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Application of dry cell battery dust to cultivated fluted pumpkin (*Telfairia occidentalis*) as a pest management strategy: implications for both the plant and the consumer's health

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SUMMARY. The study investigated the possible impact of dry cell car battery dust (DCD) on production of fluted pumpkin (*Telfairia occidentalis*). The study aims to investigate the possible implication of the application of DCD to fluted pumpkin as pest practice by some farmers in the study area. Therefore, the experiment included three different treatments: the first examined the effect of DCD on the plants after they were sown in DCD-polluted soils (DSBS); while the second was the investigation of plants on which DCD was applied after 2 weeks after sowing (DPAS). The third group was the control, wherein DCD was applied to neither plant nor soil. Results showed that plant yield, expressed in the study as the number of leaves per plant and leaf size, was better with those plant on which DCD was applied after plant establishment (32 – 48 leaves, leaf area 98.5 – 126.5 cm^2) compared with the control (13 leaves, leaf area 43.1 cm^2). Leaves in the control as well as the DSBS plants were characterized with brown spots, chlorosis, necrotic spots as well as evidence of insect pest attack. No visible sign of insect or pest attack was noticeable in the DPAS plant leaves. Although there was no significant change in proximate content of the leaves of both DCD-treated plant and the control, the leaves of DCD-impacted plants however accumulated significantly higher amounts of Pb (40.25 – 77.17 mg/kg) and Zn (13.35 – 45.87 mg/kg) than the control.

Keywords: dry cell car battery, heavy metal, hyperaccumulation, phyto-accumulation, *Telfairia occidentalis*

Introduction

Due to rapid urbanization the demand for food crops is rising day by day, and as the vegetables can be grown in small fields with intensive use of inputs within shorter period, its cultivation is gaining popularity and fetching profitability

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in urban, peri-urban and rural areas. This is a matter of serious concern as vegetables particularly leafy once, being accumulators of heavy metals provide an easy entry into the food chain. The excessive intake of these elements from the soil creates dual problems; first the harvested crops get contaminated, which serve as a source of heavy metal in our diet, and secondly the crop yield decline due to the inhibition of metabolic processes (Sanders and Adams, 1987; Singh and Agrawal, 2003).

Solid waste management constitutes a big challenge to the developing countries, especially Nigeria, Edo State inclusive because waste sorting and separation is not practiced. Thus a material that has lost its value is sent to the waste dump sites and disposed improperly. Some farmers have resorted to cultivating their vegetables on contaminated lands due to its high organic content in order to increase their yields and gains, and as a result, human health is being endangered due to heavy metal uptake by vegetables grown in soils contaminated with heavy metals (Carlson and Bazzaz, 1977; Alloway, 1996).

At a 2-Day National Training Workshop on Fruits production, concentrates processing and marketing, organized by Raw Materials Research and Dev. Council, Abuja in conjunction with the Edo State Ministry of Commerce and Industry held at Bishop Kelly Pastoral Center, Airport Rd., Benin City on November 22-23, 2012, the participants had the opportunity to discuss issues relating to possible accumulation of metals in fruits and harvestable plant parts and thus care was needed in collection fruits for processing. Particular attention was drawn to a publication by Ikhajiagbe *et al.* (2013), who reported heavy metal contents and microbial flora of fresh leaves of fluted pumpkin (*Telfairia occidentalis*) collected from road-side open markets in Benin metropolis, midwestern Nigeria. The argument was whether leafy vegetables on sales by the roadsides had the capacity for metal accumulation from nearby vehicular fumes or whether there were other sources of metal accumulation. A member of the All Farmers Association of Nigeria (AFAM) at the workshop insisted that the accumulation may be from the cropping system adopted by most farmers in growing fluted pumpkin. Accordingly, they use dry cell battery dusts on the plant stands to ward off insects and other pests. This was corroborated by most of the farmers at that workshop; insisting that the practice maid for larger and greener vegetables. Vegetable crop plants have high ability to accumulate metals from the environment and have however, been found to absorb heavy metals from the soil as well as from surface deposits on part of vegetables exposed to polluted air, which may pose risks to human health when they are on or near contaminated lands and consumed (Yusuf *et al.*, 2003). Up till the time of writing up the design for this study, the practice is still commonly practiced by a number of small scale commercial and subsistence farmers in Benin City. The present study thus becomes imperative.

The choice of *T. occidentalis* for the study is because it plays an important role in human and livestock nutrition and is an extremely important vegetable predominantly grown by small scale farmers in any available space especially in abandoned dump sites where suspected heavy metal laden materials are found in large quantity. *T. occidentalis* is a good accumulator of heavy metals (Erhenhi and Ikhajiagbe, 2012; Ikhajiagbe *et al.*, 2013).

Toxic metals may be absorbed by this vegetable through several processes and finally enter the food chain at high concentrations capable of causing serious health risks to consumers. Their toxicity can damage or reduce mental and central nervous function, lower energy levels, and damage blood composition, lungs, kidneys, liver, and other vital organs.

This study was undertaken to evaluate heavy metal concentration of the soil polluted with dry cell battery dust and *T. occidentalis* grown on such soil as well as draw conclusions from the results obtained on the suitability or otherwise of the plant cultivated for its phytoremediation ability and for human consumption as well. Also, the question the research intended to answer was whether it was possible for any vegetable plant sown in heavy metal polluted soil within 3 months of pollution could survive and give the necessary nutritional benefits required by the body.

Materials and methods

Collection and preparation of materials for the experiment

Viable seeds of pumpkin (*Telfairia occidentalis*) were obtained from New Benin Market, Benin City, Edo State. Dry cell battery dust was obtained from dry cell car batteries collected from a mechanic shop (deals in petrol-engine cars) at Spare Parts Market, Evbarekare, off Textile Mill Road, Benin City, Edo State.

Dry cell battery dust (DCD) was obtained by crushing the dry cells from car batteries irrespective of voltage or electricity or electricity capacity. The cells were carefully crushed and then grounded into near-powdery form and then stored in a closed container before use. The dust was analyzed for composition of heavy metals (see Table 1).

Top soil (0 – 10 cm) of physiochemical property predetermined (Table 1) was collected from a cleared field, beside the Botanic Garden. Thereafter, 20 kg of the sun-dried soil was collected using shovel and hand trowel, weighed and placed into buckets. The buckets were grouped into three experiments code-named as CTR, DSBS, and DPAS respectively. CTR was the control (consisting of 4 buckets). DSBS-group comprised of those buckets containing soil that was polluted with dry cell battery dust before sowing *T. occidentalis* seeds (consists of 16 buckets). The Pap-treatment comprised of those that received dry cell battery dust in already planted (2-weeks old) *T. occidentalis* stands (consists of 16 buckets).

DCD was applied to either soil (DSBS) or plant (DPAS) in 4 concentrations; 1, 5, 10, and 25% w/w, amounting 0.2, 1, 2, and 5kg of DCD added to 20kg soil or plant stands as the case may be (Fig. 1). The entire set up was exposed in the Botanic Garden (Department of Plant Biology and Biotechnology, University of Benin,

Benin City) for 3 months under prevailing weather. Afterwards, plant leaves were randomly collected and taken to the laboratory for analyses. Plants were observed for physical morphological presentations as well as nutrient contents of the leaves. The chlorophyll content index of leaves of the test plant were estimated at 10 weeks after sowing using a chlorophyll content meter; CCM-200 plus®. CCM-200 is a non-destructive chlorophyll content measuring meter that uses absorbance to estimate the chlorophyll content in leaf tissues. The detector analyzes the absorbance ratio of both wavelengths and calculates a CCI value that is proportional to the amount of chlorophyll in the sample (Apogee Instruments Inc.). Proximate analysis of the leaves was carried out according to the methods of AOAC (2005). Accumulated heavy metal (HM) contents in plant leaves were determined by atomic absorption spectrophotometry (model, Buck Scientific 210 VGP), according to the methods of SSSA (1971) and AOAC (2005). For HM determination, plants were divided into 3 partitions; the old partition comprising of entire leaves within the plant axil measuring 45 cm from the soil level; the upper (new) partition comprised of all leaves within plant axil measuring 45 cm from apical meristem, whereas the middle partition was the portion in-between the old and new partitions (Fig. 2).

Figure 1. (a) The researcher applying DCD to plant stands (b) Plant stands at 3 weeks (c) Plant stands at 4 weeks (d) plant stands at 8 weeks

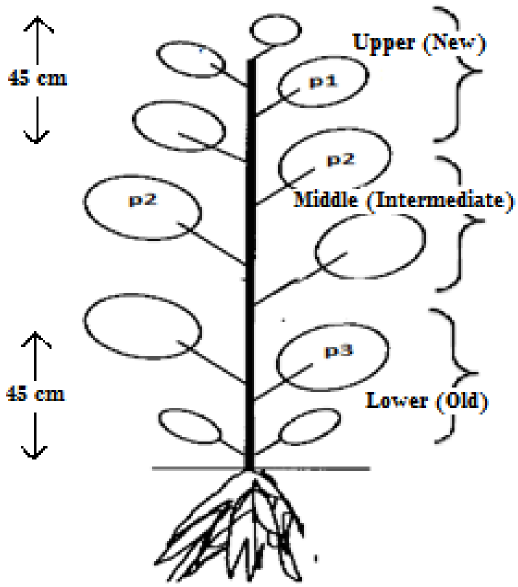

Figure 2. Leaf partitioning used in the study

Results and discussion

Physicochemical quality of soil and DCD used in the study has been presented (Table 1). This study relied on information provided by local farmers on the use of dry battery cell dust (DCD) as an alternative to insect and pest control during cultivation of fluted pumpkin. This is even more predicated on the fact that the poor economic situation in the country (Nigeria) has resulted in increase in prices of agricultural inputs including fertilizers and pesticides. The results of the study thus confirms the fear that over-reliance on this abnormal practice would only lead to catastrophe, beginning first with biomagnification of metals in the DCD-impacted plants by consumers and subsequent accumulation in the food chain.

On the 13th week, some morphological parameters of the plant were measured (Table 2, Figure 3). Stem length in the 0.2 kg DSBS plant was the highest in that category (435.42 cm), compared to 330.32 cm in 5 kg DSBS. Plant height in the plants broadcasted with DCD (DPAS-group) ranged from 474.22 cm in those plant stands that received 1kg of DCD directly (1 kg DPAS) to 300.34 cm in those plant stands dusted with 5kg of DCD (or 5 kg DPAS) respectively. The control plant was 215.65 cm. There were more leaves per plant in the plants sown in DCD-polluted soil (DSBS), ranging from 36 – 68 leaves, as well as those on which DCD was applied (DPAS-plants, 32 – 48 leaves), compared to control plants (13 leaves).

Table 1.

Physical and chemical properties of soil and dry cell battery dust used in the study

Parameters	Original soil used	Dry cell dust
pH	5.58	4.21
Electric conductivity (µs/cm)	300	ND
Total Org. carbon (%)	0.41	ND
Total Nitrogen (%)	0.10	ND
Exchangeable acidity (meq/100g)	0.20	ND
Na (meq/100g)	10.90	ND
K (meq/100g)	1.65	ND
Ca (meq/100g)	15.60	ND
Mg (meq/100g)	11.30	ND
Cl (mg/kg)	1666.00	ND
P (mg/kg)	153.00	ND
NH_4N (mg/kg)	25.40	ND
NO_2 (mg/kg)	15.01	ND
NO_3 (mg/kg)	30.75	ND
SO_4 (mg/kg)	14.63	ND
Clay (%)	4.43	NA
Silt (%)	7.82	NA
Sand (%)	87.82	NA
Fe (mg/kg)	1009.21	ND
Zn (mg/kg)	38.03	161.75
Cd (mg/kg)	0.01	7.75
Pb (mg/kg)	3.84	231.50
Ni (mg/kg)	BDL	8.85

BDL Below detection (<0.001 mg/kg); ND Not determined; NA Not applicable

Table 2.

Some measurable morphological parameters of *T. occidentalis* at 13 weeks after sowing

Parameters/ Treatments	Stem length (cm)	Stem girth (cm)	No. of leaves (Plant Yield)	Leaflet area (cm^2) (Plant Yield)	Tendril length (cm)	No. of tendrils/ plant	No. of primary stem branches	Plant fresh weight (g)	Root Length (cm)	No. of Sec. Root	Fresh root weight (g)
Control	215.65	2.3	13.2	43.1	21.3	87.7	3.72	98.63	10.3	14.6	32.6
5 kg DSBS	330.32	4.0	45.5	96.0	32.6	76.3	6.54	220.32	35.5	11.3	91.2
2 kg DSBS	340.34	3.5	36.3	86.7	28.1	84.4	5.56	254.34	25.2	12.7	53.2
1 kg DSBS	313.23	3.5	43.6	80.4	36.3	81.2	8.54	265.44	48.6	11.1	62.3
0.2 kg DSBS	435.42	4.3	58.4	93.6	45.7	119.7	5.87	258.34	50.4	10.2	80.5
5 kg DPAS	300.34	2.7	31.5	98.5	15.6	51.4	4.85	268.14	65.6	10.5	43.1
2 kg DPAS	460.35	3.2	38.3	108.1	30.7	74.8	4.76	258.43	55.2	14.7	50.6
1 kg DPAS	476.22	4.1	48.4	121.2	35.2	80.2	8.53	280.43	60.7	15.4	106.4
0.2 kg DPAS	343.75	3.5	36.3	126.5	38.4	43.5	6.75	251.34	90.3	10.8	93.6
LSD (0.05)	64.86	1.4	9.36	12.73	14.42	22.75	2.73	32.15	8.74	4.35	19.64

DSBS dry cell dust applied to soil before sowing pumpkin on polluted soils; **DPAS** dry cell dust applied to plant stands sowing in clean soils. **Stem girth** was obtained at 5cm above ground.

However, with regards to leaf size, the DPAS-plants were broader (88.5 – 142.5 cm^2) than the DSBS-plants (80.4 – 96.00 cm^2). Leaf area of control plants was 43.1 cm^2. Obviously, sprinkling DCD unto plant leaves reduced factors than retarded foliar development. Root length was lowest in the control plant (10.3 cm) compared to the DCD-exposed plants (Table 3). In the DCD-exposed plants, those that were exposed after planting (DSBS-plants) had longer roots (55.2 – 90.3 cm) compared to the DSBS-plants (25.2 – 50.4 cm). Similarly, fresh root weight was highest in 1 kg DPAS (106.4 cm) compared to the control (32.6 cm).

Accordingly, *T. occidentalis* were partitioned into new, intermediate and old leaves (Table 3). The old partition was taken as plant portion covering 45 cm from soil level; the new partition covered plant parts 45 cm from the plant apex, whereas the intermediate partition was taken as the middle leftover portion between the old and new partitions. More leaves of the old partition senesced, particularly those of the DSBS-pant category. However, more intermediate leaves were senesced in the DPAS-category (5 – 12 leaves) than in the DSBS-category (2 – 5 leaves). Similarly, more leaves senesced in the newer partition when DCD was applied unto plants (DPAS). The results also show increased CCI in leaves of DCD-impacted plants. There were no significant changes in CCI content from one partition to the other.

Table 3.

Leaf senescence and chlorophyll content index observed within partitions of *T. occidentalis*

Parameters/ Treatments	**No. of senesced per plant (from 5 – 13 WAS)**			**Chlorophyll content index (CCI) (only at 10 WAS)**		
	New partition	**Intermediate partition**	**Old partition**	**New partition**	**Intermediate partition**	**Old partition**
Control	00*	00	28	24.32	29.53	20.43
5 kg DSBS	01	05	45	36.44	38.42	34.21
2 kg DSBS	02	02	41	32.22	33.56	32.54
1 kg DSBS	02	03	35	38.42	34.29	30.29
0.2 kg DSBS	00	04	32	31.32	32.28	31.27
5 kg DPAS	09	12	25	44.34	41.69	34.35
2 kg DPAS	07	09	09	43.12	42.33	43.24
1 kg DPAS	03	10	12	38.42	39.74	40.76
0.2 kg DPAS	01	05	25	43.86	44.24	42.32
LSD (0.05)	02	03	11	5.52	5.26	6.34

*mean of 3 replicates rounded off to the nearest whole number. **WAS** weeks after sowing. **DSBS** dry cell dust applied to soil before sowing pumpkin on polluted soils; **DPAS** dry cell dust applied to plant stands sowing in clean soils; The old partition was taken as plant portion covering 45 cm from soil level, the **new** partition covered plant parts 45 cm from the plant apex, whereas the **intermediate** partition was taken as the middle leftover portion between the old and new partitions.

Physical observations of *T. occidentalis* performance in the designated plant partitions have been presented on Table 4. It was generally observed that there were no visible signs or presence of insects perching or feeding on the plant leaves on which DCD was applied after sowing (DPAS-group). Emphatically, results earlier showed that those plants treated with DCD after sowing showed better physical growth parameters – improved leaf size, reduced foliar spoilage due to insect attack. However, when applied to soil before sowing, morphological presentations of the plants declined significantly. HM toxicity diminishes plant growth and vigour, leading to death in extreme cases when significant interference of HM exists with photosynthesis, respiration, and plant-water relation (Smith *et al.*, 1989; Burd *et al.*, 2000; Chaperon and Sauvé, 2008; Ikhajiagbe and Anoliefo, 2010). It is possible that the impact on growth and morphology in the DPAS-plants was less significant compared to the DSBS-plants because of the effects of washing by rain. Since the study was carried out in the open field, there were a couple of times when it rained after DCD application. DCD which ordinarily would act on the leaf from its surface may have been reduced in concentration due to washing, thereby decreasing its effects on morphology. Baker (1981); Carlson *et al*. (1991); Haanstra and Doelman (1991); Gonzalez (1996); Halim *et al.* (2003); Ortiza and Alcañiz (2006); Wyszkowska *et al.* (2006); Martin and Griswold (2009); Nanda and Abraham (2011); Shittu and Ikhajiagbe (2013) had previously reported that effects of HM on plant growth was concentration-dependent.

Decline in growth parameters as reported in the study may be due to the inhibition of metabolic processes at higher concentrations of dry cell battery dust as earlier suggested by Sanders and Adams (1987); Singh and Agrawal (2003). Elevated concentrations of both essential and non-essential heavy metals in the soil however, can lead to toxicity symptoms and growth inhibition in most plants (Hall, 2002; Li *et al.*, 2005a,b). One possible route for HM toxicity in the plant studied is the binding of HM to sulphydryl groups in proteins; this results in impaired protein activity or disruption of structure. In some other cases, there is the displacement of an indispensable element. This cascade of activity results in deficiency effects.

Leaf senesce is one of several mechanism adopted by plants during HM stress. In the study, more leaves of the old partition senesced, particularly those of the DSBS-pant category. These are those that are close to the soil, since the only route from which phytoaccumulation of HM from soil is the root. Hence, plant leaves closer to the leaves are most likely to be more impacted. However, in the DPAS-plants, the number of senesced intermediate leaves was more. Actually, since application was from top of plant down to the bottom, it is most likely that the intermediate leaves would receive more DCD from the ones washed by rain from the upper leaves, including the ones initially applied.

The productivity of the DCD-impacted plants may have been better than in the control, given the increases chlorophyll content index. Evidently, DCD may contain some growth-promoting substances to have enhanced chlorophyll concentration in the leaves. Improved chlorophyll content index in plants implies an enhanced photosynthetic capacity of the plant during high and low sunlight.

Table 4.

Physical observations of *T. occidentalis* partitions into new, intermediate and old

	New	Intermediate	Old
5 kg DSBS	Presence of chlorosis, senesced leaves, stems and tendrils, insect eating, few brown spots, leaves become dark green, growth increases and stem wilts.	Senesced leaves, stems and tendrils, few insect biting, presence of chlorosis stem wilts.	Insect biting, branches increases, senesced leaves, stems and tendrils, leaves become dark green and tendril length increases.
2 kg DSBS	Smaller leaves, tendril length increases, few insect biting and brown spots.	Brown spots	Presence of chlorosis, senesced leaves, stems and tendrils and dryness at all parts of the plant.
1 kg DSBS	Few insect biting, wider and dark green leaves.	Branches increases	Senesced leaves, stems and tendrils.
0.2 kg DSBS	Leaf folding, increased number of tendrils and few brown spots.	Brown and cream spotting, no branching, insect and animal biting and leaf buning,	Cream colour spotting, increased branches, senesced leaves, stems and tendrils, few insect biting, wider and dark green leaves.
Control	Insect biting, cream spots, presence of chlorosis and light green leaves.	Presence of chlorosis, wilting, cream and brown spots.	Senesced leaves, stems and tendrils, cream and brown spots.
5 kg DPAS	Smaller leaves, senesced leaves, stems and tendrils.	Few brown spots on leaves; leaves become smaller and dark green.	Senesced leaves, stems and tendrils, few brown spots on leaves.
2 kg DPAS	Insect biting, brown spots and wider leaves.	Presence of chlorosis, wider and darker leaves.	Senesced leaves, stems and tendrils, drying of leaves.
1 kg DPAS	Wider and darker leaves, few brown spots.	Presence of chlorosis.	Senesced leaves, stems and tendrils, drying of leaves.
0.2 kg DPAS	Few insect biting with mucor on leaves, wider and darker leaves.	Senesced leaves, presence of chlorosis and leaf folding.	Senesced leaves, stems and tendrils, smaller leaves, few cream spots.

DSBS dry cell dust applied to soil before sowing pumpkin on polluted soils; **DPAS** dry cell dust applied to plant stands sowing in clean soils; The **old** partition was taken as plant portion covering 45 cm from soil level, the **new** partition covered plant parts 45 cm from the plant apex, whereas the **intermediate** partition was taken as the middle leftover portion between the old and new partitions.

This perhaps explains the significant changes in growth and yield of DCD-impacted plants compared to the control. It is suggested that further research could be done to isolate and characterize possible growth-promoting substances in DCD. Berndt (1997) and Vincent and Scrosati (1997) had earlier reported that dry cell batteries contained a cathode rod made up of ammonium chloride. In order to get the DCD, the entire contents, excluding the plastic casing of the battery was grounded into powered. It is suggested that the ammonium content of the DCD may be one of the growth-promoting substances for which DCD-impacted plants performed better than the control. Middleton and Smith (1979); Rhodes (1987) reported that when conditions for plant growth become unfavourable, such as acidic soils, HM toxicity, or other restrictive factors for nitrification, ammonium is the major nitrogen source for the affected plant. Most of the nitrogen from ammonium is converted to nitrate by the activities of nitrifying bacteria in the soil, which is then transported to the plant shoot, where it is reduced to ammonia and assimilated into amino acids. Blanke *et al.* (1996) reported that ammonium nutrition in pants significantly enhanced chlorophyll production.

The study also investigated heavy metal contents of soil and test plant after harvest, including proximate contents (Tables 5-7). Prior to sowing pumpkin seeds in the DCD-contaminated soil, heavy metal (HM) content of soil after 60 days was determined (Table 5). Metal concentration generally increased with increased concentration of DCD in soil. Significant increases in metal concentrations compared to the control was recorded ($p<0.05$). Zn levels ranged from 61.14 – 102.52 mg/kg in the DCD-spiked soils compared to the control (34.99 mg/kg). However, Zn level in soil was below ecological screening value (ESV) for both microbial activity and phytotoxicity. After harvest, the levels of Pb in soil were beyond ecological screening value for plants survival in Pb-contaminated soil. This value was higher before the introduction of the test plant (see Table 5), and yet higher than ESV after removal of plant, thus suggesting tolerance of the test plant to Pb.

Table 5.

Heavy metal contents of soil after test plant was harvested

	Zn	**Cd**	**Pb**	**Ni**
		Soil HM conc. before sowing test plant, DSBS		
Control	34.99	0.03	2.99	BDL
25%	102.52	6.07	337.04	6.13
10%	87.88	4.97	247.65	5.84
5%	71.26	4.02	199.90	4.54
1%	61.14	3.00	65.82	4.26
		HM conc. after plant harvest at 13 weeks, DSBS		
Control	15.07	1.04	1.14	BDL
5 kg DSBS	9.59	0.71	64.27	0.14
2 kg DSBS	11.16	0.68	53.35	0.27
1 kg DSBS	21.01	0.93	79.46	1.39
0.2 kg DSBS	9.23	1.13	101.65	0.89
5 kg DPAS	12.13	1.14	56.34	2.04
2 kg DPAS	10.05	0.28	56.80	0.57
1 kg DPAS	8.79	0.86	90.97	0.37
0.2 kg DPAS	19.82	1.08	57.14	2.43
LSD (p, 0.05)	**5.32**	**1.07**	**34.42**	**0.87**
ESVm	100.00	20.00	900.00	90.00
ESVp	50.00	4.00	50.00	30.00

DSBS dry cell dust applied to soil before sowing pumpkin on polluted soils; **DPAS** dry cell dust applied to plant stands sowing in clean soils; **BDL** beyond detectable limit (0.001mg/kg).

Concentrations of Cd in leaves of the test plant after harvest was generally below detection limit for the DSBS-plants. However, in the DPAS-plants, evidence of Cd absence in new leaves of plants exposed to low concentrations of Cd was shown (Table 6). Similarly, Cd concentrations were higher in older leaves than in the new and intermediate leaves respectively; showing thus that accumulation of Cd in plant leaves depended on the age of the leaves. Zn accumulation in the leaves of the test plant was relatively minimal from each other; no significant differences existed among the 3 partitions with respect to Zn accumulation. This shows that at any given time, the plant balances the accumulation of Zn in its leaves, irrespective of age. In the DPAS-plants and with respect to Pb accumulation, there were higher concentrations of Pb in the upper leaves than in the intermediate and the lower. Suggestively, plant rate of metabolism is higher with new plants or plant parts than with the old. This may have some consequence on Pb accumulation. There was no significant difference in the divided accumulation of Ni in the partitioned plant leaves.

Results showed lower levels of Cd were obtained in those plants sown in DCD-polluted soils. However, irrespective of the mode of DCD application to soil or plant, harvested vegetable leaves contained very high levels of Pb. When in soil, most heavy metals become bound to organic and inorganic compounds in the soil, whereas a smaller proportion remains in the available form; thses available metal forms are either adsorbed against soil colloids, or they are dissolved in soil water (Punz and Sieghardt, 1993). Consequently, metal solubility and mobility becomes highly predisposed to their affinity for other ions or compounds within the soil matrix (Punz and Sieghardt, 1993). The availability of lead in higher proportions in the study may not be unconnected with any of these factors. Being a week Lewis acid, Pb forms durable bonds with the soil organic matter (Begonia *et al.*, 1998; Päivöke, 2002; Sharma and Dubey, 2005). It also forms complexes with sulfur (Xintaras, 1992), and freely precipitates as carbonates, phosphates and hydroxides (McBride, 1994).

Although Xiong (1997); Chantachon *et al.* (2004) have reported the rhizoextraction of Pb from soil, the movement of this metal within the plant is less well characterized. Therefore, Pb translocation to harvestable plant parts, like the leaves in this study, may be limited by binding at root surfaces or in the cell walls of roots as earlier reported by Pahlsson (1989). Pb accumulation in the cell apoplast has been reported by Tung and Temple (1996) in *Zea mays,* Wierzbicka (1998) in *Allium cepa* and *Pisum sativum* and by Piechalak *et al.* (2002) in *Vicia faba*. Sharma and Dubey (2005) also reported that Pb radially moves through the root apoplast across the cortex.

The higher values for Pb in plant tissues as reported in this study were higher than statutorily provided limits for edible vegetables (Agrawal *et al.*, 2007). This has great implications for human health. These accumulated metals are non-biodegradable. Consequently, then can accumulate in body tissues and organs like the bones, kidney and liver, for a very long time, where they can a series of metabolic damage. Although the rate of toxicity of these accumulated metals depend, to a very large extent, on the level of intake of the vegetable, the fear of possible significant biomagnification of the HM in humans still exists, particularly given the fact that this vegetable is one of the most commonly sought after leafy vegetable in this part of the world (Nigeria), where it is useful as a pot vegetable as well as for ethnomedicinal purposes. Consumption of HM-laden vegetable results in decreases in blood pH, cancers, kidney failure, to mention a few (Varathon, 1997; Martin and Griswold, 2009).

The effects of dry cell battery dust on the moisture, ash, lipid, crude fibre, protein and carbohydrate contents of the plant are shown in Table 7. The percentage crude protein component of the plant decreased with increasing HM (obtained from dry cell battery dust) concentrations of the soil. Conversely, there was concomitant increase in total carbohydrate with DCD increase in soil or plants. Concentrations of carbohydrates in plants exposed to 5 kg DPAS and 5 kg DSBS did not differ from the control (carb. = 9.30%, $p < 0.05$).

Figure 3. Plants harvested at week13 (a) 1% (b) 5% (c) 10% (d) 25% (pollution before sowing)

Table 6.

Heavy metal content of *T. occidentalis* leaves (in partitions) after harvest

		Zn	Cd	Pb	Ni
Control	New leaves	21.15	BDL	0.07	4.18
	Int. leaves	17.42	BDL	0.10	4.14
	Old leaves	14.79	BDL	0.27	4.17
0.2 kg DSBS	New leaves	41.63	BDL	40.25	3.36
	Int. leaves	42.69	BDL	40.16	3.54
	Old leaves	35.76	0.01	48.64	2.65
1 kg DSBS	New leaves	45.33	BDL	56.98	1.98
	Int. leaves	43.78	0.01	61.78	2.99
	Old leaves	39.05	0.07	53.90	3.64
2 kg DSBS	New leaves	20.59	BDL	66.09	5.12
	Int. leaves	19.65	0.11	63.56	4.27
	Old leaves	13.35	0.19	65.08	3.67
5 kg DSBS	New leaves	45.87	BDL	62.03	3.91
	Int. leaves	41.35	0.05	68.65	3.07
	Old leaves	38.88	0.28	71.65	4.95
0.2 kg DPAS	New leaves	37.65	BDL	56.20	3.48
	Int. leaves	41.25	0.09	55.70	1.71
	Old leaves	29.71	0.29	53.67	2.36
1 kg DPAS	New leaves	38.77	0.05	63.76	3.58
	Int. leaves	38.81	0.23	53.70	4.12
	Old leaves	35.98	0.67	43.42	4.03
2 kg DPAS	New leaves	42.75	0.02	67.24	4.11
	Int. leaves	41.25	0.25	51.85	3.36
	Old leaves	32.98	0.67	33.85	2.96
5 kg DPAS	New leaves	40.25	0.03	77.17	3.59
	Int. leaves	47.32	0.34	44.75	3.63
	Old leaves	37.83	0.81	43.97	3.17
LSD (p, 0.05)	-	9.87	0.06	14.64	1.09
Limit (WHO/FAO)*		60.00	0.20	0.30	NA
Indian Standards*	-	50.00	1.50	2.50	NA

*(Agrawal *et al.*, 2007). **DSBS** dry cell dust applied to soil before sowing pumpkin on polluted soils; **DPAS** dry cell dust applied to plant stands sowing in clean soils; **BDL** beyond detectable limit (0.001mg/kg). **NA** not available

Table 7.

Proximate contents of *Telfairia occidentalis* leaves according to designated plant partitions

Treatments	Moisture (%)	Ash (%)	Lipid (%)	Crude fibre (%)	Crude protein (%)	Total carbohydrate (%)
Control	77.96	6.30	1.84	1.70	2.90	9.30
0.2 kg DSBS	78.40	5.06	6.77	1.21	2.99	9.63
1 kg DSBS	82.70	4.02	4.76	1.40	3.40	6.74
2 kg DSBS	73.90	6.70	3.30	1.54	2.30	13.26
5 kg DSBS	78.67	11.80	4.30	1.72	2.70	10.08
0.2 kg DPAS	70.64	9.30	7.03	1.76	2.68	8.59
1 kg DPAS	80.10	8.30	4.10	1.62	3.00	6.88
2 kg DPAS	78.20	5.40	6.23	1.33	2.59	6.25
5 kg DPAS	68.49	6.00	5.20	1.60	3.51	10.20
LSD (p, 0.05)	18.96	1.45	1.62	1.01	1.68	3.84

DSBS dry cell dust applied to soil before sowing pumpkin on polluted soils; **DPAS** dry cell dust applied to plant stands sowing in clean soils; **BDL** beyond detectable limit (0.001mg/kg). **NA** not available

Although significant morphological changes like stunted growth, chlorosis and necrosis are one of the most important parameters used to indicate HM presence in plants (Ikhajiagbe, 2016); this is even more difficult in plants that have inherent mechanisms for detoxifying accumulated metals and thus don't show clear-cut morphological changes. In such plants, it is usually difficult to tell if they were faced with HM toxicity by mere morphology. The application of HM-containing DCD to *T. occidentalis* (DPAS-group) did not significantly impair morphological development, but rather preserved the foliage from insect and pest attack, thus making it difficult to select out such vegetables from the markets.

Conclusions

The study confirms that sprinkling DCD on already growing fluted pumpkin as practice by a number of local farmers in Benin City, Nigeria, may have improved the plant's physical appearance, which is actually a yardstick for improved sales in the market, as the leaves did not show any visible evidence of pest attack; the leaves were larger and greener. However, significant accumulation of HM in the leaves beyond safe limit was also reported. The practice should, as matter of urgency, be stopped since obviously metal hyper accumulation by plants does not always imply dried-out plants. Further study is necessary to investigate the presence of likely growth-enhancing substances in the dry cell battery dust, which perhaps may have been the reason for its continual use by a few in this part of the globe.

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