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PHYTOREMEDIAITON OF CHROMIUM CONTAMINATED SOIL BY AFRICAN SPINACH (Amaranthus hybridus) IN JOS, NIGERIA

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ABSTRACT

Phytoremediation involves the use of living green plants for *in situ* risk reduction and or removal of contaminants from contaminated soil. The objective of this study therefore was to evaluate the effectiveness of African spinach (*Amaranthus hybridus*) in extraction of chromium (Cr) from contaminated soil. The research consisted of the following treatments: 0, 38, 76, 114, 156, and 190 (Cr mg/kg). Potassium dichromate was used as the source of chromium. The plant data collected were leaf count, plant height, stem diameter, shoot weight, the root weight and chromium concentration in shoot and roots which were analyzed using analysis of variance and the Fisher's pairwise comparisons. The result showed that there was no significant effect of treatments on growth parameters. However, there was significance difference in chromium concentration in the shoots of *Amaranthus hybridus* among the various treatments when compared to the control. Mean maximum extraction of chromium were within the range 58.0 to 63.0 mg/kg. This indicates that *Amaranthus hybridus* possess great potential in phyto-extraction of chromium and other heavy metals from contaminated soil.

Keywords: phytoremediation, chromium, African spinach, *Amaranthus hybridus*

INTRODUCTION

Since the beginning of the industrial revolution, pollution, and contamination of the soil environment with toxic trace metals has been on the increase. Consequently, this has resulted world-wide public health concern (Nriagu, 2010). Soil and water quality degradation by heavy metals is a critical contributor to human and animal health hazard because they bio-accumulate in the food chain (Yoon, et al, 2006). Major sources of heavy metal contaminations in urban environments include manufacturing, indiscriminate solid waste and wastewater disposal (Cheng, 2003). Accumulation of heavy metals in the soil environment decreases the soil's quality for crop production as well as jeopardizing the activities of soil organisms (Dai *et al*, 2004).

In time past, heavy metal remediation methods involved removal of the contaminated soil (Khan et al. 2000) and subsequently its disposal on landfills or treated to immobilize the heavy metals in the contaminated soil (Basta and McGowen, 2004). This is rather expensive and, in most cases, not environmentally friendly. Phytoremediation, on the other hand, is a more environmentally friendly approach, also, it is less expensive (Salt et al, 1995). Phytoremediation involves selecting plants for their ability to extract or accumulate metals in their tissues.

Industrial activities are one of the major sources whereby chromium is released into the soil. Consequently, due to its wide industrial use, chromium is considered a serious environmental pollutant (Shanker et al, 2005). Recently there is an increased global concern on soil contamination by chromium. At high concentrations chromium is toxic, mutagen, carcinogen, and teratogen (Nraigu, 2010) to human consequently Chromium in contaminated soil must be reduced to safe levels. The objective of this study therefore was to evaluate the effectiveness of African spinach (*Amaranthus hybridus*) in extraction of chromium from contaminated soil.

MATERIALS AND METHODS

Study Area

This experiment was carried out at Federal College of Forestry, Jos during the 2019, cropping season. Jos is located in the Northern region of Plateau State in Nigeria. With an average altitude of about 1,295m above sea level. The climate is a variant of the Tropical Continental climate. Also, the climate is the wet and dry type classified as tropical rainy climate. In addition, the climate is characterized by a mean annual rainfall of 1,260 mm (1050-1403 mm) which peaks between July and August (Olowolafe, 2002).

Experimental Design

Topsoil samples was collected from an undisturbed area. The soil samples were air dried and then sieved through a two (2) millimeter mesh sieve, the soil was properly mixed, and all lumps broken before the sieving process. Three kilograms of soil was weighed into the plastic pots. The amaranthus seeds was broadcasted on the soil in the plastic pots and covered with a light soil layer. After germination, the plant was thinned to one (1) plant per pot. The plants were grown during the rainy season A complete randomized design was employed for the experiment. The experiment was consisted of six (6) treatments and three (3) replicates. The treatments were mixed with the air-dried soil before commencing planting operations. The details of the treatments employed for this experiment are presented in Table 1. Potassium chromate was used to supply the chromium levels presented in Table 1.

Table 1: List of treatment for the study

Treatment	Cr (mg/kg)
T1	0
T2	38
T3	76
T4	114
T5	152
T6	190

Laboratory Analysis, Data Collection and Statistical Analysis

The following laboratory analysis were carried out on soil samples before the commencement of experiment. Particle size distribution was carried out using the Hydrometer method as described by Gee and Bauder (1986). Soil pH was determined in 0.01M $CaCl_2$ solution (McLean, 1982). Total Nitrogen was determined using the Kjeldahl method whereas organic matter was determined by the Walkley-Black dichromate wet oxidation method as described by Nelson and Sommers (1982). Available phosphorus was determined using the Bray-1 extraction method (IITA, 1979). Exchangeable potassium was determine using a flame analyzer as described by Thomas (1982).

After the growth period, both the shoot and root of the plants was sampled and analyzed for total chromium. The following plant data were collected during the growth period: plant height, leaf count, stem diameter, shoot weight, and Root weight. Analysis of variance was employed to determine the effect of treatment on the growth performance of Amaranthus and its ability to extract chromium from contaminated soil.

RESULTS AND DISCUSSION

Soil Characteristics

The characteristics of soil used for this study is presented in Table 2. The texture of the soil is loamy sand and moderately acidic (5.69). Classifications by Enwezor *et al* (1989) revealed that organic matter and available phosphorus was at moderate levels. Available Sulphur, cation exchange capacity, and exchangeable cations were low. This underscores the low fertility status of the soils.

Table 2: Characteristics of soil used for the study.

Soil property	Value	Units
Sand	88.8	%
Silt	8.4	
Clay	2.8	
pH	5.69	
N	0.065	%
Available P	12	Mg/kg
Available S	2.4	
Ca	1.48	Cmol/kg
Mg	0.084	
Na	0.0022	
K	0.13	
Exchangeable acidity	1.57	
CEC	3.68	

Growth Parameters and Chromium Concentration in African Spinach

Growth characteristics of African spinach at eight weeks of growth is presented in Figure 1. However, there was no significant difference in growth data ($P>0.05$) among the treatment during the period of growth. The Non-significant effect of chromium of growth characteristics could be due to the ability of African spinach to tolerate high levels of chromium concentration (38 to 190) without affecting growth performance. Shanker et al (2005) had noted that toxic effects of Cr on plant growth and development include alterations in the germination process as well as in the growth of roots, stems, and leaves, which may affect total dry matter production and yield.

Table 3 shows that at 8 weeks after planting there is highly significant difference ($p < 0.01$) in chromium (Cr) concentration in African spinach. Consequently, there were higher concentration of Cr in African spinach plants in treatment 3, 4, 5 and 6 indicated that African spinach was able to significantly extract chromium (Cr) from the soil at these high concentrations. This corresponds to reports by Farrag et al (2013) who documented the potential of African spinach in phytoremediation. In contrast however, the range of values recorded in this study were higher than those (2.5 – 12.7 mg/kg) reported by Farrag et al (2013) and lower than the range of 0.03 to 6.14 mg/kg reported by Oti (2015) but far lower than that reported by Ochonogor and Atagana (2014) for *Psoralea pinnata* plants (approximately 68, 000 mg/kg). It is probable, however, that the low fertility status of the soils used for this study could have negatively affected the extraction efficiency of the plants.

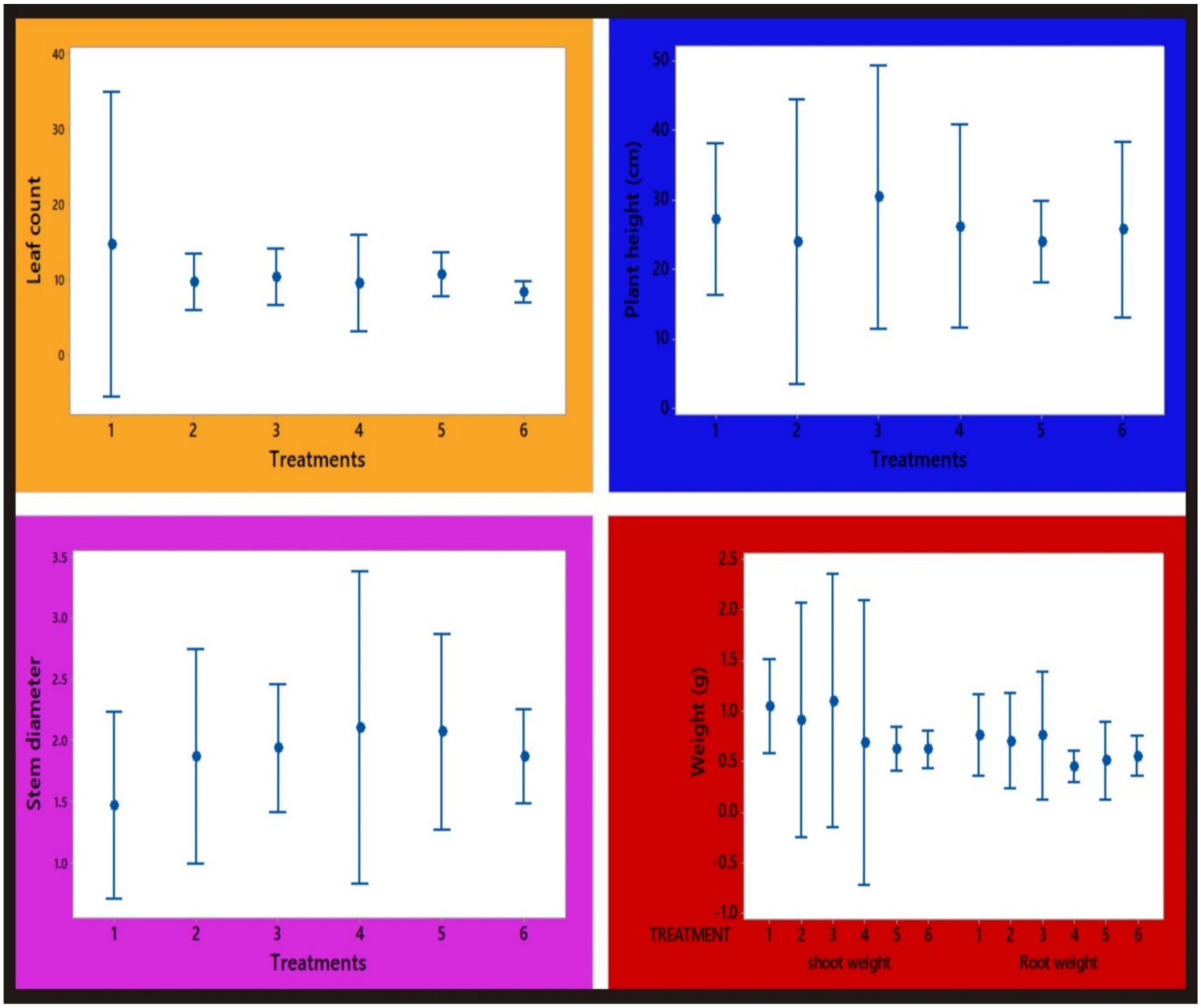

Figure 1: Growth Characteristics of African Spinach at 8 weeks of growth

Table 3: Chromium (Cr) concentration in African Spinach

Treatment	Mean (mg/kg)	Standard deviation	95% Cl
1	36.20[b]	3.38	(29.37.43.04)
2	36.47[b]	3.19	(29.63,43.30)
3	58.75[a]	8.94	(51.91,65.59)
4	61.44[a]	8.20	(54.60,68.28)
5	61.58[a]	2.32	(54.75,68.42)
6	63.08[a]	1.76	(56.25,69.92)

Note:CI= Confidence interval.

CONCLUSION

This experiment has shown that African spinach has great potential in phyto-extraction of chromium from contaminated soil even those of low fertility. In addition, this ability is further enhanced by its ability to tolerate high levels of chromium without showing toxicity symptoms. It is imperative however for further research to be carried out involving higher levels of chromium and with other types of heavy metals.

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