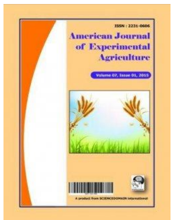

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Comparatives Effectiveness of Two Vetiveria Grasses Species *Chrysopogon zizanioides* and *Chrysopogon nigritana* for the Remediation of Soils Contaminated with Heavy Metals

M. O. Adigun[1*] and K. S. Are[2]

[1]Department of Crop Production, Olabisi Onabanjo University, Ago-Iwoye, Nigeria.
[2]Land and Water Resources Management Program, Obafemi Awolowo University, Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author KSA designed the study, wrote the protocol and wrote the first draft of the manuscript. Author MOA reviewed the experimental design and all drafts of the manuscript. Authors MOA and KSA managed the analyses of the study. Author KSA identified the plants. Authors KSA and MOA performed the statistical analysis. Both authors read and approved the final manuscript.

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ABSTRACT

The study was carried out at the screen house of the Institute of Agricultural Research and Training (I.A.R&T) to determine the responses of two vetiver grasses cultivars (*Vetiver zizanioides* and *Vetiver nigritana*) on four different contaminated soils and their potential to remediate metal contaminated soil. The experiment was a 3 x 4 factorial experiment arrange in a randomized complete block design and replicated thrice. There were three levels of vetiveria grasses (*V. zizanioides, V. nigritana,* and no vetiver) and four contaminated soils. The absorption of metal contaminants like lead, cadmium, and zinc by the two vetiver cultivars was determined in all treatments. In mechanic village soil, *V. zizanioides* absorbed more of zinc followed by *V. nigritana*

**Corresponding author: E-mail: micadigun@yahoo.com;*

with percentage reduction of 7.0 and 5.9 respectively. In industrial waste soil, the percentage reduction of heavy metal in the soil was 27.6 and 18.8 by *V. zizanioides and V. nigritana*, respectively. Also in urban waste soil, there was a percentage reduction of 13.7 and 6.1 by *V. nigritana* and *V. zizanioides*, respectively. In mechanic village soil, *V. nigritana* absorbed more of cadmium in the soil than *V. zizanioides* with percentage reduction of cadmium being 30.5 and 26.2 respectively. In urban waste soil, there were percentage reductions of 7.1 and 6.8 in *V. nigritana* and *V. zizanioides.* In mechanic village soil, *V. nigritana* absorbed more of lead than *V. zizanioides* with percentage reduction of 36.3 and 43.4 respectively. In urban waste soil, there were percentage reduction of 10.2 and 6.3 by *V. zizanioides* and *V. nigritana* respectively. In industrial waste soil, there were percentage reduction of 39.2 and 29.9 by *V. zizanioides* and *V. nigritana* respectively. *Vetiver nigritana*, the local variety, proved to have the great potential of phytoextracting the heavy metals in the contaminated soils than the exotic cultivar (*V. zizanioides*).

Keywords: V. zizanioides; phytoextracting; V. nigritana; urban waste soil; industrial waste soil; mechanic village soil.

1. INTRODUCTION

The need to meet market demand and generate additional sources of short term income by subsistence farmers and some artisans has led to expansion of cultivation to marginal lands including soil contaminated with heavy metals. The increasing use of agrochemicals to maintain and improve soil fertility has introduced unwanted elements such as Cadmium (Cd) and Zinc (Zn) from contaminated agrochemicals into agricultural soil, which of course poses a potential threat to the food chain [1]. Majority of farm land in Nigeria today where dry season vegetables are grown are dumping sites for urban wastes [2]. Due to ever increasing industrial, agricultural, and mining activities worldwide, heavy metal pollution of land and water is becoming globally important environmental, health, economic, and planning issue. There is an increase in world population, and unpleasant disposal of industrial effluents, especially in the third world countries, is causing soil pollution. Utilization of these lands for agricultural purposes and urban development's requires a safe and efficient decontamination process. The need to clean up these lands from toxic pollutants becomes more important for our society to be free from ill health. Phytoremediation becomes more important technology to clean up pollutant in the environment. Besides being an economical, energy efficient and environmental friendly method, phytoremediation can be applied to large areas and is useful for removing a wide variety of contaminants (metal, radionuclide and organic substance) from growth media (soil, sludge, sediment and water) [3]. Phytoremediation can be either phytoextraction, in which plants decontaminate soil through uptake of heavy metals into aerial part and can be thereafter harvested and removed from the site; phytostabilization, in which plants are used to minimize heavy metal mobility in contaminated soil or phytovolatilization, in which plants extract volatile metals from contaminated soil and volatilize them from foliage [4].

Vegetation is important for all phytoremediation application, it is necessary to use plants that tolerate high levels of toxic pollutants. Different plants have been used globally for phytoremediarion but the level of tolerance of most of them to toxic metals poses questions in their suitability for phytoremediation. The use of vetiver grass (*Vetiver zizanioides* (L) nash) has been well documented to have a good resistance to the execrable environment and to be able to survive in high concentration of heavy metal [5]. Application of vetiver for phytoremediation, however, depends upon various factors such as physical and chemical properties of growth media as well as agronomic practice. All these should be carefully investigated and properly considered in applying for site specific conditions to achieve the desired goal. The Vetiver System (VS), which is based on the application of vetiver grass, was first developed by the World Bank for soil and water conservation in India in the 1980s. in addition to its very important application in agricultural lands, scientific research conducted in the last 20 years has clearly demonstrated that VS is also one of the most effective and low natural methods of environmental protection.

Land degradation is becoming one of the major environmental issues in the world, especially in developing nations. Land contamination, usually accompanied by release of heavy metals, always results in a decrease or complete loss of land productivity, and produces on-site and off-site pollution to soil and water. The methods for land reclamation vary from physical to chemical to biological control. The cost of reclamation of degraded land using old methods such as liming, is huge, but far cheaper, using new biological methods. Vegetation or re-vegetation is a chief biological measure, but the key is choosing the right species of vegetation. Trees, shrubs, creepers and herbs can be used to reclaim degraded land, but the best species are grasses due to their strong residence to adverse conditions, and fast-growing features. Among the grasses that are prominently being used worldwide is vetiver grass (*V. zizanioides*) for toxic and metal contaminated soils. Vetiver has various kinds of miraculous characteristics and functions, such as rapid growth, huge biomass, massive and long roots (can grow up to 3 m soil depth). Applications around the globe indicate that vetiver has a great potential for land reclamation, including reclamation of barren mountains or hills, contaminated water and soil, mined lands, quarries etc. stiff foliage of the grass and the dense but porous nature of the hedge formed by the strip makes vetiver grass strip suitable to perform the function [6]. In previous reports, vetiver grass strips were compared with either no vetiver grass reprints, vetiver grass strips were compared with either no vetiver grass treatments or other grasses on a particular soil but there was little or no information on the potential of different species of vetiveria grass in the reclamation of metal contaminated soils.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out at the screen house of the Institute of Agricultural Research and Training (7 23º N, 3 51º E). Soil samples were collected from four different sites within Ibadan metropolis. Urban waste soil from refuse-dump site at National Horticultural Research Institute (NIHORT), industrial waste soil from Iron and Steel Industry at Oluyole Industrial Estate, mechanic village soil at Eleyele/Sango, and Agricultural soil from farm plot at I.A.R &T farm. The soil samples (20 cm depth) were collected randomly from each site and allowed to pass through a 4 mm mesh sieve to remove debris. The sieved soil samples were transferred into concrete slabs of 108 cm long and 54 cm high. The bottom of each slab has been perforated to allow free drainage while a geo-textile (tissue paper) was laid on the bottom of each slab to limit particle flushing by percolation flow. Thirty-six (36) concrete slabs were used with a slab filled with 4 mm screen sieved soil samples and compacted to a density of 1.10 Mgm^{-3}.

2.2 Experimental Layout Treatments and Analyses

Two vetiver grass species *Vetiver zizanioides* (exotic cultivar) and *Vetiver nigritana* (local species) were used for the purpose of phytoremediation. The slips of vetiver grass were prepared by cutting the shoots of the uprooted grass to a length of 20 cm. The root of each slip were treated with cow tea (cow dung mixed with water) to prevent root desiccation. Each species of vetiver grass was planted into 2 of 3 slabs containing soil samples collected from a sample site. There were 12 treatments of 4x3 factorial experiment arranged in a randomized complete block design. The experimental layout is shown in Table 1. The soil samples were sieved to take off thrashes and non soil remnants, air dried and parked into an identified slab at bulk density of 1.2 gcm^{-3}.

The soil was wet to field capacity before planting the two vetiver grasses. The vetiver slips that were planted were cut to a length of 30 cm, while their roots were treated with cow tea (cow dung slurry) to prevent desiccation before planting. These grasses were constantly wetted with water to allow normal growth and early tillering.

At 2 months after vetiver grass has been fully established the shoots were pruned to a length of 20 cm high. The biomass from the pruning was weighed (fresh and dry) to compare the biomass yield as affected by the level of contaminants. The width of the over strips was also measured before pruning subsequently, the height and width of the grass were measured on weekly basis to determine the growth rate of vetiver in each plant slab as it was affected by contaminant in the soil.

2.3 Plant Parameter and Measurement

At 1 week after pruning (WAP) of the vetiver grass shoots to a length of 20 cm, the vetiver grass shoot was measured using measuring tape graduated in centimeter from soil surface level to the tip of the plant. The height of the grass was measured at 1WAP, 2WAP, 3WAP, and 4WAP after which the shoots were pruned again. The routing height measurement were repeated for another 4 week to confirm whether there was an influence of contaminant on the physiological growth of the two cultivar of vetiver grass.

2.4 Dry Matter Yield

The dry matter yields of the two cultivars of vetiver were determined at every time the vetiver shoots were pruned. The vetiver shoot and roots were cut fresh, weighed and thereafter dried at 65ºC. Sub-sample of the dried shoots were taken for further drying at 105ºC to constant weight for the determination of dry matter yield. The sub sample of vetiver shoots dried at 65ºC was milled with milling machine for chemical analysis. The analysis of the vetiver grass shoots and roots were done to determine the part in which heavy metal accumulates.

2.5 Soil and Plant Analysis

1 g of air dried soil samples were weighed, with 1M $MgSi_2$ + 4 ml aqua-regia, was added and filtered. To the residues, 8 ml of sodium acetate solution adjusted to pH 5 with acetic acid and 4 ml of aqua regia solution. The heavy metal fractions were determined in the filtrate using Atomic Absorption Spectrophotometer (AAS) for plant analysis, 1 g of ground plant samples were digested in concentrated HNO_3 and $HClO_4$ (5:v/v) using digested block. The digested samples were analyzed for Pb, Cd, and Zn using AAS.

2.6 Statistical Analysis

Analysis of variance (ANOVA) was used to analyze the experimental data, while the mean were separated using Duncan Multiple Range Test @ $p< 0.05$ significance level.

3. RESULTS AND DISCUSSION

3.1 Soil Characteristics and Metal Concentration

The general initial properties of the soils used for this study are presented in Table 2 below. The textural class showed that urban waste soil was loamy (udic soil), mechanic village and industrial waste soils were loamy sand (vertisol), and agricultural soil was sandy loam (mollisol or histisol) with pH 6.8, 7.3, 7.1 and 5.2 respectively. The background metal concentrations indicated that heavy metals were generally high especially Cadmium (Cd) and Lead (Pb) in all soils above the permissible levels except in agricultural soil. In general, soil that contain >300 $mgkg^{-1}$ extractable Zinc (Zn), >20 $mgkg^{-1}$ Lead (Pb) and Cadmium (Cd) are considered to be phytotoxic to plants [7]. Although Lead (Pb) in agricultural soil was high, this may be unconnected to the source of the organic material used by the farmers for manuring.

3.2 Growth Performance of Vetiver Grass Cultivars

Plants absorb contaminants through root system and store them in the root biomass and or transport them to the stem and/or leaves. They may continue to absorb contaminants until they are harvested and disposed of safely. The growth performance data (survival rate, height

Table 1. Experimental layout

Treatments	Description
MV + C-ziz	Mechanic village soil + *C. zizanioides*
MV + C-nig	Mechanic village soil + *C. nigritana*
ID + C-ziz	Industrial waste soil + *C. zizanioides*
ID + C-nig	Industrial waste soil + *C. nigritana*
UW + C-ziz	Urban waste soil + *C. zizanioides*
UW + C-nig	Urban waste soil + *C. nigritana*
AS + C-ziz	Agricultural soil + *C. zizanioides*
AS + C-nig	Agricultural soil + *C. nigritana*

Table 2. Some initial properties of the soils used for the experiment

Parameter	Mechanic village soil	Industrial waste soil	Urban waste soil	Agricultural soil
Soil pH	7.3	7.1	6.8	5.2
Soil texture	Loamy	Loamy sand	Loamy sand	Sandy loam
Organic matter ($mgkg^{-1}$)	12.1	1.40	30.3	10.1
Pb ($mgkg^{-1}$)	265.2	328.8	241.2	87.6
Cd ($mgkg^{-1}$)	171.6	217.2	172.8	14.4
Zn ($mgkg^{-1}$)	61.2	122.8	87.8	18.0

and biomass) of both *V. zizanioides* and *V. nigritana* are shown in Table 3. The two vetiver grass species showed the best survival (100%) in all the soil types except in mechanic village soil where both grasses showed (75%) survival rate. This might not be unconnected with the high level of Pb in mechanic village soil.

Table 4 below shows that the concentration of lead was higher than the amount of cadmium and zinc present in different soil samples. The concentrations of heavy metals in mechanic village soil ranges between 2.47-69.77 $mgkg^{-1}$ followed by industrial waste soil (5.25-58.52 $mgkg^{-1}$) and urban waste soil (1.72-11.63 $mgkg^{-1}$). Agricultural soil has the lowest concentrations of heavy metals ranges between 0.76-9.29 $mgkg^{-1}$.

Table 5 below also shows that lead has the highest concentration in the soil samples, followed by the cadmium and zinc. Mechanic village soil has the highest amount of heavy metal concentrations which was between 5.12-50.25 $mgkg^{-1}$, industrial waste soil (7.97-26.42 mg/kg^{-1}), while urban waste soil ranged between 3.72-6.47 $mgkg^{-1}$ and agricultural soil has the least 1.37-4.17 $mgkg^{-1}$.

Table 6 below shows that the amount of heavy metal concentrations in the root of *V. zizanioides* was higher than that of *V. nigritana*.

Table 3. Survival rate, height and biomass yield of *V. zizanioides* and *V. nigritana* as affected by soil contaminants

Treatments	Survival (%)	Height (WAP) cm				Biomass (WAP) $mgkg^{-1}$	
		1	2	3	4	4	8
MV + C-ziz	75	49.7b	85.7e	93.7d	100.0b	2.30c	2.33d
MV + C-nig	75	42.5a	74.7d	88.3cd	106.6b	1.76b	2.51d
ID + C-ziz	100	42.3a	69.1bc	81.7bc	87.7a	1.31a	1.86c
ID + C-nig	100	43.2a	69.0bc	81.7bc	87.0a	1.32a	1.88c
UW + C-ziz	100	40.7a	59.7a	81.0bc	82.7a	0.94a	0.70a
UW + C-nig	100	42.7a	66.0bc	74.0ab	83.7a	0.95a	1.20b
AS + C-ziz	100	52.7b	70.3cd	78.0ab	82.0a	1.10a	1.85c
AS + C-nig	100	42.2a	65.3b	71.3a	82.2a	1.19a	1.67c

Mean values with the same letter(S) in a column are not significantly different by Duncan Multiple Range Test (ADMRT) ($P \leq 0.05$)

Table 4. Heavy metal concentrations of the soil planted with *V. zizanioides* after the experiment

Soil	Pb ($mgkg^{-1}$)	Cd ($mgkg^{-1}$)	Zn ($mgkg^{-1}$)
Mechanic village soil	69.77	40.30	2.47
Industrial waste soil	58.52	17.45	5.25
Urban waste soil	11.63	6.83	1.72
Agricultural soil	9.29	2.47	0.76
LSD	2.743	2.420	0.332

LSD=Least Significance Difference

Table 5. Heavy metal concentrations of the soil planted with *V. nigritana* after the experiment

Soil	Pb ($mgkg^{-1}$)	Cd ($mgkg^{-1}$)	Zn ($mgkg^{-1}$)
Mechanic village soil	50.25	19.82	5.12
Industrial waste soil	26.42	8.72	7.97
Urban waste soil	6.47	3.72	6.33
Agricultural soil	4.17	1.37	1.52
LSD	1.899	0.940	0.333

LSD=Least Significance Difference

Table 6. Concentrations of heavy metals in the roots of both *V. zizanioides* and *V. nigritana*

Vetiver grass	Pb ($mgkg^{-1}$)	Cd ($mgkg^{-1}$)	Zn ($mgkg^{-1}$)
V. zizanioides	14.60	3.03	40.48
V. nigritana	18.94	2.07	34.13
LSD	1.710	0.240	1.940

LSD=Least Significance Difference

4. CONCLUSION

In conclusion, the study demonstrated that vetiver grass (*V. zizanioides* and *V. nigritana*) grown in heavy metal contaminated soil have the potential to reduce the contaminants through phytoextraction. Even though the survival rate of vetiver grass in mechanic village soil was not more than 75%, both species still performed very well in extracting heavy metals contained in the soil. However, the level of organic matter in the soil can enhanced the level of absorption of heavy metal by vetiver grass especially *V. nigritana*. This was reflected in the growth performance of the grass in all the soils. Refuse dumped soil with highest organic matter content enhanced the growth and absorption rate of vetiver grass compared with other contaminated soils with low organic matter contents.

5. RECOMMENDATIONS

The use of vetiver grass should be encouraged in Nigeria to remediate contaminated soils in order to ensure food security. However, *V. nigritana* is recommended for all mechanic village soil. For industrial soil, *V. zizanioides* is recommended for use while in refuse dump sites, the two cultivars can be recommended for use since the two cultivars performed better in the phytoextraction of metals. However there is still need for further trial on the field to find out the potential of the two species of vetiver grass for phytoremediation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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