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REMEDIATION OF LEAD-CONTAMINATED SOILS BY *Hildegardia barteri* (Mast.) Kosterm.

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ABSTRACT

Lead (Pb) has been recognized as an increasing toxicant that affects multiple body systems and mainly hazardous to children. This study investigated the ability of *Hildegardia barteri* to uptake Pb and translocate it into their roots and shoots from soil contaminated with varying concentrations of Pb. Pots experiment consisting of five treatments: T0 (0 mg of Pb $(NO3)_2$ per kg of top soil (control), T1 (50 mg of Pb $(NO3)_2$ per kg of top soil), T2 (100 mg of Pb $(NO3)_2$ per kg of top soil), T3 (150 mg of Pb $(NO3)_2$ per kg of top soil) and T4 (200mg of Pb $(NO3)_2$ per kg of top soil), replicated six times in a completely randomized design were used. The study was carried out for a period of 12 Weeks After Transplanting (WAT) under natural conditions. Pb concentrations in soils before and after experiment (12 WAT) as well as those of the plants were determined using standard methods. Data were assessed using bioaccumulation (BAF) and translocation factors (TF). Respective Pb concentrations in treatments (mg/kg) before and after the experiment were T0 (1.80; 1.21), T1 (58.80, 38.11), T2 (101.80; 76.11), T3 (151.80; 119.21) and T4 (201.98; 152.55). Significant reductions were observed between the concentrations of heavy metals before and after experiment. Also, the concentrations of Pb in shoots and roots of *Hildegardia barteri* seedlings were T0 (0.27-0.31), T1 (8.19 - 11.22), T2 (10.68-12.79), T3 (12.61-16.01) and T4 (19.68-25.11) in mg/kg. The values BCF ranged between 0.29 and 0.51 while TF values were 0.75 to 0.85. Bioaccumulation and translocation factors indicated the ability of studied seedlings to remove Pb from the treatment. This study has thus shown the ability of *Hildegardia barteri* for remediating soil contaminated with Pb.

Keywords: Lead (Pb), contamination, bioaccumulation, *Hildegardia barteri*

Introduction

Urbanization, human and agricultural activities has led to generation of huge amount of wastes that has led to increasing deposition of contaminants such as Pb on the soil surface (Owoeye and Onwuka, 2016). Lead (Pb) is a cumulative toxicant that can be either inhaled through dust or ingested from plants and other source into the body and distributed to various parts such as brain, liver, kidney and bones (WHO, 2019). It is accumulated over time in the teeth and bones and its human exposure is habitually assessed through the blood. According to World Health Organization (2019), there is no level of Pb exposure that is known to be without hazardous effects. Lead is one of the naturally occurring toxic metals found on the earth's crust. Its widespread usage as a result of industrialization, human and agricultural activities has led to protracted environmental contamination, human exposure and significant public health problem in several parts of the world.

Lead contamination can comes from various sources such as mining, manufacturing and recycling activities, smelting, leaded aviation fuel, ammunitions, ceramic glazes, jewelleries, toys, continuous usage of leaded paints, leaded gasoline, pigments and solders among others (Akintola, 2014;

WHO, 2019). Human can be exposed to lead through occupational and environmental sources resulting from inhalation of lead particles through burning of materials that might emanated from smelting, recycling, stripping leaded of paint, leaded gasoline or aviation fuel and ingestion from dust, water and food as well as using certain kinds of unregulated cosmetic and medicine (Gisbert *et al.,* 2003; Onwuka *et al.*, 2012; WHO, 2019). Exposure of Pb can lead to serious environmental and health issues especially in children (Akintola *et al.*, 2020). At high level of its exposure, Pb can attack the brain and other nervous systems which can result into coma, convulsions and death. Survival of severe lead poisoning according to World Health Organization (2019) may be left with mental retardation and behavioral disorders in children while at low level of its exposure with no noticeable symptoms, lead is now known to cause a variety of damage athwart the body systems. Generally, lead can affect children's brain development which in turn can reduce their intelligence quotient (IQ), behavioural changes, educational attainment and increase their antisocial behaviour (WHO, 2019).

Apart from these, lead exposure can cause anemia, hypertension, renal impairment and toxicity to the reproductive organs. The neurological and behavioural lead effects are alleged to be irrevocable and as lead exposure increases, the variety and sternness of the symptoms increases. Thus, there is need to take a management and preventive measures to reduce its release into air, water and soil in order to minimize its adverse effect on human health and environment. Consequently, there is a significant requirement for an *insitu* treatment method that is economically and environmentally friendly as well as suitable for an extensive range and concentration of various contaminants that decontamination of the environment (Olivares, 2013; Parise, 2016; Yasin, 2015).

Phytoremediation as an emerging and effective green technology method with minimum environmental impacts as well as economically practicable has been demonstrated for cleaning up of contaminants from soil and other environmental systems (Park *et al.*, 2011;Tripathi *et al.*, 2015; Mojiri, 2016; Akintola *et al.*, 2019, 2020). Phytoremediation which is the use of plant species to reduce the levels, mobility or toxicity of contaminants in soil, groundwater or other media (USEPA, 2000), has gained a growing attention as an emerging helpful and economical method for cleaning contaminated soils (Macek *et al.*, 2000; Cincinnati et al., 2001;Susarla *et al.*, 2002; Xia *et al.*, 2003). This method has minimum impact on the environment and the plants that are used for this method reduce the level of contamination as well as the mobility of the contaminants to other area through the action of wind, rain and groundwater (EPA, 2001; Olowoyo *et al.*, 2012; Badr *et al.*, 2012).

When using this method, some of the disadvantages stated below should be taken into consideration: accumulation of contaminants in the edible parts of crops and vegetables; slow growing and low biomass production of hyper accumulator plants; several planting and harvesting are necessary for decontamination (Farraji *et al.*, 2016) restricted to the surface area and depth engaged by the root; very dawdling and seasonally efficient method (Chintakovid *et al.*, 2008); mobilization of radio-nuclides through the translocation in plants (Popa *et al.*, 2008); not appropriate for all compounds (Trapp and Karlson, 2001); management and disposing of contaminated plants through the

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phytoremediation is the major foot print of this green technology (USEPA 2000; Ahalya *et al.*, 2003; Ghosh and Singh, 2005; Italiya and Shah, 2013). Over 400 plant species has been identified as hyperaccumulator in plant families (Ghosh and Singh, 2005). *Hildegardia barteri* is a fast-growing, deciduous tree that can grow up to a height of 24 - 30 m. The tree is buttressed, with a clear bole of 9 - 12 m tall and a girth of up to 3.5 m. The tree is harvested from the wild, used locally as a food, grown sometimes as living fence; serve as source of timber and fiber. This study was therefore investigated the ability of *Hildegardia barteri* to bio-accumulate, translocate and remove lead from contaminated 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^oC. (FRIN, 2017). The area has two seasons; dry seasons usually commenced from November to March while the Raining season starts from April to October. The seeds of *Hildegardia barteri* were obtained from Department of Sustainable Forest and Management (SFM), Forestry Research Institute of Nigeria (FRIN), Ibadan, Oyo State. 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 (control), 50mg, 100mg, 10mg and 200mg as lead nitrate (Pb $(NO3)_2$.

The soils were spiked and mixed thoroughly with different concentrations of lead for some days (Kabta-Pendias and Pendias, 2001). The treatments were designated as T0 (0 mg of Pb $(NO3)_2$ per kg of top soil), T1 (50 mg of Pb $(NO3)_2$ per kg of top soil), T2 (100 mg of Pb $(NO3)_2$ per kg of top soil), T3 (150 mg of Pb $(NO3)_2$ per kg of top soil) and T4 (200mg of Pb $(NO3)_2$ 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 Completely Randomized Design and the treatments were replicated six times making a total of 30 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 (Pb) analysis. 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

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

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

Data were analyzed using one-way analysis of variance (ANOVA) and least significant difference (LSD) tests were performed to determine the statistical significance of the difference between the means.

Results and Discussion

Growth Parameters of the *Hildegardia barteri* seedlings

Table 1 showed the effect of lead contaminated soil on the *Hildegardia barteri* seedling's height for the 12 weeks after transplanting (WAT). It was evident from the Table 1 that soil raised with uncontaminated soil (T0: control) had the best performance in height with average values ranging from 8.67 to 18.53cm, followed by 50mg/kg of lead (T1) with average values of 9.40 to 16.49cm while the average values of seedlings contaminated with 100mg/kg of lead (T2), 150mg/kg of lead (T3) and 200mg/kg of lead (T4) were 10.17-15.89; 8.40-14.53 and 8.33-12.44 in cm respectively. Means with the same letter are not significantly different from each other while means with the first letter gave the highest significant effect.

Table 1: Effect of lead contaminated soil on the Height of *Hildegardia barteri* seedlings

Treatments	WAT2	WAT4	WAT6	WAT8	WAT10	WAT12
T0	8.67b	9.89b	11.51ab	14.44a	16.74a	18.53a
T1	9.50b	10.56b	11.49ab	12.00ab	14.81ab	16.49ab
T2	10.17a	10.81a	11.61a	12.77ab	14.43ab	15.89abc
T3	8.40b	9.31b	10.33b	12.01ab	13.17ab	14.53bc
T4	8.33b	9.74b	10.27b	10.54b	11.51b	12.44c
LSD	2.54	2.99	2.89	3.43	3.48	3.66
%CV	25.8	28.6	24.4	25.4	22.6	21.5

Note: WAT: Weeks after transplanting
Means with the same letter are not significantly different from each other at p=0.05.

Table 2 also revealed the effect of lead contaminated soil on leaf production of *Hildegardia barteri* seedlings. It was shown that seedlings grown in soil contaminated with 100mg/kg (T2) had the best performance in number of leaves with an average value of 14.5 leaves followed by soil contaminated with 50mg/kg (T1) with an average value 12.4 leaves while seedlings contaminated with 200mg/kg of lead (T4) performed least with an average value of 7.3 leaves at 12 weeks after transplanting.

Means with the same letter are not significantly different from each other while means with the first letter gave the highest significant effect. It was observed that at 12 weeks after transplanting, the leaf production of the *Hildegardia barteri* seedlings increases from T0 to T2 and decreasing in values from T2 to T4 and this indicated that the effect of lead concentration is evident on the leaves of the seedlings above 100mg/kg.

Table 2: Effect of lead contaminated soil on Number of leaves of *Hildegardia barteri* seedlings

Treatments	WAT2	WAT4	WAT6	WAT8	WAT10	WAT12
T0	3.00b	4.70a	5.30b	6.10b	8.70ab	10.30c
T1	3.60a	3.10c	6.70a	8.00a	11.70a	12.40b
T2	3.30b	4.60a	5.30b	6.00b	9.00ab	14.50a
T3	3.10b	3.30c	4.40b	5.00bc	6.00b	8.30d
T4	3.10b	3.90b	4.40b	5.40bc	6.90b	7.30d

LSD	1.20	1.00	1.30	1.60	1.60	2.10
%CV	35.50	21.70	25.50	27.20	24.20	26.10

Note: WAT: Weeks after transplanting

Means with the same letter are not significantly different from each other at p=0.05.

The effect of lead contaminated soil on stem diameter of *Hildegardia barteri* seedlings was presented in Table 3. At WAT12, seedlings raised on soil contaminated with 0/kg lead (control, T0) had the best performance in stem diameter with mean value of 6.7cm while those from T4 had the lowest mean value of 5.1cm. There was no significant difference among the treatments at p=0.05. This may be due to the fact that at moderately low concentration of lead in soil, plants tend to accumulate more metals than higher concentrations (Orisakwe, 2009).

Table 3: Effect of lead contaminated soil on Stem diameter of *Hildegardia barteri* seedlings

Treatments	WAT2	WAT4	WAT6	WAT8	WAT10	WAT12
T0	2.7	3.4	4.1	4.9	5.9	6.7
T1	2.8	3.4	4.2	5.0	5.6	6.4
T2	2.5	3.1	3.7	4.6	5.4	6.1
T3	2.5	2.9	3.3	4.2	4.6	5.4
T4	2.7	3.3	3.8	5.0	5.7	5.1
LSD	0.63	0.80	0.9	1.1	1.2	1.3
%CV	21.9	22.7	21.1	20.7	19.5	19.2

Note: WAT: Weeks after transplanting

Table 4. Mean Pb Concentration in potting media and *Hildegardia barteri* seedlings

Treatments	**Pb concentrations in soils (mg/kg)**		**Pb Concentrations in seedlings mg/kg**	
	Before the experiment	**After the experiment**	**Roots**	**Shoots**
T0	1.80± 0.001a	1.20± 0.01b	0.31± 0.001a	0.27± 0.001a
T1	58.80 ± 0.50a	38.11± 0.02b	11.22± 0.01a	8.19± 0.02b
T2	101.80±1.11a	76.11b± 0.01b	12.79± 0.01a	10.68± 0.05b
T3	151.80± 0.61a	119.21± 0.21b	16.01± 0.05a	12.61± 0.08b
T4	201.80± 0.88a	152.55± 0.50b	25.11± 0.02a	19.68± 0.10b

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

Table 5: Mean values of Bioaccumulations (BCF) and Translocation factors (TF) of Lead (Pb) in *Hildegardia barteri* seedlings

Treatments	Bioaccumulation factor (BCF)	Translocation factor (TF)
T0	0.48± 0.002	0.88± 0.04
T1	0.51 ± 0.001	0.75± 0.01
T2	0.31±0.002	0.85± 0.02
T3	0.24 ± 0.001	0.79± 0.01
T4	0.29± 0.001	0.81± 0.02

Pb Concentration in the potting media and *Hildegardia barteri* seedlings

The concentration of lead recorded in the soil before and after the experiment as well as its concentrations in *Hildegardia barteri* seedlings were presented in Table 4. Pb concentrations in the potting media before transplanting were T0 (1.80± 0.001), T1 (58.80 ± 0.50), T2 (101.80±1.11), T3 (151.80± 0.61) and T4 (201.80± 0.88) while after the experiment T0 were (1.20± 0.01), T1 (38.11± 0.02), T2 (76.11b± 0.01), T3 (119.21± 0.21) and T4 (152.55± 0.50). Significant reductions were observed between the concentration of heavy metals before and after planting (Table 4). The results showed that seedlings were able to uptake lead from the contaminated soil and that amount of metal (Pb) uptake was directly proportional to the contamination level. The translocation of lead in *Hildegardia barteri* seedlings was compared by considering root to shoot transport and redistribution of metals in the root and shoot system.

The Pb contents from root and shoot parts of the seedlings were presented in Table 4. The results showed that the mean amount of lead found in roots were 0.31± 0.001, 11.22± 0.01, 12.79± 0.01, 16.01± 0.05 and 25.11± 0.02 in mg/kg at contamination levels of 0 mg of Pb $(NO3)_2$ per kg of top soil, 50 mg of Pb $(NO3)_2$ per kg of top soil, 100 mg of Pb $(NO3)_2$ per kg of top soil, 150 mg of Pb $(NO3)_2$ per kg of top soil and 200mg of Pb $(NO3)_2$ per kg of top soil respectively. The amounts of Pb found also in shoots were 0.27± 0.001, 8.19± 0.02, 10.68± 0.05, 12.61± 0.08 and 19.68± 0.10 in mg/kg at contamination levels of 0 mg of Pb $(NO3)_2$ per kg of top soil, 50 mg of Pb $(NO3)_2$ per kg of top soil, 100 mg of Pb $(NO3)_2$ per kg of top soil, 150 mg of Pb $(NO3)_2$ per kg of top soil and 200mg of Pb $(NO3)_2$ per kg of top soil respectively. The results indicated that the amounts of lead in roots were higher than that found in shoots and also the amounts of lead were found to be significantly increased as the spiked amounts of lead increased. This is similar to the findings of Salama *et al.*, (2015) and Akintola *et al.*, (2020) on *Lolium multiflorum* and *Cederala odorata* respectively.

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

The bioaccumulation factor (BAF) and translocation factor (TF) of Pb in *Hildegardia barteri* seedlings were shown in Table 5. The ability of plants to absorb heavy metals from is expressed by the BAF while TF is used to assess to potential of the plants to transfer it to its part as stated in

Akintola *et al.,* (2020). The soil-plant bioaccumulation factor (BAF) for lead in the *Hildegardia barteri* seedlings was found to range from 0.29 to 0.51. However, these values are high when compared to the findings of Salama *et al.* (2015) on *Lolium multiflorum* for remediation of lead-contaminated soil. The mean values of translocation factor (TF) were 0.75 to 0.85. Naturally, all plants have a capability to uptake elements from soil and translocate them between roots and shoot systems. These can also be taken up by roots and transferred into the different parts of the plant (Ximenez-Embun *et al.,* 2002). These results indicated that the *Hildegardia barteri* has the ability to accumulate and transfer lead from soil into their different parts.

Conclusion

This study has shown that *Hildegardia barteri* have a capability to uptake Pb from soil and translocate them between roots and shoot systems. This study has further proven that phytoremediation as emerging green technology, can offer an effective treatment method for decontamination or removal of contaminants from the soil with minimum impact on the environment.

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