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Phyto-availability of chromium to fluted pumpkin (*Telfairia occidentalis* Hook F.) in an ultisol

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Abstract: The present study was conducted to determine the influence of Cr on some agronomic characters of *Telfairia occidentalis* nutrient content and uptake and some chemical properties of soil. In the greenhouse trial, chromium nitrate [$Cr(N0_3)_2$] was applied at rates of 0, 50, 100 and 200 mg per 5 kg sieved and air-dried soil obtained from a depth of 0-15cm. The rates of 0, 20, 40 and 80 $kgha^{-1}$ equivalent to pot rates were used in the field trial. Results showed that the soil used was texturally sandy loam and an ultisol as revealed by its low base saturation. In the greenhouse the soil pH, N, K, Mg, Ca, Na, Fe, Mn, Zn, free Fe and Al oxides, organic carbon, effective cation exchange capacity, exchangeable acidity, amorphous Fe and Al oxides content of the soil decreased inconsistently at various levels of Cr treatments except available P, which appreciated inconsistently. With the exception of soil pH, organic carbon, available P and amorphous Fe oxide, which increased at various levels of Cr concentrations, all other soil chemical properties determined, declined inconsistently in the field trial. The amorphous Al oxide however remained stable in the field trial. The Cr content of the soil increased with the levels of Cr treatments when compared with the control in the trials. The N, P, K, Mg, Ca, Na, Fe, Mn and Zn content of shoot and root as well as their uptake also decreased consistently with increasing Cr treatments. In addition, the Cr content as well as uptake by the shoot and root also increased consistently with increased rates of the Cr applied in the trials with the minimum levels of the Cr content and uptake recorded at the control treatments. As the Cr concentration increased, the crude protein content of both shoot and root consistently decreased with highest crude protein content recorded in the shoot compared to the root. A decrease in the dry matter yield with increased Cr treatments in shoot and root was recorded in the trials. Results also showed that the Cr influenced the height, collar girth, leaf area and number of leaves with control treatments higher than other treatments at final harvest.

Keywords: Chromium, Phyto-availabilty, Uptake, Protein, Mineral ions

INTRODUCTION

Chromium (Cr) is naturally found in the soil. It accumulates with iron in weathering residue and rarely at toxic level. Nowadays, the presence of Cr in the environment is widespread due to its usage in many industrial processes such as tanning, metallurgic and plating industries e.t.c. The disposal of this Cr into the environment ends up in the soil. The phyto-availability of Cr depends on the speciation state and nature of plant species. The Cr is thermodynamically stable in two oxidative states namely Cr (lV) considered to be mobile in the soil and Cr (III) which is less mobile and strongly attaches to soil particles.

Plants only take up Cr (III) at low concentration but when concentrations exceed certain level, negative effects occur. Shaganas *et al.* (1997) reported that high Cr associated with the soil components significantly reduced the length of shoot and root of *Vignas radiata*. Also Subramani *et al.* (1997) observed gradual decline in growth parameters of *Vigna mungo* with increase in the concentration of Cr. Chromium has also been reported to affect water status and mineral nutrition of bean plant (Azmat and Khanum, 2005).

One of the ways man can be ingest Cr is through the consumption of crops such as fluted pumpkin. The plant fluted pumpkin leaves and seeds are widely consumed in tropical Africa. It is highly nutritive with many minerals. This study therefore was undertaken to (i) determine the effect of Cr on some agronomic characters of the plant, (ii) determine parts of the plant with highest ability to accumulate Cr (iii) determine the effect of Cr on some mineral content as well as their uptake (iv) determine effect of Cr on some chemical components of the soil.

MATERIALS AND METHODS

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

Greenhouse trial: In the greenhouse study, soil samples were collected from surface 0-15cm depth of soil. The soil collected was bulked, mixed thoroughly, air dried and sieved to remove debris. Thereafter, 5 kg of the composite soil was weighed and put in the various plastic pots. The

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total number of plastic pots used was 48 with each plastic pot labeled for the various treatments. Each replicate had 16 plastic pots with 4 pots per treatment. The chromium nitrate [Cr $(NO_3)_2$] used 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 metal equilibrate with the soil. The experiment was laid out in a completely randomized design with three replicates. 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 the crop growth. Excess moisture drainage from perforation at the base of each pot was collected by a saucer placed below each pot to prevent leaching into the soil and cross contamination among pots. The plant height, number of leaves, stem girth and leaf area were taken every 10-day intervals till final harvest at 30 days after transplanting when the above-ground biomass was clipped at soil level with stainless steel blade to separate the roots and then carefully rinsed in distilled water. Both the roots and the shoot were oven dried in ventilated oven at 72°C for 48 hrs to constant dry weight used in computing the nutrient uptake.

Field trial: The field trial was conducted in order to validate results obtained under greenhouse conditions. This field trial was sited where the soil for greenhouse trial was taken. The same heavy metal source as well as levels (0, 50,100, 200 mg per 5 kg soil) equivalent to 0, 20, 40, 80 $kgCrha^{-1}$ were used. Each treatment was represented by a bed size of 2.5 m x 2.5 m separated by 50 cm space while each replicate was separated by 1m alley. The entire experimental site was 12 m x 10 m giving a total area of 120 m^2 The various levels (0, 20, 40, 80 $kgCrha^{-1}$) of the heavy metal were uniformly applied with the aid of a spreader, mixed thoroughly and then left for 7 days before transplanting the seedlings. The experiment was organized in randomized complete block design in three replicates. The pumpkin was sown at a spacing of 1m x 1m. Each bed had a plant population of 4 plants. Hand weeding was done regularly. 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. 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 contents were 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. 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 Cr and oxides were 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 plant materials were ground (< 1 mm) and then digested with a mixture of HNO_3, H_2SO_4 and $HCIO_4$ acids (IITA, 1979). The mineral ions (Na, K, Ca, Mg, Fe, Mn, Zn and Cr) were determined by the use of atomic absorption spectrophotometer. For P content (AOAC, 1970) perchloric acid digestion (wet oxidation) method was used while the micro-kjeldal method of Jackson (1962) was used for N determination

RESULTS

Properties of soil used before the trial: The properties of soil used are shown in Table 1. The soil is acidic, texturally sandy loan, low percentage base saturation, N, P, K, Mg, Ca, Na, Fe, Mn, Zn, Ca^- and Cr components.

Properties of soil used after greenhouse and field trials: Table 2 reveals the soil properties after the greenhouse and field trials. The pH, organic carbon, N, K, Mg, Ca, Na, exchangeable acidity, effective cation exchange capacity, Fe, Mn, Zn, free Fe and Al oxides, amorphous Fe and Al oxides decreased inconsistently at various levels of Cr treatments in the greenhouse trial. The available P and Cr however appreciated from 3.19 $mgkg^{-1}$ and 0.02 $mgkg^{-1}$ (Table 1) to 4.16 $mgkg^{-1}$ in 0 mgCr and 66.34 $mgkg^{-1}$ in 200 mgCr respectively (Table 2).

Similar trend of inconsistent decrease in N, K, Mg, Na, Ca, Fe, Mn, Zn, effective cation exchange capacity, exchangeable acidity, free Fe and Al oxides, amorphous Al oxide also occurred in the field trial. While the soil pH, organic carbon, P, amorphous Fe oxide increased also inconsistently from 5.64, 1.00 gkg^{-1}, 5.76 $mgkg^{-1}$, 0.08 % (Table 1) to 5.80 in 20 $kgCrha^{-1}$, 1.05 gkg^{-1} in 20 kgCrha, 7.03 $mgkg^{-1}$ in 0 $kgCrha^{-1}$, 0.11% in 20 $Crkgha^{-1}$ and 40 $kgCrha^{-1}$ respectively. The amorphous Al oxide however remained stable whereas the Cr content of the soil in the entire trial increased also with increase in Cr treatment.

Effect of Cr on some mineral content (%) and uptake ($mgkg^{-1}$) by the shoot and root of *T. occidentalis*: Table 3 shows the shoot and root mineral components as well as

Table 1. Physico-chemical properties of soil before the trials.

Properties	Greenhouse value	Field value
Soil pH(1:1)	4.71	5.64
Organic carbon (gkg^{-1})	1.11	1.00
Total N (%)	0.13	0.16
Available P ($mgkg^{-1}$)	3.19	5.76
K ($cmolkg^{-1}$)	0.11	0.13
Mg ($cmolkg^{-1}$)	0.64	0.66
Ca ($cmolkg^{-1}$)	0.96	0.97
Na ($cmolkg^{-1}$)	0.12	0.20
Exchangeable acidity	3.58	2.68
Ecec ($mgkg^{-1}$)	5.41	3.93
Fe ($mgkg^{-1}$)	0.03	0.04
Mn ($mgkg^{-1}$)	0.05	0.05
Zn ($mgkg^{-1}$)	0.65	0.67
Cr ($mgkg^{-1}$)	0.02	0.02
Percentage base saturation (%)	33.83	31.81
Free Fe oxide (%)	6.38	6.40
Free Al oxide (%)	1.73	1.21
Amorphous Fe oxide (%)	0.07	0.08
Amorphous Al oxide (%)	0.03	0.03
Sand (gkg^{-1})	865.31	864.32
Silt (gkg^{-1})	12.39	14.37
Clay (gkg^{-1})	122.30	121.31
Textural class (gkg^{-1})	Sandy loam	Sandy loam

their uptake by the plant. The N, P, K, Mg, Ca, Na, Fe, Mn, and Zn components of the shoot and root decreased as the concentration of Cr increased in both the greenhouse and field trials with the control treatments significantly higher than other treatments. In the uptake of N, P, K, Mg, Ca, Na, Fe, Mn and Zn by shoot, the control treatments were also significantly higher in the entire trials. The uptake of N, P, Mg and Mn by the root in the greenhouse revealed that there were no significant differences among the various treatments while in K, Na, Fe and Zn uptake, the 0 mgCr was significantly higher. The uptake of these minerals by the root in the field showed that the 0 $kgCrha^{-1}$ was significantly superior than other treatments. The uptake of these minerals also decreased with increase in Cr concentration in the trials. The mineral components as well as the uptake by the shoot were higher than that of the root.

Cr content (%) and uptake ($mgkg^{-1}$) by *T. occidentalis*: Table 4 shows the Cr content and uptake by the shoot and root. The accumulation of Cr by the shoot and root in the entire trials increased with increase in Cr treatment. However, the Cr content of the root in the trials was higher than that of the shoot. The Cr content of shoot in the

Table 2. Chemical properties of the soil used after the greenhouse and field trials.

Heavy metal	Rat mg/5kg soil	pH	Org C (gkg^{-1})	Av P (gkg^{-1})	Total N (%)	Mg	Ca	K	Exch acdity	ECEC	Na	Fe	Mn	Zn	Free Fe	Oxide Al	Amorph Fe (%)	Oxide Al	Cr $mgkg^{-1}$
									$Cmolkg^{-1}$				$mgkg^{-1}$						
Greenhouse trial																			
Cr	0	4.60a	9.20a	4.16a	0.3b	0.44a	0.90a	0.04a	3.07a	4.47a	0.02a	0.01a	0.03a	0.31b	4.07b	1.05a	0.05a	0.01a	0.01d
	50	4.30a	8.20a	2.77a	0.2b	0.20b	0.49b	0.05a	3.00a	3.76a	0.02a	0.02a	0.04a	0.43a	4.04b	0.85a	0.06a	0.02a	20.33c
	100	4.56a	9.30a	2.46a	0.4ab	0.24b	0.55b	0.04a	2.07a	2.93a	0.03a	0.02a	0.04a	0.45a	6.04a	0.82a	0.05a	0.01a	28.77b
	200	4.59a	9.10a	2.26a	0.6a	0.33ab	0.82ab	0.05a	3.00b	4.22a	0.02a	0.02a	0.04a	0.42a	4.12b	0.85a	0.06a	0.02a	66.34a
Field trial																			
	$Kgha^{-1}$																		
Cr	0	5.10a	9.30a	7.03a	0.80b	0.28a	0.35a	0.06a	1.80a	2.65a	0.16a	0.02a	0.03a	0.27b	6.23a	0.80b	0.08b	0.03a	0.02d
	20	5.80a	10.50a	5.77a	1.0a	0.20c	0.35a	0.03b	1.81a	2.53a	0.14a	0.03a	0.04a	0.33a	5.78b	0.74c	0.11a	0.03a	24.24c
	40	5.29a	8.20a	6.49a	0.9a	0.25b	0.39a	0.03b	1.78a	2.59a	0.14a	0.03a	0.04a	0.32a	5.80b	0.79b	0.10a	0.03a	64.41b
	80	5.39a	8.80a	4.89b	0.8b	0.21bc	0.30b	0.04b	1.82a	2.51a	0.14a	0.03a	0.04a	0.34a	5.17c	0.82a	0.08b	0.03a	139.35a

Table 3. Shoot mineral content of the plant in the greenhouse and field trials (%).

Heavy metal	Treatment mg/5kg soil	N	P	K	Mg	Ca	Na	Fe	Mn	Zn	N	P	K	Mg	Ca	Na	Fe	Mn	Zn
		Greenhouse trial																	
		Shoot									Root								
Cr	0	5.19a	0.66a	5.55a	0.93a	3.29a	4.07a	0.33a	0.44a	0.51a	1.94a	0.25a	1.20a	0.24a	1.02a	2.98a	0.052a	0.017a	0.021a
	50	4.00b	0.56	4.48b	0.85b	1.22b	3.83b	0.27b	0.35b	0.44b	1.87b	0.22b	0.91b	0.19b	0.92b	1.43b	0.042b	0.015b	0.017b
	100	3.04c	0.47c	3.97c	0.76c	1.05c	3.00c	0.21c	0.25c	0.22c	1.58c	0.11c	0.64c	0.16c	0.64c	1.06c	0.037c	0.012c	0.013c
	200	2.78c	0.41d	2.00d	0.71d	0.85d	2.24d	0.13d	0.16d	0.13d	1.03d	0.10c	0..33d	0.09d	0.43d	0.85d	0.022d	0.011d	0.011c
	$kgha^{-1}$	Shoot								Field trial	Root								
Cr	0	5.22a	0.67a	5.50a	0.94a	3.30a	4.08a	0.35a	0.48a	0.54a	1.96a	0.34a	1.23a	0.34a	1.98a	3.00a	0.055a	0.022a	0.022a
	20	4.13b	0.57b	4.48b	0.86b	1.24b	3.74b	0.29b	0.38b	0.42b	1.88b	0.31b	0.96b	0.29b	0.89b	1.50b	0.045b	0.018b	0.017b
	40	3.17c	0.50c	4.00c	0.77c	0.94c	3.00c	0.23c	0.34c	0.30c	1.61c	0.22c	0.66c	0.25c	0.64c	1.10c	0.037c	0.016c	0.015b
	80	2.86d	0.43d	2.01d	0.72d	0.86d	2.40d	0.15d	0.30d	0.21d	1.07d	0.20c	0.35d	0.19d	0.54c	0.90d	0.021d	0.014c	0.012c

Table 4. Shoot and root mineral uptake as influenced by various levels of chromium in the field and greenhouse trials ($mgkg^{-1}$)

Heavy metal	Treatment mg/5kg soil	N	P	K	Mg	Ca	Na	Fe	Mn	Zn	N	P	K	Mg	Ca	Na	Fe	Mn	Zn
		Greenhouse trial																	
		Shoot									Root								
Cr	0	175.80a	22.32a	188.94a	32.14a	111.02a	137.48a	11.17a	13.46a	17.08a	17.92a	2.19a	11.10a	1.55a	9.37a	27.64a	0.48a	0.16a	0.20a
	50	112.60b	15.67b	125.93b	23.72b	34.43b	107.73b	7.77b	9.79b	12.29b	12.93a	0.76a	6.38b	1.33a	6.69a	10.10b	0.30b	0.11a	0.12b
	100	85.70c	13.39c	111.67c	21.35b	36.12b	84.40c	5.77b	6.92c	6.11c	9.79a	0.66a	3.94c	0.98a	4.21a	6.57b	0.23c	0.08a	0.08c
	200	67.10d	9.81d	47.84d	17.09b	20.45b	54.44d	3.03c	3.88d	3.66d	6.28a	0.60a	2.02d	0.56a	2.63b	5.21b	0.13d	0.07a	0.07d
	$kgha^{-1}$	Shoot								Field trial	Root								
Cr	0	176.30a	22.76a	185.75a	31.78a	111.54a	137.91a	11.72a	16.21a	18.09a	18.62a	3.26a	11.72a	3.26a	18.81a	28.53a	0.53a	0.21a	0.21a
	20	115.80b	16.06b	125.53b	23.89b	34.62b	104.60b	8.14b	10.73b	11.76b	13.95b	2.33b	7.16b	2.13b	6.62b	11.18b	0.34b	0.13b	0.12b
	40	88.22c	14.14b	112.76c	22.01c	27.51c	84.59c	6.40c	9.69c	8.47c	10.03c	1.35c	4.20c	1.43c	4.01bc	6.84bc	0.23c	0.10c	0.09bc
	80	68.70d	10.27c	48.45d	17.25d	20.70d	57.76d	3.55d	4.89d	4.97d	6.21d	1.18c	2.03d	1.10c	3.16c	5.19c	0.12d	0.08d	0.07c

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 trials.

			Greenhouse trial					Field trial			
Heavy metal	**Treatment mg/5kg soil**	**Rate kgha^{-1}**	**Shoot Pb content**	**Root Pb content**	**Shoot Pb uptake**	**Root Pb uptake**	**Heavy Metal**	**Shoot Pb content**	**Root Pb content**	**Shoot Pb uptake**	**Root Pb uptake**
Cr	0	0	0.02 c	0.47c	0.69b	2.89d	Cr	0.00c	0.041d	0.23c	0.53d
	50	20	0.23 b	5.53b	6.53a	36.69c		0.13b	0.55c	3.57b	4.06c
	100	40	0.23 b	11.50a	6.49a	53.09b		0.25a	5.60b	7.15a	33.69b
	200	80	0.38a	19.96a	8.86a	109.08a		0.25a	6.57a	6.12a	37.63a

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

greenhouse and Cr content of root in field trial revealed the highest Cr treatments significantly higher than other treatments. While in the greenhouse, Cr content of the root recorded the 100 mgCr and 200 mgCr significantly higher. Similar trend was also recorded by shoot in the field trial with 20 kgCrha^{-1} and 40kgCrha^{-1} significantly higher.

The uptake of Cr by the root in the entire trials revealed the control treatments significantly higher than other concentrations. The Cr uptake by shoot in the greenhouse showed that 50 mgCr, 100 mgCr and 200mgCr were significantly higher while Cr uptake by shoot in the field showed that the 40 kgCrha^{-1} and 80 kgCrha^{-1} were significantly higher. Higher Cr uptake by the root was however recorded compared to the shoot.

Effect of Cr on the crude protein content of *T. occidentalis*: The crude protein content of the plant as influenced by Cr treatments is depicted in Table 4. The crude protein content of the shoot and root declined with increased Cr concentration. The shoot and root crude protein content in the entire trials revealed that the control treatments were significantly higher than other treatments in the trials. Higher crude protein was however recorded in the shoot than the root.

Effect of Cr on the dry matter yield of *T. occidentalis*: The dry matter yield of the plant is shown in Table 5. The dry matter yield decreases as the concentration of Cr treatment increases. In the greenhouse, there were no significant differences among the various treatments in shoot and root dry matter. While in the field trial, the 0 kgCrha^{-1} treatment was significantly higher than other treatments in the shoot and root dry matter yields.

Effect of Cr on plant height, stem girth, leaf area and number of leaves of *T. occidentalis*: The growth parameters are shown in Figs. 1-8. The height, stem girth, leaf area and number of leaves increased with the advancement of the plant growth stages and were highest at harvest. The plant height, stern girth, number of leaves and leaf area decreased with increase in the application of the Cr. At 30 days after transplanting in the greenhouse trial, the 0 mgCr, 50 mgCr and 100 mgCr were significantly higher in leaf area (Fig. 1) and number of leaves (Fig. 3). While 0 mgCr and 50 mgCr were significantly higher than other treatments in plant height (Fig. 5) and stem girth (Fig. 7).

In the field trial, the 0 kgCrha^{-1} and 20 kgCrha^{-1} treatments were significantly higher in leaf area (Fig 2.), plant height (Fig. 6) and stem girth (Fig. 8). The 0 kgCrha^{-1} treatment was however significantly higher than other treatments in number of leaves (Fig. 4). Generally, the control treatments were higher than other treatments in all the parameters at final harvest.

DISCUSSION

The properties of soil used indicated that the soil is low

Table 6. Effect of chromium on the crude protein content of *T. occidentalis* in greenhouse and field trials.

Heavy metal	Treatment mg/5kg soil	Greenhouse trial Shoot	Root	Heavy metal	Treatment Rate kgha^{-1}	Field trial Shoot	Root
Cr	0	32.44a	12.11a	Cr	0	32.61a	12.25a
	50	25.02b	11.69b		20	25.83b	11.73b
	100	19.02c	9.96c		40	19.81c	10.07c
	200	17.40c	6.42d		80	17.86d	6.67d

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

Table 7. Effect of chromium on the dry matter yield (g) of *Telfaira occidentalis* in greenhouse and field trials.

Heavy metal	Treatment mg/5kg soil	Greenhouse trial Shoot dry weight	Root dry weight	Heavy metals	Treatment Rate kgha^{-1}	Field trial Shoot dry weight	Root dry weight
Cr	0	3.27a	0.92a	Cr	0	3.35a	0.95a
	50	2.81a	0.70a		20	2.80b	0.74bc
	100	2.81a	0.62a		40	2.82b	0.62c
	200	2.39a	0.62a		80	2.41c	0.58c

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

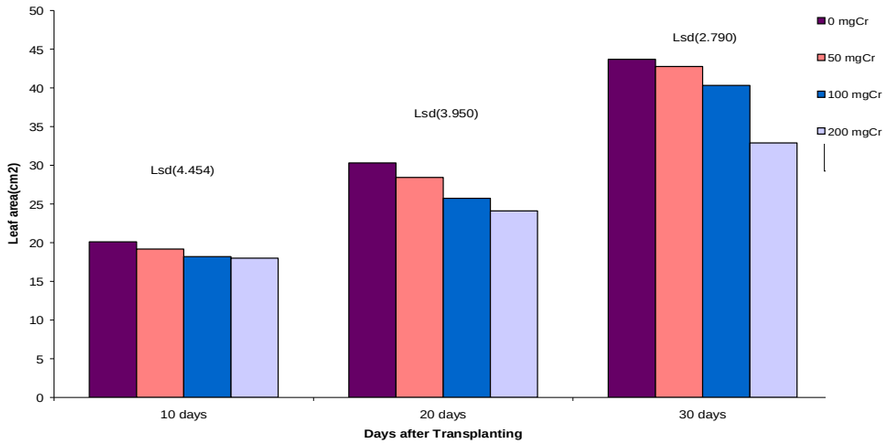

Fig. 1. *Effect of chromium on leaf area of T. occidentalis in green house trial.*

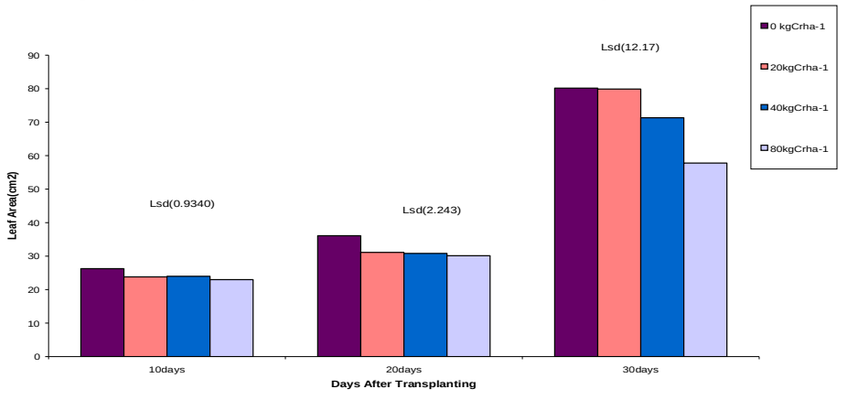

Fig. 2. *Effect of chromium on leaf area of T. occidentalis in field trial.*

in fertility that is typical of an Ultisol as shown by its low percent base saturation (less than 35%). The low base saturation distinguishes it from alfisol (Brady and Weil, 2002). The reduction in some of the soil nutrient content such as N, P, K, Mg, Ca, Na and organic carbon was not consistent. The fluctuation of these mineral nutrients may be tied to the plants' uptake at different levels of heavy metal applied. The decrease in oxides may be due to their

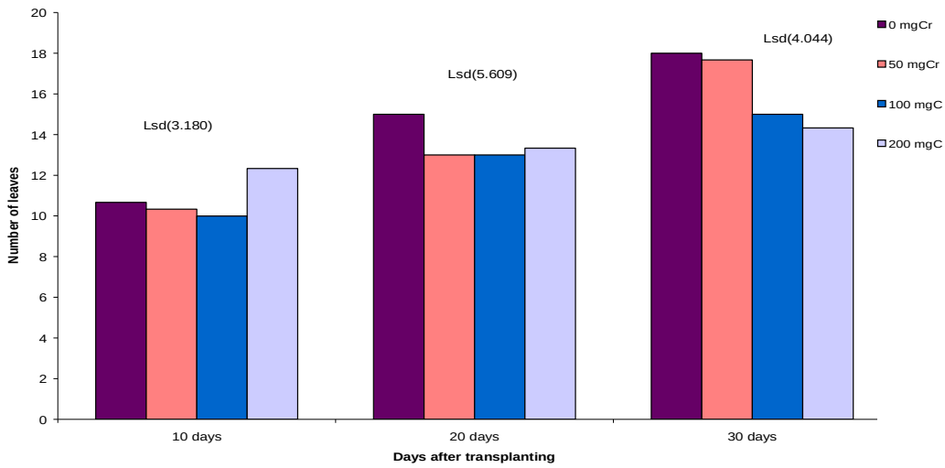

Fig. 3. *Effect of chromium on number of leaves of T. occidentalis in green house trial.*

solubility as a result of low pH in the soil used. Generally, oxides solubility is very low at the pH range of soils and depends on the particle size, crystallinity and the percent of Al substitution (Schwertmann, 1991). The pH of soil used may have favoured the reduction in the oxides. Similar result have earlier been reported by Schwertmann *et al.* (1985) who reported that the quantification of oxides in soils and sediments is often complicated by a considerable variation in crystallinity. The increase in the heavy metal content of the soil is attributed to the increase in the amount or concentration of Cr applied to the soil. Gundermann and Hactchinson (1995) and Tam and Singh (2004) have earlier reported elevated heavy metals in soil contaminated by heavy metal mine spoils. The declined in growth parameters is attributed to the influence of the metal especially in the higher dosage. This result further strengthens earlier report of Foy *et al* (1978) that heavy metals decrease plant vegetative growth. The reduced shoot and root biomass of the heavy metal plants in this study can also be due to specific toxicity of the metal to the plant, antagonism with other nutrients in the plants or inhibition of root growth in the soil. Azmat *et al.* (2006) also reported that heavy metals significantly depressed leaf sizes, stem and elongation of roots as compared to control in *Phaseolus mungo* and *Lens culinaris* plants. The decreased root growth could also be attributed to lack of oxygen as a result of Cr application. Roots, which become totally submerged in soil contaminated by heavy metals, will suffer from lack of oxygen and this will lead to slow growth and inhibitory effect of toxic metal on roots of plants (Jones *et al.*, 1973). The Cr may have altered the levels of mineral elements in the roots by physically blocking mineral ions from absorption sites of roots. In the roots, the levels of minerals were reduced with increase in the Cr supplied. The inhibition of root growth as demonstrated by the root weight after exposure to the Cr may be related with decrease in Ca in the root tips of *Telfairia occidentalis* leading to decrease in cell division. Similar findings were earlier reported by Rout and Das (2003) with Norway spruce plants and with Brahmi plants (Pande *et al.*, 2007). The observed actions in the crop appear to be indirect as

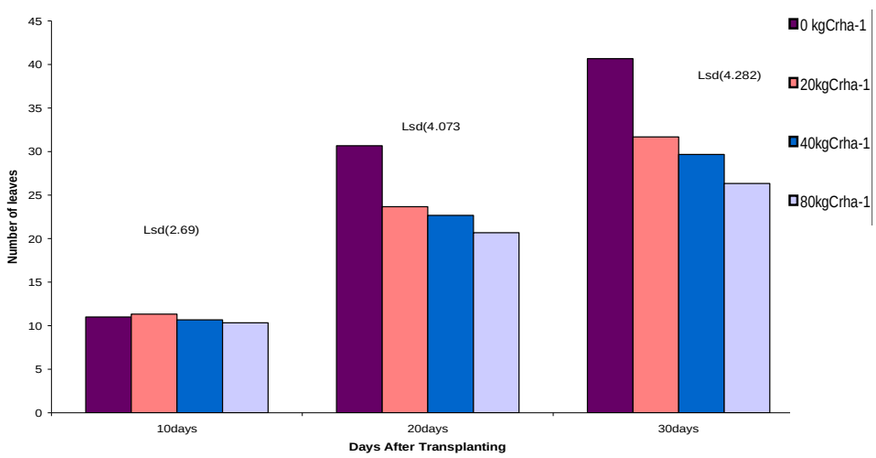

Fig. 4. *Effect of chromium on number of leaves of T. occidentalis in field trial.*

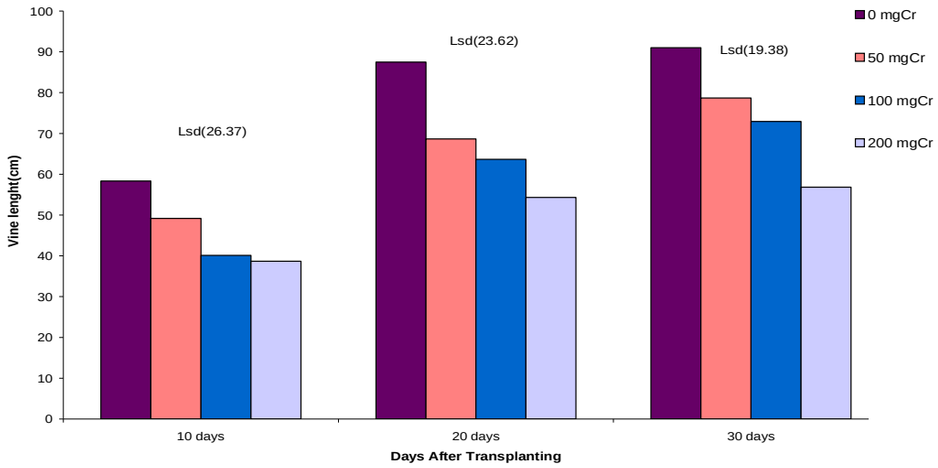

Fig. 5. *Effect of chromium on the plant height of T. occidentalis in green house trial.*

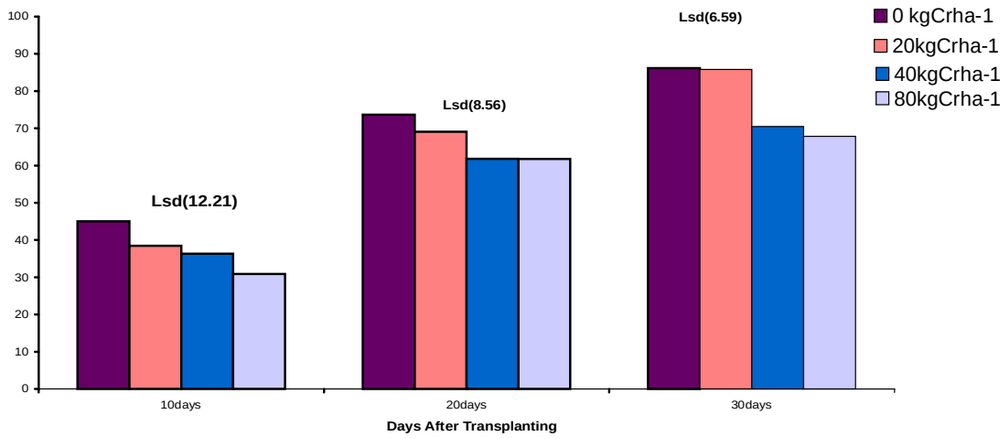

Fig. 6. *Effect of chromium on the plant height of T. occidentalis in field trial.*

a result of minerals imbalance within the tissue of *Telfairia* plants. The mineral imbalances brought significant changes in plant nutrient components. The reduction in Fe in both root and shoot in soil contaminated with the heavy metal may be due the presence of high concentration of Cr, which induced Fe deficiency in the crop due to competition by the heavy metal for functional sites of Fe binding Hewit (1963). Iron is required for the synthesis of chlorophyll and is essential part of the cytochrome which serves as electron carrier in photosynthesis and respiration. Deficiency of Fe in the plant may have caused the inhibition of photosynthesis resulting in small size of leaves of plant as shown in the polluted soil. The decrease in the concentration of Mn may have caused reduction in the concentration of chlorophyll that may be related to the reduction in quantum yield of oxygen evolved in photosynthesis (Haider *et al.,* 2006) and then depression in growth of *Telfairia* plant in soil treated with Cr. The concentration of Zn may have been lowered due to the Cr applied, which may have resulted in the stunting of plant and leaf growth. Zn as matter of fact is needed for the formation of hormone indoacetic acid, which is an enzyme activator. The increase in the Cr concentration may have led to decreased quantity of Mg in both root and shoot, which affected the process of photosynthesis as earlier observed and reported, by Haider *et al.* (2006). Reduction in nutrient content as well as in internal ratios of nutrients may have occurred in the *Telfairia* plants under Cr stress as observed earlier by Pinero *et al.* (2002). The higher Cr concentration may have damaged the tissue cells of vascular bundles, which resulted in the inhibition of conduction of water molecules from root to aerial parts of the plant hence there was reduction in plant nutrients. The deficiency of Ca generally results in an imbalance with K and Mg and it may have primarily affected leaf size and shape. Magnesium is also known to be a constituent of chlorophyll (Haider *et al.,* 2006) and is needed for activation of many enzymes involved in energy transfer. A deficiency of Mg would have seriously affected the plant growth and development as photosynthesis is directly affected (Haider *et al.,* 2006).

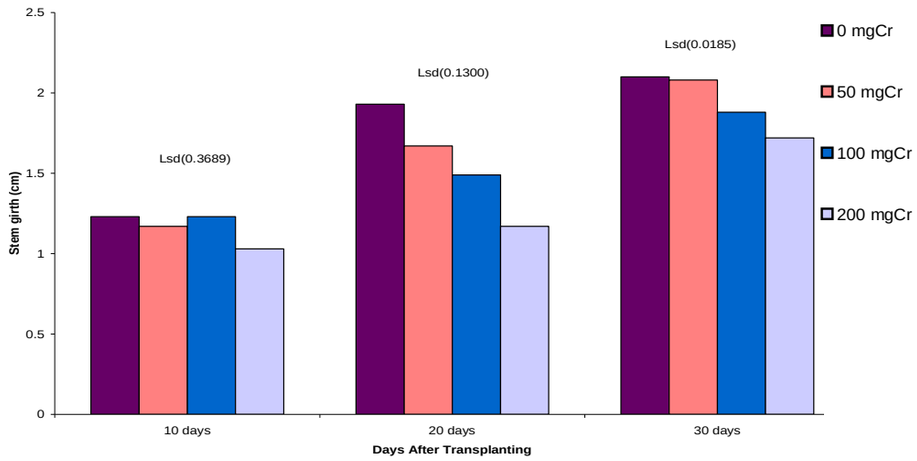

Fig. 7. *Effect of chromium on the stem girth of T. occidentalis in green house trial.*

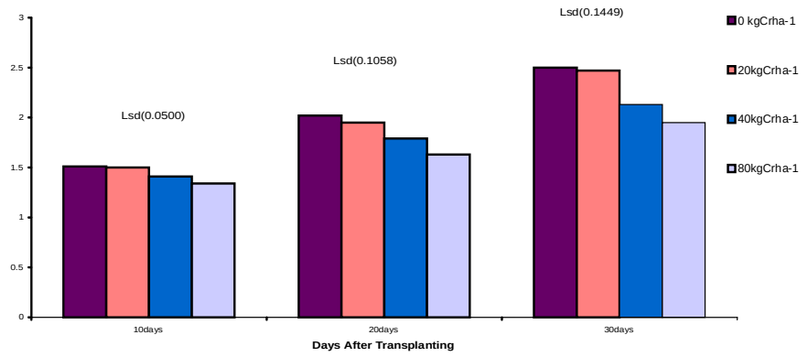

Fig. 8. *Effect of chromium on the stem girth of T. occidentalis in field trial.*

Phosphorus is known to be a constituent of ATP co-enzymes and is very important in plant energy transfer system. A deficiency can slow growth considerably (Azmat and Haider, 2007) as demonstrated by the growth of *Telfairia* plant treated with higher Cr dose. This reduction in plant nutrients is similar to the findings of Eun *et al.* (2002) and Azmat *et al.* (2006). The decrease in the uptake of nutrient by shoot and root may be attributed to a decrease in nutrient content as a result of increase in the Cr application. The decrease in Fe, Mn and Zn uptake may be due to interference of the heavy metals with the metabolism of mineral nutrients. Sharma and Pant (1994) reported reduced uptake of Fe, Mn and Zn in maize due to Cr treatments.

The protein content of both the shoot and root also decreased with increase application of the heavy metals. This result is similar to the finding of Okyto (1997) with 39.2% crude protein and Oboh (2005) who reported 38% crude protein in *Telfairia* plants grown in soils not contaminated with heavy metals. The depression of the protein content is attributed to the decrease in uptake of some minerals by the plant. For instance, the K acts as a coenzymes or activator of many enzyme systems (Kabata-Pendias and Pendia, 1992). Higher K levels according to Schreinemaker (1984) are needed for protein synthesis. In this study, this excess Cr applied may have caused leakage of K ions, which may have depressed protein formation in both shoot and root.

There was a significant difference between the shoot and root organs of the plant with respect to applied Cr and resultant accumulation trend of Cr. Higher Cr content was found in the root than the shoot making the plant *Telfairia occidentalis* a metal excluder. A metal excluder prevents metal from entering their aerial part or maintains low and constant metal concentration over a broad range of the concentration in soil and they mainly restrict metal in their root (Raskin *et al.*, 1994). The ability of a metal excluder to restrict heavy metals to root is based on the mechanisms that actively growing roots provide a barrier, which restricts the movement of heavy metal to above ground parts of plants. Davies and White (1981) with assorted vegetables and Kachenko and Singh (2004) with broadleaf vegetables and herbs grown in soils with high concentration of heavy metals have earlier reported higher levels of heavy metals in their roots.

Conclusion

The physiological, nutritional implications of Cr on *Telfairia* plant and on some soil physico-chemical properties were studied. The application of Cr had an effect on the plant performance by altering the rate of nutrient uptake, synthesis and translocation of vital mineral elements in the plants. The plants treated with the Cr had a declined vegetative growth, dry matter accumulation, nutrient elements as well as reduced nutrient uptake showing the existence of interaction between the Cr with the nutrient elements in the soil. Significant differences between the root and shoot accumulation of Cr was also recorded with the root of the plant accumulating higher Cr than the shoot. There were fluctuations in most mineral components of the soil. The accumulation of Cr in the control plants was low and compared favourably well with the WHO (1984) maximum acceptable level of 0.3 $mgkg^{-1}$ for most vegetables whereas those treated with the Cr had higher levels of the metal making it hazardous to health when regularly consumed. It then means that planting of *Telfairia occidentalis* near or in refuse dumps may not be advisable since such areas are likely to contain high amounts of this metal. However, this plant could be used to phytoremediate Cr contaminated soils.

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