The effect of biochar soil amendment on bioavailability of Lead (Pb) in contaminated soil of Kabwe District of Zambia

By
KABENUKA MUNTHALI

Supervisors
Dr. Benson Chishala-ZAMBIA
Dr. Elijah Phiri-ZAMBIA
Dr. Yoshitaka UCHIDA-JAPAN
Prof. Samuel Mutiti-USA

INTRODUCTION

- Soil contamination is an excess of any element or compound, through direct or secondary exposure, which causes a toxic response to biota or humans, resulting in unacceptable environmental risks (Adriano, 2001; Abrahams, 2002; Vangronsveld et al., 2009).

- Accumulation of such high levels of heavy metals is highly toxic and would certainly kill the common nonaccumulator plant and adversely affect human life.

- Lead (Pb)belongs to those elements(heavy metals) that are poorly mobile and rarely available to plants. However, it may create different organic and inorganic compounds, easily absorbed by roots.

INTRODUCTION

- Contamination of soils with both organic and inorganic toxins occurs worldwide (Mench et al., 2010) and Kabwe town in Zambia has been one of the most worst affected by previous mining activities (Kamona et al., 1998)

- Organic materials are a popular choice for this as they are derived from biological matter and often require little pre-treatment before they may be directly applied to soils.

- Reliable indications from experimental trials that suggest biochar as a dependable technology for immobilizing and improving the physical, chemical and biological status of soils.

INTRODUCTION

- Biochars are also produced by combustion processes (pyrolysis), but the source materials are generally limited to biological residues (e.g. wood, poultry litter, crop residues etc) and not

- However , the process involved in the remediation of contaminated soils through the applications of various amendments is a long-term one.

- The desired outcome of such plans is mainly to reduce the transfer of pollutants to nearby water bodies and to reduce uptake by plants as well as useful microbes.

INTRODUCTION

- However, in hyperaccumulator species, such concentrations are attainable. Nevertheless, the extent of metal removal is ultimately limited by plant ability to extract and tolerate only a finite amount of metals (Verheijen et al., 2010).

- The amendment of soils for their remediation is a long standing procedure, with the aim of reducing the risk of pollutant transfer to proximal waters or receptor organisms.

Statement of the Problem

- In Zambia waste landfills are currently the most widely used method for municipal waste disposal and this is raising some environmental concerns. Due to the fact that landfills can be an active source of a large number of Heavy metals, in this case Pb, because heavy metals are able to through air fallout or leachate release. This poses a greater risk, because at this point their exposure is broad and non-selective on various species throughout the food chain, thus posing a serious threat to the environment, animals, and humans.

Justification

- Heavy metal elements have proven to be toxic even in small amounts, this is due to their non-biodegradable and cumulative nature. In addition, conventional methods of remediation or environmental clean-up have with time demonstrated to be an uneconomical approach to this problem. These huge costs render them unsustainable in third world countries that face an urgent need for a clean and safe environment to enhance social and economic productivity. It is in this regard that *in situ* phytoremediation as become popular in the modern agenda as it provides a low cost and environmentally acceptable approach to reducing risk by pollutant transfer.

OBJECTIVES

Overall objective

- The overall objective of the study was to evaluate the effects of biochar as a soil amendment on the bioavailability of lead (Pb) in lead contaminated soils

Specific objectives were to:

- To determine if the amount of biochar added to the soil affects the bioavailability of lead concentrations in the soil profile
- To analyze the effects of biochar on plant growth (Biomass) in the context of ecological restoration of contaminated soils

Hypotheses

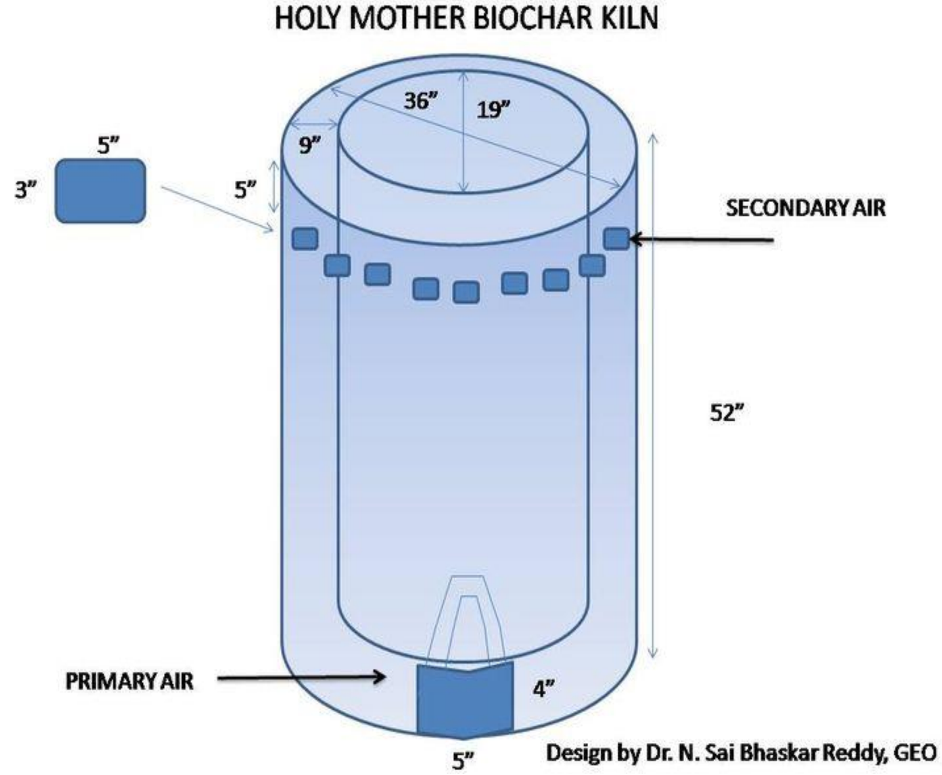
- There is not significant difference in the bioavailability concentrations of lead in the soil profile.
- There is no significant difference in the effects of biochar on plant growth in the context of ecological restoration of contaminated soils.

METHODS AND MATERIALS

- **Location:** The soil was collected from the identified site in Kabwe (14º27’55.92” S, 028º26’40.02” E) in bulk (650kilograms from the top 30cm of the soil). This experiment was done at the University of Zambia, school of agricultural sciences-Located at S15º23’38.8” and E028º20’03.3” under greenhouse conditions.

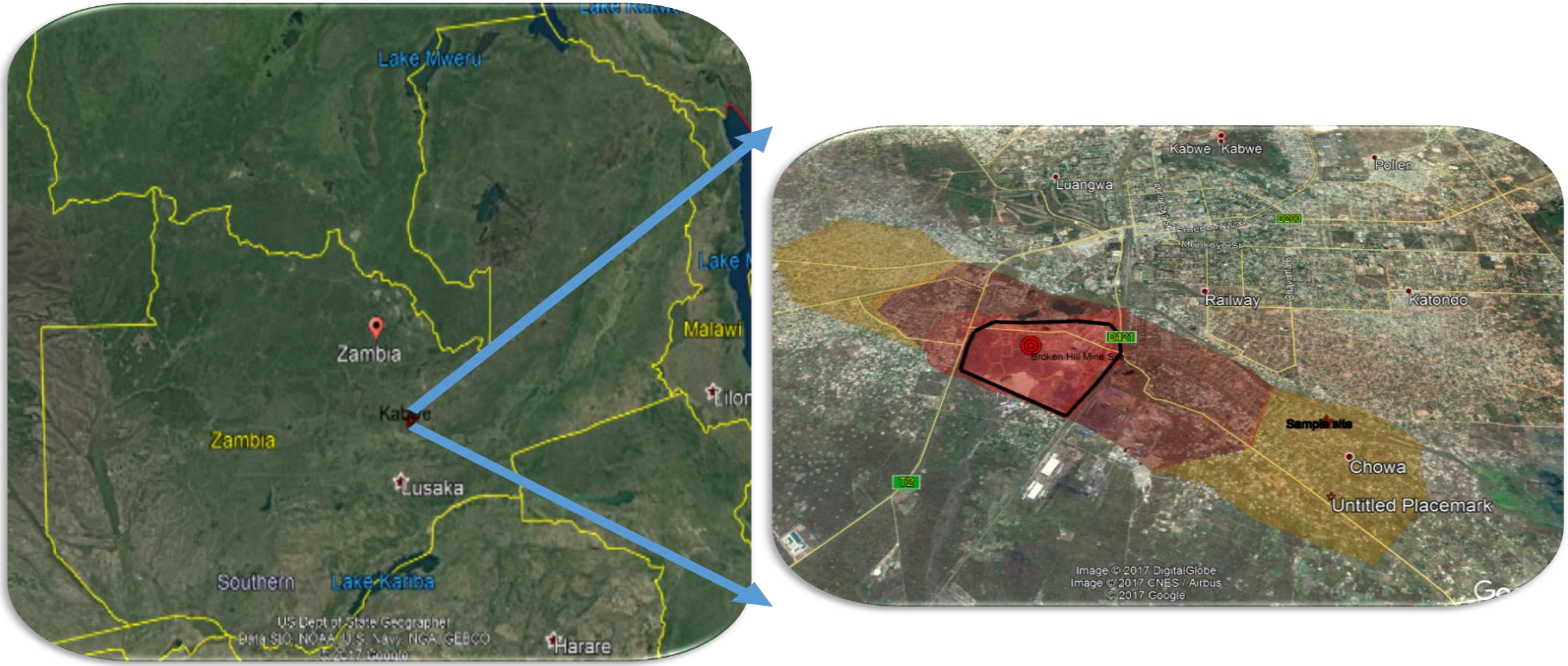
- **TEST CROPS:** The test crops were Chinese cabbage (*Brassica pekinensis*) and Tithonia (*Tithonia diversifolia*). The experiment was a two by four (2x 4) factorial experiment which will take the form of a Split plot design. This experiment had four (4) treatments at four levels of biochar application rates of 0 (Control), 5, 10 and 20 t ha^{-1}. The treatments was replicated four (4) times. Planting date 14th January, 2017.

MATERIALS AND METHODS



METHODS AND MATERIALS

MAP OF ZAMBIA AND LOCATION OF KABWE



Tithonia (*Tithonia diversifolia*)


Chinese cabbage (*Brassica pekinensis*)

METHODS AND MATERIALS

- **Soil and Biochar information:** Sampling was done at 20cm depth and the sampling was done before and after planting. Standard methods were used to analyze the physio-chemical properties of the soil and results are shown in Table 1.
- Field layout and randomization was done as shown in figure 1 below:

TD_{A3}	TD_{A0}	TD_{D1}	TD_{B1}
TD_{C1}	TD_{C3}	TD_{B2}	TD_{C0}
TD_{B3}	TD_{D0}	TD_{D3}	TD_{A2}
TD_{B0}	TD_{A1}	TD_{C2}	TD_{D2}
BP_{D0}	BP_{D2}	BP_{B2}	BP_{A3}
BP_{C1}	BP_{A1}	BP_{A0}	BP_{B0}
BP_{A2}	BP_{C0}	BP_{B3}	BP_{D3}
BP_{B1}	BP_{D1}	BP_{C2}	BP_{C3}

Figure 1: Field layout (Randomization)

Significance of study

- This study will contribute to understanding the capacities and roles of plants and soils amendments in the phytoremediation process respectively. It will also provide a quantitative and qualitative description of this low risk strategy in the mitigation of environmental hazards of areas polluted with heavy metals. Underlining the significance of phytoremediation in the environmental cleanup process will help build up more efficient management strategies

RESULTS AND DISCUSSION

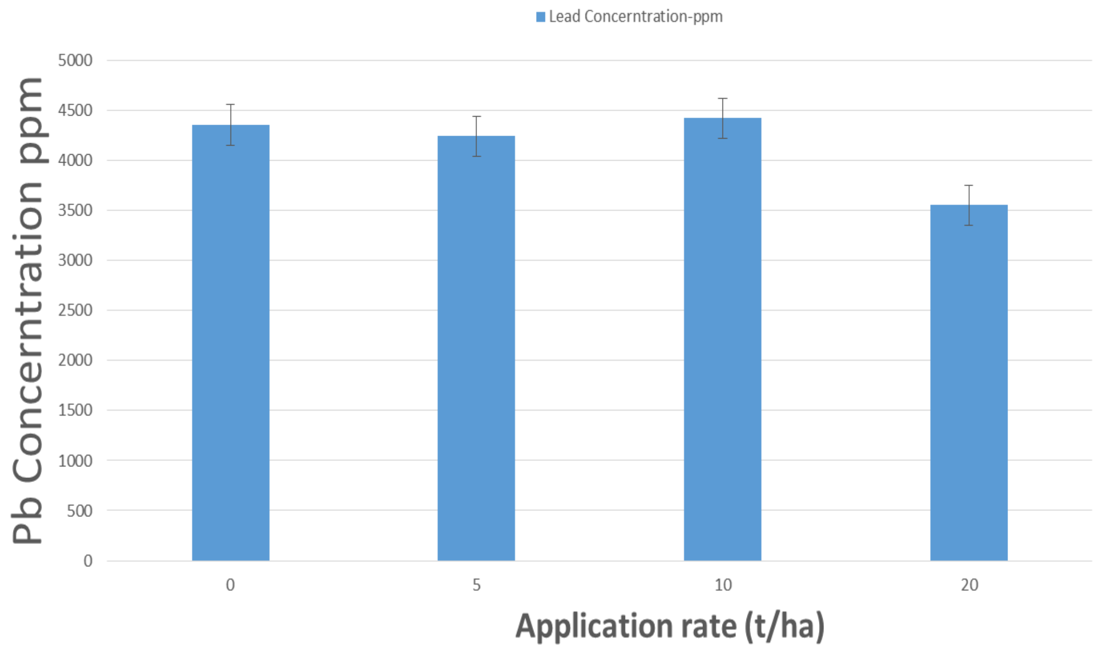
RESULTS AND DISCUSSION

Table 1: Physical and chemical characterization of soils and biochars used in the experiment

PARAMETER	Kabwe Soil	Biochar	Control
$pHCaCl_2$	4.3	9.4	5.8
CEC	8.9	41.8	15.8
Total N-%	0.09	0.3	0.8
Mn-ppm	37	0	0
Fe-ppm	687	43	115
Zn-ppm	237	-	<0.01
Cu-ppm	345	-	<0.01
Pb-PPm	6458	-	-
% Sand	44.3	-	17
%Clay	32.8	-	57
%Silt	17.4	-	26
Texture	SCL	-	CL

SCL: sandy clay loam; **CL: Clay Loam**

RESULTS AND DISCUSSION



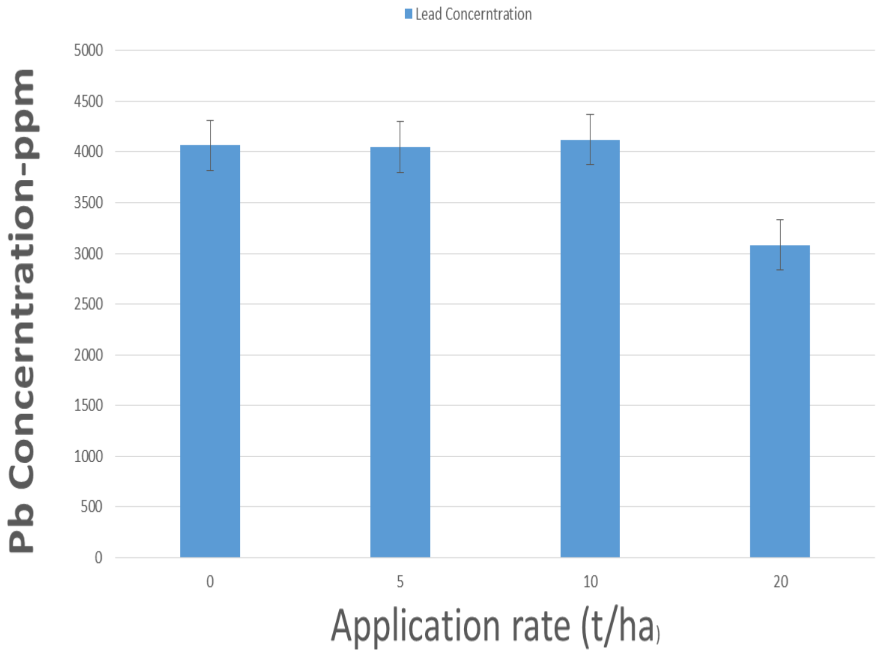


Figure 2: Lead concentration (ppm) in Tithonia for the four application rates(t/ha) of biochar

Figure 3: Lead concentration (ppm) in Chinese Cabbage for the four application rates(t/ha) of biochar

RESULTS AND DISCUSSION

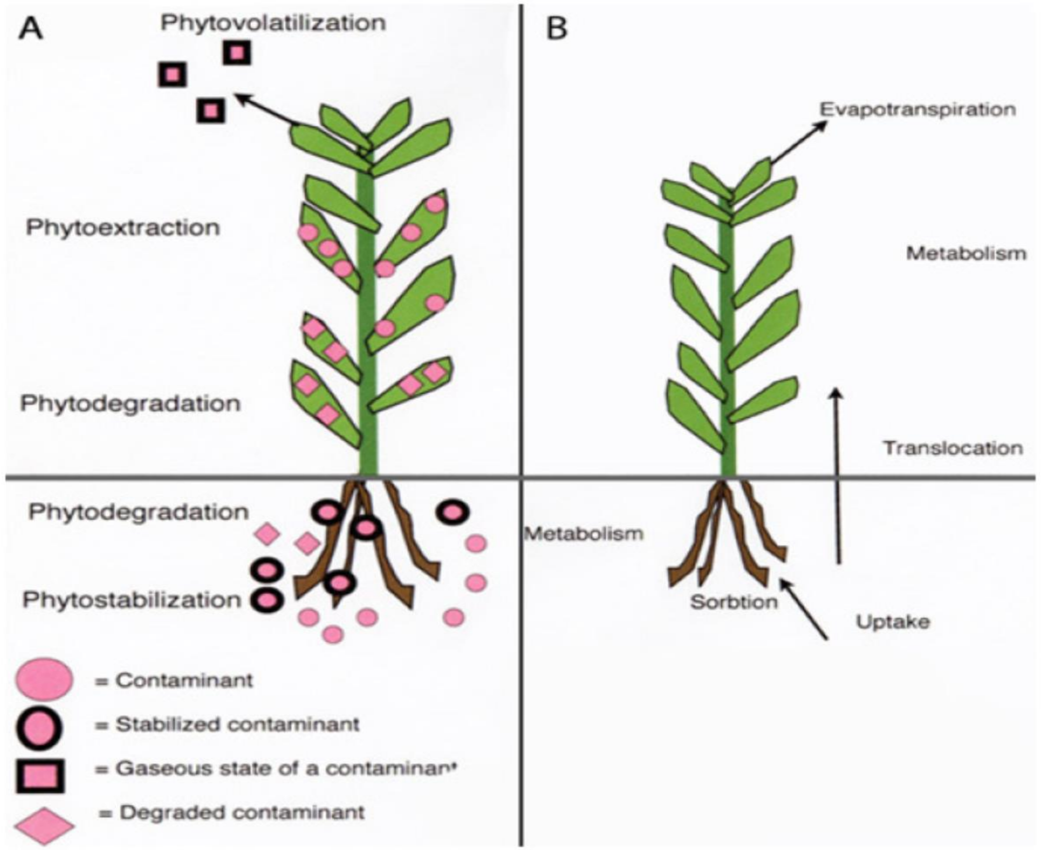


Figure 4: Schematic model of different phytoremediation technologies involving removal and containment of contaminants; **(B)** physiological processes that take place in plants during phytoremediation **(SOURCE**; http://www.nature.com).

Figure 2: Greenhouse experiment with the Chinese cabbage and Tithonia

RESULTS AND DISCUSSION

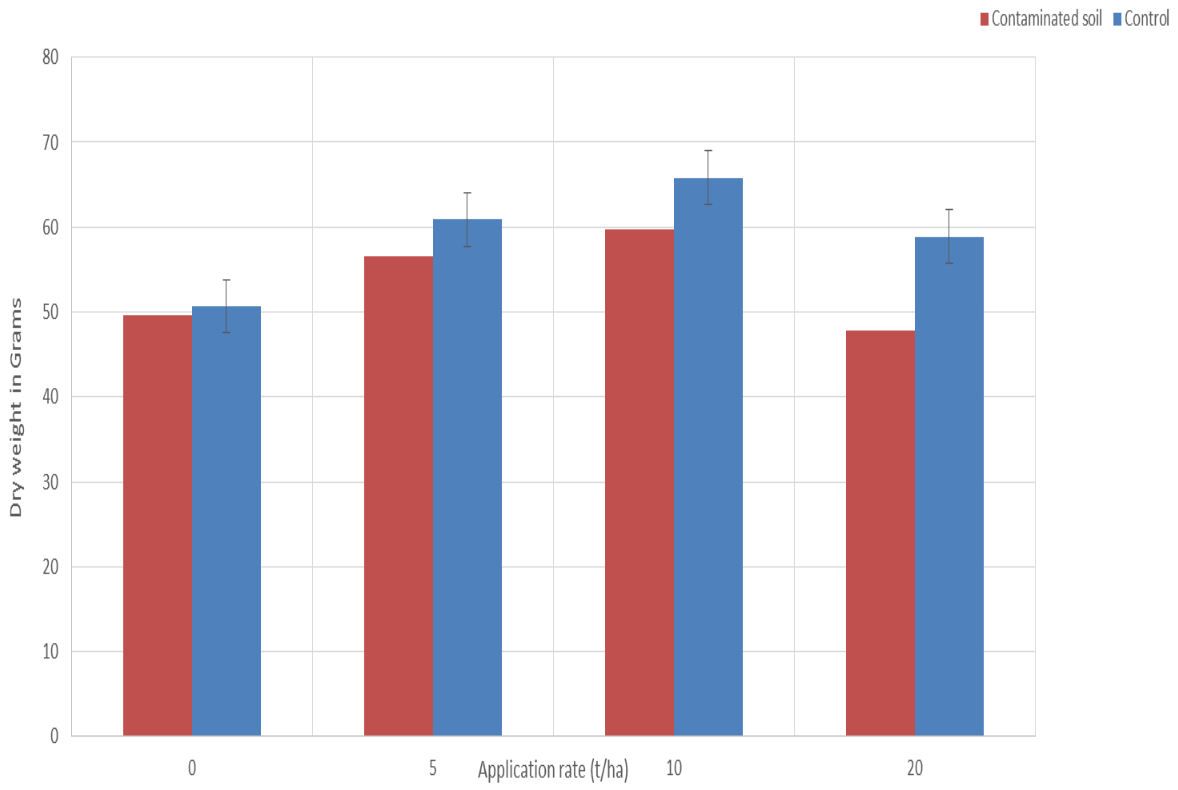


Figure 6: Biomass yield of Tithonia on dry weight (grams) in the four application rates

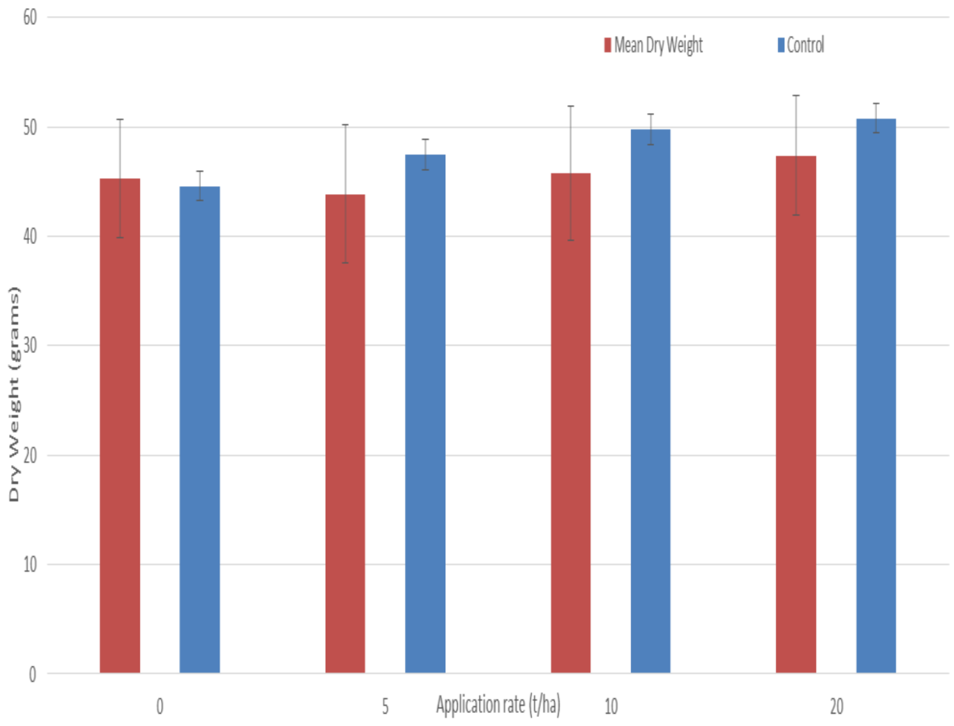


Figure 7: Biomass yield of Tithonia on dry weight (grams) in the four application rates

RESULTS AND DISCUSSION

- Figures 2 and 3 show the effect of biochar amendment on the bioavailable Pb in kabwe soils, it was revealed that the Pb was significantly (P<0.05) reduced at 20 t/ha application rate.

- Figure 4 and 5 shows that biochar application did not have a significant effect (P>0.05) the biomass yield of Chinese cabbage and Tithonia on dry mass basis.

- Biomass was measured on dry weight basis to reduce error arising from variability in the moisture content of the plants used in the experiment.

CONCLUSIONS

- From the results it cant be concluded that in the short term, the higher levels of biochar amendment showed significant results in immobilizing Pb.

- This experiment combined phytostabilization and phytoextraction as remediation technologies. A schematic figure was depicted in figure 4 to explain the complexation of the Pb ion and the translocation of the bioavailable Pb in the plant system for uptake.

RECOMMENDATIONS

- It would be important to exploit various organic materials as a source of biochar and measure their ability to chelating heavy metals as a phytoremediation measure
- It is also important to measure the quantities of biochar that may be economical but still achieve the necessary results from the study.
- Additionally the practice of soil amendment may also be a convenient route to the disposal of organic residues surplus to requirement.

Acknowledgements

- I would like to thank my supervisors; Dr. B. Chishala, Dr. E. Phiri and Prof. S. Mutiti, Prof. Yoshitaka Uchida for their support & guidance they provided during the project.
- I am also thanking APPSA/GOVERNMENT OF ZAMBIA/WORLD BANK and JICA for financial support to pursue the MSc in ISFM. I would also want to thank all staffs from Soils Department for their support. Finally, I wish to thank my family their support and encouragement.

REFERENCES

- Lehmann, J. *et al.* (2011b) ‘Biochar effects on soil biota - A review’, *Soil Biology and Biochemistry*, 43(9), pp. 1812–1836. doi: 10.1016/j.soilbio.2011.04.022.
- Major, J., Lehmann, J., *et al.* (2010) ‘Fate of soil-applied black carbon: Downward migration, leaching and soil respiration’, *Global Change Biology*, 16(4), pp. 1366–1379. doi: 10.1111/j.1365-2486.2009.02044.x.
- Novak, J. M. *et al.* (2009) ‘Impact of Biochar Amendment on Fertility of a Southeastern Coastal Plain Soil’, *Soil Science*,.
- Pandian, K. *et al.* (2016) ‘Effect of biochar amendment on soil physical, chemical and biological properties and groundnut yield in rainfed Alfisol of semi-arid tropics’, *Archives of Agronomy and Soil Science*,

THE END

ARIGATO GOZAIMASU