Remediation Potential of *Jatropha integerrima* (Jacq) in Lead Contaminated Soil

O.O. Akintola[1*]; J.T. Arojojoye[2]; M.O. Ojo[3]; and R.T. Ibode[1]

[1]Federal College of Forestry, Ibadan, Nigeria.
[2]Department of Forestry, University of Ibadan, Nigeria.
[3]Forestry Research Institute of Nigeria, Ibadan, Nigeria

E-mail: toyinakintola73@gmail.com*

ABSTRACT

Increase in heavy metal concentrations, particularly lead (Pb) in the soil and plants has significantly grown to be a serious environmental threat. The use of plants has become an effective and efficient method for cleaning up of heavy metals from contaminated soils. This study assessed the potential of *Jatropha integerrima* for *in-situ* remediation of Pb contaminated soils. The soil was spiked with different concentrations of lead and thoroughly mixed. Pot experiment was conducted for a period of 12 weeks. Results of study showed that increases in Pb concentration contribute to a reduction in the growth parameters of *Jatropha integerrima* seedlings. Significant concentrations of Pb accumulated in the studied plants parts with increases in Pb concentrations showed the ability of *J. integerrima* to uptake the studied heavy metal. The concentrations of Pb were found to be higher in shoots of the plant than in its roots. This study has shown that *Jatropha integerrima* seedlings have the potential to bioaccumulate and transfer Pb into its tissue parts. Thus, with careful management, the plant can be used to remediate Pb contaminated soil.

(Keywords: anthropogenic heavy metal pollution, lead, Pb, bioaccumulation, industrialization, bioaccumulation, bioremediation, sustainability)

INTRODUCTION

Industrialization and population growth has led to increases in heavy metal concentrations in the biosphere and this has significantly become a serious environmental threat. Heavy metal contamination can be considered as one of the most critical threats to soil and water resources as well as to human health (Yoon, et al., 2006). Sources of heavy metals include anthropogenic and geological activities.

Development of industrial activities and population growth has contributed to the increment of the waste generation and changes in consumption pattern and this in turn has greatly contributed to the number of heavy metals in the environment (Chua, et al., 2011). Soil becomes contaminated when uncontrolled and unmonitored leachate decomposed from wastes, picks up soluble heavy metals, and gets to the soil through surface run off, infiltration, and percolation among others (Tewari, et al., 2010).

The long- term ecological impact of pollution on the biosphere has resulted in an increased interest in evaluating the interactions between pollutants, the environment, and biota (Chaudhary, et al., 1996). Heavy metals at elevated concentrations are known to affect soil and water microbial populations and their associated activities, which may directly influence the soil fertility and water quality (Smith, 1996). Heavy metal concentrations in the soil range from less than 1mg/kg to as high as 100,000mg/kg, whether due to the geological origin of the soil or as a result of human activity (Blaylock and Huang, 2000).

Heavy metals such as Cd, Cr, Cu, Ni, and Zn in soil according to Gardea-Torresdey, et al. (1996) and Meagher (2000) have caused disruption of natural aquatic and terrestrial ecosystems. Although some metals are immobile and persistent, other metals are mobile, and therefore the potential of transfer either through the soil, percolation into the groundwater aquifer, or via plant-root uptake (bioavailability) is likely. Cadmium and Lead, which have no known beneficial effects, may become toxic to plants and animals if their concentration exceeds certain values (Adriano, 2001; Lin, et al., 2013). Lead (Pb) is a naturally occurring heavy metal (Kabata-Pendias, 2011) and can be released into the environment through techno- and geogenic-processes. Lead is a naturally occurring heavy metal and the Earth's crust is rich in lead (Kabata-Pendias, 2011). High concentrations of lead in soils can be associated with leaded gasoline additives, coal combustion, manufacture and application of fertilizers, leachates from waste disposal sites, and insecticides and pesticides among other sources (Agwaramgbo, et al., 2012).

Lead has been reported to affect human health and exposures can result in delayed metal development and impaired learning and cognitive abilities in children (Canfield, et al., 2003; Miranda, et al., 2007) and can cause brain problems, renal disease, and kidney and liver damage in adults (Lin, et al., 2013; Needleman, et al., 2003; Shih, et al., 2007). The Agency of Toxic Substances and Disease Registry (ASTDR, 2005) has positioned Pb as the number one heavy metal pollutant and number two out of all hazardous substances. Thus, there is a need for remediating soils that are contaminated with Pb to avert its hazardous threat to the environment and human health.

Over the past decades, researchers have developed a method that is ecologically friendly, economical, and suitable for the removal of contaminants from the environment. Phytoremediation is a promising technology that uses plants to clean up contaminated areas. It is a low-cost, long-term, environmentally and aesthetically friendly method of immobilizing/stabilizing, degrading, transferring, removing, or detoxifying contaminants, including metals, pesticides, hydrocarbons, and chlorinated solvents (Jadia and Fulekar, 2008; Zhang, et al., 2016).

It has been reported that plants selectively take up elements and heavy metals from soil through the roots and spread or circulate to their stems as well as their leaves, fruits and seeds (Cunningham, et al., 1996; Cunningham and Berti, 2000). Studies have shown the phytoremediation potential of numerous plant species in contaminated soils (Badr, et al., 2012; Akintola and Bodede, 2019; Akintola, et al., 2019a & b; Akintola, et al., 2021). For a successful phytoremediation procedure, the accumulation of heavy metals in plants and the role of plants to extract transfer and stabilize heavy metals from soil and water must be understood.

Jatropha integerrima (Jacq.) is an evergreen woody shrub or small tree that belongs to the family of Euphorbiaceae. It is native to West Indies, Cuba, and widely cultivated in many tropical and subtropical countries. It is commonly known as peregrina or spicy Jatropha and firecracker. Plants reach 3 - 4.5 m tall and 2 - 3 m wide with slender, graceful branches (Ghani, 2003). The leaves are 10 - 20 cm long and 3 - 8 cm wide, simple, alternate, green in color, entire margins with cuspidate or acuminate tip and sometimes have three-lobed (Ratha and Paramathma, 2009 ; Kolawole, et al., 2016). Thus, this study assessed the potential of Jatropha integerrima for remediation of Pb in soil contaminated with different Pb concentrations.

MATERIALS AND METHODS

The experiment was carried out in the screen house of Forestry Technology Department, Federal College of Forestry, Ibadan, Oyo State, Nigeria. The area lies between Latitude 7°26′N and Longitude 3°51′E. The climate pattern of the area is tropically dominated by annual rainfall ranging from 1400 mm – 1500 mm and average relative humidity of about 65%, the average temperature is about 26°C (Akintola, et al., 2021).

The area has two seasons; dry seasons usually commence from November to March while the rainy season runs from April to October. Seeds of *Jatropha integerrima* were collected from Igangan in Ibarapa North Local Government Area of Oyo State. The soil samples were collected within the Federal College of Forestry, Ibadan, Nigeria. The soil samples were collected at the depth of 0-20 cm, air-dried, and sieved with 2 mm diameter mesh. Lead was added to the soil as lead nitrate (Pb $(NO_3)_2$, and 3g of Pb $(NO_3)_2$ was dissolved in 1,000 ml of distilled water in a conical flask and was stirred until all the lead salt was completely dissolved to make stock solutions of 3,000 ppm. The flask was covered with aluminum foil to avoid exposure to light while continuous stirring of the solution was done at room temperature until it was used. These different concentrations were then measured from the stock solutions into a 100 mL capacity measuring cylinder and made up to the mark for 0 ppm (control, T1), 50 ppm (T2), 100 ppm (T3), 150 ppm (T4) and 200 ppm (T5) metal concentrations.

The soil was spiked with different concentrations of lead and thoroughly mixed. The spiking of soils with different concentrations of lead salt was replicated 6 times making a total of thirty growing mixtures and left for a week with continuous stirring. Sixty (60) healthy seedlings after two weeks of sowing was taken from germination box and transplanted into polythene pot of 30 cm by 15 cm containing different treatment mixtures of lead nitrate (Pb $(NO_3)_2$. Intercultural operation such as weeding and watering was done daily to ensure normal conditions.

The pots were arranged in a completely randomized design and the experiment lasted for 12 weeks (3 months). Growth parameters such as plant height stem diameter and leaf production were assessed weekly for three months. At the end of pot experiment, plant roots and shoots (stems and leaves) were taken for lead concentration analysis. Control soil sample before planting were analyzed for physiochemical and lead concentration. Soil treatments before and after transplanting (at the end of the experiment) were taken to the laboratory for necessary analysis.

The particle size distribution, pH, organic carbon, organic matter content, total nitrogen, total phosphorus and Pb were carried out on the collected soil samples before transplanting while analysis of lead concentrations was done on the soil samples after transplanting. Particle size distribution test was carried out using hydrometer method of Brown (2009). Soil pH was obtained using soil: distilled water (1:2.5), 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 (TN) was determined using the method given by Stanford and Smith (1978) and Kjeldahl nitrogen (Kjeltech analyzer) (Jackson 1958) while available phosphorous were estimated by method of Olsen, et al. (1983) and stannous chloride method given by Sparling, et al. (1985) followed by hot plate digestion in HNO_3:$HClO_3$ (3:1) at 180ºC for 6 h. Analyses of Pb concentration were analyzed using atomic absorption spectrophotometer (AAS, MEDTECH). The roots and shoots of *Jatropha integerrima* seedlings were also analyzed for Pb concentration.

The efficiency of *Jatropha integerrima* seedlings to accumulate lead in soils was assessed through the following indices. Bioaccumulation coefficient factor (BCF) and translocation factor (TF) were calculated using the formula Malik, et al., (2010) as given in Equation 1 and 2 while the biological accumulation coefficient (BAC) and accumulation factor (AF) were calculated using the respective formulas given by (Baker 1981) as indicated in Equations 3 and 4.

$$BCF = \frac{\text{heavy metal concentration in root}}{\text{heavy metal concentration in soil}} \quad \text{Equation 1}$$

$$TF = \frac{\text{heavy metal concentration in shoot (mg/kg)}}{\text{heavy metal concentration in root (mg/kg)}} \; \ldots \quad \text{Equation 2}$$

$$BAC = \frac{\text{heavy metal concentration in shoot(mg/kg)}}{\text{heavy metal concentration in soil(mg/kg)}} \quad \text{Equation 3}$$

$$AF = \frac{\text{heavy metal concentration in plant(mg/kg)}}{\text{heavy metal concentration in soil(mg/kg)}} \; \ldots \quad \text{Euation 4}$$

Statistical analyses were performed using the SPSS (version 20). The mean values of the six replicates for each treatment in soils and seedlings were calculated. Data were evaluated using one-way ANOVA and comparison of mean values was done by using Tukey's significant difference test at $p \leq 0.05$.

RESULTS

Physiochemical Parameters of the Potting Media

The textures of the soil from the potting media were sand (70.50-72.00%), silt (14.00-15.00%), and clay (13.80-15.00%). The observed characteristics of the soil texture showed that the topsoil collected is a sandy-loam. The pH of the soil ranged from 5.48-5.92 and a significant different was observed between the topsoil (control) and those treated with lead salt at different concentrations. Also, there was a reduction in the acidity of the soil as the level of lead increases but were not significantly different from each other at $p \leq 0.05$ (Table 1).

The respective values of the organic matter content (OMC), total nitrogen (TN), and available phosphorous (AP) in the growing media were 1.89 - 2.48 %, 0.05 - 0.16 %, 0.02 - 0.11%.

Table 1: Values of Physicochemical Parameters of the Growing Media before Transplanting.

Treatments	pH	Sand (%)	Silt (%)	Clay (%)	OMC (%)	TN (%)	AP (%)
T0	5.92[a]	70.50[a]	14.50[a]	15.00[a]	2.48[a]	0.16[a]	0.11[a]
T1	5.48[b]	71.00[a]	15.00[a]	14.00[a]	2.22[b]	0.09[b]	0.07[b]
T2	5.51[b]	72.00[a]	14.00[a]	14.00[a]	2.18[b]	0.08[b]	0.07[b]
T3	5.49[b]	71.00[a]	15.00[a]	14.00[a]	1.98[c]	0.05[c]	0.03[c]
T4	5.50[b]	71.20[a]	15.00[a]	13.80[a]	1.89[c]	0.05[c]	0.02[c]

OMC- Organic matter content; TN-Total nitrogen; AP- Available phosphorus.
Values with the same letters are significantly different from each other at P≤0.05

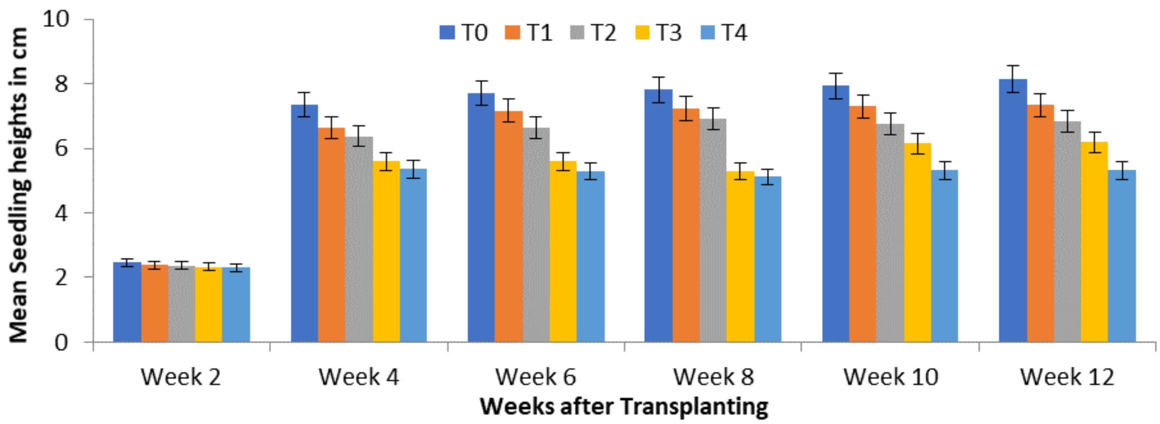

Figure 1: Mean Values for *Jatropha integerrima* Seedling Heights.

Reduction in the values of organic matter content (OM), total nitrogen (TN) and available phosphorous (AP) were observed as the concentration of lead in the growing media increases. Significant differences were observed among the soil media at p ≤0.05. Also, the values of physicochemical parameters of the growing media before and after experiment were considered in Table 1.

Effects of Pb on Growth Parameters

Figure 1 showed the effect of lead (Pb) on the height of *Jatropha integerrima* seedlings. It was observed that at the early weeks of growth after transplanting (week 2), there was no significant difference among the seedling height. But, from week 4 to the last week of the experiment, as shown in Figure 2, T0 (topsoil with 0 ppm of Pb) recorded the highest mean value (7.37-8.14cm), followed by T1 (6.63-7.33 cm) while T4 recorded the least mean value of 2.30-5.31cm. However significant differences at different weeks after transplanting were observed among the treatments at p ≤0.05 as shown in Figure 1.

Figure 2 showed the mean values of leaf number of Jatropha integerrima seedlings in the potting media over the period of 12 weeks of the study. Week 2 and 4 showed slow steady growth due to the changing of the environment of the plants. T0 recorded increase and highest mean value of leaf number (1.85-4.67) throughout the twelve weeks of planting.

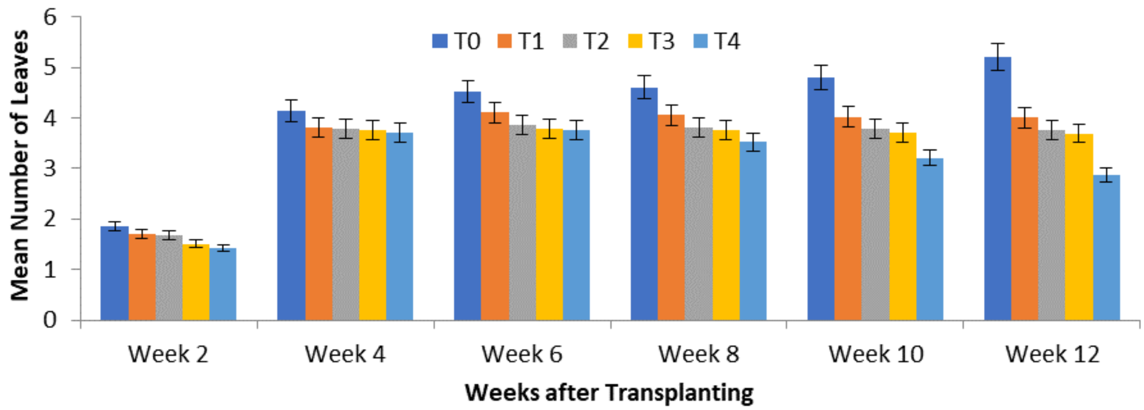

Figure 2: Mean Values of Leaf Number of *Jatropha integerrima* Seedlings.

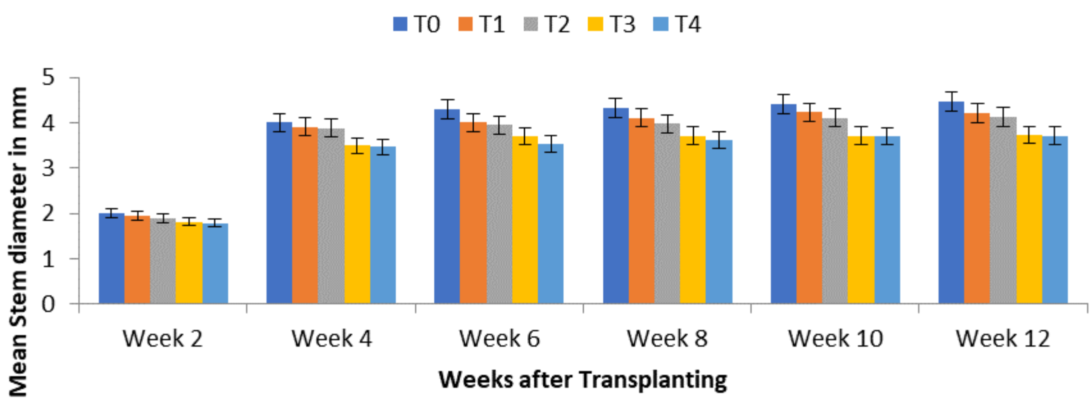

Figure 3: Mean Values for Stem Diameter of *Jatropha integerrima* Seedlings.

T_0 recorded increase and highest mean value of leaf number (1.85-4.67) throughout the twelve weeks of planting. Mean numbers of seedling leaf were found to increase from week 2 to week 6 of transplanting in T1 (1.7-4.11), T2 (1.68-3.86), T3 (1.51-3.79) and T4 (1.42-3.79) while reduction in the mean numbers of leaf were observed from week 6 to week 12 of the experiment as shown in Figure 2. Significant difference at $p \leq 0.05$ was observed between the control (T0) and those contaminated with Pb.

Figure 3 showed mean stem diameter of the *Jatropha integerrima* in the growing media of different concentrations of lead. The mean stem diameter of *Jatropha integerrima* seedlings had little or no discrepancy in the first two weeks of transplanting. T_0 (2.01- 4.47 mm) had the highest mean values of stem diameter all through to the 12 weeks of transplanting. The mean stem diameters of the studied seedling from the growing media: T_1 (1.94- 4.21 mm) and T_2 (1.89- 4.13 mm) were not significantly different from each other throughout the end of the experiment. Similar trend was also observed from those grown in T3 (1.82- 3.73 mm) and T4 (1.79- 3.72 mm) as shown in Figure 3. However, significant difference at $p \leq 0.05$ was observed between the control (T0) and those contaminated with Pb.

Lead (Pb) Concentrations in the Potting Media

Lead concentrations in the soil used before planting and after harvest is presented in Figure 4. Pb concentration in soils used before planting were T0 (1.8mg/kg), T1 (51.80mg/kg), T2 (101.80mg/kg), T3 (151.80mg/kg) and T4

(201.80mg/kg) while those after harvest were T0 (0.61mg/kg), T1 (21.21mg/kg), T2 (49.40mg/kg), T3 (97.20mg/kg) and T4 (142.11mg/kg). The reduction rates of the soils after harvest and before planting were T0 (33.80%), T1 (40.95%), T2 (48.50%), T3 (60.70%) and T4 (70.4%). It was observed that T4 recorded the highest reduction rate followed by T3 while T0 had the lowest reduction rate.

Pb Concentrations in Jatropha integerrima Seedling Parts

Lead (Pb) concentrations in different parts (root and shoot) of *Jatropha integerrima* seedlings after 12 weeks of planting were presented in Figure 5. There were higher concentrations of Pb in the shoot of the seedlings than the roots and these increases with the concentration of the lead in the soils used. In each of the contaminated soils, the concentrations of Pb in the shoots were 0.64mg/kg (T0), 15.11mg/kg (T1), 18.21mg/kg (T2), 36.98mg/kg (T3) and37.79mg/kg (T4) while in the roots were 0.45mg/kg (T0), 9.01mg/kg (T1), 12.11mg/kg (T2), 20.01mg/kg (T3) and 22.81mg/kg (T4). Significant differences at p ≤0.05 were observed between the concentration of lead in the shoot and root of *Jatropha integerrima* seedlings.

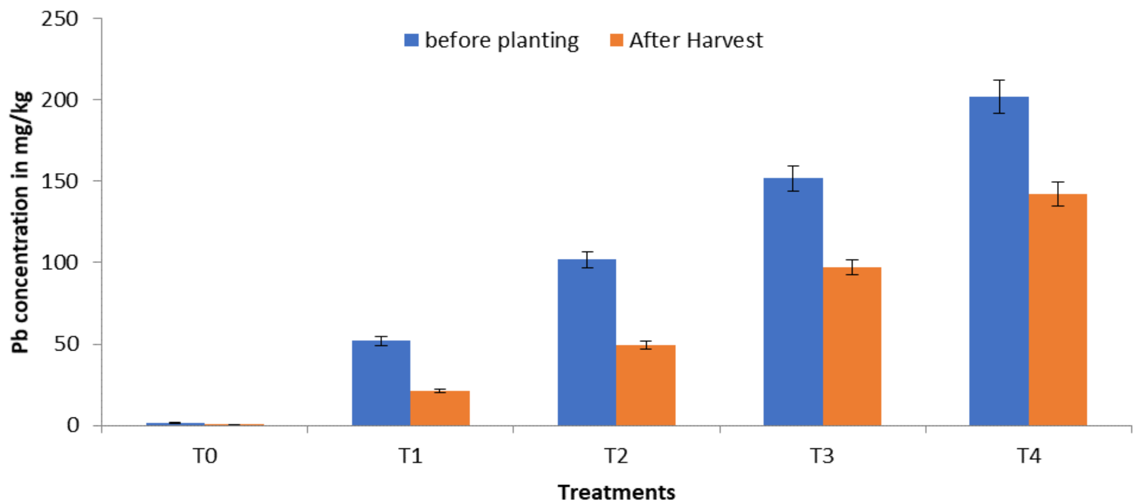

Figure 4: Pb Concentrations in the Growing Media.

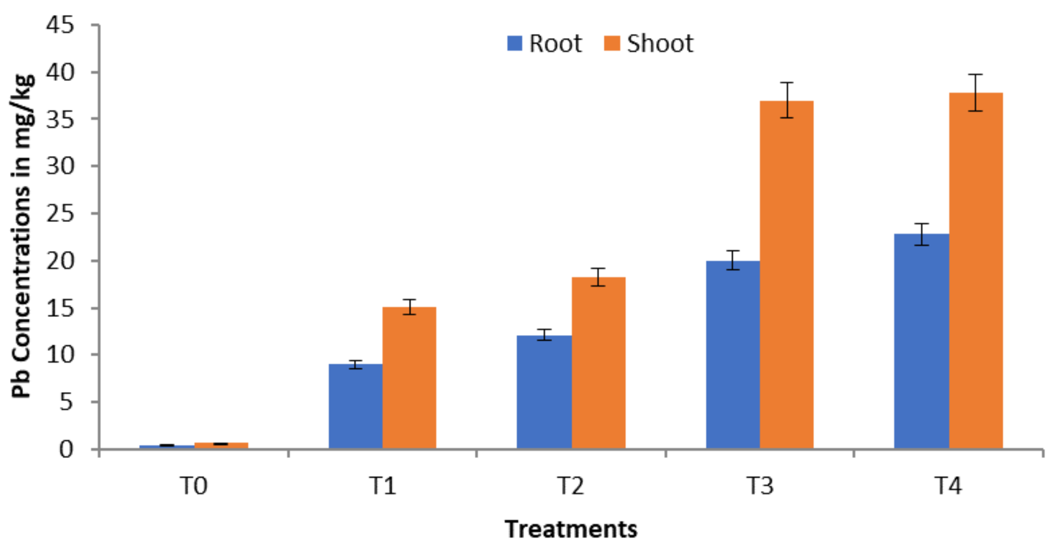

Figure 5: Pb Concentrations in *Jatropha integerrima* Seedling Parts.

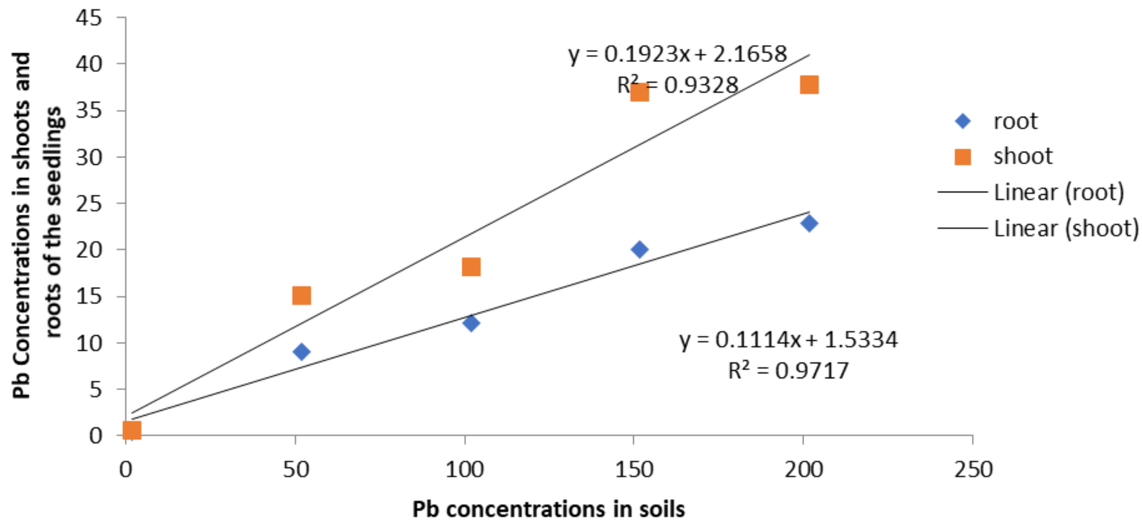

Figure 6: Accumulation of Pb Concentration in Roots and Shoots of *Jatropha integerrima* Seedlings grown in Pb Contaminated Soil.

The results also showed that the seedlings absorbed substantial concentrations of lead in its parts. The concentrations of lead in the seedlings parts was plotted against the concentrations of lead in the soil used before transplanting in order to know if they are significantly correlated (Figure 6).

The linear graphs deduced showed that values of R^2 for roots and shoots of the *Jatropha integerrima* seedlings were 0.97 and 0.93, respectively. This implies that the concentration of lead accumulated by roots and transferred to shoot can be determined at higher concentrations using the regression equation generated in Figure 6, taken into consideration the plant types, harvest period and the concentration of the heavy metals used. It means that if the Pb concentration in soil is 500mg/kg, then the concentration of Pb in the roots and the shoots will be 57.03mg/kg and 98.17mg/kg (Figure 6).

Pb Accumulation Efficiency in *Jatropha integerrima* Seedlings

The potential of *Jatropha integerrima* seedlings to accumulate Pb from the soil and transfer it to its various parts was assessed and shown in Figure 7. The results from Figure 7 showed that *Jatropha integerrima* seedlings at 1.18mg/kg, 51.80mg/kg had AF values > 1 while at 101.80mg/kg, 151.80mg/kg and 201.80mg/kg had AF <1. Also, TF values at the different concentrations of Pb studied were greater than I. The values of BAC reduced from 1.04 to 0.27 with increasing Pb concentrations over the 12 weeks of the experiment as shown in Figure 7.

The bioaccumulation coefficient factor (BCF) also showed reduction values from 0.73 to 0.16 with increasing Pb concentrations. Highest values of AF, BAC and BCF were observed in control growing medium (T0, soil with 1.18mg/kg of Pb) while the highest TF values was observed in T4 (soil with 151.80mg/kg of lead). The mean values of AF, TF, BAC and BCF were 0.89, 1.56, 0.55, and 0.35, respectively.

DISCUSSION

The physicochemical properties of growing media before transplanting indicated that the soils used for the study were sandy loam and this soil according to Akintola, et al. (2019a,b) are good and suitable for plant growth and development due to the presence of high nutrient contents and the high water holding capacity. The pH values of the growing media are within the recommended range for soils as given by FEPA (1998). The reduction and significant difference observed in pH values between the control (T0) and others (T1-T4) may be attributed to the addition of Pb concentration as contaminant in the growing media.

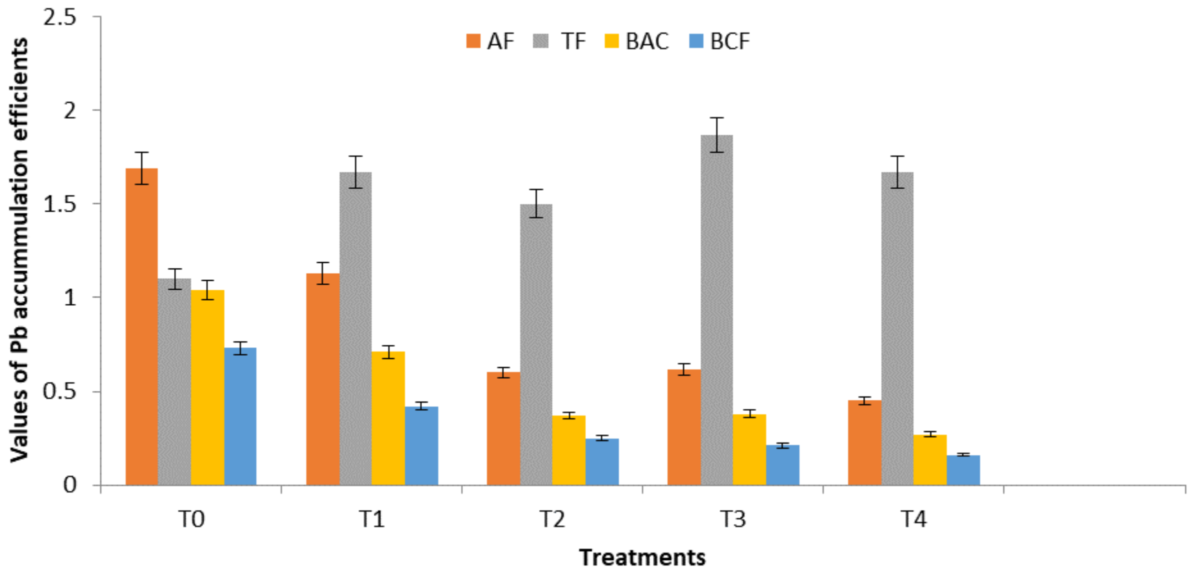

Figure 7: Translocation Factor (TF), Bioconcentration Factor (BCF), Biological Accumulation Coefficient (BAC), and Accumulation Factor (AF) Index of *Jatropha integerrima* Seedlings Exposed to different Pb Concentrations in Soils for 12 weeks.

Soil pH affects the mobility and availability of heavy metals in soil, if the pH value, clay and organic matter and contents of soil is high, the mobility and availability of heavy metals to plants will be low (Jung and Thornton, 1996; Rosselli, et al., 2003). This implies that, low pH values recorded in this study will be mobile and available to the seedlings used in this study. The changes observed in the OMC, TN, and AP values may be attributed to the introduction of lead concentrations into the growing media.

Study results from Ryser and Sauder (2006) have shown that addition of Pb into the soils can influence the soil properties. The present study agreed with the similar work conducted on *Ricinnus communis* by Akintola, *et al*. (2021) where they observed a change in soil properties when contaminated with lead. Thus, according to Aransiola, *et al.* (2013), heavy metal bioavailability in soils is an active process that depends on particular combinations of biological, chemical and environmental factors.

The high values observed in the growth parameters of *Jatropha integerrima* seedlings in control (T0) medium 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 promotes plant growth (Ideriah, *et al*., 2010). This also agrees with the findings of Akintola, et al. (2019b) and Akintola, et al. (2021) related to heavy metal enrichment and remediation potential of *Jatropha curcas* seedlings in dumpsite contaminated soil. The reduction in the growth parameters of *Jatropha integerrima* seedlings from the potting media contaminated with Pb may be due to the availability of the Pb concentrations and uptake by the plants.

Likewise, the reduction noticed in the concentrations of Pb added to the potting media before planting and after harvest might indicate the uptake of this metal by the *Jatropha integerrima* seedlings. This may be due to availability and mobility of Pb concentrations to the plants (Jung and Thornton, 1996; Rosselli, et al., 2003). Some of the Pb concentrations could also have fugitive into the air and this is in accordance with USEPA (2000) that stated that when heavy metals were taken up by plants, some of these heavy metals may likely escape into the air. The results of this study are in line with findings of Aransiola, et al. (2013) and Akintola, et al. (2021) where they obtained reduction in the concentrations of Pb in soils used after harvesting the plants and attributed it to the potential of the plants for phytoextraction.

The substantial Pb concentrations in *Jatropha integerrima* seedling parts with increasing Pb concentrations in the potting media may be attributed to the low pH, clay, and organic matter contents as well as availability and mobility of the metal since plants take up heavy metals based on the availability in the soil.

The linear graphs deduced and the (R^2) values for roots and shoots of the *Jatropha integerrima* seedlings in this study showed high, positive and significant relationship between the soils and plants. This further confirmed the earlier claims that the higher the Pb concentrations in soil, the more its uptake by plants. This result agreed with the findings of Benzati, et al. (2008) where he reported the relationship as linear.

High Pb concentrations observed in shoots than in roots of *Jatropha integerrima* seedlings agreed with the findings of Akintola, et al. (2021) and Aransiola, et al. (2013), thus this plant has the potential to uptake, precipitate, and transfer Pb concentrations from the soils to its roots and its other parts (stems and leaves). This study also agreed with the reports that plants can be used successfully to remove heavy metals from the soils and this process (phytoremediation) depends on the plant species, plant growth rates, as well as the ability of the plants to absorb the metals and transfer it into their shoots thus preserving the soils and sustaining the environment (Yargholi, et al., 2008; Liu, et al., 2015).

This potential of *Jatropha integerrima* seedlings is called phytoextration according to Emerging Technology for phytoremediation of metals in soil: ETPMS (1997). The higher Pb concentrations observed in shoots than the roots of the studied plants is contrary to the reports that most species roots accumulated substantial higher amounts of Pb than roots (Lee, et al., 2013; Romeh, et al., 2015). This reason for these differences may be attributed to the different plant species, time of harvest, soil types and concentration of the metals in the soil, among others.

Pollard, et al. (2002) and Sahi, et al. (2002) in their separate works stated that plant species that can be considered as lead hyperaccumulators must have more than 0.01% of the metal into their dry shoots (stems and leaves) without any toxic response and these plants must have rapid growth. *Jatropha integerrima* seedlings have been able to demonstrate that in this study.

The highest AF (Pb concentrations in plants to Pb concentrations in soils) recorded *Jatropha integerrima* seedlings grown in T0 and T1 (control growing media with 1.80mg/kg of lead and soil with 51.80mg/kg) and lower values recorded in T2, T3 and T4 may be due to the ability plants to accumulate more Pb at moderately low concentrations than higher concentrations (Berzanti, et al., 2008). According to the classification given by Baker (1981) that AF with values greater than 1 are accumulators while plants with AF values less than 1 are excluders. Thus, *Jatropha integerrima* seedlings can be classified as accumulators, this further affirmed the past reports that stated that plants that have more metals in its shoot than its roots can be classified as accumulator for phytoremediation (Yargholi, et al., 2008; Liu, et al., 2015).

One of the vital indices used in assessing the potential of plants for phytoremediation is translocation factor (TF) which is the ratio of concentrations of metals in shoots to metal concentrations in roots (Usman and Mohammed, 2009; Akintola, et al., 2019). The values of TF greater than one are classified as high potential for plants for transferring heavy metals from roots to their shoots. TF values at the different concentrations of Pb (T0-T4, growing media) studied were greater than 1. TF values greater than 1 have been attributed to plant species that have the ability to uptake metals form soils, accumulate, and distribute them into their different parts (Wei and Chen, 2006). Thus, *Jatropha integerrima* seedlings could be said to be good phytoremediator of Pb.

Furthermore, reduction in BAC (biological accumulation coefficient) and BCF (bioaccumulation coefficient factor) values observed as the concentration of Pb in the growing media increases may be attributed to the ability of the plants to remove more Pb concentration at moderately concentrations than higher concentrations. The moderate values of BAC and BCF also supports the result of this findings. Padmavathiamma (2007) reported that natural metal hyperaccumulators plants are those than can accumulate higher amounts of heavy metals in their aboveground tissues and should be tolerant of metal contaminants and other site conditions that may limit plant growth. This study has shown that phytoremediation may provide a sustainable alternative for remediation of Pb contaminated soils. Thus, *Jatropha integerrima* could be considered as Pb hyperaccumulator and could be used as phytoextractor plant.

CONCLUSION

This study assessed the potential of Jatropha *integerrima* for remediation of Pb contaminated soils. Results of study showed that increased in Pb concentration has lead to reduction in the growth parameters of *Jatropha integerrima* seedlings. Significant concentrations of Pb were accumulated in the studied plants parts with increased in Pb concentrations. This was found to be higher in shoots than in roots of the plants.

This study has shown that Jatropha *integerrima* seedlings has the potential to bioaccumulate and transfer it into its tissue parts. Pb phytoextraction potential of *Jatropha integerrima* seedlings may provide an effective soil decontamination approach. Thus, with careful management, the plant may be used to remediate Pb contaminated soil.

CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interest related to this article.

DECLARATION OF FUNDING

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