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

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ABSTRACT: These greenhouse and field trials were aimed at determining the residual influence of Cr on some agronomic characters, nutrient content, nutrient uptake and crude protein content of fluted pumpkin in soils previously treated with 0, 50, 100, 200 mg $Cr(NO_3)_3.9H_2O$ per 5 kg soil in the greenhouse and 0, 20, 40, 80 $kgha^{-1}$ Cr ($(NO_3)_3.9H2O$ in the field trial. The completely and randomized complete block designs were used in the greenhouse and field trials respectively. The soils used were left uncultivated for 10 weeks prior to the residual trials. Results revealed that the plant height, stem girth, leaf area, number of leaves, dry matter yield, crude protein nutrient content and uptake declined with increased Cr concentrations. As the soil Cr concentration increased, the Cr content and uptake by root and shoot increased. There were however depressions in Cr uptake by the root at 100 mgCr in the greenhouse and in Cr uptake by the root and shoot at 40 $kgha^{-1}$ concentration in the field trial. However, the root accumulated higher Cr than the shoot whereas the shoot had higher nutrient content, nutrient uptake, crude protein, and dry matter yield. The soil nutrient components were not affected negatively by the increased Cr concentrations. The Cr content of the soil was however, not exhausted at the end of these trials. @JASEM

Keywords: *Residual, uptake, crude protein, growth, ultisol, chromium*

The chromium exists thermodynamically in soils as Cr (III) and Cr (VI). The Cr (IV) is highly mobile and easily leached out of the reach of plants and can easily contaminate ground water. It is more toxic to man and animals than Cr (III). The Cr (III) on the other hand is not very mobile and therefore very recalcitrant in the soil. It attaches to the various soil particles firmly. It is this form of Cr that is highly available to plants.

The persistence of this Cr in the soil can lead to increase in uptake by the plants. This higher Cr (III) uptake has been reported to be detrimental to crops. The effect of Cr (III) on *Vigna radiate* germination and seedlings revealed that high Cr concentration had a significant reduction in shoot and root length (Shaganas *et al.,* 1997). Investigation carried out by Subramani *et al* (1997) showed that the growth parameters of black grain (*Vigna mungo* (L) Hepper) declined with increase in the concentration of Cr. The Chromium has also been found to reduce water status and mineral nutrition of bean plant (Azmat and Khanum, 2005).

The crop *Telfairia occidentalis* is widely cultivated and consumed in tropical Africa because of high nutritive value of the leaves and seeds. The uptake of this Cr in excess by this plant is one the means of introducing this metal into the food chain and high consumption of Cr is detrimental to the health of man and animals. This study was aimed at investigating the residual effect of Cr on some agronomic characters, nutrient content, nutrient uptake, Cr accumulation in the plant 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, 200 mg Cr ($(NO_3)_2.9H_2O$ rates were used in 5 kg soil. Each replicate had 16 pots making 48 pots. For this residual trial, the 48 pots left for 8 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 a completely randomize design with 3 replicates. The plant height, number of leaves, stem girth and leaf area were taken 30 days after transplanting. Thereafter, the shoot was separated from the roots and rinsed in distilled water. Both the roots and above ground biomass was oven dried in ventilated oven at 72^0C for 48 hours to constant dry weight used in computing the nutrient uptake.

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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 same fluted pumpkin and Cr sources as well as levels (0, 50, 100, 200 mg per 5kg soil) equivalent to 0, 20, 40, 80 $kgha^{-1}$ were earlier used. The trial earlier organized in randomized complete block design had 3 replicates. Each treatment, which was represented by a bed size of 2.5 m x 2.5 m, 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 doe regularly. Similar greenhouse basal dressing with N-P-K was carried out in the field trial. The trial also lasted 30 days in the field. The mode of data collection was similar to that of greenhouse residual treat soil analysis.

Soil analysis: Soil samples were collected at the beginning and at the end of the trials to determine the following. 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). The protein content was determined using the method of Azmat and Haider, (2007). 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. The exchangeable acidity 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 Cr was determined by methods of Soon and Abboud (1993).The data generated were analyzed by Genstat statistical version 6.1.0.234. (Payne, 2002).

Plant Analysis: The Na, K, Ca, Mg, Fe, Mn, Zn and Cr were determined by the use of atomic absorption spectrophotometer after digesting in a mixture of HNO_3, H_2SO_4 and $HClO_4$ acids (IITA, 1979) while the micro-kjeldal method of Jackson (1962) was used for N determination. The A OA C (1970) perchloric acid digestion (wet oxidation) method was used for P determination.

RESULTS AND DISCUSSION

The properties of soil before the trials are shown in Table 1. The soil is moderately acidic and texturally sandy. The soil contained organic carbon, N, P, Mg, Ca, Na, Fe, Mn, Zn as well as Cr components. The properties of the soil after greenhouse trial are shown in Table 2. The organic carbon, available P, N, Mg, Ca, K, Na, exchangeable acidity, effective cation exchange capacity, Fe, Mn, Zn, and Cr content of the soil decreased at various levels of Cr residual concentrations while the soil pH on the other hand increased at various levels of Cr concentrations. However, significant differences were detected among the various Cr concentrations in available P, K, Ca, Na, Mg, Zn, exchangeable acidity, effective cation exchange capacity and Cr of the soil while non- significant differences were recorded among the various Cr concentrations in soil pH, organic carbon, N, Fe and Mn components.

The properties of the soil after field trial are shown in Table 2. The soil pH, organic carbon, available P, Ca, Mg, Na, Fe, Mn, Zn, exchangeable acidity and Cr components of the soil declined at various residual Cr concentrations while the N, K and effective cation exchange capacity however increased at various levels of Cr concentrations. There were however no significant differences among the various residual Cr concentration in soil pH, organic carbon, Ca, exchangeable acidity, effective cation exchange capacity, Fe, Mg and Mn whereas in P, N, K, Na, Zn and Cr content of the soil significant differences were recorded.

Tables 3 and 4 show the residual effect of Cr on the nutrient content and uptake by the plant in the greenhouse and field trials respectively As the Cr concentrations increased, the N, P, K, Mg, Ca, Na, Fe, Mn, Zn content of the plant in the greenhouse (Table 3) and field trials (Table 4) declined significantly among the various residual Cr concentrations. The uptake of N, P, K, Mg, Ca, Na, Fe, Mn, Zn also decreased significantly with increased residual Cr concentrations in the greenhouse (Table 3) and field trials (Table 4).

Table 3: Shoot mineral content (%) and uptake (mgkg^{-1}) by the plant in greenhouse residual trial

Heavy metals	Rate mg/5Kg Soil	N	P	K	Mg	Ca	Na	Fe	Mn	Zn
				Mineral	content					
Cr	0	3.03a	0.34a	2.09a	0.33a	1.28a	3.07a	0.32a	0.36a	0.49a
	50	2.89a	0.24b	1.58b	0.23b	0.93b	2.74b	0.26b	0.27b	0.33b
	100	2.01b	0.20c	1.01c	0.19c	0.77c	1.37c	0.19c	0.21c	0.20c
	200	1.75c	0.16d	0.86c	0.14d	0.56d	0.83d	0.12d	0.16d	0.13d
				Mineral	uptake					
Cr	0	42.88a	4.82a	29.61a	18.18a	4.63a	43.49a	4.57a	5.15a	6.99a
	50	41.08a	3.40a	20.55a	13.16b	3.23a	38.73a	3.10b	3.77a	4.65a
	100	27.14b	2.72b	13.55b	10.37c	2.50a	18.68b	2.59b	2.83a	2.56b
	200	16.77c	1.55c	8.38c	5.31d	1.36b	8.26c	1.08c	1.50b	1.20c

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

Table 4: Shoot mineral content (%) and uptake (mgkg^{-1}) by the plant in field residual trial

Heavy Metals	Rate kgha^{-1}	N	P	K	Ca	Mg	Na	Fe	Mn	Zn
						Mineral	content			
Cr	0	4.16a	0.59a	4.07a	2.96a	0.81a	3.17a	0.32a	0.37a	0.42a
	20	3.18b	0.50b	3.26b	0.99b	0.77a	2.85b	0.26b	0.24b	0.35b
	40	2.79c	0.45c	2.91c	0.85c	0.66b	2.08c	0.18c	0.22b	0.23c
	80	2.03d	0.40d	1.00d	0.74d	0.63b	1.38d	0.13d	0.15c	0.17d
						Mineral	uptake			
Cr	0	53.22a	7.60a	52.11a	37.93a	10.35a	40.79a	4.17a	4.74a	5.38a
	20	36.99b	5.82b	37.89b	11.48b	8.96b	33.27b	3.07b	2.75b	4.11b
	40	26.33c	4.22c	27.32b	7.96c	6.19c	19.43c	1.72c	2.03c	2.20c
	80	17.19d	3.06d	8.50c	6.27d	5.50c	11.69d	1.06d	1.25d	1.47d

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

Table 5: Chromium content (%) and uptake (mgkg^{-1}) by *Telfaira occidentalis* in greenhouse and field residual trials

Heavy metals	Rate mg/5kg soil	Greenhouse		Heavy metals	Rate kgha^{-1}	Field	
		Shoot Cr content	Root Cr content			Shoot Cr content	Root Cr content
Cr	0	0.01a	0.02a	Cr	0	0.003d	0.003d
	50	0.02a	0.04a		20	0.11b	0.29 b
	100	0.02a	0.04a		40	0.08c	0.15c
	200	0.04a	0.05a		80	0.21a	0.62a
		Shoot Cr uptake	Root Cr uptake			Shoot Cr uptake	Root Cr uptake
Cr	0	0.18a	0.20b	Cr	0	0.04d	0.03d
	50	0.25a	0.29a		20	2.26a	2.30b
	100	0.35a	0.25a		40	0.77c	1.15c
	200	0.42a	0.28a		80	1.48b	4.44a

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

Table 7: Effect of chromium concentrations on some agronomic characters and dry matter yield of *Telfaira occidentalis* in greenhouse and field trials

Heavy metal	Rate (mg/5kg soil)	Plant height (cm)	Stem girth (cm)	Leaf area (cm^2)	Number of leaves	Root dry Weight(g)	Shoot dry Weight(g)
				Greenhouse	Trial		
Cr	0	70.67a	2.24a	44.33a	17.00a	0.89a	1.42a
	50	67.73a	2.17b	41.82b	15.33a	0.69b	1.41a
	100	67.67a	1.98c	39.47c	14.33a	0.64b	1.35a
	200	66.40a	1.82d	33.33d	14.33a	0.62b	0.94b
	$kgha^{-1}$			Field	Trial		
Cr	0	77.93a	2.17a	63.47a	32.33a	0.83a	1.28a
	20	67.16b	2.07a	58.63b	25.00b	0.81a	1.16b
	40	61.48c	2.05a	52.97c	22.67b	0.79b	0.94c
	80	53.17d	1.99a	40.53d	20.67b	0.72c	0.85d

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

The Cr content and uptake by the plant are depicted in Table 5. The shoot and root Cr content of the plant in the greenhouse trial increased with increased residual Cr concentrations while the elevation of Cr content in the shoot and root were not consistent with increased residual Cr concentrations in the field trial. A depression in shoot and root Cr content at 40 $kgCrha^{-1}$ concentrations in the field was recorded. The 80 $kgCrha^{-1}$ concentration was significantly higher than other concentrations and higher Cr content accumulation was recorded in the root than the shoot.

As the concentrations of Cr increased, the uptake of Cr by shoot increased consistently in the greenhouse with no significant differences detected among the various Cr concentrations whereas Cr uptake by the root in the greenhouse, recorded no definite pattern with increased residual Cr concentrations. There was however, a depression in Cr uptake by the root at 100 mgCr in the greenhouse. The root and shoot uptake of Cr were also not consistent with increasing Cr concentrations in the field trial. Higher Cr uptake was however detected in the root than the shoot.

The crude protein content of both root and shoot (Table 6) in the entire trial decreased significantly with increased in the residual Cr concentrations of the soil. However, higher crude protein content was observed in the shoot than the root.

The effect of residual Cr on the plant height, leaf area, number of leaves, stem girth and dry matter yield of the plant are shown in Table 7. As the residual Cr content of the soil increased, the dry matter yield decreased with increasing Cr concentrations. The plant height, leaf area, number of leaves and stem girth also declined with increased residual content of Cr in both the greenhouse and field trials.

The fluctuation of most of the soil mineral components was due to their uptake by the plant at different level of residual Cr influence. However, in the field trial, the increase in N, K, Mn may tied up to the mineralization of the earlier ploughed-in organic matter at various residual levels of Cr while the persistence of this Cr in the soil is a result of its low mobility and recalcitrant nature of the metal as earlier reported by Brady and Weil (2002).

The decrease in growth parameters is attributed to the residual influence of the Cr treatments. Stunted growth of the plants grown in soil laden with heavy metals has been reported by Foy *et al.,* (1978) and Azmat *et al.,* (2006). Azmat and Haider (2007) have earlier reported that high concentration of heavy metals depressed leaf sizes, stem and root elongation of *Phaseolus mungo.* Jones *et al.,* (1973) also reported that plants that become totally submerged in soil contaminated by heavy metals will suffer lack of oxygen and this will lead to slow growth and inhibitory effect of toxic metal in root of plants. Slow growth may also have been recorded because of imbalances of plant nutrients in soils with high Cr concentrations. This deficiency of the minerals may have reduced most of the physiological processes that would have supported the growth of the plant and crude protein accumulation. The depression in nutrient uptake especially in the soil laden with Cr is as result of decline in the nutrient content as earlier reported by Eun *et al. (*2002). Sharma and Pant (1994) also reported reduced uptake of Fe, Mn and Zn in maize due to Cr application.

The shoot had lower values of Cr content and uptake compared to the root. This higher accumulation of Cr in the root makes the plant a metal excluder (Raskin *et al,* 1994). This metal excluder restricts metals from being translocated to their aerial part or maintains low and constant metal concentration over a wide range of concentration in soil and maintains higher metal content in their roots as detected in *Telfairia occidentalis.* Similar results have earlier been reported by Orhue (2008) and Malone *et al* (1974).

Conclusion: In the light of the results obtained, the plant height, number of leaves, stem girth, leaf area, dry matter yield, crude protein, nutrient content and uptake decreased with increased residual Cr concentrations. Higher Cr content and uptake were detected in the root compared to the shoot. The Cr concentrations had no pronounce negative effect on the soil chemical properties. The low Cr concentration in the shoot of control treatments is below the specified maximum acceptable level of 0.3 $mgkg^{-1}$ of WHO (1984) for most of the leafy vegetables. This low level of Cr in the control makes the plant safe for consumption. However, the anthropogenic disposal of Cr laden materials into the environment should be avoided and suspected areas such as dump sites where heavy metals are likely to accumulate should not be used for *Telfairia occidentalis* cultivation.

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

Heavy Metals	Rate mg/5kg soil	pH($H_2$0 1:1)	Org C	Av P	Total N	Mg	Ca	K	Exch acidity	ECEC	Na	Fe	Mn	Zn	Cr
			gkg^{-1}	$mgkg^{-1}$	gkg^{-1}			$cmolkg^{-1}$					[1]	$mgkg^{-1}$	
								Greenhouse	Trial						
Cr	0	4.60	9.2	4.16	0.3b	0.44	0.90	0.04	3.07	4.47	0.02	0.01	0.03	0.31	0.01
	50	4.30	8.2	2.77	0.2	0.20	0.49	0.05	3.00	3.76	0.02	0.02	0.04	0.43	20.33
	100	4.56	9.3	2.46	0.4	0.24	0.55	0.04	2.07	2.93	0.03	0.02	0.04	0.45	28.77
	200	4.59	9.1	2.26	0.6	0.33	0.8	0.05	3.00	4.22	0.02	0.02	0.04	0.42	66.34
	$Kgha^{-1}$							Field	Trial						
Cr	0	6.10	9.3	7.03	0.8	0.35	0.28	0.06	0.16	1.80	2.65	0.02	0.03	0.27	0.02
	20	5.80	10.5	5.77	1.0	0.35	0.20	0.03	0.14	1.81	2.53	0.03	0.04	0.33	24.2
	40	6.29	8.2	6.49	0.9	0.39	0.25	0.03	0.14	1.78	2.59	0.03	0.04	0.32	64.41
	80	5.39	8.8	4.89	0.8	0.30	0.21	0.04	0.14	1.82	2.51	0.03	0.04	0.34	139.35

Table 2: Chemical properties of the soil after the greenhouse and field residual trials

Heavy metals	Rate mg/5kg soil	pH($H_2$0 1:1)	Org C	Av P	Total N	Mg	Ca	K	Na	Exch Acidity	ECEC	Fe	Mn	Zn	Cr
			gkg^{-1}	mgkg-1	gkg^{-1}			Cmolkg-1					mgkg-1		
								Greenhouse	Trial						
Cr	0	4.47a	8.0a	2.70a	0.2a	0.26a	0.69a	0.02b	0.01b	2.87a	3.85a	0.004a	0.003a	0.12b	0.00d
	50	4.46a	7.4a	1.78b	0.3a	0.02c	0.47b	0.04a	0.04a	2.86a	3.43b	0.01a	0.02a	0.18a	16.63c
	100	4.63a	8.1a	1.26b	0.3a	0.03c	0.45b	0.03b	0.02b	2.87a	3.40b	0.01a	0.02a	0.20a	24.64b
	200	4.70a	8.7a	1.75ab	0.4a	0.06b	0.67a	0.02b	0.02b	2.67b	3.44b	0.01a	0.02a	0.20a	62.29a
	$Kgha^{-1}$							Field	Trial						
Cr	0	5.55a	8.2a	2.20a	2.3a	0.27a	0.07a	0.09a	0.07a	1.49a	1.99a	0.01a	0.01a	0.18b	0.02c
	20	5.54a	7.5a	2.42a	3.0a	0.29a	0.06a	0.08a	0.03b	1.39a	1.85a	0.02a	0.02a	0.21a	32.51b
	40	5.20a	7.0a	0.94b	1.3b	0.21a	0.05a	0.06c	0.03b	1.36a	1.71a	0.02a	0.02a	0.23a	32.53b
	80	5.25a	8.0a	1.19b	2.0a	0.19a	0.04a	0.07bc	0.02b	1.40a	1.72a	0.02a	0.02a	0.23a	34.46ac

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

Table 6: Effect of chromium on crude protein content of *Telfaira occidentalis* in greenhouse and field residual trials (%)

Heavy metal	Rate mg/5kg soil	Greenhouse Trial		Heavy metals	Rate $kgha^{-1}$	Field Trial	
		Shoot	Root			Shoot	Root
Cr	0	18.91a	12.04a	Cr	0	25.98a	12.17a
	50	18.08a	11.50b		20	19.87b	11.54b
	100	12.56b	9.52c		40	17.44c	9.77c
	200	10.96c	6.21d		80	12.53d	6.38d

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