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HEAVY METALS STATUS OF SOIL AND THEIR UPTAKE BY FLUTED PUMPKIN (*Telfairia occidentalis* Hook F) CULTIVATED ALONG IKPOBA RIVER BANK, BENIN CITY

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ABSTRACT

This study was carried out to assess the status of heavy metals in the soil and fluted pumpkin cultivated on the bank of Ikpoba River at Benin City. The sample area was 9000 m^2. Soil samples were collected at 0-30 cm and 30-60 cm depths at 30 locations giving a total of 60 samples. The plants were also sampled along with the sampling of the soils giving a total of 30 plant samples. Similar numbers of soil samples along with 30 plant samples were collected at University of Benin demonstration farm, a distance of about 10 km away from the river bank to represent the control. Samplings were carried out during dry and rainy seasons. Result showed that the Fe, Cu, Mn and Cr content of soil increased significantly with increasing depth in both the control and river bank during dry and rainy seasons. The content of Fe, Cu, Mn and Cr in river bank soil was however, higher during dry season compared to that of control and rainy season. The Cd component of the river bank soil was minimal and fairly stable with increasing soil depth during dry and rainy seasons. The Cd was however not detected in the control soils. The Pb content of the river bank soil decreased with increasing depth during dry and rainy seasons while in the control sites, the Pb was below detectable level during the dry and rainy seasons. Significantly, higher contents of Fe, Cu, Mn, Cr, Cd and Pb and their uptake by fluted pumpkin at river bank were recorded compared to uptake by plants at the control sites. The sand correlated negatively with Cr, Cd and Pb uptake by the plant while the clay and soil pH correlated negatively with the uptake of Fe, Cu, Mn, Cr, Cd and Pb. The silt and organic matter however correlated positively with the uptake of Fe, Cu, Mn, Cr, Cd and Pb by the plant. The transfer Factor was higher in Cu compared to other metals.

INTRODUCTION

Food production and its attendant security is an aspect of a nation's economic stability and is a measure for any growing economy. Food and vegetable production in developing and under developed countries require access to fertile land, uncontaminated water and in some cases chemical fertilizers (Abdullahi *et al.*, 2007). Sometimes, the land and water available to farmers especially in the urban area are contaminated. One of the major contaminants is the heavy metals. The anthropogenic sources of these heavy metals include burning of fossil fuels, smelting, and application of inorganic fertilizers, industrial wastes such as battery, plastic, paint and steel industries e. t. c. Heavy metals may enter the food chain from the soil through uptake by crops or environmental contamination as in application of agricultural inputs such as pesticides, fertilizers or use of polluted river water as means of irrigating crops (Onianwa *et al.*, 2001; Audu and Lawal, 2005). In few concentrations, many metals are essential to life but in excess the same chemicals can be poisonous (Karshif *et al.*, 2009). Some of these heavy metals are not needed at all by man because they are perpetually dangerous to man. Such heavy metals include Cd, Pb, As and Hg etc.

Ikpoba River is one of the major rivers that ran across Benin City metropolis and all the wastes end up in this river. Oguzie (2002), Obasohan *et al.* (2008) and Oguzie and Okhagbuzo (2010), have earlier reported higher concentrations of various heavy metals in Ikpoba River water. Along the stretch of the bank, horticultural crop productions are carried out at both rainy and dry seasons. In dry season, the river serves as means of irrigation for the cultivation of assorted vegetables of which fluted pumpkin is a major horticultural crop. Vegetables irrigated with such contaminated water may pose a great threat to mankind. The fluted pumpkin constitutes an important part of human diet in Benin City because of the nutritive value. This vegetable has not been investigated to know the total amount of heavy metals before consumption or disposing into the market for sales. Therefore, this study was carried out to determine the level heavy metals in the crop and the river bank soil.

MATERIALS AND METHODS

The trial was conducted in Benin City. Benin City which lies within latitude of 6.5^o N and longitude 5.8^o E is characterised by dry and rainy seasons with mean annual temperature and rainfall of 32 ^oC and 2300 mm respectively. Rainy season is April-October while the dry season is September-March. It has a mean relative humidity of about 70 %. The study was carried out on fluted pumpkin farmland occupying an area of 9000 m^2 on the bank of Ikpoba River, Benin City. Soil samples were collected at 0-30 cm and 30-60 cm depths at 30 locations giving a total of 60 samples. The fluted pumpkin plants were also collected from the corresponding spots. Similar numbers of soil samples along with 30 plant samples were collected at University of Benin demonstration farm, a distance of about 10 km away from the river bank to represent the control. Samplings were carried out during dry and rainy seasons in December, 2010 and July, 2011 respectively. The collected plant samples were packaged in paper bags and labelled. These were immediately taken to the laboratory for processing. In the laboratory, the plant samples were washed with tap water and thereafter with distilled water and then oven dried in the oven at 78 ^oC for 48 hours to a constant weight used in computing heavy metals uptake. Soil samples from each site were air-dried for 7 days. Particle size distribution was determined by hydrometer method procedure of Rayment and Higginson (1992), while soil pH was measured potentiometrically in 1: 1 soil–water ratio. Soil organic carbon was estimated by method of Udo *et al.* (2009).

The air-dried soil samples were sieved to pass through 2 mm sieve while the plant samples were ground (< mm). Thereafter, 2 g of each sample was digested using 20 ml of concentrated mixture of HNO_3, $HCIO_4$ and H_2SO_4 in 2:1:1 ratio on temperature controlled hot plate. When the volume was reduced with clear digested solution, the contents were allowed to cool and transferred to a 50 ml volumetric flask. The volume was made up to the mark. The Fe, Cu, Mn, Pb, Cr and Cd were determined by atomic absorption spectrophotometer (AAS UNICAM 969 Model). The heavy metal uptake by the plant was calculated as follows: Heavy mental content (%) x Dry weight of plant (g). The Transfer factor (TF) for each metal was calculated according to the following formula: TF = Ps ($ug\ g^{-1}$ dry weight) /St ($ug\ g^{-1}$ dry weight) where Ps is plant contents originating from soil and St is the metal contents in soil (Harrison and Chingawi, 1989). Data collected were analysed by Genstat statistical version 6. 1. 0. 234 (Payne, 2002).

RESULTS AND DISCUSSION

Soil physico-chemical properties

The river bank and the control sites were dominated by high % sand followed by % clay fraction and then the % silt fraction (Table 1). Both the river bank and the control sites were acidic while the river bank soils had high organic matter compared to control.

Heavy metals concentration in the soils

Heavy metal components of the river bank and control soils in both the dry and rainy seasons are shown on Tables 1 and 2 respectively. The Fe, Cu, Mn and Cr significantly ($P< 0.05$) increased while the Pb decreased with increase in soil depth of the river bank sites during dry and rainy season's cultivation of the crop. In the control sites, the Pb content was below detectable level in both growing seasons. While the Cd content of the soil was fairly stable in the river bank and below detectable level in control area during dry and rainy seasons. The heavy metal components of the river bank soils were significantly ($P< 0.05$) higher than those of the control. Generally, high amount of metals were recorded in dry season in the river bank than the rainy season. The trend of occurrence of heavy metals in the studied soils and control revealed that the river bank soils during season cultivation had Fe > Cu > Mn > Pb > Cr > Cd while the dry season control soils had Fe > Cu > Mn > Cr > Cd = Pb. In rainy season, the river bank soils had heavy metals in order of Cu > Fe > Mn > Pb > Cr > Cd whereas the control soils had Fe > Cu > Mn > Cr > Cd = Pb. The occurrence of these metals in both the river bank and control areas indicates common sources of these metals which could be related to known geochemical association between the metals. Similar results have earlier been reported by Owode *et al.* (2008). When the levels of these metals in the study area were compared with values reported in literature, the means of Cu, Fe, Mn, Cd and Pb were below the permissible limit of 100 $mgkg^{-1}$ (NEPM, 1999), 100 $mgkg^{-1}$ (USEPA,1986), 0.3 $mgkg^{-1}$ (WHO, 1984), 3 $mgkg^{-1}$ (MAFF,1992) and 50 $mgkg^{-1}$ (NEPM, 1999 and EC, 1986) respectively. Even though the Fe, Cu, Mn, Mn, Cd and Pb were below the permissible level, their persistent levels could result in high accumulation in soil with time. This high accumulation could bring about higher uptake by some crops cultivated on the soil. The Cr was however; higher than the WHO (1984) permissible level of 0.3 $mgkg^{-1}$.

Concentration of heavy metals in Telfairia occidentalis

The concentrations of the heavy metals in the *Telfairia occidentalis* plant during the dry and rainy season's cultivation are shown in Table 3. The result indicated that the concentrations of the metals during dry and rainy seasons in the river bank *Telfairia occidentalis* were significantly higher than those of the control sites. The occurrence of these metals in river bank in *Telfairia occidentalis* during dry season was in order of Fe > Cu > Mn > Cr > Pb > Cd while in control area, the metals was in order of Fe > Cu > Mn = Cr = Cd =Pb in the plant In rainy season, the river bank *Telfairia occidentalis* had the heavy metals concentrations was in order of Fe >Mn > Cu > Cr > Pb > Cd whereas in control, the order of metals concentrations was Fe > Cu > Mn > Cr = Pb >Cd. Similar result of high concentration of heavy metals in crops grown by the river bank have earlier been reported by Kashif *et al.* (2009) and Lawal and Audu (2011). The concentrations of Fe, Cu and Mn in the plant were discovered to be above the FAO/WHO (2001) and WHO/EU (1993) permissible limits of 0.3 $mgkg^{-1}$ during dry and rainy season cultivation in the river bank. The Cr was below the FAO/WHO (2001) recommended maximum limits of 2.30 $mgkg^{-1}$ while Cd and Pb were below the FAO/WHO (2001) permissible level of 0.3 $mgkg^{-1}$. In control sites during rainy season, only the Fe was found to be above the FAO/WHO (2001) permissible limit of 0.3 $mgkg^{-1}$ while the Cu, Mn, Cr, Cd and Pd were below the FAO/WHO (2001) recommended maximum limit of 0.3 $mgkg^{-1}$ in dry and rainy seasons

Uptake of heavy metals by Telfairia occidentalis

The uptake of the heavy metals by the plant is shown in Table 4. The uptake of Fe, Cu, Mn, Cr, Cd and Pb by *Telfairia occidentalis* during dry season in the river bank and control was higher than those of the rainy season at river bank site and control. In both dry and rainy seasons, the uptake of these metals was in order of Fe > Cu > Mn > Cr > Pb > Cd.

Correlation coefficient between the heavy metal uptake and soil physico-chemical properties

Table 5 reveals the correlation coefficient between sand, silt, clay, pH and organic matter components of the soils and heavy metal uptake by *Telfairia occidentalis*. The sand non-significantly correlated negatively with Cr, Cd and Pb and positively correlated with Fe, Cu and Mn. The silt and organic matter fractions of the soil correlated positively with all the heavy metals studied. The organic matter however, significantly ($P < 0.05$) correlated positively with Cu and Pb. The soil pH and clay non-significantly correlated negatively with Fe, Cu, Mn, Cr, Cd and Pb uptake. The implication of positive correlation is that, as the soil factor increases, the uptake of the heavy metal in question increases while the negative correlation indicates that as the soil factor in question decreases the uptake of the metal increases. Similar negative correlations of pH and clay with heavy metal uptake by plant have earlier been reported by Orhue (2008) and Orhue *et al.* (2011).

The Transfer Factors (TF) for the heavy metals from soil to Telfairia occidentalis

Table 6 shows the Transfer Factors (TF) of Fe, Cu, Mn, Cr, Cd and Pb from soil to *Telfaiaria occidentalis.* With the exception of Cu which falls within the Kloke *et al.* (1984) suggested ranges of 1-10, all other metals were below the range. The TF quantifies the relative differences in bioavailability of metals to plant or the efficiency of plant species to accumulate a given metal. Therefore, high Cu TF suggested that Cu is less retained in the soil than other metals. The efficiency of *Telfairia occidentalis* to accumulate the studied metals may be attributed to the presence of some soil factors such as sand, silt, pH and organic matter as revealed by the correlation coefficient.

CONCLUSION

This study revealed high accumulation of metals in the river bank compared to control sites during dry and rainy seasons. The concentration and uptake of the heavy metals by the fluted pumpkin were also higher at the river bank than the control. Therefore, continuous cultivation of fluted pumpkin may result to increased accumulation of heavy metals and consumption of this crop could cause long term potential health hazard to mankind.

Table 1: Heavy metals components (Mean ± STD) of the River bank and control soils during dry season

Soil Depth (cm)	Fe	Cu	Mn	Cr	Cd	Pb
	←			mg kg^{-1}		→
		River	Bank			
0-30	29.64 ± 0.02b	23.09 ± 0.09b	1.41 ± 0.01b	0.62 ± 0.02a	0.013 ± 0.001a	1.27 ± 0.02a
30-60	36.69 ± 0.02a	36.35 ± 0.02a	2.51 ± 0.02a	0.96 ± 0.0025a	0.013 ± 0.001a	1,18 ± 0.002b
			Control			
0-30	10.92 ± 0.02d	4.08 ± 0.02d	0.15 ± 0.01d	0.013 ± 0.001c	BDL	BDL
30-60	14.57 ± 0.02c	9.55 ± 0.02c	0.31 ± 0.01c	0.013 ± 0.001c	BDL	BDL

Mean values with the same letter(s) in the colum are not significantly different from one another at $P < 0.05$ BDL: Below Detectable Level STD: Standar Deviation

Table 2: Heavy metals components (Mean ± STD) of the River bank and control soils during rainy season

Soil Depth (cm)	Fe	Cu	Mn	Cr	Cd	Pb
	←			mg kg^{-1}		→
		River	Bank			
0-30	17.69 ± 1.00a	20.69 ± 0.01b	0.74 ± 0.02b	0.24 ± 0.02b	0.001 ± 0.00a	1.09 ± 0.015a
A30-60	18,86 ± 1.00a	24.58 ± 0.02a	0.98 ± 0.05a	0.56 ± 0.01a	0.001 ± 0.00a	0.46 ± 0.02b
			Control			
0-30	4.37 ± 0.01c	1.63 ± 0.03d	0.06 ± 0.02d	0.001 ± 0.00c	BDL	BDL
30-60	10.08 ± 0.02b	4. 78 ± 0.02c	0.25 ± 0.015c	0.001 ± 0.00c	BDL	BDL

Mean values with the same letter(s) in the colum are not significantly different from one another at $P < 0.05$
STD: Standard Deviation
BDL: below detectable level

Table 3: Concentrations (Mean ± STD) of heavy metals in *Telfairia occidentalis* during dry and rainy season

Study Site	Fe	Cu	Mn	Cr	Cd	Pb
	←		$\%^{-1}$			→
		Dry	Season			
River bank	1.46 ± 0.02a	0.64 ± 0.02a	0.61 ± 0.01a	0.12 ± 0.02a	0.001 ± 0.00a	0.011 ± 0.001a
Control	0.83 ± 0.01c	0.16 ± 0.02c	0.05 ± 0.01c	0.003 ± 0.001b	0.003 ± 0.00a	0.0003 ± 0.00c
		Rainy	Season			
River bank	1.22 ± 0.02b	0.34 ± 0.04b	0.43 ± 0.01b	0.007 ± 0.002b	0.0001 ± 0.00a	0.003 ± 0.001b
Control	0.42 ± 0.02d	0.08 ± 0.01d	0.03 ± 0.01d	0.0001 ± 0.00b	0.00005 ± 0.00a	0,0001 ± 0.00c

Mean values with the same letter(s) in the column are not significantly different from one another at $P < 0.05$
STD: Standard Deviation

Table 4: Uptake (Mean ± STD) of heavy metals by *Telfairia occidentalis* during dry season and rainy season in the sites

Study Site	Fe	Cu	Mn	Cr	Cd	Pb
	←		mg kg^{-1}			→
		Dry	Season			
River bank	1386.64 ± 1.00a	606.53 ± 1.00a	578.10 ± 0.10a	113.72 ± 0.02a	0.95 ± 0.01a	10.42 ± 0.002a
Control	665.08 ± 1.00c	128.21 ± 0.01c	40.07 ± 0.02c	0.24 ± 0.01c	0.24 ± 0.01b	0.24 ± 0.01c
			Rainy	Season		
River bank	1244.40 ± 1.00b	349.01 ± 1.00b	441.40 ± 1.00b	7.19 ± 0.19b	0.11 ± 0.01c	3.08 ± 0.02b
Control	366.03 ± 1.00d	69.72 ± 0.02d	26 .15 ± 2.00d	0.09 ± 0.01d	0.04 ± 0.01d	0.08 ± 0.001d

Mean values with the same letter(s) in the colum are not significantly different from one another at $P < 0.05$
STD: Standar Deviation

Table 5: Correlation coefficient (r) between some soil factors and uptake of the heavy metal by *Telfairia occidentalis*

Soil		Heavy	metal	uptake		
Factors	Fe	Cu	Mn	Cr	Cd	Pb
Sand	0.412	0.006	0.187	-0.123	-0.333	-0.025
Silt	0.313	0.692	0.496	0.360	0.949	0.782
Clay	- 0.793	-0.609	-0.667	-0.580	-0.392	-0.639
pH	-0.120	-0.543	-0.315	-0.762	-0.877	-0.649
Organic matter	0.867	0.996*	0.956	0.887	0.864	0.962*

- Significant at P < 0.05

Table 6: Transfer Factor of the heavy metals from the soils to *Telfairia occidentalis*

Heavy metals	Transfer Factors (Mean ± STD)
Fe	0.05 ± 0.05d
Cu	1.03 ± 0.0058a
Mn	0.43 ± 0.01b
Cr	0.19 ± 0.01c
Cd	0.01 ± 0.01e
Pb	0.01 ± 0.01e

Mean values with the same letter(s) in the column are not significantly different from one another at P < 0.05

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