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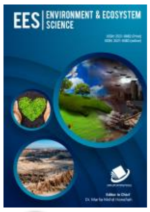

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COMPARATIVE HEAVY METAL UPTAKE AND PHYTOREMEDIATION POTENTIAL OF THREE JATROPHA SPECIES

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ABSTRACT

The comparative metal uptake and phytoremediation capacity of *Jatropha curcas, Jatropha gossypifolia,* and *Jatropha multifida* in heavy metal contaminated soil from a dumpsite in Ibadan Nigeria were studied. Plants were transplanted into polythene pots containing 2kg of soil (control and dumpsite), using a 3×2 factorial laid out in complete randomized designed. Cu, Zn, Cr, Cd, Pb and Ni concentration was determined in the soil before planting and after harvesting as well as in the roots and shoots of the plant after 12 weeks using the standard method. The heavy metal levels in the control soil are within the permissible limits of WHO/FAO while only Cr and Ni in the contaminated soils are within the limit. The heavy metals concentration in the root of the plants ranged from 0.27-63.14 mg/kg (Cu), 4.82-54.18 mg/kg (Zn), 0.48-3.47 mg/kg (Cr), 1.75-72.37 mg/kg (Pb) and 0.05-3.23 mg/kg (Ni); in the shoots, the concentration ranged from 0.25-33.36 mg/kg (Cu), 5.40-12.48 mg/kg (Zn), 0.29-1.45 mg/kg (Cr), 0.58-8.26 mg/kg (Pb) and 0.05-3.23 mg/kg (Ni). Cd was not detected in the root and shoot of the three Jatropha species. Analysis of variance shows heavy metal uptake was influenced by the interaction of contamination level and Jatropha species. Bioaccumulation factor and Translocation factor ranged from 0.07-0.16 and 0.53-0.6 (Cu); <0.01-0.03 and 0.21-0.30 (Zn); 0.07-0.18 and 0.41-1.01 (Cr); 0.01-0.35 and 0.11-0.32 (Pb); <0.01-0.04 and 0.64-0.97 (Ni) respectively. More accumulation occurs in the root than shoot, therefore, *Jatropha* spp exhibit species variation in the uptake of heavy metals.

KEYWORDS

Jatropha species, Phytoremediation, Heavy metals, Contamination.

1. INTRODUCTION

The contamination of soils and water presents serious environmental and public health issues globally and exposure to chemical threats such as heavy metals may occur via consumption of crops raised on the polluted lands or ingesting contaminated water source [1]. Soil contamination is caused by chemicals released from human activities or other negative changes in the normal soil environment. It is typically caused by industrial activity, agricultural chemicals or improper disposal of waste [2]. Pollution by heavy metal is one of the leading environmental issues that is triggered as a result of the persistent, arbitrary, and unrestrained release of dangerous chemicals including heavy metals from diverse sources into the immediate environment [3, 4]. Runoffs and leaching of contaminants from dumpsites are some of the ways through which contamination of agricultural and habited lands by toxic metals occurs and key problems with the accumulation of toxic metals in agricultural soils centres on safety, public health concern, and the harmful effects to the components of the soil ecosystem. The remediation of soil contaminated with hazardous substances exploiting the inherent abilities of plants is largely called phytoremediation. It is an in situ environmentally friendly and long-lasting approach requiring no particular tools [5]. Several plants species have been reported for their ability to absorb and store pollutants into their body mass, one of such plant belong to the genus Jatropha.

Jatropha is a genus that belongs to the Euphorbiaceae family, it has wide topographical spread and is made up of over 170 species of herbaceous perennials, shrub, woody trees. It is broadly dispersed within the tropic and subtropical locale particularly in Africa and America. Jatropha species are utilized in conventional medication to remedy different ailments in Africa, Asia, and Latin America or as ornamental plants and energy crops. A few known species from genus Jatropha have been detailed for their therapeutic employments, chemical constituents, and biodiesel generation such as *Jatropha curcas*, *Jatropha elliptica*, *Jatropha gossypifolia*, and *Jatropha multifida*, among others [6].

Some studies have investigated the tendency of heavy metal uptake from contaminated growth media in Jatropha species; most of these studies largely focused on the use of *J. curcas*. The ability of *J. curcas* to phytoremediate cadmium and lead from polluted soil was reported by Mangkoedihardjo and Surahmaida, [7], the plant was also reported to uptake metals from sewage sludge contaminated soil demonstrating its potential to absorb zinc, copper and chromium [8] while, its heavy metals absorption in soil contaminated with sawdust sludge was previously examined [9], showing it can accumulate a significant amount of copper, iron, aluminium, lead and zinc in the roots. Studies by Wu *et al.* [10] showed the ability of *J. curcas* in the phytostabilization of toxic metals present in polymetallic acid mine tailings, Luhach and Chaudhry, [11] assessed the tolerance to toxic metals and the potential of *J. curcas* for phytoremediation in refinery sludge thereby, reporting a significant absorption of copper and chromium into the root of the plant. Some of these studies clearly demonstrated the potential of *J. curcas* to phytoremediate heavy metals contaminated media. For the other species, the effect of EDTA on the phytoextraction of heavy metals by *J. gossypifolia* from dumpsite was reported by Awokunmi *et al.* [12]. The success of *J. curcas* is attributed to its highly effective and dedicated mechanism against abiotic pressures making it possible to endure severe climatic condition including excessive dryness, arid and seriously polluted soils [13, 14]. However, little studies are available investigating the potential of other species such as *J. gossypifolia* and *J. multifida* in the uptake of toxic metals from contaminated soil. The aim of this study is to assess the comparative heavy metal uptake of *J. curcas, J. gossypifolia* and *J. multifida* in other to establish a mutual pattern among them and also other potential phytoremediators in the Jatropha species.

2. MATERIALS AND METHODS

The pot experiment was conducted at the Forestry Research Institute of Nigeria, Ibadan which lies between 7°23'N and 3°51'E, the annual rainfall ranged from 1800mm – 2000mm in January to March 2016. The Seeds of *Jatropha curcas, Jatropha gossypifolia* and *Jatropha multifida* were sourced from the National Centre for Genetic Resources and Biotechnology (NACGRAB), Apata, Ibadan, identification was done at the taxonomy section of Forestry Research Institute of Nigeria (FRIN), Ibadan, Oyo State.

Soil samples within the depth of 0 – 15cm was collected randomly around the location with a soil auger at the dump site sited at Arapaja, Ibadan Oyo state, Nigeria (7°18'N and 3°50'E), this dumpsite had been in use since 1993. Coarse and other unwanted materials were removed from the soil samples before potting. Control soil was sourced from the teak plantation of the Forestry Research Institute of Nigeria. Samples from the dump site soil and control soil were air dried, sieved with 2 mm mesh, followed by routine soil analysis and determination of heavy metals (Copper (Cu), Zinc (Zn), Chromium (Cr), Cadmium (Cd), Lead (Pb), and Nickel (Ni) using standard procedures. Seeds of *J. curcas*, *J. gossypifolia* and *J. multifida* were planted into a germination tray, seedlings of about 5cm, and in good condition were transplanted into polythene pots containing 2kg (control and dumpsite soils). The experiment was set up in a 3 × 2 factorial, laid out in complete randomized design (CRD) and replicated four times [15, 16]. The treatments imposed include:

T1 - *Jatropha curcas/*Control Soil, T2 - *Jatropha gossypifolia*/Control Soil, T3 - *Jatropha multifida*/Control Soil, T4 – *Jatropha curcas/*Contaminated soil, T5 – *Jatropha gossypifolia*/Contaminated Soil, T6 – *Jatropha multifida*/Contaminated Soil.

The control soil was considered the background level for the metals in comparison with the dumpsite soil which is very much contaminated with heavy metals from the result of the pre-planting analysis (Table 1). Samples of the plants part (root and shoot) were harvested and soil samples taken from the pots containing contaminated soils after 12 weeks of transplanting for heavy metal analysis. Heavy metals were analysed using Atomic Absorption Spectrophotometer (AAS) after acid digestion with diacid mixture of HCl and HNO_3 (aqua regia) at 100 °C for 3h [9].

The phytoremediation potential of each *Jatropha spp* was further assessed using the bioaccumulation factor and the translocation factors [17-20]. These are given by the equation:

$$Bioaccumulation\ factor = \frac{C_{root}}{C_{soil}} \quad \text{....... (1)}$$

$$Translocation\ factor = \frac{C_{shoot}}{C_{root}} \quad \text{....... (2)}$$

The data generated were subjected to Student's t-test, Analysis of Variance and subsequently, Duncan tests was used to separate mean where differences exist as appropriate, probability level of $p<0.05$ was considered significant. SPSS version 20 was employed in the analysis of data.

3. RESULTS

Table 1 shows the result of the routine soil analysis for both control and contaminated soil. Both soil samples were characterized as sandy loam, the pH of the control soil is slightly acidic while that of the contaminated soil is slightly basic. The contaminated soil has a higher organic carbon and cation exchange capacity. The results of the heavy metal concentration in both the control soil and soil from the dump site before transplanting is presented in Table 2. The levels of heavy metals obtained in the soil samples from the dump site were significantly higher than the levels in the control site indicating that the soil samples from the dump site are grossly contaminated with heavy metals and the values were higher than the recommended standard except for Chromium and Nickel which are within the set standard. The heavy metal levels in the control soil are within the permissible limit set by WHO/FAO.

Table 1: Pre-Planting Soil Analysis

Soil parameter	Control	Contaminated
pH	6.9	7.77
Particle size		
Sand (%)	85.80	86.20
Silt (%)	8.80	10.40
Clay (%)	5.40	3.40
Exchangeable bases		
Ca (cmol)	14.01	60.75
Mg (cmol)	2.51	2.63
K (cmol)	0.44	7.92
Na (cmol)	0.98	14.54
Al+H (cmol)	0.06	0.05
ECEC (cmol)	17.77	85.89
Base saturation (%)	99.67	99.94
Total Nitrogen (%)	0.09	0.21
Total Organic Carbon (%)	0.89	3.38
Av. P P (mg/kg)	12.31	16.70
Micro-nutrients		
Mn (mg/kg)	66.62	53.15
Fe (mg/kg)	39.42	17.65
Cu (mg/kg)	1.07	1.10
Zn (mg/kg)	7.15	1.20

Table 2: Heavy Metal Concentrations in Pre-Planting Control and Contaminated Soil

Metal (mg/kg)	Control soil	Contaminated soil	WHO/FAO*
Cu	4.23±1.32a	525.75±73.25b	100
Zn	32.00±5.37a	1940.38±150.14b	300
Cr	2.63±0.23	25.63±3.29	100
Cd	0.50±0.10a	6.88±1.20b	3.0
Pb	6.00±2.45a	325.15±50.05b	50
Ni	1.88±0.86a	41.75±3.80b	50

* [21]

3.1 Heavy Metal Levels in Pre-Planting Soil and Post-Harvest Soil Contaminated Soil

Table 3 presents the result of the heavy metal concentration in the pre-planting and post-harvest contaminated growth media. The result shows a reduced concentration of heavy metals in the post-planting growth media as compared with the pre-planting growth media. The percentage reduction of each metal in the respective contaminated soils of *J. curcas, J. gossypifolia* and *J. multifida* shows 18.9%, 11.4%, 22.6% respectively for copper; 8.2%, 6.5%, 4.9% respectively for zinc, 22.9%, 12.2%, 19.5% respectively for chromium, 37.1%, 2.4%, 27.9% for lead and 21.3%, 27.8%, 1.8% respectively for nickel.

Table 3: Heavy Metal Composition of the Pre-Planting and Post-Harvest Contaminated Soil

	Pre-planting Soil (Initial)	Post-Harvest soil (After)		
Metal	Contaminated soil	*J. curcas* soil	*J. gossypifolia* soil	*J. multifida* soil
Cu	525.75	426.50	466.00	407.00
Zn	1940.38	1781.88	1814.00	1844.75
Cr	25.63	19.75	22.50	20.63
Cd	6.88	6.58	5.88	6.79
Pb	325.15	204.38	317.75	234.50
Ni	41.75	32.88	30.13	41.00

3.2 Heavy Metal Uptake into Root and Shoot of *Jatropha spp*

Table 4 and 5 present the result of the heavy metal uptake into the root and shoot of *Jatropha sp.* The heavy metals concentration in the root of the plants ranged from 0.27-63.14 mg/kg for Copper, Zinc: 4.82-54.18 mg/kg, Chromium: 0.48-3.47 mg/kg, Lead: 1.75-72.37 mg/kg and Nickel: 0.05-3.23 mg/kg; while in the shoot of the Jatropha species, the concentration ranged from 0.25-33.36 mg/kg for Copper, Zinc: 5.40-12.48 mg/kg, Chromium: 0.29-1.45 mg/kg, Lead: 0.58-8.26 mg/kg and Nickel: 0.05-3.23 mg/kg while, cadmium was not detected in the root and shoot of the three Jatropha species. Results from the analysis of variance show that there was an interaction effect between the contamination level and species of Jatropha in all the heavy metals assessed, this suggests that the accumulation of various metals into the root and shoot of the plant was dependent on both the level of contamination and Jatropha species type. This implies further that, while the level of contamination greatly affected the uptake, that is, more uptake by the plants was observed in the contaminated soil, specific species of Jatropha was able to accumulate heavy metals into the roots and shoots to a greater extent.

Table 4: Heavy metals (mg/kg) uptake into the root of Jatropha species

Contamination	Species	Cu	Zn	Cr	Cd	Pb	Ni
Control	*J. curcas*	1.41±0.04^{b}	4.82±0.03^{a}	0.61±0.01^{a}	ND	1.75±0.02^{a}	0.12±0.01^{b}
	J. gossypifolia	0.27±0.03^{a}	10.88±0.03^{b}	0.48±0.00^{a}	ND	2.50±0.04^{b}	0.05±0.01^{a}
	J. multifida	0.43±0.04^{a}	15.85±0.06^{c}	0.62±0.04^{a}	ND	1.59±0.02^{a}	0.11±0.03^{b}
Contaminated	*J. curcas*	63.14±0.83^{e}	54.18±0.77^{f}	3.47±0.19^{c}	ND	72.37±1.02^{e}	3.23±0.05^{d}
	J. gossypifolia	30.59±0.13^{c}	42.18±0.90^{e}	1.61±0.37^{b}	ND	4.54±0.13^{c}	1.12±0.04^{c}
	J. multifida	41.75±0.21^{d}	32.46±1.22^{d}	1.43±0.04^{b}	ND	55.72±0.14^{d}	0.13±0.01^{b}

Mean with the same alphabets in the same column are not significantly different at P< 0.05 ND: Not Detected

Table 5: Heavy metal (mg/kg) uptake into the shoot of jatropha species

Soil Type	Species	Cu	Zn	Cr*	Cd	Pb	Ni
Control	*J. curcas*	0.95±0.02^{a}	6.16±0.02^{a}	0.43±0.01	ND	1.57±0.01^{b}	0.05±0.01^{a}
	J. gossypifolia	0.25±0.04^{a}	5.40±0.02^{a}	0.29±0.03	ND	0.58±0.03^{a}	0.09±0.01^{ab}
	J. multifida	0.34±0.02^{a}	7.33±0.08^{b}	0.30±0.03	ND	1.55±0.02^{b}	0.12±0.01^{b}
Contaminated	*J. curcas*	33.36±0.23^{d}	11.16±0.71^{d}	1.41±0.08	ND	8.26±0.35^{c}	2.06±0.05^{d}
	J. gossypifolia	18.33±0.03^{b}	12.48±0.16^{e}	1.45±0.03	ND	1.46±0.06^{b}	1.09±0.00^{c}
	J. multifida	22.14±1.01^{c}	9.52±0.88^{c}	1.45±0.17	ND	8.02±0.49^{c}	0.12±0.06^{b}

*ns – not significant; Mean with the same alphabets in the same column are not significantly different at P< 0.05 ND: Not Detected

3.3 Bioaccumulation Factor and Translocation Factor

The result of the assessment of the BAF and TF is shown in Table 6. BAF and TF ranged from 0.07-0.16 and 0.53-0.6 for copper; <0.01-0.03 and 0.21-0.30 for zinc; 0.07-0.18 and 0.41-1.01 for chromium; 0.01-0.35 and 0.11-0.32 for lead; <0.01-0.04 and 0.64-0.97 for nickel respectively.

Table 6: Bioaccumulation Factor and Translocation Factor of Heavy Metals in the *Jatropha spp*

	J. curcas		***J. gossypifolia***		***J. multifida***	
Metals	**BAF Soil/ Root**	**TF Root/ Shoot**	**BAF Soil/ Root**	**TF Root/ Shoot**	**BAF Soil/ Root**	**TF Root/ Shoot**
Cu	0.16	0.53	0.07	0.60	0.10	0.53
Zn	0.03	0.21	0.02	0.30	<0.01	0.29
Cr	0.18	0.41	0.07	0.90	0.07	1.01
Pb	0.35	0.11	0.01	0.32	0.24	0.14
Ni	0.03	0.64	0.04	0.97	<0.01	0.92

4. DISCUSSION

Heavy metal analysis of the soil samples from the dumpsite shows a significantly (p<0.05) high level of contamination when compared with the control soil sample, however only nickel and chromium were found to be within the WHO/FAO permissible limit for heavy metals in the soil. The concentrations of copper, zinc, cadmium and lead in the dumpsite soil were far higher than the established standards for heavy metals in soil [21]. This implies that dumpsites may serve as a likely source of heavy metal contamination and proper management plans must be in place to mitigate its potential environmental impact. Phytoremediation offers one way to mitigate the environmental impacts of the high level of heavy metals in dumpsites.

The concentration of heavy metals in the contaminated soil before planting was compared with what is left in the contaminated soil after harvesting. It was observed that the post-harvest soil heavy metals for all the species was reduced correspondingly to what is reported in other studies [8, 9, 22], albeit not significantly in all the post-harvest pots. The low and insignificant reduction may be due to the high level of contamination in the soil as the plants may need more time beyond the three months the plants were monitored to get acclimatized to the toxic environment, the phytotoxic effect of the heavy metals on the three Jatropha species is already documented [23]. The analysis of heavy metals in the *Jatropha* plant's part shows that the *Jatropha spp* were found to be able to efficiently remove the studied metals in varying degree, cadmium, however, was not detected in the plant parts of the three Jatropha species. From this study, it was generally observed that metal accumulation was significantly greater in the roots than the shoot of the plants. Plant samples in the control soils demonstrated insignificant metal uptake into the plant parts when compared with the contaminated samples thus, *J. curcas* in the contaminated soil accumulated a significantly (p< 0.05) higher concentration of copper in the root when compared with what is absorbed into the shoot and the level of uptake by the other species in the contaminated soil (Figure 1). This is in agreement with the findings of Majid *et al.* [9] and Moursy et al. [22] who also reported higher concentrations of copper in the root of *J. curcas* raised in heavy metal contaminated sludge, than other parts of the plant and also in *Acacia mangium* raised on graded level of copper contaminated soils [20]. More copper was also found to be accumulated in the root than shoot by Luhach and Chaudhry, [11] and Ahmadpour *et al.* [8] but to a lesser extent. This same trend was observed in *J. gossypifolia* and *J. multifida*, however, the concentration of copper accumulated in the root of *J. gossypifolia* in this study is lower than that reported by Awokunmi *et al.* [12] for copper translocated to the root of *J. gossypifolia* in heavy metal contaminated soil from different dumpsites. Also, the accumulation of copper both in the root and shoot progresses as *J. curcas* had the highest followed by *J. multifida,* then *J. gossypifolia* having the least. Correlation studies show a significant (p<0.05) positive relationship in the copper levels in the soil/root, soil/shoot and root/shoot with a coefficient of 0.90, 0.92 and 0.99 respectively. This suggests that the three Jatropha species could directly uptake copper from contaminated soil environment, thus, a good accumulator of copper with the trend: *J. curcas >J. multifida>J. gossypifolia.*

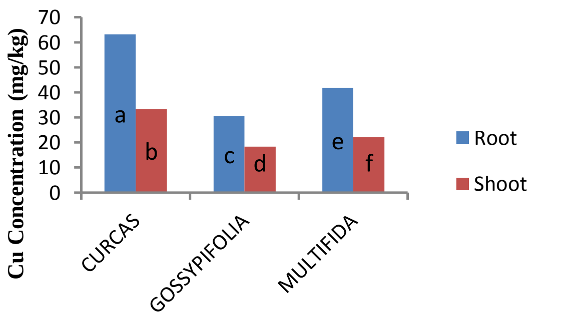

Figure 1: Comparative Copper Concentration in the Root and Shoot of *Jatropha spp.* Bars with different letters indicate significant difference at p< 0.05

The accumulation of zinc into the roots and shoots of *Jatropha spp* follows a similar pattern as observed for copper, more zinc is accumulated in root than shoot in all the species (Figure 2). The result obtained for *J. curcas* is in agreement with what is widely reported in previous studies [8, 9, 22]. However, in this study, a higher concentration of zinc was translocated to the root of *J. gossypifolia*; this is contrary to the very low concentration translocated into the root of *J. gossypifolia* reported by Awokunmi *et al.* [12] even though the general trend root concentration > shoot concentration was maintained in their study. Comparatively, *J. curcas* significantly (p<0.05) accumulated more zinc from the soil into the root than the other species, also the accumulation of zinc in the shoot of *J. curcas* and *J. gossypifolia* is comparable (P<0.05). Results from the correlation analysis indicate a significant positive correlation between the Zn concentration in the soil/root, soil/shoot and root/shoot with a coefficient of 0.91, 0.91 and 0.92 respectively which also suggest easy translocation of the metal from contaminated soil to the plants' tissues.

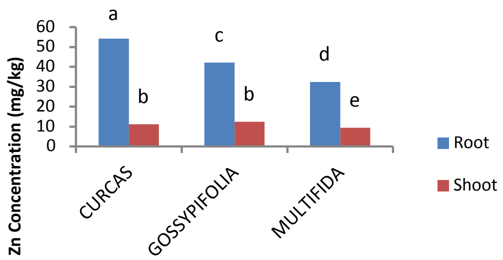

Figure 2: Comparative Zinc Concentration in the Root and Shoot of *Jatropha spp.* Bars with different letters indicate significant difference at p<0.05

Chromium was more concentrated in the root of *J. curcas* than the shoot and significantly (p<0.05) different from *J. gossypifolia* and *J. multifida* (Figure 3). This is in contrast to what was reported by Luhach and Chaudhry, [11] where chromium was found to be more concentrated in the shoot than the root. Ahmadpour *et al.* [8], on the other hand, reported equal translocation of chromium in both root and shoot of *J. curcas*, this is not the case in this study for *J. curcas* where more Cr was domiciled in the root; however, *J. gossypifolia* and *J. multifida* exhibited this trend reported by Ahmadpour *et al.* [8] for curcas. In the correlation analysis, a positive correlation was found between the Cr levels in the soil/root and root/shoot with a coefficient of 0.76 and 0.73 respectively, which is not significant at p<0.05, however, the soil/shoot relationship showed highly positive significant correlation with a coefficient of 0.99. This may suggest possible direct translocation of Cr to the aerial part of the Jatropha species from the contaminated soil.

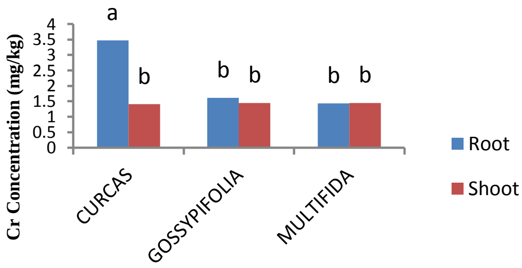

Figure 3: Comparative Chromium Concentration in the Root and Shoot of *Jatropha spp.* Bars with different letters indicate significant difference at p<0.05

Lead metal was more concentrated in the root of all the *Jatropha spp* than in the shoot, *J. curcas* had the highest concentration of lead in the root which is significantly different (P<0.05) from the other species (Figure 4). This trend is comparable to that reported by Majid *et al.* [9]. The value of lead absorbed into root and shoot of *J. gossypifolia* in this study is low compared to what Awokunmi *et al.* [12] reported where more lead was translocated into the stem than the root of *J. gossypifolia*. *J. multifida* also shows the potential to accumulate Pb into the root than shoot and in greater proportion than *J. gossypifolia*. Like in this study, *Jatropha curcas* was shown to have phytoremediation potential for Pb, albeit, it was not an accumulator for Pb [7]. Correlation analysis revealed an insignificant positive relationship between the Pb in the soil/root and soil/shoot with a coefficient of 0.51 and 0.52 respectively while root/shoot correlation is significant (p<0.05) with a coefficient 0.99, these trends may suggest a similar source of metal translocation from the soil to the root and shoot of the plants.

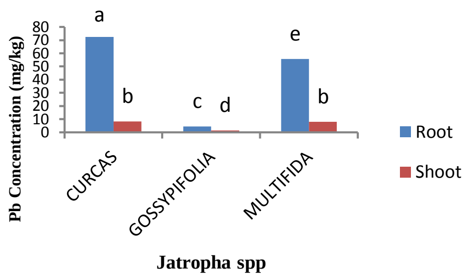

Figure 4: Comparative Lead Concentrations in the Root and Shoot of *Jatropha spp.* Bars with different letters indicate significant difference at p<0.05

Jatropha spp. was found to accumulate nickel in the root than shoot; *J. curcas* had the highest root accumulation of nickel compared to the other species (Figure 5). This observation is in agreement with that of Luhach and Chaudhry, [11] for nickel accumulation in the root of *J. curcas*. Nickel concentration absorbed into *J. gossypifolia* is root is similarly in agreement with Awokunmi *et al.* [12]. *J. multifida* accumulated significantly less nickel into the root and shoot; this may suggest that *J. multifida* is may not be a ¦good phytoremediator for nickel. Correlation analysis shows that a positive correlation was found between the Ni levels in the soil/root and soil/shoot with a coefficient of 0.51 and 0.55 respectively, which is not significant at p<0.05, however, the root/shoot relationship showed highly positive significant correlation with a coefficient of 0.98. This may also suggest the same source of Ni from the contaminated soil.

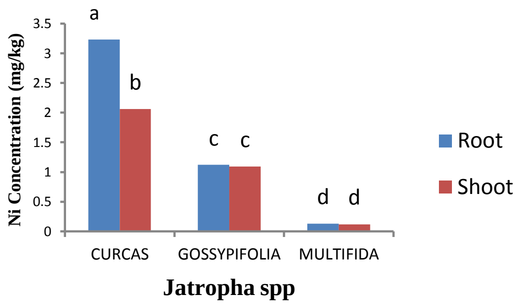

Figure 5: Comparative Nickel Concentrations in the Root and Shoot of *Jatropha spp.* Bars with different letters indicates significant difference at p<0.05

In other to further assess potentials for phytoremediation among the Jatropha species, bioaccumulation factor also referred to as bioconcentration factor in some literature, and translocation factor was calculated for each metal for each Jatropha species. The process for the tolerance of plant species to heavy metals with respect to their BAF and TF value can classify them into either hyperaccumulator that accumulate large concentration of metals into their harvestable aerial parts, or metal excluders that accumulate toxic metals from the soil to their roots but restrict their transport into the aerial part of the plant [24], hence, these groups of plants will have a BAF >1 and TF<1 and therefore have low potential for the extraction of metals but could be efficient for the phytostabilization of heavy metals. For a plant to possess phytoremediation potential, the bioaccumulation factor and by extension, the translocation factor must be greater than 1 [19], accordingly, efficient metal movement from roots to shoots is a vital characteristic of metal hyperaccumulators [25]. Results from the bioaccumulation factor indicate that BAF is less than 1 for all the studied metals which suggest that the *Jatropha spp* could favour retaining toxic metals in the soil. The translocation factor which describes the ability of the plant to translocate toxic metals from the root to the shoot of the plant was found to be less than 1 for most of the metals except *J. multifida* with a translocation factor of 1.01 for chromium which suggests that it could favour phytoabsorption of chromium. Awokunmi *et al.* [12] reported a BAF and TF greater than 1 on *J. gossypifolia* contrary to that obtained in this studied, this may be due to the use of EDTA, a metal chelating agent to aid the phytoextraction of some of the studied metals. TF less than 1 shows a restriction of the internal transport of metals from root to shoots leading to a higher concentration of heavy metals in the roots of the plants [26], this is a general observation among the three Jatropha species investigated.

5. CONCLUSION

The study has shown that *Jatropha spp* were able to accumulate heavy metals into their roots and shoots and could therefore, be a phytoremediator for studied metals. The mechanism observed tends towards phytostabilization though not well defined due to BAF which is less than 1 across all the Jatropha species, however, the concentration of toxic metals in the root was favoured by the three species. *J. curcas* has the potential to be a phytoremediator for all the heavy metals determined while *J. gossypifolia* is also potentially a phytoremediator for zinc, chromium and nickel, *J. multifida* is also concluded to be a phytoremediator for copper and lead and not for nickel. The summary of their comparative phytoremediating ability is summarised as follows for Copper: *J. curcas* > *J. multifida* > *J. gossypifolia*; Zinc: *J. curcas* > *J. gossypifolia* > *J. multifidi*; Chromium: *J. curcas* > *J. multifida* > *J. gossypifolia*; Lead: *J. curcas* > *J. multifida* > *J. gossypifolia* and Nickel: *J. curcas* > *J. gossypifolia* > *J. multifida*.

REFERENCES

[1] McLaughlin, M.J., Zarcinas, B.A., Stevens, D.P., Cook, N. 2000. Soil testing for heavy metals. Communication in Soil Science and Plant Analysis, 31(11-14), 1661–1700.

[2] Panagos, P., Van Liedekerke, M., Yigini, Y., Montanarella, L. 2013. Contaminated sites in Europe: Review of the current situation based on data collected through a European Network. Journal of environmental and Public Health, 2013, Article ID 158764. http://dx.doi.org/10.1155/2013/158764

[3] Navarro, M.C., Perez-Sirvent, C., Martinez-Sanchez, M.J., Vidal, J., Tovar, P.J., Bech, J. 2008. Abandoned mine sites as a source of contamination by heavy metals: a case study in a semi-arid zone. Journal of Geochemical Exploration, 96, 183–193.

[4] Suciu, I., Cosma, C., Todica, M., Bolboaca, S.D., Jantschi, L. 2008. Analysis of soil heavy metal pollution and pattern in Central Transylvania. International Journal of Molecular Science, 9, 434–453.

[5] Ganesan, V. 2012. Rhizoremediation: A Pragmatic Approach for Remediation of Heavy Metal-Contaminated Soil. In A. Zaidi et al. (eds.), Toxicity of Heavy Metals to Legumes and Bioremediation, Springer-Verlag Wien. DOI 10.1007/978-3-7091-0730-0_9

[6] Sabandar, C.W., Ahmat, N., Jaafar, F.M. and Sahidin, I. 2013. Medicinal property, phytochemistry and pharmacology of several Jatropha species (Euphorbiaceae): a review. Phytochemistry, 85, 7–29.

[7] Mangkoedihardjo, S. and Surahmaida. 2008. *Jatropha curcas* L. for Phytoremediation of Lead and Cadmium Polluted Soil. World Applied Sciences Journal, 4(4), 519-522.

[8] Ahmadpour, P., Nawi, A.M., Abdu, A., Abdul-Hamid, H. Singh, D.K., Hassan, A. Majid, N.M. and Jusop, S. 2010. Uptake of heavy metals by *Jatropha curcas* L. planted in Soils Containing Sewage Sludge. American Journal of Applied Sciences, 7(10), 1291-1299.

[9] Majid, N.M., Islam, M.M. and Riasmi, R. 2012. Heavy metal uptake and translocation by *Jatropha curcas* L. in sawdust sludge contaminated soils. Australian Journal of Crop Science, 6(5), 891-898.

[10] Wu, Q., Wang, S., Thangavel, P., Li, Q., Zheng, H., Bai, J., Qiu, R. 2011. Phytostabilization potential of *Jatropha curcas* L. in polymetallic acid mine tailings. International Journal of Phytoremediation, 13(8), 788-804.

[11] Luhach, J. and Chaudhry, S. 2012. Phytoremediation potential of *Jatropha curcas* for removal of heavy metals from refinery sludge. International Journal of Scientific and Engineering Research, 3(10), 1-5.

[12] Awokunmi, E.E., Asaolu, S.S., Ajayi, O.O. and Adebayo, O.A. 2012. The role of EDTA on heavy metals phytoextraction by *Jatropha gossypifolia* grown on soil collected from dumpsites in Ekiti State Nigeria. *British Journal of Environment & Climate Change*, 2(2), 153-162.

[13] Maes, A., Achten, M.H., Reubens, W.M.J., Samson, B., Muys, B. 2009. Plant-water relationships and growth strategies of *Jatropha curcas* L. saplings under different levels of drought stress. Journal of Arid Environments, 73, 877–884.

[14] Kamusoko, R. and Jingura, R.M. 2017. Utility of Jatropha for Phytoremediation of Heavy Metals and Emerging Contaminants of Water Resources: A Review. Clean Soil Air Water, 45(11), 1700444. DOI: 10.1002/clen.201700444

[15] Rahimi, M., Poor, M.R.A., Farhadi, R. and Bagherifard, A. 2013. Effects of potassium and phosphorus fertilizers on arsenic phytotoxicity and essential oil yield of two basil cultivars. Bulletin of Environment, Pharmacology and Life Sciences, 2(5), 86-92.

[16] Kazemi, R., Karimian, N., Ronaghi, A. and Yasrebi, J. 2016. The effect of two humic substances on the growth and lead uptake of corn in calcareous soil. Iran Agricultural Research, 35(1), 39-48.

[17] Zhuang, P., Yang, Q.W., Wang, H.B., and Shu, W.S., 2007. Phytoextraction of heavy metals by eight plant species in the field. Water, Air and Soil Pollution, 184, 235-242.

[18] Adesodun, J.K., Atayese, M.O., Agbaje, T.A., Osadiaye, B.A., Mafe, O.F. and Soretire A.A., 2010. Phytoremediation potentials of sunflowers (*Tithonia diversifolia* and *Helianthus annus*) for metals in soils contaminated with zinc and lead nitrates, Water, Air and Soil Pollution, 207, 195-201.

[19] Rezvani, M. and Zaefarian, F. 2011. Bioaccumulation and translocation factors of cadmium and lead in *Aeluropus littoralis*. Australian Journal of Agricultural Engineering, 2(4), 114-119.

[20] Majid, N.K., Islam, M.M., Justin, V., Abdu, A. and Ahmadpour, P. 2011. Evaluation of heavy metal uptake and translocation by *Acacia mangium* as a phytoremediator of copper contaminated soil. African Journal of Biotechnology, 10(42), 8373-8379.

[21] WHO/FAO. 2001. Codex alimentarius commission. Food additives and contaminants. Joint FAO/WHO Food Standards Programme, ALINORM 10/12A.

[22] Moursy, A.A., Abdel Aziz, H.A. and Mostafa, A.Z. 2014. The effect of irradiated and non irradiated sewage sludge application on Uptake of Heavy Metals by *Jatropha curcas* L plants. International Journal of Advanced Research, 2(1), 1072-1080.

[23] Awotedu, O.L., Ogunbamowo, P.O., Awotedu, B.F. and Emmanuel, I.B. 2018. Comparative growth response of three Jatropha species on heavy metal contaminated soil. International Annals of Science, 5(1), 26-32.

[24] Malik, N. and Biswas, A.K. 2012. Role of higher plants in remediation of metal contaminated sites. Scientific Reviews and Chemical Communication, 2, 141-146.

[25] Zhao, F.J., Jiang, R.F., Dunham, S.J., McGrath, S.P. 2006. Cadmium uptake, translocation and tolerance in the Hyperaccumulator *Arabidopsis halleri*. New Phytologist, 172, 646–654. https://doi.org/10.1111/j.1469-8137.2006.01867.x

[26] Turan, M. and Esringu, A. 2007. Phytoremediation based on canola (*Brassica napus* L.) and Indian mustard (*Brassica juncea* L.) planted on spiked soil by aliquot amount of Cd, Cu, Pb and Zn. Plant Soil Environment, 53, 7-15.