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Residual Effect of Lead on Early Growth of Fluted Pumpkin (*Telfairia occidentalis* Hook F) in an Ultisol

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ABSTRACT: The greenhouse and field trials were carried out at Faculty of Agriculture, University of Benin, Benin City to find out the residual influence of Pb on some *Telfairia occidentalis* agronomic characters and soil chemical properties. The soils used were previously treated with 0, 50, 100, 200 mg per 5 kg soil in the greenhouse while 0, 20, 40, 80 $kgha^{-1}$ equivalent to that of greenhouse were used in the field trial. The soils were previously used for *Telfairia occidentalis* cultivation. The completely randomized and randomized complete block designs were used in greenhouse and field trials respectively. Results indicated that with the exception of N and K in the field trial all other soil nutrient components decreased inconsistently with increased Pb concentrations in the trials compared to pre-trial soil nutrient content. The Pb, N, P, K, Mg, Ca, Na, Fe, Mn, Zn and their uptake by the plant decreased significantly with increase in Pb concentrations. The crude protein content of the plant also reduced significantly with increased Pb concentrations. The dry matter yield, plant height, stem girth and number of leaves were depressed significantly by the Pb compared to the control. @JASEM

Keywords: Residual, effect, ultisol, excluder, growth, protein

The lead (Pb) is one of those heavy metals that is typically immobile in agricultural soils because of its low solubility and therefore accumulates in the upper soil horizons. This persistent Pb has been estimated to have a soil retention time of 150-5000 years (Shaw, 1990) and Carl (2002) reported that very little Pb move through the soil and can persist for a long time. The threat that Pb generally pose to human and animal health is aggravated by their long-term persistence in the environment (Begonia 2006). Higher Pb concentrations can result in higher levels of uptake by plants. This high Pb accumulation in soil and subsequent higher uptake by plant is an important exposure pathway for people who consume vegetable grown in Pb contaminated soils. Often, the condition level of Pb in garden soils is neither known nor documented before cultivation. Therefore, exposure to toxic levels of the Pb metals can occur.

The Pb has been known to retard growth and development of *Phaseolus vulgaris* (Haider *et al.,* 2006) alf-alfa, rye grass (Pinero *et al.,* 2002). The protein and N component of young pea plant have been reported to be reduced (Keresan *et al.,* 2001) while Ean *et al.,* (2002) recorded a decrease in Ca, Fe, Zn content of root tip of maize due to increase in Pb treatments. Geeblen *et al* (2002) reported a significant decrease in Ca, Fe, Mn and Zn uptake by *Phaseolus vulgaris* because of Pb application The fluted pumpkin (*Telfairia occidentalis*) is widely cultivated in the tropics for its highly nutritive seeds and leaves. Presently, this plant is cultivated in available soil especially abandoned dumpsites where heavy metal laden materials are in large quantities. This recent development calls for the study of influence of residual Pb on some soil chemical properties as well as growth of *Telfairia occidentalis*. So, the present study was undertaken to investigate the influence of residual Pb on some *Telfairia occidentalis* agronomic characters, nutrient content and their uptake and some soil chemical properties.

MATERIALS AND METHODS

Site of the Trial: The greenhouse and field trials were carried out at the Faculty of Agriculture experimental site, University of Benin, Benin City, Nigeria.

Greenhouse Trial: The soil used in this trial was previously used for the cultivation of fluted pumpkin in a trial organized in a completely randomized design with 3 replicates. In the previous trial, the following 0, 50, 100, 200mg $(PbNO_3)_2$ rates were used per 5 kg soil. Each replicate had 16 pots making 48 pots. For this residual trial, the 48 pots left for 12 weeks after the first trial were air-dried, sieved to remove debris. Thereafter, each pot moistened to field capacity before transplanting the 3 weeks old fluted pumpkin seedlings. Basal dressing of nitrogen-phosphorus-potassium (N-P-K) at 15 $kgha^{-1}$, 20 $kgha^{-1}$ and 15 $kgha^{-1}$ was applied as urea, single superphosphate and muriate of potash respectively. The plants were watered with distilled water throughout the period of growth and weeding done regularly. This residual trial was also organized in

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completely randomize design with 3 replicates. The plant height, number of leaves and stem girth were taken at 30 days after transplanting. Thereafter the aerial part was clipped at soil level with stainless steel blade to separate the roots. The roots were carefully rinsed in distilled water. The roots and shoots were oven dried in ventilated oven at 72^0C for 48 hours to constant dry weight used in computing the nutrient uptake.

Field Trial: The residual field trial was conducted in order to validate results obtained under greenhouse residual conditions. This residual field trial was sited where the soil for greenhouse was taken. The Pb levels of 0, 20, 40, 80 $kgha^{-1}$ were earlier used. The earlier randomized complete block design with 3 replicates was adopted. Each treatment represented by a bed size of 2.5m x 2.5m was separated by 50cm space while each replicate was separated by 1m alley. The entire experimental site of 12 m x 10 m gave area of 120 m^2

The beds used for the first trial were pulverized again after the removal of weeds and the 3 weeks old fluted pumpkin seedlings transplanted using spacing of 90 cm x 90 cm. Each bed had a plant population of 4 plants per bed. Hand weeding and watering done regularly. Similar greenhouse basal dressing with N-P-K was carried out in the field trial. The mode of data collection was similar to that of greenhouse trial.

Soil analysis: Soil samples were collected at the beginning and at the end of the trials to determine the following. In the field trial, soil samples were taken at a depth of 0-30 cm. 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 as modified by Day (1965).The organic carbon content of the soil was determined by using the chromic acid wet oxidation procedure as described by Jackson (1962). The nitrogen was determined by micro-kjeldal procedure 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 Ca and Mg content of the extract were determined volumetrically by the EDTA titration procedure (Black, 1965). The K and Na were determined by flame photometry and magnesium content obtained by difference. This was determined by 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 Pb was determined by methods of Soon and Abboud (1993).The data generated were analyzed by Genstat statistical version 6.1.0.234.

Plant Analysis: The plant materials were digested with a mixture of HNO_3, H_2SO_4 and $HClO_4$ acids (IITA, 1979). The mineral ions (Na, K, Ca, Mg, Fe, Mn, Zn and Pb) were determined by the use of atomic absorption spectrophotometer. For P content (A O A C, 1970) perchloric acid digestion (wet oxidation) method was used while the micro-kjeldal method of Jackson (1962) was used for N determination. The protein contents were determined using the method of Azmat and Haider, (2007).

RESULTS AND DISCUSSION

Table 1 reveals the properties of soil before the trials. The soil is moderately acidic and low in fertility which is typical of an ultisol. The N, P, K, for instance were below the critical level of 1.5 gkg^{-1}, 10-16 $mgkg^{-1}$, 0.18-20 $cmolkg^{-1}$ respectively (Enwenzor *et al,* 1979). The properties of soil after the trials are shown in Table 2. With the exception of N and K, in the field trial, all other mineral ions in both trials compared to pre-trial soil components (Table 1) decreased inconsistently at various levels of residual Pb concentrations. The Pb component of the soil increased with increased concentrations. This fluctuation in these nutrients may be tied to the uptake by the plant. While increase in N and K in the field trial may be attributed to the decomposition of the previous organic matter ploughed in the soil. Kachenko and Singh (2004) have earlier reported similar results while the high Pb component in the soil is because of its low solubility as earlier reported by (Carl, 2002).

Table 3 shows the mineral ions and their uptake by the plant. The N, P, K, Mg, Ca, Na, Fe, Mn and Zn components and their uptake by the plant decreased significantly with increased residual Pb concentration in the entire trial. The decrease in the nutrient content and uptake is due to their limited availability under the Pb condition. Similar results have earlier been reported by (Pinero *et al*, 2002) and (Eun *et al*, 2002). The Pb content and uptake by *Telfaria occidentalis* are depicted in Table 4. The Pb content and its uptake increased with increase in the concentration of residual Pb with significant differences recorded among various Pb concentrations. However, higher Pb accumulation was found in the root compared to the shoot. The low solubility of Pb may explain the reason for its high concentration in the root. This high accumulation of

Pb in the root makes the plant a metal excluder (Raskin *et al*, 1994). Some earlier researchers such as Davis and White (1981), Kachencho and Singh (2004) and Begonia (2006) found similar results in different broadleaf vegetable. The effect of residual Pb on the protein content of the plant is shown in Table 5. The percentage crude protein component of the plant decreased significantly with increased residual Pb concentrations of the soil. The decrease may be attributed to the reduction in most of the mineral ions needed for protein synthesis as reported earlier by (Azmat *et al*, 2006)**.** However, higher crude protein was found in the shoot than the root.

Table1: Chemical properties of the soil before the greenhouse and field trials

Heavy Metal	Rate mg/5kg soil	pH (H_20 1:1)	Org C gkg-1	Av P mgkg-	TN gkg^{-1}	Mg	Ca	K cmolkg-1	Exch acidity	ECEC	Na	Fe	Mn	Zn $mgkg^{-1}$	Pb
								Green house	Trial						
Pb	0	4.3	.9.2	3.65	0.6	0.28	0.90	0.04	3.07	4.28	0.02	0.01	0.03	0.32	0.002
	50	4.3	9.2	2.77	0.5	0.22	0.80	0.06	3.07	4.18	0.03	0.02	0.04	0.42	38.56
	100	4.6	8.8	4.21	0.4	0.31	0.61	0.05	3.00	3.99	0.02	0.02	0.04	0.40	70.01
	200	4.2	9.5	4.45	0.6	0.30	0.68	0.06	2.37	3.44	0.03	0.02	0.04	0.41	127.57
								Field	Trial						
Pb	0	6.5	9.8	4.56	1.1	0.36	0.28	0.02	0.17	1.60	2.30	0.02	0.03	0.28	0.003
	20	5.8	9.4	5.88	1.1	0.32	0.20	0.04	0.14	1.71	2.41	0.03	0.04	0.32	24.73
	40	5.5	8.4	5.55	1.1	0.31	0.27	0.03	0.13	1.82	2.56	0.03	0.04	0.34	55.82
	80	6.2	10.4	5.62	1.1	0.36	0.22	0.04	0.16	1.82	2.68	0.03	0.04	0.33	108.8

The effect of residual Pb on the plant height, stem girth, number of leaves and dry matter yield of the plant are revealed in Table 6. The average dry matter yield of the shoot and root also decreased with increase in the residual Pb in compared to control. In the greenhouse, significant differences were detected in root dry matter yield while in the shoot; no significant difference was recorded among the various Pb concentrations. The control was however significantly higher in both the shoot and root dry matter yield in the field trial. The adverse effect of Pb on the dry matter yield may be due to specific toxicity of Pb and antagonism of most nutrients (Azmat *et al.* (2006).

Table 2: Chemical properties of the soil after the greenhouse and field trials
Mean values with the same letter in the column are not significantly different from one another at $P < 0.05$

Heavy metal	Rate mg/5kg soil	pH(H_20 1:1)	Org C gkg^{-1}	Av P mgkg-1	Total N gkg^{-1}	Mg	Ca	K Cmolkg-1	Na	Exch acidity	ECEC	Fe	Mn	Zn mgkg-1	Pb
							Greenhouse								
Pb	0	4.19a	7.3a	1.94a	0.3a	0.29a	0.69a	0.03b	0.02b	3.15a	4.18a	0.004a	0.003a	0.12b	0.001c
	50	4.25a	7.5a	2.46a	0.3a	0.09b	0.67a	0.04a	0.02b	3.06b	3.80b	0.01a	0.02a	0.19a	29.98b
	100	4.44a	7.7a	1.83a	0.3a	0.02c	0.53b	0.03b	0.02b	3.06b	3.66c	0.01a	0.02a	0.21a	59.65b
	200	4.37a	8.1a	1.92a	0.2a	0.05d	0.67a	0.04a	0.02b	2.76c	3.54d	0.01a	0.02a	0.20a	94.24a
	Kg^{-1}						Field								
Pb	0	5.49a	8.6a	2.16a	3.0a	0.28a	0.07a	0.09a	0.03c	1.42a	1.89a	0.01a	0.01a	0.17b	0.002c
	20	5.00a	8.6a	0.97b	2.0a	0.19a	0.05a	0.08a	0.09a	1.41a	1.82a	0.02a	0.02a	0.20a	29.87b
	40	5.14a	7.1a	1.61a	1.8b	0.25a	0.06a	0.08a	0.06b	1.40a	1.85a	0.02a	0.02a	0.25a	42.17a
	80	5.28a	8.2a	1.66a	2.3a	0.26a	0.07a	0.09a	0.08a	1.48a	1.98a	0.02a	0.02a	0.28a	45.86a

The plant height, stem girth and number of leaves were depressed with increase in the residual Pb concentrations in the entire study. The plants with higher residual concentration had significant reduced growth parameters compared to control. The decrease in the growth parameters in Pb laden soil is because of the antagonism of most macro and micronutrients needed for growth as earlier reported by Azmat *et al* (2006) and Foy *et al* (1978).

Table 4: Lead content (%) and uptake ($mgkg^{-1}$) by *Telfaira occidentalis* in greenhouse and field trials

		Greenhouse Pb content				Field Pb content	
Heavy metal	Rate mg/5kg soil	Shoot	Root	Heavy metals	Rate $kgha^{-1}$	Shoot	Root
Pb	0	0.05b	0.22c	Pb	0	0.003d	0.005d
	50	0.11 b	0.25c		20	0.13c	0.32c
	100	0.12a	0.42b		40	0.29b	0.61b
	200	0.13a	0.63a		80	0.53a	0.80a
		Greenhouse Pb uptake				Field Pb uptake	
Pb	0	1.37b	1.79c	Pb	0	0.03d	0.04d
	50	2.17a	1.87c		20	1.65c	2.68c
	100	2.29a	2.75b		40	2.95b	4.50b
	200	2.44a	3.63a		80	4.63a	5.59a

Table 5: Effect of residual lead on crude protein content (%) of *Telfaira* *occidentalis* in greenhouse and field trials

	Greenhouse				Field Trial		
Heavy metal	Rate mg/5kg soil	Shoot	Root	Heavy metal	Rate $kgha^{-1}$	Shoot	Root
Pb	0	19.16a	11.90a	Pb	0	29.28a	12.00a
	50	18.77a	11.25b		20	22.87b	11.46b
	100	12.48b	9.63c		40	17.02c	9.55c
	200	10.86c	6.46d		80	11.31d	7.63d

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

Table 6: Effect of residual Pb on plant height, number of leaves, stem girth and dry matter yield of *Telfairia occidentalis* in greenhouse and field trials

Heavy Metal	Rate mg/5kg soil	Plant height (cm)	Number of leaves	Stem girth (cm)	Root dry Weight (g)	Shoot dry Weight(g)
		Greenhouse	Trial			
Pb	0	58.50a	13.00a	2.23a	0.82ab	2.89a
	50	56.33a	13.00a	2.16b	0.77abc	2.30ab
	100	39.80b	11.67ab	1.94c	0.66cd	1.95ab
	200	37.43b	11.00b	1.81d	0.57d	1.94ab
	$Kgha^{-1}$	Field	Trial			
Pb	0	86.23a	29.00a	2.27a	0.87a	1.23a
	20	76.60b	25.00a	2.14ab	0.83b	1.13b
	40	68.73b	22.67a	2.01bc	0.74d	1.01c
	80	53.73c	18.33c	1.88c	0.70e	0.91d

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

Conclusion: The results indicated that residual Pb had a negative effect on the plant growth, dry matter yield, crude protein, nutrient content and uptake of most essential mineral ions. Significant Pb also accumulated in the shoot and root of the plant in soils treated with Pb compared to the control. The root however accumulated more Pb than the shoot and there were fluctuations in most of the soil nutrients because of uptake by the plant. The results of the trials suggest that indiscriminate disposal of solid wastes or effluents containing Pb should be discouraged. In addition, the roots of fluted pumpkin plants should not be eaten since large quantities of Pb are often bioaccumulated in the roots. However, *Telfairia occidentalis* plant could be used to phyto-remediate Pb polluted soil since the roots are not usually eaten.

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Table 3: Shoot mineral content (%) and uptake (mgkg^{-1}) by the plant in the greenhouse and field trials .Mean values with the same letter in the column are not significantly different from one another at P< 0.05

Heavy metal	Rate mg/5Kg Soil	N	P	K	Mg	Ca	Na	Fe	Mn	Zn	N	P	K	Mg	Ca	Na	Fe	Mn	Zn
						Greenhouse	mineral	Ions						Field	mineral	ions			
Pb	0	3.0a	0.28a	2.04a	0.34a	1.06a	3.21a	0.33a	0.38a	0.49a	4.68a	0.61a	3.33a	2.95a	0.81a	3.25a	033a	0.36a	0.45a
	50	3.0a	0.21b	1.06b	0.26b	0.88b	2.16b	0.26b	0.29b	0.36b	3.66b	0.54b	2.65b	0.89b	0.72b	2.22b	0.27b	0.27b	0.36b
	100	2.0b	0.19c	0.81cd	0.19c	0.63c	1.76c	0.19c	0.22c	0.17c	2.71c	0.46c	1.00c	0.73c	0.66c	1.99c	0.14c	0.22c	0.23c
	200	1.7c	0.17d	0.72d	0.16d	0.48d	0.94d	0.13d	0.14d	0.12d	1.81d	0.30d	0.92c	0.63d	0.42d	1.92d	0.10d	0.16d	0.12d
	Kg^{-1}					Greenhouse	mineral	uptake						Field	mineral	uptake			
Pb	0	82.7a	7.49a	55.65a	9.31a	28.97a	87.00a	8.94a	10.48a	13.31a	57.93a	7.52a	41.12a	9.99a	36.54a	40.08a	4.04a	4.44a	5.55a
	20	69.1ab	4.89ab	24.44b	5.89b	20.86ab	50.06ab	5.80b	8.58ab	8.26b	41.51b	6.16b	30.07b	8.13b	10.09b	25.16b	3.08b	3.10b	4.11b
	40	39.0b	3.75b	15.73b	3.68b	12.38b	31.93b	3.53bc	4.25b	3.32bc	27.29c	4.61c	10.10c	6.63c	7.34c	20.14c	1.43c	2.19c	2.32c
	80	35.1b	3.36b	13.94b	3.64b	18.04ab	18.25b	1.80c	2.75b	2.24c	16.48d	2.60d	8.42d	3.79d	5.76d	17.49d	0.91d	1.37d	1.12d