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ORIGINAL RESEARCH

Assessment of composted kitchen waste and poultry manure amendments on growth, yield and heavy metal uptake by Jute mallow *Corchorus olitorius* Linn.

Oladele A. Oguntade[1] · Titilola S. Olagbenro[1] · Olubunmi A. Odusanya[1] · Solomon O. Olagunju[1] · Kayode M. Adewusi[1] · Adedotun T. Adegoke[1]

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Abstract

Purpose This study was carried out to compare the effects of composted kitchen waste (KW) and poultry manure (PM) soil amendments on growth, yield and heavy metal uptake in edible leaf of *Corchorus olitorius*.

Methods Kitchen waste and PM composted for 8 weeks were applied as soil amendment at the rate of 0 (no amendment), 5, 10 and 15 t ha^{-1}. Corchorus seeds were sown 2 weeks after incorporation of amendment. Compost amendments were the main treatments while application rates were in sub-plots. Treatments were replicated three times in a randomized complete block design. Corchorus were harvested 6 weeks after sowing, following which growth and yield parameters were measured. Concentrations of manganese (Mn), iron (Fe), copper (Cu) and zinc (Zn) in leaf tissue and plant uptake were also determined.

Results Result showed that PM increased Corchorus leaf production than KW. Poultry manure significantly ($p \leq 0.01$) increased Cu accumulation in leaf. Bioaccumulation of Cu was 0.005 and 0.011 mg kg^{-1} for KW and PM, respectively. The metals except Zn in leaf tissue showed significant ($p \leq 0.01$) correlation with both fresh and dry weights of Corchorus. Despite high concentration of heavy metals in the compost, bioaccumulation in leaf was lower than maximum allowable limit of 0.1 mg kg^{-1} for Cu and 0.3 mg kg^{-1} for Mn, Fe and Zn in vegetables by WHO/FAO/FEPA.

Conclusion Soil amended with composted KW and PM promoted Corchorus growth and yield. Accumulations of heavy metals in leaf tissue are within allowable limit for vegetables.

Keywords Bioaccumulation · Compost · *Corchorus olitorius* · Edible leaf · Soil amendment

Introduction

Management of domestic solid waste generated in most Nigerian homes is a growing challenge that requires urgent attention. Poor management of domestic waste impacts on our environment negatively. With larger proportion of the domestic wastes being organic, an alternative source of compostable materials that could serve as soil ameliorant could become attractive. Use of compostable solid waste as soil amendment in crop production is a sustainable way of recycling that reduces disposal to landfill (Petersen et al. 2003; Chen and Jiang 2014). Compost is an important resource for soil amendment in organic farming with the benefits of being environment-friendly. Composted manure helps to modify physical, chemical, and biological properties of the soil, provides slow release of nutrients and increases crop yield (Agbede et al. 2008; Moral et al. 2009). Composted organic manure especially from poultry wastes have been reported to improve mineral composition in tissues of vegetables such as Jute mallow (Mazen et al. 2010; Jonathan et al. 2012). In contrast to the beneficial roles of compost, it could also be a potential source of contaminants depending on its origin (Petersen et al. 2003; Hanč et al. 2008).

Leafy vegetables have the potentials of accumulating heavy metals in their edible and non-edible portions in concentrations that could cause health problems to consumers when grown in contaminated medium (Alam et al. 2003; Oguntade et al. 2015). Uptake of heavy metals by vegetables in high concentration could also hinder metabolic processes

✉ Oladele A. Oguntade
deletade@yahoo.com; dele.oguntade@oouagoiwoye.edu.ng

[1] Department of Crop Production, College of Agricultural Sciences, Olabisi Onabanjo University, P.M.B. 0012, Ayetoro Campus, Ayetoro, Ogun State, Nigeria

such as photosynthesis and growth in such plant and consequently lead to reduction in yield (Yang et al. 2002; Wang et al. 2013; Ng et al. 2016). *Corchorus olitorius* known as Jute mallow is a popular green leafy vegetable consumed by various communities in many African countries including Nigeria (Schippers 2002; Samra et al. 2007). The slimy sticky sauce of its cooked leaves is often considered as the best and more acceptable one than okro in western Nigeria even at social gathering for consumption of any starchy staples served (Denloye et al. 2014). *Corchorus olitorius* is a vegetable consumed for its dietary fiber, vitamins, minerals, protein as well as abundant β-carotene and other carotenoids needed for good health (Schippers 2002). The leaf is also a rich source of iron, protein, calcium, thiamin, riboflavin, niacin, foliate, and dietary fiber (Oyedele et al. 2006; Samra et al. 2007).

Considering the economic and environmental benefits of organic wastes, the use of composted organic waste in production of *Corchorus olitorius* could be an alternative strategy of waste management and disposal. Although, information on the use of manure for vegetable production is well documented, little is, however, known on the use of composted kitchen waste and poultry manure for jute mallow production. This study, therefore, focuses on the growth, yield and heavy metal bioaccumulation in edible leaf of *Corchorus olitorius* grown on soil amended with composted kitchen waste and poultry manure.

Materials and methods

Description of the study site

This study was conducted at the Teaching and Research Farm of the Olabisi Onabanjo University, College of Agricultural Sciences, Ayetoro Campus, Ogun State, Nigeria. Ayetoro is in the derived savannah ecology of Ogun State with mean annual rainfall of 1250 mm and mean temperature of 26 °C. It has a bimodal rainfall pattern with its peaks in June and September. The experimental site was located at 07.23076°N, 03.04540°E and 89 m above sea level.

Collection and preparation of kitchen waste and poultry manure as compost

Decomposable kitchen wastes collected from various homes and from leftovers of food at social gatherings were used for this study. Similarly, poultry manure from birds fed with maize and groundnut cake-based feed was collected from the University's poultry farm at Ayetoro campus for the compost preparation. The kitchen waste and poultry manure were composted for 8 weeks following the Chinese rural composting-high temperature method (Misra et al. 2003). Composts were then air-dried for 2 weeks and sieved with 2 mm sieve to remove undecomposed materials before field application (Plate 1). Sub-samples of the composted wastes were analyzed in the laboratory for its chemical properties (Table 1).

Plot establishment, soil sample collection and preparation

The experiment was a split-plot arrangement in a Randomized Complete Block Design (RCBD) replicated three times. Main-plot treatments were the composted kitchen waste and poultry manure, while sub-plot treatments were compost rates of 0 (no amendment/control), 5, 10, 15 t ha^{-1}. The treatment plots were laid out with a spacing of 1 m between treatments and 2 m between replicates. Each of the treatments (compost) was incorporated into the soil on 1 m by 1 m elevated bed 2 weeks before sowing (WBS). Prior to treatments application, core soil samples were randomly collected (0–15 cm) from the experimental plot with a soil auger and bulked to obtain composite sample. Thereafter, the composite soil sample was air-dried and sieved with 2 mm sieve for routine analysis in the laboratory.

Corchorus seeds preparation and sowing

Prior to sowing, Corchorus seeds were pre-treated with hot water at 90 °C for 4 s to break its dormancy and later air-dried for a day (Jayasuriya et al. 2007; Tolorunse et al. 2015). The air-dried seeds were then drilled on elevated beds earlier amended with either composted KW or PM at the spacing of about 10 cm between rows. Due to irregular rainfall between the second and the fourth week after sowing

Table 1 Chemical properties of composted kitchen waste and poultry manure

Chemical composition	Units	Kitchen waste	Poultry manure
pH (H_2O)		8.80	8.75
Total N	g kg^{-1}	2.90	3.20
Total organic carbon		50.40	55.90
Total P	mg kg^{-1}	0.46	0.35
C/N ratio		17.38	17.47
Ca	cmol kg^{-1}	2.83	3.05
Mg		0.74	0.57
Na		1.51	0.71
K		1.46	0.69
Heavy metals			
Mn	mg kg^{-1}	4000.00	7000.00
Fe		4200.00	6800.00
Cu		30.00	45.00
Zn		278.00	354.00

(WAS), each treatment plot was irrigated with equal volume (10 L) of fresh water collected from adjoining stream every evening. Overhead method of irrigation was adopted with the use of watering can. This is similar to the practice of local farmers in the area. Corchorus seedlings were thinned at 2 WAS to 1 plant per stand at about 4 cm within the row. Weeding was done manually by uprooting weeds regularly and retaining them on their various plots.

Agronomic data collection

At 6 WAS, agronomic parameters of twenty (20) stands of *Corchorus olitorius* taken from a quadrant of 0.5 m by 0.5 m placed on each treatment plot were recorded. Plant height was measured with a meter rule from the soil surface to the terminal bud. The number of leaves and primary branches was determined by direct counting. The edible portions of the leaves excluding the petiole were then plucked and the fresh weight was determined. Thereafter, the leaves were cleaned with fresh tap water, air-dried and later oven-dried at 60 °C to constant weight to determine the dry weight. After drying, leaves were ground with pestle and mortar for chemical analysis.

Chemical analysis of compost manure

The pH of the composted manure was determined with the glass electrode pH meter. Nitrogen (N) was determined by Kjeldahl method, organic carbon by wet oxidation method (Nelson and Sommer 1996), while phosphorus (P) was determined colourimetrically. The calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na), as well as Mn, Fe, Cu, and Zn in the compost samples were determined by atomic absorption spectrophotometer, AAS (Buck Scientific 210VGP Model, Inc., East Norwalk, CT, USA) according to Udo et al. (2009).

Soil analysis

The pH of the soil in water was determined by glass electrode pH meter. Total N was determined by micro-Kjeldahl method, organic carbon content was determined by Walkley and Black method (1934) using dichromate ($K_2Cr_2O_7$) as oxidizing agent. Available P was determined colourimetrically by Bray-1- method (Bray and Kurtz 1945). Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with 1 N ammonium acetate (NH_4OAc pH 7.0) after which Ca^{2+} and Mg^{2+} were read on AAS, while K^+ and Na^+ were determined with flame photometer. Exchangeable acidity was determined by titration method following extraction of soil samples with 1 N KCl solution (Anderson and Ingram 1993). The effective cation exchange capacity (ECEC) was estimated by summation of exchangeable acidity ($H^+ + Al^{3+}$) and exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+). Base saturation was calculated as the ratio of sum of exchangeable cations to ECEC expressed in percentage. The heavy metals including Fe, Cu, Zn, and Mn in the soil were determined by wet digestion method and read on AAS. The analyses followed the procedures in Okalebo et al. (1993) and Udo et al. (2009). Particle size distribution was analyzed by the hydrometer method (Bouyoucos 1951).

Heavy metal analysis in plant samples

Earlier ground Corchorus leaves were weighed (0.5 g) into digestion tubes; then 10 ml of mixture of nitric and perchloric acid (2:1) was added. The content in the tubes was digested for the first 90 min at 150 °C. Thereafter, 2 ml of concentrated HCl and distilled water was added and the temperature of the digest was raised to 230 °C and further digested for another 30 min. The digest was then allowed to cool at room temperature after which the content was transferred into a 50-ml volumetric flask and made up to mark with distilled water. The concentrations of Mn, Fe, Cu and Zn in the sample solutions were then determined using atomic absorption spectrophotometer. Plant uptake was estimated on dry weight basis as the product of metal concentration and dry weight.

Data analysis

The data obtained were subjected to analysis of variance (ANOVA). Treatment means were separated using Fisher's Protected Least Significant Difference (LSD) at 5% probability.

Results

Chemical composition of compost manure

Chemical compositions of the composted KW and PM are presented in Table 1. The pH of the two composts was moderately alkaline with PM being more alkaline than KW. The total N was 2.90 g kg^{-1} in KW and 3.20 g kg^{-1} in PM. Organic carbon was lower in KW than in PM. Total phosphorus was higher in KW than in PM. Poultry manure and KW composts had the same C/N ratio level, which reflected its carbon and N contents. Except for Ca, the total Mg, Na and K were found to be higher in the KW than in PM. The concentrations of heavy metals including Mn, Fe, Cu and Zn of 4000, 4200, 30 and 278 mg kg^{-1}, respectively, in KW were lower than 7000, 6800, 45 and 354 mg kg^{-1}, respectively, in PM (Table 1).

Physicochemical soil properties of the experimental site indicated that pH of the soil was moderately acidic

Table 2 Physicochemical soil properties of the experimental site

Soil properties	Units	Values
pH (H_2O)		5.95
Total N	g kg^{-1}	0.90
Total organic carbon		11.79
Available P	mg kg^{-1}	17.68
Ca	cmol kg^{-1}	8.38
Mg		2.21
Na		0.50
K		0.30
Exchangeable acidity		0.08
ECEC		11.47
Base saturation	%	99.93
Mn	mg kg^{-1}	16.80
Fe		20.80
Cu		0.70
Zn		4.80
Sand	g kg^{-1}	828.00
Silt		54.00
Clay		118.00
Texture		Loamy sand

(Table 2). Total N and organic carbon were very low, while available P was high. The exchangeable cations in the soil which were 8.38, 2.21, 0.50 and 0.30 cmol kg^{-1} for Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}, respectively, were high. The exchangeable acidity was very low. Available form of Mn in the soil was 16.80 mg kg^{-1}. The available Fe and Zn of 20.80 and 4.80 mg kg^{-1}, respectively, in the soil were quite high. The texture of the soil was loamy sand with high proportion of sand, low silt and moderately low clay content (Table 2).

Table 3 shows the effects of different rates of composted KW and PM amendments on the growth and yield of *Corchorus olitorius*. The effects of the two amendments on growth and yield parameters were not significantly different except on the number of leaves. Poultry manure significantly ($p \leq 0.05$) increased the number of leaves in Corchorus compared to KW. The different rate of amendment applied increased plant height, number of leaves and primary branches significantly ($p \leq 0.01$) (Table 3). The Corchorus grown in soil without amendment gave the least mean plant height, number of leaves and primary branches, while those grown with 15 t ha^{-1} of the amendment gave the highest growth parameters recorded. Meanwhile, there were no significant differences on both fresh and dry biomass yields at the different rate of amendment.

The interactive effects of the type of compost and its rates of application contributed significantly ($p \leq 0.01$) to increased Corchorus height and number of primary branches (Figs. 1 and 2). In particular, at compost rate of 15 t ha^{-1}, the mean plant height was higher with PM than with KW (Fig. 1). Meanwhile, the difference in mean number of primary branches observed at 10 t ha^{-1} of the amendment showed that PM was higher than KW in inducing primary branches in Corchorus (Fig. 2).

Accumulation of heavy metals in leaf tissue (dry weight) of Corchorus grown on compost amended soil is presented in Table 4. Among the metals, only Cu was significantly ($p \leq 0.01$) taken up and bioaccumulated in leaf tissue of Corchorus. The amount of Cu which accumulated in the leaf of Corchorus grown on PM amended soil was

Table 3 Effects of compost types and their rates of application on growth and yield of *Corchorus olitorius* at 6WAS

Source of variation	Plant height (cm)	Number of leaves	Number of primary branches	Leaf fresh weight (t ha^{-1})	Leaf dry weight (t ha^{-1})
Compost type					
KW	20.61	7.76	3.35	1.67	0.54
PM	20.96	8.75	3.36	1.72	0.55
(Sig.)	ns	*	ns	ns	ns
$LSD_{(0.05)}$	1.01	0.78	0.08	0.60	0.17
Rates					
0	17.55	7.18	2.36	1.43	0.47
5	19.53	7.88	3.19	1.62	0.53
10	21.08	8.42	3.60	2.06	0.63
15	24.96	9.54	4.28	1.68	0.54
(Sig.)	**	**	**	ns	ns
$LSD_{(0.05)}$	1.42	1.10	0.11	0.85	0.23
Compost * rate	**	ns	**	ns	ns

ns not significant

*,**Significant at 5% and 1%, respectively, using Fisher's protected LSD

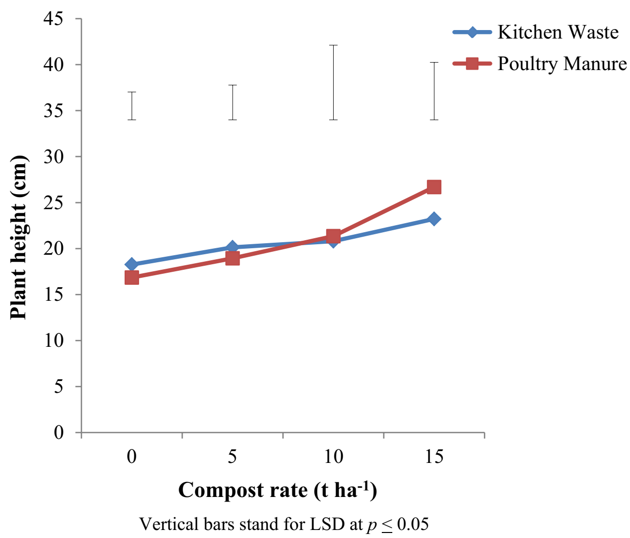

Fig. 1 Responses of Corchorus height to rates of compost amendment. Vertical bars stand for LSD at $p \leq 0.05$

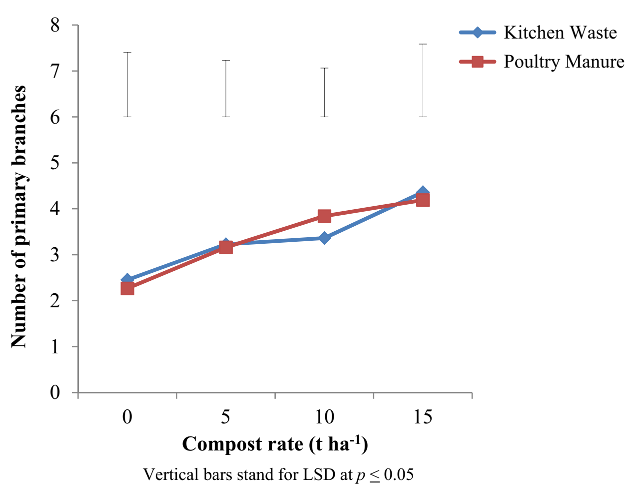

Fig. 2 Responses of primary branches of Corchorus to rates of compost amendment. Vertical bars stand for LSD at $p \leq 0.05$

more than double compared to 0.005 mg kg^{-1} with KW amendment. The results also showed that various rates of compost amendment used were not significantly different on the heavy metal uptake in Corchorus leaf. However, interactive effects of the compost types and its rates further showed significant ($p \leq 0.05$) uptake and accumulation of Cu in Corchorus leaf. The study showed that positive and significant ($p \leq 0.01$) correlation exists between the heavy metals uptake in leaf tissue and biomass yield of Corchorus (Table 5). Both fresh and dry biomass of Corchorus leaf were highly correlated ($p \leq 0.01$) with the heavy metals uptake except for Zn. Manganese and Zn uptake correlated significantly ($p \leq 0.05$) with the number of primary branches, while Cu and Mn uptake were correlated ($p \leq 0.05$) with the plant height. Only Cu also showed significant correlation with mean number of leaves produced by Corchorus.

Discussion

The proximate composition of composted KW and PM applied as soil amendment in this study revealed that PM was higher in its organic constituent than KW. This explains why PM promoted significant increase in the number of leaves in Corchorus compared to KW. The higher concentration of total P, Mg, Na and K found in the composted KW relative to PM was an indication of the presence of salts of these nutrients in the KW than PM. This showed that KW can serve as a good alternative to PM in supplying mineral nutrients required for growth and structural development of crops. This probably explains why there was no significant difference between KW and PM on growth and yield recorded except on the number of leaves. However, higher concentration of heavy metals in PM than KW observed could be primarily from the feeds and drugs given to the poultry birds (Zhang et al. 2005; van Zanten et al. 2014). High concentration of heavy metals in PM compared to KW could, therefore, limit its use to reduce bioaccumulation of the metals in edible portion of Corchorus. Since heavy metals are known to be resistant to biodegradation with long biological half-life, coupled with the tendency of been taken up by *Corchorus olitorius* from amended soil, it follows that the metals can persist in the growth medium and contaminate the food chain (Garbarino et al. 2003; Jackson et al. 2003; Sapkota et al. 2007).

The poor quality of the soil used for this study, as depicted by low concentration of nitrogen when compared with critical level of 1.5–2.0 g kg^{-1} reported by Sobulo and Osiname (1981), justifies the need for organic amendment in such soil for production of leafy vegetable like Corchorus. Application of composted KW and PM as soil amendments increased Corchorus growth and yield in comparison with the control soil without amendment. However, the high ECEC of the soil indicated that the soil exchange site was dominated by exchangeable bases particularly Ca^{2+} and Mg^{2+}. Calcium, Mg^{2+}, Na^{+} and K^{+} concentrations in the soil were higher than critical levels of 1.5 cmol kg^{-1} for Ca^{2+} (Enwezor et al. 1990), 0.28 cmol kg^{-1} for Mg^{2+} (Agboola and Ayodele 1985; FMANR 1990), 0.02 cmol kg^{-1} for Na^{+} (Amalu 1997) and 0.15 cmol kg^{-1} for K^{+} (Uponi and Adeoye 2000). Meanwhile, the concentration of Mn was higher than critical level of 1.00 mg kg^{-1} (Udoh et al. 2008). Iron was in several folds higher than critical level of 4.50 mg kg^{-1} reported by Lindsay and Norvell (1978). Available Cu in

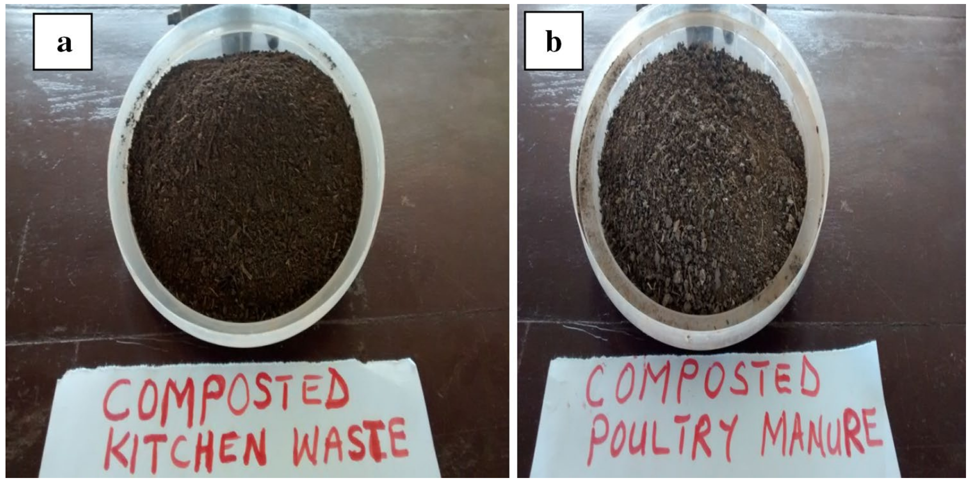

Plate 1 Composted kitchen waste (**a**) and poultry manure (**b**) used as soil amendment

Table 4 Heavy metal uptake by *Corchorus olitorius* leaves grown on soil amended with composted kitchen waste and poultry manure 6WAS

Source of variation	Mn (mg kg^{-1})	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})
Compost type				
Kitchen waste	0.014	0.210	0.005	0.016
Poultry manure	0.015	0.212	0.011	0.010
(Sig.)	ns	ns	**	ns
$LSD_{(0.05)}$	0.005	0.067	0.003	0.015
Rates (t ha^{-1})				
0	0.011	0.178	0.006	0.006
5	0.013	0.196	0.006	0.008
10	0.018	0.254	0.010	0.012
15	0.017	0.218	0.009	0.025
(Sig.)	ns	ns	ns	ns
$LSD_{(0.05)}$	0.007	0.094	0.004	0.022
Compost * rates	ns	ns	*	ns
FAO/WHO/FEPA maximum limits	0.30	0.30	0.10	0.30

ns not significant, *FEPA* Federal Environmental Protection Agency, Nigeria

*,**Significant at 5% and 1%, respectively, using Fisher's protected LSD

Table 5 Correlation analysis between yield parameters and heavy metal uptake in *Corchorus olitorius* leaves

Parameters	Cu	Fe	Mn	Zn	LDW (t ha^{-1})	LFW (t ha^{-1})	NPB	PHt. (cm)	NL
Cu									
Fe	0.71**	–							
Mn	0.75**	0.97**	–						
Zn	−0.02ns	0.15ns	0.24ns	–					
LDW (t ha^{-1})	0.68**	0.98**	0.94**	0.12ns	–				
LFW (t ha^{-1})	0.71**	0.98**	0.95**	0.10ns	0.99**	–			
NPB	0.33ns	0.25ns	0.43*	0.44*	0.18ns	0.20ns	–		
PHt. (cm)	0.46*	0.34ns	0.47*	0.11ns	0.27ns	0.28ns	0.78**	–	
NL	0.47*	0.16ns	0.31ns	0.30ns	0.12ns	0.31ns	0.73**	0.63**	–

LDW leave dry weight, *LFW* leaves fresh weight, *NPB* number of primary branches, *PHt.* plant height, *NL* number of leaves, *ns* not significant

*,**Correlation is significant at 5% and 1%, respectively, using Fisher's protected LSD

this soil was above the critical value of 0.2 mg kg^{-1} given by Sims and Johnson (1991). Similarly, concentration of Zn in the soil was higher than critical value of 0.8 mg kg^{-1} reported by Lindsay and Norvell (1978) and 0.5 mg kg^{-1} according to Udoh et al. (2008).

The contribution of compost amendment to higher growth and yield of Corchorus compared to control soil without amendment was a reflection of the beneficial roles played by the compost amendment in enhancing crop yield (Chiu et al. 2006; Agbede et al. 2008). Although, beyond 10 t ha^{-1} rate, PM-amended soil contributed to higher yield of Corchorus than KW, it may not be safe to use higher rate of PM as soil amendment since PM contains higher concentration of heavy metals. This, in a way, can reduce the source of contaminant and subsequent transfer of heavy metal to edible portion of Corchorus. Previous studies have reported that the origin of a particular compost material could be a potential source of heavy metals in the plant tissues (Petersen et al. 2003; Hanč et al. 2008).

The higher accumulation of Cu in Corchorus leaf with PM than KW reflected the higher concentration of Cu in PM amendment over KW. This observation implies that larger proportion of Cu from PM amended soil was translocated through roots to the leaf probably due to its high mobility. This finding is contrary to what Hanč et al. (2008) found in biomass of oat grown on soil amended with compost having high level of Cu. A lower uptake of Cu reported was adduced to localization in root tissue of oat. This showed that Cu uptake and mobility to upper part of the plant are not consistent and could vary with the type of crop. The declined Mn, Fe and Cu uptake at higher compost rate of 15 t ha^{-1}, despite higher concentration of the metals in the soil, corroborates previous studies on the chelating impact of compost and organic amendments on heavy metal uptake by crops (Angelova et al. 2010). Although, the compost used in this study, especially the PM, had high levels of heavy metals, bioaccumulation in Corchorus leaf was lower than the maximum allowable limits by WHO/FAO/FEPA in vegetables. This was due to chelating reaction of the organic compounds in the compost or the role played by humic portion of the compost which immobilized the heavy metals (Tlustoš et al. 2006; Cooper et al. 2011; Oguntade et al. 2015). This showed that production of Corchorus with these composts under this condition was safe for human consumption without threat to health of the consumers.

The significant correlation of biomass yield with heavy metal uptake by Corchorus indicated that Mn, Fe and Cu contributed to leaf development and yield. In a similar study (Hanč et al. 2008), an increased in Cu uptake was found to be in close correlation with biomass yield of oat. Moreover, the correlation of Mn and Zn with the number of primary branches indicated that these metals induced primary branching in Corchorus.

Conclusion

It is evident in this study that composted KW can support Corchorus production favourably like composted PM. The higher concentration of P, K, Mg and Na in composted KW than PM in this study is worthy of note. Although, composted PM had higher concentration of nitrogen and calcium than KW, the higher concentrations of heavy metals in the PM could be a major source of contaminant. Hence, usage of PM in vegetable production could contribute largely to heavy metal contamination of food crops than KW. Application of 10 t ha^{-1} of composted KW and PM is suggested as soil amendment for optimum yield of Corchorus to reduce soil and food chain contamination by the toxic metals. However, while converting compostable wastes into organic fertilizer, it is imperative to investigate the potential heavy metal status of any waste to be used in production of food crops to reduce possible transfer of toxic metals to human.

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