



Heavy Metal Enrichment and Remediation Potential of *Jatropha curcas* Linn Seedlings in Dumpsite Contaminated Soil

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ABSTRACT: Heavy metals contamination in water, soil, and plants is a frightening portent around the globe and their bio-amplification through the food chain can cause dangerous health hazards. This study assessed the ability of *Jatropha curcas* seedlings to uptake and distributes heavy metals to their tissue parts from dumpsite soil. Heavy metals concentration in dumpsite soils before plantings were Cu (48.01 – 356.71), Zn (39.99 – 437.88), Pb (28.42 – 260.48), Cd (0.69 – 9.75), Co (16.89 – 27.22) and Cr (20.01 – 30.11) while their concentration after planting were Cu (7.01 - 221.22), Zn (6.22- 301.99), Pb (10.26 – 225.98), Cd (0.48 – 4.01), Co (7.09 – 14.61) and Cr (9.56 – 15.89) in mg/kg. Concentration of heavy metal (mg/kg) in roots were Cu (12.99 - 28.99), Zn (11.97 – 30.22), Pb (9.51 – 17.31), Cd (0.19 - 0.99), Co (6.01 – 8.56) and Cr (8.22 – 9.56) and shoots were Cu (25.22- 46.21), Zn (26.09 – 48.01), Pb (11.46 – 17.31), Cd (0.25 – 1.23), Co (9.22 – 12.98) and Cr (10.98 – 14.01) showed the uptake and enrichment level of heavy metals in the plants. Enrichment and distribution factors were 0.10 to 1.92 and 1.21 to 2.17 respectively. Reduction in the concentration of heavy metals after planting indicated their enrichment in the plant tissues. Medium to high values of enrichment and distribution factors indicated ability of *Jatropha curcas* seedlings to uptake heavy metals from the soil and distributes them into its parts. This study has further proven the potency of *Jatropha curcas* seedlings as phytoextractor plants.

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Contamination of heavy metals from mining, smelting, tanning industries, electroplating, manufacturing, agricultural and waste disposal technologies in the environment is a major global concern despite their toxicity and threat to human life and environment ((Shanker *et al.*, 2005; Yruela, 2005; Ceribasi and Yetis, 2001; Hernandez-Ochoa *et al.*, 2005). Phytoremediation is the act of using green plants and their associated microbes to remove environmental contaminants or to make them harmless; (Kambhampati and Vu, 2013). It is a plant-based technology that employs the use of natural processes where the plants are combined with microbial rhizosphere to vitiate and take up pollutants both organic and inorganic thus, heightening environmental clean-up (Pilon-Smiths, 2005; Cook and Hesterberg, 2013). Most organic pollutants that are released into the environment are anthropogenic and toxic and carcinogenic (Meagher, 2000). Specific plants and wild species (accumulators) that are used in this technique are effective in accumulating high amounts of toxic heavy metals (Ghosh and Singh, 2005; Brunet *et al.*, 2008). They accumulate heavy metals at higher concentrations (≥ 100 times) above ground than non-hyper accumulators growing in the same conditions, without showing any notice of symptoms in their tissues (Barceló and Poschenrieder,

2003). Nagaraju and Karimulla (2002) stated that plants such as *Jatropha curcas* (from Euphorbiaceae), *Dodonaea viscosa* (from Sapindaceae), and *Cassia auriculata* (from Fabaceae) can be applied to detoxify areas with trivial pollution of metal nutrients, organic matter, or contaminants as they had potential for remediation of soils polluted with different kinds of trace and major elements. *Jatropha curcas* belong to the family (Euphorbiaceae) which grows well under adverse climatic conditions because of its low moisture demands and tolerance to high temperatures (Augustus *et al.*, 2002), have the capability to grow in dry and poor soils and it also has the ability to scavenge heavy metals from wastelands (Majid *et al.*, 2012; Zhang *et al.*, 2013; Chang *et al.*, 2014). This study thus, assessed the ability *Jatropha curcas* to accumulate and distribute heavy metals (Cu, Cd, Pb, Zn, Cd, Cr and Co) in their roots and shoots planted in dumpsite soil.

MATERIALS AND METHODS

Study Location: A pot experiment was carried out in Screen house of Forestry Technology Department, Federal College of Forestry, Ibadan, Oyo state. The experimental site lies between Latitude 7°26'N and Longitude 3°54'E. The climate of the area is tropical. The annual rainfall ranges from 1400mm – 1500mm

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and average relative humidity of about 65%, the average temperature is 31.8°C. (FRIN Meteorological Station, 2015). Topsoil used in this study was collected from a dumpsite located in Lapite village, within Akinyele Local Government area, Ibadan. It is situated between old Oyo road and newly constructed Ibadan-Oyo express road (Fig.1). The dumpsite covers an area of 200 by 400 meters, sited on high elevation; weathered and fractured rocks (Akintola, 2014). Tones of wastes generated and collected from various locations in Ibadan and its environs are deposited on a daily basis onto the dumpsite, giving rise to large heap of waste of varying composition, up to 3.0m high relative to the ground surface (Akintola, 2014). Lapite dumpsite and its environ are underlain by Basement Complex rocks of Southwestern Nigeria. The major rock types in area and its environ are migmatite and banded gneisses (Akintola, 2014). Composite topsoil was collected within the dumpsite and about 500m lateral distance on the upslope side of the site at the depth of 0.20m. Topsoil collected within dumpsite is T1 while those collected from the upslope side of the dumpsite was control soil (T2). Soil sample was air-dried and sieved using 2 mm sieve to remove stones, roots and other materials that may be detrimental to the emergence of the young plants from the seeds.

Experimental method and Design: 60 healthy seedlings was picked from germination boxes and transplanted into polythene pot of 30cm by 15cm containing 2kg of soil at different treatment levels to ensure normal growth of the seedlings. The experiment consisting of three seedlings each in the two treatments, replicated ten times making a total of twenty (20) pots for the study and 60 seedlings. The pots were arranged in a completely randomized design and the experiment lasted for 12 weeks (3 months). Growth parameters; plant height, stem diameter, Leaf area and leaf production were assessed fortnightly for three months. At the end of pot experiment, plant biomass was determined, soil samples before and after planting were collected and taken to the laboratory for chemical analysis.

Particle size and texture of soil samples were determined and soil pH was measured by means of a glass electrode pH meter by dipping the glass electrode into a 1:1 according to Thomas (1996). Soil organic carbon was determined by the chromic acid digestion method of Walkley and Black (Sparks, 2003). Plant parts (roots, stems and leaves) and soil samples were analyzed for heavy metal (Cu, Zn, Pb, Cd, Cr and Co) concentrations using Inductively Couple Plasma Mass Spectrometry (ICP-MS) method.

Enrichment Factors (EF) and distribution Factors (DF) were calculated by using the equation 1 and 2 given by Chen *et al.*, (2005):

$$EF = \frac{C_{plants}}{C_{Soils}} \quad 1$$

$$DF = \frac{C_{plant shoot}}{C_{plant root}} \quad 2$$

Where C_{plants} = concentration of heavy metals in plants; C_{plants} = concentration of heavy metals in soils; $C_{plant shoot}$ = concentration of heavy metals in plant shoots; $C_{plant root}$ = concentration of heavy metals in plant roots

Analysis of variance (ANOVA) for the growth parameters and heavy metals concentrations in the samples were done using the Duncan's multiple range test DMRT ($p=0.05$) method. The statistical variations were considered significant at $p<0.05$. Data were computed using graphical methods.

RESULTS AND DISCUSSION

Physiochemical parameters of the potting media: Results of the physiochemical parameters of the soils used for this study are presented in Table 1. Particle sizes of the soils used were sand (73-79%), silt (14-16%) and clay (10-13%). The soils were sandy loamy and are suitable for seedling growth and development because it contains high nutrients, CEC and high water holding capacity. This is in line with similar work conducted on *Cedrela odorata* by Akintola and Bodede (2019). The pH of the soils after planting (5.16 -6.05) decreased when compared to soil before planting (5.99 - 6.70). Since accumulation of chemical element in plants do not absolutely depend on their content in soil but also on the level of soil acidic-alkaline and reductive oxidative conditions and content of organic matter (Akintola and Bodede, 2019; Ovisagie and Ndiokere, 2008). Therefore, soil pH may affect the solubility and bioavailability of elements in the soil for plant uptake (Akintola and Bodede, 2019). Organic matter content (OMC) of the soils after planting were (1.01 – 3.19%) while before planting were (2.31- 5.88 %). Highest organic matter content were recorded in T1 (dumpsite soil) than control and this can be attributed to decomposition and composting processes of the wastes deposited in the study area. Solid waste dumpsites are rich in organic matter which is the source of nitrogen and phosphorus which enhance soil fertility and promote plant growth (Akintola and Bodede, 2019). Concentrations of nitrogen (0.28 – 0.62%) in T2 were higher than Control soil (0.09 – 0.21 %). Similar trend was observed in the concentrations of phosphorus in T1

and T2. Reduction in pH, nitrogen, phosphorus and organic carbon content noticed in the soils after planting when compared to those at the onset of the

experiment may be due to the effect of the plants growing in the media.

Table 1. Physiochemical parameter of the soils

Treatments	Planting	pH	OMC (%)	N (%)	P (mg/kg)	Sand (%)	Silt (%)	Clay (%)
T1	Before	6.70	5.88	0.62	105.22	79.00	16.00	13.00
	After	6.05	3.19	0.28	87.22	75.00	14.00	11.00
T2	Before	5.99	2.31	0.21	34.22	75.00	15.00	10.00
	After	3.16	1.01	0.09	25.99	73.00	16.00	11.00

Growth performance of Jatropha curcas in potting media: Table 2 showed the effects of dumpsites contaminated soil on the growth performance of *Jatropha curcas* seedlings. Highest mean values of seedling height (23.64 cm), leaf area (70.11 cm²), stem diameter (0.42 cm), leaf production (16.88) and biomass production (258.22 g) were recorded from seedlings grown in dumpsite soil (T1) while lower values of seedling height (18.22 cm), leaf area (54.22 cm²), leaf diameter (0.28 cm), stem diameter (0.42 cm), leaf production (11.27) and biomass production (175.02 g) were recorded in control soil (T2). These values are higher when compared with the study of *Jatropha curcas* seedlings grown in soil contaminated

with varying amounts of spent engine oil (Akintola, 2019). The high values observed in the growth parameters of *Jatropha curcas* seedlings could be attributed to the soil being rich in organic matter which is the source of most of the nitrogen and phosphorus which enhances soil fertility and promote plant growth (Ideriah *et al.*, 2010). The biomass of the plant varied significantly. The results showed that biomass production for plants gradually increased with treatments (Table 2) indicating that the amounts of heavy metals in the soils did not affect biomass production or induce phytotoxicity symptoms in the plant (Akintola and Bodede, 2019).

Table 2. Growth performance of *Jatropha curcas* in potting media

Treatment	Seedling height, cm	Leaf Area, cm ²	Stem Diameter, cm	Leaf production g	Biomass, g
T1	23.65 ^a	70.11 ^a	0.42 ^a	16.88 ^a	258.22 ^a
T2	18.22 ^b	54.22 ^b	0.28 ^a	11.27 ^a	175.02 ^b

Heavy Metal Concentrations in potting media: Heavy metals concentrations in the treatment media before and after planting (BP and AP) are shown in Table 3. Heavy metal concentrations in dumpsite soils Cu (221.22 – 356.71), Zn (301.99 – 437.88), Pb (225.98 – 260.48), Cd (4.01 – 9.75), Co (14.61 – 27.22) and Cr (15.89 – 30.11) were higher than those of control Cu (7.01 – 48.01), Zn (6.22 – 39.99), Pb (10.26 – 28.42), Cd (0.48 – 0.69), Co (7.09 – 16.89) and Cr (9.56 – 20.01) in mg/kg. The observed high heavy metal

concentrations in dumpsite soils can be related to high deposit of metal-rich waste in the area (Akintola and Bodede, 2019). Heavy metal concentrations in soil before planting were found to be significantly higher than after planting. Heavy metals concentration in the soils are in the order of Zn > Cu > Pb > Cr > Co > Cd. Although the concentrations of these metals are higher in dumpsite soil and do require urgent clean up according to USEPA (2002), these amounts might contribute to human health risks (NYSDEC, 2006).

Table 3. Heavy Metal Concentrations in potting media

Treatments	Planting	Heavy Metals in mg/kg					
		Cu	Zn	Pb	Cd	Co	Cr
T1	Before	356.71	437.88	260.48	9.57	27.22	30.11
	After	221.22	301.99	225.98	4.01	14.61	15.89
T2	Before	48.01	39.99	28.42	0.69	16.89	20.01
	After	7.01	6.22	10.26	0.48	7.09	9.56

Heavy metal concentrations in root and shoot of Jatropha curcas: Mean concentration values of heavy metals determined in seedling parts (shoots and roots) of *Jatropha curcas* are presented in Table 4. Heavy metal concentrations in roots of the studied plants Cu (12.99 – 28.99), Zn (11.97 – 30.22), Pb (9.51 – 17.31), Cd (0.19 – 0.99), Co (6.01 – 8.56) and Cr (8.22 – 9.56) were lower than their concentrations in the shoots Cu

(25.22 – 46.21), Zn (26.09 – 48.01), Pb (11.46 – 17.31), Cd (0.25 – 1.23), Co (9.22 – 12.98) and Cr (10.98 – 14.01) in mg/kg. It was observed that *Jatropha curcas* accumulated significant amounts Zn, Cu and Pb in their parts. Highest concentrations of these heavy metals were recorded in shoot than the root and this might be attributed to its importance in biochemical reactions especially in photosynthesis (Mohd *et*

al.,2013). The high concentrations of heavy metals in the shoots may indicate active translocation of these metals from roots to shoots. Heavy metals translocation to different plant part varies by species (Antosiewicz, 1992). The phenomena of high accumulation of metals in the roots apparently occur, as roots will also permit metal ions to pass through their system when taking up water and nutrients (Clemens *et al.*, 2002). From the roots, dissolved

metal ions will be translocated to other parts of plant (Punz and Sieghardt, 1993). Metal uptake by plants can be affected by several factors including metal concentrations in soils, soil pH, cation exchange capacity, organic matter content, types and varieties of plants and plant age. It is generally accepted that the metal concentration in soil is the dominant factor (Adriano, 2000).

Table 4. Heavy metal concentrations in roots and shoots of *Jatropha curcas*

Treatments	Planting	Heavy Metals in mg/kg					
		Cu	Zn	Pb	Cd	Co	Cr
T1	Root	28.99	30.22	17.31	0.99	8.56	9.56
	Shoot	46.21	48.01	22.59	1.23	12.98	14.01
T2	Root	12.99	11.97	9.51	0.19	6.01	8.22
	Shoot	25.22	26.09	11.46	0.25	9.22	10.98

Enrichment and Distribution Factors: The potential of *Jatropha curcas* seedlings to accumulate and transport metals was characterized by determining their enrichment factor (EF) and distribution factor (DF) in Table 5. Enrichment factors were lower in plant grown in dumpsite soils (0.10 – 0.60) when compared to control soils (0.39 – 1.92) and could be attributed to the higher concentration of heavy metals in the dumpsite soil and it will take a longer time for the plants to accumulate higher amount of it. But in the case of control soil, the concentrations of the heavy metals were lower, so the plants took the one it can tolerate within the time of the experiment (Akintola and Bode, 2019). Thus, heavy metal uptake by plants from soil depends on the level of metal concentrations in the soil, time and other factors. Distribution factors (DF) of heavy metals from the root to shoot of *Jatropha curcas* plant's parts were high (1.21 – 2.17) indicating the ability of the plants to accumulate heavy metal from the soil and distribute it to different parts of its tissue. The results showed that *Jatropha curcas* seedlings have low to high EF and this showed that the plants had great ability to uptake and subsequently translocate these metals in their parts. It was believed that *Jatropha curcas* seedlings varied in tolerance to heavy metals toxicity. Furthermore, their efficiency of extracting of heavy metals from soils is dependent on their concentration in the contaminated soil and the properties of the soil.

Table 5. Enrichment and Distribution Factors

Heavy Metals	Enrichment Factors (EF)		Distribution Factors (DF)	
	T1	T2	T1	T2
	Cu	0.13	1.72	1.59
Zn	0.10	1.92	1.58	2.17
Pb	0.10	0.92	1.31	1.21
Cd	0.24	0.39	1.24	1.31
Co	0.58	0.85	1.51	1.53
Cr	0.60	0.85	1.47	1.34

Conclusion: The significant reduction observed in concentrations of heavy metals in soils before and after planting indicated their accumulation in the plant tissues. Low to high enrichment and high distribution factors proved the efficiency of the plants for phytoextraction of metals from contaminated soils. The study had further proven the efficacy of *Jatropha curcas* for cleaning up of heavy metals in soils.

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