Heavy Metal Accumulation in Cockscomb (Celosia Argentea Linn) Grown in Soil Amended With Chicken Manure

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Research Article

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Abstract

Heavy metals such as Cadmium (Cd), Copper (Cu) and Manganese (Mn) in chicken manure can contaminate soil and bioaccumulate in edible tissues of plant to cause food chain contamination. This study investigated the influence of chicken manure on heavy metal load of soil and accumulation in tissues of *Celosia argentea*. Air-dried chicken manure from battery cages (conventional chicken manure-CCM) and free range birds (local chicken manure-LCM) were used for the pot culture. Chicken manure was applied as amendment at the rate of 0, 4, 6, 8 and 10 t ha^{-1} in 5 kg soil. Treatments were replicated trice in a Completely Randomized Design. Results showed that soil metal pollution increased with rates of amendment. Metal pollution indices; contamination factor, degree of contamination, elemental pollution index, pollution load index and total contamination factor were significantly ($p \leq 0.001$) higher in soil amended with CCM than LCM. Bioaccumulation coefficients (BAC), bioaccumulation factor

(BAF) and transfer factor (TF) of metals were higher in tissues of celosia grown with CCM than LCM. Furthermore, above 4 t ha^{-1}, growth and yield were not significantly influenced by amendment rates. Mobility of metals from soil to tissues of celosia increased in the order Cu > Mn > Cd. Chicken manure above 4 t ha^{-1} potent health risks of Cu exposure to consumers of celosia.

Keywords: Bioaccumulation. Celosia. Chicken manure. Edible tissues. Heavy metals. Pollution indices. Soil.

Introduction

Meeting the demand for healthy and safe food has led to intensive organic farming where soil amendment with animal manure has become the global practice among farmers. Animal manure especially from poultry birds is a rich and good source of plant nutrients that are eco-friendly unlike inorganic fertilizers (Mortola et al. 2019; Oguntade et al. 2019). The consequence of over utilization of animal manure on heavy metal pollution of soil is of environmental concern. This is because of its associated threat to ecosystem and possible food chain contamination (Eugenio et al. 2020; Oguntade et al. 2020). Although, the geochemical characteristics of soils generally possess some background levels of nutrient elements including metals which are inherent in them but often does not cause pollution. Application of chicken manure amendment to soils for organic farming is on the trend that requires attention to reduce soil pollution and minimize contamination of food crops. This is because livestock manure including poultry waste has been recognized as a source of heavy metal contaminant to agricultural soils while improving soil fertility (Hanč et al. 2008; Luo et al. 2009; Oguntade et al. 2018). Hence, unconscious deposition of metal contaminants in soils through over fertilization with manure can increase heavy metal load of soil, contaminate food crops and endanger soil health and food chain (Khan et al. 2017; Kobierski et al. 2017).

Plant nutrients and toxic metals found in chicken manure are primarily from the concentrate feeds, supplements and veterinary drugs given to the birds (Nicholson et al. 1999; Adeli et al. 2007; Chastain et al. 2010; Oguntade et al. 2019). More often residues of metals in amended soils is dependent on the quality and quantity of manure applied (Nicholson et al. 1999; He et al. 2009). Studies have shown high levels of toxic metals including arsenic, iron, zinc, copper, cadmium, chromium, manganese and lead in soils amended with chicken manure sourced from conventional battery cages (Zhang et al. 2012; Oguntade, et al. 2017). The manure is enriched with toxic metals because some of the trace metals consumed by the chicken are not absorbed through the digestive system (Adeli et al. 2007). However, little is documented on the environmental impact of metallic elements in manure of local chicken raised on free range system. Free range locally raised chicken depend on foods like insects, worms/larva and grasses from the natural or wild environment. The source of feed for local chicken perhaps is an indication of low levels of toxic metals in its manure and applying such could reduce metal loads in soils.

Copper (Cu), cadmium (Cd) and manganese (Mn) are among the trace metals found in the feed additives and supplements given to chicken kept in battery cages for optimal production (Oguntade et al. 2018). These metals have densities greater than 5 g cm^{-3}, long biological half-life and their presence in chicken manure at elevated concentration may cause pollution of amended soil. Soil amendment with livestock manure can enhance accumulation of trace metals in soils and become available for crop uptake (Antonious et al. 2012; Wajid et al. 2020; Ugulu et al. 2021). Since soil-plant movement of trace elements is part of the natural means of nutrient cycling. However, consumption of crops that bio-accumulate trace metals in its edible part is one of the means of human exposure to toxic metals and could be life threatening. This is because of the damaging effects toxic metals could have on body organs such as the brain, lungs, liver and kidney (Salem et al. 2000; Bandow and Simon 2016; Shakoor et al. 2016).

Pollution load index is one of the means for assessing intensity of heavy metal pollution of soils (Jorfi et al. 2017). Pollution indices can give quantitative assessment of soil pollution levels from build-up of toxic metals through agricultural activities (Shomar and Kalavrouziotis 2013). Furthermore, it is a useful tool for monitoring and evaluating the degree of soil contamination for predicting sustainability in agro-ecosystems (Kowalska et al. 2018). Several authors including (Cabrera et al. 1999; Hough et al. 2003; Kalavrouziotis and Koukoulakis 2012) have developed various pollution indices for monitoring and assessing heavy metal risks in soil-plant system. Among these indices are; contamination factor (CF), degree of contamination (DC), elemental pollution index (EPI) and pollution load index (PLI). However, it may not be enough to assess pollution potential of soil amended with chicken manure without evaluating extraction and bioaccumulation potentials of celosia grown on such soil. This is germane when monitoring metal transfer through soil-plants-human system. Studies have shown that crops growing on metal contaminated soils and environment cannot prevent metal uptake but can only restrict accumulation concentration in the plant tissues depending on the metal (Baker 1981; Jamali et al. 2009; Oguntade et al. 2020). Properties such as Bioconcentration factor (BCF), Bioaccumulation coefficient (BAC) and Translocation factor (TF) are often used in evaluating toxic metals accumulation potentials of plants (Yoon et al. 2006; Amin et al. 2018; Simanek and Holden 2020). These properties can give insights on the ability of celosia in translocating metals taken up from manure amended soil into its edible shoot. Knowledge provided thereof is expedient for valuable information on better management of chicken manure in promoting organic farming for healthy soil, improved yield and better quality of crops.

Cockscomb (*Celosia argentea* Linn) is a leafy vegetable that is rich in nutrients and other essential minerals required for balanced diet. Besides, it is a popular vegetable among farmers in western Nigeria because of its fast growth rate and yield in addition to possibility of several harvests from a single plant (Oguntade et al. 2017; Oguntade et al. 2020). Celosia is one of the vegetable that has the potentials of accumulating heavy metals in its edible and non-edible parts beyond allowable limits when grown on contaminated soils and environment (Alam et al. 2003; Yoon et al. 2006; Oguntade et al. 2020). Dietary consequence of consuming such vegetable can constitute health related problems. This study therefore aimed to investigate; (i) accumulation of heavy metals in soil amended with chicken manure from different sources, (ii) determine pollution index of the soil and (iii) bioaccumulation in celosia tissues through metal transfer to edible and non-edible parts.

Materials and methods

Study area

The study was carried out at the Department of Crop Production, College of Agricultural Sciences, Ayetoro campus of Olabisi Onabanjo University, Nigeria. Soil used for the study was collected from the field lying on latitude 7.2339° N, longitude 3.0595° E and 109.75 m above sea level at Teaching and Research Farm of the College.

Soil and chicken manure collection and preparation

The soil was collected from 0-15 cm depth at the farm and air-dried for 7 days. Following drying, soil for the pot experiment was sieved with 7 mm mesh to remove stone and plant debris. Sub-sample for physicochemical analysis was however sieved with 2 mm mesh. Fresh droppings from layers bird in battery cages used as conventional chicken manure (CCM) was collected from the College's poultry farm. The layer birds were on concentrate feed compounded from maize and groundnut cake (Oguntade et al. 2019). Local chicken droppings from free range system (LCM) were also collected within Ayetoro town from their coop/chicken pens. Collected droppings were air-dried for 4 weeks, crushed and sieved with 7 mm mesh. Sub-samples each of the soil and manure were subsequently taken for laboratory analysis.

Experimental setup

Buckets of 7 litre capacity each was filled with 5 kg soil homogenized with each type of amended chicken manure at the rate of 0 (control), 4, 6, 8 and 10 t ha^{-1} on dry weight (*d/w*) basis. The study was a factorial experiment fitted into a completely randomized design (CRD) and replicated three times. The amended potted soils were left for two weeks prior to sowing of cockscomb (*Celosia argentea*) seeds. Seedlings of the leafy vegetable were thinned to one stand per pot 2 weeks after sowing (WAS). Each pot was watered with 250 mls of fresh water every other day for the first 3 weeks and thereafter every day until 6 WAS when plants were harvested. Weeds from each pot were removed manually and returned in-situ per pot. At harvesting, plant height, numbers of leave and primary branches were recorded. Plants samples were thereafter separated into its edible (shoot) and non-edible (root) parts. Each plant part was separately cleaned with running tap water, briskly rinsed with distilled water to remove adhered particles, air-dried and fresh weights determined. Plant samples were later oven-dried at 65 ^{o}C to constant weight for determination of dry weight and then ground for chemical analysis. Sub-sample of soils from each pot was also taken for laboratory analysis.

Chicken manure analysis

The pH of the chicken manure was determined with glass electrode pH meter. Concentrations of calcium, (Ca), magnesium (Mg), potassium (K), sodium (Na) as well as copper (Cu), iron (Fe), manganese (Mn) Zinc (Zn) cobalt (Co), nickel (Ni), chromium (Cr), cadmium (Cd) and lead (Pb) were also determined. The analyses were carried out with the use of atomic absorption spectrophotometer, AAS (Buck Scientific 210VGP Model, Inc., East Norwalk, CT, USA) according to Udo et al. (2009). Total Organic carbon (OC) was determined by wet oxidation method (Nelson and Sommer 1996) and nitrogen (N) by Kjeldahl method (Bremner and Mulvaney 1982). Phosphorus (P) content was determined by colourimetric method (Nelson and Sommers 1996).

Soil analysis

The soil's pH was determined with glass electrode pH meter in 1:2 soil/water suspension (McLean et al., 1982). Exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) in the soil were extracted with 1 N ammonium acetate solution. Calcium and Mg^{2+} were determined with AAS while K^{+} and Na^{+} were read on flame photometer. The soil exchangeable acidity (Al^{3+}+H^{+}) was extracted with 1 N KCl solution and determined by titration method (Anderson and Ingram 1993). Effective cation exchange capacity (ECEC) was estimated as addition of exchangeable bases and acidity. Base saturation (BS) was calculated in percentage as the ratio of exchangeable bases to ECEC according to Udo et al. (2009). Total Organic carbon was determined by oxidation method (Walkley and Black 1934), while total N was determined by macro-Kjeldahl method (Bremner and Mulvaney 1982). Extractable P was determined by Bray-1 method (Nelson and Sommers 1996). Particle size analysis of the soil was determined by the hydrometer method (Bouyoucos 1962). Heavy metals (Cu, Fe, Mn, Zn, Co, Ni, Cr, Cd and Pb) in the soil were determined on atomic absorption spectrophotometer-AAS (Udo et al. 2009).

Plant analysis

Plant samples (0.5 g) were digested with 10 ml concentrated nitric (HNO_3) and perchloric ($HClO_4$) acids (2:1 *v/v*) for the first 90 minutes at 150 ^{0}C. Thereafter, 2 ml concentrated HCl was added to the digests and the temperature was raised to 230 ^{0}C for the next 30 minutes. Digested samples were cooled down at room temperature, digests transferred to 50 ml volumetric flask and diluted to volume with deionized water. The total contents of Cu, Cd and Mn in the digests were then determined by AAS (Buck Scientific 210 VGP model, Inc., East Norwalk, CT, USA) according to Udo et al. (2009).

Soil contamination measurement

Contamination factor (CF)

The soil contamination or pollution factor was determined according to the equation (Håkanson 1980);

$$CF=\frac{\text{C metal}}{\text{C bkg}} \quad \text{Equation} \quad \ldots\ldots\ldots\ldots(1)$$

where C metal is the concentration (mg kg^{-1}) of a given heavy metal in soil and C bkg is the background or preindustrial concentrations (mg kg^{-1}). For the pre industrial concentration of metals, we adopted values reported by Turekian and Wedepohl (1961) for carbonate soils with similar sedimentary origin. The geochemical background concentration values of Cd, Cu and Mn were; 0.035, 4.0 and 1100.0 mg kg^{-1}, respectively. The selected metals were among trace elements found in drugs and supplements given to the conventionally raised chicken (Oguntade et al. 2019), residues of which might be in the amended soil.

Degree of contamination (DC)

Degree of contamination of the soil by the selected metals was calculated as the sum of the CFs, according to Fiori et al. (2013) as follows:

$$DC = \sum CF \quad \text{Equation} \quad \ldots\ldots\ldots\ldots(2)$$

The degree of soil contamination has been categorized into four as follows depending on intensity. Low CF < 1; moderate 1 < CF < 3; considerable 3 < CF < 6; high CF > 6 (Gong et al. 2008; Islam et al. 2015).

Total contamination factor (TCF)

The TCF = $(M1 + M2 + M3 + \cdots Mn)/(M1r + M2r + M3r + \cdots Mnr)$ Equation …… (3)

where; *M1, M2, M3* + …. *Mn* represents the selected heavy metals, (*M1r* + *M2r* + *M3r* + ... *Mnr*) are the corresponding reference values of the metals with *n* as the number of analyzed heavy metals (mg kg^{-1}) (Shomar and Kalavrouziotis 2013).

Elemental pollution index (EPI)

The EPI was calculated as follows; EPI = $n\sqrt{M1\ x\ M2x\ M3 \ldots \ldots Mn}$ Equation ……. (4)

where; *M1, M2, M3*,… *Mn*, represents the selected heavy metals (Shomar and Kalavrouziotis 2013)

Pollution load index (PLI)

The PLI was calculated according to (Tomlinson et al. 1980) as;

PLI = $n\sqrt{CF1\ x\ CF2x\ CF3 \ldots \ldots CFn}$ Equation ……………… (5)

where; *n* is the number of metals, while *CF1, CF2* and *CF3* ..…… *CFn* are contamination factors of the selected metals. According to Tomlinson et al. (1980), pollution levels are categorized as follows; no contamination (PLI < 1); moderate contamination (1~2); severe contamination (2~5); extreme contamination (PLI ≥ 5).

Phytoextraction efficiency

In order to determine heavy metal phytoextraction potential of *Celosia argentea* grown on soil amended with chicken manure, the plant Bioconcentration factor (BCF), Bioaccumulation coefficient (BAC) and Translocation factor (TF) were calculated (Baker 1981; Bu-Olayan and Thomas 2009; Jamali et al. 2009;

Amin et al. 2018).

Bioconcentration factor was calculated as; $BCF = \frac{\text{C root}}{\text{C soil}}$ Equation …………….. (6)

Bioaccumulation coefficient was calculated as; $BAC = \frac{\text{C shoot}}{\text{C soil}}$ Equation …………… (7)

Translocation factor was calculated as; $TF = \frac{\text{C shoot}}{\text{C root}}$ Equation………………(8)

where; C_{root}, C_{shoot} and C_{soil} are concentrations (mg kg^{-1}) of heavy metals in root, shoot and soil, respectively.

Statistical analysis

All data generated were subjected to analysis of variance (ANOVA). Significant treatment means were separated by Fisher's protected Least Significant Difference (LSD) at 5% level of probability. Pearson's moment correlation analysis (r) and Principal Component Analysis (PCA) were also carried out to determine the association between the manure types and rates on soil chemical properties, soil metal pollution and accumulation in plant tissues.

Results and discussion

Physicochemical characteristics of soil and chicken manure used for this study are shown in Table 1. The pH of the soil was moderately acidic. The soil was high in exchangeable bases (Ca, Mg, K and Na) with low level of exchangeable acidity. Effective CEC of the soil was above the critical level of 6.0 cmol kg^{-1} reported by Esu (1991). The base saturation was high, indicating dominance of basic cations at the soils exchange complex. Organic carbon was moderate (FAO 1976; Udo et al. 2009) while total N of 1.73 g kg^{-1} in the soil falls within the critical level of 1.5-2.0 g kg^{-1} (Sobulo and Osiname 1981). The extractable P was lower than critical range of 10-16 mg kg^{-1} (Adeoye and Agboola 1985). Hence, for optimal growth and yield of celosia in this type of soil, addition of organic amendment such as chicken manure may be

Table 1 Physicochemical properties of the experimental soil and chicken manure amendments

Properties	Soil	unit	Chicken manure		unit
			Conventional	Local	
pH	5.73		9.86	7.47	
Calcium	7.58	$cmol\ kg^{-1}$	15.00	6.10	$g\ kg^{-1}$
Magnesium	3.60		23.40	8.70	
Potassium	0.22		7.10	6.70	
Sodium	0.35		2.10	4.00	
Exch. Acidity	0.11		-	-	
ECEC	11.86		-	-	
Base saturation	99.07	%	-	-	
Total Org. C.	21.50	$g\ kg^{-1}$	163.10	141.90	$g\ kg^{-1}$
Total N	1.73	$mg\ kg^{-1}$	39.80	41.70	$mg\ kg^{-1}$
C/N ratio	-		4.10	3.40	
Phosphorus	8.38		4.90	2.00	
Manganese	39.65		785.00	166.00	
Iron	82.90		738.00	5300.00	
Copper	1.19		266.40	56.10	
Zinc	7.51		624.20	554.60	
Cobalt	BDL		BDL	BDL	
Nickel	9.91		3.30	4.75	
Chromium	BDL		BDL	BDL	
Cadmium	7.31		18.10	17.50	
Lead	BDL		BDL	BDL	
Sand	866.00	$g\ kg^{-1}$	-	-	
Silt	54.00		-	-	
Clay	80.00		-	-	
Textural class	Loamy sand		-	-	

BDL = below detection limits of 0.05, 0.003 and 0.04 mg kg^{-1} for Co, Cr and Pb, respectively.

necessary. Manganese and Fe in the soil were high, while Cu level was within the critical limit of 0.21-2.0 mg kg^{-1} reported by Esu (1991). Extractable Zn was also higher than critical soil range of 0.8-2.0 mg kg^{-1} (Esu 1991). Cobalt, Cr and Pb were below soil detection limits while Ni and Cd were 9.91 and 7.31 mg kg^{-1}, respectively. The soil was inherently high in extractable Cd since it has value higher than 3 mg kg^{-1} limit recommended by FAO/WHO (2001) and European Commission (2006).

Chemical composition of the chicken manure showed that pH of CCM was strongly alkaline while that of LCM was very slightly alkaline (Table 1). Calcium and Mg were more than two folds higher in conventional than local manure. This could be attributed to the composition of diet given to egg laying birds in the battery cages. Potassium content in the CCM was also higher than that in the LCM but Na content of LCM was almost double the amount in CCM. Total organic carbon in CCM was higher than in LCM but the trend was reversed for total N. The lower N content in CCM than LCM could be due to mobility of N from volatilization in CCM during air-drying. The C/N ratio of the CCM was higher than that of the LCM and was a reflection of the carbon content of the manure. Phosphorus concentration in CCM was more than double that of LCM. Manganese was more than four folds higher in conventional than local manure. Meanwhile, Iron was seven folds higher in local than conventional manure. Concentration of Cu was more than four times higher in CCM than LCM. Zinc was also higher in conventional than local manure. Nickel followed the pattern of Fe with higher content in local than conventional manure. Cadmium was also higher in conventional than local manure. The higher contents of Fe and Ni in LCM than CCM could be traced to what the birds fed on including small stones and pebbles form the surrounding soil. Conversely, high concentrations of Mn, Cu, Zn and Cd in CCM reflected the residue from feeds and drugs given to the chicken. Previous studies had traced high content of heavy metals in poultry manure to feeds and drugs administered on the birds (Zhang et al. 2005; Van Zanten et al. 2014; Oguntade et al. 2019). However, Co, Cr and Pb were below detection limits in both the conventional and local manure.

Table 2 shows the effects of chicken manure amendment on chemical properties of the soil.

Table 2 Effects of chicken manure amendment on chemical properties of soil at 6 WAS

Sources of Variation	pH	Total N	Org. C	Avail P	Al+H	Ca	K	Mg	Na	ECEC	Extractable Cu	Extractable Fe	Extractable Mn	Extractable Zn
		($g\ kg^{-1}$)		($mg\ kg^{-1}$)	($cmol\ kg^{-1}$)						($mg\ kg^{-1}$)			
Manure sources														
Conventional	6.08	0.75	6.30	12.88	0.13	6.99	0.18	3.55	0.70	11.54	1.56	3.01	18.91	1.26
Local	5.93	0.56	4.15	10.82	0.14	6.31	0.14	3.43	0.81	10.82	1.15	3.60	14.54	0.93
(sig.)	***	***	***	***	**	***	***	ns	***	***	***	***	***	***
LSD	0.02	0.07	0.13	0.08	0.01	0.07	0.01	0.13	0.01	0.17	0.03	0.03	0.18	0.03
Manure rates ($t\ ha^{-1}$)														
0	5.77	0.65	8.07	7.09	0.11	5.58	0.10	3.08	0.31	9.16	0.64	1.67	9.77	0.40
4	6.00	0.80	5.48	9.97	0.13	6.12	0.12	3.32	0.81	10.51	1.17	3.33	14.19	0.99
6	6.12	0.55	4.75	12.64	0.13	6.48	0.15	3.53	0.92	11.20	1.42	3.43	16.90	1.10
8	6.10	0.60	3.62	14.16	0.14	6.79	0.18	3.62	0.94	11.66	1.64	3.85	19.96	1.37
10	6.02	0.68	4.22	15.39	0.14	8.28	0.24	3.91	0.80	13.37	1.90	4.25	22.81	1.60
(sig.)	***	**	***	***	***	***	***	***	***	***	***	***	***	***
LSD	0.03	0.11	0.20	0.13	0.01	0.10	0.01	0.21	0.02	0.27	0.05	0.05	0.28	0.04
Manure sources x Rates	***	**	***	***	ns	***	**	ns	***	***	***	***	***	***
LSD	0.04	0.16	0.28	0.19	0.01	0.15	0.02	0.30	0.02	0.38	0.06	0.07	0.40	0.06

***, ** = significant at $p \leq 0.001$, 0.01, respectively; *ns* = not significant

Except for exchangeable acidity, Na and Fe, the chemical properties of soil increased significantly in soil amended with CCM over LCM. Generally, the soil chemical properties increased significantly with manure rate irrespective of the sources. The interaction of sources and rates of manure was also significant on the soil chemical properties except for exchangeable acidity and Mg. Across manure rates, CCM showed positive relationships with OC, total N and available P unlike LCM with negative relationships except at 10 t ha^{-1}. The CCM at 4 t ha^{-1} maintained a strong direct relationship with total N and OC. The CCM at 10 t ha^{-1} had the strongest and most direct relationships with available P while 6 t ha^{-1} had the least influence. Amendment with 6 t ha^{-1} of the CCM directly reversed the low pH of the soil. On the other hand LCM showed strong association with the pH, ECEC among other soil chemical properties. Although, 8 t ha^{-1} of LCM had the highest influence on the ECEC and pH, its effect on the soil OC and total N was negative. Meanwhile, the LCM was more directly associated with pH at 4 t ha^{-1} but had stronger effect on the ECEC at 6 t ha^{-1} (Fig. 1). The trace metals (Cu, Fe, Mn and Zn) among other nutrients were highest in soil amended with the highest manure rate of 10 t ha^{-1}. This observation was a reflection of the nutrient content of the two manure sources. The inverse relationships exhibited by CCM on the soil pH and ECEC can be attributed to its strong alkalinity. The higher accumulation of trace metals in soil which increased with manure rate indicated potential soil pollution. Kobierski et al. (2017) have also reported increased soil chemical properties in soil fertilized with poultry manure.

The effect of chicken manure amendment on total concentration and pollution index of the selected heavy metals is shown in Table 3. Total concentration of Cd, Cu and Mn as well as their pollution indices (CF, DC, EPI, PLI and TCF) in amended soil were significantly ($p \leq 0.001$) higher with CCM than LCM. Total concentration of metal in soil at the lowest manure rate of 4 t ha^{-1} was significantly higher than in control soil without amendment. Concentration of Cd at the lowest manure rate of 4 t ha^{-1} was above 3 mg kg^{-1} limit allowable by FAO/WHO (2001) and European Commission (2006). Meanwhile across rates of amendments, Cu and Mn were below the soil limits of 100 and 2000 mg kg^{-1}, respectively. Heavy metal pollution of soil increased significantly with manure rate with the

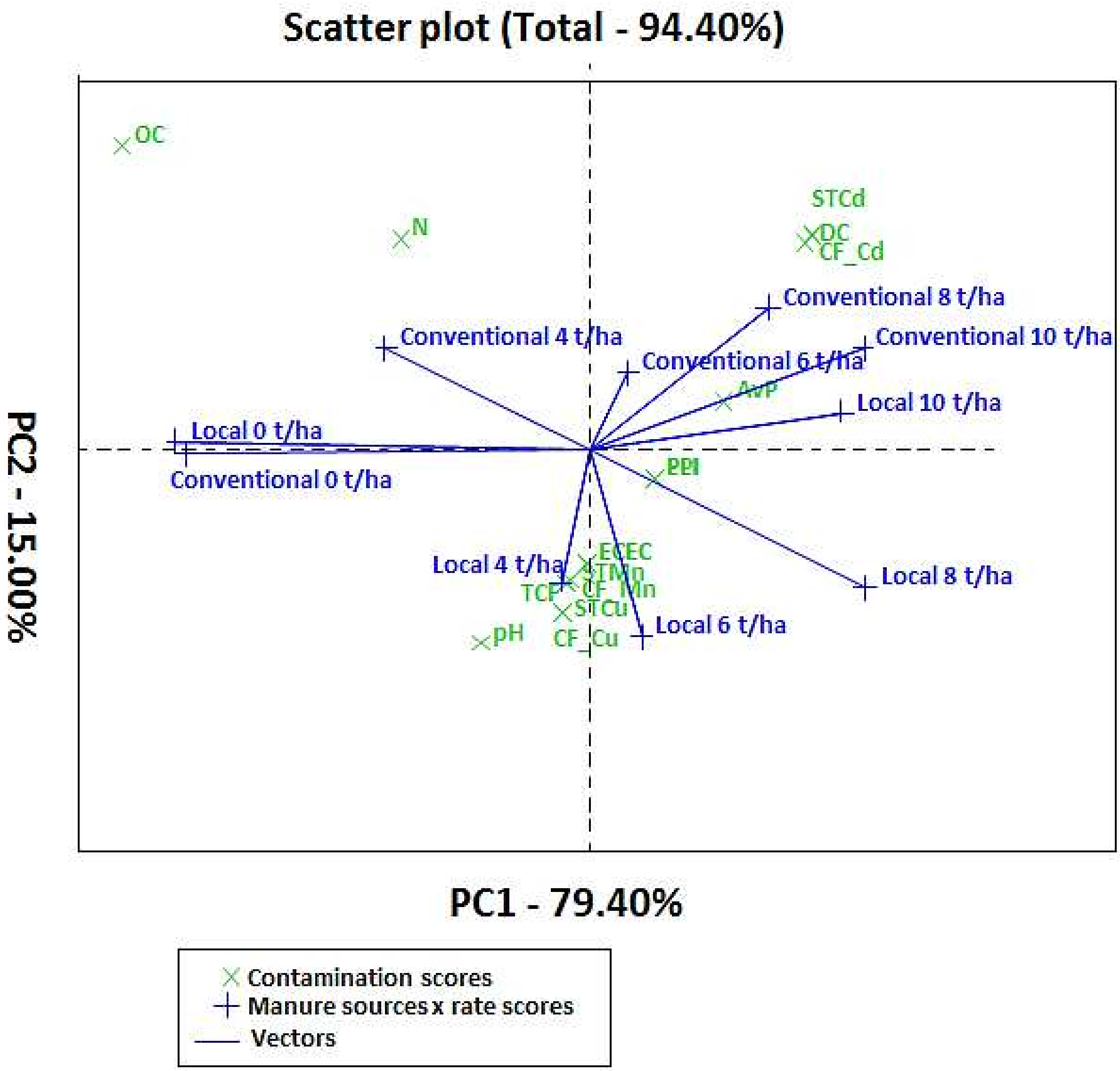

Fig. 1 Principal component analysis biplot of manure sources and rates on soil chemical properties, metal concentration and pollution indices.

Table 3 Influence of chicken manure amendment on the contamination and pollution of soil by cadmium, copper and manganese at 6 WAS

Sources of Variation	Total Soil-Cd	Total Soil-Cu	Total Soil-Mn	CF-Cd	CF-Cu	CF-Mn	DC	EPI	PLI	TCF
		(mg kg^{-1})								
Manure sources										
Conventional	4.58	12.61	316.31	130.93	3.15	0.29	134.37	26.12	4.87	0.30
Local	3.69	12.15	298.84	105.45	3.04	0.27	108.76	23.54	4.39	0.29
(sig.)	***	***	***	***	***	***	***	***	***	***
LSD	0.07	0.05	1.89	1.85	0.01	0.01	1.85	0.15	0.03	0.01
Manure rates (t ha^{-1})										
0	1.88	10.06	250.16	53.57	2.51	0.23	56.31	16.77	2.13	0.24
4	3.47	12.35	304.25	99.24	3.09	0.27	102.60	23.52	4.39	0.29
6	4.08	12.79	312.64	116.48	3.20	0.28	119.96	25.25	4.71	0.30
8	5.25	13.07	327.59	150.10	3.27	0.30	153.66	28.19	5.26	0.31
10	6.01	13.62	343.24	171.57	3.40	0.31	175.29	30.39	5.67	0.33
(sig.)	***	***	***	***	***	***	***	***	***	***
LSD	0.10	0.09	2.98	2.92	0.02	0.01	2.92	0.23	0.04	0.01
Manure sources x Rates	***	***	***	***	***	***	***	***	***	***
LSD	0.15	0.12	4.22	4.13	0.03	0.01	4.13	0.33	0.06	0.01

*** = significant at $p \leq 0.001$

highest metal load at 10 t ha^{-1}. Interaction of manure sources and rates was also significant for the soil pollution indices. The CCM across rates contributed directly to the total soil Cd, CF-Cd and DC. The contribution was highest at 10 t ha^{-1} and least at 6 t ha^{-1}. However, while the 8 t ha^{-1} showed the strongest relationships, the 4 t ha^{-1} had weakest relationships with the indices (Fig. 1). Unlike the CCM, the LCM across rate except at 10 t ha^{-1} was more associated with total soil Cu, CF-Cu, total soil Mn, CF-Mn, TCF and PLI. The 8 t ha^{-1} of LCM had the strongest and the most direct influence on the PLI. Meanwhile, the 6 t ha^{-1} had stronger association than 4 t/ha with the Cu and Mn soil contamination factors. Indices like CF and DC showed that the amended soil was very highly polluted with Cd, moderate with Cu and low in Mn since the CF values was > 6 for Cd;$1 \leq CF \geq 3$ for Cu and CF < 1 for Mn (Gong et al. 2008; Goher et al. 2014). The PLI of 2.14 in control soil which was moderately contaminated may be attributed to geochemical or local background of the soil (Dung et al. 2013). However, at amendment rates of 4 and 6 t ha^{-1}, PLI value of the soil reflected a severe contamination. At manure rates of 8 and 10 t ha^{-1}, the PLI were 5.26 and 5.67, respectively which indicated that the soil was extremely contaminated due to $PLI \geq 5$ (Tomlinson et al. 1980). The TCF also showed that the higher the rate of manure amendment the higher the metal loads in the soil. This further reinforced the effects of chicken manure rate of 6 t ha^{-1} and above on soil metal pollution loads which farmers should be wary of to minimize toxic metals transfer to food crops. Enrichment of soils with organic fertilizer amendments can contribute to heavy metals load in agricultural soils (Su et al. 2014; Kowalska et al. 2018).

Except for shoot dry weight, the growth and yield characteristics of *Celosia argenta* were not affected by chicken manure sources (Table 4). This showed that chicken manure from both sources have similar effects on growth and yield potentials of *Celosia argentea*. Soil amendment with chicken manure of 4 t ha^{-1} significantly ($p \leq 0.001$) increased plant height, numbers of leaves and primary branches as well as yield of *Celosia argentea* over no amendment (control). Generally, the growth and yield attributes increased significantly with increased manure rate up to 8 t ha^{-1}, above which the attributes declined. Chicken manure amendment of 8 t ha^{-1} was not significantly different from 6 t ha^{-1} in all parameters.

Table 4 Mean effects of chicken manure amendment on growth and dry matter yield of *Celosia argentea* at 6 WAS

Sources of Variation	Plant height	No of leaves plant^{-1}	No of primary branches plant^{-1}	Shoot fresh weight	Root fresh weight	Shoot dry weight	Root dry weight
	(cm)			(g)			
Manure sources							
Conventional	50.19	31.00	21.87	39.56	7.38	3.20	0.91
Local	47.55	30.27	21.53	37.34	6.97	2.32	0.67
(sig.)	ns	ns	ns	ns	ns	**	ns
LSD	5.00	1.88	2.52	10.19	1.84	0.63	0.25
Manure rates (t ha^{-1})							
0	28.67	22.50	9.33	9.91	3.06	0.97	0.26
4	46.80	30.17	21.83	33.67	4.49	2.58	0.56
6	57.90	34.67	26.67	47.20	10.19	3.31	1.04
8	60.17	34.66	27.83	51.22	10.26	3.83	1.19
10	50.82	31.17	22.83	50.23	7.86	3.10	0.91
(sig.)	***	***	***	***	***	***	***
LSD	7.91	2.97	3.98	16.11	2.90	0.99	0.39
Manure sources x Rates	*	**	*	ns	*	ns	ns
LSD	11.19	4.21	5.63	22.78	4.10	1.40	0.56

***, **, * = significant at $p \leq 0.001, 0.01, 0.05$, respectively; *ns* = not significant.

Manure rate of 6 t ha^{-1} was also not different from 4 t ha^{-1} in shoot fresh and dry weights. The optimum dry matter yield at 8 t ha^{-1} might have been influenced by soil pollution factors induced by the amendment. According to Kalavrouziotis and Koukoulakis (2012), dry matter yield of plant was a reference point in determining extent of soil pollution through CF or PLI. In pot culture such as in this study, it is economical, better and healthier to amend soil with chicken manure at 4 t ha^{-1} than higher rate. Application of 4 t ha^{-1} in this study still gave the optimum yield, this will reduce buildup of heavy metals in soil and consequently lower transfer to the food chain. The interaction of manure sources and the rates was also significant for plant height, numbers of leaves, primary branches and root fresh weight.

Bioaccumulation of Cu and Mn was significantly higher in tissues of celosia grown on CCM than LCM except for TF-Cu where LCM was higher than CCM (Table 5). Bioaccumulation of both Cu and Mn increased significantly with manure rate over no amendment (control) soil. Meanwhile, BAC of Cu in the tissues of celosia which initially declined from 0.94 in no amendment soil to 0.88 at 4 t ha^{-1} was > 1 at 8 and 10 t ha^{-1} with highest of 1.09 at 10 t ha^{-1}. Conversely, the highest BAC values of 0.19 - 0.22 were recorded for Mn at 6 - 10 t ha^{-1}. In a similar trend to BAC-Cu, the BCF-Cu also declined from 0.75 to 0.72 at 0 and 4 t ha^{-1}, respectively. Thereafter, a significant increase in BCF-Cu of up to 1 was observed with manure rate at 10 t ha^{-1}. However, BCF-Mn increased with rate of amendment significantly and was highest at 8 t ha^{-1}. The TF of Cu and Mn from amended soil to plant decreased with manure rate from 0 to 6 t ha^{-1} for Cu and through 8 t ha^{-1} for Mn. There were no significant differences in TF-Mn at 4 and 6 t ha^{-1} of the amendment. Interaction of manure sources and rate showed that BAC and BCF of Cu and Mn increased significantly with manure rate in celosia tissues. Metal accumulation potential of celosia varied with types of manure and rates. The BAC-Cu and BCF-Cu in tissues of celosia were strongly influenced by the CCM in the order 10 > 8 > 6 t ha^{-1}. Only the 10 t/ha of LCM had direct relationships with least effect on bioaccumulation of Cu (Fig. 2). Conversely, BAC-Mn and BCF-Mn were directly and strongly influenced by LCM in the order 8 > 6 t ha^{-1}. However, CCM at 4 t/ha also exhibited a direct but weak association with BAC-Mn and BCF-Mn while it maintained an inverse relationships with BAC-Cu and

Table 5 Bioaccumulation of heavy metals in root and shoot tissues of *Celosia argentea* grown on soil amended with chicken manure at 6 WAS

Sources of Variation	BAC-Cu	BAC-Mn	BCF-Cu	BCF-Mn	TF-Cu	TF-Mn
Manure sources						
Conventional	1.01	0.21	0.92	0.18	1.11	1.17
Local	0.94	0.18	0.80	0.17	1.19	1.07
(sig.)	***	***	***	***	***	***
LSD	0.01	0.01	0.02	0.01	0.02	0.02
Manure rates (t ha^{-1})						
0	0.94	0.17	0.75	0.13	1.25	1.27
4	0.88	0.18	0.72	0.16	1.23	1.13
6	0.92	0.22	0.89	0.20	1.05	1.11
8	1.05	0.21	0.94	0.21	1.13	1.03
10	1.09	0.19	1.00	0.18	1.09	1.06
(sig.)	***	***	***	***	***	***
LSD	0.02	0.01	0.03	0.01	0.04	0.03
Manure sources x Rates	***	***	***	***	***	***
LSD	0.03	0.01	0.04	0.01	0.05	0.04

*** = significant at $p \leq 0.001$

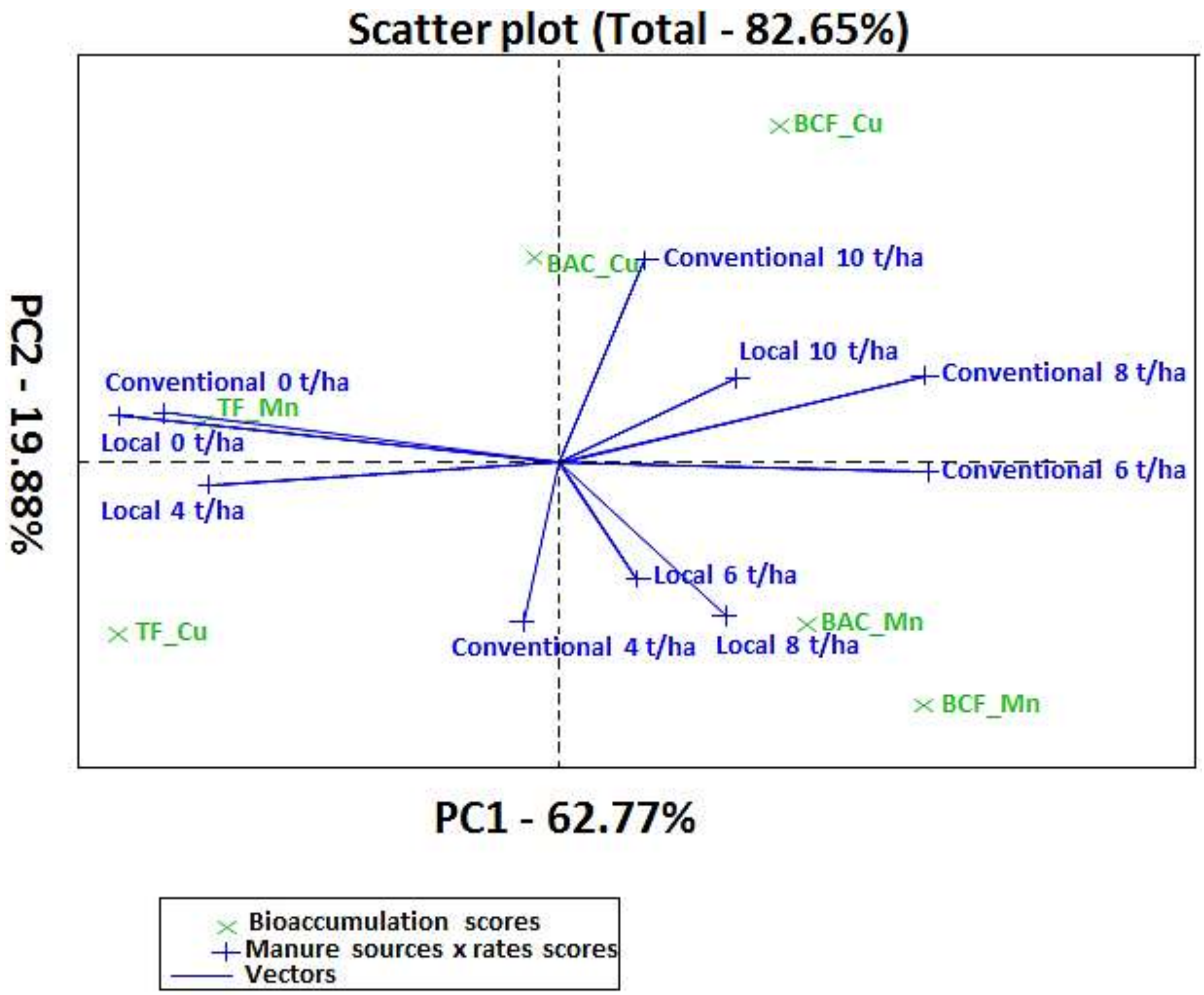

Fig. 2 Principal component analysis biplot of manure sources and rates on bioaccumulation of heavy metal in tissues of *Celosia argentea*

BCF-Cu. The TF was highest for Mn and Cu in the control soil followed by soil amended with 4 t ha^{-1}. At 4 t ha^{-1}, the LCM had stronger relationships with transfer factor of both metals than CCM. The association showed that at 4 t ha^{-1}, LCM contributed more to TF of both Cu and Mn than CCM, though the effect was higher for TF-Cu. According to Hanen et al. (2010) the total amount of metals that accumulate in shoot is the most important feature that determines phytoextraction potential of a plant. This observation indicated that extraction and bioaccumulation of Cu was higher than Mn by celosia despite higher total concentration of Mn in the soil. Hence, bioaccumulation capacity of celosia is more of metal dependent than total concentration in the soil. Celosia can therefore, be regarded as good extractor of Cu but poor extractor of Mn from the amended soil. Studies have shown that plants with BAC value of > 1 are promising phytoextractor of heavy metals (Fitz and Wenzel 2002; Amin et al. 2018). Hence, soil amendment with chicken manure above 6 t ha^{-1} is not encouraged for cultivation of celosia to reduce bioaccumulation of metal in the edible shoot and minimize food chain contamination. The Cu BCF of 1 at 8 and 10 t ha^{-1} manure rate indicated that celosia can suitably extract significant amount of Cu than Mn from the growth medium (Jamali et al. 2009). This means that there is potential danger of human exposure to Cu when celosia grown on soil amended with chicken manures above 6 t ha^{-1} is consumed. According to Ugulu et al. (2021) bioconcentration factor is a key component of determining exposure of potentially toxic metals via the food chain. The low accumulation of Mn in celosia tissues than Cu is an indication of tolerance to Mn hence, restriction of its transfer from soil to root and root to shoot (Yoon et al. 2006). The TF of > 1 for both Cu and Mn showed that celosia is a potential extractor of these metals (Yoon et al. 2006; Amin et al. 2018). This signified that Cu and Mn extracted from the amended soil were transferred to edible shoot of the vegetable with potential risks of food chain contamination. The highest TF of Cu and Mn in control soil without amendment in this study was similar to previous observation of Beesley et al. (2014) and Oguntade et al. (2018). They opined that metal ions are freely available in soil without organic amendment and hence exhibited low metals binding potentials due to low soil pH and organic matter. Our observation of close association exhibitted by LCM at 4 t ha^{-1} to TF-Mn and TF-Cu unlike CCM at 4 t ha^{-1} which contributed more to OC corroborate this earlier assertions. The declined TF with manure rate was therefore a reflection of, complexation, chelation and adsorption capacity exhibited by ligands in the organic manure (Chiu et al. 2006; Beesley et al. 2014; Oguntade et al. 2017). However, chicken manure rate of between 4 and 6 t ha^{-1} may be reasonable for this purpose to reduce soil metal contamination at higher rates.

Mean concentration and uptake of heavy metal by shoot and root tissues of celosia were shown in Table 6. Concentration and uptake of Cu and Mn were significantly ($p \leq 0.001$) higher in tissues of celosia grown on soil amended with CCM than LCM. The concentration and uptake of both metals were higher in shoot than root of the vegetable. The lowest Cu concentration of 9.42 and 7.55 mg kg^{-1} was recorded in shoot and root, respectively from the soil without manure amendment. Meanwhile, at the highest manure rate of 10 t ha^{-1}, concentration of Cu in shoot and root was 14.85 and 13.63 mg kg^{-1}, respectively. Cadmium was below detection limit in tissues of the vegetable. However, shoot and root-Mn, Cu-uptake as well as Mn-uptake which increased significantly with manure rate was highest at 8 t ha^{-1} and decreased afterwards. Copper uptake by root at 6 t ha^{-1} was not different from 8 t ha^{-1}. Similarly, Mn uptake by celosia roots and shoots at 6 and 8 t ha^{-1} was not different significantly. The interaction of manure sources and the rate of amendment were significant for concentrations of Cu and Mn in root and shoot tissues of celosia but not significant for its uptake. The decline in metals uptake despite higher concentration at higher rates of amendment could be due to presence of soluble organic matter which may have chelated the metals amidst increased pH of the amended soil. Other authors have also observed that combination of organic matter and elevated pH of soils limits bioavailability of heavy metals in plants thus, reduces uptake (Jung and Thornton 1996; Rosselli et al. 2003; Yoon et al. 2006). Higher concentration of metals in shoot than root in this study was an indication of mobility of the metals to upper part of the plant. This was contrary to reports of Yoon et al. (2006) who found higher concentrations of metals (Pb, Cu and Zn) in root than shoot of plant samples due to low mobility.

Table 7 shows the correlation matrix of celosia growth, yield and concentration of selected heavy metals

Table 6 Concentrations and uptake of heavy metals by root and shoot tissues of *Celosia argentea* grown on soil amended with chicken manure from different sources at 6 WAS

Sources of Variation	shoot-Cu	root-Cu	shoot-Cd	root-Cd	shoot-Mn	root-Mn	shoot-Cu uptake	root-Cu uptake	shoot-Mn uptake	root-Mn uptake
	($mg\ kg^{-1}$)						($mg\ plant^{-1}$)			
Manure sources										
Conventional	12.82	11.78	BDL	BDL	66.71	57.80	0.043	0.012	0.23	0.060
Local	11.49	9.74	BDL	BDL	53.90	51.59	0.028	0.007	0.13	0.039
(sig.)	***	***			***	***	***	**	***	**
LSD	0.14	0.20			0.76	0.54	0.01	0.00	0.04	0.02
Manure rates ($t\ ha^{-1}$)										
0	9.42	7.55	BDL	BDL	41.32	32.53	0.009	0.002	0.04	0.009
4	10.88	8.88	BDL	BDL	55.23	48.82	0.028	0.005	0.15	0.028
6	11.82	11.42	BDL	BDL	69.15	61.87	0.039	0.013	0.23	0.068
8	13.80	12.32	BDL	BDL	70.67	68.90	0.054	0.016	0.27	0.086
10	14.85	13.63	BDL	BDL	65.17	61.37	0.046	0.013	0.20	0.056
(sig.)	***	***			***	***	***	***	***	***
LSD	0.22	0.31			1.19	0.85	0.01	0.01	0.07	0.02
Manure sources x Rates	***	***			***	***	ns	ns	ns	ns
LSD	0.31	0.44			1.69	1.20	0.02	0.01	0.09	0.03

***,** = significant at $p \leq 0.001$, 0.01, respectively; *ns* = not significant; BDL = below detection limit (Cd < 0.002 $mg\ kg^{-1}$)

Table 7 Relationships between growth, yield of celosia and total concentration of heavy metals in soil amended with chicken manure

	No of primary braches	No of leaf	Plant height (cm)	Root DMY (g)	Shoot DMY (g)	Total soil-Cd (mg kg^{-1})	Total soil-Cu (mg kg^{-1})	Total soil-Mn (mg kg^{-1})
No of primary braches	-							
No of leave	0.97^{***}	-						
Plant height	0.97^{***}	0.96^{***}	-					
Root DMY	0.68^{***}	0.71^{***}	0.75^{***}	-				
Shoot DMY	0.79^{***}	0.76^{***}	0.84^{***}	0.75^{***}	-			
Total soil-Cd	0.65^{***}	0.63^{***}	0.68^{***}	0.66^{***}	0.72^{***}	-		
Total soil-Cu	0.71^{***}	0.68^{***}	0.71^{***}	0.64^{***}	0.71^{***}	0.91^{***}	-	
Total soil-Mn	0.66^{***}	0.63^{***}	0.67^{***}	0.65^{***}	0.72^{***}	0.94^{***}	0.99^{***}	-

*** significant at $p \leq 0.001$; DMY = Dry Matter Yield in soil amended with chicken manure. Significant associations were found between growth, yield characteristics of celosia and total concentration of Cd, Cu and Mn in the amended soil. This indicates that significant amount of Cd, Cu and Mn taken up by celosia from the soil actually contributed to the growth and yield. In a previous study by (Oguntade et al. 2019), a significant correlation was reported between the growth, yield and heavy metals (Cu and Mn) uptake by Jute mallow (*Corchorus olitorius*) a similar leafy vegetable. Hanč et al. (2008) had also reported that close relationship exists between Cu taken up by oat and its biomass yield.

Correlation coefficients of selected soil properties, TF, root and shoot uptake of Cu and Mn as well as bioaccumulation of Cu and Mn in tissues of celosia are shown in Table 8. Soil pH significantly and directly influenced ECEC, root-Cu uptake, root-Mn uptake, shoot-Cu uptake, shoot-Mn uptake and bioaccumulation of Cu and Mn in celosia tissues. Meanwhile, the pH was inversely related with TF of the metals with a significant negative relationship with TF-Cu ($r = -0.79^{***}$). This showed that increased pH of amended soil lowered TF of the metals which was significant for Cu. Soil organic carbon was significantly and negatively correlated with ECEC ($r = -0.49^{**}$) but strongly correlated with TF-Mn ($r = 0.85^{***}$). Though the correlation between organic carbon, uptake and bioaccumulation of Cu and Mn were not significant, an inverse relationship exists amongst them. According to Jung and Thornton (1996); Rosselli et al. (2003) combination of high organic matter and soil pH are key determinants in reducing heavy metal uptake by plants. A significant negative relationship was found between ECEC, TF-Cu ($r = -0.55^{**}$) and TF-Mn ($r = -0.44^{*}$). This showed that as the soil exchange site was buffered with cations, TF of Cu and Mn into celosia tissues decreased. However, the relationship between ECEC, root and shoot uptake as well as bioaccumulation of Cu and Mn were positive. Generally, the TF of Cu and Mn were significantly and negatively correlated with uptake and bioaccumulation of the metals in celosia tissues. Root uptake of Cu and Mn were significantly ($p \leq 0.001$) and positively correlated with each other as well as with BAC and BCF of both metals. A similar relationship was observed between shoot uptake of the metals, its BAC and BCF. Except for BAC of Cu and Mn which was not significant, the relationships

Table 8 Relationships between soil properties, metal transfer, uptake and bioaccumulation in tissues of celosia at 6 WAS

	pH	Org C.	ECEC	TF-Cu	TF-Mn	Root-Cu uptake	Root-Mn uptake	Shoot-Cu uptake	Shoot-Mn uptake	BAC-Cu	BAC-Mn	BCF-Cu	BCF-Mn
pH	-												
Org C.	-0.24^{ns}	-											
ECEC	0.56^{**}	-0.49^{**}	-										
TF-Cu	-0.79^{***}	0.13^{ns}	-0.55^{**}	-									
TF-Mn	-0.29^{ns}	0.85^{***}	-0.44^{*}	0.06^{ns}	-								
Root-Cu uptake	0.71^{***}	-0.28^{ns}	0.64^{***}	-0.65^{***}	-0.37^{*}	-							
Root-Mn uptake	0.74^{***}	-0.33^{ns}	0.58^{***}	-0.61^{***}	-0.45^{*}	0.98^{***}	-						
Shoot-Cu uptake	0.78^{***}	-0.31^{ns}	0.70^{***}	-0.62^{***}	-0.44^{*}	0.79^{***}	0.80^{***}	-					
Shoot-Mn uptake	0.86^{***}	-0.22^{ns}	0.59^{***}	-0.70^{***}	-0.30^{ns}	0.77^{***}	0.80^{***}	0.96^{***}	-				
BAC-Cu	0.38^{*}	-0.14^{ns}	0.75^{***}	-0.47^{**}	-0.22^{ns}	0.64^{***}	0.56^{**}	0.66^{***}	0.53^{**}	-			
BAC-Mn	0.81^{***}	-0.02^{ns}	0.35^{ns}	-0.71^{***}	0.06^{ns}	0.50^{**}	0.55^{**}	0.57^{**}	0.73^{***}	0.34^{ns}	-		
BCF-Cu	0.69^{***}	-0.13^{ns}	0.74^{***}	-0.86^{***}	-0.13^{ns}	0.74^{***}	0.67^{***}	0.74^{***}	0.72^{***}	0.85^{***}	0.62^{***}	-	
BCF-Mn	0.83^{***}	-0.50^{**}	0.52^{**}	-0.61^{***}	-0.53^{**}	0.64^{***}	0.73^{***}	0.73^{***}	0.79^{***}	0.43^{*}	0.81^{***}	0.60^{***}	-

***, **, * = Significant at $p \leq 0.001, 0.01, 0.05$, respectively; *ns* = not significant; WAS = weeks after sowing between BAC and BCF of Cu and Mn in tissues of celosia were positive. The positive and significant relationship showed that the metals were taken up by the root, translocated to edible shoot and accumulated in tissues of celosia.

Conclusion

Soil amendment with CCM contributed significant amount of metals (Cu, Cd and Mn) to soil pollution indices compared to LCM. Heavy metals pollution of amended soil increased with manure rates. Bioaccumulation of heavy metals in celosia tissues increased with rate of amendment. Phytoextraction potentials of Cu by celosia was higher compared to Mn. Mobility of metals from soil via the root to shoot tissues depends not only on total concentration in soil but also on the type of metals involved. Soil amendment with chicken manures above 6 t ha^{-1} is not encouraged to avoid buildup of toxic metals in soils and its subsequent transfer to food crops.

Declarations

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Consent to participate: Not applicable.

Consent for publication: Not applicable.

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