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Nickel and chromium concentrations in plant tissues of accessions of Okro (*Abelmoschus esculentus* (L) Moench.) grown in soil contaminated with paint waste

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ABSTRACT: The proper disposal of paint waste from Paint Factories should be a concern to Environmentalists and Regulators. In this study, six accessions of *Abelmoschus esculentus* (okro) were grown in paint waste contaminated soil. Parameters studied were plant height, stem girth, leaf elongation rate, and chlorophyll contents. Others were tissue concentrations of Ni and Cr of plant organs. Soil chemical analysis showed that the contaminant increased pH and organic C. Ni and Cr were detected in the contaminated soils only. The paint waste contamination depressed all plant parameters studied. Differences between values obtained for control and treatment were significant for plant height, and leaf elongation rate ($\alpha = 0.05$). Responses to the treatment vary among the accessions as some were depressed more than others. The plant tissue analyses show that Ni and Cr were present in all organs (root, stem, and fruit) of the plants in control and paint waste contaminated soils for all accessions, indicating the translocation of these metals from root through stem to fruits. This has implication where the plant is grown in a soil contaminated by toxic heavy metals. The differences in metal concentration of tissues as exhibited among the accessions showed three out of six to have low tissue concentration of Ni and Cr consistently.

Key Words: Okro; *Abelmoschus esculentus*; Metal contamination; Nickel; Chromium; Plant tissues; Environmental pollution.

Introduction

Paint waste must be looked at as a veritable source of metal contamination to the soil and the paint industry as one of the major industries operating in Nigeria producing hazardous and non-hazardous solid, liquid and gaseous particulate wastes. EPA/ROC (1994) reported paint production as one of the most serious sources of soil contamination. Metal contamination of soil from paint is yet to be reported as widespread. It is necessary to recognize it as a problem in the light of the drive for industrialization of the economy of Nigeria. Paint production will definitely continue and intensify as construction and production increases.

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Paint waste contamination of the environment is basically due to improper disposal of the waste. Available information indicates that paint waste contamination of natural aquatic system is more common and often reported than soil contamination (Anonymous 2002). Water based paint wastes contain biodegradable substances such as surfactants and cellulose thickeners, which as they breakdown, can reduce oxygen levels in water, threatening the survival of fish and other aquatic organisms. The toxic nature of solvent-based paints may cause tumor to form in animals such as fish. These paints (water- and solvent- based) contain heavy metals such as lead, chromium, mercury and zinc (Anonymous, 2002).

Actually, large areas of land are contaminated with heavy metals derived from urban activities (municipal sewage and waste incinerators), agricultural operations (fertilizers and pesticides) and industrial processing (metaliferous mining, smelting industry, paint factory and tannery) (Sebastiani *et al.,* 2004). Heavy metal contaminated waste can be disposed in landfills, but this solution negatively affects human health, wild flora and fauna, as well as productivity of crop plants and livestock (Lasat, 2002). The management of heavy metal contaminated water or bio-solids is becoming challenging as stricter regulations to improve water quality and soil fertility are imposed (Sebastiani *et al.,* 2004) by Environment Regulating Bodies. In Nigeria, many of the paint factories need a sustainable alternative to disposal of paint waste in open, vacant and fallow plots and abandoned farmlands. In this way of disposal, rainwater washes the paint waste materials gradually into the soil and natural watercourses. This observation formed the basis of the study reported here.

In this study, the effect of paint waste (water based) contaminated soil on plant height, stem girth, leaf elongation rate, chlorophyll content of leaves and concentration of nickel and chromium in plant parts of six local accessions of *Abelmoschus esculentus* (L) Moench. (Okro; dwarf type) were determined. Okro is a vegetable commonly cultivated in various agricultural production systems especially in home gardens in Nigeria. It is grown for its fruits, seeds, floral parts, stem and leaves. In these forms, they are consumed when immature and beaten into a gelatinous soup. The soup is used for consuming coarse textured starchy food commonly the diet of the people. It contributes to protein, mineral, vitamins and source of roughage in human diet. A 100g edible portion of okro has been reported to contain 90g of water, 2g of protein, 6g of carbohydrate,1g of fibre with traces of fat, vitamins A and C with traces of vitamin B, calcium, phosphorus and iron (Siemonsma and Hamon, 2002). Energy value of 140kg/100g; a comparable value to FAO recommended nutrient requirement is also reported. The seeds contain about 20% protein similar in amino acid composition of soya bean and 20% oil similar in fatty acid composition to cotton seed (Schipper, 2000). The oil fraction in seed include oleic acid and linoleic acid.

Okro also has medicinal and industrial potentials. In medicine, the mucilage is used as plasma replacement or blood volume expander (Siemonsma and Hamon, 2002). Leaves are used as a basis for poultices, as an emollient, surdorific antiscorbutic and also to treat dysuria (Siemonsma and Hamon, 2002). The fibres present are suitable for spinning into rope and in the manufacture of paper and cardboard. Locally in Nigeria, the fibres are braid together and used for fish line, game traps and sponges.

Materials and Methods

Plant Material

Dry capsules (fruits) of *Abelmoschus esculentus* (L) Moench. (dwarf species) were obtained from farmers in Ugoneki village near Benin City. The six (6) local accessions were identified based on fruit morphological characters as outlined by Schippers (2000) which included length, tip curved or pointed, absence or presence of indentation at the base, base protruding or flat, number of ridges, ridges split above or below the dented base etc. The six accessions were labeled as follows:

S/N	Accession	Origin/ Source	Latitude & Longitude
1.	DEV/IKP-OHA/RAM 007 (DIOR – 007)	Ugoneki	06°13′ S, 06° 06′W
2.	DEV/IKP-OHA/RAM 008 (DIOR – 008)	Ugoneki	06°13′ S, 06° 06′W
3.	DEV/IKP-OHA/RAM 009 (DIOR – 009)	Ugoneki	06°13′ S, 06° 06′W
4.	DEV/IKP-OHA/RAM 010 (DIOR – 010)	Ugoneki	06°13′ S, 06° 06′W
5.	DEV/IKP-OHA/RAM 011 (DIOR – 011)	Ugoneki	06°13′ S, 06° 06′W
6.	DEV/IKP-OHA/RAM 012 (DIOR – 012)	Ugoneki	06°13′ S, 06° 06′W

Paint Waste Collection

The paint waste (water based) in solid form was obtained from a paint factory in Benin City.

Preparation and Contamination (Treatment) of Soil Samples

The soil used in the study was obtained as a composite (pooled) sample of top -soil (0 – 20 cm depth), from the University of Benin Teaching and Research Farm, Benin City. Eighty (80kg) kilogram quantity of soil was spread evenly on a flat surface as a bed. Paint waste (water-based, solid form) that was ground into powder 3.5 kg, was evenly spread on top of the soil. The paint waste and soil were thoroughly mixed and spread out on the bed. It was then watered twice for a week and allowed to dry for another two weeks before putting in experimental pots (2kg each). Control soil was prepared the same way except that paint waste was not added. A total of seventy two pots including control were prepared and transferred to the field.

Soil Chemical Determination

Samples of paint waste contaminated and uncontaminated (control) soil were analysed. The soil samples were air dried for one week and sieved using 180-µm sieve. One gram (1g) of soil samples was subjected to wet digestion using HF (hydrofluoric) acid for total elemental content. Standard methods were followed for the determination of N, organic C, P, Na, K and Mg. Elements like Zn, Fe, Cu, Ca, Mn, Cd, Co, Al, Cr, Ni and Pb were determined using AAS (flame atomic absorption spectroscopy). Soil pH of the samples were determined in distilled water and 0.01 M $CaCl_2$ in ratio 1:3 (soil : solution medium).

Planting and Thinning

After carrying out viability test, three seeds were sown in each pot at a depth of approximately 3 cm. The plants were watered once daily. The experiment was conducted between December 2003 and March 2004. The six accessions (6) had six replications each in control and paint waste contaminated soil. Thinning to one plant per pot was done after three weeks of planting.

Growth Parameters

i. **Plant Height**: plant height was determined fortnightly using a standard meter rule from soil level to the tip.
ii. **Stem Girth**: measured fortnightly by holding a thread around the base of the plant. The length of the thread was subsequently determined by placing it on the standard meter rule to give the stem girth in centimeters.
iii. **Leaf Elongation Rate**: the length of marked leaves were measured for four consecutive days and used to determine the leaf elongation rate according to the formula: $K = \frac{(L_2 - L_1) + (L_3 - L_2) + (L_4 - L_3)}{3}$

where K = Leaf elongation rate/day (mm/day)
L_1, L_2, L_3 and L_4 = Length of leaf at day 1, 2, 3 & 4 respectively.

Chlorophyll Content Determination

Chlorophyll content of leaves located at the third node from apex in plants of the six local accessions in both control and paint waste contaminated soil was determined according to standard operating procedure SOP # 2030 of the U.S. Environmental Protection Agency (1994). Each leaf was cut to an area of 1000 mm^2, weighed and ground with acid washed sand and 2 ml of a mixture of 0.1 N NH_4OH and acetone (1:9) respectively. After centrifugation at 3000 r.p.m for 5 minutes, the supernatant was decanted and diluted to 10 ml with 80% acetone and then read spectrophotmetrically at wavelengths 663 nm and 645 nm. Using this result, chlorophyll a and b were calculated.

Nickel and Chromium Determination in Plant Tissues (Root, Stem and Leaves)

Nickel and Chromium concentration in plant tissues were determined using dried plant parts (root, stem and fruit) of each accession in control and contaminated soils. The plant parts were ground using an electric powered grinding machine. One gram (1g) of each ground sample was put in a 50 ml porcelain beaker and placed in a muffle furnace for ashing at 550°C for 5 hours. The dry ashed sample was dissolved in 20% concentrated nitric acid (HNO_3) and warmed on a hot plate for 15 minutes and stirred with a glass rod to enable it dissolve. The solution was allowed to cool and made up to 50 ml with distilled water. Metal concentration (Ni and Cr) in plant tissue samples was determined by flame atomic absorption spectroscopy (AAS).

Statistical Analysis

Data collected were analyzed using GENSTAT. Where significant F values were obtained, differences between individual means were separated using Duncan Multiple Range test (Steele and Torie, 1980).

Results

Soil Chemical Analysis

The chemical analysis of uncontaminated (control) and paint waste contaminated soil samples is reported in Table 1. The values obtained for percent (%) carbon and K, Ca, Na, Al and Mn was higher in paint waste contaminated soil. The values obtained for % N, P, Fe, Zn, Cu, Co, Cd and Pb was higher in uncontaminated (control) soil samples. Two metals, Chromium (Cr) and Nickel (Ni), were undetected in control soil but present in paint waste contaminated soil. The pH reading recorded for the soil samples is shown in Table 6. The paint waste contamination increased the pH in both media (distilled water and 0.01 M $CaCl_2$ solution).

Plant Growth

i. **Height:** showed a strong response to contaminant as differences in the height of control and treated plants were observed. Control plants attained greater heights. 8 weeks after planting, height range for control plants was between 22.00 cm and 26.30 cm while for treated plants was between 16.13 cm and 18.33 cm. Statistical analysis of result showed significant difference.

ii. **Stem Girth:** was affected by the paint waste contamination of soil as the results show differences between control and treated plants in all accessions studied.

iii. **Leaf Elongation Rate:** shows distinct response to treatment as control plants gave higher values in all accessions. There was significant difference between control and paint waste treated plants ($p = 0.05$).

Chlorophyll Content: The values obtained for control plants of four accessions (DIOR 007, DIOR 008, DIOR 010 and DIOR 012) were higher than for treated. Range of values obtained showed depression in total chlorophyll content of treated plants (Table 5). Statistical analysis showed no significant difference.

Plant Tissue Concentration of Nickel and Chromium

i. Nickel (Ni): Figures 1 and 2 show the nickel content of tissues of plants grown in control and paint waste contaminated soils respectively.
ii. Chromium (Cr): Figures 3 and 4 show chromium content of tissues of plants grown in control and paint waste contaminated soils respectively.

Table 1: Chemical analysis of soil samples (uncontaminated and paint waste contaminated) before planting

Elements	%C	%N	P	K	Ca	Na	Al	Fe	Zn	Cu	Mn	Co	Cd	Pb	Cr	Ni
			◄---------- ppm ----------►													
Uncontaminated	0.85	0.60	135.01	642.5	868.3	682.5	5.0	1947	370.7	24.1	289.2	36.7	60.0	137.0	-	-
contaminated	2.43	0.50	105.0	707.6	918.3	884.5	15.0	1921	275.9	23.3	608.4	30.0	36.7	129.6	41.2	27.5

Table 2: Mean height (cm) of plants of six local accessions of *A. esculentus* (dwarf okro) after 8 weeks of growth in paint waste contaminated soil.

	Duration	Two weeks	Four weeks	Six weeks	Eight weeks
	Treatment				
DIOR 007	control	$6.53^{a,b,c,d} \pm 0.62$	$11.33^{a,b} \pm 0.83$	$18.20^{a,b} \pm 1.71$	$23.40^{b,c} \pm 1.17$
	contaminated	$5.80^{c,d} \pm 0.86$	$8.30^{e} \pm 0.59$	$13.18^{d} \pm 1.95$	$16.13^{d} \pm 2.31$
DIOR 008	control	$7.50^{a,b} \pm 2.03$	$12.85^{a} \pm 3.31$	$19.03^{a} \pm 4.30$	$22.00^{c} \pm 3.45$
	contaminated	$5.32^{d} \pm 0.58$	$8.70^{d,e} \pm 1.17$	$13.65^{c,d} \pm 2.12$	$17.55^{d} \pm 2.75$
DIOR 009	control	$7.03^{a,b,c} \pm 1.61$	$11.13^{a,b,c} \pm 2.60$	$19.30^{a} \pm 3.43$	$25.00^{a,b} \pm 2.49$
	contaminated	$6.47^{a,b,c,d} \pm 0.45$	$9.12^{c,d,e} \pm 1.45$	$14.25^{c,d} \pm 1.68$	$17.25^{d} \pm 1.33$
DIOR 010	control	$6.80^{a,b,c} \pm 0.57$	$10.75^{a,b,c,d} \pm 1.23$	$17.17^{a,b} \pm 1.20$	$26.30^{a} \pm 2.14$
	contaminated	$7.60^{a} \pm 0.37$	$10.27^{b,c,d,e} \pm 0.60$	$14.35^{c,d} \pm 1.35$	$17.98^{d} \pm 2.29$
DIOR 011	control	$6.22^{b,c,d} \pm 1.30$	$11.55^{a,b} \pm 1.97$	$17.45^{a,b} \pm 2.10$	$24.02^{a,b,c} \pm 1.46$
	contaminated	$6.85^{a,b,c} \pm 0.39$	$10.82^{a,b,c,d} \pm 1.65$	$13.83^{c,d} \pm 1.03$	$17.55^{d} \pm 1.80$
DIOR 012	control	$7.10^{a,b,c} \pm 0.54$	$11.50^{a,b} \pm 1.30$	$18.07^{a,b} \pm 1.02$	$25.87^{a,b} \pm 1.42$
	contaminated	$7.08^{a,b,c} \pm 0.49$	$9.95^{b,c,d,e} \pm 0.27$	$16.18^{b,c} \pm 1.83$	$18.33^{d} \pm 1.94$

Figures = Mean ± S.D. , n=6; Figures in the same column with similar alphabets are not significantly different ($\alpha = 0.05$).

Table 3: Stem girth (cm) of plants of six local accessions of *A esculentus* after eight weeks of growth in paint waste contaminated soil.

	Duration	Four weeks	Six weeks	Eight weeks
	Treatment			
DIOR 007	control	$1.37^{a} \pm 0.19$	$1.82^{a} \pm 0.12$	$2.15^{a} \pm 0.24$
	contaminated	$1.08^{b,c,d} \pm 0.15$	$1.42^{b,c,d} \pm 0.12$	$1.70^{c,d} \pm 0.14$
DIOR 008	control	$1.28^{a,b} \pm 0.45$	$1.80^{a} \pm 0.33$	$2.13^{a,b} \pm 0.29$
	contaminated	$1.15^{b,c,d} \pm 0.26$	$1.48^{b,c,d} \pm 0.38$	$1.63^{c,d} \pm 0.37$
DIOR 009	control	$1.18^{a,b,c} \pm 0.13$	$1.53^{a,b,c} \pm 0.37$	$1.83^{b,c} \pm 0.37$
	contaminated	$1.22^{a,b,c} \pm 0.19$	$1.37^{c,d} \pm 0.19$	$1.68^{c,d} \pm 0.15$
DIOR 010	control	$1.23^{a,b} \pm 0.16$	$1.67^{a,b} \pm 0.18$	$2.25^{a} \pm 0.21$
	contaminated	$0.97^{d} \pm 0.12$	$1.28^{c,d} \pm 0.24$	$1.33^{e} \pm 0.19$
DIOR 011	control	$1.18^{a,b,c} \pm 0.12$	$1.55^{a,b,c} \pm 0.12$	$2.05^{a,b} \pm 0.24$
	contaminated	$1.02^{c,d} \pm 0.08$	$1.25^{c,d} \pm 0.12$	$1.42^{d,e} \pm 0.23$
DIOR 012	control	$1.17^{a,b,c,d} \pm 0.10$	$1.68^{a,b} \pm 0.18$	$2.07^{a,b} \pm 0.25$
	contaminated	$1.08^{b,c,d} \pm 0.17$	$1.20^{d} \pm 0.18$	$1.32^{e} \pm 0.19$

Figures = Mean ± S.D , n=6

Table 4: Mean rate of leaf elongation (mm per day) of plants of *A. esculentus* grown in paint waste contaminated soil.

	Treatment	First Determination (mm)	Second Determination (mm)	Third Determination (mm)
DIOR 007	control	$6.83^{a} \pm 2.23$	$7.00^{a} \pm 2.68$	$10.33^{a} \pm 2.81$
	contaminated	$2.33^{b} \pm 0.82$	$2.17^{b} \pm 1.17$	$3.50^{d} \pm 0.55$
DIOR 008	control	$9.00^{a} \pm 2.97$	$5.17^{a} \pm 2.71$	$6.83^{b,c} \pm 2.40$
	contaminated	$2.50^{b} \pm 1.05$	$2.00^{b} \pm 1.27$	$2.17^{d} \pm 0.75$
DIOR 009	control	$7.33^{a} \pm 3.72$	$5.83^{a} \pm 2.14$	$6.67^{b,c} \pm 4.18$
	contaminated	$2.00^{b} \pm 0.89$	$2.50^{b} \pm 1.05$	$4.17^{c,d} \pm 2.23$
DIOR 010	control	$6.17^{a} \pm 4.58$	$5.00^{a} \pm 1.67$	$7.00^{b} \pm 3.35$
	contaminated	$1.83^{b} \pm 0.75$	$1.83^{b} \pm 0.98$	$3.33^{d} \pm 1.51$
DIOR 011	control	$6.67^{a} \pm 3.93$	$5.00^{a} \pm 2.45$	$7.67^{b} \pm 1.86$
	contaminated	$1.17^{b} \pm 0.41$	$1.67^{b} \pm 1.03$	$2.67^{d} \pm 1.21$
DIOR 012	control	$9.00^{a} \pm 3.69$	$7.33^{a} \pm 2.34$	$7.17^{b} \pm 1.33$
	contaminated	$1.33^{b} \pm 0.82$	$2.17^{b} \pm 1.17$	$3.50^{d} \pm 1.38$

Figures = Mean ± S.D.,

Discussion

Soil Chemical Analysis

The result of soil analysis for element concentrations in both control and paint waste contaminated soils (Table 1) indicated higher concentration of some elements such as Pb and Fe in control soil as well as the detection of Ni and Cr in paint waste contaminated soil only. Control and contaminated soil had pH ranges from 6 – 7. The contaminated soils had pH values closer to neutral than control soil. Acidic conditions favour nutrient absorption and availability of some heavy metals (Wong *et. al.*, 2001).

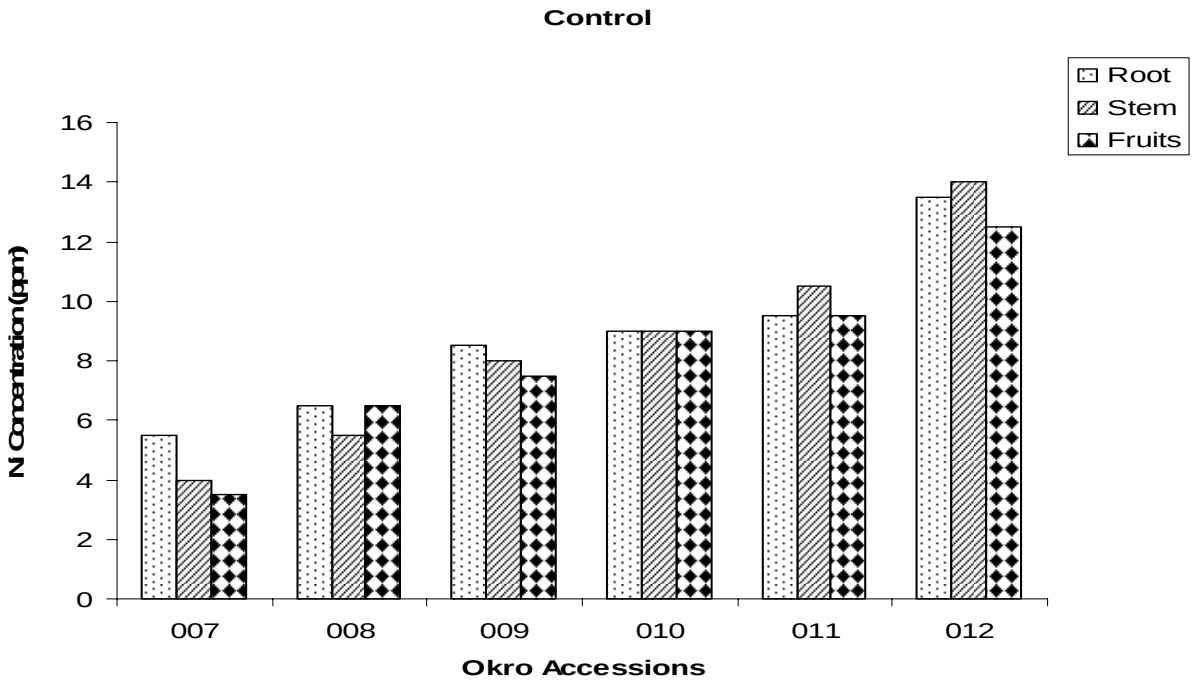

Figure 1: Ni concentration in tissues of plants grown in uncontaminated (control) soil

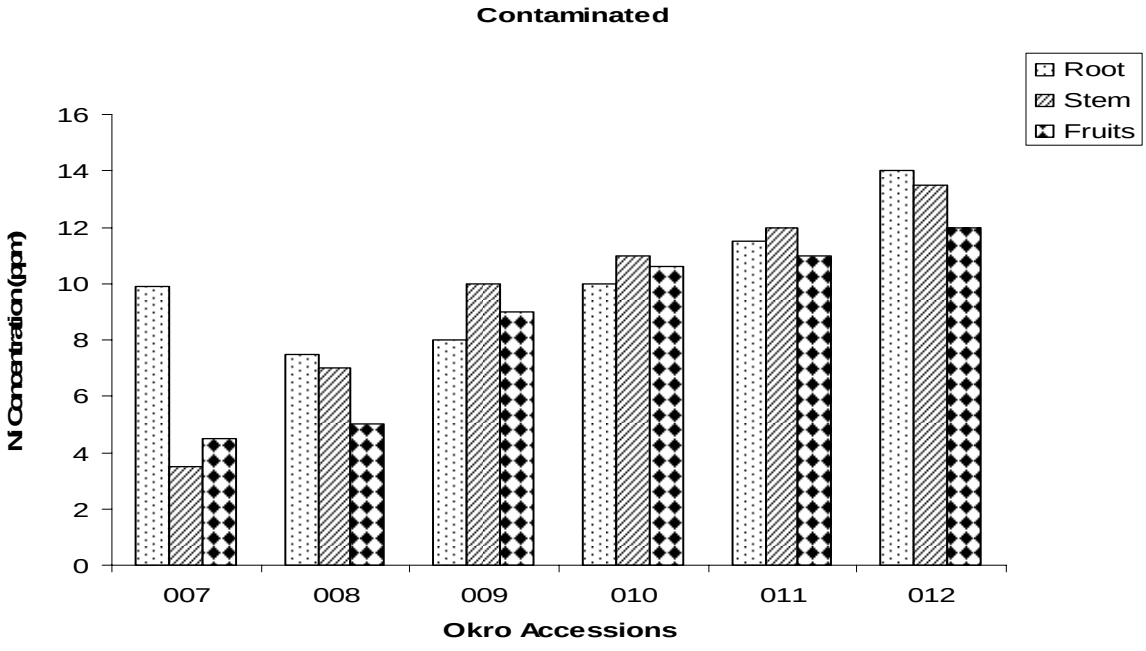

Figure 2: Ni concentration in tissues of plants grown in paint waste contaminated (treatment) soil

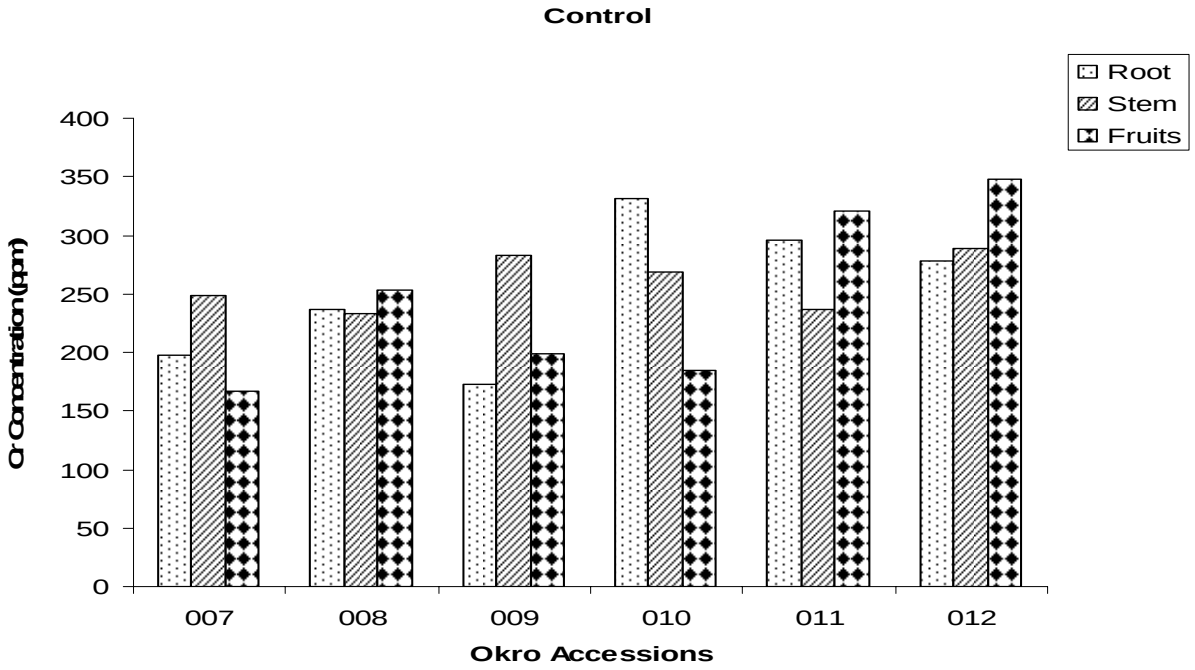

Figure 3: Cr concentration in tissues of plants grown in uncontaminated (control) soil

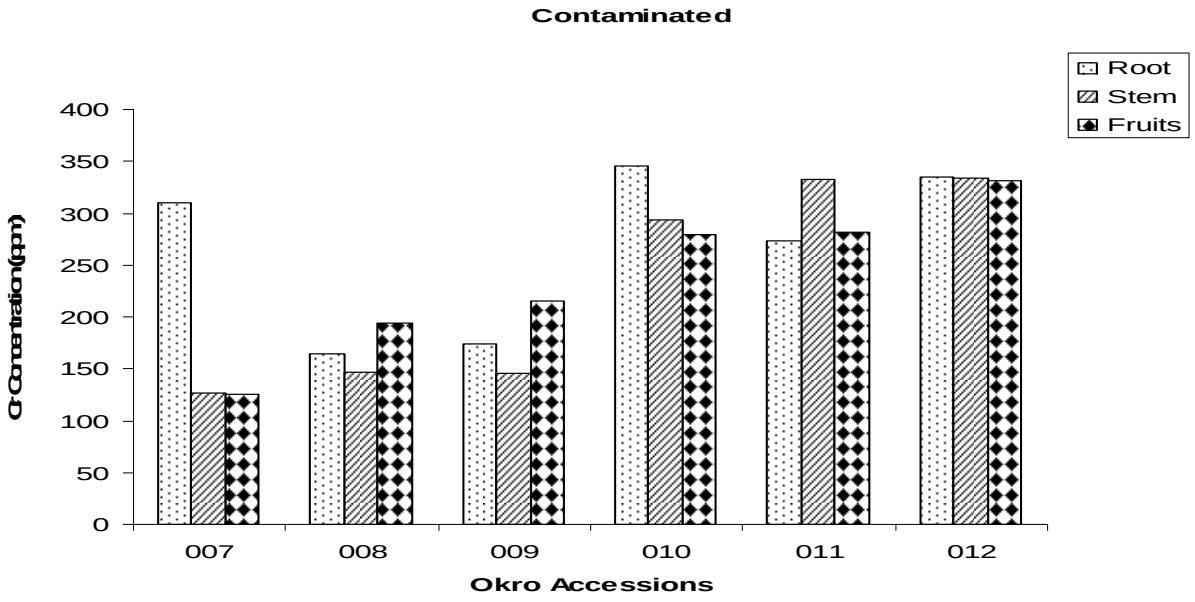

Figure 4: Cr concentration in tissues of plants grown in paint waste contaminated (treatment) soil.

Table 5: Total chlorophyll content (Chl a + Chl b) of leaves of six local accessions of *A.esculentus* grown in paint waste contaminated soil

Accession No.	Control ← µg cm^{-2} →	Contaminated
DIOR 007	103.4055	28.2526
DIOR 008	50.8174	45.5676
DIOR 009	39.5315	44.3997
DIOR 010	68.3499	30.6537
DIOR 011	24.9323	42.3083
DIOR 012	59.4677	29.8694

Table 6: Mean pH values of control and contaminated soil before planting

Soil sample	Medium	
	Distilled water	0.01M $CaCl_2$
Uncontaminated (control)	6.78	6.07
Contaminated	6.89	6.22

(soil : medium = 1:3)

Plant Growth

Plant height, stem girth and leaf elongation rate were depressed by the paint waste contaminant in the soil. The reduction in plant height and leaf elongation rate were found to be significant ($\alpha = 0.05$). The treatment depressed plant height by 31%,20%, 31%, 32%, 27% and 29% when compared to the control in accessions DIOR 007, 008, 009, 010, 011 and 012 respectively, after eight weeks of growth. Reduction in height and biomass have been reported by many authors (Anoliefo *et al*.,2000; Wong *et al*., 2001; Salim *et al*., 1993; Renault *et al*., 2000; Vwioko and Fashemi, 2005) as visible impacts of substances that are toxic and inhibit plant growth. The presence of paint waste in the soil affected the general physiology and metabolism of the plants. It is believed that the contaminant due to its metallic content interfered with mitotic division in leaves (Fiskesjo, 1988). Leaves from plants grown in paint waste contaminated soil gave lower chlorophyll contents. This was observed in four out of six accessions. Among the accessions, DIOR 007 and DIOR 012 gave very low values of total chlorophyll in treated plants. These two showed signs of leaf yellowing during growth. Bohner *et al*. (1980) reported that excess concentration of some heavy metals such as Co, Cu, and Cr decreased chlorophyll concentration by inhibiting electron transport. Also, accumulation of heavy metals in sensitive plant tissues cause alterations in various vital growth processes such as photosynthesis and photosynthetic electron transport and biosynthesis of chlorophyll (Mocquot *et al*., 1996).

Nickel and Chromium Concentration in Roots

Statistical analysis of data obtained for Nickel and Chromium concentration in roots of plants grown on control and contaminated soils show no significant difference ($P = 0.05$). Fifty percent of plants grown on paint waste contaminated soil have higher Ni and Cr content in the roots than in other parts. This is consistent with the report of Zurayk *et al.* (2000) that the restriction of shoot entry of Ni is not observed in all species. Nickel uptake by the roots ranged between 5.50 ppm and 13.50 ppm for control and 8.00 ppm and 14.00 ppm for contaminated soil. Chromium uptake by the roots of control plants ranged between 173.00 ppm and 331 ppm while for plants grown on contaminated soil the range was between 164.50 ppm

and 346.00 ppm. This result is striking especially for the control plants, since Ni and Cr were undetected in control soil but present in paint waste contaminated soil. Peralta-Videa *et al.* (2002) studied the effect of mixed cadmium, copper, nickel and zinc at different pHs upon alfalfa growth and heavy metal uptake. They observed that the concentration of some metals in plant tissues were considerably higher than the initial soil concentrations. They considered this observation to be an indication that alfalfa plant is capable of competing with the bentonite clay to remove and fix metal ions from soil matrix.

Another feature observed in the study was that three out of six local accessions gave higher concentrations of chromium in the root both in control and paint waste contaminated soil. This is important because it indicated roughly, the variability in uptake of chromium from the soil by the six different accessions of *A. esculentus* studied. This is an expression of genetic differences among accessions.

Nickel and Chromium Concentration in Stems

Nickel and Chromium were detected in the stem tissues of plants grown on control and paint waste contaminated soil. This shows that there was translocation of metals after root uptake (Peralta-Videa *et al.,* 2002). Cr content in stems of plants grown on control soil ranged between 233.50 ppm and 289.00 ppm while for stems of plants grown on contaminated soil the range was between 127.00 ppm and 333.50 ppm. The range for Nickel in stems from plants of control soil is 4.00 ppm and 14.00 ppm while stems from plants of contaminated soil gave a range of 3.50 ppm and 13.50 ppm. The ratio of Nickel concentration of stem/root in the six local accessions showed that for plants in control soil, the range was between 0.72 – 1.11 and 0.35 – 1.25 for plants in contaminated soil. This indicates that the contamination of the soil by paint waste did not increase significantly the uptake and distribution for nickel in tissues of the accessions studied. This is not surprising as the contaminant was about 8% (w/w) of the soil. Thus, plant tissue concentration of metals depends on soil concentration. Wong *et al.,* (2000) reported higher Cr contents in plant tissues grown in soil amended with Yuen Long sludge when compared to those grown on Tai Po sludge due to a greater concentration of Cr in Yuen Long sludge than in Tai Po sludge. Also, the results obtained by Salim *et al.,* (1993) indicated a general trend of increase in the metal ion content in the various plant parts with the increase of metal ions in solutions used for treatment of plants by either root or foliar treatment.

Agarwala *et al.* (1977) stated that excess nickel in soil would result in visible symptoms in plants. None of such symptoms were observed in this study, most likely because, the concentration of Ni in stems and other tissues of plants were low when compared to values obtained for Cr. The values for Cr were at least twenty-eight and above times (28>) higher than nickel concentrated within the plant tissues.

Nickel and Chromium Concentration in Fruits

Fruits harvested from plants grown on control and paint waste contaminated soil show the presence of Ni and Cr. Lin (1991) carried out a survey of vegetables and other food crops from farmers in Taiwan and reported the presence of eight accumulated metals in these edible parts. The presence of Ni and Cr in fruits of the six local accessions in both control and paint waste contaminated soil strongly suggests an even distribution of these two metals in all parts of the plant within each accession approximately. Cr content in fruits of plants grown on control ranged from 166.50 ppm to 348.00 ppm. While for plants grown on paint waste contaminated soil the range was between 125.00 ppm and 331.00 ppm. Ni concentration by fruits of plants grown on control soil showed a range of 3.50 ppm to 12.50 ppm. For plants grown on paint waste contaminated soil, the range was 4.50 ppm – 12.00 ppm.

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