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PHYTOREMEDIATION OF AGRICULTURAL SOILS POLLUTED WITH NICKEL AND CHROMIUM USING FLUTED PUMPKIN PLANT (*Telfairia occidentalis*)

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ABSTRACT

Phytoremediation is a new remediating technology which gives a great prospect for cleanup of many harmful wastes, including heavy metals on agricultural land. This research work aimed at evaluating the potential of fluted pumpkin plant (*Telfairia occidentalis*) for phytoremediation of nickel and chromium from soil. Soil sample collected at a depth of 20 cm were used for the experiment. The pH, organic carbon, nitrogen, phosphorus and potassium content of the soil were determined. The experimental design for this study consist of 5 treatments, each of these treatment were divided into 3 replicates, each containing 4 kg of soil including soil without concentration of Ni and Cr to serve as control. Three (3) polythene bags, each contaminated with 1 g/dm^3 and 3 g/dm^3 concentration of Ni and Cr. Three (3) fresh fluted pumpkin seeds were planted on each of the soil sample at a depth of 5cm and the setup was monitored properly in crop production department nursery garden. Samples were taken for analysis at every 2 weeks interval for a period of 8 weeks. Results obtained at every 2 weeks interval showed reduction in the concentration of Ni and Cr in the soil. The analytical results of the plant assessment upon harvest confirmed an uptake and accumulation in the aerial parts and root of the plant. It can thus be concluded that fluted pumpkin plant is a good phytoplant having undistorted growth in the presence of Ni and Cr, and be used for remediating soils polluted Ni, Cr and their compounds. The implication is that fluted pumpkin meant for consumption should not be planted on soil rich in heavy metal to avoid uptake of heavy metals by man.

Keywords: *fluted pumpkin plant, heavy metals, agricultural soils, phytoplant, crop quality*

1. INTRODUCTION

Environmental build up of waste products which are rich in heavy metals are of great concern in recent time. Contamination of soil, air and water by these metals has been on drastic increase since the early 20th century due to rapid growth in the world population coupled with increase in exploitation, production and consumption of the earth's raw material such as fossil fuel and minerals (Appel and Ma, 2002). Soils on the other hand are the major recipients and accumulators of these metals due to its high capacity for metal retention.

Nickel (Ni) and Chromium (Cr) are among the most prominent heavy metals disturbing soil quality and human health because of their diverse roles in industrial and agricultural sectors (Appel and Ma, 2002). These metals do not only affect the quality of crop but also the quantity as they pose threat to microorganism causing abiotic stress which is often detrimental.

Phytoremediation is gaining popularity recently as an alternative to mechanical and chemical methods of removing contaminant from soil. The preference given to this method is due to the fact that it is an inexpensive technology which generates fewer secondary wastes making it environmental friendly (Cullaj et al. 2004; Usman and Shuaibu, 2011).

The search for the available indigenous plant that has the potential to survive and reproduce under heavy metal stress field condition is pivotal to the applicability of this technology (Yoon et al., 2006). Literature has shown that some plants (vegetables inclusive) have high tolerance for heavy metal and thus accumulate them in various parts of their system (Cheng, 2003; Yusuf et al., 2002).

If an agricultural soil is rich in heavy metals, the toxic substance consistency of the cultivated vegetable on those soils will also be high. Hence, ensuring good status of soil to be used for cultivating edible crop is very paramount to both subsistence and commercial system of farming (Agbogidi and Enujeke, 2011).

To this end, this study focused on evaluating the potential of fluted pumpkin plant (*Telfairia Occidentalis*) for phytoremediation of agricultural soil contaminated with nickel and chromium.

METHODOLOGY

Study Area

The study was conducted in Crop Production Departmental Garden, in School of Agricultural and Agricultural Technology, Federal University of Technology Minna, Nigeria, Gidan Kwanu campus. The collected soil sample is well drained and has high water infiltration rate.

Materials

Fluted pumpkin seeds used for the experiment were obtained at kasua Ngwari, (Gwari market) Minna. Nickel (II) nitrate hexahydrate [Ni $(NO_3)_2.6H_2O$] and chromic nitrate [Cr $(NO_3)_2$.9H2O] were used as artificial sources of Ni and Cr in soil

Soil Sampling

Soil samples were collected within the study area at a depth of 20cm. Three fresh fluted pumpkin seeds were planted in polythene bags containing 4 kg of the soil at a depth of 5cm. The experimental design used was 5 by 3 which consist of 5 treatments (including the control) and 3 replicates. Three polythene bags without nickel and chromium to serve as control, three polythene bags contaminated with 1 g/dm^3 concentration of nickel, three polythene bags contaminated with 3 g/dm^3 concentration of nickel, three polythene bags contaminated with 1 g/dm^3 concentration of Chromium and three polythene bags contaminated with 3 g/dm^3 concentration of Chromium (Plate 1). The control and contaminated soil samples were taken for initial analysis before planting of the seeds. After seed planting, samples were also collected and analyzed for heavy metal content at two weeks interval for a period of eight weeks. At the end of the 8^{th} week, after the collection of soil samples, the plants were uprooted and the leaves, stem and root were also analyzed for the heavy metal content.

Plate 1: Experimental set up

Sample preparation and analysis

The soil samples in each of the polyethylene bags were dried and ground. The ground samples were then passed through 0.25 mm sieve mesh to obtain a fine particle. The samples were digested using nitric acid-perchloric acid digestion (Otaru et al, 2013). Some 0.5 g of the finely ground soil samples were weighed using a digital weighing balance and placed in a 50 ml beaker. Some 20 ml of a mixture of nitric acid and perchloric acid in 1:1 molar ratio was poured into the soil in the beaker and the content was placed on a hot plate and heated gently at low temperature until dense white fumes of $HClO_3$ appears. The digested soil sample was allowed to cool before it was filtered into a 50 ml standard volumetric flask which was made up to mark with deionised water and the samples were placed in storage containers and taken for analysis.

At the end of 8th week, Plant samples (leaves, stem and root) were digested using method illustrated by Hornwitz (1980). The samples were oven dried and grounded to powdery form. Some 0.5 g of the sample was weighed into a 50 ml beaker. 5.0 ml of concentrated nitric acid was added and the beaker heated on a hot plate in a fume cupboard to a small volume. Same amount of concentrated Perchloric acid was also added and then boiled again for few minutes after which 15.0 ml of deionised water was added and allowed to cool to room temperature. The whole mixture was then transferred to a 100 ml volumetric flask and made up to the mark with deionised water. These solutions were placed in storage container and used for the analysis

The samples (both plant and soil) were analysed for Cr and Ni content using atomic absorption spectrometer (AAS).

Before the treatment of the soil sample, some physicochemical properties of the samples were determined. The soil textural class, soil pH and organic carbon were determined using Bouyoucos Hydrometer method, pH meter and Walkey-Black method respectively. While phosphorus was determined with flame photometer, potassium and nitrogen were determined using oxidation kjedal method respectively.

2. RESULTS AND DISCUSSIONS

The results of the physicochemical properties of the soil before contaminated with Cr and Ni are presented in Table 1. The mean value for particle distribution (74% of sand, 9% of silt and 17% of clay) of the soil showed that the soil can be classified as sandy loam based on textural classification.

pH is an important parameter, as it regulates most of the biological and chemical reaction in soil (Ahaneku and Sadiq, 2014). While high soil pH can stabilize soil toxic

Table 1: Physicochemical parameters of soil in the study area

Parameters	Mean Value
Sand (%)	74
Silt (%)	9
Clay (%)	17
pH	6.9
Organic Carbon (g/kg)	14
Available Phosphorus (mg/kg)	21
Potassium (Cmol/Kg)	0.40
Total Nitrogen **(%)**	1.42

elements, pH value of less than 5.5 poses a threat to most microbial activities (Li et al., 2005; Solomon, 2008). The soil used for the experiment has a mean pH value of 6.9 showing its tendency for considerable stabilization of the soil and a probable consequent of low absorbability of the metal elements from the soil solution by the plant, as opined by Ogbemudia and Mbong (2013).

The presence of organic carbon (14 g/Kg) in the soil can also favour increase in leaching of some heavy metals from the soil (Carmona et al, 2008).

The presence of phosphorus (21 mg/kg), potassium (0.40 Cmol/kg) and nitrogen (1.42%) also indicated good quality of the soil for agricultural purposes.

The potential of fluted pumpkin plant in removing chromium and nickel from contaminated soil was evaluated. The average concentration of Cr and Ni in soil sample at week zero (initial stage) was 0.11 mg/kg and 0.028 mg/kg for the control, 0.94 mg/kg and 0.83 mg/kg for soil contaminated with 1g/dm^3 and 2.96 mg/kg and 2.29 mg/kg for 3g/dm^3 contaminated soil sample respectively (Figure 1). The values observed in the control showed the presence of the two heavy metals in the uncontaminated soil, though at small amount. The low value observed for Ni and Cr content in the control sample was not unexpected as soil with neutral pH value are usually low in heavy metal contents particularly Ni content as opined by Cempel and Nikel (2006).

This result agrees with the findings of Ahaneku and Sadeeq (2014) which claimed that some heavy metals are present in agricultural soils of Gidan kwano.

The observed mean concentration at the end of week 2 showed a reduction in the Cr and Ni concentration in each of the three samples (Figure 2). The control sample has a value of 0.09mg/kg for Cr and 0.02mg/kg for Ni. The values of the metals in soil contaminated with 1g/dm^3 reduced to 0.51 mg/kg and 0.49 mg/kg, while the values in soil contaminated with 3 g/dm^3 reduced to 2.1 mg/kg and 1.37 mg/kg for Cr and Ni respectively. This showed a probable transport of the metal into the plant via the root. While the amount lost in each of the samples varies, the highest reduction was recorded in soil samples with highest concentration (3g/dm^3) for both metals. This suggests that the higher the concentration of the contaminant in the soil, the more the pollutant transported to the plant

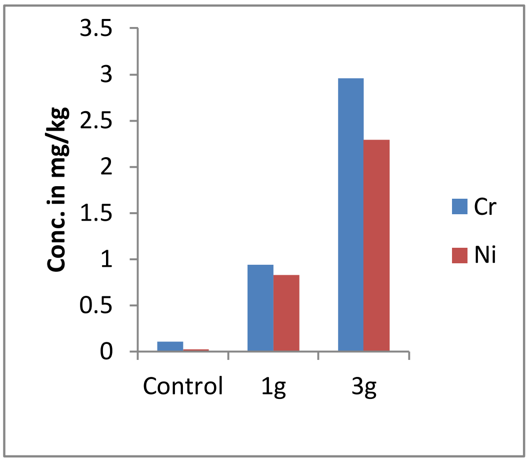

Figure 1: Sample at week 0

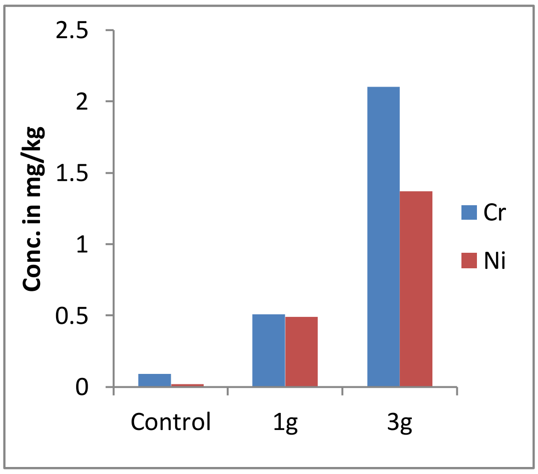

Figure 2: Sample at week 2

The result of the soil analysis at the end of 4th week of the experiment showed a further reduction in Cr and Ni content of the soil samples. The mean concentrations of Cr and Ni in the control sample were 0.07 mg/kg and 0.013mg/kg respectively (Figure 3). At 1g/dm^3 contamination the respective mean concentrations of Cr and Ni were 0.27 mg/kg and 0.22 mg/kg while at 3g/dm^3 contamination 1.46 mg/kg and 1.09 mg/kg were recorded for Cr and Ni respectively.

At the end of 6th week of experiment, the average concentrations of Cr and Ni in the control sample were 0.06mg/kg and 0.009mg/kg respectively (Figure 4). The average mean of Cr and Ni at 1g/dm^3 contamination was 0.12 mg/kg and 0.11 mg/kg respectively, while at 3g/dm^3 contamination; 1.08 mg/kg was recorded for Cr and 0.64 mg/kg for Ni. Likewise, the average mean level of Ni at 1g contamination was 0.11mg/kg while at 3g contamination was 0.64 mg/kg. These results showed a continuous reduction in the amount of Cr and Ni in both the controlled and the contaminated soil, indicating more quantities of both metals have probably been absorbed by the fluted pumpkin plant.

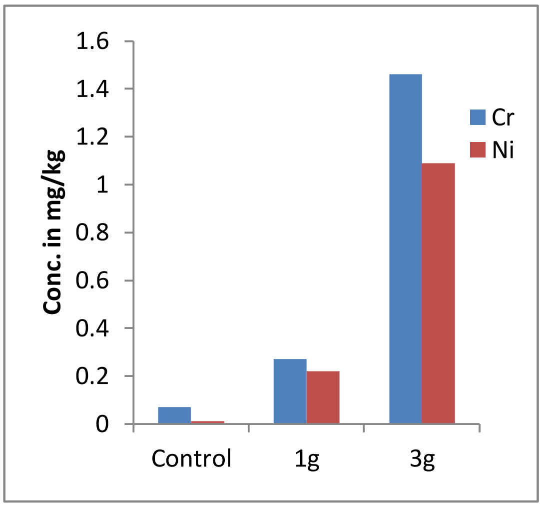

Figure 3: Sample at week 4

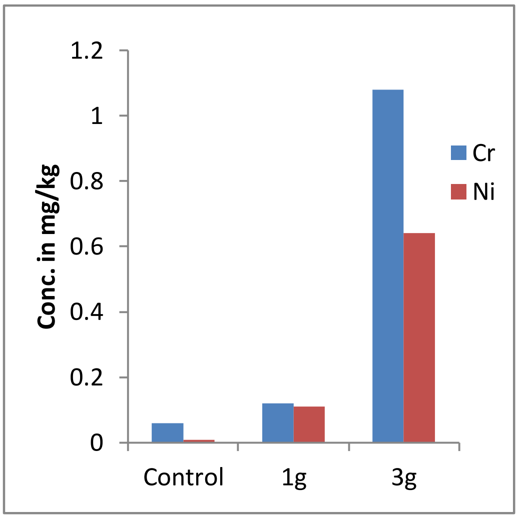

Figure 4: Sample at week 6

At end of 8th week of experiment, the mean concentrations of Cr and Ni in the control sample of the soil were 0.04mg/kg and 0.007 mg/kg respectively (Figure 5). The mean concentration of both Cr and Ni at 1g/dm^3 contamination was 0.0 6mg/kg (both having the same value). At 3 g/dm^3 contamination, Cr was 0.69 mg/kg while Ni was 0.31 mg/kg. The results obtained at the end of every two weeks up to week 8 showed consistence

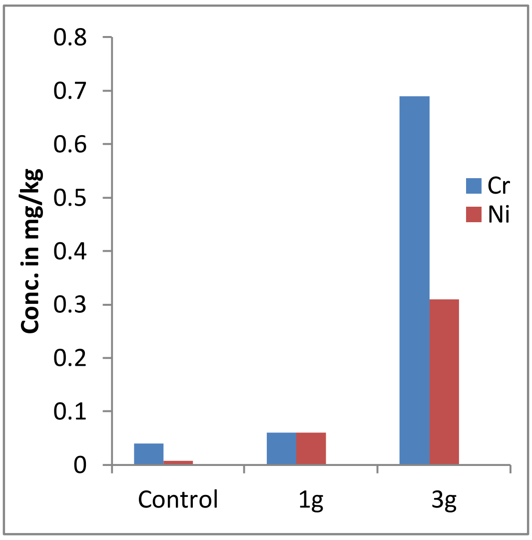

Figure 5: Sample at week 8

reduction in the amount of the heavy metal in the soil samples.

Though, the growth of fluted pumpkin plant was not distorted, the amount of heavy metals lost in the soil has probably been absorbed by the plant.

The parts of the harvested plant (leaf, stem and root) were analysed for heavy metal presence at the end of the week 8. The average mean value of Ni in the leaf, stem and root of the control sample was 0.01 mg kg-1 (all assuming the same mean value). At 1g contamination, the leaf, stem and root have mean values of 0.28 mg kg-1, 0.22 mg kg-1 and 0.20 mg kg-1 respectively for Ni content, while at 3g contamination, the leaf, stem and root have mean values of 1.06 mg kg-1, 0.59 mg kg-1 and 0.33 mg kg-1 respectively (Figure 6).

The Cr content in the leaf, stem and root of the control sample was 0.03 mg kg-1, 0.02 mg kg-1 and 0.01 mg kg-1 respectively. At 1g contamination, the leaf, stem and root have mean values of 0.32 mg kg-1, 0.24 mg kg-1 and 0.19 mg kg-1 respectively for Cr content and at 3g/dm^3 contamination, the leaf, stem and root has mean values of 1.28 mg kg-1, 0.70 mg kg-1 and 0.2 mg kg-11 respectively for Cr content (Figure 7).

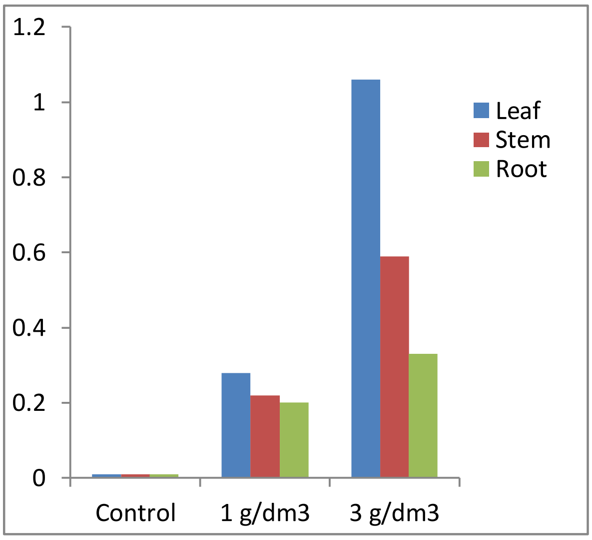

Figure 6: Concentration Nickel of in Plant Part

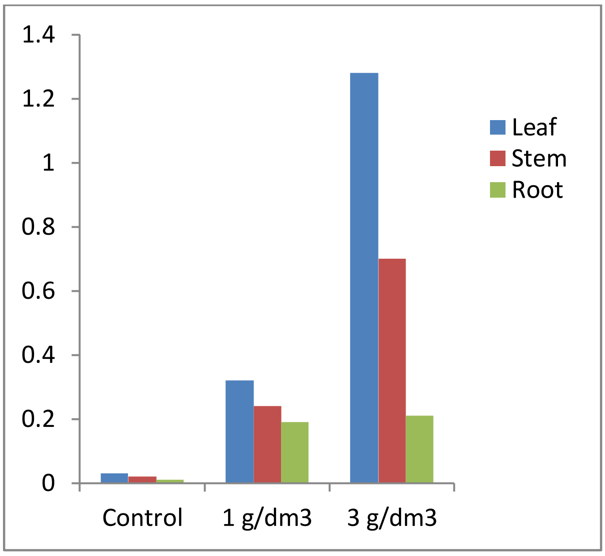

Figure 7: Concentration of Chromium in Plant Part

The results showed that though, the heavy metals are present in the aerial parts and root of the plant, the distribution varies. The leave accumulated higher contents of both metals followed by stem and root in a respective order. The results agree with the finding of Cullaj et al. (2004) and Bada and Olarinre (2012).

3. CONCLUSION

This work demonstrated the use of fluted pumpkin plant for phytoremediation of nickel and chromium. It was noted that the higher concentration of the metals (Ni and Cr) are stored in the leaves. The results of the finding also showed that the higher the concentration of the available metals, the more the uptake by the plant. It thus implies that fluted pumpkin plant meant for consumption by man or even animal should not be cultivated on highly polluted soils to avoid excess intake of the metals either directly or through food chain. More so, the study showed that the pH of the soils for cultivating fluted pumpkin plant should not be acidic to control or reduce uptake of the metals by the plant. Though, the plant uptake the two metals, it showed a relatively tolerance for nickel.

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