PHYTOEXTRACTION OF HEAVY METALS BY *Jatropha curcas* L. GROWN UNDER HEAVY METAL CONTAMINATED SOIL AMENDED WITH COW DUNG AND POULTRY DROPPINGS

A.M. GUMI* and L.M. AISHA
Department of Biological Sciences, Usmanu Danfodiyo University Sokoto

ABSTRACT

Growth and heavy metals uptake of *Jatropha curcas* L. on heavy metal contaminated soil amended with cow dung and poultry droppings were investigated. Amendments markedly influenced growth parameters (plant height, number of leaves and dry matter accumulation) of *J. curcas*. Apart from the control treatment (garden soil), treatment CSC (Contaminated soil amended with cow dung) revealed highest overall growth performance and survival rate of the plant as compared to treatment CS (heavy metal contaminated soil) and treatment CSP (contaminated soil + poultry droppings). Heavy metals uptake and sequestration by *J. curcas* differs among the treatments used. Treatments CSP (contaminated soil + poultry droppings) enhanced higher and rapid uptake of heavy metals (Se, Cu and Cr) as compared to CSC and CS treatments. In addition, treatment CSC (contaminated soil + cow dung) revealed higher tolerance index (92.61%) of the *J. curcas* genotype studied while treatments CS and CSP has 90.52% and 71.83% respectively. The roots of *J. curcas* were found to be suitable for uptake of heavy metals in contaminated soil (Phyto-extraction) and the plant can tolerate the effect of heavy metal toxicity (with the help of amendments) through successful biomass accumulation even under heavy metal stress. The plant is therefore recommended as a potential Phytoremediator in heavy metal degraded soils.

Key words: heavy metals, amendments, *Jatropha curcas*, phyto-extraction, Phytoremediator, degraded soils

*correspondence: amgumi@udusok.edu.ng or muhammadag@yahoo.co.uk
+234-806-5974255

INTRODUCTION

Urbanization and rapid development in technology has increased the welfare of life but also posed serious environmental problems through mining, mineral, tannery operations and agrochemicals. The effects of heavy metal contaminated soils on plants resulted in growth inhibition, structural damage, biochemical pathways deviation from norm and a number of plants functions (Sopper, 1993; Oancea *et al.*, 2005).

The sensitivity of plants to heavy metals depends on an interrelated network of physiological and molecular mechanisms such as (i) uptake and accumulation of metals through binding to extra cellular exudates and cell wall constituents; (ii) efflux of heavy metals from cytoplasm to extra nuclear compartments including vacuoles; (iii) Complexation of heavy metal ions inside the cell by various substances such as amino acids and phytochelatins; (iv) accumulation of osmolytes and osmoprotectants and (v) activation or modification of plant metabolism to allow adequate function of metabolic pathways and rapid repair of damaged cell structures (Cho *et al.*, 2003).

Jatropha curcas (L.) belongs to the spurge family, *Euphorbiaceae*. It is a small tree native to tropical regions around the world and grows all over Northern Nigeria under different climatic conditions most often used as fence for demarcation of farmlands. Its seeds yield bio-diesel and the plant can effectively clean up polluted environment (bio-cleaning). Phytoremediation (green technology) is the use of vegetation for the in situ or ex situ treatments of contaminated soils, sediments and polluted water to detoxify organic and inorganic metals (Damian and Damian, 2007; Afkar *et al.*, 2010). For effective and long term remediation of degraded lands, non edible and metal tolerant species of plants are recommended (Juwarka *et al.*, 2006).

Current researches have focused on the use of plants to reclaimed degraded soil through the process of phytoremediation. Despite being a new approach, abundant data on this approach are available (Cooke and Johnson, 2002; Cho *et al.*, 2003; Juwarka *et al.*, 2006; Ahmad *et al.*, 2009). This research aimed to determine the response of *J. curcas* to heavy metal contaminated soil with a view to find out its potentials of phytoremediation (bio-cleaning).

MATERIAL AND METHODS

This study was conducted in Biological garden and Science central laboratory in Usmanu Danfodiyo University, Sokoto (UDUS).

Samples Collection and Handling

The seeds of *J. curcas* were obtained from Biological garden, UDUS. Metal contaminated soil was obtained from “Makerar Gandu” in Sokoto metropolis and amendments (cow dung and poultry droppings) were obtained from a local farm in Sokoto.

The seeds of *J. curcas* were first sown in nursery bed and uniformly germinated seedlings (14 days old) were selected and transferred to polythene bags containing different composition of amended contaminated soils.

Experimental Treatments

The selected seedlings were grouped into four treatments; the control (GS) which consist of garden soil only, treatment CS (contaminated soil), Treatment CSC (contaminated soil amended with cow dung) and treatment CSP (contaminated soil amended with poultry droppings). A completely randomized design (CRD) was used for the study and each treatment was replicated three (3) times and each replicate consist of two (2) seedlings.

Heavy metal content of collected soil and plant parts

Samples of the collected soil was air dried and analyzed for heavy metal concentration by inductively coupled plasma mass spectrometry (ICP-MS) following the methods of Sahoo *et al.* (2009). Also harvested *J. curcas* plants were analysed for heavy metal content using same method.

Morphological characterization

After a growth period of two months, *J. curcas* plants were harvested. Growth performance (number of leaves, plant height and dry weight) were determined per plant. For dry weight, samples were left in a desiccator for 48 hours until constant weight was obtained.

Tolerance Index

Tolerance index of *J. curcas* to heavy metal stress was computed according to the formula of Wilkins (1978);

$$\text{Tolerance index} = \frac{\text{Mean height of plant on contaminated soil}}{\text{Mean height of plant on garden soil}} \times 100$$

Statistical Analysis

The results obtained were subjected to analysis of variance (ANOVA) using MINITAB statistical software.

RESULTS AND DISCUSSION

The contaminated soil used for this study contained high concentration of Selenium (Se) and Chromium (Cr) as shown in Table 1. Heavy metal contaminated soil affected the growth and performance of *J. curcas* in different treatments used. The control (garden soil) has the highest length of stem while treatment CSC (contaminated soil + cow dung) yielded the highest number of leaves per plant and treatment CS (contaminated soil with no amendments) has the highest dry matter accumulation (Fig. 1). These findings inferred that among the amendments used, cow dung treatments resulted in better growth performance than poultry droppings and contaminated soil with no amendments. This is due to the fact that cow dung contained better nutrients composition and enhanced microbial activity than poultry droppings (CSP). This result is in accordance with previous findings that reported growth inhibition of plants due to nutrients deficiency, metal toxicity and water potential imbalance imposed by heavy metal stress (Cooke and Johnson, 2002; Yadav *et al.*, 2009; Gupta *et al.*, 2011).

Jatropha curcas revealed highest tolerance index of 92.61% at treatment CSC while treatments CS and CSP has 90.52 and 71.83% respectively. These findings illustrated that cow dung amendment (CSC treatment) enhanced growth and establishments of *J. curcas* more than other treatments. Organic amendments are known to reduce bioavailability of heavy metals in growth medium thus permitting the re-establishment of vegetation on contaminated soil as reported by Tordoff *et al.* (2000) and Walker *et al.* (2004).

Heavy metal sequestration by *J. curcas* also varied according to treatments. *J. curcas* in general showed effective and potential property of phytoremediation (through hyper accumulation) of degraded lands (Table 2). Higher uptake and sequestration of heavy metals was higher in treatment CSP (contaminated soil + poultry droppings) averaging; 0.01, 7.42 and 31.35 mg Kg^{-1} for Cu, Cr and Se respectively. Treatment CSC (contaminated soil + cow dung) showed lower uptake and sequestration of heavy metals with 5.70 mg Kg^{-1} for Chromium (Cr) while Cu and Se were not detected. This trend explained why treatment CSC has the highest growth performance because of its selective regulation and uptake of heavy metals to ensure long term survival and sustainability of *J. curcas*. Whereas treatment CS and CSP effectively and rapidly removed the heavy metals, growth performance and survival were inhibited. Obute *et al.* (2001) noted that plants that do well in heavy metal polluted soil may have evolved a means of sequestering these toxic materials so as to prevent its toxicity on them.

CONCLUSION

Jatropha curcas has shown to be an effective and suitable Phytoremediator because of its ability to reclaimed contaminated soil and accumulated high amount of heavy metals. Amendments have also enhanced its remediating potentials and cow dung proved more effective.

ACKNOWLEDGMENTS

Much gratitude goes to members of staff of Biological Science Department, Usmanu Danfodiyo University, Sokoto, We are equally grateful to Malam Aliyu Gandu of Biological garden and Malam Ahmad Modi of central laboratory, Usmanu Danfodiyo University, Sokoto for their technical support.

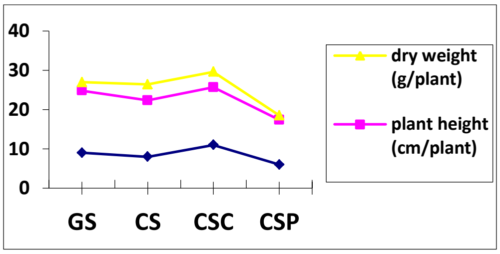

Fig. 1: Growth performance of *J. curcas* planted on garden soil and contaminated soil with and without amendments.
N.B: GS = garden soil, CS = contaminated soil, CSC = contaminated soil + cow dung and CSP = contaminated soil + poultry droppings.

Table 1: Heavy metal content of contaminated soil before amendments and planting *J. curcas*

Heavy Metals	**Concentration** (mgKg^{1})
Zinc (Zn)	Nd*
Copper (Cu)	0.010
Nickel (Ni)	Nd*
Lead (Pb)	Nd*
Chromium (Cr)	8.74
Selenium (Se)	31.60

*Nd = Not detected

Table 2: Heavy metal content of *J. curcas* planted in garden soil, contaminated soil with and without amendments.

Treatments	**Cu** (mg Kg^{-1})	**Cr** (mg Kg^{-1})	**Se** (mg Kg^{-1})	**Zn** (mg Kg^{-1})
GS (garden soil)	0.08	0.01^{a}	Na*	0.04
CS (contaminated soil)	0.01	9.24^{d}	7.35	Na*
CSC (contaminated soil + cow dung)	0.00	5.70^{b}	Na*	Na*
CSP (contaminated soil + poultry droppings)	0.01	7.42^{c}	31.35	Na*

Results are presented as means of three replicates and means followed by different letters are significantly different using LSD. *Na = not available.

REFERENCE

Afkar, E., H. Ababna and A.A. Fathi (2010): Toxicological response of the green alga *Chlorella vulgaris*, to some heavy metals. *American Journal of Environmental Science*, **6**: 230-237. DOI: 10.3844/.2010.230.237

Ahmad, P., John, R., Gadgil, K. and Sharma, S (2009): Heavy metal toxicity: effects on plant growth, biochemical parameters and metal accumulation by *Brassica juncea* L. *International Journal of Plant Production*, **3:** 3-5.

Cho, M., Chardonnes, A.N. and Dietz, K.J (2003): Differential heavy metal tolerance of *Arabidopsis halleri* and *Arabidopsis thaliana*: A leaf slice test. *New Phytol.*, **158:** 287-293.

Cooke, J.A. and M.S. Johnson (2002): Ecological restoration of land with particular reference to the mining of metals and industrial minerals; a review of theory and practice. *Environ. Rev.*, **10**: 41-71. DOI: 10.1139/a01-014

Damian, F. and G. Damian (2007): Detoxification of heavy metal contaminated soils. *American Journal of Environmental Science*, **3**: 193-198. DOI: 10.3844/.2007.193.198

Gupta, A.K., Singh, S.N. and Rakhee Sinha (2011): Effect of nickel salt on growth and yield of *Vigna radiata. Plant.Archives*, **11** (1), 319-321.

Juwarkar, A.A., Singh, S.K., Devotta, S (2006): Revegetation of mining wastelands with economically important species through Biotechnological interventions. In: *Proceedings of the International Symposium*, Environment Issues of Mineral Industry, Mintech, India, pp. 207–216.

Oancea Servilia, Foca, N. and Airinel, A (2005): Effect of heavy metal on plant growth and photosynthetic activity. Tomul I, S. *Biofizica Fizica Medicala si Fizica Mediului*.

Sahoo, B.K., B.P. Das and D. Mukherjee (2009): Relativistic coupled-cluster studies of ionization

Potentials, lifetimes and polarizabilities in singly ionized calcium. *Phys*. *Rev*. *A*, **79**: 1-9. DOI: 10.1103/PhysRevA.79.052511

Sopper, W.E (1993): *Municipal Sludge Use in Land Reclamation*. Lewis Publishers, CRC Press, Inc., Berlin.

Tordoff, G.M., Baker, A.J.M. and Willis, A.J (2000): Current approaches to the revegetation and reclamation of metalliferous mine wastes. *Chemosphere* **41**, 219–228.

Walker, D.J., Clemente, R., Bernal, M.P (2004): Contrasting effects of manure and compost on soil pH, heavy metal availability and growth of Chenopodium album L. in a soil contaminated by pyritic mine waste. *Chemosphere* **57**, 215–224.

Wilkins, D.A (1978): The measurement of tolerance to edaphic factors by means of root growth. *New Phytol*. **80**, 623–633.

Yadav, S.K., A.A. Juwarkar, G.P. Kumar, P.R. Thawale and S.K. Singh (2009): Bioaccumulation and Phyto-translocation of arsenic, chromium and zinc by *Jatropha curcas* L.: Impact of dairy sludge and biofertilizer. *Bioresources Technol*ogy, **100**: 4616-4622.DOI: 10.1016/j.biortech.2009.04.062