Effects of The Characterization of Heavy Metal in Amaranthus Hybridus L., Grown On Poultry Manure and Refuse Dump Compost

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***Abstract*—** The effects of the characterization of heavy metal in Amaranthus hybridus L, grown on poultry manure and refuse dump compost were assessed in a screen house. Seedlings of A. hybridus were transplanted into various soil treatments: Treatment A, garden soil and river sand in ratio of 3:1, control; B (garden soil, refuse dump compost and river sand in ratio 3:2:1; and C (garden soil, poultry manure and river sand in ratio 3:2:1. Completely randomized design with five experimental units were used. At intervals of 2 weeks for 14 weeks, growth parameters and concentrations of heavy metals in the plant parts at the beginning and end of the experiment were assessed. Data obtained were subjected to ANOVA and means separated using DNMRT at $P < 0.05$. Treatment C produced the highest mean plant height, number of leaves, leaf area, fresh and dry weight of leaves, stems, roots and seeds, suggesting higher yield over other treatments. Treatment B performed better than A, indicating some improvement in the soil fertility with the application of refuse dump compost. Cadmium and lead in Treatment B were above the FAO/WHO limits for heavy metals in vegetables. Thus, A. hybridus grown with refuse dump compost is unsafe for consumption since they greatly accumulate toxic heavy metals.

***Keywords*—** cadmium, chromium, copper, heavy metals, lead, zinc.

INTRODUCTION

Sustainable agriculture can only be achieved through the proper management of organic matter by the use of organic amendments available or locally produced. Ogunlela *et al*. (2005) reported that as long as organic manures are available and comparable with inorganic fertilizers in yield improvements, their use as sources of plant nutrients for growing vegetable crops could assume increasing importance. The application of organic wastes from different origins (manure, sewage sludge and refuse dump composts) to degraded soils is a practice globally accepted to recover, replenish and preserve organic matter, fertility and vegetation. Civeira and Lavado (2006) reported that organic manures contain high nitrogen, phosphorus, potassium and other essential nutrients. In contrast to chemical fertilizer, it adds organic matter to soil, which improves soil structure, nutrient retention, aeration, moisture holding capacity and water infiltration. Added to that, Nigerian farmers now use agrochemicals to the barest minimum due to non-availability, unequal distribution or high cost of procurement.

Amaranthus hybridus is an annual herbaceous plant of 1-6 feet high. In Nigeria, it is referred to as "tete" in Yoruba, "alaiyaho" in Hausa and "inine" in Igbo. The leaves are alternate petioled, 3 – 6 inches long, dull green, rough, hairy, ovate or rhombic with wavy margins. The flowers are small, with greenish or red terminal panicles borne in dense elongated clusters, usually on the tips of the branches. The taproot is long, fleshy red or pink. The small seeds of *A. hybridus* are usually shiny black in colour, lenticellular in shape with each seed averaging 1.0 – 1.5 mm in diameter and 1000 seeds weighing 0.6 – 1.2 grams. It is rather a common species in waste places, cultivated fields and barnyards (Akubugwu *et al*., 2007). Agronomically, amaranths require some well-drained soil rich in nitrogen, phosphorus and potassium and will perform better in non-acidic conditions (Mbonu and Arifalo, 2006). *A. hybridus* is one of the few dicotyledonous plants that exhibit C_4 metabolism, a much more efficient form of photosynthesis than the more common C_3, which predisposes it to high productivity and is thus an essential vegetable candidate to ensure food and nutritional security in developing countries of Africa. (Grubben, 2004). The consumption of vegetables in diet has been reported to protect the human body from degenerative diseases and the main protective action of vegetables had been attributed to the antioxidants present in them (Ogunlesi *et al*., 2010).

In Nigeria, *A. hybridus*, including other common vegetables, though frequently grown by the urban populace in a bid to augment personal incomes and offset food insecurity occasioned by rural-urban drift are often consumed by a greater part of the entire population (Shagal *et al*., 2012). Under this system, all forms of available lands including contaminated sites such as derelict waste dumps, banks of polluted rivers and streams, high way shoulders and industrial areas are indiscriminately cultivated owing to land tenure problems, inadequate regulation and enforcement system. Adefemi *et al*. (2012) reported that the contaminated sites as well as the soil amendments (fertilizers, manures, sludge, compost), irrigation water and pesticides frequently applied to enhance soil fertility and boost the yield may inadvertently bear chemical stressors including the toxic heavy metals – lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg) and nickel (Ni). Evidence keeps mounting that vegetables and other food crops grown under such unwholesome conditions may bioaccumulate the toxic heavy metals at levels exceeding statutory or advisory limits whether measured as metal concentrations in produce or expressed as projected daily intakes (Nabulo *et al*., 2010).

The intake of vegetables is an important path of heavy metal toxicity to humans. Lokeshwari and Chandrappa (2006) reported that the main sources of heavy metals to vegetable crops are their growth media (soil, air, nutrient solutions) from which these heavy metals are taken up by the roots or foliage. Vegetables can take up and accumulate heavy metals in quantities high enough to cause clinical problems to humans (Alam *et al*., 2003). The toxic and detrimental impacts of heavy metals become apparent only when long-term consumption of contaminated vegetables occurs. Therefore, the regular monitoring of heavy metals in vegetables and other food items should be performed in order to prevent excessive build-up of these heavy metals in the human food chain (Khanna and Khanna, 2011). The aim and objectives of this study is:

- To determine the nutrient compositions and heavy metals content of refuse dump compost and poultry manure.
- To assess the impact of refuse dump compost and poultry manure on the growth and yield of *A. hybridus.*
- To assess the concentration of heavy metals accumulation and their deposition in various parts of *A. hybridus* (leaves, stems, roots and seeds).

MATERIALS AND METHODS

The experiment was carried out in the screen house of the Botanical Garden of the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka. Viable seeds of *Amaranthus hybridus* were obtained from the Department of Crop Science, University of Nigeria, Nsukka. The refuse dump compost (RDC) was collected from a refuse dumpsite at Mkpor Junction, Nsukka and sieved with a 2 mm sieve to remove the undecomposed materials. Fresh poultry manure (PM) was collected from a poultry farm in Government Reserved Area (G.R.A), Nsukka. The garden soil (GS) was collected from the Botanical Garden of the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka while the river sand was collected from Uhere River in Opi, Nsukka. The soil samples, garden soil and river sand for the experiment were sterilized by heating in a drum to a temperature of about 100ºC (to minimize the incidence of spores and disease causing organisms) and then allowed to cool before use. *Amaranthus hybridus* were first raised in a nursery in a medium composed of garden soil, poultry manure and river sand in the ratio of 3:2:1, and transplanted at 3 weeks into the treatment media.

The media were as follows: Treatment A (Control) consisting of Garden soil + River sand (GS + RS) in the ratio of 2:1; Treatment B, Garden soil + Poultry manure + River sand (GS + PM + RS) in the ratio of 3:2:1; and Treatment C, Garden soil + Refuse dump compost + River sand (GS + RDC + RS) in the ratio of 3:2:1). The experiment was carried out in a completely randomized design (CRD) comprising of three media treatments. Each treatment was replicated 9 times. The river sand was added to improve capillarity in the media.

Physico-chemical properties of refuse dump compost and poultry manure

The refuse dump compost and poultry manure were air-dried and large aggregates of each, crushed and sieved with a 2 mm sieve. The total nitrogen (%) and available phosphorous (%) were determined using the modified Kjeldahl digestion and Bray methods respectively as outlined by Landor (1991). Exchangeable bases (K, Na, Mg, and Ca) were determined using the method described by Thomas (1982). Total organic carbon was determined using the Walkey and Black wet oxidation method as described by Carter (1993). The pH was measured with a glass electrode in 1:2 sample-water ratio suspension using Jenway pH, conductivity and temperature meters. Moisture content was also determined following the procedures of Kebir and Bouhadjera (2009).

Heavy metals analysis of refuse dump compost and poultry manure

The process described by Ogundiran and Osibanjo, (2008) was used for the analysis. A sample of 1g each of the air-dried compost and poultry manure was weighed out into a to 100 cm^3 tall-form beakers. About $20cm^3$ of (1:1) HNO_3/HCl acid mixture was added and boiled gently on a hotplate until the volume of nitric acid mixture was reduced to about 5 cm^3. Deionized water ($20cm^3$) was then added and boiled gently again until the volume was approximately $10cm^3$. The resulting suspension was cooled and filtered through a Whatman No. 42 filter paper, while washing the beaker and the filter paper with small portions of deionized water until a volume of about $25cm^3$ was obtained. The filtrate was then transferred to a $50cm^3$ graduated flasks and made up to the mark using deionized water. The filtrate was then analyzed for Hg, Cu, Cd, Zn, Pb, Cr and Fe using an Atomic Absorption Spectrophotometer (Analyst 200 Perkin Elmer) as described by AOAC (2005).

Growth and yield parameters

Five plants were picked at random from each treatment. The plant height, number of leaves, leaf area, wet and dry weights of leaves, stem, root and seeds on maturity of *A. hybridus* were determined at an interval of 2 weeks for 14 weeks.

Concentrations of heavy metals in A. hybridus

The dried samples of different parts of vegetables were ground into fine powder using a commercial blender and stored in polyethylene. The digestion was carried out in triplicates for all the analysis. The procedure of Awofolu (2005) was used for the digestion of the plant samples. The samples (0.5g) were weighed into $100cm^3$ beaker. A mixture of 5ml concentrated HNO_3 and 2ml $HClO_4$ was added to dissolve the sample.

The beaker was heated at moderate temperature of 110°C on a hot plate for one hour in a fume hood until the content was about 2ml. The digest was allowed to cool, filtered into $50cm^3$ standard volumetric flasks and made up to the mark with distilled deionized water. A serial dilution method was used to prepare the working standards and the concentrations of the metals in each sample digest was then determined using Atomic Absorption Spectrophotometer (AAS).

The absorbance obtained from AAS instrument for each standard of a particular element was used to draw the calibration curve. The blank and sample solutions were respectively aspirated into the AAS and the absorbance recorded. The instrument was fitted with specific lamp of a particular metal. The instrument was calibrated using manually prepared standard solution of respective heavy metals as well as drift blanks.

Statistical analysis

The data from each treatment was subjected to ANOVA using SPSS Windows, version 14.0 and the means compared using DNMRT at the confidence level of $P < 0.05$.

RESULTS

Refuse dump compost and poultry manure analysis

The results of the physico-chemical and heavy metals analysis (Table 1) showed that poultry manure contained higher amounts of essential elements (7.15 % N, 2.1 % P, 1.5 $cmolkg^{-1}$ K) than the refuse dump compost with 2.32 % N, 1.7 % P and 0.38 $cmolkg^{-1}$ K. The pH level of poultry manure was slightly acidic (6.30) while refuse dump compost was slightly alkaline (7.80). Refuse dump compost contained the highest amounts of heavy metals.

Growth and yield parameters

Plant height (cm)

The plant height (Table 2) increased from 2 to 14 weeks after transplanting (WAT) across all the treatments with Garden soil + Poultry manure + River sand (GS+PM+RS), Treatment C, having the highest plant mean height of 18.1 cm at 2 WAT and 88.00 cm at 14 WAT. This was followed by Garden soil + Refuse dump compost + River sand (GS+RDC+RS), Treatment B, with a plant mean height of 14.52 cm at 2 WAT and 71.60 cm at 14 WAT. Garden soil + River sand (GS+RS), Treatment A, which is the control had the lowest plant mean height of 13.78 cm at 2 WAT and 59.60 cm at 14 WAT. Also, in Table 2, DNMRT ($P \leq 0.05$) showed that Treatment C differed significantly ($P \leq 0.05$) from treatments A and B across the weeks. There was no significant difference ($P \leq 0.05$) between treatments A and B at 2 – 6 WAT but they differed significantly ($P \leq 0.05$) at 10 – 14 WAT. Analysis of variance also showed significant differences ($P \leq 0.05$) on plant height across the weeks between the treatments.

Number of leaves

Treatment B (GS+RDC+RS) produced the highest mean number of leaves (12.40) at 2 WAT; 16.80 at 4 WAT and 25.00 at 6 WAT while treatment C (GS+PM+RS) produced the highest number of leaves at 8 -14 WAT with the highest mean number of leaves (55.80) at 14 WAT. The lowest number of leaves across the weeks was observed in treatment A with a mean leaf number of 51.20 at 14 WAT (Table 3). DNMRT ($P \leq 0.05$), Table 3 showed that there were no significant differences between treatments A and B and between all the treatments at 8 - 14 WAT. However, there was significant difference (P ≤ 0.05) between treatments A and C at 2 - 10 WAT; and between A and B at 2 - 6 WAT. Analysis of variance showed significant difference (P ≤ 0.05) in the mean number of leaves between the treatments at 2 – 6 WAT but there was no significant difference (P ≤ 0.05) at 8 – 14 WAT.

Leaf area (cm^2)

The highest mean leaf area of 140.89 cm^2 at 14 WAT was produced by treatment C (GS+PM+RS) followed by treatment B (GS+RDC+RS) with a mean leaf area of 134.44 cm^2 but DNMRT (P ≤ 0.05) showed that they were not significantly different from each other (Table 4). Treatment A (GS+RS) produced the lowest leaf area of 116.03 cm^2 at 14 WAT and was significantly different (P<0.05) from treatments B and C (Table 4). However, there was no significant difference (P<0.05) between the treatments at 6 WAT; between treatments A and B at 2, 6 and 8 WAT; and between B and C at 4, 6, and 14 WAT. The treatments (A, B and C) were significantly different (P<0.05) from each other at 10 and 12 WAT. ANOVA also showed that treatments were significantly different (P< 0.05) except at 6 WAT.

Fresh weight of leaves (g)

The mean fresh weight of leaves increased with the age of plant (Table 5) from 1.44 g at 2 WAT to 52.47 g at 14 WAT with Treatment C (GS+PM+RS) having the highest mean fresh weights of leaves followed by Treatment B (GS+RDC+RS) while treatment A (GS+RS) had the lowest mean fresh weight of leaves. At 4 and 8 WAT, DNMRT showed that the treatments were significantly different from each other (P ≤ 0.05) but not significantly different at 12 WAT. In addition, there was no significant difference between Treatments B and C at 10 – 14 WAT and between treatments A and B at 2, 6, 10, 12, 14 WAT (Table 5). ANOVA showed that treatments were significantly different at 2, 4, 6, 8, 10 and 14 WAT but was not significantly different (P<0.05) at 12 WAT.

Fresh weight of stems (g)

Treatment C (GS+PM+RD) produced the highest mean fresh weight of stem with 41.57 g at 14 WAT followed by treatment B (GS+RDC+RS) with 37.45 g (Table 5). The lowest mean fresh weight of stem (33.46 g) was observed in treatment A (GS+RS). Table 5 also showed that there was no significant difference (P <0.05) in mean fresh weight of stem between the treatments at 14 WAT; between treatments A and B at 2, 10 and 14 WAT and treatments B and C at 12 and 14 WAT. Treatments differed significantly from each other (P<0.05) at 4 – 8 WAT while treatment C differed significantly from treatments A and B at 2 – 10 WAT. ANOVA showed significant difference (P<0.05) between treatments at 2 – 14 WAT and no significant difference (P<0.05) at 14 WAT.

Fresh weight of roots (g)

Table 5 showed that treatment C (GS+PM+RS) had the highest mean fresh weight of roots (10.19 g) followed by treatment B (GS+RDC+RS) with a mean fresh weight of 9.92 g at 14 WAT but were not significantly different (P<0.05). Treatment A (GS+RS) had the lowest mean fresh weight of root (8.48 g) at 14 WAT but was not significantly different (P<0.05) from treatment B. The treatments were significantly different (P<0.05) from each other at 6 and 8 WAT but were not significantly different at 12 WAT. Analysis of variance showed that the treatments were significantly different (P<0.05) 2 – 8 WAT but were not significantly different at 10 – 14 WAT.

Dry weight of leaves (g)

Table 6 showed that treatment C (GS+PM+RS) had the highest mean dry weight of leaves (5.36 g) followed by treatment B (GS+RDC+RS) with 4.74 g. Treatment A (GS+RS) had the lowest mean dry weight of leaves of 4.21 g but the treatments were not significantly different (P<0.05) from each other across the weeks. ANOVA also showed no significant difference (P< 0.05) between the treatments.

Dry weight of stems (g)

The treatments were not significantly different (P<0.05) across the weeks as shown in Table 6 but treatment C (GS+PM+RS) had the highest mean dry weight of stem (3.96 g) followed by treatment B (GS+RDC+GS) with 3.76 g. Treatment A (GS+RS) had the lowest mean dry weight of stems with 3.16 g. ANOVA of the effects of refuse dump compost and poultry manure on the dry weight of stems also showed no significant difference (P<0.05) between treatments.

Dry weight of roots (g)

Tables 6 showed no significant difference (P<0.05) in the mean dry weight of roots between treatments. As shown in Table 6, Treatment C (GS+RDC+RS) had the highest dry weight of roots (1.78 g) followed by Treatment B (GS+PM+RS) with 1.42 g; Treatment A (GS+RS) had the lowest mean dry weight of roots (0.76 g). ANOVA also showed no significant difference (P<0.05) in the mean dry weight of roots between treatments.

Fresh and Dry Weight of Seeds (g)

The highest fresh and dry weights of seeds were produced by Treatment C (GS+PM+RS) with 0.24 g and 0.19 g respectively followed by Treatment B (GS+RDC+RS) with 0.17 g and 0.12 g fresh and dry weight respectively (Table 7). Treatment A had the least fresh weight of 0.15 g. However, Treatment A and B had the same dry weight of seeds of 0.12 g respectively. ANOVA and DNMRT showed no significant difference (P< 0.05) in fresh and dry weights of seeds between the treatments.

Heavy metals analysis

Concentrations of heavy metals (mg/kg) in the leaves of A. hybridus

The concentrations of heavy metals in the leaves of *A. hybridus* (Table 8) showed that *A. hybridus* grown in Treatment B (GS+RDC+RS) accumulated the highest heavy metals in the leaves and was significantly different (P<0.05) from Treatments A (GS+RS) and C (GS+PM+RS). ANOVA showed significant difference (P<0.05) in heavy metals accumulation in the leaves of *A. hybridus*.

Cadmium, mercury, and lead were not detected in the leaves of *A. hybridus* that was grown in Treatments A and C. The concentrations of copper, zinc, mercury and chromium that were detected were all within the FAO/WHO maximum limits for heavy metals in vegetables. However, the concentrations of cadmium and lead (0.263 mg/kg and 2.833 mg/kg respectively) that were detected in *A. hybridus* grown in Treatment B were above FAO/WHO limits of 0.20 mg/kg for cadmium and 0.30 mg/kg for lead.

Concentrations of heavy metals (mg/kg) in the stems of A. hybridus

As shown in Table 8, the highest concentrations of heavy metals were detected in the stems of *A. hybridus* grown in Treatment B (GS+RDC+RS) and was significantly different (P<0.05) from Treatments A (GS+RS) and C (GS+PM+RS). Cadmium, chromium, mercury and lead were not detected in the stems of *A. hybridus* that was grown in Treatments A and C.

However, the concentrations of cadmium (0.300 mg/kg) and lead (0.380 mg/kg) that were detected in the stems of *A. hybridus* grown in Treatment B were above the FAO/WHO recommended limits of 0.20 mg/kg for cadmium and 0.30 mg/kg for lead in vegetables. ANOVA also showed significant differences (P ≤ 0.05) in the concentrations of heavy metals in the stems of *A. hybridus*.

Concentrations of heavy metals (mg/kg) in the roots of A. hybridus

Table 8 showed significant differences (P<0.05) in concentrations of heavy metals in the roots of *A. hybridus* between treatments. *Amaranthus hybridus* that was grown in Treatment B (GS+RDC+PM) had the highest concentrations of heavy metals in the roots and was significantly different (P<0.05) from Treatments A (GS+RS) and B (GS+PM+RS). The concentrations of heavy metals that were detected in the roots of *A. hybridus* grown in Treatments A and C were not significantly different at P<0.05. *A. hybridus* grown in Treatment B had the highest concentrations of heavy metals in the roots and was significantly different from Treatments A and C (Table 8) However, the concentrations of all the heavy metals that were detected in the roots *A. hybridus* were within the FAO/WHO recommended limits for heavy metals in vegetables.

Concentrations of heavy metals (mg/kg) in the seeds of A. hybridus

Table 8 showed that mercury was not detected in the seeds of Treatments A, B and C. Cadmium, chromium, and lead were not detected in the seeds of *A. hybridus* grown in Treatments A (GS+RS) and C (GS+PM+RS). On the contrary, cadmium, chromium, lead, copper and zinc were detected in seeds from Treatment B (GS+RDC+GS) (Table 8). ANOVA showed that there was no significant difference (P < 0.05) in the concentrations of chromium in the seeds between treatments. However, the concentrations of all the heavy metals that were detected in the seeds of *A. hybridus* were within the FAO/WHO recommended limits for the heavy metal in vegetables.

DISCUSSION

In search for a relatively cheap, readily available and environmentally friendly alternative to inorganic fertilizers, the use of organic manures is inevitable. The results of the Physico-chemical properties of poultry manure and refuse dump compost revealed that poultry manure contained high amounts of the major nutrients (NPK) and hence, significant improvements in plant growth and yield parameters on application were expected. This conforms to the findings of Civeira and Lavado (2006) who reported that organic manures contain high nitrogen, phosphorus, potassium and other essential nutrients. Essential plant nutrients (NPK) required for plant growth and yield were also recorded in refuse dump compost, though the values obtained were lower than that in poultry manure. This conforms to the findings of John and Effiong (2008) who reported that organic materials, which constitute a greater portion of the waste in dumpsites, contain varying levels of both macro and micronutrients needed by growing plants for sustainable growth and optimum yield, though the levels of essential plant nutrients (NPK) in refuse dump compost are generally low. Application of large amounts of decomposed refuse dump compost (50 % and above) could however, significantly improve the growth and yield of crops.

The heavy metals content of the refuse dump compost are quite typical of composts collected from unorganized dumpsites. Sources such as electronics, batteries, plastics, polyethene bags, solid wastes and scrap metals are characteristic of Mkpor Junction refuse dumpsite where the compost was collected could also account for the increase of heavy metals in the refuse dump compost. Similar results were obtained by Ebong *et al.* (2007) who attributed the high levels of heavy metals in dumpsites to the huge amount of waste products disposed of at the dumpsites. The high levels of these heavy metals present the sites as potentially hazardous and highly inimical to the food chain. Adefemi *et al*. (2012) also reported the presence of toxic heavy metals in contaminated sites as well as the soil amendments (fertilizers, manures, sludge, compost), irrigation water and pesticides frequently applied to enhance soil fertility and boost the yield. Heavy metals were also detected in the poultry manure; though in lesser concentrations. Continuous and over-application of poultry manure to soils could therefore, accumulate such heavy metals, which could also be potentially bioavailable. Han *et al.* (2000) also reported considerable accumulation of Cu and Zn in a poultry manure-amended soil over 25 years. Therefore, the increased and repeated use of poultry manure could also increase the Zn and Cu concentrations of soils.

Results also showed that all the tested heavy metals were detected in the poultry manure and refuse dump compost. Han *et al*. (2000) reported that not all metals in the soil have the potential of being taken up by plants. Only those in the available forms are easily absorbed by the root system of the plant through nutrient uptake and thus are able to enter the food chain and later pose a risk to human life. Soils that have been cropped for many years that may be deficient in nutrients such as zinc and copper, etc could therefore be mitigated through the application of organic manures with heavy metals.

The highest mean plant height of *A. hybridus* was recorded in Treatment C (GS+PM+RS) from 2- 14 weeks after transplanting. This could be attributed to the addition of poultry manure, which is a potential source of nutrients to the soil and thus enhanced mineralization of nutrients in the soils. This is in conformity with the report of Awoddinn (2007) who also reported significant increase in plant height of *Telfairia occidentalis* on application of poultry manure. Treatment B (GS+RDC+PM) also performed better than Treatment A (GS+RS) probably due to the higher nutrient content of the refuse dump compost. This result conforms to the findings of Egherevba and Ogbe (2002) and Ibeawuchi *et al*. (2006) who also reported increased nutrient status of the soil through gradual release of nutrients on the application of organic manure.

The highest plant height, number of leaves, leaf area, fresh and dry weights of leaves, stems, roots and seeds were obtained in Treatment C (GS+PM+RS) probably because of the plant's ability to quickly dissolve and absorb essential nutrients that promotes easy plant uptake for their growth as well as the balanced nutrient content of the poultry manure. Treatment B produced the second best and appreciable values for all the parameters measured probably due to its lower nutrient composition and the slower release of these nutrients to the plants. However, the mean number of leaves of Treatment B was not significantly different from that observed in Treatment C indicating the ability of refuse dump compost to also provide essential nutrients required for plant production. The appreciable but non-significant difference in weight of 1000 seeds that was observed in all the Treatments may be due to genetic make-up and size of the seeds.

The results of the concentrations of heavy metals in *Amaranthus hybridus* showed that *A. hybridus* grown in Treatment B (GS+RDC+RS) accumulated the heaviest metals than those grown in Treatments A (GS+RS) and C (GS+PM+RS). This might probably be as a result of the high heavy metals content of the refuse dump compost. This result conforms with the findings of Sharma *et al*. (2007), who also reported greater accumulation of heavy metals by crops and vegetables grown in soils contaminated with heavy metals than those grown in uncontaminated soils. Ebong *et al*. (2008) also reported higher metal concentrations in *Carica papaya* and *Talinum triangulare* grown in municipal and rural dumpsite soils and rate of accumulation than did their counterparts obtained from normal agricultural soil. The results of the study also showed variations in the concentrations of heavy metals in the various plant parts of *A. hybridus* probably because of the different concentrations of the metals in the different media and the ability of the plant to absorb and transport these metals to the various plant parts. Cui *et al*. (2004) also reported similar variations in transfer factor among different vegetables, which they attributed to differences in the concentration of metals in soil and differences in element uptake by different vegetables.

Lokeshwari and Chandrappa (2006) reported that cadmium is retained less strongly in the soil and is more mobile than other metals. The concentration of cadmium that was recorded in the stems and leaves of *A. hybridus* grown in Treatment B (GS+RDC+RS) were higher than the concentration of cadmium in the roots (Stems > Leaves > Roots > Seeds) probably because the plant was able to transfer the heavy metal to the aerial parts. This also agrees with the findings of Adu *et al*. (2012) who reported that cadmium is a highly mobile metal, which is easily absorbed by plants through root surface and transferred to the upper parts of plants. Cadmium was only detected in the roots of *A. hybridus* grown in Treatment C (GS+PM+RS) but was not detected in any part of that grown in Treatment A (GS+RS). The concentrations of cadmium present in the roots and seeds of *A. hybridus* grown in Treatment B and in the roots of that grown in Treatment C were all within the FAO/WHO recommended limits. However, the concentrations of cadmium in the leaves and stems of *A. hybridus* grown on Treatment B were above FAO/WHO recommended limits. This could probably be because high cadmium concentration in plants does not show any quality reduction (Lokeshappa *et al*., 2012). Cadmium is a toxic non-essential metal and so, the consumption of *A. hybridus* grown on Treatment B could be detrimental. Yadav *et al*. (2013) also reported that this high concentration of cadmium in leafy vegetables might be a threat for the consumers.

Lead was not detected in any plant part of *A. hybridus* grown in Treatment A (GS+RS) and in the leaves, stems and seeds of that grown in Treatment C (GS+PM+RS). However, lead was detected in all the plant parts of *A. hybridus* that was grown in Treatment B with the highest concentration in the leaves (Leaves > Stems > Roots > Seeds). Lokeshappa *et al*. (2012) reported that lead is a toxic element that can be harmful to plants, although plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield. The concentrations of lead in the leaves and stems of *A. hybridus* grown in Treatment B were above the FAO/WHO recommended limits but that in the roots and seeds were within the recommended limits. Uka *et al*. (2013) and Inoti *et al*. (2012) also reported high concentrations of lead in the leaves of *A. hybridus* grown on waste dumpsites. The values obtained were also above FAO/WHO recommended limits and hence, consumption of *A. hybridus* grown on such dumpsites could be dangerous.

Copper is an essential micronutrient, which functions as a biocatalyst and is required for body pigmentation. In addition, it also helps to maintain a healthy central nervous system and prevent anaemia (Akinyele and Osibanjo, 1982). Copper was detected in all plant parts of *A. hybridus* grown in all the treatments with the highest concentrations in the leaves of *A. hybridus* grown in Treatment B. The heavy metals followed the sequence: Roots > Leaves > Stems > Seeds for *A. hybridus* that was grown in Treatments A and C but followed the sequence: Leaves > Roots > Stems > Seeds for that grown in Treatment B. The concentrations of copper in all the plant parts were below FAO/WHO recommended limits.

Zinc was detected in all the plant parts of *A. hybridus* that was grown in all the treatments probably because it is an essential plant element and also as observed by Shaibu *et al*. (2013) and Salgueiro *et al*. (2000) zinc is the least toxic and an essential element in human diet, as it is required to maintain the functioning of the immune system. Zinc deficiency in diet may be highly detrimental to human health than too much zinc. The concentrations of zinc in *A. hybridus* followed the sequence: Leaves ≥ Roots > Stems > Seeds for Treatment A (GS+RS); Roots > Stems > Leaves > Seeds for Treatment B (GS+RDC+RS) and Stems > Leaves ≥ Roots > Seeds for Treatment C (GS+PM+RS). Regular consumption of these vegetables may therefore assist in preventing the adverse effect of zinc deficiency, which results in retarded growth and delayed sexual maturation because of its role in nucleic acid metabolism and protein synthesis.

Premaranthna *et al*. (2011) reported that plants may exhibit phytotoxicity for Zn and Cu and, therefore, food chain transformation can be restricted. As plants show toxicity symptoms in their tissue under high zinc and copper concentrations, plant quality and/or yield could be affected before Zn or Cu concentrations reach levels that could be detrimental to consumers. This could be the reason why the concentrations of zinc and copper that was detected in all the plant parts of *A. hybridus* grown in all the treatments were below the FAO/WHO recommended limits.

Chromium recorded the highest concentration in the roots of *A. hybridus* that was grown in Treatment B (GS+RDC+RS) and the least in the seeds (Roots > Stems > Leaves > Seeds). Chromium was not detected in the leaves, stems and roots of *A. hybridus* grown in Treatment C (GS+PM+RS) but was absent in the seeds. Chromium was not detected in any part of *A. hybridus* that was grown in Treatment A (GS+RS). The concentrations of chromium detected in all the plant parts were within FAO/WHO recommended limits probably because chromium occurs only in trace amounts and in forms not readily taken up by plants (Woodbury, 1993).

Mercury is a ubiquitous environmental toxin that produces a wide range of adverse health effects in humans. Mercury can enter and accumulate in the food chain in form of methyl mercury. The highest concentration of mercury was detected in the root of *A. hybridus* grown in Treatment B (GS+RDC+PM). Mercury was not detected in any plant part of *A. hybridus* that was grown in Treatment A (GS+RS) and in the leaves, stems and seeds of that grown in Treatment C (GS+PM+RS). Mercury was also not detected in the seeds of *A. hybridus* that was grown in all the treatments. The concentrations of mercury that was detected in all the plant parts were below FAO/WHO recommended limits probably because of the low concentration of mercury in the soil and thus there was little likelihood of significant uptake by plants (Woodbury, 1993).

CONCLUSION

The application of poultry manure significantly resulted in better performance of growth and yield parameters such as plant height, number of leaves, leaf area, fresh and dry weight of leaves, stems, roots and seeds of *Amaranthus hybridus*, thus, justifying its frequent land application by farmers. The application of refuse dump compost also produced appreciable results than the control, therefore, the use of refuse dump compost is an important recycling opportunity. The ability of *A. hybridus* to absorb and translocate these heavy metals to the various plant parts shows that *A. hybridus* is a heavy metal accumulator. Therefore, if grown on heavy metals-contaminated soil, and if plant and soil factors are favorable for the transfer of heavy metals from soil to plant, contamination can occur. The mean concentrations of cadmium and lead (in the leaves and stems) of *Amaranthus hybridus* grown in refuse dump compost-treated soils were higher than the FAO/WHO recommended limits for the heavy metals in vegetables. *A. hybridus* therefore tend to absorb and accumulate high levels of cadmium and lead in the stems and leaves, the most consumed parts of the plant. In view of their important role in the food chain, it is therefore recommended that *A. hybridus* should not be cultivated in farms and fields contaminated with such refuse dump compost because the consumption of Cd and Pb through vegetables poses substantial health risk to consumers. Even though the mean concentrations of chromium, copper, mercury and zinc were within the FAO/WHO recommended limits, the increase in vegetable consumption by man could worsen the situation in the future. This thus emphasizes the need for proper methods to manage and reduce the health risk and the extent of heavy metals contamination, which could be done by sorting of refuse as well as regular monitoring of heavy metals in vegetables grown in refuse dumpsites to prevent their excessive build-up in the food chain. Finally, the ability of *Amaranthus hybridus* to accumulate heavy metals can be used as an advantage in the phytoremediation of heavy metals in contaminated sites.

Table 1: *Physico-chemical properties and heavy metals content of refuse dump compost and poultry manure used in media preparation.*

Physico-chemical Properties	**Poultry manure**	**Refuse dump compost**
N (%)	7.15	2.32
P (%)	2.1	1.7
K ($cmolkg^{-1}$)	1.5	0.38
Na ($cmolkg^{-1}$)	0.60	0.08
pH	6.30	7.80
Mg ($cmolkg^{-1}$)	3.28	0.18
Ca ($cmolkg^{-1}$)	4.16	0.45
C (%)	23.80	17.52
Fe (mg/kg)	14.9	20.6
Moisture content (%)	49.11	26.2
Cd (mg/kg)	0.27	1.77
Cr (mg/kg)	10.1	25.5
Cu (mg/kg)	23.90	52.60
Hg (mg/kg)	0.11	0.78
Pb (mg/kg)	3.20	34.20
Zn (mg/kg)	22.01	28.5

Table 2: *The effects of refuse dump compost and poultry manure on the plant height (cm) of A. hybridus*

Treatments	Weeks After Treatment (WAT) Mean Plant Height ± SE						
	2	4	6	8	10	12	14
A	13.78±0.26^{b}	21.30±0.54^{b}	34.10±1.18^{b}	45.90±2.88^{c}	49.40±1.47^{c}	54.20±0.58^{c}	59.60±1.03^{c}
B	14.52±0.63^{b}	24.30±0.54^{b}	35.70±0.51^{b}	55.20±2.15^{b}	61.80±2.09^{b}	65.40±1.86^{b}	71.60±2.32^{b}
C	18.10±0.81^{a}	35.70±1.68^{a}	51.00±0.89^{a}	64.20±1.52^{a}	70.10±1.45^{a}	80.70±5.81^{a}	88.00±5.13^{a}

Values with the same letter in each column are not significantly different from each other by DNMRT ($P \leq 0.05$)

A = GS+RS; B= GS+RDC+RS and C= GS+PM+RS. Where: GS= garden soil; RDC= refuse dump compost; PM= poultry manure; RS= river sand.

Table 3: *The effects of refuse dump compost and poultry manure on the number of leaves of A. hybridus*

Treatments	Weeks After Treatment (WAT) Mean leaf Number ± SE						
	2	**4**	**6**	**8**	**10**	**12**	**14**
A	10.20±0.58^{b}	12.40±1.03^{b}	20.60±0.60^{b}	33.20±0.80^{ns}	33.80±1.24^{ns}	38.60±2.77^{ns}	51.20±4.95^{ns}
B	12.40±0.40^{a}	16.80±0.37^{a}	25.00±0.89^{a}	35.60±2.16^{ns}	36.20±1.56^{ns}	45.40±3.75^{ns}	54.40±2.73^{ns}
C	11.00±0.55^{a,b}	16.20±0.86^{a}	24.00±0.55^{a}	40.20±2.73^{ns}	38.00±1.05^{ns}	46.60±3.46^{ns}	55.80±2.62^{ns}

Values sharing the same letter in each column are not significantly different from each other by DNMRT ($P \leq 0.05$)

^{ns} *Not significantly different at $P \leq 0.05$*

A= GS+RS; B= GS+RDC+RS; C= GS+PM+RS Where: GS= garden soil; RDC= refuse dump compost; PM= poultry manure; RS= river sand; WAT= Weeks after transplanting

Table 4: *The effects of refuse dump compost and poultry manure on the leaf area (cm^2) of A. hybridus*

Treatments	Weeks After Treatment (WAT) Mean Leaf area ± SE						
	2	**4**	**6**	**8**	**10**	**12**	**14**
A	8.83±0.85^{b}	21.06±2.73^{b}	42.83±3.02^{ns}	59.83±2.62^{b}	68.73±3.50^{c}	102.26±5.12^{c}	116.03±5.82^{b}
B	9.07±0.59^{b}	33.74±2.80^{a}	44.62±6.00^{ns}	64.54±3.96^{b}	84.98±3.13^{b}	119.48±3.32^{b}	134.44±4.28^{a}
C	14.30±1.46^{a}	38.91±3.23^{a}	45.07±4.75^{ns}	78.33±5.07^{a}	107.75±5.83^{a}	137.99±1.74^{a}	140.89±6.92^{a}

Values sharing the same letter in each column are not significantly different from each other by DNMRT ($P \leq 0.05$)

^{ns} *Not significantly different at $P \leq 0.05$*

A= GS+RS; B= GS+RDC+RS; C= GS+PM+RS Where: GS= garden soil; RDC= refuse dump compost; PM= poultry manure; RS= river sand; WAT= Weeks after transplanting

Table 5: *The effects of refuse dump compost and poultry manure on the fresh weight (g) of leaves, stems, and roots of A. hybridus*

	Weeks After Treatment (WAT) Mean Weight ± SE						
	2	**4**	**6**	**8**	**10**	**12**	**14**
Leaves							
A	1.44±0.17^{b}	4.87±0.44^{c}	7.16±0.61^{b}	10.97±0.53^{c}	24.68±1.66^{b}	27.97±2.48^{ns}	37.09±1.97^{b}
B	2.11±0.28^{b}	6.69±0.57^{b}	8.91±0.25^{b}	14.42±0.53^{b}	28.04±3.34^{a,b}	33.20±2.40^{ns}	47.41±5.74^{a,b}
C	4.02±0.33^{a}	9.17±0.48^{a}	19.99±1.62^{a}	24.49±0.79^{a}	35.68±2.62^{a}	36.50±3.16^{ns}	52.47±1.42^{a}
Stems							
A	0.87±0.08^{b}	3.03±0.17^{c}	5.46±0.72^{c}	7.53±0.65^{c}	14.10±0.91^{b}	26.32±3.63^{b}	33.46±4.64^{ns}
B	1.27±0.20^{b}	4.64±0.44^{b}	8.30±0.53^{b}	11.91±0.57^{b}	19.85±0.83^{b}	36.42±2.60^{a}	37.45±5.61^{ns}
C	2.17±0.19^{a}	11.35±0.38^{a}	16.00±1.28^{a}	18.92±0.45^{a}	29.10±3.24^{a}	40.23±2.85^{a}	41.57±2.10^{ns}
Roots							
A	0.34±0.06^{b}	0.66±0.17^{b}	1.09±0.15^{c}	3.93±0.32^{c}	5.10±0.59^{ns}	6.22±1.09^{ns}	8.48±0.63^{ns}
B	0.37±0.06^{b}	1.06±0.06^{b}	1.95±0.48^{b}	5.06±0.24^{b}	5.60±0.51^{ns}	7.12±0.21^{ns}	9.92±0.32^{ns}
C	0.88±0.04^{a}	2.57±0.27^{a}	3.07±0.30^{a}	6.17±0.30^{a}	6.66±0.21^{ns}	7.44±0.16^{ns}	10.19±0.41^{ns}

Values sharing the same letter in each column are not significantly different from each other by DNMRT ($P \leq 0.05$)

ns Not significantly different at $P \leq 0.05$

A= GS+RS; B= GS+RDC+RS; C= GS+PM+RS Where: GS= garden soil; RDC= refuse dump compost; PM= poultry manure; RS= river sand;

Table 6: *The effects of refuse dump compost and poultry manure on the dry weight (g) of leaves, stems and roots of A. hybridus*

	Weeks After Treatment (WAT) Mean ± SE						
	2	**4**	**6**	**8**	**10**	**12**	**14**
Leaves							
A	0.13±0.05^{ns}	0.27±0.11^{ns}	1.56±0.65^{ns}	2.06±0.85^{ns}	2.98±1.23^{ns}	3.36±1.39^{ns}	4.21±1.70^{ns}
B	0.16±0.07^{ns}	0.55±0.25^{ns}	1.89±0.78^{ns}	2.56±1.06^{ns}	3.36±1.39^{ns}	3.60±1.49^{ns}	4.74±1.96^{ns}
C	0.32±0.13^{ns}	0.93±0.39^{ns}	2.16±0.89^{ns}	2.96±1.23^{ns}	3.96±1.69^{ns}	3.98±1.64^{ns}	5.36±2.21^{ns}
Stems							
A	0.05±0.02^{ns}	0.09±0.04^{ns}	0.54±0.19^{ns}	1.16±0.48^{ns}	1.96±0.81^{ns}	2.56±1.06^{ns}	3.16±1.30^{ns}
B	0.07±0.03^{ns}	0.11±0.05^{ns}	0.55±0.23^{ns}	1.80±0.74^{ns}	2.16±0.89^{ns}	2.98±1.23^{ns}	3.76±1.55^{ns}
C	0.09±0.04^{ns}	0.33±0.14^{ns}	0.76±0.32^{ns}	1.96±0.63^{ns}	2.56±1.06^{ns}	3.36±1.38^{ns}	3.96±1.63^{ns}
Roots							
A	0.02±0.01^{ns}	0.04±0.02^{ns}	0.36±0.15^{ns}	0.58±0.24^{ns}	0.78±0.32^{ns}	0.80±0.30^{ns}	0.76±0.32^{ns}
B	0.02±0.01^{ns}	0.05±0.02^{ns}	0.38±0.16^{ns}	0.62±0.26^{ns}	0.82±0.34^{ns}	0.96±0.40^{ns}	1.42±0.59^{ns}
C	0.04±0.02^{ns}	0.10±0.04^{ns}	0.56±0.24^{ns}	0.90±0.37^{ns}	1.08±0.45^{ns}	1.18±0.49^{ns}	1.78±0.74^{ns}

Values sharing the same letter in each column are not significantly different from each other by DNMRT ($P \leq 0.05$)

A= GS+RS; B= GS+RDC+RS; C= GS+PM+RS Where: GS= garden soil; RDC= refuse dump compost; PM= poultry manure; RS= river sand.

Table 7: *The effects of refuse dump compost and poultry manure on the fresh and dry weight (g) of seeds of A. hybridus*

TREATMENTS	FRESH WEIGHT	DRY WEIGHT
A	0.15±0.06^{ns}	0.12±0.05^{ns}
B	0.17±0.07^{ns}	0.12±0.05^{ns}
C	0.24±0.10^{ns}	0.19±0.08^{ns}

Values sharing the same letter in each column are not significantly different from each other by DNMRT ($P < 0.05$)

ns Not significantly different at $P < 0.05$

A= GS+RS; B= GS+RDC+RS; C= GS+PM+RS Where: GS= garden soil; RDC= refuse dump compost; PM= poultry manure; RS= river sand

Table 8: *Concentrations of heavy metals (mg/kg) in A. hybridus grown on refuse dump compost and poultry manure*

	Weight Mean ± SE					
	Cd	**Cr**	**Cu**	**Hg**	**Pb**	**Zn**
Leaves						
A	0.000±0.000^{b}	0.000±0.000^{b}	0.033±0.007^{b}	0.000±0.000^{b}	0.000±0.000^{b}	0.030±0.010^{b}
B	0.263±0.019^{a}	0.640±0.137^{a}	12.233±1.743^{a}	0.033±0.009^{a}	2.833±0.708^{a}	3.400±0.875^{a}
C	0.000±0.000^{b}	0.007±0.003^{b}	0.753±0.227^{b}	0.000±0.000^{b}	0.000±0.000^{b}	0.967±0.280^{b}
Stems						
A	0.000±0.000^{b}	0.000±0.000^{b}	0.023±0.009^{b}	0.000±0.000^{b}	0.000±0.000^{b}	0.017±.0003^{b}
B	0.300±0.010^{a}	0.647±0.188^{a}	2.707±0.782^{a}	0.030±0.012^{a}	0.380±0.111^{a}	5.300±1.530^{a}
C	0.000±0.000^{b}	0.003±0.003^{b}	0.367±0.113^{b}	0.000±0.000^{b}	0.000±0.000^{b}	1.000±0.318^{b}
Roots						
A	0.003±0.003^{b}	0.000±0.000^{b}	0.040±0.006^{b}	0.000±0.000^{b}	0.000±0.000^{b}	0.030±0.012
B	0.033±0.009^{a}	0.743±0.217^{a}	4.333±1.250^{a}	0.100±0.029^{a}	0.033±0.009^{a}	7.783±2.249^{a}
C	0.007±0.003^{b}	0.003±0.003^{b}	0.833±0.240^{b}	0.003±0.003^{b}	0.003±0.003^{b}	0.967±0.280^{b}
Seeds						
A	0.000±0.000^{b}	0.000±0.000^{a}	0.003±0.003^{b}	0.000±0.000^{a}	0.000±0.000^{b}	0.001±0.003^{b}
B	0.017±0.003^{a}	0.007±0.003^{a}	1.007±0.292^{a}	0.000±0.000^{a}	0.013±0.003^{a}	1.227±0.355^{a}
C	0.000±0.000^{b}	0.000±0.000^{a}	0.363±0.107^{b}	0.000±0.000^{a}	0.000±0.000^{b}	0.020±0.006^{b}

FAO/WHO limits	0.20	2.3	73.30	1.00	0.30	99.40

Values sharing the same letter in each column are not significantly different from each other by DNMRT ($P \leq 0.05$)

A= GS+RS; B= GS+RDC+RS; C= GS+PM+RS Where: GS= garden soil; RDC= refuse dump compost; PM= poultry manure; RS= river sand; WAT= Weeks after transplanting

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