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REMEDIATION POTENTIAL OF *Ricinus communis* L. IN LEAD (Pb) CONTAMINATED SOIL.

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ABSTRACT

Lead (Pb) is the major contaminant in soil that has been posing significant environmental problems and health risks for humans especially children. This study assessed the potential of *Ricinus communis* to accumulate and transfer Pb in their roots and shoots from soil contaminated with Pb. Five treatments consisting of T0 (0 mg of Pb $(NO_3)_2$ per kg of top soil), T1 (50 mg of Pb $(NO_3)_2$ per kg of top soil), T2 (100 mg of Pb $(NO_3)_2$ per kg of top soil), T3 (150 mg of Pb $(NO_3)_2$ per kg of top soil) and T4 (200mg of Pb $(NO_3)_2$ per kg of top soil) were replicated seven times and arranged in a completely randomized design. Roots and shoots from different potting media after 12 weeks of transplanting as well as soils before and after transplanting were collected and analyzed for Pb concentrations using standard instrumentation methods. Data were assessed using bioaccumulation (BAF) and translocation factors (TF). Pre study Pb concentrations (mg/kg) were T0 (2.11± 0.05), T1 (51.20 ± 1.22), T2 (100.25±1.67), T3 (150.21± 0.98) and T4 (200.13± 1.01) while those after the experiment T0 were (0.70± 0.01), T1 (18.21± 0.01), T2 (27.01± 0.16), T3 (56.42± 0.09) and T4 (109.89± 1.05).. The concentrations of Pb in the roots of *Ricinus comnunis* seedlings were T0 (0.45± 0.02), T1 (18.21± 0.01), T2 (27.01± 0.16), T3 (38.21± 0.05) and T4 (41.09± 0.11) in mg/kg while the concentrations in shoot were T0 (0.38± 0.01), T1 (11.35± 0.03), T2 (18.09± 0.05), T3 (24.06± 0.01) and T4 (27.09± 0.04) in mg/kg. Values of BAF ranged between 0.62± 0.01 and 1.19± 0.02 while TF values were 0.62± 0.001 to 0.84± 0.005 indicating the potential of *Ricinus comnunis* as remediator of Pb. This study has shown the ability of *Ricinus comnunis* for phytoremediation of Pb from contaminated soil.

Keywords: Lead (Pb), contamination, bioaccumulation, translocation, potential,

Introduction

The intense and inappropriate use of fertilizers and pesticides in the soil, coupled with the increase in industrial activity and mining are the main reasons for the contamination of soil, waterways and the water table by heavy metals. Among the existing pollutants, lead (Pb) is the major contaminant in the soil that has been posing significant environmental problems and health risks for humans especially children (Lasat, 2002; Shen *et al.*, 2002; Gratão *et al.*, 2005). Rapid industrial development and urbanization during the past two decades have increased the quantity and diversity of toxic and hazardous wastes on land. Heavy metal pollution has become serious concern and the dramatic acceleration of heavy metal contamination in soil is mainly due to industrial revolution, for instance, mining, mineral, and smelting and tannery industries (Wang *et al.*, 2001. Akintola, 2014). Most common heavy metal contaminants are lead, cadmium, chromium, copper, mercury and zinc (Kabata-Pendias and Pendias, 2001).

Higher doses of these metals may cause metabolic disorders and growth inhibition for most of the plant species, often leading to death (Wang *et al.*, 2003). Since, heavy metals are not subjected to degradation; they remain almost indefinitely in the environment and become hazardous (Raskin and Ensley 2000). There is need to reduce their concentrations in the environment to a barely minimum. Lasat *et al.*(2000) reported that remediation of heavy metals of polluted soils could be carried out using physico-chemicals processes such as ion- exchange, precipitation, reverse osmosis, evaporation and chemical reduction; however, these measures are costly and cause toxicity to the soil. But phytoremediation, a method of remediating soil using plants and microorganism has become an alternative to all other techniques due to its effectiveness, economic, environmentally-sustainable solution in the stabilization and potential recovery of contaminated land by which plant is applied to absorb, transform and detoxify heavy metals (Schnoor and McCutcheon, 2003).

Lead absorption is regulated by pH, cation exchange capacity of the soil, as well as by exudation and physicochemical parameters (Alloway, 1995; Lasat *et al*,, 2000). Absorption by roots from the soil occurs via the plasma membrane, probably involving cationic channels such as calcium channels. Roots are capable of accumulating significant quantities of this heavy metal and simultaneously restrict its translocation to the shoot (Akintola *et al.*, 2019). Usman *et al*., (2020) reported that Pb was listed as the number one heavy metal on Earth in 2015 and is generally toxic to most plants at a soil concentration higher than 30 mg/kg. In a study using three cultivars of lettuce, Michalska (2001) showed that 0.5 mMPb in the nutrient solution resulted in greater Pb accumulation in roots. Ultrastructural studies have revealed the presence of Pb mainly in the intercellular spaces, cell wall, and vacuoles with little deposited in the endoplasmatic reticulum, dictyosomes and vesicles derived from the dictyosomes. The cell wall and the vacuole together account for 96% of the Pb absorbed (Wierzbicka and Antosiewicz, 1993).

Castor bean (*Ricinus communis* L) a member of the family Euphorbiaceae. *Ricinus communis* has been selected because it has been found to grow luxuriantly in the Pb contaminated sites produces high biomass in industrial and polluted urban areas without exhibiting any morphological changes and toxic symptoms and it is known to have the ability to accumulate potentially toxic metals (Juhasz *et al*., 2016; Zhi-Xin *et al*., 2007). Thus, this study aimed at assessing the remediation potential of *Ricinus communis* in lead polluted soil.

Materials and Method

The experiment was carried out in the screen house of Forestry technology department, Federal College of Forestry Ibadan, Oyo State. The area lies between Latitude (7^o26'N - 7^o28'N) and Longitude (3^o51'E - 3^o54'E). The Climate pattern of the area is tropically dominated by annual rainfall ranging from 1300mm-1500mm and average relative humidity of about 65%, the average temperature is about 26^{o}C. (FRIN, 2014). The area has two seasons; dry seasons usually commenced from November to March while the Raining season starts from April to October. Seeds of *Ricinus communis* were collected from Igangan in Ibarapa North Local Government.

The lead salt was purchased from a scientific laboratory in Lagos. Composite topsoil samples were collected at the depth of 0.15cm from within the premises of Federal College of Forestry, Ibadan. The soil samples were air-dried and sieved with 2mm diameter mesh. Lead was added to 1kg of soil each at 0mg, 50mg, 100mg, 10mg and 200mg as lead nitrate (Pb $(NO_3)_2$. The soils were spiked and mixed thoroughly with different concentrations of lead for some days (Kabta-Pendias and Pendias, 1984). The treatments were designated as T0 (0 mg of Pb $(NO_3)_2$ per kg of top soil), T1 (50 mg of Pb $(NO_3)_2$ per kg of top soil), T2 (100 mg of Pb $(NO_3)_2$ per kg of top soil), T3(150 mg of Pb $(NO_3)_2$ per kg of top soil) and T4 (200mg of Pb $(NO_3)_2$ per kg of top soil). The seeds were sown into constructed germination bed at the nursery for 4 weeks, after which they were transplanted into polythene pots The experiment was laid out in a complete randomized design and the treatments were replicated seven times making a total of 35 potting media. Watering was done twice a day (early in the morning and evening). Regular weeding was also carried out when necessary. Data were collected on number of leaves, seedling heights and stem diameter weekly for 12 weeks of the experiment. At the end of pot experiment, roots and shoots of the plants were collected for heavy metal analysis. Composite soil samples (before and after planting) from each of the treatment pots were analyzed for physiochemical and heavy metal. The pH of the soil samples was determined using electrode pH meter (PCE-228) in water-soil solution (1:1), while the organic carbon contents of the soils were determined using Walkley and Black (1934) method and then multiplied by 1.724 to calculate soil organic matter content. Total nitrogen and available phosphorus were determined by micro-kjeldhal digestion-distillation methods (Bramner, 1965) and electrophotometer method (Bray and Kurtz, 1945). Analysis of Pb was done using atomic absorption spectrophotometer (AAS).

Bioaccumulation factor (BCF) and Translocation factor (TF) were calculated using the formula of Yadav *et al*., (2009) as

$$\text{Bioaccumulation factor (BCF)} = \frac{\text{heavy metal concentration in plant}}{\text{heavy metal concentration in soil}} \ldots \text{ Equation 1}$$

$$\text{Translocation factor(TF)} = \frac{\text{heavy metal concentration in shoot}}{\text{heavy metal concentration in root}} \ldots \text{. Equation 2}$$

Descriptive statistics and one-way analysis of variance (ANOVA) were used to analyse the data obtained while least significant difference (LSD) tests were performed to determine the statistical significance of the difference between means of treatments.

Results and Discussion

Physiochemical characteristics of the growing media

Physiochemical characteristics of the soil before planting are presented in Table 1. Grain size distribution of the treatment soils were sand (68.20 – 72.00%), clay (14.00 – 15.00%) and silt (14.50 – 15.00%). Based on the particle sizes of the soil, the soil used for this study can be classified as sandy loamy soil. The pH of the treatment soil ranged from 5.48 to 5.92, indicating slightly acidic. The pH of the treatments (T2-T5) contaminated with Pb was lower than the control treatment soils (T0), indicating that the presence of Pb may increase the acidic nature of the soils. Organic matter content describes the levels of mineral elements for plant development and growth. Thus, it plays an important role in soil structure, water retention, cat-ion exchange and in the formation of complexes (Alloway, 1995). Organic matter content (OMC), available phosphorus (AP) and total nitrogen (TN) of the treated soils ranged from 1.61 – 2.48%; 1.09 – 1.44% and 0.01-0.12% respectively. Reduction in the values of OMC, AP and TN were observed from T1 to T5 indicating the increase in the concentration of Pb in the soils.

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Table 1: Physiochemical analysis of the growing media

Treatment	PH	Sand (%)	Silt (%)	Clay (%)	AP (%)	O.M (%)	T.N (%)
T0	5.92	70.50	14.50	15.00	1.44	2.48	0.12
T1	5.81	68.20	15.00	14.70	1.31	2.22	0.08
T2	5.68	71.00	15.00	14.00	1.25	2.01	0.06
T3	5.51	72.00	14.00	14.00	1.18	1.98	0.04
T4	5.48	71.00	15.00	14.00	1.09	1.61	0.01

Effect of Lead contaminated soils on Growth Parameters of *Ricinus comnunis* seedlings

Effects of lead contaminated soil on the seedling heights, leaf production and stem diameter were presented in Table 2-4. Table 2 revealed the effect of lead contaminated soil on the height of *Ricinus comnunis* seedlings. It was evident from the Table 2 that the control soil with 0mg/kg of lead (T0) had the best performance in plant height at the early weeks of growth up to week 6 followed by seedlings contaminated with 50mg/kg of lead (T1) while seedlings contaminated with 200mg/kg of lead (T4) performed least. From week 8 up to week 12, it was observed that the effect of the lead concentrations in the soils has affected the growth by reducing the seedling heights of *Ricinus comnunis* in the contaminated soils and the seedling heights of *Ricinus comnunis* in the control soil(T0) increases with an average value of 21.60cm at week 12, this was followed by seedlings contaminated with 50mg/kg of lead (T1), 20.50cm while seedlings contaminated with 200mg/kg of lead (T4) performed least with an average value of 15.00cm. Means were separated using Duncan multiple range test. Means with the same letter are not significantly different from each other while means with the first letter gave the highest significant effect. The indication is that *Ricinus communis* seedlings mopped up substantial concentration of lead. This agreed with the findings of Wang *et al*. (2001) that plants can remove between 180 and 530 kg/ha of lead per year, making remediation of sites contaminated with up to 2,500 mg/kg possible in fewer than 10 years (Eapen and D'souza 2011).

Table 3 also revealed the effect of lead contaminated soil on leaf production of *Ricinus comnunis* seedlings. It was shown from the table that seedlings grown on uncontaminated soil (control) had the best performance in number of leaves with an average value of 21.60 leaves. Seedlings raised on soil contaminated with 50mg/kg of lead (T1) performed second best while seedlings contaminated with 200mg/kg of lead (T4) performed least with an average value of 20.80 leaves. Majid and Argue (2001) stated that, natural metal hyperaccumulators can accumulate large amounts of heavy metals in their aboveground tissues and should be tolerant of metal contaminants and other site conditions that may limit plant growth.

Table 2. Effect of lead contaminated soil on the Height of *Ricinus comnunis* seedlings

Treatments	WAT2	WAT4	WAT6	WAT8	WAT10	WAT12
T0	5.90b	8.10b	11.00ab	14.60a	17.30a	21.60a
T1	6.90b	9.80a	12.40a	13.30ab	16.20b	20.50a
T2	7.30a	9.00ab	11.40ab	12.90ab	15.50bc	18.20b
T3	7.20a	8.80ab	10.90ab	12.20b	14.60c	17.70bc
T4	6.70ab	8.20b	9.90b	11.60bc	13.80d	15.00c
LSD	1.00	1.30	1.70	1.80	2.10	2.20
%CV	14.10	13.60	13.90	15.60	13.50	16.30

Note: Means with the same letter are not significantly different from each other.

Table 4 showed the effect of lead contaminated soil on stem diameter of *Ricinus comnunis* seedlings. Seedlings raised on soil contaminated with 100mg/kg of lead (T1) performed second best with an average value of 5.20cm while seedlings contaminated with 200mg/kg of lead (T4) performed least with an average value of 4.10cm.

Table 3: Effect of lead contaminated soil on leaf production of *Ricinus comnunis* seedlings

Treatments	WAT2	WAT4	WAT6	WAT8	WAT10	WAT12
T0	4.10	7.00a	10.20a	16.40a	21.20a	26.90a
T1	4.10	6.90a	9.90ab	15.20b	19.70ab	23.20ab
T2	4.00	6.60ab	9.80a	14.10bc	18.40b	22.10ab
T3	4.00	5.30b	8.20b	14.10bc	18.40b	22.10ab
T4	3.90	5.70b	7.30bc	12.80c	16.3bc	20.80b
LSD	0.32	0.76	1.25	1.42	2.70	3.10
%CV	7.30	15.40	17.70	14.80	19.30	19.60

Note: Means with the same letter are not significantly different from each other.

Pb Concentration in the potting media and *Ricinus comnunis* seedlings

The concentration of lead recorded in the soil before and after the experiment as well as its concentrations *Ricinus comnunis* seedlings were presented in Table 5. Pb concentrations in the potting media before were T0 (2.11± 0.05), T1 (51.20 ± 1.22), T2 (100.25±1.67), T3 (150.21± 0.98) and T4 (200.13± 1.01) while after the experiment T0 were (0.70± 0.01), T1 (18.21± 0.01), T2 (27.01± 0.16), T3 (56.42± 0.09) and T4 (109.89± 1.05). Significant reductions were observed between the concentration of heavy metals before and after planting (Table 5). This could be due to the ability of the plant to uptake some quantity of Pb concentration from the soil. This is similar to the findings of Akintola *et al* (2020), where *Cedrela odorata* was used for possibly removal of lead from contaminated soil.

Table 4: Effect of lead contaminated soil on stem diameter of *Ricinus comnunis* seedlings

Treatments	WAT2	WAT4	WAT6	WAT8	WAT10	WAT12
T0	2.20b	3.20ab	3.60ab	3.9ab	4.10b	4.30bc
T1	3.10a	3.50a	4.20a	4.60a	5.10a	5.60a
T2	2.50ab	3.50a	4.10a	4.40a	4.70ab	5.20ab
T3	2.60ab	3.10b	3.50ab	3.80ab	4.30b	4.80b
T4	2.80ab	3.00b	3.20b	3.50b	3.80bc	4.10c
LSD	0.69	0.27	0.30	0.44	0.37	0.67
%CV	23.70	7.60	10.40	11.40	9.60	17.70

Note: Means with the same letter are not significantly different from each other.

It was observed that the roots of the studied seedlings have higher concentrations of lead than the shoots of the seedlings. This agreed with the findings of Gutsch *et al*., (2019) that Pb accumulates differently in plant tissue parts, especially in the root. The concentrations of Pb in the roots of *Ricinus comnunis* seedlings were T0 (0.45± 0.02), T1 (18.21± 0.01), T2 (27.01± 0.16), T3 (38.21± 0.05) and T4 (41.09± 0.11) in mg/kg while the concentrations in shoot were T0 (0.38± 0.01), T1 (11.35± 0.03), T2

(18.09± 0.05), T3 (24.06± 0.01) and T4 (27.09± 0.04) in mg/kg. The Pb content in the seedlings is attributed to the availability of lead in the soils because plants absorb metals.

The retention of Pb in roots involves binding to the cell wall and extracellular precipitation, mainly in the form of lead carbonate, which is deposited in the cell wall. At low concentration, Pb can move through root tissue, mainly via the apoplast and radially through the cortex where it accumulates near the endoderm. The endoderm acts as a partial barrier to the translocation of Pb through the root to the shoot. This may be one of the reasons for the much greater accumulation of Pb in roots than in shoots (Verma and Dubey, 2003; Orisakwe, 2009). Huang and Cunningham (1996) and Blaylock *et al*.,(1997) established that plants can remove between 180 and 530 kg/ha of Pb/year, making remediation of sites contaminated with up to 2,500mg/kg possible in fewer than 10 years. This indicates that about 250mg/kg can be removed in a year at an average of 21mg/kg in 4 weeks.. Thus, the results showed that *Ricinus comnunis* plant has a potential to accumulate Pb.

Table 5. Mean Pb Concentration in potting media and *Ricinus comnunis* seedlings

Treatments	**Pb concentrations in soils (mg/kg)**		**Pb Concentrations in seedlings mg/kg**	
	Before the experiment	**After the experiment**	**Root**	**Shoots**
T0	2.11± 0.05a	0.70± 0.01b	0.45± 0.02a	0.38± 0.01b
T1	51.20 ± 1.22a	25.22± 0.81b	18.21± 0.01a	11.35± 0.03b
T2	100.25±1.67a	43.11b± 0.02b	27.01± 0.16a	18.09± 0.05b
T3	150.21± 0.98a	56.42± 0.09b	38.21± 0.05a	24.06± 0.01b
T4	200.13± 1.01a	109.89± 1.05b	41.09± 0.11a	27.09± 0.04b

Values with different letters within the same row were differ from each other at P=0.05

Table 6: Mean values of Bioaccumulations (BAF) and Translocation factors (TF)

Treatments	**Bioaccumulation factor (BAF)**	**Translocation factor (TF)**
T0	1.19± 0.02	0.84± 0.005
T1	1.17 ± 0.01	0.62± 0.001

T2	1.11±0.01	0.67± 0.003
T3	1.05 ± 0.01	0.62± 0.001
T4	0.62± 0.01	0.69± 0.001

Bioaccumulations (BAF) and Translocation factors (TF) of lead concentrations into *Ricinus comnunis* seedlings' parts

Table 6 showed the bioaccumulation factor (BAF) and translocation factor (TF) of Pb in *Ricinus comnunis* seedlings. The ability of plants to absorb heavy metals from soil is expressed by the BAF while TF is used to assess to potential of the plants to transfer it to its part. It is given by the ratio of concentration of metal in the shoot to that in the roots (Cui *et al.,* 2004). Translocation factors of lead from root to shoot of *Ricinus comnunis* seedlings ranged from 0.62± 0.001 to 0.84± 0.005whileBAFvaluesranged between 0.62± 0.01 and 1.19± 0.02. There was no significant difference in TF and BAF of Pb among the treatments at *P*=0.05 significance level. Baker (1981) reported that plants with BAF values > 1 are accumulators, while plants with BCF values < 1 are excluders. Some researchers also stated that plants can be classified as potential hyperaccumulators if the BCF values are > 10 (Jung and Thornpton, 1996; Blaylock *et al.*, 2010). Plants with TF values > 1 are classified as high-efficiency plants for heavy metal translocation from the roots to shoots (Ma *et al.*, 2001). Based on the BAF and TF values of this study, *Ricinus comnunis* can be classified Pb accumulator plant and have the potential to transfer it into its part.

Conclusion

This study has shown that the presence of lead in the growing media increase the acidity and decrease the nutrient content of the soils. The growth parameters were reduced with increase in concentration of the Lead Nitrate added to the growing media. Also, heavy metal concentration in the soils before and after plantings indicated uptake of heavy metal concentrations in the parts of *Ricinus comnunis*. Bioaccumulation and translocation of Pb in *Ricinus comnunis* seedlings Indicated the potential of this plant for removal of soil contaminated with Pb. This study has thus shown the potential of *Ricinus communis* as a phytoremediating plant.

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