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REMEDIATION POTENTIAL OF *Albizia lebbeck* L. Benth. IN CHROMIUM CONTAMINATED SOIL

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ABSTRACT

Heavy metals contamination has been of great concern in the last decades because of their health hazards to man and other organisms when accumulated within a biological system. This study investigated Albizia lebbeck species for removal of chromium (Cr) from contaminated soil. Pots experiment consisting of five treatments (Control: 0mg Cr/kg), (50 mg Cr/kg), (100mg Cr/ kg), (150mg Cr /kg), (200mg Cr/kg) and replicated five times in a completely randomized design were used in this study. The study was carried out for a period of 12 weeks after transplanting. Growth parameters such as seedling heights stem diameter and number of leaves were assessed at the end of the experiment. Bioaccumulation factor (BAF) and translocation factor (TF) were used to assess the phytoremediation potentials of the seedlings. Physicochemical properties of the soils; Cr concentrations in soils before and after experiment and those of the plants were determined using standard instrumentation techniques. The respective mean seedling heights, stem diameter and leaf production throughout the weeks of the experiment from the treatments were: 0mg Cr/kg (6.11-14.32cm; 0.20 - 0.30mm; 1.50 - 3.21), 50mg Cr/kg (10.56-18.67cm; 0.20 - 0.28mm; 1.60 – 3.22), 100mg Cr/kg(10.99-12.03cm; 0.21 – 0.27mm; 1.61 – 2.21), 150mg Cr /kg(11.87-15.12cm; 0.22 – 0.26mm; 1.41 – 2.32) and 200mg Cr/kg(12.02-15.78cm; 0.21 – 0.26mm; 1.10 – 2.43). There were no significant differences among the treatments for the growth parameters of the Albizia lebbeck seedlings at $p \leq 0.05$. Values of BAF (0.00-0.11) and TF (0.00-0.61) of Cr in the plants indicate low potential of this plant for phytoextraction of chromium. This study has shown that Albizia lebbeck are low- efficient plant for remediation of soil contaminated with chromium

Keywords: Chromium (Cr), *Albizia lebbeck*, Accumulation, phytoextraction

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INTRODUCTION

Heavy metals are widespread environmental pollutant and their excessive levels in agricultural soil causes serious risk, not only for plant growth and crop yield but also for human health (Akintola *et al.,* 2019).Heavy metalsare described as metallic chemical elements and metalloids which are toxic to the environment and humans (Anjum Zia *et al*., 2017; Duffus, 2002,;Lenntech, 2018). Heavy metals have their density of being greater than 5 g/cm^3 and are more common in our everyday life. Examples of common heavy metals are: titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper,zinc, arsenic, molybdenum, silver, cadmium, tin among others (Shanker, 2005).The uptake of these heavy metals by plants results in their bioaccumulation, which according to Alloway (1996); Kabata-Pendias and Szteke. (2015) can cause a serious risk to human health when plant-based food stuff is consumed.

Chromium (Cr) is the 17th most abundant element in the earth's mantle (Avudainayagam, 2003). According to Babula (2008), chromium occurs naturally in form of chromite ($FeCr_2O_4$) in ultramafic and serpentine rocks, or complex with other metals like crocoite (PbCrO4) and tarapacaite (K_2CrO_4). Chromium is widely used in industries as plating, alloying, tanning of animal hides, textile dyes and ceramic glazes, which makes it a contaminant or pollutant to the soil (Avudainayagam *et al*., 2003). The increasingly use of chromium (Cr) has become severe anthropogenic activities which has led to soil contamination, this thus call for concern (Zayed and Terry, 2003). Chromium can be taken up by plants through carriers of essential ions such as sulphate chromium, translocate to different parts of plant tissue and can become toxic to plant. Chromium is a highly toxic metal to living organisms with many adverse effects on humans, animals, plants, and microorganism (Layon, and Gallagher, 1990; Velma *et al*., 2009). Therefore, solutions must be made to clean and rehabilitate the soils from this toxic metal. Plants are known to sequester, degrade and stimulatethe degradation of organic contaminants in soil (Anderson *et al*., 1993; Shimp *et al*., 1993). The removal of heavy metals by plants is an effective method of reducingheavy metal contamination in soil (Cunningham *et al*.,1995). The method of removing toxicants using green plants is known as phytoremediation. Plants are known to accumulate a variety of toxicants from soil (Paterson *et al*., 1990).

Phytoremediation has been gaining importance in rehabilitation of contaminated soil because of it economic effective and eco-friendly. *Albizia lebbeck* belongs to family Fabaceae. It is a multipurpose, medium-sized, deciduous tree species that is characterized by its rapid growth, ability to fix nitrogen and improve soil structure (Faisal *et al.*, 2012). *A. lebbeck* is grown for shelter belts, and as a shading tree in coffee and tea plantations (Orwa *et al.*, 2009). Its coppicing ability, site adaptability and nitrogen fixing property, make it one of the most suitable tree species for reforestation of degraded sites, fuelwood plantations and agroforestry systems (Kumar *et al.*, 2018). This study thus investigated the potential of Albizia *lebbeck* Benth species for removal of chromium (Cr) contaminated soil.

MATERIALS AND METHODS

Study area

The experiment was carried out at Federal College of Forestry, Ibadan, Oyo State. The institution is located in Ibadan North West Local government. The area lies between latitude (7º26'N - 7º28'N) and Longitude (3º51'E- 3º54'E). The climate pattern of the area is tropically dominated by annual rainfall pattern ranging from 1,300mm – 1,500mm and average relative humidity of about 65%, the average temperature is about 26º C. The area has two seasons, dry seasons usually commenced from November to March while the raining season start from April to October (FRIN, 2015).

Sampling Collection and experimental design

Topsoil was crushed and sieved to facilitate easy mixing. *Albizia lebbeck* seeds were planted into germination box with sterilized river sand. The chromium salt ($K_2Cr_2O_7$) was weighed in different grams in the laboratory. The pots were filled with 1kg of topsoil with four different treatment of Chromium salt (50mg, 100mg, 150mg and 200mg) in liquid form and left for two weeks for metal stabilization in soil, the mixture was done thoroughly at regular intervals to maintain even concentration of metal in soil and its proper stabilization before sowing. The treatments were: T1 (Control 0mg Cr/kg), T2 (50 mg Cr/kg), T3 (100 mg Cr/ kg), T4 (150 mg Cr /kg), T5 (200 mg Cr/kg). The sprouted seedlings (2 each) were transplanted into polythene pots at different five treatment levels. All treatments were structured as five replicates in a completely randomized design. Inter-culture operation such as weeding and watering was done every day. The experiment lasted for 12 weeks after transplanting (WAT). The seedlings were watered twice a day. The parameters such as stem diameter, seedling height and Leaf production were assessed throughout the period of the experiment.

Sample analysis

Physiochemical and heavy metal analysis of the topsoil was done before the commencement of the experiment using appropriate methods. Chromiun concentrations in each of the treatments after the experiment were analyzed. The concentration of chromium in the roots and shoots of *Albizialebbeck* seedlings at the end of the experiment were also analysed using atomic absorption spectrophotometer (AAS).

Data Analysis

Bioaccumulation factor (BAF) and Translocation factor (TF) given by Yadav *et al*.,

(2009) were calculated to to assess the potential of the plants in removing the Cr concentrations in the growing media as shown in Equation 1 and 2:

$BAF = HMCP/HMCS$ …… (1)
Where:
BAF - Bioaccumulation factor
HMCI - heavy metal concentration in plant
HMCS - heavy metal concentration in soil

$TF = HMCS/HMCR$…… (2)
Where:
BAF – Translocation factor
HMCI - heavy metal concentration in shoot
HMCS - heavy metal concentration in root

Data were analyzed using one-way analysis of variance (ANOVA) and mean were separated using Duncan Multiple Range Test (DMRT).

RESULTS

Properties of the soil used

The physiochemical and heavy metal content of soil used in this study are presented in Table 1. Particle sizes of the topsoil were sand (72.01%), silt (18.20%) and clay (9.79%). Based on the particle sizes of the soil, the soil used for this study can be classified as sandy loamy soil. Texture is an important soil characteristic that plays important role in management and crop production as it contains high nutrients, CEC and high-water holding capacity. The pH of the topsoil was 6.81 and it is slightly acidic. Organic matter content of the soil was 4.17% while total nitrogen and available phosphorus were 0.67% and 20.19mg/kg respectively. Heavy metal concentrations in the soil were ZN (8.78 mg/kg), Cu (32.71 mg/kg), Fe (795.72 mg/kg), Mn (607.82 mg/kg), Pb (2.51mg/kg), Ni (5.61mg/kg) and Co (2.1 mg/kg) while Cr and Cd were not detected in the soil.

Table 1: Physicochemical parameter and heavy metal content in the top soil

Parameter	Values
pH	6.81
Calcium (Ca)	1.70cmol/kg
Potassium (K)	0.04cmol/kg
Sodium (Na)	0.47cmol/kg
Magnesium (Mg)	0.93cmol/kg
%Clay	9.79
%Silt	18.20
%Sand	72.01
Available phosphorus	20.19mg/kg
Organic matter content	4.17%
Total nitrogen	0.06%
Zinc (Zn)	8.78mg/kg
Copper (Cu)	32.71mg/kg
Iron (Fe)	795.72mg/kg
Manganese (Mn)	607.8mg/kg
Lead (Pb)	2.51
Nickel (Ni)	5.61
Cobalt (Co)	2.19
Chromium (Cr)	ND
Arsenic (As)	ND
Cadmium (Cd)	ND

Key: ND means not detected

Effect of chromium on growth parameters of *Albizia lebbeck*

Figure 1 showed the effect of varying concentrations of chromium on the mean plant height weeks after transplanting. The mean seedling heights from week two after transplanting to week12 after transplanting were 0mg Cr/kg (6.11-14.32cm), 50mg Cr/kg (10.56-18.67 cm), 100 mg Cr/kg (10.99-12.03 cm), 150mg Cr /kg (11.87-15.12 cm) and 200mg Cr/kg (12.02-15.78cm). An increase in seedling heights were observed from weeks after transplanting to end of the experiment (`2 WAT to 12 WAT) for *Albizia lebbeck* grown in 0mg Cr/kg and 50mg Cr/kg while reduction in heights were observed from 6 weeks after transplanting to the end of the experiment (6 WAT to 12 WAT) for seedlings grown in 100mg Cr/kg, 150mg Cr /kg and 200mg Cr/kg..

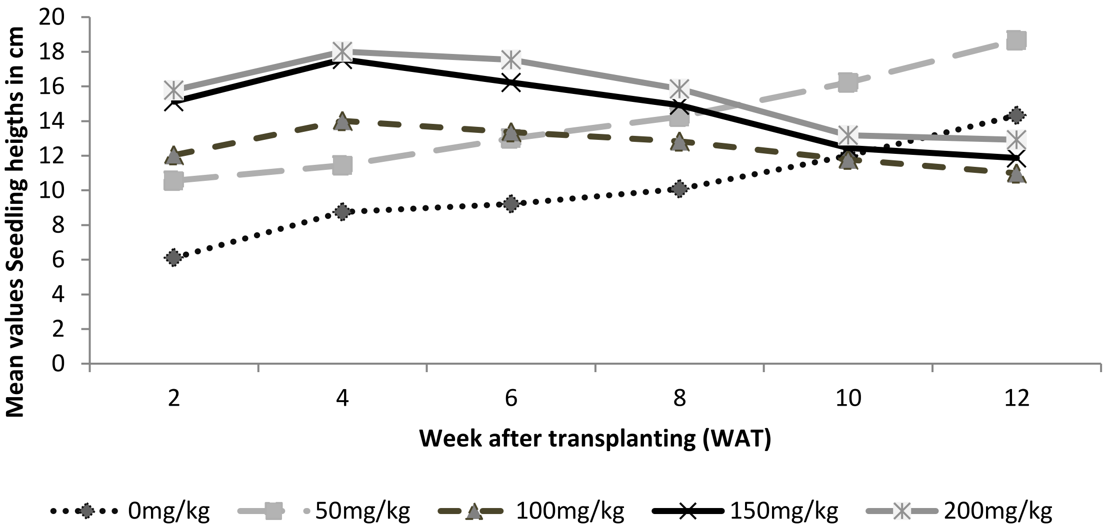

Figure 1: Seedling heights of *Albizia lebbeck*i grown in chromium contaminated soil

Figure 2 also shows the effect of varying concentrations of chromium on the stem diameter of *Albizia lebbeck*, weeks after transplanting. The mean stem diameter values from week two after transplanting to week12 after transplanting were 0mg Cr/kg (0.20 - 0.30mm), 50mg Cr/kg (0.20 - 0.28mm), 100mg Cr/kg(0.21 – 0.27mm), 150mg Cr /kg(0.22 – 0.26mm) and 200mg Cr/kg (0.21 – 0.26mm). Results show that there were increases in stem diameter for all the treatments throughout the weeks of study. The control (0mg Cr/kg), 50mg Cr/kg) and 100mg Cr/kg recorded the highest stem diameter across the weeks. The lowest stem diameter was observed in the treatments with 150mg Cr/kg and 200mg Cr/kg at 12 WAT.

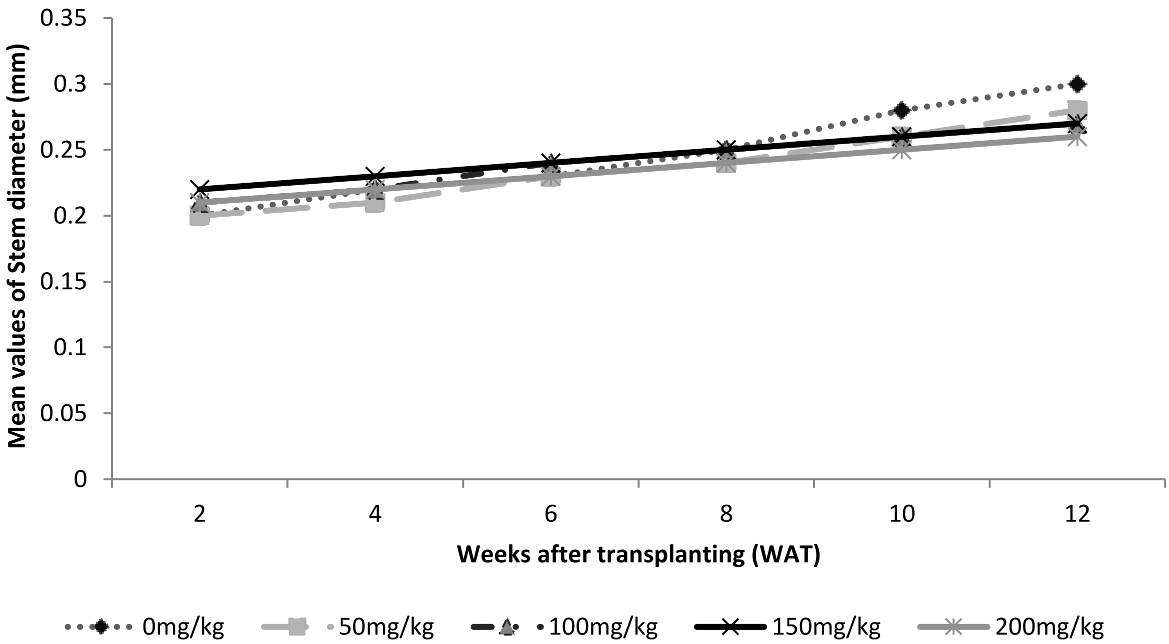

Figure 2: Stem diameter of *Albizia lebbeck* grown in chromium contaminated soil

Figure 3 further shows the effect of varying concentrations of chromium on the numbers of leaves of *Albizia lebbeck* weeks after transplanting. Result obtained of leaf production increased throughout the weeks of the experiment were 0 mg Cr/kg (1.50 - 3.21), 50mg Cr/kg (1.60 – 3.22), 100mg Cr/kg (1.61 – 2.21), 150 mg Cr /kg (1.41 – 2.32) and 200 mg Cr/kg (1.10 – 2.43). A reduction in leaf production was noticed from week 6 after planting for 100mg Cr/kg, 150 mg Cr /kg and 200 mg Cr/kg (Figure 3). There was no significant difference among the treatment on the leaf production of *Albizia lebbeck* at P≤0.05.

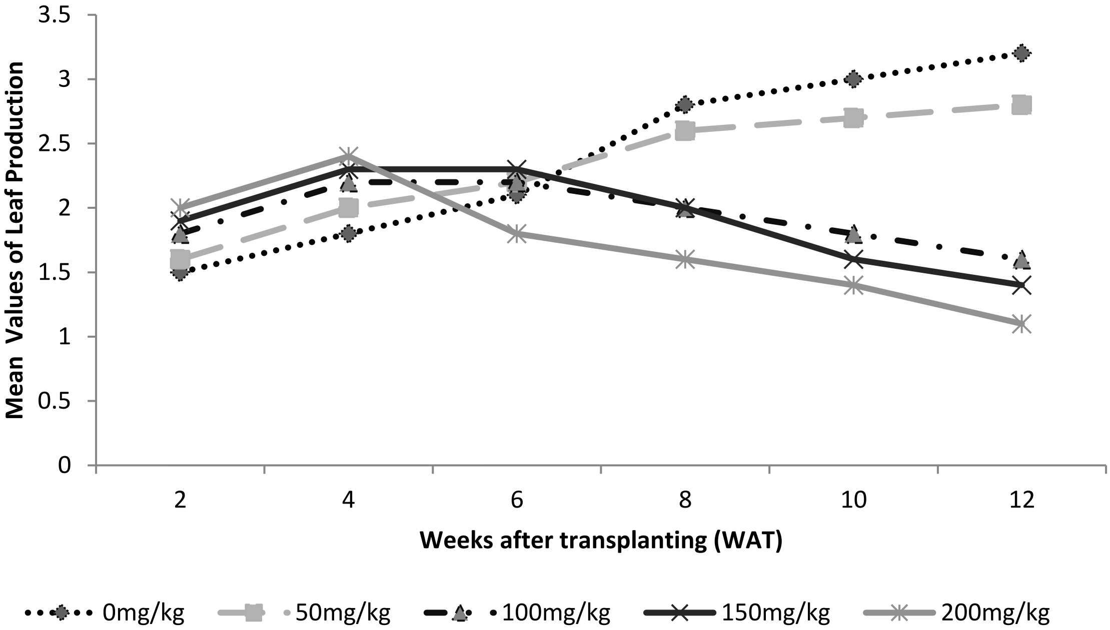

Figure.3: Leaf production of *Albizia lebbeck* grown in chromium contaminated soil

Chromium (Cr) concentration in soils and seedling parts

Heavy metal (Cr) concentrations in the potting media before and after experimentare shown in Table.2. Chromium concentrations in soil before experiment (0.00 – 200.00mg/kg) were found to be higher than after the experiment (0.00 -153.89mg/kg). This indicated the potential of the seedlings to uptake the elements into its parts. The uptake of chromium concentrations in roots and shoots in *Albizialebbeck* seedlings were shown in Table 2 It was observed that the roots of (0.00 - 10.43mg/kg) *Albizia lebbeck* seedlings have higher concentration of Cr than the shoots (0.00 – 6.50 mg/kg) of the seedlings.

Table 2 Chromium concentrations in potting media and the seedling parts

Treatments	Cr concentrations (ng/kg)			
	Before Experiment	**After experiment**	**Shoots**	**Roots**
0mg Cr/kg	0.0	0.00	0.00	0.00
50mg Cr/kg	50	35.80	1.01	1.85
100mg Cr/kg	100	82.67	3..01	5.25
150mg Cr/kg	150	128.11	4.23	7.30
200mg Cr/kg	200	153.89	6.50	10.43

Table 3. Value of Bioaccumulation factor and Translocation of *Albizia lebbeck*

Treatments	Bioaccumulation factor	Translocation
0mg Cr/kg	0.00	0.00
50mg Cr/kg	0.08	0.55
100mg Cr/kg	0.10	0.57
150mg Cr/kg	0.09	0.58
200mg Cr/kg	0.11	0.61

Potential of *Albizialebbeck* seedlings for removal of Cr concentrations

Table 3 showed the bioaccumulation factor (BAF) andtranslocation factor (TF) of Cr in *Albizia lebbeck*. BAF and TF are the key elements for the evaluation and selection of plants for phytoremediation purposes (Wu *et al*., 2015; Hou *et al*, 2019). The values BAF for the various concentration of Cr ranged from 0.00-0.11. This value is lower than 1 given as BAF value, for plants than can be used as phytoremediation.The low values obtained could also be attributed to the period (12 WAT) used for the experiment.The value of translocation factor greater than 1 indicates the transfer of the metal from root to above-ground part (Jamil *et al*., 2009). The TF value (0.00 - 0.62) in this study is less than indicating Cr concentrations is more accumulated in roots than the shoots of the plants.

DISCUSSION

The organic matter content in the soil is considered as medium according to Akintola (2014). The values of total nitrogen and organic carbon were 0.67 and 0.06% respectively. Many factors such as poor physical structure, low water and nutrient holding capacity, deficiency of major nutrients (N, P, K), acidity and alkalinity, water supply, toxic materials, salinity, stability and surface temperature can affect plants (Bradshaw and Chadwick, 1980). The values of physiochemical and the determined heavy metals in the soil are within the stipulated values recommended by various studies (Arshad and Coen, 1992, Burger and Kelting, 1999; FAO, 2003, Kumar *et al*., 2013). The results of is in line with the finding of Shivhara and Sharma (2012), that the height of plants decreased as the heavy metal concentration increased. There was no significant difference at $P \leq 0.05$ in seedling height of plants under varying Cr concentrations. There is evident that plant grown on Cr polluted soil exhibit retarded growth as stated by (Habiba *et al*., 2018). Result of study showed that stem diameter decreases as Cr concentration increased. There was no significant difference among the treatment on the stem diameter of *Albizialebbeck*at $P \leq 0.05$. Low reductions in the values of Cr concentration in the soil before and after experiment were observed and this could be attributed to low period of planting which limit the uptake capacity of the plants. The low values of Cr in the shoots may be attributed to the time frame for the experiment or the inability of the plants to transfer it to its different part. According to Nagendran *et al*., (2006) hyperaccumulators plants extract metals from soil and accumulate them in shoots, but in this study, the chrominum concentrations are more accumulated in the roots than in the shoots of *Albizia lebbeck* seedlings. Translocation factors in this study agreed with the findings of lee *et al*, (2013) and Romeh *et al*, (2015) that most species roots accumulated substantial higher amounts of heavy metals than the shoot. The 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. According to Yoon *et al*. (2006), plant species which have both BAF and TF greater than 1 have the potential to be used for phytoextraction. Also, Madanan *et al*. (2021) and Yadav *et al*. (2009) stated that plants with BAF values > 1 are accumulators, while plants with BAF values less than 1 are excluders. Plants with BAF values were > 10 were classified as hyper accumulators. Furthermore, Plants with TF values > 1 are classified as high-efficiency while those with TF< 1 are classified as low-efficiency plants for metal translocation from the roots to shoots. Based on this study, Albizia *lebbeck* seedlings be classified as excluders and low efficient plant for chromium translocation from roots to shoots.

CONCLUSION

The results of *Albizia lebbeck* as potential remediation of Cr contaminated soils showed that seedling heights and number of leaves increased at low concentration of Cr, but decreased with high concentration levels of chromium in the soils. There were no significant differences among the treatments for the growth parameters of the *Albizia lebbeck* seedlings. Low values of bioaccumulation and translocation factors indicate low potential of *Albizia lebbeck* species for phytoextraction of Cr contaminated soil.

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