

Residual effect of composted poultry manure on yield and bioaccumulation of Iron, Zinc, Lead and Cadmium in tissues of Common Cockscomb (*Celosia argentea* L.) grown on soils from waste dumpsite and farmland

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ABSTRACT

Composted poultry manure used as soil amendment can contribute to soil heavy metal load and increased metal bioaccumulation in crops. This study investigated residual impact of composted poultry manure amendment on quality of celosia grown on two soil types. Common cockscomb (*Celosia argentea*) grown on 5 kg potted soils collected from abandoned waste dumpsite and farmland earlier amended with poultry manure compost rates of 0, 10, 20 and 30 t ha⁻¹ were studied for six weeks. The treatments were replicated three times in a Completely Randomized Design (CRD). Growth and yield parameters of celosia were measured at six weeks after sowing (WAS), edible shoot and root tissues were analyzed for Fe, Zn, Pb and Cd. Results showed significant ($p < 0.05$) increase in dry matter yield (DMY) with increased compost rates. Bioaccumulation of heavy metals was higher in tissues of celosia grown on waste dumpsite than farmland soil. Compost rate of 10 t ha⁻¹ increased bioaccumulation of Fe, Zn and Pb by 100.6, 6.0 and 3.1 %, respectively in edible shoot of celosia grown on dumpsite than farmland soil. In both tissues of celosia, bioaccumulation of heavy metals decreased with increased compost manure rate: 10 t ha⁻¹ > 20 t ha⁻¹ > 30 t ha⁻¹. Compost amendment from poultry source has potential for slow release of nutrients and trace metals that could improve yield and raise bioaccumulation of metals in tissues of vegetables.

Keywords: bioavailability, celosia, compost, plant tissue, soil amendment.

INTRODUCTION

Intensive cultivation of farmland due to pressure on agricultural land has led to growing of food crops on contaminated lands such as abandoned or old dumpsite soil in Nigeria. The small scale low income farmers that characterized developing

countries regarded abandoned dumpsite soils as nutrient enriched medium for crop production without any need for fertilizers or additional input. Meanwhile, studies have shown that crops grown on abandoned or old dumpsite soil could uptake and bioaccumulate toxic metals in their tissues

which can lead to food chain contamination (Magaji, 2012; Oguntade *et al.*, 2015). Besides, heavy metals found in contaminated soils are of economic importance in crop production due to their bioavailability for plant uptake and consequently biomagnification in food chain (USEPA 1996; Chehregani and Malayeri, 2007) thus, may have detrimental effect on consumers (Sharma, *et al.*, 2008).

Application of compost manure as soil amendment is a sustainable way of improving the physical, chemical and biological properties of soils, which gradually releases nutrients and enhances crop production (FAO, 2005; Ibeawuchi *et al.*, 2006; Mahmoud *et al.*, 2014). At the same time, the added organic manure could also adsorb heavy metals in the soil by immobilizing them and thereby reducing its uptake by plants (Putwattana *et al.*, 2010; Arunakumara *et al.*, 2013). Hence, playing the beneficial role of ameliorating soil contaminated with heavy metals (Clemente *et al.*, 2005; Oguntade *et al.*, 2015). On the other hand, lasting effect of organic manure amendment on soil could lead to accumulation of heavy metals in their stable forms at the organic horizon of the soil (Kabata-Pendias, 2001). Consequently, bioaccumulation of the metals in tissues of subsequent crops which could be influenced by sources of the compost manure and species of crop plant grown (Putwattana *et al.*, 2010)

Leafy vegetable crops grown on contaminated soils and environment have the tendency to bioaccumulate heavy metals in its tissues to toxic levels which may be transferred to man (Long *et al.*, 2002; Sharma *et al.*, 2009; Oguntade *et al.*, 2015). Common cockscomb is one of the popular leafy vegetable cultivated in Nigeria for its nutritional benefits of rich protein, minerals and fiber contents. It is often preferred by peasant farmers because of its fast growth

rate and regenerative ability after several harvests from single plant which brings more economic returns. It is a recognized fact that organic amendments have residual effects which could be both beneficial and detrimental on the soil and successive crops. In spite of the residual effects of organic amendment in crop production, there is still dire need of information on safety of *Celosia argentea* grown on waste dumpsite soil amended with composted poultry manure. Hence, this study assessed the yield and level of heavy metals in tissues of celosia grown on waste dumpsite and farmland soils earlier amended with composted poultry manure.

MATERIALS AND METHODS

The Pot Experiment

The study which consisted of 24 pots of 5 kg soil each arranged in Completely Randomized Design with three replicates was a residual one. The two soil types used for the experiment were collected from an old waste dumpsite (dumpsite soil) in Ayetoro and from the crop farmland (farmland soil) of Teaching and Research farm of College of Agricultural Sciences, Olabisi Onabanjo University, Ayetoro campus. The treatments earlier applied were: 0, 10, 20, 30 t ha⁻¹ of poultry manure composted for 8 weeks before application. Physicochemical properties of the dumpsite and farmland soils before manure amendment are presented in Table 1. The study which commenced two weeks after the first cycle of celosia grew for 6 weeks were harvested from the pots did not receive any further treatments. Prior to sowing of celosia seeds, the soil content of each pot was upturned into a bigger bucket, homogenized and returned to its individual pot. At two weeks after sowing (WAS), seedlings were thinned to one plant per pot. Weeding and watering were carried out regularly. At 6WAS, agronomic parameters of celosia

including plant height, number of leaves, stem thickness were measured. Thereafter, plants were harvested, separated to its edible (shoot) and non-edible (root) portions. Following water cleaning of the plant parts to remove air and soil particles from the edible and non-edible portions, respectively fresh weights of the plant parts were determined. Plant samples were later oven dried at 60°C to constant weight and the dry weight was measured.

Plant Analysis

The oven dried plant samples were ground with pestle on mortar for chemical analysis of plant tissues. Sub sample (0.5 g) of ground plant part was subjected to acid digestion with 10 ml of the mixture of nitric (HNO₃) and perchloric (HClO₄) acid in the ratio 2:1 in a digestion tube at 150 °C for the first 1½ hour. Afterwards, the temperature was raised to 230 °C for another ½ an hour following addition of 2 ml concentrated HCl to the digest (wet oxidation method) as described by Piper (1944) and modified by Udo *et al.* (2009). At the end of digestion period, the digest were allowed to cool down at room temperature, content of each digestion tube was transferred into 50 ml volumetric flask and made up to mark with distilled water. The concentrations of Iron (Fe), Zinc (Zn), Lead (Pb) and Cadmium (Cd) in the digested solutions were then determined on Atomic Absorption Spectrophotometer - AAS (Buck Scientific 210 VGP model, Inc., East Norwalk, CT, USA).

Data Analysis

Data obtained from agronomic and chemical analyses were subjected to Analysis of

Variance (ANOVA) using Genstat 12th Edition (Payne *et al.*, 2009). Treatment means were separated at 5% probability level using Fischer's Protected LSD.

RESULTS

The yield parameters measured showed that celosia grown on farmland soil had higher yield than those on dumpsite soil without any compost manure amendment (Table 2). Poultry manure compost rate of 10 t ha⁻¹ increased plant height from 35.1 cm to 43.2 cm in dumpsite soil and significantly (p<0.05) from 44.5 cm to 61.1 cm in the farmland soil. The percentage increase in number of leaves was 28.9 % and 24.6 % in the dumpsite and farmland soils, respectively. Stem thickness increased from 0.50 to 0.64 cm in dumpsite and from 0.65 to 0.66 cm in the farmland soil. The shoot fresh weight in dumpsite soil increased significantly by 42.0 % while in the farmland soil, it increased by 27.6 %. The 10 t ha⁻¹ compost rate increased root fresh weight significantly (p<0.05) by 107.7 % and 46.4 % in dumpsite and farmland soils, respectively.

Dry matter yield increased by 64.3 % and 72.7 % respectively, in soils of dumpsite and farmland. While the root dry weight increased by 85.0 % and 81.1 % in the dumpsite and farmland soils, respectively. Poultry manure compost rate of 20 t ha⁻¹ significantly (p<0.05) increased plant height, shoot fresh weight, shoot dry weight and root dry weight to 52.0 cm, 37.2 g, 3.2 g and 0.55 g, respectively in the dumpsite soil.

Table 1: Properties of the dumpsite and farmland soils used for the study

Properties	Dumpsite soil	Farmland soil
pH (H ₂ O)	7.60	6.60
Total organic C (%)	1.87	1.55
Total N (%)	0.16	0.12
Available P (mg kg ⁻¹)	52.48	7.43
Calcium (cmol kg ⁻¹)	51.75	13.08
Magnesium (cmol kg ⁻¹)	5.29	3.44
Potassium (cmol kg ⁻¹)	1.38	0.78
Sodium (cmol kg ⁻¹)	2.54	1.45
Exchangeable acidity (cmol kg ⁻¹)	0.05	0.07
ECEC (cmol kg ⁻¹)	61.01	18.82
Iron (mg kg ⁻¹)	2.15	5.05
Zinc (mg kg ⁻¹)	54.8	15.60
Cadmium (mg kg ⁻¹)	BDL	BDL
Lead (mg kg ⁻¹)	0.26	0.19
Sand (%)	77.50	85.40
Silt (%)	8.30	7.40
Clay (%)	14.20	7.20
Textural classes	Loamy sand	Loamy sand

BDL= Below Detection Limit of 0.002 mg kg⁻¹Source: Oguntade *et al.*, 2015

Table 2: Residual effect of composted poultry manure on growth and yield of *Celosia argentea* grown on dumpsite and farmland soils

Manure Rate (t ha ⁻¹)	Plant height (cm)		Number of leaves		Stem thickness (cm)		Shoot fresh weight (g)		Root fresh weight (g)		Shoot dry weight (g)		Root dry weight (g)	
	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil
0	35.1	44.5	17.33	19.00	0.50	0.65	20.5	33.7	1.3	2.8	1.4	2.2	0.20	0.37
10	43.2	61.1	22.33	23.67	0.64	0.66	29.1	43.0	2.7	4.1	2.3	3.8	0.37	0.67
20	52.0	59.6	22.33	23.00	0.68	0.71	37.2	43.0	3.4	4.5	3.2	3.5	0.55	0.66
30	46.8	62.8	21.67	24.33	0.72	0.79	33.9	46.1	3.2	5.0	2.9	4.1	0.52	0.80
LSD (0.05)	9.66		2.29		0.113		7.80		1.17		0.94		0.21	

At the rate of 30 t ha⁻¹ of the compost manure, plant height, number of leaves, shoot and root fresh weights as well as shoot and root dry weights decreased in dumpsite soil. Meanwhile, an increase in the growth and yield parameters were recorded in the farmland soil.

As shown in Table 3, composted poultry manure amendment rate of 10 t ha⁻¹ increased bioaccumulation of Fe, Zn and Pb significantly ($p < 0.05$) in shoot tissue of celosia in several folds in both soils except Cd when compared with no amendment. In the shoot tissue, concentration of Fe was 1446.0 and 721.0 mg kg⁻¹ in dumpsite and farmland soils, respectively. Zinc was 534.7 mg kg⁻¹ in dumpsite soil and 502.7 mg kg⁻¹ in farmland soil. Concentration of Pb in the edible shoot of celosia was 10.0 and 9.7 mg kg⁻¹ in dumpsite and farmland soils, respectively. Amendment with 10 t ha⁻¹ only increased bioaccumulation of Cd in shoot tissue of celosia grown on dumpsite soil by 5.9 %. Poultry manure compost rate of 20 t ha⁻¹ resulted in a declined bioaccumulation of the metals in shoot of celosia grown in both soils except Pb (20.3 mg kg⁻¹) in dumpsite soil. At poultry manure rate of 30 t ha⁻¹ bioaccumulation of Fe in celosia shoot grown on dumpsite soil decreased significantly ($p < 0.05$) by 9.5 % while those on farmland soil decreased by 5.4 %. The 30 t ha⁻¹ of the amendment lowered Zn bioaccumulation in shoot of celosia by 20.4 % in dumpsite and by 1.1 % in farmland soil. Shoot bioaccumulation of Pb decreased from 20.3 to 13.6 mg kg⁻¹ in dumpsite while the reduction was from 7.3 to 6.8 mg kg⁻¹ in farmland soil with 30 t ha⁻¹ compost rate. There was no difference in concentration of Cd in celosia shoot at 20 t ha⁻¹ and 30 t ha⁻¹ rates in dumpsite soil but 23.7 % reduction was recorded in the farmland soil at 30 t ha⁻¹ rate.

Bioaccumulations of heavy metals in root tissues of celosia are presented in Table 4. In soil with no compost manure (control), concentrations of the heavy metals except Fe were higher in root of celosia from dumpsite than farmland soils. At manure compost rate of 10 t ha⁻¹ significant concentration of Fe in the root tissue was 1473.0 and 881.00 mg kg⁻¹ in dumpsite and farmland soils, respectively. Zinc concentration was 544.8 and 522.3 mg kg⁻¹ in the root of celosia from dumpsite and farmland soils, respectively. Bioaccumulation of Pb in the root tissue was higher in dumpsite (26.8 mg kg⁻¹) than farmland (17.0 mg kg⁻¹) soil. Cadmium concentration of 4.5 mg kg⁻¹ in root of celosia from dumpsite soil was also higher than 3.0 mg kg⁻¹ in farmland soil. The manure compost amendment rate of 20 t ha⁻¹ also increased bioaccumulation of Fe (1521.00 mg kg⁻¹) as well as Pb (31.30 mg kg⁻¹) significantly ($P < 0.005$) in root tissue of celosia grown on dumpsite soil. With manure compost rate of 30 t ha⁻¹, root bioaccumulation of the heavy metals declined in both soils and was significant for most of the metals in the dumpsite soil.

Table 3: Residual Effect of composted poultry manure on heavy metal concentration in shoot of *Celosia argentea* grown on dumpsite and farmland soils

Manure Rate (t ha ⁻¹)	Fe (mg kg ⁻¹)		Zn (mg kg ⁻¹)		Pb (mg kg ⁻¹)		Cd (mg kg ⁻¹)	
	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil
0	345.1	358.3	305.2	270.2	4.0	2.3	1.7	1.3
10	1446.0	721.0	534.7	502.7	10.0	9.7	1.8	1.3
20	1424.7	644.3	504.0	409.3	20.3	7.3	1.7	1.3
30	1289.0	609.2	401.3	405.0	13.6	6.8	1.7	1.0
LSD (0.05)	53.79		17.78		3.72		0.83	

Table 4: Residual effect of composted poultry manure on heavy metal concentration in root of *Celosia argentea* grown on dumpsite and farmland soils

Manure Rate (t ha ⁻¹)	Fe (mg kg ⁻¹)		Zn (mg kg ⁻¹)		Pb (mg kg ⁻¹)		Cd (mg kg ⁻¹)	
	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil	Dumpsite soil	Farmland soil
0	394.56	416.43	341.47	293.76	7.70	4.00	2.70	2.00
10	1473.00	881.00	544.80	522.30	26.80	17.00	4.50	3.00
20	1521.00	825.00	537.30	503.50	31.30	15.30	4.00	3.70
30	1275.00	786.00	521.20	471.30	28.10	10.70	3.70	2.60
LSD (0.05)	97.5		13.43		4.03		1.97	

DISCUSSION

The higher celosia yield recorded in dumpsite soil compared to farmland soil without compost amendment could be attributed to higher nutrient status of the dumpsite soil particularly N, P and K as well as the ECEC. This study showed that the residual effect of poultry manure compost amendment at 10 t ha⁻¹ contributed to higher celosia yield than 20 t ha⁻¹ and 30 t ha⁻¹ rates. In particular, the effects were more pronounced on growth and yield parameters of celosia grown on dumpsite soil. This showed that composted poultry manure released more nutrients to the soil which in addition to those inherent in the dumpsite

soil led to higher growth and yields recorded. The contribution of poultry manure compost amendment to higher yields of celosia in both soils was in recognition of significant influence it had on soil properties and in enhancing crop growth and development (Ibeawuchi *et al.*, 2006; Mahmoud *et al.*, 2014).

The higher heavy metals concentration in both root and edible shoot of celosia in dumpsite soil than farmland soil as well as higher concentration of Fe in celosia grown in farmland soil without composted poultry manure amendment indicated that availability and bioaccumulation of heavy

metals was a function of its inherent concentration in the soil. Hence, crop grown on soils higher in a particular heavy metal could take up the metal and bioaccumulate it in its tissues. Bioaccumulation of heavy metals in several folds in tissues of celosia at amendment rate of 10 t ha⁻¹ compared with control indicated that substantial amount of Fe, Zn, Pb mineralized from the composted poultry manure were taken up by the root and translocated into the shoot. This observation is in consonance with the report of Kos *et al.* (2004) on Zn and Cd uptake by *Amaranthus* spp from soil amended with farm yard manure. The higher concentration of these metals in edible shoot of celosia following composted poultry manure amendment indicated that poultry manure is a source of these metals and could have originated from diet given to the poultry birds. Studies have also shown that the source of compost manure could contribute to increased accumulation of heavy metals in the soil and consequently bioavailability to plant tissues (Putwattana *et al.*, 2010; Thomas *et al.*, 2012).

The declined availability and hence low bioaccumulation of most of the metals at composted poultry manure amendment rate of 20 t ha⁻¹ and for all the metals at 30 t ha⁻¹ could be due to the chelation, complexation, adsorption or fixation roles played by ligands of the organic amendment in the soil (Alloway, 1995; Harter and Naidu, 1995; Chiu *et al.*, 2006; Hamid and Jawaaid, 2013). The lower concentration of heavy metals in plant tissues with increased composted poultry manure rate showed that composted poultry manure previously applied to the soil could have a lasting effect on soil properties which influenced availability of the metals for plant uptake.

Comparatively, higher concentration of heavy metals in the root tissue than shoot of celosia might be due to mass flow of the metals to the root surface due to direct

contact at the soil-plant root interface. The significant role of cation exchange which occurs at the soil-plant root interface has been attributed to be part of mechanism through which metal ions enters the plasmalemma of the root for active absorption (Hanč *et al.*, 2008). It also indicated that only certain proportions of the heavy metals taken up by the root system were translocated to the above ground biomass.

In conclusion subsequent generation of vegetable grown on soil amended with composted poultry manure could still benefit substantially for optimum growth and yield from slow released nutrients by the manure. The poultry manure used as source of compost amendment in this study apart from being a good source of macronutrients also supplied high concentrations of Fe, Zn, Pb and Cd which bioaccumulated in edible shoot of celosia. This study revealed that application of this type of compost above the rate of 10 t ha⁻¹ may not be economical for vegetable production and hence not safe for consumption as it could lead to biomagnification of the heavy metals in food chain. It will be suggested that manure product of high quality with low heavy metals content would be appropriate in reducing uptake of toxic heavy metals by crop plant grown on contaminated soil.

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