organic fertilizer) on the growth of amaranthus and their effectiveness in reducing heavy metal concentration in plant tissue.

2. MATERIALS AND METHOD

The study was conducted in the screen house of the Department of Agronomy, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria. The soil used for this experiment was collected from Ile-Igbon, situated in Lagelu Local Government; Oyo State (7° 29' 0" N, 4° 5' 0" E). It was a dumpsite of the defunct West Africa Battery Manufacturing Company (Exide Battery). The land became contaminated with heavy metals due to indiscriminate dumping of battery wastes of the company. Thus, the soil was made unsuitable for agricultural purposes in general and crop production in particular. Lead level exceeded Nigeria limit for lead which is 500 mg/kg and can be classified as extremely hazardous waste (FEPA, 1991). The soil used for the experiment was subject to chemical analysis. The particle size distribution of the soil indicated that the textural class was sandy loam. The available P was 29.16 mg/kg, exchangeable Ca and Mg (11.10 and 2.77 cmol/kg, respectively). Pb, Zn and Cu were 58350, 1465 and 864 mg/kg, respectively.

The experimental design used was completely randomized design (CRD) with 16 treatment combinations replicated three times, giving a total of 48 experimental materials / pots. After passing through a 2mm diameter sieve, 5kg soil was mixed with fertilizer materials (according to treatment) and packed into polythene bags. *Amaranthus cruentus* seeds were broadcasted on top soil contained in seed tray, watered regularly and allowed to germinate. Transplanting of four seedlings per pot was done after two weeks into the polythene bags and were watered regularly, thinned to two plants per pot after two weeks of transplanting.

The parameters measured during crop growth include plant height, number of leaves, leaf area and stem girth from three to six weeks after transplanting**.** The plants were harvested at six weeks when the above ground portions were dried at 70°C to a constant weight, milled and wet-digested. Nutrient composition in the plant tissue and uptake by plants were determined.

Statistical Analysis: Data collected were subjected to Analysis of Variance (ANOVA) and treatment means separated using Duncan's Multiple Range Test (DMRT).

3. RESULTS AND DISCUSSION

Pre-cropping physico-chemical properties of the soil: According to WHO/FAO (Codex Alimentarius Commission, 2001), the permissible levels of Pb, Cu and Zn in vegetables are 0.3, 0.3 and 50 mg/kg respectively. FEPA classified Pb as extremely hazardous waste when maximum concentration in extract is more than 500ml/L and dangerous waste when the concentration in extract is between 2-20ml/L (FEPA, 1991). The concentrations of these heavy metals are far greater than the maximum permissible levels and Pb can be categorized as extremely hazardous and dangerous waste. The soil chemical analysis revealed high Pb concentration, most probably because the soil was taken from a lead acid battery dump site, and production of lead acid battery include lead based materials (Nnorom and Osibanjo, 2006).

Effects of fertilizer treatment on growth parameters of *Amaranthus cruentus*

Plant height: The effects of the various fertilizer treatments on the growth of amaranthus are summarized in Table 1. It is evident that fertilizer treatment significantly increased the height of the crop, with the combined application of OF and U having the largest influence. Thus, OF + U treated plants were 11.50, 13.55, 18.37 and 19.74 cm tall compared to untreated plants that were 4.88, 5.20, 6.43 and 6.51 cm tall at 3, 4, 5 and 6 weeks after transplanting, respectively.

Stem girth: Evaluation of the effects of fertilizer treatment on stem girth showed that plants grown on soil amended with OF + U had thicker stems (0.24, 0.25, 0.42 and 0.53 cm) than the control plants which were 0.05, 0.08, 0.08 and 0.14 cm thick at 3, 4, 5 and 6 weeks after transplanting, respectively across the successive growth periods.

Similarly plants grown with soil amendments had significantly higher leaf area, number of leaves than the untreated plants. This may be due to the ability of these amendments to reduce the bioavailability of the metals besides being able to supply essential nutrients needed for crop growth and development. The amendments provide nutrients and reduce toxicity on plants which in turn lead to reduced heavy metal availability, improved soil fertility, and increased plant growth (Clemente *et al*, 2006).

Tables 3 summarize the effects of the various fertilizer treatments on the growth parameters. The effects were significant (p=0.05) in all the cases. It is noteworthy that the application of OF+U led to the respective highest values throughout the period of growth. In all instances the control plants had least performance. Combined application of organic fertilizer and urea gave higher number of leaves, plant height, leaf area and stem girth than each of the other amendments. This could be due to the ability of organic amendment to release a high proportion of humified organic matter capable of decreasing bioavailability of the heavy metals in soil.

Table 1: Effects of different fertilizer treatments on height and stem girth of *Amaranthus cruentus* at successive growth periods

Treatments	Plant Height (cm)				Stem Girth (cm)			
	Weeks After Transplanting				Weeks After Transplanting			
	3	4	5	6	3	4	5	6
CONTROL	4.88d	5.19d	6.43d	6.51d	0.05a	0.08c	0.08e	0.14c
Urea(U)	6.34bcd	7.28d	7.85cd	8.30d	0.07a	0.17b	0.15d	0.18c
Single Super Phosphate (SSP)	9.24abcd	9.88bcd	10.88c	12.05cd	0.12a	0.18b	0.17c	0.21c
U+SSP	7.16abcd	8.19cd	8.81cd	9.78d	0.16a	0.25a	0.20c	0.26c
Organic Fertilizer (OF)	9.38abcd	12.24ab	13.38bc	15.04c	0.12a	0.16b	0.28b	0.37b
OF+U	11.5a	13.55a	18.37a	19.74a	0.24a	0.25a	0.42a	0.53a
OF+SSP	10.39ab	11.27abc	13.86bc	15.30bc	0.15a	0.25a	0.30b	0.37b
OF+SSP+U	10.23abc	12.83ab	15.37b	1816ab	0.19a	0.29a	0.38a	0.43b

Means followed by the same letter in the same column are not significantly different from each other at $p<0.05$

Table 2: Effects of different fertilizer treatments on leaf area and number of leaves of *Amaranthus Cruentus* at successive growth periods

Treatments	Leaf Area (cm^2)				Number of Leaves			
	Weeks After Transplanting				Weeks After Transplanting			
	3	4	5	6	3	4	5	6
CONTROL	1.31b	1.69c	2.15d	2.42d	5.92g	7.18g	7.17e	7.08h
Urea(U)	1.91b	2.40c	2.64d	2.80d	7.25f	9.29f	8.25de	8.35f
Single Super Phosphate (SSP)	3.67a	4.47b	4.33bc	4.95c	8.17c	11.00d	9.25d	9.08e
U+SSP	1.40b	2.67c	2.99cd	3.26d	7.50e	9.33f	8.08de	8.17g
Organic Fertilizer (OF)	4.46a	5.34b	5.84b	6.91b	7.92d	10.50e	12.17c	12.00d
OF+U	5.36a	7.10a	7.93a	9.78a	10.15a	15.50a	15.25a	15.17a
OF+SSP	4.79a	4.78b	5.83b	6.32bc	9.42b	11.83c	13.5b	13.50c
OF+SSP+U	4.41a	5.90b	7.03a	7.46b	7.84d	13.92b	14.33ab	14.50b

Means followed by the same letter in the same column are not significantly different from each other at $p<0.05$

Table 3: Effect of different fertilizer treatments on the growth and yield of *Amaranthus cruentus* after 6 weeks 0f growth

Treatments	**Plant Height (cm)**	**Stem Girth (cm)**	**Leaf Area (cm^2)**	**Number of Leaves**	**Biomass weight (g/pot) Dry**
CONTROL	6.51d	0.14c	2.42d	7.08h	0.71a
Urea(U)	8.30d	0.18c	2.80d	8.35f	1.30b
Single Super Phosphate (SSP)	12.05cd	0.21c	4.95c	9.08e	3.24c
U+SSP	9.78d	0.26c	3.26d	8.17g	1.01b
Organic Fertilizer (OF)	15.04c	0.37b	6.91b	12.00d	4.15d
OF+U	19.74a	0.53a	9.78a	15.17a	12.01g
OF+SSP	15.30bc	0.37b	6.32bc	13.50c	4.38e
OF+SSP+U	18.16ab	0.43b	7.46b	14.50b	5.09f

Means followed by the same letter in the same column are not significantly different from each other at $p<0.05$

Effects of fertilizer treatments on Pb, Zn and Cu in the tissue of *Amaranthus cruentus*: The effects of various fertilizer treatments are summarized in Table 4. It is evident that fertilizer treatments significantly decreased the concentration Pb, Zn and Cu in the crop; with combined application of OF + U having the least concentration. OF + U treated plants had Pb, Zn and Cu concentration (647.00, 198.50, 16.50 mg/kg) compared to untreated plants that were 2562.50, 695.00 and 66.00 mg/kg. Augustina Branzini and Marta Susana Zubillaga (2011) found that combination of organic and inorganic amendments are needed for immobilizing different metals. Anita Singh and Madhoolika Agrawa (2011) also found that plants grown in Farmyard Manure alone and Farm Yard Manure in combination with NPK and N showed better growth compared to other amendments which suggest that combination of organic fertilizer with inorganic fertilizer (urea) reduces bioavailability and phytoavailability of heavy metals . Walker and Baker (1990) opined that enhanced plant growth obtained from the combination of organic and inorganic fertilizers (organic fertilizer and urea) might also be attributed to rapid mineralization of N from inorganic fertilizer and steady release of N in organic fertilizer which might have met the N requirement of crop at critical stages, this reconfirms the work of Maheshbabu *et al.* (2007) who showed that manure functions as reservoir of nutrient and when they decompose release nutrient slowly during growth periods.

Table 4: Effects of fertilizer treatments on heavy metal (lead, zinc and copper) concentration in plant tissue of *Amaranthus cruentus*

Treatments	**Pb (mg/kg)**	**Zn (mg/kg)**	**Cu (mg/kg)**
CONTROL	2562.50a	695.00a	66.00a
Urea (U)	1407.00bc	361.39b	33.53b
Single Superphosphate (SSP)	1490.00b	304.88bc	39.55b
U+SSP	1154.00bc	452.25b	49.77a
Organic Fertilizer (OF)	1103.50bc	328.20c	35.76b
OF+U	647.00c	198.50c	16.50b
OF+SSP	187.50bc	255.84bc	24.34b
OF+SSP+U	1013.50bc	293.85bc	30.15b

Means followed by the same letter in the same column are not significantly different from each other at $p<0.05$

Table 5: Effects of fertilizer treatments on nutrient concentration (%) and uptake (mg/pot) by *Amaranthus cruentus*

Treatments	**N**		**P**		**K**		**Ca**		**Mg**	
	(%)	**(mg/pot)**	**(%)**	**(mg/pot)**	**(%)**	**(mg/pot)**	**(%)**	**(mg/pot)**	**(%)**	**(mg/pot)**
CONTROL	1.66a	1.19a	0.19a	0.14a	2.38a	1.70a	2.04a	1.46a	0.72a	0.51a
Urea (U)	2.07a	2.68	0.21a	0.27a	5.27a	6.85a	4.80a	6.24b	1.11a	1.44a
SSP	2.16bc	7.00a	0.21a	0.68a	10.32b	33.44b	10.09b	32.69c	2.32b	7.52b
U+SSP	2.04a	2.06a	0.27a	0.27a	5.90a	5.96a	6.30a	6.36b	1.27a	1.28a
Organic Fertilizer(OF)	1.81a	7.49a	0.38a	1.58ab	14.08bc	58.43c	9.80b	40.67d	2.38b	9.88b
OF+U	2.11b	25.31b	0.53a	6.37b	15.42c	185.19d	11.85b	142.32f	2.36b	28.34c
OF+SSP	2.60c	11.41a	0.46a	2.01ab	14.21bc	62.24c	11.12b	48.71e	2.78b	12.18b
OF+SSP+U	2.18bc	11.11a	0.45a	2.34ab	12.74bc	64.83c	9.65b	49.11e	2.21b	11.25b

Means followed by the same letter in the same column are not significantly different from each other at $p<0.05$

Nutrient concentration and uptake in *Amaranthus cruentus* tissue: Ca and K concentrations in crop tissue grown in the treated soil are listed in Table 5, compared with the control Ca and K concentrations increased significantly with combined application of OF and U having the highest (11.85 and 15.42 %). Among all the amendments Ca and K concentrations were highest in the crop grown on combined application of OF and U .Uptake of P, K, Ca were also highest with application of OF and U.

4. CONCLUSION

Heavy metal concentration was highest in the plant grown on the unamended soils while low concentrations were found in plants of the amended soils. Plants grown with organic fertilizer and urea combined performed better compared to other amendments and the control. They had the lowest concentrations of Pb, Cu and Zn. It is evident that fertilizer application enhanced crop growth through increased soil fertility, and reduction of heavy metal concentration in plant tissue. Field experimentation is being conducted in our Department of Agronomy to authenticate the high potential of combined application of organic and mineral fertilizers in this regard.

5. REFERENCES

- Cao XD, Ma QY, Chen M, Singh SP, Harris WG. 2002. Impacts of phosphate amendments on lead biogeochemistry at a contaminated site. *Environ Science Technology*, 24: 5296–5304.
- Cao XD, Ma QY, Rhue DR and Appel CS. 2004. Mechanisms of lead, copper and zinc retention by phosphate rock. *Environ Pollution*, 131: 435–444.
- Clemente R., Escolar, A and Bernal M.P. 2006. Heavy metal fractionating and organic matter mineralization in contaminated calcareous soil amended with organic materials. *Bioresourse Technology* 97:1894-1901.
- FAO/WHO 1978. List of maximum levels recommended for contaminants by joint FAO/WHO codex. Alimentaries Commission 3rd Series Rome, FAO/WHO.CAL/FAL 4-1978.
- FEPA 1991. National interim guidelines and standards for industrial effluents, gaseous emission and hazardous wastes management in Nigeria, pp 28-30.
- Kachenko, A.C. and B. Singh 2006. Heavy metal contamination in vegetables grown in urban and metal smelter contaminated sites in Australia. *Water Air Soil Pollution*. 169, 101 – 123.
- Long X. X., Yang X. E., Ni. W. Z., Ye Z. Q., He, Z. L., Calvert D. V., Stoffella, J. P. 2003. Assessing zinc thresholds for phytotoxicity and potential dietary toxicity in selected vegetable crops. *Commun Soil Sci Plant Anal.* 34 (9 & 10):1421–1434.
- M. Mench, J. Vangronsveld, C. Beckx, and A. Ruttens, 2006. Progress in assisted natural remediation of an arsenic contaminated agricultural soil, *Environmental Pollution*, vol. 144, no. 1, pp. 51–61.
- Nicklow, C. W., P. H. Comas-Haezebrouck and W. A. Feder, 1983. Influence of varying soil Lead levels on Lead uptake of leafy and root vegetables. J. Am. Soc. *Hortic. Sci*. 108: 193-195.

- Singh, C.M., P.K. Sharma, P. Kishor, P.K. Mishra, A.P. Singh, R. Verma and P. Raha, 2011. Impact of integrated nutrient management on growth, yield and nutrient uptake by wheat (*Triticum aestivum* L.). Asian J. Agric. Res., 5: 76-82.
- Singh, Anita, Agrawal, Madhoolika and Marshall, Fiona M., 2010. The role of organic vs. inorganic fertilizers in reducing phytoavailability of heavy metals in a wastewater-irrigated area. *Ecological Engineering*, 36 (12). pp. 1733-1740.
- Singh, S. and M. Kumar, 2006. Heavy metal load of soil, water and vegetables in peri-urban Delhi Environ. Monitor. Assess., 120: 79-91.
- XieZheng-miao, Wang Bi-ling, Sun Ye-fang, Li Jing, 2006. Field demonstration of reduction of lead availability in soil and cabbage (*Brassica Chinensis* L.) contaminated by mining tailings using phosphorus fertilizers .*Journal of Zhejiang University SCIENCE* B Vol. 7 No. 1 p. 43-50.
- Yang X. E., Long X. X., Ni W. Z, Ye Z. Q., He ZL, Stoffella P. J, Calvert D V. 2002. Assessing copper thresholds for phytotoxicity and potential dietary toxicity in selected vegetables crops. *J Environ Sci Health.*; B37 (6):625–635.