Chapter

Evaluation of Ornamental Plants for Phytoremediation of Contaminated Soil

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Abstract

A completely randomized design with three replicates was conducted at the Screen house of the Department of Crop Soil and Pest Management, Federal University of Technology Akure, Ondo State, to examine the phytoremediation potential of *Codiaeum variegatum* and *Basella alba* on contaminated soils from four locations. Soils were collected from the Mechanic workshop, Dumpsite, Forest Topsoils, and Effluent site, and filled into the buckets. Initial soil analysis was conducted on all the soils to determine heavy metal concentration (Cu, Cd, Ni, Pb, and Zn). At 12 weeks after planting, soil and plant (root and shoot) samples were analyzed to determine the heavy metals accumulated. WHO permissible limit value for heavy metal concentration in soil and plant were used as a standard to evaluate plant phytoremediation potential. Results from the study confirm the phytoremediation potential of *C. variegatum* and its high tolerance for the accumulation of heavy metals. *B. alba* plant also shows its potential in removing heavy metals from the soil, but it was not as tolerant as *C. variegatum* as *B. alba* planted in soils from mechanic workshop and effluent site had stunted growth.

Keywords: ornamental plants, metals, toxics, phytoremediation

1. Introduction

Environmental pollution has been on the rise over the past decades because of the increasing human activities on energy reservoirs, unsafe agricultural practices, and rapid industrialization. The result of these technogenic and anthropogenic activities are the major sources of heavy metals in the environment [1]. In Nigeria, soil contaminations is caused by industrial and agricultural practices such as chemical fertilizer and pesticide application, wastewater irrigation, mining activities, and metal smelting. All these human activities have contributed to problems hindering the nation's agriculture from attaining food security.

However, agriculture in Nigeria has been facing two challenges for a long time, these challenges are; promoting environmental sustainability and enhancing food production. To ameliorate these challenges, there is a need to adopt management techniques that promote environmental sustainability. Phytoremediation has been identified as a cost-effective and easy way to sustain our environment by removing toxic elements from contaminated soils. Phytoremediation is a technique that relies on the use of plant interactions (physical, biochemical, biological, chemical, and microbiological) in polluted sites to mitigate the toxic effects of pollutants [2]. In Nigeria, heavy metals, pesticides, greenhouse gases, and hydrocarbons are pollutants that are of environmental and public health concerns.

The toxicity of heavy metals in the biota is because of their bioaccumulative nature and persistence in the environment thereby contaminating the food chains. The soil-to-plant transfer of heavy metals made it easy for metal transfer into the food chains. Metals are absorbed by plant roots and transferred to herbivorous animals along the food chain [3]. When plants like vegetables or cereals are planted in contaminated soils, the consumption of such food becomes a serious health issue to man [4].

However, because of the threat posed by the heavy metals on the growth and development of arable crops, scientists have warned against the use of crops as a phytoremediator because of their risk on human health after consumption. This is the reason for the shift to ornamental plants. The use of ornamentals continues to attract attention in recent years. In Nigeria, most ornamentals plants are not edible, therefore, the risk of contaminants entering the food chain is reduced.

The use of ornamental plants as a test plant in a phytoremediation experiment is because of their high biomass which means they can accumulate more heavy-metal concentration through their roots, into their tissues. Many studies have been conducted to evaluate the potentials of ornamental plants as in phytoremediation [5–8]. However, most of the selected ornamental plants used in all the studies were not indigenous and not commonly cultivated in Nigeria. Therefore, this study aims to evaluate the phytoremediation potential of two ornamental plants in common, although not indigenous in Nigeria. In addition, *Codiaeum variegatum* and *Basella alba* were used in this study because they grow well in heavy metal contaminated soils, but their mechanism to resist the heavy metals has not been reported. *B. alba* belongs to the family of Basellaceae and commonly refers to as Indian spinach, Malabar spinach, Ceylon spinach, and vine spinach. The plant is an underutilized vegetable in Nigeria compare to *Amaranthus* spp. and *Telfairia occidentalis.* In addition to being edible, *B alba* is also grown as an ornamental foliage vine. *Codiaeum variegatum* is an ornamental plant species that belongs to the genus Codiaeum, and the family Euphorbiaceae.

2. Objective

To examine the phytoremediation potential of *C. variegatum* and *B. alba* in heavy metal contaminated soils collected from four sites. The study also analyzed part of the plant with higher heavy metal concentration (shoots or roots) and the heavy metal concentration left in the soil after the experiment.

3. Materials and methods

A Completely Randomized Design with three replicates was conducted at the Screen house of the Department of Crop Soil and Pest Management, Federal University of Technology Akure, Ondo State located in the rain forest vegetation zone of Nigeria (7°16′N, 5°12′E). Soils were collected from four sites (Mechanic workshop, Dumpsite, Forest topsoil, and Effluent site) and filled into the buckets and transported to the screen house. The soils from the four locations served as the treatments. A total of 12 plastic buckets were used for each ornamental plant (4 locations replicated three times), to make it 24 plastic buckets for both ornamental plants (*C. variegatum* and *B. alba*). The planting material was obtained from

LUCADO horticultural garden located in Akure (less than 5 km to the experimental site). The seeds of *B. alba* were planted while the seedlings of *C. variegatum* were purchased from the horticultural garden and it was repotted. Watering was done daily and weeds were hand-pulled.

Initial soil analysis was conducted on all the soils to determine heavy metal concentration. The heavy metal tested on soil and plant samples were, Cu, Cd, Ni, Pb, and Zn using Atomic Absorption Spectrometer [9]. The plant growth traits were recording, including; plant height (cm), stem girth (cm), leaf length (cm) and leaf numbers. At 12 weeks after planting (WAP), soil analysis was done to determine the remaining heavy metal concentration in the soil in order to determine the percentage of contamination reduction. In the final week of the experiment (12 weeks after planting), soil and plant (root and shoot) samples were again analyzed to determine the heavy metal concentration. WHO [10] permissible limit for heavy metal concentration in the soil and plant were used as standard and as a rating for each plant phytoremediation potential. The data were subjected to analysis of variance (ANOVA) using Statistical Package for Social Sciences (Version 17). Significant means were from each other using Tukey Test at 5% level of probability.

4. Results and discussion

4.1 Effect of heavy metal on plant growth parameters

Significant differences were recorded across the treatments (soils from different locations) for the growth parameters of *C. variegatum* (**Table 1**). There was no consistency in the growth performance as severe impact was felt on the number of leaves, stem girth, and leaf length of *C. variegatum* planted in soils from the effluent site as they had the least mean value. *C. variegatum* planted in soils collected from dumpsite had the highest mean value for number of leaves, stem girth, and leaf length. The severe impact felt on *C. variegatum* planted on the effluent site could be attributed to excess levels of metals which may have inhibits physiologically active enzymes as earlier speculated by Gadd [11]. Significant differences were recorded across the treatments for the growth parameters of *B. alba* (**Table 1**). The results

Treatments	Plant height	Number of leaves	Stem girth	Leaf length
C. variegatum				
MS	11.88a	10.00ab	0.79a	23.72c
ES	15.10c	8.00a	0.75a	19.27a
DS	14.36b	17.00c	0.96b	24.02d
FS	13.83b	10.00ab	0.89ab	21.68b
B. alba				
MS	21.96a	10.45a	0.51a	10.14a
ES	30.78b	15.17c	0.62a	10.08a
DS	60.19c	15.00c	0.72a	12.89b
FS	65.55d	14.00bc	0.66a	11.23ab

Means with the same letter in the same column are not significantly different from one another at $p < 0.05$ based Duncan test.
MS—soils from mechanic workshop; ES—effluent site; DS—dumpsite; FS—forest topsoil.

Table 1.
Effect of soil from different sites on growth parameters of the ornamental plants.

revealed that *B. alba* planted in soils from dumpsite and forest topsoil gave the highest mean value for plant height, number of leaves, and leaf length. Plants on the two soils appeared healthy because the forest topsoils served as the control. The good performance of *B. alba* planted on the dumpsite soils could be a result of a high level of organic matter content.

4.2 Initial and final metal concentrations in plant tissues and in soils

The result presented in **Table 2** shows the initial concentration of heavy metals in the root and shoot of *C. variegatum* and *B. alba*. The concentration of the heavy metals present in the plant was within the permissible value recommended by the WHO (**Table 3**) for except for the Zn concentration (in both plants), and Cd (*B. alba* only). The initial Zn concentration present in root part of *B. alba* was above the minimum plant permissible limit (3.056 mg/kg) while the concentration present at the shoot part was below the permissible limit (0.421 mg/kg).

The result presented in **Table 4** and **Figure 1** shows the initial and final heavy metal concentration of soils from the four sources. The results revealed that the initial and final heavy metal concentrations in all the soils were below the target value recommended by WHO for soils. However, soils from the mechanic workshop site show a considerable decrease in the heavy metal concentration present at the end of the experiment. The initial Pb concentration for the soil was 0.215 but was reduced to 0.093 in the pot where *B. alba* was planted while it was absorbed below the detective limit by *C. variegatum*. A similar trend was also observed for soils collected from an effluent and dumpsite site for all the heavy metals measured. However, there was a slight change in this trend for soils collected from forest topsoil, as there was a slight increase in the final heavy metal concentration recorded for metals such as Cu (initial 0.751; final 0.892 *B. alba,* 1.073 *C. variegatum*), Cd **(initial** 0.072; **final** 0.097, *B. alba*), and Zn (**initial** 27.525; **final** 27.095 *B. alba* 28.1 *C. variegatum*).

Result presented in **Table 5** shows the final heavy metal concentration present in the plant parts for all the soils. For soils collected from the mechanic workshop, the Cd (0.06 for *B. alba* and *C. variegatum*) and Zn concentration present in both plants were above the WHO permissible limit, while the remaining metals were within the permissible limit. Similar trends or results were also recorded for soils collected from the effluent site, dumpsite, and forest topsoil. The growth of both plants were affected variably by the stress of heavy metals such as Zn and Cd. High concentrations of Zn and Cd resulted in stunted growth, reduced biomass production and produced characteristic visible effects similar to those described by other workers in different plant species [12, 13]. These observations are substantiated by a significant concentration in the level of Zn and Cd present in the plant tissue of both

Heavy metals	*B. alba*		*C. variegatum*	
	Root	Shoot	Root	Shoot
Cu	0.455	0.193	0.572	0.49
Cd	0.054	0.01	0.01	BDL
Ni	0.082	0.027	0.09	0.01
Pb	0.034	BDL	0.032	BDL
Zn	3.056	0.421	3.25	2.081

*BDL = Below Instrument Detection Limit (<0.001 ppm) *1 mg/kg = 1 ppm.*
MS—soils from mechanic workshop; ES—effluent site; DS—dumpsite; FS—forest topsoil.

Table 2.
Initial analysis to determine heavy metal conc. in plant root and shoot (ppm).

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Heavy metals	Target value of soil (mg/kg)	Permissible value of Plant (mg/kg)
Cu	36	10
Cd	0.8	0.02
Ni	35	10
Pb	85	2
Zn	50	0.60

Target values are specified to indicate desirable maximum levels of elements in unpolluted soils.
Source: WHO [10].

Table 3.
WHO permissible limit of Cu, Cd, Ni, Pb and Zn in soil and plant by WHO [10].

Soil source	Initial	Final Conc.	
		B. alba	*C. variegatum*
Mechanic			
Cu	1.567	0.836	1.484
Cd	0.11	0.088	0.085
Ni	0.89	0.26	0.314
Pb	0.215	0.093	BDL
Zn	37.17	24.9	31.274
Effluent			
Cu	2.122	1.75	1.823
Cd	0.153	0.11	0.142
Ni	1.27	0.494	0.829
Pb	0.262	0.21	0.069
Zn	42.57	26.35	32.923
Dumpsite			
Cu	2.014	0.962	1.216
Cd	0.289	0.068	0.092
Ni	1.276	0.398	0.483
Pb	0.312	BDL	0.077
Zn	32.036	28.719	30.136
Forest topsoil			
Cu	0.751	0.892	1.073
Cd	0.072	0.097	0.047
Ni	0.558	0.085	0.048
Pb	0.134	0.145	0.066
Zn	27.525	27.095	28.1

*BDL = Below Instrument Detection Limit (< 0.001 ppm) *1 mg/kg = 1 ppm.*
MS—soils from mechanic workshop; ES—effluent site; DS—dumpsite; FS—forest topsoil.

Table 4.
Soil heavy metal concentration (mg/kg).

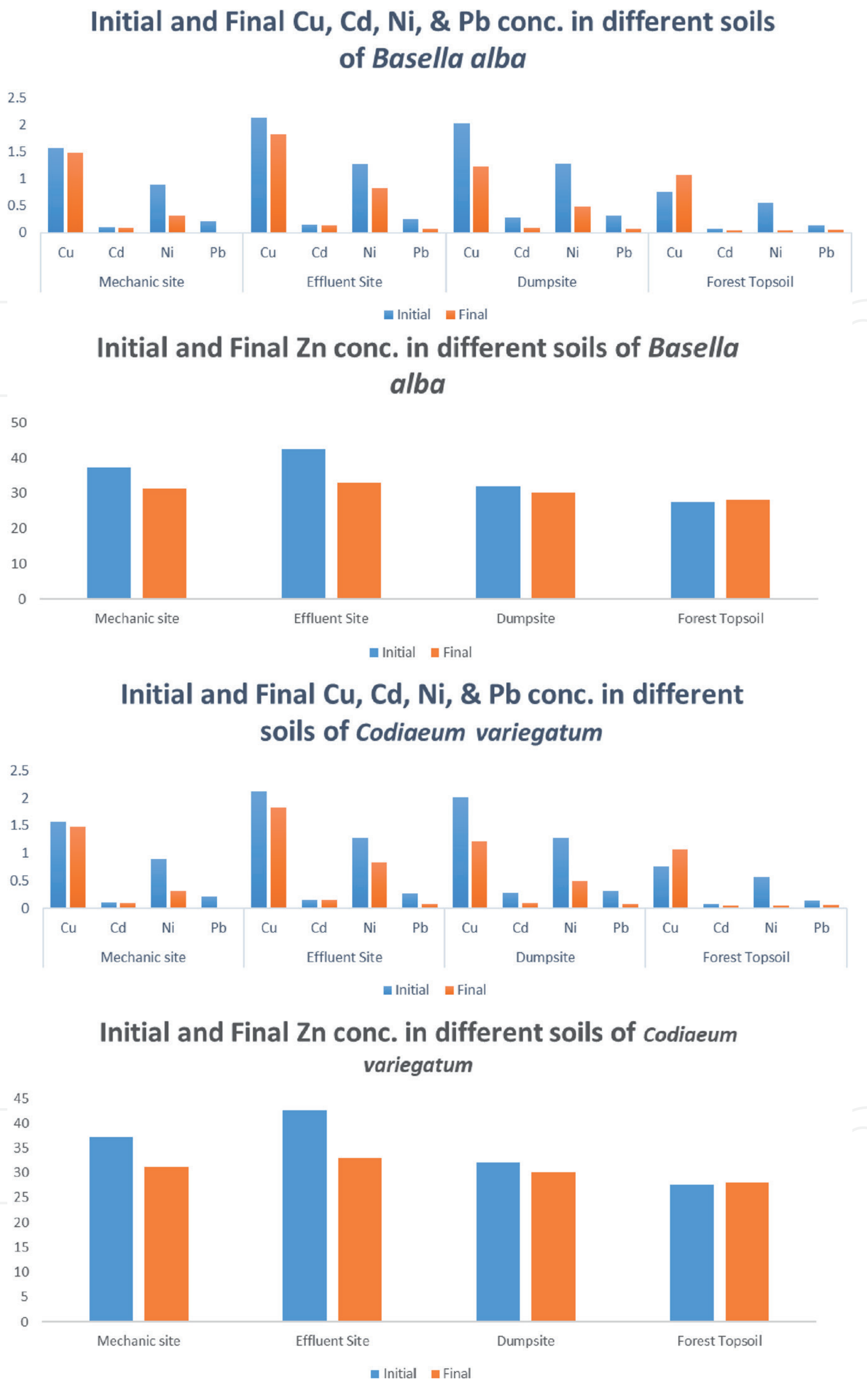

Figure 1.
Initial and final heavy metal concentration (mg/kg) for C. variegatum *and* B. alba.

ornamental plants. The decrease in the mean value of growth parameters of *B. alba* and *C. variegatum* planted on soils from effluents and mechanic site may be attributed to the significantly high concentration of Cd and Zn value which is higher than the permissible limit. These findings agree with Pandey and Pathak [14]. Metal stress in plants leads to a decrease in growth parameters and dry matter of plants [14, 15].

	B. alba		***C. variegatum***	
	Root	**Shoot**	**Root**	**Shoot**
Mechanic				
Cu	0.627	0.038	0.915	0.085
Cd	0.049	0.012	0.049	0.011
Ni	0.078	0.031	0.079	0.011
Pb	0.011	BDL	BDL	BDL
Zn	3.038	0.32	3.063	0.475
Effluent				
Cu	0.484	0.041	0.915	0.059
Cd	0.037	0.01	0.051	BDL
Ni	0.087	0.03	0.065	0.02
Pb	BDL	BDL	0.017	BDL
Zn	2.737	0.299	2.873	0.628
Dumpsite				
Cu	1.096	0.12	0.838	0.514
Cd	0.052	0.013	0.024	0.01
Ni	0.07	0.025	0.085	0.026
Pb	0.015	0.01	0.02	0.01
Zn	3.173	0.125	2.955	0.315
Forest topsoil				
Cu	0.537	0.3	0.563	0.05
Cd	0.057	0.021	0.023	BDL
Ni	0.092	0.04	0.06	BDL
Pb	0.009	0.003	BDL	BDL
Zn	2.859	0.538	3.425	0.211

*BDL = Below Instrument Detection Limit (<0.001 ppm)*1 mg/kg = 1 ppm.*
MS—soils from mechanic workshop; ES—effluent site; DS—dumpsite; FS—forest topsoil.

Table 5.
Concentration of heavy metals in plants part soil source.

5. Conclusion

This study was conducted to determine the phytoremediation potential of two ornamental plants (*B. alba* and *C. variegatum*). The study reveals the ability of both plants in removing heavy metals (hyperaccumulators), but most heavy concentration was accumulated in the roots more than shoots. However, the accumulation of Cd and Zn at the end of the study was higher than the permissible limit. However, the use of *B. alba* to remediate the soil may not be advisable because of its less phytoremediation potential compare to *C. variegatum*. Also the former is edible and could pose a serious threat to health when consumed. Finally, additional studies are needed to investigate the phytoremediation performance of more indigenous ornamental plants in Nigeria.

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References

[1] Woranan N, Orapan M, Prasad M. Chapter 9: Potential of ornamental plants for phytoremediation of heavy metals and income generation. In: Prasad MNV, editor. Bioremediation and Bioeconomy. UK: Elsevier; 2016. pp. 177-217. DOI: 10.1016/B978-0-12-802830-8.00009-5

[2] Alaboudi K, Ahmed B, Brodie G. Phytoremediation of Pb and Cd contaminated soils by using sunflower (*Helianthus annuus*) plant. Annals of Agricultural Science. 2018;**63**(1):123-127. DOI: 10.1016/j.aoas.2018.05.007. ISSN: 0570-1783

[3] Nica DV, Bura M, Gergen I, Harmanescu M, Bordean D-M. Bioaccumulative and conchological assessment of heavy metal transfer in a soil-plant-snail food chain. Chemistry Central Journal. 2012;**6**(1):55

[4] Orisakwe OE, Nduka JK, Amadi CN, Dike DO, Bede O. Heavy metals health risk assessment for population via consumption of food crops and fruits in Owerri, South Eastern, Nigeria. Chemistry Central Journal. 2012;**6**(1):77

[5] Liu H, Zhao H, Wu L, Liu A, Zhao F, Xu W. Heavy metal ATPase 3 (HMA3) confers cadmium hypertolerance on the cadmium/zinc hyperaccumulator *Sedum plumbizincicola*. The New Phytologist. 2017;**215**(2):687-698

[6] Shuang C, Tingan Z, Shanlin Z, Ping L, Qixing Z, Qianru Z, et al. Evaluation of three ornamental plants for phytoremediation of Pb-contaminated soil. International Journal of Phytoremediation. 2013;**15**(4):299-306. DOI: 10.1080/15226514.2012.694502

[7] Miao Q, Yan J. Comparison of three ornamental plants for phytoextraction potential of chromium removal from tannery sludge. Journal of Material Cycles and Waste Management. 2013;**15**(1):98-105

[8] Wang X, Zhou Q. Ecotoxicological effects of cadmium on three ornamental plants. Chemosphere. 2005;**60**(1):16-21

[9] Shaltout A, Ibrahim M. Detection limit enhancement of Cd, Ni, Pb and Zn determined by flame atomic absorption spectroscopy. Canadian Journal of Analytical Sciences and Spectroscopy. 2007;**52**:5

[10] World Health Organization. Permissible Limits of Heavy Metals in Soil and Plants. Geneva, Switzerland: WHO; 1996

[11] Gadd GM. Geomycology: Biogeochemical transformations of rocks, minerals, metals and radionuclides by fungi, bioweathering and bioremediation. Mycological Research. 2007;**2007**(111):3-49

[12] Zhou W, Qiu B. Effects of cadmium hyperaccumulation on physiological characteristics of *Sedum alfredii* Hance (Crassulaceae). Plant Science. 2005;**169**:737-745

[13] Gajewska E, Sklodowska M. Relations between tocopherol, chlorophyll and lipid peroxides contents in shots of Ni-treated wheat. Plant Physiology. 2007;**164**:364-366

[14] Pandey N, Pathak GC. Nickel alters antioxidative defence and water status in greengram. Indian Journal of Plant Physiology. 2006;**11**:113-118

[15] Ryser P, Sauder WR. Effects of heavy-metal-contaminated soil on growth, phenology and biomass turnover of *Hieracium piloselloides*. Environmental Pollututon. 2006;**140**:52-61