EVALUATION OF THE PHYTOREMEDIATION POTENTIAL OF LEMON GRASS (*Cymbopogon citratus*) AND VETIVER GRASS (*Chrysopogon zizanioides*) IN LEAD CONTAMINATED SOILS

AUTHORS

MWANSA MUKUKA
DR. CHISHALA BENSON H.
DR. MUTITI SAMUEL
DR. UCHIDA YOSHITAKA

APPSA CONFERENCE

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Presentation Outline

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Introduction

- ❖ The Lead (Pb) mining activities in Kabwe started at the beginning of the 20th century and continued for 90 years until 1994.
- ❖ These mining activities left a lot of heavy metal contamination in Kabwe between 600 ppm and 27000 ppm within 2 km of the mine.
- ❖ The heavy metal contamination of the soils near and adjacent the Pb mine tailings arose from;
  - ✓ the physical dumping of the mining wastes and,
  - ✓ a large variety of industrial fumes with high heavy metals when they precipitated on the soil surface.

Introduction

- Mine metal tailings have a high concentration of toxic elements.
- These usually inhibit plant growth as most plants fail to withstand the toxicity. As such, the tailings are mostly bare.
- These tailings are prone to erosion as their top soils develop on unstable materials with low aggregation.
- An appropriate vegetation cover may reduce the erosion and immobilize toxic metals.

Statement of the Problem

- Heavy metals are a significant category of industrial pollutants due to their unique characteristics.
- The challenge of Pb contaminations in soil, also extends to include;
  - ✓ How to sustainably and cost effectively, remove the heavy metal contaminants.
  - ✓ How to dispose of the extracted heavy metals safely and,
  - ✓ Pb tolerant plants to use for revegetation of Pb contaminated soils.
- Most of the known phytoremediators are expensive to manage.
  - ✓ They have a lot of nutritional, water and re-planting requirements e.g. Chinese cabbage and sunflower.

Justification

- ❖ Vetiver and lemon grass are able to grow and thrive in many conditions inclusive of floods and droughts.
- ❖ These grasses do not necessarily require re-planting every year and are able to regain their growth vigor with rainfall once established.
- ❖ And since they're not directly edible, it poses no significant threat for re-introduction into the active environment.
- ❖ Vetiver grass is mostly used for soil erosion controls and soil stability exercises.
  - ✓ However, little work has been done in Zambia to assess its phytoremediation potential for use in Pb contaminated soils.

Study Objectives

- ❖ **Main Objective**
  - ✓ To evaluate the growth response and Pb uptake of vetiver and lemon grass in Pb contaminated soil.
- ❖ **Specific Objectives**
  - ✓ To determine the uptake and distribution of Pb in vetiver grass.
  - ✓ To determine the uptake and distribution of Pb in lemon grass.
  - ✓ To evaluate the growth response of vetiver grass to Pb contamination.
  - ✓ To evaluate the growth response of lemon grass to Pb contamination.

Materials and Methods

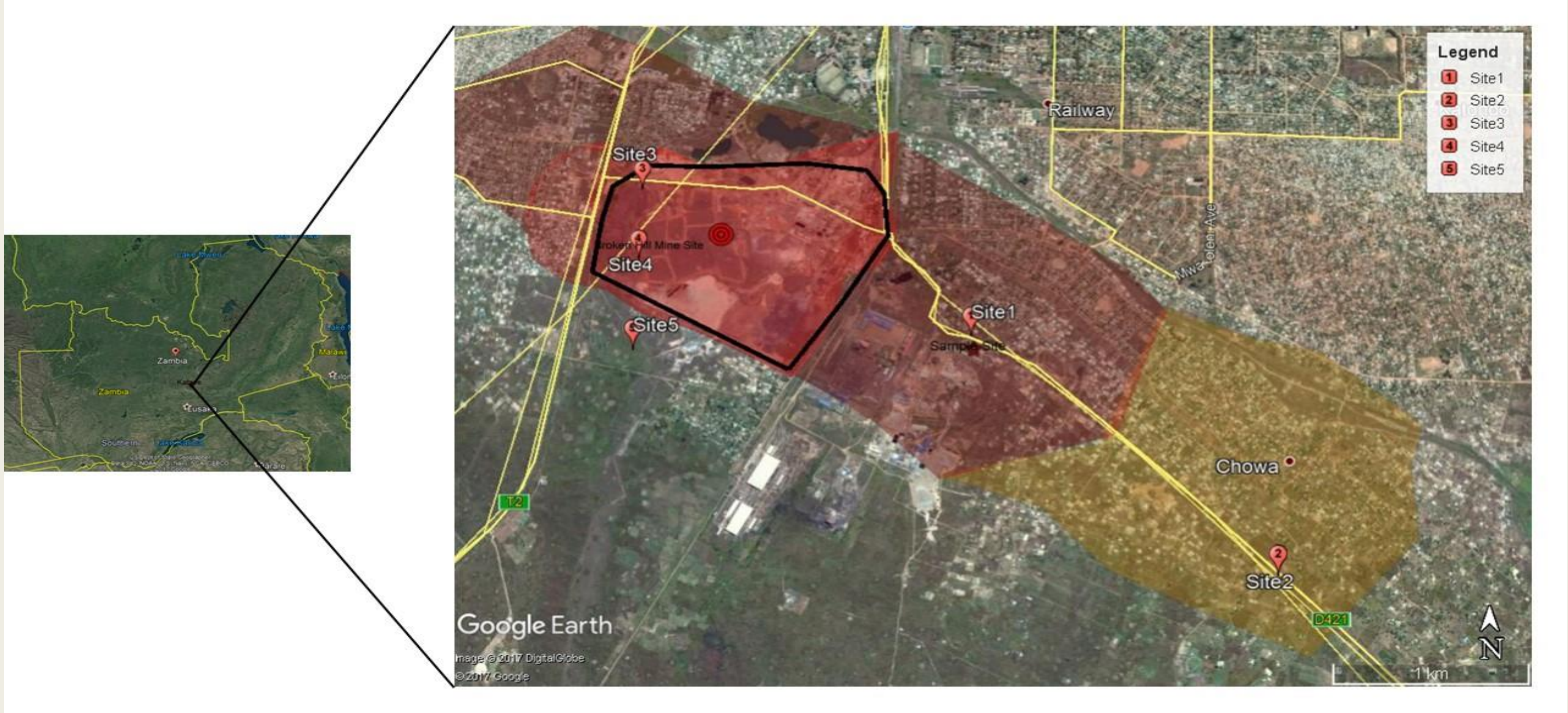

Figure 1: The soil sampling sites (Kabwe, 2016)

Materials and Methods

- **Study Site;**
  - ✓ The experiment was done at the University of Zambia, Great East Road Campus, School of Agricultural Sciences, Soil Science Department; under greenhouse conditions. The soil samples were collected from Kabwe.

Materials and Methods

Table 1: Standard methods of Analysis

PARAMETER	METHOD (SOIL)	METHOD(PLANTS)
pH	0.01MCaCl2	N/A
Electrical Conductivity	Potentiometric	N/A
Ca, Mg, Na, K	Ammonium Acetate	Dry ashing
Total Nitrogen	Kjeldahl	Kjeldahl
Phosphorous	Bray 1	Bray 1
Cu, Zn, Fe, Pb	DTPA	Dry ashing
Organic matter	Walkley % Black	N/A
Total Pb	Aqua Regia	N/A
Bulk density	Core ring	N/A
Texture	Hydrometer	N/A

Standard methods were used to analyze the physical-chemical properties of the soil using the Analyst PerkinElmer 400-AAS.

Materials and Methods

- The vetiver and lemon grass (obtained from Chongwe area), was cut to a uniform height of 13 cm and 10 cm before planting.
- The treatments were replicated four times with each pot having 7 Kg of soil.
- The plants were grown for 120 days.

Materials and Methods

- The experimental design was Randomized Complete Block Design (RCBD).
- The data collected was analyzed using Analysis of Variance (ANOVA) to determine the effect of Pb on the plants.
- All tests were done at 95% confidence interval (or $P \leq 0.05$ for significant difference).
- Mean separation was done using Duncan’s Multiple range test.
- The GenStat version 18 software package was used in the analysis.

Results and Discussion

Table 2: General properties of the Pb and Zn mine tailings

PROPERTY	CONTROL	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5
Soil texture	Loam	Sandy loam	Sandy loam	Loamy sand	Loamy sand	Loamy sand
Bulk density (g/cm^3)	1.4	1.1	1.4	1	1	1
pH	4.76	4.82	5.15	4.73	4.52	5.07
EC (mS/cm)	0.10	0.08	0.06	0.55	0.13	0.27
CEC (cmol/kg)	1.29	4.75	3.57	7.71	5.08	2.56
ESP	1.51	5.21	5.41	2.05	4.94	4.75
%O.M.	2.76	0.37	2.21	1.39	1.37	0.73
Pb_{total} (mg/kg)	0.00	3223.30	2701.70	30966.00	5823.30	20773.00
Pb_{DTPA} (mg/kg)	0.00	865.50	720.50	1587.70	1510.00	1551.80
$\%N_{total}$	0.66	0.45	0.39	0.35	0.21	0.27
P (mg/kg)	18.70	1.46	16.57	1.02	0.83	1.40
K (cmol/kg)	0.76	0.46	0.73	0.30	0.37	0.24
Ca (cmol/kg)	0.32	3.67	2.02	6.63	4.21	1.89
Mg (cmol/kg)	0.19	0.34	0.58	0.61	0.21	0.27
Ca: Mg ratio	1.70	10.77	3.46	10.87	20.15	7.02
Zn (mg/kg)	1.63	8.47	12.53	14.75	12.53	16.20
Fe (mg/kg)	10.74	6.23	2.62	3.97	6.03	4.20
Cu (mg/kg)	1.39	1.67	3.07	12.43	12.35	12.02

Results and Discussion

Table 4: Lead content of vetiver grass and lemon grass

Site	DTPA extractable Pb in soil (mg/kg)	Vetiver grass (%Pb) shoots	Vetiver grass (%Pb) roots	Lemon grass (%Pb) shoots	Lemon grass (%Pb) roots
Control	0.00^{e}	0.0^{i}	0.0^{p}	0.00^{f}	0.0^{p}
Site 1	865.50^{d}	0.02^{f}	0.10^{q}	0.00^{f}	0.30^{q}
Site 2	720.50^{c}	0.02^{f}	0.06^{r}	0.02^{g}	0.01^{p}
Site 3	1587.70^{a}	0.29^{h}	0.46^{n}	0.13^{h}	0.73^{n}
Site 4	1510.00^{a}	0.08^{g}	0.21^{m}	0.02^{g}	0.22^{m}
Site 5	1551.80^{b}	0.11^{j}	0.41^{k}	0.04^{j}	0.64^{k}
Mean		0.10	0.25	0.04	0.38

Note: Values in the same column with the same superscripts are not statistically different at 95% C.I. ($P > 0.05$)

Results and Discussion

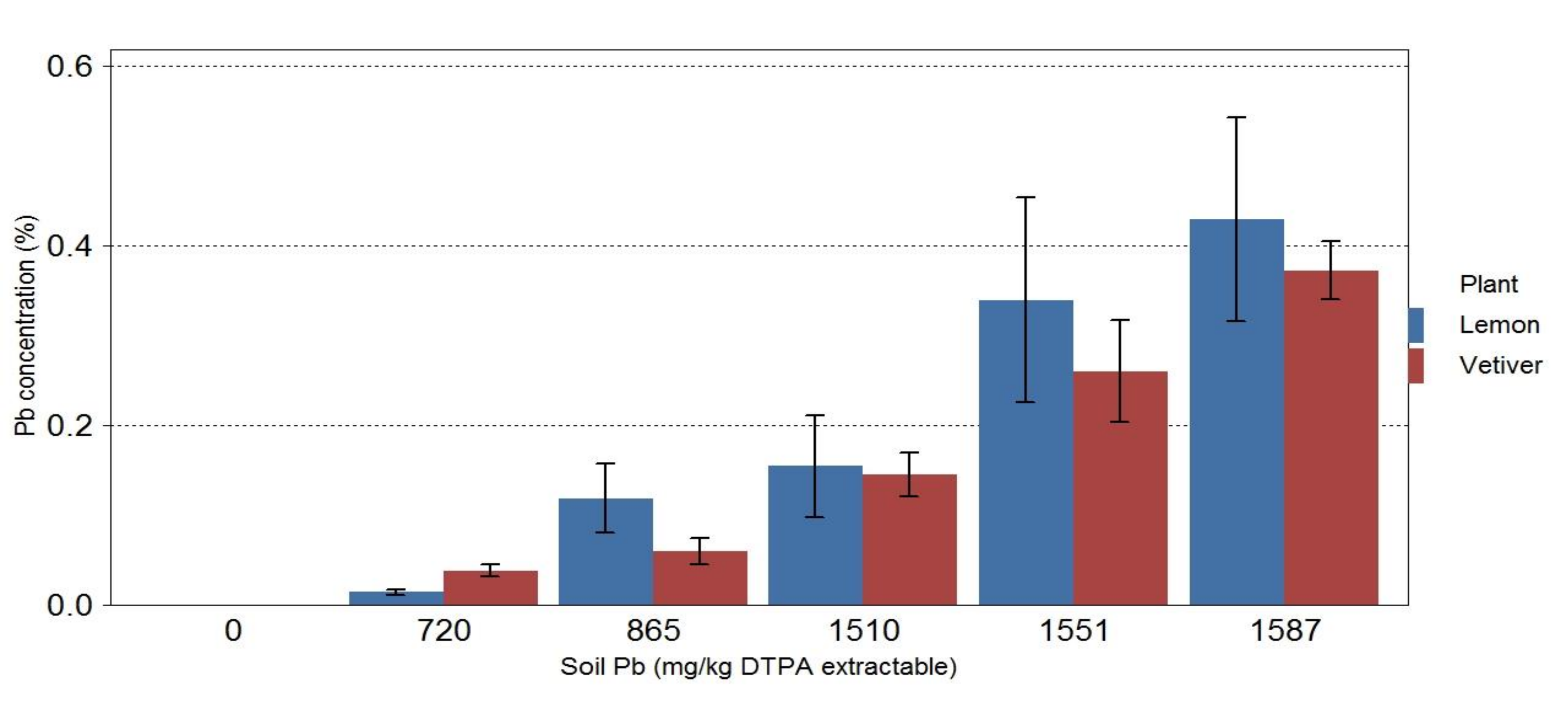

Figure 2: Pb uptake by vetiver and lemon grasses

Results and Discussion

Table 5: Pb distribution efficiency in vetiver and lemon grass

	Vetiver grass			Lemon grass		
Sample Site	TF	BAF	BCF	TF	BAF	BCF
control	0	0	0	0	0	0
Site 1	0.21	0.24	1.14	0.02	0.06	3.51
Site 2	0.37	0.29	0.77	3.46	0.30	0.09
Site 3	0.63	1.81	2.88	0.18	0.82	4.59
Site 4	0.38	0.53	1.38	0.08	0.11	1.46
Site 5	0.27	0.71	2.64	0.06	0.24	4.13
Mean	0.37	0.72	1.76	0.76	0.31	2.76

Results and Discussion

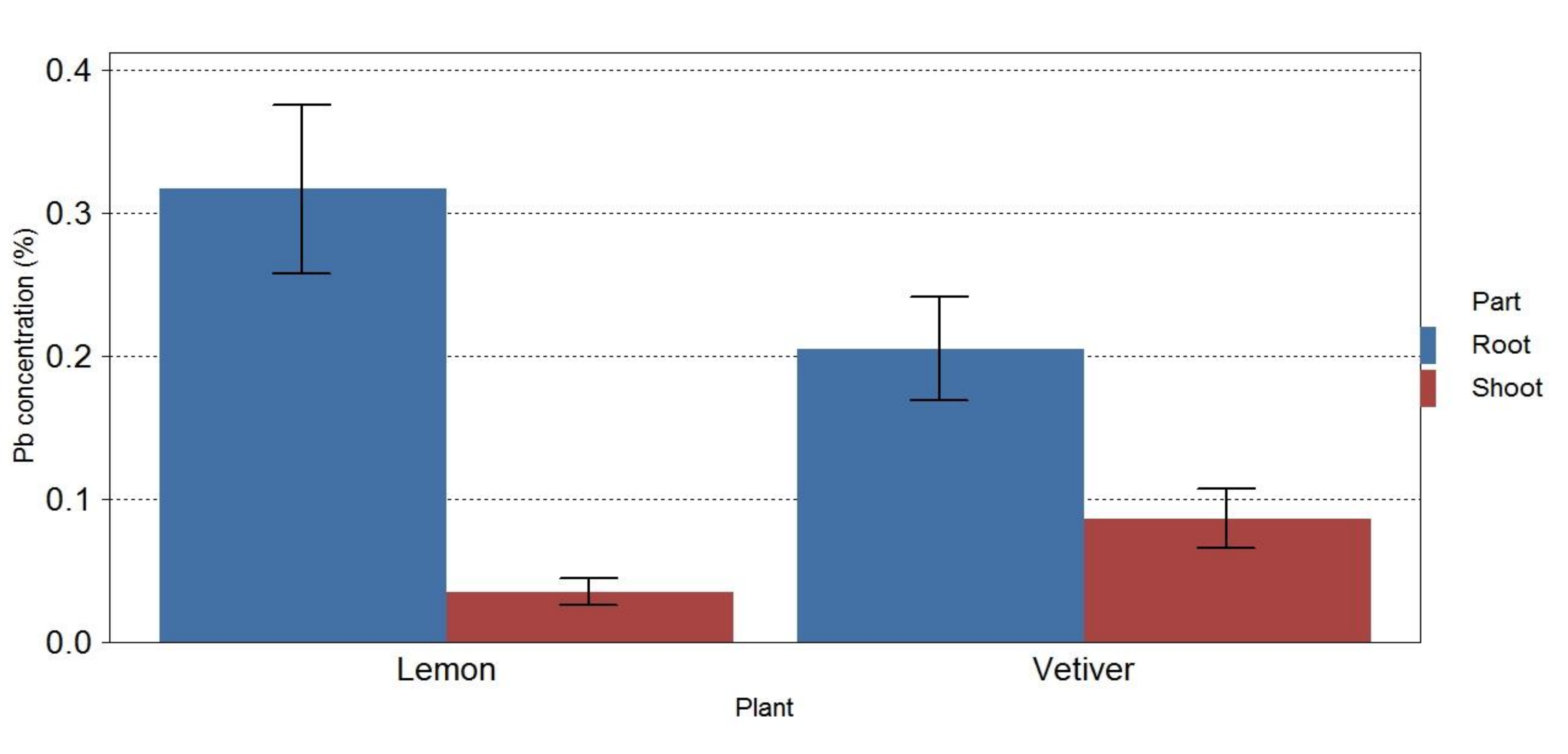

Figure 3: Distribution of Pb in vetiver and lemon grass

Results and Discussion

Table 6: General nutritional content of lemon grass and vetiver grass

	CONTROL		SITE 1		SITE 2		SITE 3		SITE 4		SITE 5	
	LG	VG	LG	VG	LG	VG	LG	VG	LG	VG	LG	VG
%N_{total}	0.14^{f}	0.09^{a}	0.09^{g}	0.04^{e}	0.11^{i}	0.03^{b}	0.06^{h}	0.05^{c}	0.09^{g}	0.07^{d}	0.09^{g}	0.07^{d}
%P	0.12^{a}	0.36^{e}	0.10^{b}	0.07^{f}	0.09^{c}	0.08^{g}	0.10^{b}	0.07^{h}	0.06^{d}	0.07^{h}	0.06^{d}	0.05^{i}
%K	1.23^{f}	1.50^{j}	1.09^{h}	1.41^{j}	0.96^{i}	1.43^{j}	1.15^{g}	1.06^{k}	1.11^{gh}	1.01^{k}	0.91^{i}	1.01^{k}
%Ca	1.98^{j}	0.90^{n}	6.10^{g}	2.94^{km}	3.88^{h}	2.90^{km}	3.82^{h}	3.47^{k}	4.00^{h}	2.64^{m}	1.98^{i}	2.91^{km}
%Mg	0.60^{a}	0.42^{i}	0.53^{b}	0.48^{h}	0.60^{a}	0.62^{f}	0.39^{c}	0.47^{h}	0.53^{b}	0.37^{j}	0.50^{b}	0.57^{g}
%Zn	8.86E-03^{k}	7.90E-03^{r}	1.00E-02^{j}	2.91E-02^{q}	4.75E-02^{g}	6.99E-02^{m}	6.05E-02^{f}	5.36E-02^{p}	4.01E-02^{h}	6.28E-02^{n}	4.97E-02^{g}	5.44E-02^{p}
%Fe	3.03E-02^{m}	5.42E-02^{t}	1.06E-01^{k}	3.23E-01^{q}	1.10E-01^{jk}	2.79E-01^{s}	2.42E-01^{g}	3.09E-01^{r}	1.66E-01^{h}	3.30E-01^{p}	1.35E-01^{j}	3.43E-01^{n}
%Cu	4.15E-03^{f}	2.10E-03^{p}	1.09E-03^{i}	1.39E-03^{q}	3.99E-03^{f}	1.75E-03^{r}	1.42E-03^{h}	3.55E-03^{n}	1.94E-03^{g}	5.02E-03^{m}	8.13E-04^{j}	8.88E-03^{j}

NOTE:

- Values with the same superscripts in the same row are statistically the same at 95% confidence interval (C.I.) ($P > 0.05$)

LG = Lemon grass
VG = Vetiver grass
E = X 10^(n); where n is the stated number

Results and Discussion

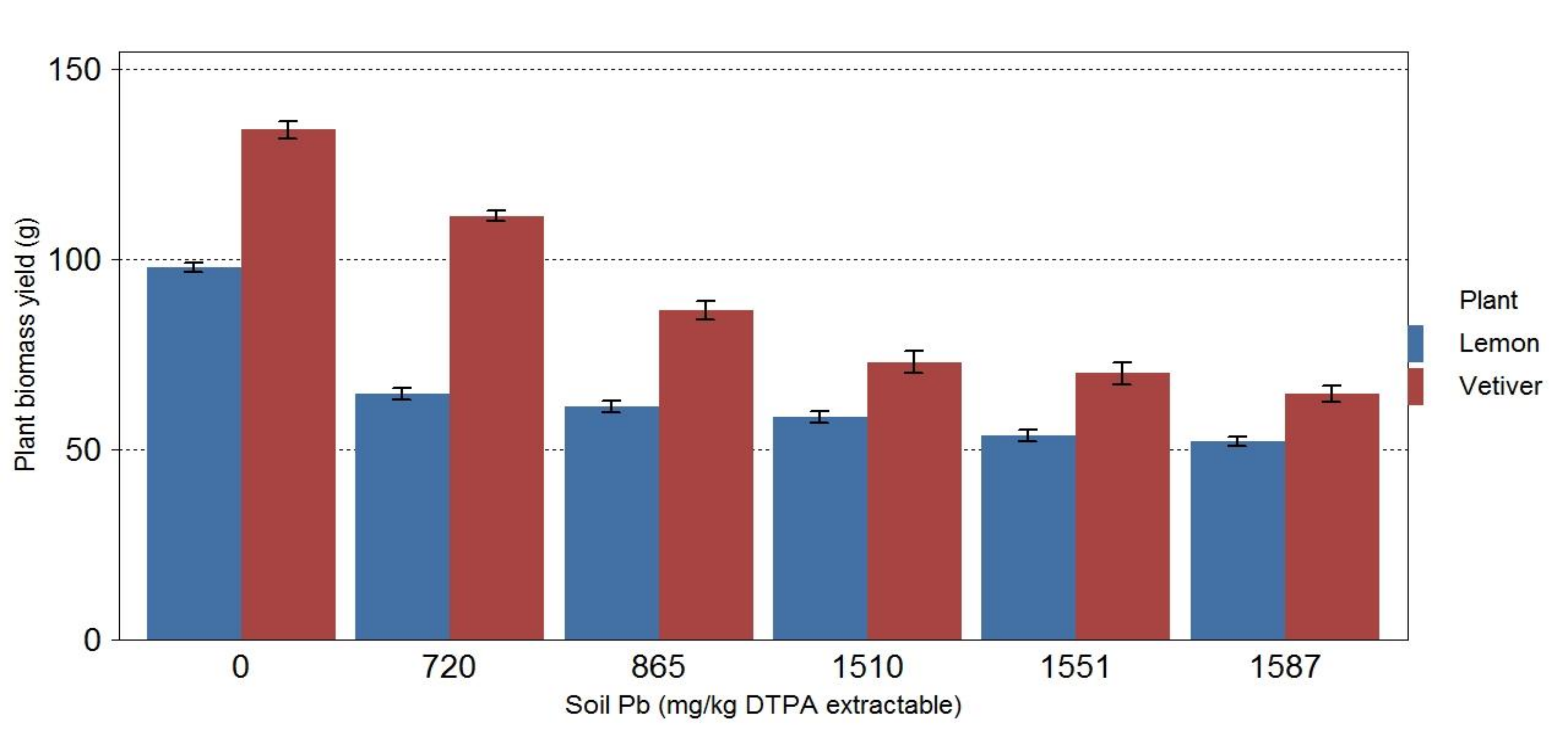

Figure 4: Biomass yield of vetiver and lemon grass in soil Pb

Results and Discussion

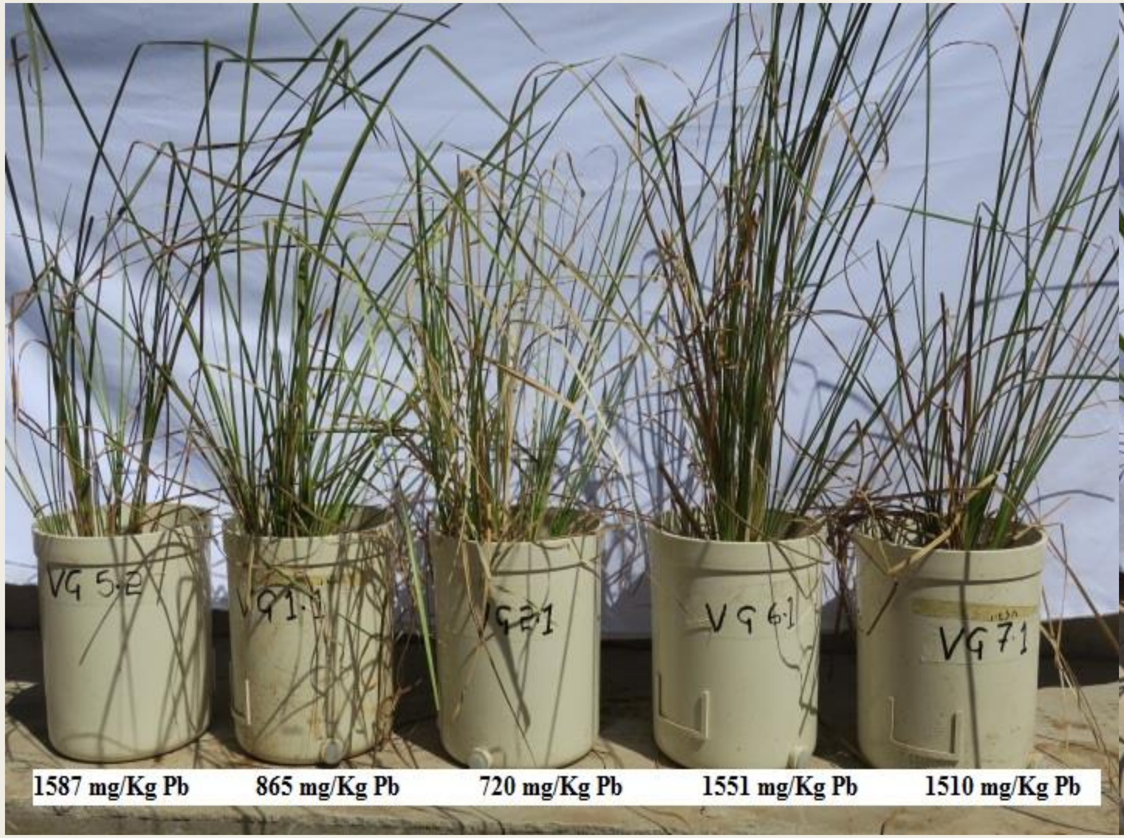

Figure 5: Vetiver grass shoot at harvest

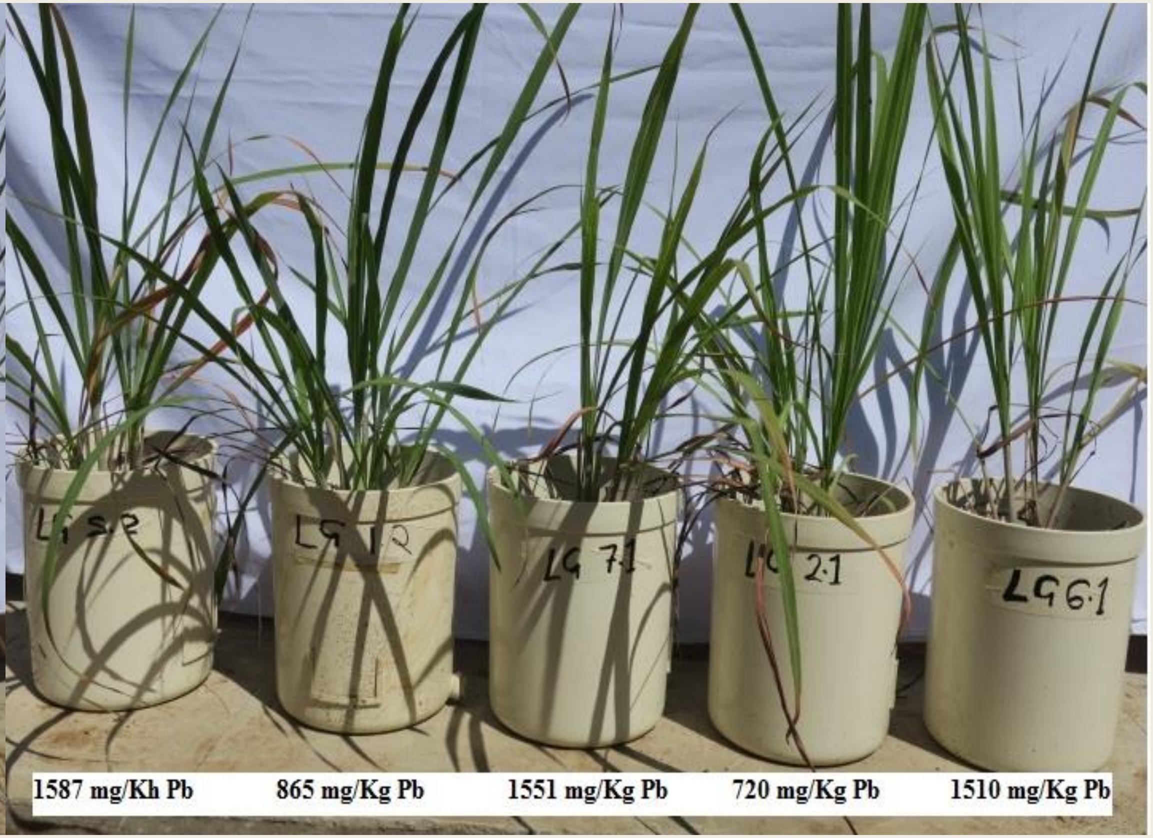

Figure 6: Lemon grass shoot at harvest

Results and Discussion

Figure 7: Vetiver grass roots at harvest

Figure 8: Lemon grass roots at harvest

Conclusions

- The study established that both vetiver and lemon grass can grow in Pb contaminated soils.
- There was a decrease in biomass yield in vetiver and lemon grass with the increase in the Pb in the soil.
- The grasses were able to produce a substantial amount of root system despite the high levels of Pb, low pH, low O.M. content and low soil nutrition.

Conclusions

- Both lemon grass and vetiver grass took up Pb.
- Both lemon and vetiver grasses accumulated more Pb in the roots than the shoots (BAF < 1, BCF > 1).
- However, lemon grass translocated more Pb to the shoots than did vetiver grass (TF lemon grass > TF vetiver).
- Lemon grass accumulated an average of 0.38% Pb in the roots, and 0.04% Pb in the shoot.
- Vetiver grass accumulated an average of 0.25% Pb in the roots and 0.10% Pb in the shoots.
- Both lemon and vetiver grass can be used for phytostabilisation and revegetation.

Recommendation

- The ability to withstand the Pb toxicity and grow in the low fertility soil environment of the Pb tailing soils, makes vetiver and lemon grass a viable option for re-vegetation of the said place.
- With its fibrous and deep reaching root system, vetiver will be able to retain moisture in the soil, which may, in turn promote microbial and vegetative growth.
- The high amounts of Pb it accumulated in the roots (BCF > 1) by both vetiver and lemon grass also entails their ability to phytostabilise the Pb-contaminated mine tailings.
- Moreover, because both plants are not directly edible and may not necessarily require nutritional supplementation, they may be the sustainable green solution for the Pb/ Zn bare mine tailing of Kabwe and others.

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THE END

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