Health Risk Assessment of *Amaranthus* Species Grown on Inorganic and Organic Fertilizers

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ABSTRACT

Human health and environmental issues associated with intensive and vastly industrialized agriculture is the main cause of the constantly growing interest in organic farming. The objective of this study was to assess the heavy metals (Cd, Cr, and Pb) in *Amaranthus cruentus* (AC) and *Amaranthus spinosus* (AS) grown on organic fertilizer (poultry droppings (PD)) and mineral fertilizer (NPK 15:15:15).

The seeds of AC and AS were sown separately in a pot containing 5kg soil. Each Amaranthus variety consisted of these treatments: control (C), organic fertilizer (PD) and mineral fertilizer (NPK 15:15:15); all laid out in completely randomized design and replicated four times. Pre physico-chemical properties and heavy metals of the experimental soil and treatments were analyzed using standard procedures, also Health Risk Index (HRI) was determined. Application of NPK at 4g/5kg soil and PD 10g/5kg soil was done and left for 7 days for better nutrient mineralization. Plants were thinned to 2 stands per pot after two weeks-after-sowing (WAS). Parameter(s) on growth were taken at 2, 4, and 5-WAS, while that of yield at harvest was done at 5-WAS.

Data were analyzed using Analysis of Variance ($p<0.05$). Results showed significant differences ($p<0.05$) in growth parameters from *A. cruentus* and *A. spinosus* at 2, 4 and 5 WAS across all treatments (C, PD and NPK) applied. Results obtained at 5WAS showed the control with highest leaf area (34.13 cm^2) from *A. spinosus*, while PD had 29.45 cm^2. Also, *A. cruentus* treated with poultry droppings and control had 30.00 cm^2 and 27.48 cm^2, respectively. At fresh weight (yield) *A. cruentus* had the highest value (259.00g) treated with NPK compared to PD (167.75 g) and control (129.75 g), while *A. spinosus* had 179.75 g treated with NPK compared to control (162.75 g) and PD (135.75g). The control had high total dry weight of 35.50g from *A. spinosus* and 28.50g from *A. cruentus*. This study showed that NPK applied 4g/5kg soil gave the best performances in growth, fresh and dry matter yield in A. *cruentus* when compared to *A. spinosus*.

Heavy metals result showed that Cd concentration was not detected in soil, root and shoot samples of A. *cruentus* and A. *spinosus*. Chromium levels were within the FAO/WHO (2001) tolerance level (Cr = 0.2 mg/kg), while concentrations of Pb were exceedingly higher in root and shoot samples of *A. cruentus* and *A. spinosus* above the permissible level (Pb = 0.3 mg/kg) in NPK treatments than poultry droppings. The HRI of Cr for *A cruentus* in root was<1 in poultry droppings and NPK 15:15:15, while Pb >1 in poultry dropping treatments of root and shoot. Consumption of vegetables with remarkably high contents of Pb especially in NPK 15:15:15 plots and high values of the Health Risk Index in poultry droppings should be well considered by the populace. Monitoring of vegetables grown on both organic and mineral fertilizers is required for quality food and safety.

(Key words: poultry droppings, NPK 15:15:15, Amaranthus species, heavy metals toxicity, health risk)

INTRODUCTION

In modern agriculture, there are a number of indications showing that the intensive use of mineral fertilizers and pesticides significantly affect soil fertility and microbial communities which are crucial for many ecosystem services (Hafez and Theimann, 2003). Organic farming is a sustainable system, which encompasses numerous positive effects on biosphere.

According to Food and Agriculture Organization of the United Nations (FAO, 2021), Organic agriculture is a practice that avoids the use of synthetic fertilizers and pesticides to minimize pollution of soil, water and air and as such promoting and enhancing agroecosystem health. Also, soil fertility in organic farming is achieved using composted materials derived by agronomic practices such as crop rotation and planting of nitrogen fixing crop. Compost enhances the soil fertility by modifying physical, chemical, and biological properties of soil and often used as an amendment agent for remediating metal polluted (Terzano, *et al*., 2008) and other pollutants in soils**.**

Vegetables are important edible crops and are an essential part of human diet. They are rich in nutrients essential for human health and are a vital source of carbohydrates, vitamins, minerals, and fibers. Leafy vegetables are widely used for cooking purposes, they are also used to increase the quality of soup and for nutritional purposes (Sobukola, *et al*., 2007). They contain cellulose and form roughage which help the bowel to function regularly in the removal of unwanted materials from the body. They also contain 70-75% water which is essential to the body system. Vegetables are very important protecting foods, beneficial for the maintenance of health, prevention, and treatment of many diseases (D'Mello, 2003).

In the past decade, there has been growing attention in determining heavy metals and other contaminants in foods. The poisoning effects of heavy metals are due to their interference with normal body biochemistry in the normal metabolic processes (Okunola, *et al*., 2011). Heavy metals accumulation in agricultural soil may not only result in contamination of soil but also in increased uptake by food crops which may affect its quality and safety (Muchuweti, *et al*., 2006). Contamination of vegetables by heavy metals has recently received notable research attention because vegetables are consumed relatively in large amounts and have the capacity to bioaccumulate heavy metals (Oluwatosin *et al.,* 2010) consequently posing risk to human health (Fayinminnu and Adekunle-Jimoh, 2015). Most of heavy metals are toxic to human and animals even at low concentrations (Shahid, *et al*., 2015).

Vegetables of different types accumulate various heavy metals through their absorption abilities which vary in different biological species due to their diverse physiological character (Adesuyi, *et al*., 2016). According to Cui *et al*. (2004), there is an appropriate method of calculating the relative differences of bioavailability of heavy metals to plants, the transfer quotient and assessment which is also used for human Health Risk Index (HRI). Risk of intake of metal contaminated vegetables to human health was characterized by Hazard Quotient (HQ). This is the ratio of determined dose to reference dose (RD). In the HRI, the population will pose no risk if the ratio is less than 1 (<1) and if the ratio is equal or greater than 1(>1), the population will experience health risk according to Integrated Risk Information System (IRIS, 2003).

Fear of contaminants in food which always results in low quality and safety especially from conventional products is the main reason why people prefer organic foods. Consumers believe that vegetables organically grown are healthy, safe and of good qualities. However, such grown vegetables may also accumulate heavy metals in their tissues thereby posing human health risk. Thus, this study was carried out to evaluate heavy metals and health risk of *Amaranthus cruentus* and *Amaranthus spinosus* grown on mineral and organic amendment soils.

Therefore, the objectives of this study were, 1) to determine the growth and yield parameters of *Amaranthus cruentus* and *Amaranthus spinosus* grown in mineral and organic amendment soil and 2) to determine the concentration of heavy metals and human health risk assessment of *Amaranthus cruentus* and *Amaranthus spinosus* grown in mineral and organic amendment soils.

MATERIALS AND METHODS

Sample site

This study was carried out at the crop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria. The Department is located within latitude 7° 43"N and longitude 3° 54"E at an altitude of 200 m with annual rainfall between 1,250-1,500 mm spanning eight months (March-October) with dry spell in August; annual average temperature of 21.3°C and relative humidity of 70-80%. The experiment was carried out in an open field using 5kg pots.

Treatments and Experimental Design

The experiment was a 2x3 factorial laid out in a randomized complete block design, with five treatments (including the control) replicated four times; the treatments were:

***Amaranthus cruentus* L.**
Control (only soil), cured Poultry dropping, NPK 15:15:15

***Amaranthus spinosus* L.**
Control (only soil)**,** cured Poultry dropping. NPK 15:15:15

SAMPLE COLLECTION

Planting Materials

Seeds of *Amaranthus cruentus* and *Amaranthus spinosus* were purchased from National Horticultural Research Institute (NIHORT), Jericho, Ibadan, Oyo State. Experimental soil was collected from crop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan. Organic manure (poultry droppings) layers set was collected from the Teaching and Research Farm, University of Ibadan and synthetic fertilizer (NPK 15:15:15) was bought from Eagle Agro Allied shop at Ajibode, Ibadan, Oyo State.

Before the sowing of Amaranthus seeds, mixing of soil with cured poultry dropping (PD) at 10g per 5kg soil and NPK 15:15:15 at 4g per 5kg soil were applied and left for one week (for better mineralization). Afterwards seeds were sown through broadcasting, followed by thinning to two stands per 5kg soil two weeks after sowing (WAS).

Physico-Chemical Determination of Experimental Soil

Physico-chemical properties of the experimental soil were done before sowing of *Amaranthus cruentus* and *Amaranthus spinosus* seeds. The pH of soil was determined using the method of Hendershot *et al*. (1993). The procedures of Association of Official Analytical Chemists (AOAC, 2003) were used to determine the organic carbon, nitrogen, while phosphorus was determined according to the Bray method (Olsen *et al*., 1954). Exchangeable bases Cu^{2+}, K^{2+}, Mn^{2+} and Mg^{2+} were determined using the IITA method (2002).

Preparation of Soil Samples for Heavy Metals Analysis

Soil samples collection was done from each replicate of treatments from the same spot where *Amaranthus cruentus* and *Amaranthus spinosus* plant samples were carefully uprooted. Samples collected from each pot were mixed separately to form the composite soils and were kept in paper packs, labeled properly and air dried in the Toxicology Research Laboratory of the Department of Crop Protection and Environmental Biology (CPEB), University of Ibadan at room temperature (27±2°C) for 14 days.

Later the samples were sieved with 0.5 mm sieve to give fine soil samples required for the heavy metal analysis. The heavy metal analysis was carried out at the Soil Analytical Laboratory of Department of Agronomy, University of Ibadan. A 1g of each was transferred to 100 mL tall-form beaker, 20 mL of 1:1 HNO_3 (analytical grade) was added using measuring cylinder and boiled inside fume cupboard until the volume of nitric acid was reduced to about 5 mL then add 200 mL of de-ionized water and boiled gently again until the volume was approximately 10 mL. The suspensions were cooled and filtered through a Whatman No.540 filter paper. The beaker and filter paper were washed with small portion of de-ionized water until the volume of about 25 mL was obtained. The filtrates were transferred to a 100 mL graduated flask and made up to the mark with de-ionized water (AOAC, 2003).

Vegetable Preparation for Heavy Metals Analysis

Amaranthus cruentus and *Amaranthus spinosus* samples were collected at maturity five weeks after sowing. They were uprooted carefully by hand, ensuring that no part of the root was lost washed thoroughly with tap water to remove soil particles from the plants. Plant samples were rinsed with distilled water, labeled, packed in sampling packs and taken to the Toxicology Research Laboratory of CPEB, University of Ibadan. Each representative plant samples were separated into shoot and root parts and oven-dried at 60°C for 72 hours, then ground using QASA grinder (QBL15L40 model) and passed through 2mm mesh size. Heavy metals analysis was done at the Soil Analytical Laboratory of Department of Agronomy, University of Ibadan.

Half a gram (0.5g) of each sample was weighed and put into porcelain crucible. They were ignited in a muffle furnace for 6-8 hours at 450°C-500°C until greyish-white ashes were obtained. A 5 mL of 2N HNO_3 was added to each sample in a test-tube, then filtered using Whatman No.540 filter paper.

The filtrates were transferred to 100 mL graduated flask and made up to the mark with distilled water. The filtrates were transferred to sample-bottles and taken for heavy metals analysis (Ogundiran, 2007). Trace metals (Cd, Pb, and Cr) were analyzed using AAS (Buck Scientific Model 210 VGP) following the procedure of Association of Official Analytical Chemist (AOAC, 2003). The instrument setting and operational conditions were done in accordance with the manufacturers' specifications.

Assessment and Determination of Potential Health Risk for Vegetables

Assessment of Health Risk Index (HRI): The HRI is determined based on Daily Intake of Metals (DIM according to IRIS (2003) using the following equations:

$$DIM = C_{metal} \times C_{factor} \times D_{intake} / B_{average\ weight} \quad \textbf{(1)}$$

Charry *et al*. (2008)

Where:
C_{metal} = Heavy metals concentration in plants (mg/kg)

C_{factor} = Conversion factor

D_{intake} = Daily Intake of Vegetables

$B_{average\ weight}$ = Average body weight of adult was considered to be 60 kg, while that of children was 32.5 kg (FAO/WHO,1999; Sobukola, 2010).

Conversion factor of 0.085 was used to convert fresh weight vegetable to dry weight (Khan, *et al*., 2008). Average daily vegetable intake was considered to be 0.250 kg/person/day (Chubike, *et al*., 2013)

Determination of Health Risk Index (HRI): The HRI for the consumption of contaminated vegetables was obtained as the ratio of the daily intake of metals to the reference oral dose (RfD) of each metal using this expression:

$$HRI = DIM/RfD \quad \textbf{(2)}$$

Jan *et al*. (2010)

Oral reference doses (RfD) for the heavy metals were considered to be $1x10^{-3}$, 1.5 and $3.5x10^{-3}$ for Cd, Cr, and Pb, respectively (US-EPA, IRIS 2006). If the value of HRI is less than 1(<1) then the exposed population is said to be safe (IRIS, 2003) and if the HRI is greater than 1(>1) the exposed population is said to be at risk.

DATA ANALYSIS

Statistical Analysis

Data collected from the study were analysed using the Analysis of Variance (ANOVA) with the SAS statistical package (SAS Institute, 2003). Means were separated using Duncan Multiple Range Test (DMRT) at 5 % probability level.

RESULTS

Physico-Chemical Parameters of Soil

The physical and chemical analysis of the experimental soil studied is presented in Table 1. Based on the analysis the soil was loamy sand with a pH of 5.3 (slightly acidic). There were low values in nitrogen, potassium, copper, and exchangeable acidity. The low soil contents for the main nutrients signify the need for improvement of *Amaranthus cruentus* and *Amaranthus spinosus* performance.

Heavy Metals Concentration of Soil, Poultry Droppings and NPK done before Sowing

Results presented in Table 2 revealed the heavy metals concentration of soil, poultry droppings and NPK carried out before sowing.

Table 1: Physico-Chemical Properties of the Soil done before Planting.

Parameter	Value
Ph	5.30
Organic Carbon (g/kg)	20.2
Nitrogen (g/kg)	3.90
Exchange Acidity	0.38
Iron (Cmol/kg)	0.82
Maganese (Cmol/kg)	3.55
Zinc (Cmol/kg)	0.16
Magnesium (Cmol/kg)	1.85
Potassium (Cmol/kg)	0.63
Copper (Cmol/kg)	0.023
%clay	17.60
%silt	1.40
%sand	83.50
Textural Class	Loamy sand

Table 2: Heavy Metals Concentration of Soil, Poultry Droppings, and NPK done before Sowing.

Samples	Cr mg/kg	Cd mg/kg	Pb mg/kg
Soil	11.14	-	-
Poultry Dropping	5.55	-	-
NPK15:15:15	-	-	-
WHO/FAO for poultry dropping (2001)	2.30	0.20	0.30
WHO/FAO for soil (2001)	64.00	1.40	70.00

(Source: WHO/FAO-Codex Alimentarious Commission, 2001) Cr – Chromium, Cd – Cadmium, Pb – Lead

The Cr in the poultry droppings (5.55 mg/kg) was found to be above the WHO/FAO (2001) permissible level (2.30 mg/kg), however not detected in NPK. Cadmium (Cd) and Pb were not detected in the soil, poultry droppings and NPK. The value of Cr (11.14 mg/kg) in the soil was below the WHO/FAO (2001) permissible level (64.00 mg/kg).

Effects of Mineral (NPK) and Organic Fertilizers (Poultry Droppings) on Mean Plant Height (cm) of *Amaranthus cruentus* and *Amaranthus spinosus*

In Table 3, Plant heights of Amaranthus varieties revealed significant difference ($p<0.05$) at 2 weeks after sowing (WAS). *Amaranthus cruentus* recorded higher plant height values (16.18 cm) from plots treated with NPK 15:15:15, closely followed by organic fertilizer (poultry droppings) with a value of 16.13cm. *Amaranthus spinosus* treated with NPK 15:15:15, had the lowest value (7.73 cm). However, higher value of 14.78cm was obtained from *A. cruentus* at control, while 11.60cm was recorded from *A. spinosus*.

Plant heights of *Amaranthus cruentus* and *Amaranthus spinosus* showed no significant differences ($p>0.05$) at 4 and 5 WAS across the treatments.

Effects of Mineral and Organic Fertilizers on Mean Number of Leaves of *Amaranthus cruentus* and *Amaranthus spinosus*

The effects of mineral (NPK 15:15:15) and organic (poultry droppings) fertilizers on mean number of leaves of *Amaranthus cruentus* and *Amaranthus spinosus* are shown in Table 3 had no significant differences ($p>0.05$) among the treatments at 2 WAS.

Table 3: Effects of Mineral and Organic Fertilizer on Mean Plant Height (cm) Number of Leaves, Stem Diameter (cm), and Leaf Area (cm^2) of *Amaranthus cruentus* and *Amaranthus spinosus*

Treatment	Amaranthus Spp	Plant Height (cm)			No of Leaves			Stem Diameter (cm)			Leaf Area (cm^2)		
		2 WAS	4 WAS	5 WAS	2 WAS	4 WAS	5 WAS	2 WAS	4 WAS	5 WAS	2 WAS	4 WAS	5 WAS
Control	*Amaranthus cruentus*	14.78a ±2.07	29.25a ±1.64	33.15a ±1.61	8.50a ±0.65	10.75a ±1.23	8.50a ±0.91	1.55a ±0.12	2.05a ±0.16	2.38a ±0.19	7.48b ±1.4676	23.5b ±2.0639	27.48b ±1.9943
	Amaranthus spinosus	11.6ab ±0.76	24.28a ±1.72	28.55a ±1.95	10.00a ±0.41	12.00ab ±0.96	10.50ab ±0.85	1.275a ±0.10	2.10a ±0.23	2.60a ±0.09	7.43a ±1.3609	29.5a ±2.5409	34.13a ±2.2309
Poultry Droppings	*Amaranthus cruentus*	16.13a ±1.81	27.83a ±3.08	33.18a ±2.88	10.75a ±1.49	10.00a ±0.87	9.00a ±0.87	1.55a ±0.17	2.18a ±0.13	2.53a ±0.16	10.90ab ±1.9030	24.6b ±2.3921	30.00ab ±2.9962
	Amarathus spinosus	12.83a ±0.37	22.08a ±1.32	26.98a ±2.32	9.75a ±0.25	9.25b ±0.50	8.25b ±0.25	1.25a ±0.07	2.03a ±0.05	2.35a ±0.09	8.10a ±0.8436	24.15ab ±1.4097	29.45a ±1.5944
NPK (15:15:15)	*Amaranthus cruentus*	16.18a ±0.98	27.98a ±3.88	36.13a ±5.50	9.75a ±0.48	10.50a ±0.29	9.50a ±0.50	1.43a ±0.13	2.23a ±0.20	2.55a ±0.19	12.83a ±1.3536	31.13a ±5.6887	36.05a ±5.6861
	Amaranthus spinosus	7.73b ±2.70	21.58a ±1.17	26.30a ±1.25	7.25a ±2.43	14.25a ±1.89	12.25a ±1.44	0.95a ±0.32	1.98a ±0.07	2.38a ±0.08	7.25a ±2.4618	21.5b ±1.375	27.5a ±1.1205

The values represent the means ± S. D. Means within a column with same alphabet (s) are not significantly different at 5% level of significance.
WAS – Weeks after Sowing,

However, the highest number of leaves 10.75 was recorded in poultry droppings, and 8.50 (lowest) in control for *Amaranthus cruentus*, while *Amaranthus spinosus* had 10.00 (highest), 9.75 and 7.25 in control, poultry droppings and NPK 15:15:15, respectively. At 4 WAS, significant difference ($p<0.05$) was observed in the number of leaves (10.75) produced in the control from *Amaranthus cruentus* and *Amaranthus spinosus* (12.00), poultry droppings *Amaranthus cruentus* (10.00) although highest number 14.25 was recorded for *Amaranthus spinosus* when compared to 10.50 for *Amaranthus cruentus* from NPK treatment.

There was significant difference ($p<0.05$) in the control at 5WAS, NPK 15:15:15 and poultry droppings. *Amaranthus cruentus* had 8.50, 9.00 and 9.50, while *Amaranthus spinosus* had 10.50, 8.25 and 12.25, respectively.

Effects of Mineral and Organic Fertilizers on Mean Stem Diameter (cm) of *Amaranthus cruentus* and *Amaranthus spinosus*

Effects of mineral and organic fertilizer on mean stem diameter (cm) of *Amaranthus cruentus* and *Amaranthus spinosus* from 2 to 5 WAS are presented in Table 3. There were no significant differences ($p>0.05$) in stem diameter across all treatments at 2, 4 and 5 WAS.

Effects of Mineral and Organic Fertilizers on Mean Leaf Area (cm^2) of *Amaranthus cruentus* and *Amaranthus spinosus*

The Effects of mineral and organic fertilizer on mean leaf area (cm^2) of *Amaranthus cruentus* and *Amaranthus spinosus* from 2 to 5 WAS are presented in Table 3. There were significant differences ($p<0.05$) in leaf area (cm^2) in the control, NPK 15:15:15 and poultry droppings at 2 WAS. *Amaranthus cruentus* had high value 10.90cm^2 in poultry droppings and control 7.48cm^2, while *Amaranthus spinosus* had 8.10cm^2 in poultry droppings. However, *Amaranthus cruentus* had the highest value of 12.83cm^2 while *Amaranthus spinosus* had the lowest value 7.25cm^2 in in NPK 15:15:15 but showed no significant differences ($p>0.05$).

Table 4: Effects of Mineral and Organic Fertilizer on Fresh Weight (yield (g)) Dried Matter Yield (g) (Root, Shoot, and Total Dry Weight) of *Amaranthus cruentus* and *Amaranthus spinosus.*

Treatment	Amaranthus spp	Fresh-weight (g/pot)	Dry weight (root) (g/pot)	Dry weight (shoot) (g/pot)	Total dry weight (g/pot)
Control	*Amaranthus cruentus*	129.75c ±6.84	6.25b ±0.86	22.25b ±1.32	28.50bc±0.96
	Amaranthus spinosus	162.75b ±13.31	8.25a ±0.63	27.25ab±1.32	35.50ab ±1.66
Poultry droppings	*Amaranthus cruentus*	167.75ab ±18.90	8.75a ±0.63	25.25b ±4.64	34.00b ±4.74
	Amarathus spinosus	135.75bc ±8.14	7.50a ±0.65	22.50bc ±2.63	30.00b ±2.92
NPK 15:15:15	*Amaranthus cruentus*	259.00a ±12.19	9.00a ±0.41	43.75a ±2.46	52.75a ±2.29
	Amaranthus spinosus	179.75b ±25.22	7.25a ±1.03	32.00a ±5.43	39.25a ±6.42

The values represent the means ± S. D. Mean within a column with same alphabet (s) are not significantly different at 5% level of significance.

There were significant differences ($p<0.05$) in all treatments at 4 WAS on mean leaf area of the Amaranthus. *Amaranthus cruentus* had the highest value 31.13cm^2 in NPK 15:15:15, 24.60cm^2 poultry droppings and low value in control with 23.50 cm^2. *Amaranthus spinosus* had high value of 29.50cm^2 in control followed by 24.15cm^2 in poultry droppings, lowest value 21.50cm^2 was from NPK 15:15:15 at 4 WAS.

There were significant differences ($p<0.05$) in NPK 15:15:15, poultry droppings and control at 5 WAS. *Amaranthus cruentus* had high value of 30.00cm^2 in poultry droppings and lowest value of 27.48cm^2 in control, while *Amaranthus spinosus* had high value of 34.13cm^2 in control, low value of 29.45cm^2 from poultry droppings. The *Amaranthus cruentus* had the highest value of 36.05cm^2 from NPK 15:15:15 compared to 27.50cm^2 of *Amaranthus spinosus* which showed no significant differences ($p>0.05$) amongst them.

Effects of Mineral and Organic Fertilizers on Fresh Weight (yield (g)) of *Amaranthus cruentus* and *Amaranthus spinosus*

Results on Table 4. showed the effects of mineral and organic fertilizer on fresh weight (yield (g)) of *Amaranthus cruentus* and *Amaranthus spinosus*. There were significant differences ($p<0.05$) in control, poultry droppings and NPK 15:15:15. The highest value of 259.00g was recorded from NPK 15:15:15 and 167.75g from poultry droppings for *Amaranthus cruentus*. Low values of 179.75g in NPK 15:15:15 and 135.75g from poultry droppings for *Amaranthus spinosus*. Control had high value 162.75g for *Amaranthus spinosus* and low value 129.75cm for *Amaranthus cruentus.*

Effects of Mineral and Organic Fertilizers on Dried Matter Yield (g) (Root, Shoot, and Total Dry Weight) of *Amaranthus cruentus* and *Amaranthus spinosus*

The effects of mineral and organic fertilizer on dried matter yield (g) (root, shoot and total dry weight) of *Amaranthus cruentus* and *Amaranthus spinosus* are shown in Table 4. Root dry matter (yield) showed significant differences ($p<0.05$), the control of *Amaranthus spinosus* had high value of 8.25g and low value of 6.25g for *Amaranthus cruentus*.

The treatments of poultry dropping, and control had the values of 25.25g and 22.25g for *Amaranthus cruentus* and 22.50g and 27.25g for *Amaranthus spinosus* with significant differences ($p<0.05$) in shoot dry matter (yield).

The total dry matter (yield) showed significant differences ($p<0.05$) among the treatments. *Amaranthus spinosus* had high value of 35.50g in control, while low value was obtained from *Amaranthus cruentus* 28.50g from control.

Table 5: Heavy Metals Concentration of *Amaranthus cruentus* and *Amaranthus spinosus* in Soil.

Treatment	Amaranthus spp	Sample	Cr mg/kg	Cd mg/kg	Pb mg/kg
Control	*A. cruentus*	Soil	21.00 g±0.00	0.00d ±0.00	328.00a ±0.00
Control	*A. spinosus*	Soil	30.33c ±0.00	0.00d ±0.00	270.00c ±0.00
Poultry droppings	*A. cruentus*	Soil	30.00c ±0.00	0.00 ±0.00	277.67b ±0.33
Poultry droppings	*A. spinosus*	Soil	26.00f ±0.00	0.00d ±0.00	209.67 ±0.33
NPK 15:15:15	*A. cruentus*	Soil	27.00e ±0.00	0.00d ±0.00	189.33f ±0.33
NPK 15:15:15	*A. spinosus*	Soil	28.00d ±0.00	0.00d ±0.00	224.00d ±0.00
FAO/WHO (2001)			64.00	3.00	300.00

Table 6: Heavy Metals Concentrations in *Amaranthus cruentus* and *Amaranthus spinosus* in Root and Shoot Parts after Harvest.

Heavy metals in Amaranthus spp Root part						Heavy metals in Amaranthus spp Shoot part				
Treatment	Amaranthus Spp	Veg. part	Cr mg/kg	Cd mg/kg	Pb mg/kg	Amaranthus Spp	Veg. Part	Cr mg/kg	Cd mg/kg	Pb mg/kg
Control	*A. cruentus*	Root	0.00d ± 0.00	0.00d ±0.00	38.67d ±0.33	*A. cruentus*	Shoot	0.00d ±0.00	0.00d ±0.00	15.00c ±0.00
Control	*A. spinosus*	Root	0.00d ± 0.00	0.00d ±0.00	37.67d ±0.33	*A. spinosus*	Shoot	0.00d ±0.00	0.00d ±0.00	16.6b ±0.33
Poultry Dropping	*A. cruentus*	Root	5.00c ±0.00	0.00d ±0.00	58.67c ±0.33	*A. cruentus*	Shoot	0.00d ±0.00	0.00d ±0.00	15.00c ±0.00
Poultry Dropping	*A. spinosus*	Root	11.33a ±0.33	0.00d ±0.00	6.97f ±3.03	*A. spinosus*	Shoot	0.00d ±0.00	0.00d ±0.00	0.80f ±0.00
NPK 15:15:15	*A. cruentus*	Root	8.00b ±0.00	0.00d ±0.00	114.67a ±0.33	*A. cruentus*	Shoot	0.00d ±0.00	0.00d ±0.00	13.00e ±0.00
NPK 15:15:15	*A. spinosus*	Root	0.00d ±0.00	0.00d ±0.00	69.00b ±0.00	*A. spinosus*	Shoot	0.00d ±0.00	0.00d ±0.00	23.00a ±0.00
FAO/WHO (2001)			2.30	0.20	0.30			2.30	0.20	0.30

The NPK 15:15:15 had the highest value 52.75g and 34.00 g in poultry droppings in *Amaranthus cruentus,* while 39.25g and 30.00g in *Amaranthus spinosus* were from NPK and poultry droppings, respectively although with no significant differences ($p>0.05$).

<u>Heavy Metals Concentration of *Amaranthus cruentus* and *Amaranthus spinosus* in Soil</u>

Significant differences ($p<0.05$) were observed in Cr and Pb heavy metals concentration in soil as shown in Table 5. Highest value (328.00 mg/kg) of Pb in the control soil was recorded, while the lowest value (189.33 mg/kg) was obtained from NPK 15:15:15 of *A. cruentus*. While in *A. spinosus* Pb value was 270.00 mg/kg and 224.00 mg/kg in control and NPK 15:15:15, respectively.

In *Amaranthus cruentus* plots treated with poultry droppings, Pb recorded high level (277.67 mg/kg) and low level (209.67 mg/kg) in *Amaranthus spinosus*.. Highest level of Cr (30.33 mg/kg) was recorded from the control in *Amaranthus spinosus* and lowest value (21.00 mg/kg) also in control soil from *Amaranthus cruentus.* High level of Cr (30.00 mg/kg) was recorded in poultry droppings from *Amaranthus cruentus* and low level (26.00 mg/kg) was from *Amaranthus spinosus.* The NPK 15:15:15 plots recorded 27.00 mg/kg of Cr from *Amaranthus cruentus* and 28.00 from *Amaranthus spinosus*. However, Cd was not detected in the soil samples of both *Amaranthus cruentus* and *Amaranthus spinosus*.

<u>Heavy Metals of *Amaranthus cruentus* and *Amaranthus spinosus* in Root and Shoot Parts</u>

Results presented on Table 6, revealed heavy metals concentration of Amaranthus species in both root and shoot parts. In root, significant differences ($p<0.05$) were observed in Pb and Cr in poultry droppings and NPK 15:15:15.

Table 7: Health Risk Index (HRI) of Heavy Metals in Root and Shoot Parts of *Amaranthus cruentus* and *Amaranthus spinosus.*

HRI of Heavy metals in *Amaranth spp* Root Part							HRI of Heavy metals in *Amaranth spp* Shoot Part					
Treatment	Amaranth Spp	Veg. Part	Individual	Cr	Cd	Pb	Amaranth Spp	Veg. Part	Individual	Cr	Cd	Pb
Control	*A. cruentus*	Root	Adult Children	0.0 0.0	0.0 0.0	5.0 7.5	*A. cruentus*	Shoot	Adult Children	0.0 0.0	0.0 0.0	2.5 2.5
Control	*A. spinosus*	Root	Adult Children	0.0 0.0	0.0 0.0	5.0 7.5	*A. spinosus*	Shoot	Adult Children	0.0 0.0	0.0 0.0	2.5 2.5
PD	*A. cruentus*	Root	Adult Children	0.4 0.6	0.0 0.0	7.5 10.0	*A. cruentus*	Shoot	Adult Children	0.0 0.0	0.0 0.0	1.0 2.5
PD	*A. spinosus*	Root	Adult Children	2.0 2.0	0.0 0.0	2.5 2.5	*A. spinosus*	Shoot	Adult Children	0.0 0.0	0.0 0.0	2.5 2.5
NPK 15:15:15	*A. cruentus*	Root	Adult Children	0.8 1.0	0.0 0.0	15.0 20.0	*A. cruentus*	Shoot	Adult Children	0.0 0.0	0.0 0.0	0.0 0.0
NPK 15:15:15	*A. spinosus*	Root	Adult Children	0.0 0.0	0.0 0.0	7.5 12.5	*A. spinosus*	Shoot	Adult Children	0.0 0.0	0.0 0.0	0.0 0.0

Veg. – Vegetable, PD – Poultry Dropping
HRI <1 indicates no adverse health effects, while HRI>1 or =1 indicates that adverse health effects are likely to occur.
If the value of HRI<1, the exposed population is said to be safe and if the HRI is = or >1, it is considered to be unsafe for human health therefore potential health risk may occur and relative interventions and protective measures must be taken.

In poultry droppings, Cr had the maximum value (11.33 mg/kg) in *A. spinosus* followed by 5.00 mg/kg in *A. cruentus*, and in NPK 15:15:15 *A. cruentus* had the highest value of 8.00 mg/kg, while 0.00mg/kg in *A. spinosus*. While Pb had highest value of 58.67 mg/kg in *A. cruentus* and *A. spinosus* recorded the lowest value 6.97 mg/kg of Pb from poultry droppings. Highest Pb value (114.67 mg/kg) was obtained from *A. cruentus* followed by *A. spinosus* having 69.00 mg/kg from NPK 15:15:15 treated plots. However, Cd was not detectable in the root samples of both *A. cruentus* and *A. spinosus*. No significant differences (p>0.05) were observed between the control treatments.

Heavy metals recorded from *A. cruentus* and *A. spinosus* in their shoot samples are shown in Table 6. Significant differences (p<0.05) were observed only in Pb concentrations from control, poultry droppings and NPK 15:15:15 treated plots. Highest value (23.00 mg/kg) and lowest value (0.80 mg/kg) of Pb were recorded from *A. spinosus* treated with NPK 15:15:15 and poultry droppings, respectively. While *A. cruentus* had 15.00 mg/kg and 13.00 mg/kg of Pb from poultry droppings and NPK 15:15:15. The control treatments revealed *A. spinosus* having 16.67 mg/kg of Pb and 15.00 m/kg of Pb in *A. cruentus*.

Health Risk Index (HRI) of Heavy Metals in Root and Shoot samples of *Amaranthus cruentus* and *Amaranthus spinosus*

The HRI results for root samples in adult and children revealed extremely Pb level > 1, which ranged from 2.5 - 20.0 in both *Amaranthus cruentus* and *Amaranthus spinosus* from control, poultry and NPK 15:15:15 treatments. Highest value (20) in children was obtained in *A. cruentus* from NPK 15:15:15 and lowest value (2.5) was recorded for both adults and children in *A. spinosus* from poultry droppings, respectively. In Cr heavy metal, HRI value (2.0) was >1 only in *A. spinosus* from poultry droppings for adult and children (Table 7).

Results of HRI of heavy metals in shoot samples for *A. cruentus* and *A. spinosus* are presented in Table7. Higher HRI values of Pb (2.5) >1 was recorded in both Amaranth varieties from only control and poultry droppings treated plots. However, HRI values obtained for *A. cruentus* and *A. spinosus* from NPK 15:15:15 treatments were at zero value (0.00 mg/kg) for Cr, Cd, and Pb heavy metals.

DISCUSSION

This study revealed that the pre cropping analysis (physico-chemical) of the experimental site soil was low in Organic matter, N and available P. Also, the soil was acidic and less suitable for Amaranth vegetables which require pH 5.5-7.5 as recommendation. The soil required addition of fertilizers for optimum crop production.

The application of mineral fertilizer (NPK 15:15:15) and organic manure (poultry droppings) affected the *Amaranthus cruentus* and *Amaranthus spinosus* growth and yield parameters as shown in the results. The *Amaranthus cruentus* treated with NPK 15:15:15 gave highest values in plant height, number of leaves and stem diameter. This is in agreement with Olowoake and Ojo (2014) who reported that increase plant height, number of leaves and stem diameter may be probably due to favorable nutrient mineralization of this fertilizer (NPK 15:15:15). This revealed that the synthetic fertilizer (NPK 15:15:15) had influence on its mineral components over the organic fertilizer (poultry droppings) contents which is also in agreement with the findings of Taylor *et al*. (1993) that NPK application could have increased N and P concentrations in *A. cruentus*.

Good performance in leaf area in *Amaranthus cruentus* by NPK 15:15:15 conforms to the study reported by Ahmad *et al*. (2019) that the role of nitrogen in synthetic fertilizers promotes vigorous vegetative growth in leafy vegetables. However, *A. spinosus* treated with poultry droppings and control had high value in plant height, number of leaves, stem diameter and leaf area. This agrees with the work of Carsky *et al.* (2001) and Osaigbovo *et al.* (2010) whose reports revealed that good growth parameters may be due to nutrients of organic manure and thereby improving the soil physico-chemical properties such as increased infiltration rate, water retention, soil aggregate and nutrient stabilizers.

Effects of different fertilizers ((NPK 15:15:15 and poultry droppings) on fresh yield had all the treatments being differed significantly from the control for *A. cruentus*. Increase in fresh yield of *Amaranthus cruentus* was in the order NPK 15:15:15 > poultry droppings > control, this is in agreement with the findings of Moyinjesu (2007) and Adeoye *et al*. (2008) that mineral fertilizers (NPK 15:15:15) easily release their nutrients to the soil. Also yield of *Amaranthus spinosus* was in the order NPK 15:15:15 > control > poultry droppings. This study revealed favorable shoot and total dry yield of *Amaranthus cruentus* and *Amaranthus spinosus* treated with NPK 15:15:15 when compared to other treatments such as control and poultry droppings. This also agrees with report of Olowoake and Ojo (2014) that the application of organic and mineral fertilizers served as good enhancement of Amaranthus or vegetable yield.

It is noteworthy from this study that, all growth and yield parameters of *Amaranthus crusentus* and *A. spinosus* to application of poultry droppings and fertilizer were found to increase the plant height, stem diameter and number of leaves over control which conforms with Olowoake and Ojo (2014).

This study also found that *Amaranthus cruentus* had very good performance in growth and yield parameters over *Amaranthus spinosus*. This may be due to morphological characteristics of *Amaranthus cruentus* such as inflorescence, shape and density, branching index, stem thickness and terminal inflorescence attitude (Grubben, 2004).

Results obtained from this study showed that Cd concentration was not detected in soil, root and shoot samples of *Amaranthus cruentus* and *Amaranthus spinosus*. Chromium levels were within the FAO/WHO (2001) tolerance level (Cr = 0.2 mg/kg), while concentrations of Pb were exceedingly higher in root and shoot samples of *Amaranthus cruentus* and *Amaranthus spinosus* above the permissible level (Pb = 0.3 mg/kg). High levels of Pb obtained may probably be attributed to pollutants in irrigation water or farm soil which was shown in the control of the experimental site, this agrees with Njoku *et al*. (2007). An appreciable amount of Pb was detected in the roots and shoots of the Amaranth species which could be as a result of Pb transferred from the experimental soil which agrees with Oluwatomisin *et al*. (2008) that plants have a key function in the biotransformation of chemical elements from soil, air and water. Reduction in Pb and Cr levels in roots and shoots of *A cruentus* and *A. spinosus* treated with poultry droppings and NPK 15:15:15 may be due to the application of these treatments recommended rates in accordance to the work of Yassen *et al*. (2007) who reported that humus and other organic compounds present in the organic fertilizers can chelate heavy metals and form stable molecules altering their bioavailability.

The observed Health Risk Index (HRI) of Cr and Pb>1 in the root and shoot samples of *A cruentus* and *A. spinosus* indicated high risk to human health and poses adverse effects as reported by Li *et al*. (2014); Fayinminnu and Jimoh-Adekunle (2015). Health Risk Index of Cr for *A*. *cruentus* in root was<1 in poultry droppings and NPK 15:15:15 and Pb >1 in most treatments of root and shoot.

Long time exposure of Cr could cause damages to liver, kidney, circulatory and nerve tissues as well as skin irritation in adult humans, while in children can lead to asthma, respiratory complications including coughing, nasal blockage, and facial erythema (Wilbur, *et a*l., 2012). The Pb can affect every organ of the body. Its long exposure in adults could result into reduced performance, weakness in fingers, wrist or ankles, brain and kidney damages, increase in blood pressure and ultimately cause death. Exposed levels of Pb negatively affects intelligence and increased impulsivity in school age children and retardation (Hong, *et al*., 2015).

CONCLUSION

The treatments of organic (poultry droppings) and synthetic fertilizer (NPK 15:15:15) showed to have a significant change in growth and yield parameters when compared to control (untreated). This may be due to the presence of required nutrients needed for the growth and development of *Amaranthus cruentus* and *Amaranthus spinosus* being supplied by the fertilizers. The NPK 15:15:15 had favorable yield on both Amaranths this maybe the fact that the mineral contents of NPK was readily and easily accessible to the Amaranths' roots for uptake.

Amaranthus cruentus and *Amaranthus spinosus* responded differently to application of organic (poultry droppings) and synthetic fertilizers (NPK15:15:15) at different stages of growth and yield. This study found that NPK15:15:15 as well as poultry manure could enhance the soil fertility and soil moisture holding capacity therefore, they are good for the growth of both Amaranthus spp. Although NPK 15:15:15 gave favorable growth and yield parameters.

Results obtained from the study revealed that Cd was not detected in the soil, root and shoot samples of *Amaranthus cruentus* and *Amaranthus spinosus*, Cr level was within the tolerance level of FAO/WHO (2001), while Pb was extremely high in all samples above the tolerance level. The Health Risk Index in Cr<1, while Pb>1 in most treatments which may have adverse effects on human health in years to come.

Based on the findings in this study, the following recommendations can be said:

- Farmers should make use of synthetic fertilizer (NPK 15:15:15) for faster growth and development of their vegetable, because the nutrients are readily available for the plant usage or uptake.
- *Amaranthus cruentus* should be grown because of its rapid response to nutrients supplied by the mineral and organic fertilizers and its morphological attributes such as inflorescence shape and density, branching index, stem thickness and terminal inflorescence attitude.
- Exceedingly high-level contents of Pb were detected in root and shoot samples of synthetic fertilizer (NPK15:15:15) when compared with poultry dropping (organic fertilizer). Farmers should consider this information because of bioaccumulation and ill effects of Pb over time to the consumers
- Health Risk Index is <1 in shoot vegetable samples treated with NPK fertilizer indicating safety of the consumers
- Monitoring of vegetables grown on both organic and mineral fertilizers should be encouraged among the farmers/consumers to ensure quality food nutrition and safety.

REFERENCES

1. Abdulrazzaq, A. 2002. "Effects of Chicken Manure, Sheep Manure and Inorganic Fertilizer on Yield and Nutrients Uptake by Onion". *Pak. Biol. Sci*. 266-268.
2. Adesuyi, A.A., M.O. Ngwoke, M.O. Akinola, K.L. Njoku, and A.O. Jolaoso. 2016. "Physicochemical Assessment of Sediments from Nwaja Creek.Niger Delta, Nigeria". *Journal of Geoscience and Environment Protection*. 4:16–27.

3. Adesuyi, A.A., Njoku, K.L., and Akinola, M.O. (2015). Assessment of Heavy Metals Pollution in Soils and Vegetation around Selected Industries in Lagos State, Nigeria. Journal of Geoscience and Environment Protection, 3: 11-19.

4. Adewuyi G.O., F.A. Dawodu, and N.N. Jibiri. 2010. "Studies of the Concentration Levels of Heavy Metals in Vegetable (*Amaranthus caudatus*) Grown on Dumpsites within Lagos Metropolis, Nigeria". *The Pacific Journal of Science and Technology*. 11(1): 616-620.

5. Adriano, D.C. 2001. *Trace Elements in Terrestrial Environment. Biogeochemistry, Bioavailability and Risk of Metals*. Springer Verlag: New York, NY. 353.

6. Akanbi, W.B. and A.O. Togun. 2002. "The Influence of Maize- Stover Compost and Nitrogen Fertilizer on Growth Yield and Nutrient Uptake of Amaranth". *Sci Hortic* 93:1–8.

7. Babatola, L.A. and J.O. Olaniyi. 2013. "Performance of *Amaranthus caudatus* at Diff. Levels of NPK Fertiliz. and Under Diff. Storage Methods". *Proceeds. 16th Ann. Conf. of Hort. Soc. of Nigeria.* UNAAB, Abeaokuta, Nigeria. 36-40.

8. Barea, J.M., R. Azcon, and C. Azcon-Aguiliar. 2002. "Mycorrhizosphere Interactions to Improve Plant Fitness and Soil Quality". *Antone Van Leeuwenhock*. 81:343–351.

9. Bhatnagar, R.K. and R.K. Palta. 1991. *Earthworm: Vermiculture and Vermicomposting*. Kalyani Publishers: Ludhiana, Punjab, India.

10. Chary, N.S., C.T. Kamala, and D.S. Raj. 2008. "Assessing Risk of Heavy Metals from Consuming Food Grown on Sewage Irrigated Soils and Food Chain Transfer". *Ecotoxicol. Environ. Safety*. 69(3): 513-524.

11. Chen, S. and M. Wu. 2007. "Note on Four Newly Nationalized Plants in Taiwan". *Taiwania*, 52(1): 59-69. http://taiz.ntu.edu.tw/taiwania.

12. Chubike, N.E., J.C. Okaka, and E.C. Okoli. 2013. "Evaluation of Vegetable Consumption in South Eastern Nigeria". *International Journal of Nutrition and Metabolism*. 5(4): 57-60.

13. Craine, J.M. and R.D. Jackson. 2010. "Plant Nitrogen and Phosphorus Limitation in 98 North American Grassland Soils". *Plant Soil*. 334(73–84):1007. doi:10.1007/s11104-009-0237-1.

14. Cruz, A.F., T. Ishii, and K. Kadoya. 2000. "Effects of *Arbuscular mycorrhizal* Fungi on Tree Growth, Leaf Water Potential, and Levels of 1-aminocyclopropane-1-carboxylic acid and Ethylene in the Roots of Papaya under Water-Stress Conditions". *Mycorrhiza*. 10(3):121–123.

15. Cui, Y.L., R.H. Zhu, R.H. Zhi, D.Y. Chen, Y.Z. Huang, and Y. Qiu, 2004. "Transfer of Metals from Soils to Vegetables in an Area Near a Smelter in Nanning, China". *Environ. Intl.* 30: 785-791.

16. Czerwiński, J., E. Bartnikowska, H. Leontowicz, et al. 2004. "Oat (*Avena sativa* L.) and Amaranth (*Amaranthus hypochondriacus*) Meals Positively Affect Plasma Lipid Profile in Rats Fed Cholesterol-Containing Diets". *J Nutr Biochem*. 15(10): 622–629.

17. D'Mello, J.P.F., 2003. *Food Safety: Contaminants and Toxins*. CABI Publishing: Wallingford, UK.

18. Department of Environment, Food and Rural Affairs (DEFRA), P.J. Meng and Shieh, 2002. "Daily intake of Cu, (1999). Total Diet Study for Fishermen in Taiwan". *Science Total Environment*. 285: 177-185.

19. Dosumu, O.O., N. Salami, and F.A. Adekola. 2003. "Comparative Study of Trace Element Levels in some Local Vegetable Varieties and Irrigation Waters from Different Locations in Ilorin, Nigeria". *Bull. Chem. Soc. Ethiop.* 17(1), 107-112.

20. Dunlop, E; J. Hardcastle, and N.J. Shah. 2005. "Cousin and Cousine Islands Status and Management of Alien Invasive Species".

21. Elmar, K. and W. Wolfang. 1990. "Organic Manures-No Alternative to Mineral Fertilizers for Developing Countries. BASF Agriculture News, 2:90, pp. 820.

22. FAO. 2008. Food and Agriculture Organization. *Organic Material as Fertilizers*. Longman/FAO. Rome, Italy.

23. FAO. 2021. *Organic Foods- Are they Safer? Food Safety Technical Toolkit for Asia and the Pacific*. No. 6. Bangkok.

24. FAO/WHO. 2001. "Food Additives and Contaminants, Joint Codex Alimentarius Commission". FAO/WHO. Food standards Programme, ALINORM 01/12A.

25. FAO. 2008. *Food and Agriculture Organization. Organic Material as Fertilizers*. Longman/FAO. Rome, Italy.

26. FAO/WHO. 1999. "Joint Expert of Food Additives, Summary and Conclusions". In: *Proceedings of the 53 Meeting of Joint FAO/WHO Expert Committee on Food Additives and Contaminants*. Joint FAO/WHO Food Standards Programme, ALINORM 01/12A:1-289.

27. Farooq, M., F. Anwar, and U. Rashid. 2008. “Appraisal of Heavy Metal Contents in Different Vegetables Grown in the Vicinity of an Industrial Area”. *Pak. J. Bot*. 40: 2099-2106.

28. FDA (Food and Drug Administration). 2001. “Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc”. Report of the Panel on Micronutrients. National Academy Press, Washington, DC, Food and Drug Administration. Dietary supplements. Center for Food Safety and Applied Nutrition.

29. Fayinminnu, O.O. and J.M. Adekunle-Jimoh. 2015. “Evaluation of Heavy Metals and Health Risk Index in *Amaranthus hybridus* L. Vegetable Grown in Selected Farms in Ibadan, Nigeria”. *Nigerian Journal of Science*. 49: 11 – 21.

30. Garcia-Rico, L., J. Leyva-Perez, and M.E. Jara Marini. 2007. “Content and Daily Intake of Copper, Zinc, Lead, Cadmium, and Mercury from Dietary Supplements in Mexico”. *Food Chemistry and Toxicology*. 45:15991605.

31. Ghosh, A.K., M.A. Bhatt, and H.P. Agrawal. 2012. “Effect of Long-Term Application of Treated Sewage Water on Heavy Metal Accumulation in Vegetables Grown in Northern India”. *Environ. Monit. Assess*. 184(2): 1025-1036.

32. Grubben, G.J.H. 2004. “*Amaranthus cruentus* L.” In: Grubben G.J.H, Denton O.A, eds. PROTA (Plant Resources of Tropical Africa. Vegetables/Resources végétales de l’Afrique tropicale. Légumes. . Wageningen, The Netherlands: Fondation PROTA, Backhuys Publishers; 2. 73–79.

33. Hang, X., H. Wang, J. Zhou, C. Ma, C. Du, and X. Chen. 2009. “Risk Assessment of Potentially Toxic Element Pollution in Soils and Rice (*Oryza sativa*) in a Tyoical Area of the Yangtze River Delta”. *Environmental Pollution*. 12: 315-324.

34. Hafez, H.F.H. and W.H.P. Theimann. 2003. “Persistence and Biodegradation of Iazinone and Imidacloprid in Soil”. In: *Proceedings of the 12th Symposium in Pesticide Chemistry*. Congress Centre Universita Cattolica: Piacenza, Italy. 35-42.

35. IRIS. 2003. “Integrated Risk Information System-China via consumption of Vegetables and Fish”. Science Database, US Environmental Protection Agency: Washington, DC.

36. Islam, A. and S. Akbar. 2013. “Transfer of Metals from Soil to Vegetables and Possible Health Risk Assessment”. *SpringerPlus*, 2: 385–391.

37. Jan, F.A., M. Ishaq, S. Khan, I. Ihsanullah, I. Ahmad, and M. Shakirullah. 2010. “A Comparative Study of Human Health Risks via Consumption of Food Crops Grown on Wastewater Irrigated Soil (Peshawar) and Relatively Clean Water Irrigated Soil (lower Dir)”. *Journal of Hazard Materials*. 179: 612–621.

38. Jarup, L. 2003. “Hazards of Heavy Metals Contamination”. *Br. Med. Bull*. 68:167-182.

39. Jolaoso, A.O., K.L. Njoku, M.O. Akinola, A.A. Adesuyi, and A.H. Adedokun. 2016. “Heavy Metal Analyses and Nutritional Composition of Raw and Smoked Fishes from Ologe and Lagos Lagoon, Lagos, Nigeria”. *Journal of Applied Science and Environmental Management*. 20(2): 277-285.

40. Kachenko, A.E. and B. Singh. 2006. “Heavy Metals Contamination in Vegetables grown in Urban and Metal Smelter contaminated sites in Australia”. *Water, Air and Soil Pollution*. 169:101 – 123.

41. Kanwar, J.S. and M.S. Sandha. 2000. “Waste Water Pollution Injury to Vegetable Crops, A Review”. *Agric. Review*. 21(2): 133-136.

42. Khan M.T., T. Akhtar, and M. Niazi. 2010. “Prevalence of Anemia among University of Peshawar Students”. *Journal of Postgraduate Medical Institute*. 24: 265-269.

43. Khan, S., Q.Y.Z. Cao, Y.Z. Huang, and Y.G. Zhu. 2008. “Health Risks of Heavy Metals in Contaminated Soils and Food Crops Irrigated with Wastewater in Beijing, China”. *Environmental Pollution.* 125(3): 686-692.

44. Kinderson, D. 2008. “The Rodale Institute Farming System Trial.: The First Fifteen Years”. *Kurztown*. 27-54.

45. Kumar, S.R., M. Agrawal, and F. Marshall. 2007. “Heavy Metal Contamination of Soil and Vegetables in Suburban Areas of Varanasi, India”. *Ecotoxicology and Environmental Safety*. 66: 258–266.

46. Lide, D.R. 1992. *CRC Handbook of Chemistry and Physics. 73rd ed.* CRC press: Boca Raton, FL. 2472 pp.

47. Makinde, E.A., L. Ayeni, and S.O. Ojeniyi. 2010. “Morphological Characteristics of *Amaranthus cruentus* L. as Influenced by Kola Pod Husk, Organomineral and NPK Fertilizers in Southwestern Nigeria”. *New York Sci Journal*. 2010;3(5):130–134.

48. 4Mlakar E.A., M. Turinek, M. Jakop, M. Bavec, and F. Bavec. 2009. “Nutrition Value and Use of

Grain Amaranth: Potential Future Application in Bread Making". *Agricultura*. 6:43-53.

49. Muchuweti, M., J.W. Birkett, E. Chinyanga, R. Zvauya, M.D. Scrimshaw, and J.N. Lester. 2006. "Heavy Metal Content of Vegetables Irrigated with Mixture of Waste Water and Sewage Sludge in Zimbabwe: Implications for Human Health". *Agriculture, Ecosystem and Environment*. 112: 4148.

50. Nagajyoti, P.C, K.D. Lee, and T.V.M. Sreekanth. 2010. "Heavy Metals, Occurrence and Toxicity for Plants: A Review". *Environmental Chemistry Letters*. 8(3): 199-216. 63.

51. Nazir, R., M. Khan, M. Masab, H.U. Rehman, N.U. Rauf, S. Shahab, and Z. Shaheen. 2015. "Accumulation of Heavy Metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the Soil, Water and Plants and Analysis of Physico-Chemical Parameters of Soil and Water Collected from Tanda Dam Kohat". *Journal of Pharmaceutical Sciences and Research*. 7(3):89. 64.

52. Nolan, A.L., E. Lombi, and M.J. McLaughlin. 2003. "Metal Bioaccumulation and Toxicity in Soils - Why Bother with Speciation?". *Australia J. Chem*. 56:77-91.

53. Okunola O.J., Y. Alhassan, G.G. Yebpella, A. Uzairu, A.I. Tsafe, E.S. Abechi, and E. Apene. 2011. "Risk Assessment of using Coated Mobile Recharge Cards in Nigeria". *Journal of Environmental Chemistry and Ecotoxicology*. 3(4): 80-85.

54. Olowoake, A.A. 2014. "Influence of Organic Mineral and Organomineral Fertilizers on Growth, Yield, and Soil Properties in Grain Amaranth (*Amaranthus cruentus* L.)". *Journal of Organics*. 1(1): .39–47.

55. Oluwatosin, G.A., A.O. Adeoyolanu, A.O. Ojo, K.S. Are, T.O. Dauda, and V.O. Aduramigba-Modupe. 2010. "Heavy Metal Uptake and Accumulation by Edible Leafy Vegetable (*Amaranthus hybridus*) Grown on Urban Valley Bottom Soils in Southwestern Nigeria". *Soil and Sediment Contamination*. 19: 1-20.

56. Rattan, R.K., S.P. Datta, P.K. Chhonkar, K. Suribabu, and A.K. Singh. 2005. "Long-Term Impact of Irrigation with Sewage Effluents on Heavy Metal Content in Soils, Crops and Groundwater: A Case Study". *Agriculture, Ecosystem and Environment*. 109: 310-322.

57. Raskin. I., P.N. Kumar, S. Dushenkov, and D.E. Salt. 1994. "Bioconcentration of Heavy Metals by Plants". *Current Opinion in Biotechnology*. 5(3): 285-290. 75.

58. Sabine, M. and G. Wendy. 2009. "Human Health Effects of Heavy Metals". *Journal of Environmental Science and Technology Briefs for Citizens.* Issue 15, March (2009). www.engg.ksu.edu/CHSR

59. Singh, S. and M. Kumar. 2006. "Heavy Metal Load of Soil, Water, and Vegetables in Peri-Urban Delhi". *Environ. Monit. and Assessm.* 120: 79-91.

60. Sneddon, J. 1997. *Atomic Absorption Spectroscopy. Handbook of Instrumental Techniques for Analytical Chemistry*. Settle, F. (Editor). Prentice Hall: Upper, Saddle River, NJ. 375-376, 385-387.

61. Sobukola, O.P., O.M. Adeniran, A.A. Odedairo, and O.E. Kajihausa. 2010. "Heavy Metal Levels of some Fruits and Leafy Vegetables from Selected Markets in Lagos, Nigeria". *Afr. J. Food Sci*. 4(2): 389 – 393.

62. Sobukola, O.P., O.U. Dairo, L.O. Sanni, A.V. Odunewu, and B.O. Fafiolu. 2007. "Thin Layer Drying Process of some Leafy Vegetables under Open Sun". *Food Sci .Technol. Int*. 13(1): 35-40.

63. Tindall, H.D. 1983. *Vegetables in the Tropics, 1st edn*. Macmillian Education Ltd.: Houndmills, Hampshire, UK. 553

64. Tsafe, A.I., L.G. Hassan, D.M. Sahabi, Y. Alhassan, and B.M. Bala. 2012. "Evaluation of Heavy Metals Uptake and Risk Assessment of Vegetables Grown in Yargalma of Northern Nigeria". *Journal of Basic and Applied Science Research*. 2(7): 6708-6714.

65. US-EPA. 2006. Integrated Risk Information System (IRIS). US Environmental Protection Agency: Washington, DC. http://www.epa. gov/iris/subst.

66. USEPA. 2010. Integrated Risk Information System. (IRIS). US Environmental Protection Agency: Washington, DC. http://www.epa.gov/iris/index.html (accessed on 4 May 2016).

67. Wang, X., T. Sato, B. Xing, and S. Tao. 2005. "Health Risks of Heavy Metals to the General Public in Tianjin, China via Consumption of Vegetables and Fish". *Science and Total Environment*. 350: 28–37.

68. Wołosik, K., M. Knaś, A. Zalewska, M. Niczyporuk, and A.W. Przystupa. 2013. "The Importance and Perspective of Plant-Based Squalene in Cosmetology". *J. Cosmet. Sci*. 64(1): 59–66.

69. Zheng, N., Q. Wang, X. Zhang, D. Zheng, Z. Zhang, and S. Zhang. 2007. "Population Health

Risk Due to Dietary Intake of Heavy Metals in the Industrial Area of Huludao City, China". *Science and Total Environment*. 387: 96–104.

70. Zhou, Q., Y. Wu, and X. Xiong. 1994. "Compound Pollution of Cd and Zn and its Ecological Effect on Rice Plant". *Chin. J. Appl. Ecol.* 5: 428-441.

71. Zhigila, D.A., U.A. Yuguda, J.J. Akawu, and F.A. Oladele. 2014. "Palynomorphs and Floral Bloom as Taxonomic Characters in some Species of the Genus *Amaranthus* L. (Aamaranthaceae)". *Bayero J. Pure App. Sci*. 7(2): 164–168.

72. Zirwas, M.J. and M.A. Molenda. 2009. "Dietary Nickel as a Cause of Systemic Contact Dermatitis". *Journal of Clinical and Aesthetic Dermatology*. 2(6): 3943.

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