INFLUENCE OF SOME SOIL PROPERTIES ON THE UPTAKE OF LEAD AND CHROMIUM BY *Telfairia occidentalis*

Orhue, R. E.
Uzu, F.
Department of Soil Science, Faculty of Agriculture
University of Benin, Benin City, Edo State, Nigeria
** E-mail: orhuerob@yahoo.com*

ABSTRACT

Trials were conducted between September and December in the year 2009 to determine the relationship between some soil properties and heavy metal uptake by Telfairia occidentalis using correlation coefficient (r) analysis. In the greenhouse, soil sample collected from surface 0-15 depth of soil was bulked mixed thoroughly, air dried, sieved and thereafter 5 kg weighed and put in each of the 96 pots. Each of the heavy metals (chromium nitrate Cr (N03)2 .9H20 and lead nitrate Pb (N03)2) was applied at 0, 50, 100, 200 mg per 5 kg soil. While in the field, the heavy metal rates of 0, 20, 40, 80 kgha-1 equivalents to 0, 50,100,200 mg per 5 kg soil were used in a treatment combination of 2 x 4 factorial organized in Randomized Complete Block Design in three replicates and each replicate had 32 pots. Results revealed that the soil pH, amorphous Al oxide, amorphous Fe oxide, free Al oxide, free Fe oxide, available Phosphorus (P), effective cation exchange capacity, organic carbon (C), sand, silt and clay negatively correlated with lead (Pb) and chromium (Cr) uptake by the plant and were significant at (P<0.05) level of probability. Also, revealed that increase in these soil properties decrease the uptake of these metals. Therefore, it is advisable to maintain these soil properties at higher levels to reduce the heavy metal uptake by Telfairia occidentalis

Key words: *chromium correlation, lead, Soil, uptake, ultisol,*

INTRODUCTION

Specific soil properties such as soil pH, oxides, organic matter, Calcium (Ca), phosphorus (P), clay etc. have been identified to influence heavy metal concentrations in the soil and uptake by plants. The clay fraction of most soils tends to accumulate heavy metals because the clay size particles have a large number of ionic binding sites due to higher amount of surface area (Boon and Soltanpour 1972) resulting in the immobilization of heavy metals.

Silts are also able to accommodate heavy metals because of their decreased sizes and specific surface area (Zhang et al., 2003) and the lowest concentrations of total and available heavy metals are found in sandy soils because heavy metals in sandy soils are readily transported to surface water with suspended particles. Higher levels of Calcium ion (Ca^{2+}) decrease the amount of most heavy metals that is assimilated by plants (Larlson et al., 2000) due to small size of Calcium ion (Ca^{2+}), which is indistinguishable from most of the heavy metals. The presence of Calcium (Ca) tends to aid increase in soil pH level making most of the heavy metals to precipitate. Soil pH seems to have the greatest effect of any single factor in the solubility or retention of metals in soils.

The P also precipitates metal ions by forming complex compounds. Heavy metals and their derivatives are retained by interaction with organic matter (Tan, 1996) due to the presence of functional groups such as the carboxyl (COOH) and hydroxyl (OH), which aid to drive the complex reactions in the organic matter. The oxides help clean or acts as efficient sink for heavy metals due to oxide higher specific surface area (Silveira et al., 2005). The test plant is widely cultivated for its leaves and seed consumption in tropical African. The soils used for the cultivation is often not investigated or analysed to know the entire heavy metal components. Therefore, this study was aimed at knowing the relationship between the heavy metal uptake and some soil properties using correlation coefficient (r) analysis.

MATERIAL AND METHODS

The greenhouse and field trials were conducted between September and December 2009 at the experimental site of Faculty of Agriculture, University of Benin, Benin City, Nigeria. In the greenhouse study, soil samples were collected from surface 0-15cm depth of soil at University of Benin. The samples collected were bulked, mixed thoroughly air dried and sieved to remove debris. Thereafter, 5 kg of the composite soil was weighed and put in each of the plastic pots. A total number of plastic pots used were 96. The experiment was 2 x 4 factorial laid in a completely randomized design with three replicates. Each replicate had 32 plastic pots with 4 pots per treatment. The heavy metals used were chromium nitrate Cr (N03)2 .9H20 and lead nitrate Pb (N03)2. Each of these was applied at 0, 50, 100, 200 mg per 5 kg soil. The applied heavy metal was thoroughly mixed with the soil and then left for 7 days to enable the heavy metals equilibrate with the soil. Before transplanting the seedlings, the soil was moistened to field capacity with distilled water. The plants were watered with distilled water throughout the period of crop growth. At 30 days after transplanting, the shoot was clipped at soil level with stainless steel blade to separate the root. The root was carefully rinsed in distilled water. Both the root and shoot was dried in a ventilated oven at 72oC for 48 hrs to constant dry weight used in computing the heavy uptake.

The field trial was conducted in order to validate results obtained under greenhouse conditions. This field trial was sited where the soil for greenhouse trials was taken. The heavy metal rates of 0, 20, 40, 80 kgha-1 equivalent to 0, 50,100,200 mg per 5 kg soil were used. The treatment combination was 2 x 4 factorial organized in Randomized Complete Block Design in three replicates. Each treatment was represented by a bed size of 5 m x 5 m separated by 50 cm space while each replicate was separated by 1m alley. The entire experimental site was 45.50 m x 19 m giving a total area of 864.5m2..The various levels of the heavy metals were uniformly applied with the aid of a spreader, mixed thoroughly and then left for 7 days before transplanting the seedlings. The pumpkin was sown at a spacing of 1m x 1m.Each bed had a plant population of 16 plants per bed. Hand weeding was done regularly. The mode of data collection was similar to that of greenhouse trial.

The soil pH was determined at a soil to water ratio of 1:1 using a glass electrode pH meter. Particle size analysis was determined by the hydrometer method of Bouyoucos (1951) as modified by Day (1965).The organic carbon and N content of the soil were determined by using the chromic acid wet oxidation procedure and micro-kjeldal procedure respectively as described by Jackson (1962). Phosphorus was extracted by using Bray No. 1 P solution (Bray and Kurtz 1945) and the P in the extract assayed colorimetrically by the molybdenum blue colour method of Murphy and Riley (1962). The exchangeable bases were extracted using IN neutral ammonium acetate solution. The Calcium (Ca) and Magnesium (Mg) content of the extract were determined volumetrically by the EDTA titration procedure (Black, 1965). The Potassium (K) and Sodium (Na) were determined by flame photometry and magnesium content obtained by difference. This was determined by Potassium chloride (KCl) extraction and titration methods of Mclean (1965). The effective cation exchange capacity was calculated as the sum of exchangeable bases (Ca, Mg, K, and Na) and exchangeable acidity. The heavy metals and oxides were determined by methods of Soon and Abboud (1993).

The lead (Pb) and chromium (Cr) were determined by the use of atomic absorption spectrophotometer after digesting in a mixture of nitric acid (HN03), sulphuric acid (H2SO4) and perchloric acid (HCI04) (IITA, 1979) The data generated were subjected to correlation coefficient (r) analysis.

RESULTS AND DISCUSSION

Table 1 shows the properties of soil used in the trial. The soil contained low nutrient content and low base saturation typical of an ultisol. It was texturally sandy loam and moderately acidic. The correlation coefficient (r) between the heavy metal uptake and some soil properties are shown in Table 2. The uptake of these heavy metals by the plant was influenced by some soil factors as shown by the correlation coefficient (r) analysis. The result indicated negative correlation between the heavy metal uptake and soil pH, Amorphous Al and Fe oxides; Free Fe and Al oxides, available Phosphorus (P), effective cation exchange capacity, organic carbon, sand, silt and clay properties of the soil and were significant at ($P<0.05$) levels of probability. This negative correlation indicates that an increase in these soil factors leads to decrease in the uptake of the heavy metals.

Soil pH negatively correlated with the uptake of the heavy metals in the study. Soil pH affects not only metal bioavailability but also the very process of metal uptake into the roots. Soil pH also plays a major role in the sorption of heavy metals as it directly controls the ability of metal hydroxides, metal carbonates and phosphates. This result of negative correlation between soil pH and the heavy metals further strengthen the earlier results of Altin et al (1999), McBride (1994), Appel and Ma (2002) and Brown et al (1995).

The negative correlation between the uptake of these metals and soil organic fraction is similar to the earlier findings of Silveira et al (2005). The soil organic fraction is a recognized sites for metals due to the presence of legends such as phenolic (Ph-0H) and carboxylic (-COOH) groups in and higher humic and fulvic acids which form complex compounds with metals at a wide range of soil pH.

The negative correlation between oxides and the heavy metal uptake may be due to the ability of oxides to act as efficient sink for the heavy metals. Similar findings have earlier been reported by Martinez and McBride (1998) and Fan et al (2004) Silveira et al (2005) that oxides high specific surface area used for the adsorption of the heavy metals.

This negative correlation established between P and uptake of the heavy metals may be attributed to the complex formation of the metals with P leading to the precipitation of metal ions. Similar result have been reported by Blaylock and Huang (1999) that Pb a major soil contaminant was notorious for lack of mobility, primarily due to precipitation as insoluble phosphates earlier reported. Chaney et al (2000) who obtained similar result also reported that the addition of Phosphorus (P) fertilizer could lead to metal precipitation as pyromorphite and chloropyromorphite. Such mechanisms may have occurred in the soil used hence the negative correlation between the heavy metals and its uptake.

There were also negative correlation between effective cation exchange capacity (ecec) and the heavy metal uptake. The effective cation exchange capacity is directly related to the soil capacity of absorbing heavy metals. The greater the ecec values, the more exchange sites on soil minerals for metal retention hence the negative correlation. The presence of competitive cations can also affect metal adsorption in soils. Similar results of ecec negative correlation with metal uptake have earlier been reported by Silveira et al (2005).

The sand, silt and clay were also negatively correlated which means that as sand, silt and clay increase, the uptake of these metals by Telfairia decrease. Similar result with sand have been reported by Ferrara et al (2003) that the lowest concentration of total and available heavy metals are found in sandy soils due to the fact that heavy metals in sandy soils are readily transported to surface water with suspended particles. This result of clay negative correlation with heavy metal uptake is in accordance with earlier findings of Kabrala and Singh (2001) that metals incorporated in crystalline lattices of clay appear inactive that the clay content have been found to be one of the most soil properties and components influencing labiality and biological uptake of heavy metals as demonstrated in the negative correlation. Also this result is similar that of Zhang et al (2003) that the clay and silt are able to accommodate heavy metal because of their decreased aggregate sizes and specific surface area and strong ionic bonds formed between the metals and the clay particle and it is only acidic conditions that do cause desorption of these metals into solution making them available for uptake by plants.

CONCLUSION

The greenhouse trials were conducted between September and December 2009 to determine the relationship between some soil properties and heavy metal uptake by Telfairia occidentalis using correlation coefficient (r) analysis. Soil samples collected from surface 0-15 depth of soil was bulked mixed thoroughly, air dried, sieved and thereafter 5 kg weighed and put in each of the 96 pots. The soil properties determined negatively correlated with the uptake of Cr and Pb by Telfairia occidentalis. The implication of this is that increase in these soil properties decreases the uptake of these metals. Therefore, it is advisable to maintain these soil properties at higher levels to the reduce heavy metal uptake by Telfairia occidentalis.

Table 1: Physico-chemical properties of the soil used in the trials

Properties	Greenhouse	Field
pH(1:1)	4.71	5.64
Organic carbon (gkg-1)	11..1	10.0
Total N (gkg-1)	1..3	1.6
Av P(mgkg-1)	3.19	5.76
Ca cmol kg-1	0.96	0.97
Mg cmol kg-1	0.64	0.66
K cmol kg-1	0.11	0.13
Na cmol kg-1	0.12	0.20
Exch Acidity cmol kg-1	3.58	2.68
ECEC cmolkg-1	5.41	3.93
Base saturation (%)	33.23	31.21
Free Fe Oxides %	6.38	6.40
Free Al Oxides %	1.73	1.21
Amorphous Fe oxide %	0.07	0.08
Amorphous Al oxide %	0.03	0.03
Pb mgkg-1	0.3	0.04
Cr mgkg-1	0.02	0.02
Fe mgkg-1	0.03	0.04
Mn mgkg-1	0.05	0.05
Zn mgkg-1	0.65	0.67
Sand gkg1	865.31	864.32
Silt gkg1	12.39	14.37
Clay gkg1	122.30	121.31
Textural class	Sandy loam	Sandy loam

Source: Fieldwork, 2009

Table 2: Correlation coefficient (r) between Pb and Cr uptake by Telfaira occidentalis and some soil factors in the trials

	Greenhouse Trial		Field Trial	
Soil properties	Pb uptake*	Cr uptake*	Pb uptake*	Cr uptake*
Soil pH	-0.999	-0.998	-0.998	-0.998
Amorphous Al oxide	-0.990	-0.996	-0.882	-0.991
Amorphous Fe oxide	-0.945	-0.949	-0.992	-0.990
Free Fe oxide	-0.997	-0.983	-0.997	-0.998
Free Al oxide	-0.999	-0.995	-0.997	-0.999
Available P	-0.986	-0.969	-0.998	-0.991
ECEC	-0.997	-0.989	-0.998	-1.000
Organic carbon	-0.999	-0.997	-0.997	-0.998
Sand	0.999	-0.998	-1.000	-1.000
Silt	-0.977	-0.997	-0.995	-0.993
Clay	-0.999	-0.999	-1.000	-1.000

* Significant at $(P< 0.05)$

REFERENCES

Altin O., Ozbelge H., and **Dogu T**. (1999). Effect of pH, flow rate and concentration on the sorption of Pb and Cd on montmorillonite: 1. Experimental. *Journal of Chemical Technology and Biotechnology,* 74: 1131-1138.

Appel, C. and **Ma, L.** (2002). Concentration, pH and surface charge effects on Cadmium and lead sorption in three tropical soils. *Journal of Environmental Quality,* 31:581- 589.

Black, C. A. (1965). Methods of soil analysis. Agronomy No 9 Part 2 America Society of Agronomy Madison, Wisconsin.

Blaylock, M. J. and **Huang, J. W.** (1999). *Phytoextraction of metals.* In Rasken, B. and Evisley D (eds) *Phyto-remediation of toxic metals: Using plants to clean up the Environment.* New York: John Wiley.

Boon, D. Y. and **Soltanpour, P. N** (1972). Lead, cadmium and Zinc contamination of Aspen garden soils and vegetables. *Journal of Environmental Quality,* 21: 82-86.

Bouyoucos, G. J. (1951) A recalibration of hydrometer method for making mechanical analysis of soil. *Agronomy Journal,* 43: 34-39.

Bray, R. H. and **Kurtz, L. T.** (1945)Determination of total organic and Available forms of phosphorus in soils. *Soil Science,* 59: 39-48.

Brown S. L., Chaney R., Angle J. J. and **Raker A. J. M.** (1995) Zinc and cadmium uptake by hyperaceumulator Thlaspsi caerulescens and metal tolerant Silene vulgaris grown on sludge-amended soils. *Environmental Science and Technology,* 29:1581- 1585.

Chaney R. L., Brown S. L., Li, Y. M., Angle J. S., Reeves R. D., Malik M. and **Chin M.** (2000). *Progress in risk assessment for soil metals and insituremediation and phytoextractions of metals from hazardous contaminated soils.* In Terry N. and Baielos G. (ed) *Phyto-remediation of contaminated soil and water.* Boca Raton: Lewis Publishers, FL. 129-158.

Day, P. R. (1965). *Particle fractionation and particle size analysis.* In Black, C.A. (ed) *Methods of soil analysis: Agronomy No 9 Part 1.* Wisconsin: American Society of Agronomy Madison.

Fan M. T., Boonfuene I., Xu Y., Axe L. and **Tyson T. A**. (2004). Modeling Pb absorptions to microporous amorphous oxides as discrete particles and coatings. *Journal of Colloid interface science*, 281, 39 - 48.

Ferrara G., Brunneti G., Sensi N., Mondelli D. and **Ghezza V. L.** (2003). Total and potentially phytotoxic trace metals in southeastern Italian soils. *Food, Agriculture and Environment,* Vol. 1(1), 279-286.

International Institute of Tropical Agriculture (IITA) 1979 Selected methods for soil and plant analysis. Manual Series No 1. pp70.

Jackson, M. L. (1962). *Soil chemical analysis.* New York: Prentice Hall.

Kabrala, C. and **Singh, R. R.** (2001). Fractionation and Mobility of Copper, Lead and Zinc in soil profiles in the vicinity of a copper smelter. *Journal of Environmental Quality,* 30:485-492.

Larlson J., Likenss G., Fitzpatrick J. and **Coock J.** (2000). Cadmium toxicity among wildlife in Colorado rocky mountains. *Nature,* 406, 181-183.

Martinez, C. E. and **McBride, M. B.** (1998). Solubility of Cd, Cu, Pb and Zn in aged coprecipitates with amorphous iron hydroxides. *Environmental Science Technology,* 32, 743-748.

McBride, M. B. (1994). *Environmental Chemistry in Soils.* Oxford: University Press.

McLean, E. O. (1965). *Aluminium.* In Black C.A (ed) Methods of soil analysis: Agronomy No 9 Part 2. American Society of Agronomy 978-998.

Murphy, J. and **Riley, J. P.** (1962). Analytical chemistry. *Acta* 27:31-36.

Soon, Y. K. and **Abboud, S.** (1993). Cadmium, chromium, lead and nickel. In Carter M. R. (eds) Soil sampling and methods of soil analysis. *Canadian Society of Soil Science,* 101-108

Silveira M. L. A., Alleoni L. R. F. and **Guilhherme L. R. G.** (2005). Biosolids and heavy metals in soils. *Scienta Agriccola,* 60: 793-806

Tan, K. H. (1996). *Environmental soil science.* New York: Macel Dekker.

Zhang M. K., He Z. L., Calvert D. V., Stofella P. J., Yang V. E. and **Le Y. C.** (2003) Phosphorus and Heavy Metal Attachment and Release in Sandy Soil Aggregate. Oxford: University Press.