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Research Article

Chromium Levels at Some Selected Growth Stages of Roadside Grown Wheat and Maize near the Kano-Zaria Highway, Nigeria

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Abstract: Consumption of food crops grown on agricultural soils contaminated with heavy metals is a major food chain route for human exposure, and of increasing concern due to food safety issues and potential health risks. Zea mays L. (TZEE-yellow maize), Zea mays everta L. (popcorn) and *Tritium aestivum* (Pavon-76 and Siettecerros) are two varieties of wheat and maize widely cultivated in northern Nigeria. The research examined the health risks assessment of heavy metals in food crops grown on roadside soils. The uptake/accumulation of Cr in the soil than in the plant parts (leaves, stems and roots) of the cereal crops suggests enrichment from the soil. However, Cr levels exceeded the permissible limits of the Joint FAO/WHO food standards (2006) of 1.30mg/kg, whereas the soil Cr levels was below the allowable limits. This study demonstrates that Cr may not pose a threat to public health, since the toxicity of Cr is yet uncovered. However, cultivation of food crops should be restricted from the roadside and further research should be carried out on the toxicity of Cr on humans and livestock.

Keywords: Chromium, roadside soil, wheat, maize.

INTRODUCTION

The increase of metals into the biosphere from anthropogenic and natural sources requires constant global monitoring. In the past decades, due to rapid industrial and technological growth, the emissions of these metals from various human activities have increased. Consequently, the translocation of these toxic metals from the environment to living systems, and their accumulation are the concern of most environmental protection agencies[1].The mechanism of uptake of trace elements by plants is based on root uptake of metals and foliar absorption, including deposition of particulate matter on the plant leaves. Kloke *et al.*[2] reported that Cd, Ti and Zn have the highest soil to plant transfer coefficient, in part because of their relatively poor sorption in the soil, while elements such as Cu, Co, Cr and Pb have low transfer coefficient, and are stably board to the soil structure. The intensity of extent of the uptake therefore, influences the actual content of an element in the plant[1].

Plants respond to metal stress by several mechanisms. In particular, Baker[3, 4]divides plants into three main categories with respect to their response to excess in amounts of metals in their growing substrate: excluders, indicators and accumulators. Excluders (e.g. sudangrass, bromegrass, fescue, etc.) would survive by avoidance mechanisms and are sensitive over a wide range of metal concentrations in soil. Indicators (e.g. corn, soybean, wheat, oats, etc.) can regulate the extent and speed of uptake and transport of metals, with internal concentrations mirroring external concentrations. Accumulators (e.g. tobacco, mustard, lettuce, spinach, etc.) can survive by physiological tolerance mechanisms[5]. The amount of any metal taken up by plants from the metal polluted atmosphere or metal contaminated soils has been suggested as of central importance in assessing the risk of toxicity.

The primary concern with the uptake of contaminants by plants is the presence of contaminants in produce consumed by humans and their livestock. Several researches in Nigeria have been largely focused on the agronomic of agricultural crops, agricultural land use management practices, soil fertility and assessments etc., with less emphasis on ecotoxicological study. Ecotoxicity is an ongoing battle that stems from many sources and can affect everything and everyone in the ecosystem[6]. Cr is an essential element for man and animal, and it plays a major role in the so-called glucose tolerance factor i. e. the return of excess levels of glucose in the blood to normal levels. Chromium is one of those heavy metals whose environmental concentration is steadily increasing due to industrial growth, especially the development of metal, chemical and tanning industries. Other sources of chromium permeating the environment are air and water erosion of rocks, power plants, liquid fuels, brown and hard coal, and industrial and municipal waste. Many researchers have investigated the uptake and accumulation of metals like Pb, Cd, Zn, Cu, Cr, Mn in different plant species[7-9]. However the mechanism of accumulation of heavy metals is still not completely understood. Uptake of Cr in maize and wheat is poorly documented. Among crop plant species, maize and wheat are among the most important and are grown throughout the world. In this present research, the uptake, transfer and translocation of Cr in two economically important cultivars each of wheat and maize in the semi-arid area of Kano State situated in the Sudan Savannah zone of Nigeria were investigated.

MATERIALS AND METHODS

Determination of Physico-chemical properties of Soil: Prior to sowing of the two varieties each of wheat and maize, soil samples were collected in duplicates and analyzed for the following physico-chemical parameters; soil pH was determined using a standardised pH meter[10], soil particle-size distribution was determined according to Bouyoucos[11], organic matter and organic carbon content was determined according to Walkley and Black[12] and Nelson and Sommers [13] respectively. Cation exchange capacity was analysed according to Black[14].

Soil and Plant Sampling and Analyses: A total of 216 plant samples and 144 corresponding soil samples were collected from four sampling units. Two varieties each of wheat and maize namely; *Triticum aestivum* L., var., Pavon-76 and Siettecerros, *Zea mays* L.var. TZEE-Y (yellow maize) and *Zea mays everta* L. were collected in a randomised block design setup. Both the soil and plant samples were collected fortnightly at the 15 days, 30 days, 45 days, 60 days, 75 days and 90 days which are the germination or seedling , tillering, jointing/booting, heading/earing ,flowering and ripening stages respectively.

Soil and plants samples were collected in duplicates and triplicates respectively at a vertical depth of 25cm, carefully packed into polyethene bags and transported to the laboratory. In laboratory, the roots of each cereal crop were carefully separated from the soil particles samples by washing under running tapwater and were divided into root, stem and leaf and then air-dried at room temperature. The dried plant samples were ground, using a grinding mill model Foss Cyclotec ™ 1093 based on Tecator™ technology and then kept in clean polyethylene bags for analysis. The soil samples were air dried at room temperature, ground in an agate mortar, sieved through 22 mm mesh sieve, then kept in clean polyethylene bags for analysis. The ground plant samples were well packaged and Cr was determined using the multi-elemental technique- Energy Dispersive X-ray Fluorescent (EDXRF) at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria.

RESULTS

The physic-chemical parameters of soil at the sampling sites before sowing are shown in **Table 1** below.

Table-1: Physicochemical Analysis of Soils from Doruwa Salau at close proximity to the Kano-Zaria road and the Irrigation Research Station before sowing.

Site	% Sand	% Silt	% Clay	Textural Class	pH H_20 1:1	pH HCL 1:1	% OC	% OM	CEC
SU 1	62. 9	15. 2	21. 9	Sandy Clay loam	6. 41	5. 77	0. 88	1. 50	7. 25
SU 2	75. 5	12. 4	12. 1	Sandy loam	5. 48	4. 66	0. 65	1. 12	5. 9
SU 3	71.6	13.5	14. 9	Sandy loam	5.75	4. 86	1. 82	1. 05	6. 3
SU 4	60. 5	17. 2	22. 3	Sandy clay loam	6. 21	5. 40	0. 78	1. 36	8. 01

Key:

SU 1 = Wheat (Pavon-76) on Doruwa Salau at close proximity to the Kano-Zaria road;
SU 2 = Wheat (Siettecerros) at the Control Site (Irrigation Research Station-IRS), Kadawa;
SU 3 = Yellow Maize on Doruwa Salau at close proximity to the Kano –Zaria road
SU 4 = Popcorn at the Control Site (Irrigation Research Station-IRS), Kadawa

The experimental (SU 3) and control (SU 2) sites where *Zea mays* L. var yellow maize (TZEE-Y) and *Triticum aestivum* L. var. Siettecerros respectively were cultivated has the same soil texture and Cr levels , despite the wide distances between the two sites. SU 3 is 100m away from the highway while SU 2 is 1934.61m away from SU 3 (**Table 1**). Similarly, SU 1 and SU 4 also have the same soil texture of sand clay loam and moderately acidic pH slightly higher than at SU 2 and SU 3. SU 3 and

SU 1 which are the sampling units at the experimental site had a higher % organic content and % organic matter respectively than at SU 2 and SU 4 at the control site (**Table 1**). Soil Cr after sowing was higher than the preliminary soil Cr in both varieties of *Triticum aestivum* L. at the experimental and the control sites (**Table 2**). Whereas preliminary soil Cr was higher than soil Cr after sowing in both varieties of maize, *Zea mays* L. and *Zea mays everta* L. (**Table 2**).

Table-2: Soil Cr before and after sowing at the four Sampling sites

Sampling Sites	**SU 1**	**SU 2**	**SU 3**	**SU 4**
Chromium levels before sowing (mg/kg)	58.16	62	62	59
Chromium levels during growth and development (mg/kg)	58.45	63.36	55.06	53.33

Table-3: Soil Chromium at the four sampling sites among the selected growth Stages

Growth Stages (days)	**Chromium Levels (mg/kg) At The Sampling Sites**			
	SU 1	**SU 2**	**SU 3**	**SU 4**
15 days	56	60.35	61.6	61.1
30 days	74.7	62	61.6	57.46
45 days	59.53	67.2	64.6	59.85
60 days	55.5	59.93	55.15	39.49
75 days	55.25	54.9	53.93	57.8
90 days	49.7	75.8	33.5	44.25
TOTAL	350.68	380.18	330.38	319.95
MEAN	58.44	63.36	55.06	53.32
SD	8.56	7.26	11.33	9.09
SE	3.50	2.97	4.64	3.72

Table 4: Allowable Limits of Heavy Metal Concentrations in soil (mg/kg) of other countries

Heavy Metal	**Austria**	**Germany**	**France**	**Luxembourg**	**Netherlands**	**Sweden**	**United Kingdom**
Cr	100	60	150	100 to 200	30	60	400

Source: ECDGE (2010)

Soil Cr ranged from 33.5mg/kg in SU 3 at the 90 days growth stage to 75.8mg/kg in SU 3, also at the 90 days growth stage (**Table 3**). Comparison of soil Cr concentrations in this study with other countries was below the permissible limits (**Table 4**). Chromium levels were highest in the soils than in the four varieties of the crops observed at the four sampling units (**Table 5**). Cr concentrations in the two cultivars of wheat and maize ranged from 3.25mg/kg in *Zea mays* L. (yellow maize) at SU 3 at the 30 days growth stage to 20.65mg/kg in *Zea mays everta* L. (popcorn) at SU 4 at the 90 days growth stage. The comparison of Cr concentrations in the two cultivars of wheat and maize in this present study with the Codex Alimentarius of the Joint FAO/WHO Expert Committee on food standards[15] exceeded the permissible limits of 1.30mg/kg. Also Pais and Jones[16] reported that, Cr concentrations higher than 10mg/kg had a phytotoxic effect on plants. On the other hand, Cr in hexavalent form is a potential carcinogenic element for humans and plants[17].

Table-5: Plant Chromium levels (mg/kg) at the four sampling sites among the selected growth stages

Growth Stages (days)	Chromium Levels (mg/kg) At The Sampling Sites			
	SU 1	SU 2	SU 3	SU 4
15 days	12.93	11.44	12.02	9.88
30 days	12.16	12.77	3.25	13.74
45 days	11.73	10.58	11.4	10.82
60 days	11.87	12	14.91	11.89
75 days	11.53	11.55	11.33	11.74
90 days	13.25	16.2	13.66	20.65
TOTAL	73.47	74.54	66.57	78.72
MEAN	12.24	12.42	11.09	13.12
SD	0.69	1.98	4.09	3.90
SE	0.29	0.81	1.67	1.60

Table-6: Plant Uptake Factor (PUF) for Wheat and Maize at the Four Sampling Sites

Growth stages (days)	SAMPLING ITES			
	SU 1	SU 3	SU 2	SU 4
15 days	0.213	0.127	0.126	0.134
30 days	0.091	0.047	0.123	0.160
45 days	0.134	0.119	0.109	0.121
60 days	0.138	0.148	0.130	0.193
75 days	0.139	0.142	0.136	0.130
90 days	0.167	0.219	0.153	0.322

Cr PUF for the investigated cultivars of wheat and maize, obtained at the four different sampling sites within the vicinity of a major highway is shown in **Table 6**. The two cultivars of *Triticum aestivum* L. (Pavon-76 and Siettecerros) and *Zea mays* L. (yellow maize and popcorn) showed low uptake of Cr from particulate atmospheric deposition. PUF which is the ratio of the metal concentration in mg/kg in the aerial plant parts (leaf and stem) to the soil metal concentration (mg/kg) suggests that, the Cr levels in the leaves and stems may have been derived from the soil, despite the high levels of Cr in the cultivars of *Triticum aestivum* L. and *Zea mays* L. as earlier mentioned.

Table-7: Translocation Factor (TF) for Wheat and Maize at the Four Sampling Sites

Growth Stages (days)	SAMPLING SITES			
	SU 1	SU 3	SU 2	SU 4
15 days	6.535	0.944	0.955	2.476
30 days	0.583	6	0.811	1.246
45 days	1.053	1.035	1.058	0.940
60 days	0.933	0.506	0.894	0.858
75 days	1.005	1.049	0.943	1.020
90 days	0.823	0.606	1.108	1.051

The highest translocation factor (6.535) was found in SU 1 at the 30 days growth stage, followed by SU 3(6) and in one of the control site SU 4 (2.476) at the farthest distance from the major highway (Table 7). Pavon -76 and *Zea mays everta* L. with the highest TF suggests that, the Cr levels were translocated from the soil to the root and then, from the root to the aerial plant parts. According to Collins *et al*.,[18], translocation which is the major mechanism for movement of water, nutrients and energy-rich photosynthate[19], is also the principal route by which contaminants move from the root system to stems, leaves and storage organs[20]. The lowest TF (0.583) was in SU 1 also at the 30 days growth stage. A lower than one TFs of Cr in the two cultivars of wheat and maize means that the physiological need of the plant for Cr is rather limited[21].

Table-8: Soil- Plant transfer Coefficient (TC) for Wheat and Maize at the Four Sampling Sites

Growth Stages (days)	**SAMPLING SITES**			
	SU 1	**SU 3**	**SU 2**	**SU 4**
15 days	0.040	0.020	0.013	0.037
30 days	0.030	0.006	0.259	0.060
45 days	0.033	0.029	0.022	0.042
60 days	0.029	0.021	0.060	0.034
75 days	0.019	0.032	0.030	0.029
90 days	0.027	0.045	0.030	0.053

Baker[3] and Zu *et al*.[22] reported that TC higher than 1.0 were regarded as accumulator species, whereas TC typically lower than 1.0 are metal excluder species. A very low transfer coefficient for Cr was observable among the crop plant species at all the selected growth stages (Table 8) suggesting that , the Cr levels determined in the plants are of anthropogenic origin especially from particulate atmospheric deposition. Once particles are deposited on plant foliage, they are subject to removal and degradation[18].

The most likely transfer pathway is through physical contact between the particle and the waxy leaf surface, where chemical transfer occurs through diffusion. Organic chemicals entering the plant cuticle become adsorbed to the lipophilic tissues or permeate into the interior[23]. The two cultivars each of *Triticum aestivum* L. and *Zea mays* L. could be regarded as Cr excluder species, reflecting the absence of an efficient ability to transport Cr from root to leaf. Ghosh and Singh [24] observed that, the non-biodegradability of Cr is responsible for its persistence in the environment; once mixed in soil, it undergoes transformation into various mobile forms before ending into the environmental sink[25, 26].

Although Cr toxicity in the environment is relatively rare, it still presents some risks to human health since chromium can be accumulated on skin, lungs, muscles fat, and it accumulates in liver, dorsal spine, hair, nails and placenta where it is heavyable to various heath conditions[27]. However, Momani *et al*.[28,] remarks that, enrichment coefficient greater than unity suggests anthropogenic origin. Plant accumulation of metals from soils, depends on their bio-availability and on atmospheric deposition[1, 29], either directly entering the plants through stomata or taken up by plant roots after its deposition on the soil surface[30, 31].

SU 2 and SU 4 which are the control sites, had the highest leaf Cr concentration at the 90 days growth stage, while lower concentrations of Cr at SU 1, SU 2 and SU 4 was obtained with the lowest concentration at SU 3 and at the 30 days growth stage (**Fig.1**)

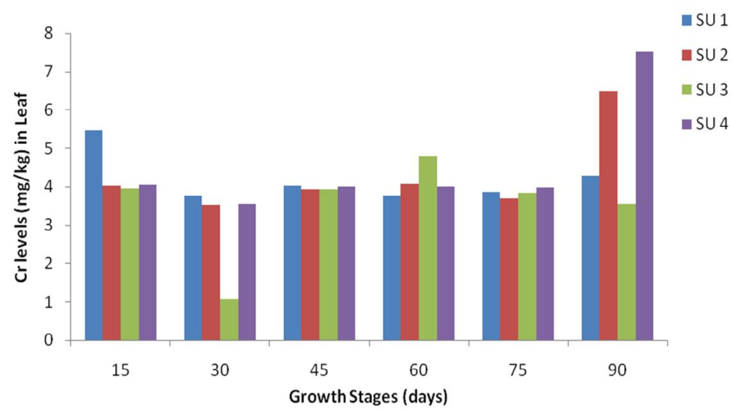

Fig 1: Comparison of Leaf Chromium levels between the sampling units among the selected growth stages.

The highest concentration of stem Cr was highest at the SU 2, SU 3 and SU 4 at the 90 days growth stage; at SU 1 at the 15 days growth stage and at SU 4 at the 30 days growth stage (**Fig.2),** whereas the lowest was at SU 3 at the 30 days growth stage.

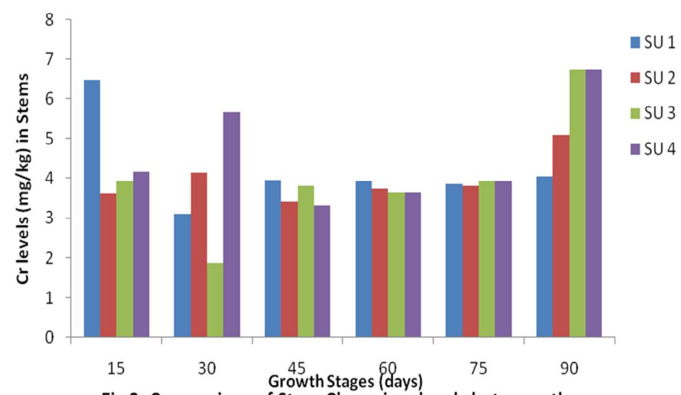

Fig 2: Comparison of Stem Chromium levels between the sampling units among the selected growth stages

The 15 and especially the 30 and 90 days growth stages which represent the germination or seedling and, tillering and ripening stages respectively with the highest occurrence suggests the susceptibility or sensitivity of those stages of growth to metal accumulation. It is also a known fact that metal sensitivity and toxicity to plants are influenced, by not only the concentration and the toxicant types, but are also dependent to several developmental stages of the plants[32, 33]. Chromium concentrations were higher in the leaves and stems than in the roots (**Figs 1, 2 and 3**).

SU 3 also had the lowest Cr concentrations in the leaf, stem and root at the 30 days growth stage (**Figs 1, 2 and 3**) and the magnitude of concentration among the plant parts was stem> leaf > root. Low levels of Cr in the plant parts have been attributed to its insolubility under most soil conditions[34], and it did not affect the plant growth unless the concentrations were very large[35]. This supported the findings of Ghani *et al*., (2010)[36]. Our present study also showed that, the yellow maize roots and popcorn leaves to be the least and highest accumulator of Cr, respectively. Necessity of Cr for plant growth has not been proved. The mobility of Cr within the plant is extremely low[37,38].

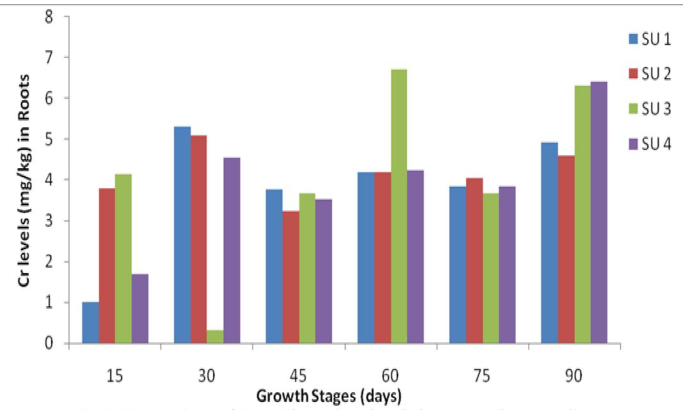

Fig 3: Comparison of Root Chromium levels between the sampling units among the selected growth stages

It thus remains in that part where the uptake took place. Toxicity of Cr levels at high concentration levels has not been reported. However, it was noted that chromium concentrations in all the cases were above permissible limits of 1.30 mg kg[-15](WHO, 2006). Cr levels were highly significant only in the two varieties of *Zea mays* L. at the growth stages. This indicates selective ability of certain metals in certain species of crop plants. This could also be due to the wide and exposed surface of the leaves of both cultivars in collecting these particulate deposits.

CONCLUSION

The TF was higher in both varieties of *Triticum aestivum* L. and *Zea mays* L. than the PUF and soil-plant TC. Also the cereal crops at close proximity to the Kano-Zaria highway had higher TF than at the control- Irrigation Research Station (IRS). The 90 days (ripening) growth stage had the highest levels of Cr. The 15, 30 and 90 days growth stages which are the seedling/germination, tillering and ripening stages respectively accumulated higher levels of heavy metals than the other growth stages expressing their sensitivity to Cr. Although, soil Cr levels was below the allowable limits in other countries and plant Cr was above the Joint [15]FAO/WHO food standard, 2006, continuous monitoring studies is required to ascertain the physiological, morphological and toxicity effects of Cr on these cereal crops particularly at the selected growth stages.

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