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RESIDUAL EFFECT OF COMPOSTED KITCHEN WASTE AND POULTRY MANURE SOIL AMENDMENTS ON YIELD AND CONCENTRATIONS OF COPPER, IRON, MANGANESE AND ZINC IN LEAF TISSUE OF JUTE MALLOW (*CORCHORUS OLITORIUS* LINN)

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ABSTRACT

Source of organic amendment for the production of vegetable crops is of prime importance for safe soil to prevent contamination of the food chain. This study assessed residual effects of composted kitchen waste (KW) and poultry manure (PM) soil amendments on growth, leaf dry weight (LDW), accumulation and transfer of four heavy metals: copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) in leaf tissue of Jute mallow (Corchorus olitorius) under field condition. The main treatments (KW and PM) and sub-treatments amendment rates (0, 5, 10, 15 t ha^{-1}) were replicated three times in a Randomized Complete Block Design (RCBD). At six weeks after sowing, plants were harvested and leaf tissue was analyzed. Data collected were subjected to analysis of variance (ANOVA) and result showed that plant amended with PM gave significantly ($p \leq 0.05$) higher fresh biomass and LDW than those with KW at 10 t ha^{-1}. Heavy metal accumulation in leaf tissue of Jute mallow was higher across rates with PM than KW amendment. Transfer factor (TF) of metals from soil to the leaves was highest with KW than PM at 5 t ha^{-1}. Intensity of metal accumulation is in the order of TF for Zn (1.46-2.38) > Cu (0.77-1.37) > Mn (0.24-0.40) > Fe (0.026-0.039). The TF decreased with increased amendment rate despite increased total concentration of metals in the soil. Poultry manure with higher metal binding effect can immobilize metals better than KW.

Key words: accumulation, amendment, composted, heavy metals, transfer factor

INTRODUCTION

Soil amendment with composted organic materials is an environmental friendly approach in organic farming from which ethically acceptable crops can be grown. Depending on the source, composted organic manure applied as amendment can raise natural levels of metals in soils and contribute to food chain contamination apart from modifying physical, chemical and biological properties of the soil (Hanč *et al*., 2008; Luo *et al*., 2009). Metals such as copper, iron, manganese and zinc, although are needed by plants and animals for biological functions, they are also known to be toxic at higher doses or concentrations in living organisms (Tamás and Martinoia 2005; Tamás *et al*., 2014). These metals are referred to as toxic heavy metals because they have densities greater than 5g cm^{-3} and are usually associated with contamination and toxicity in the environment (Azeez *et al*., 2013).

As a substitute for chemical fertilizer, composted manure amendment had been reported in many studies as a good source of improving soil productivity which enhances crop growth and mineral composition of vegetables such as Jute mallow (Jonathan *et al*., 2012; Emuh 2013; Asmaa *et al*., 2014). Emuh (2013) had reported higher Jute mallow yield with 20 t ha^{-1} of poultry manure. Composted manure of up to 60 kg N resulted in highest biomass yield and chemical nutrient accumulation in leaf tissues of Jute mallow than lower rates of 45 and 30 kg N (Asmaa *et al*., 2014). Kitchen organic waste applied inform of compost amendment can be a better and safe option of managing food waste out of the problems of greenhouse gases from landfills (Salemdeeb *et al*., 2017) which can improve soil nutrients status. In addition to promoting root growth and biomass development in leafy vegetables such as Jute mallow, organic amendment can also stimulate absorption of metallic element from the soil (Zapata and Axman, 1995; Asmaa *et al*., 2014). However, application of biosolid amendment from compost and livestock manures could be one of the major sources of heavy metals through soil to plant tissues (Summer, 2000; Basta *et al*., 2005; Chehregani and Malayeri 2007). Hence, while improving soil productivity with organic manure, residues of toxic materials from feed ingredient and veterinary drugs given to poultry birds can increase soil metal contamination and subsequent uptake by crops (Zhang *et al*., 2005; Li *et al*., 2011, van Zanten *et al*., 2014). Hitherto, the role of compost, manure and organic wastes in amelioration of heavy metals in contaminated soils through immobilization and reduction in plant uptake is generally acknowledged (Clemente *et al*., 2005 a; Li, *et al*., 2006; Alamgir *et al*., 2011).

Jute mallow is an important leafy vegetable cultivated for its mucilaginous leaves in many African countries including Nigeria (Zakaria *et al*., 2006; Asmaa *et al*., 2014). The leaves of Jute mallow prepared as soup is regularly consumed in an average home in Nigeria due to its rich source of protein, carotenoids, vitamins, minerals as well as dietary fiber which make people consider it as health vegetable (Schipper, 2000; Asmaa *et al*., 2014). Jute mallow grown in soil amended with compost manure had been reported to bio-accumulate nutrient elements and mineral nutrients in its tissues compared with no amendment (Asmaa *et al*., 2014).

When trace metals like copper, iron, manganese and zinc bio-accumulate above threshold level in edible leaves of Jute mallow, it can lead to contamination of the food chain. Consumption of vegetable grown in heavy metals contaminated soil is one of the routes of heavy metal intake by human beings (Khan *et al*., 2009; Oguntade *et al*., 2015). Due to possible risk of transfer of metals from residues of composted poultry manure and kitchen waste soil amendment to plant and to food chain, there is need to ascertain that there is no risk of heavy metal contamination on Jute mallow grown with these composted materials. This study therefore evaluate the residual implication of composted poultry manure vis-à-vis kitchen waste applied as soil amendment on growth and metal accumulation in edible leaves of Jute mallow.

MATERIALS AND METHODS

Description of the study Area

This study was carried out at the Teaching and Research Farm of the College of Agricultural Sciences, Ayetoro Campus of Olabisi Onabanjo University, Ogun State, Nigeria. The campus is located in the derived savannah agro ecology of Ogun State. The area has a bimodal rainfall pattern with its peaks in June and September. It has mean annual rainfall of 1250 mm and temperature of 26 ^{o}C. The geographical position system (GPS) coordinate of the experiment site was on Longitude 07.23076^{0} N; Latitude 03.04540^{o} E and 89 metres above sea level (ASL).

Experimental procedure

This study was a residual study and as such was predicated on our previously studied experimental plot. Composted kitchen waste (KW) and poultry manure (PM) applied as soil amendments at the rate of 0, 5, 10 and 15 tons ha^{-1} were used for the trial. The lay-out of the experiment was a Randomized Complete Block Design (RCBD) replicated thrice. The total plot size used for the study was 20 m x 8 m. Each replicate of 6 m x 8 m was divided into 8 treatment plots of 1 m x 1 m elevated beds such that there were spacing of 1 m between treatments and 2 m between replicates. Compost from KW and PM were the main-plot treatments while compost rates (0, 5, 10, 15 tons ha^{-1}) were sub-plot treatments. The first cycle of jute mallow grown on the plots for six weeks before harvesting, was sown two weeks after the amendments were applied. After two weeks of harvesting the first cycle of Jute mallow from the plots, the treatment plots were minimally tilled to pulverize the soil. Seeds of Jute mallow earlier pre-treated with hot water were then sown by drilling method. At two weeks after sowing (WAS), plant populations were monitored by thinning seedlings while weeds were uprooted regularly. At 6 WAS, agronomic data of 20 plants randomly selected from a quadrant placed at the middle of the each plot were taken. Plant height was measured with measuring tape, number of leaves and primary branches were counted. Fresh leaves were oven dry at (60 ^{o}C), weights were monitored until a constant weight was obtained. After harvesting of the vegetable, soil samples were collected from each treatment plot at 0-15 cm depth, air dried and sieved for chemical analysis.

Heavy metals analysis in plant and soil

For heavy metal analysis, 0.5 g of dried plant or soil sample was weighed into a digestion tube, 10 ml of the mixture of nitric and perchloric acid (2:1 v/v) was added. The samples were then digested in a microwave digester for 90 minutes at 150 ^{o}C at first and for another 30 minutes at 230 ^{o}C after adding 2 ml of concentrated HCl and distilled water. The digest were cooled at room temperature, after which its contents were transferred into volumetric flask and made up to mark with distilled water (Udo *et al*., 2009). The digested plant or soil samples were then analyzed for concentration of Cu, Fe, Mn and Zn by Atomic Absorption Spectrophotometer (AAS; Buck Scientific 210 VGP, Inc., East Norwalk, CT, USA).

Determination of Transfer Factor of metals from soil to plant

The plant metal Transfer Factor (TF) was estimated on dry weight basis as the concentration of metal in edible leaves of the plant divided by the total concentration of the metal in the soil (Cui *et al*., 2004; Kachenko and Singh, 2006). The TF was calculated as follows:

$$TF = C_{plant}/C_{soil}.$$

where; C_{plant} and C_{soil} represents metal concentrations in plants and soils, respectively. Data collected were subjected to analysis of variance (ANOVA). Treatment means were separated using Fisher's Protected Least Square Difference (LSD) at 5% probability.

RESULTS AND DISCUSSION

Growth and yield of Jute mallow

Table 1 shows that the mean plant height, number of leaves and primary branches of Jute mallow grown on soil amended with KW were not significantly different from those with PM. Meanwhile, the leaf fresh biomass yield was significantly ($p \leq 0.05$) higher in Jute mallow grown with PM (42.38 t ha^{-1}) than with KW (34.51 t ha^{-1}). The different rates of composted KW and PM soil amendments generally increased growth characteristics and biomass yield of Jute mallow over no compost amendment (control) Table 2. There were no significant differences between KW and PM at the different rates on plant height. The highest plant heights at 15 t ha^{-1} of the amendments were 43.13 and 42.03 cm for KW and PM, respectively. This is an indication that both KW and PM amendments can compete favourably well in supporting the growth of Jute mallow. Poultry manure significantly ($p \leq 0.05$) increased mean number of leaves at 5 t ha^{-1} (17.33) and 10 t ha^{-1} (18.36) rates over control (15.17). At the rates of 5 and 10 t ha^{-1}, number of leaves and primary branches were higher with the use of PM than KW. But at 15 t ha^{-1} KW gave higher mean number of leaves (18.73) and number of primary branches (12.87) which were significantly higher than number of leaves (15.97) and primary branches (10.37) with PM. At 10 t ha^{-1} of the compost, highest fresh biomass yield (leaf fresh weight) of 52.67 t ha^{-1} was produced by plant treated with KW. The role of composted KW and PM in improving growth of Jute mallow was a reflection of slow release of its nutrients from previous amendment which was more readily available now for plant use (Clemente *et al*., 2005 b). At compost rate of 5 t ha^{-1}, PM (7.67 t ha^{-1}) gave higher LDW than KW (6.20 t ha^{-1}). The highest LDW of 11.10 t ha^{-1} recorded with PM was significantly ($p \leq 0.05$) higher than 8.17 t ha^{-1} with KW at 10 t ha^{-1} rate. This is an indication of the quality of PM over KW in contributing to higher LDW.

Table 1: Analysis of variance showing the main effect of composted kitchen waste and poultry manure on growth and yield of Jute mallow (*Corchorus olitorius*) at 6 WAS

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					
Kitchen waste	41.11	17.09	11.15	34.51	7.61
Poultry manure	39.58	16.71	10.56	42.38	8.88
Sig.	ns	ns	ns	*	ns
LSD (0.05)	8.211	0.981	1.084	6.944	1.442

* significant at 5% probability level; ns = not significant

Table 2: Residual influence of composted kitchen waste and poultry manure rates on growth and yield of Jute mallow (*Corchorus olitorius*) at 6 WAS

Compost rate (t ha^{-1})	Plant height (cm)		Number of leaves		Number of primary branches		Leaf fresh weight (t ha^{-1})		Leaf dry weight (t ha^{-1})	
	Kitchen waste	Poultry manure	Kitchen waste	Poultry manure	Kitchen waste	Poultry manure	Kitchen waste	Poultry manure	Kitchen waste	Poultry manure
0	36.01	35.87	14.83	15.17	8.63	8.60	26.33	27.97	5.07	5.43
5	42.53	41.72	15.93	17.33	9.50	10.83	29.50	34.50	6.20	7.67
10	38.76	38.70	15.84	18.36	10.58	12.44	36.90	52.67	8.17	11.10
15	43.13	42.03	18.73	15.97	12.87	10.37	35.30	40.37	8.10	8.57
LSD (0.05)	16.443		1.962		2.167		13.889		2.884	

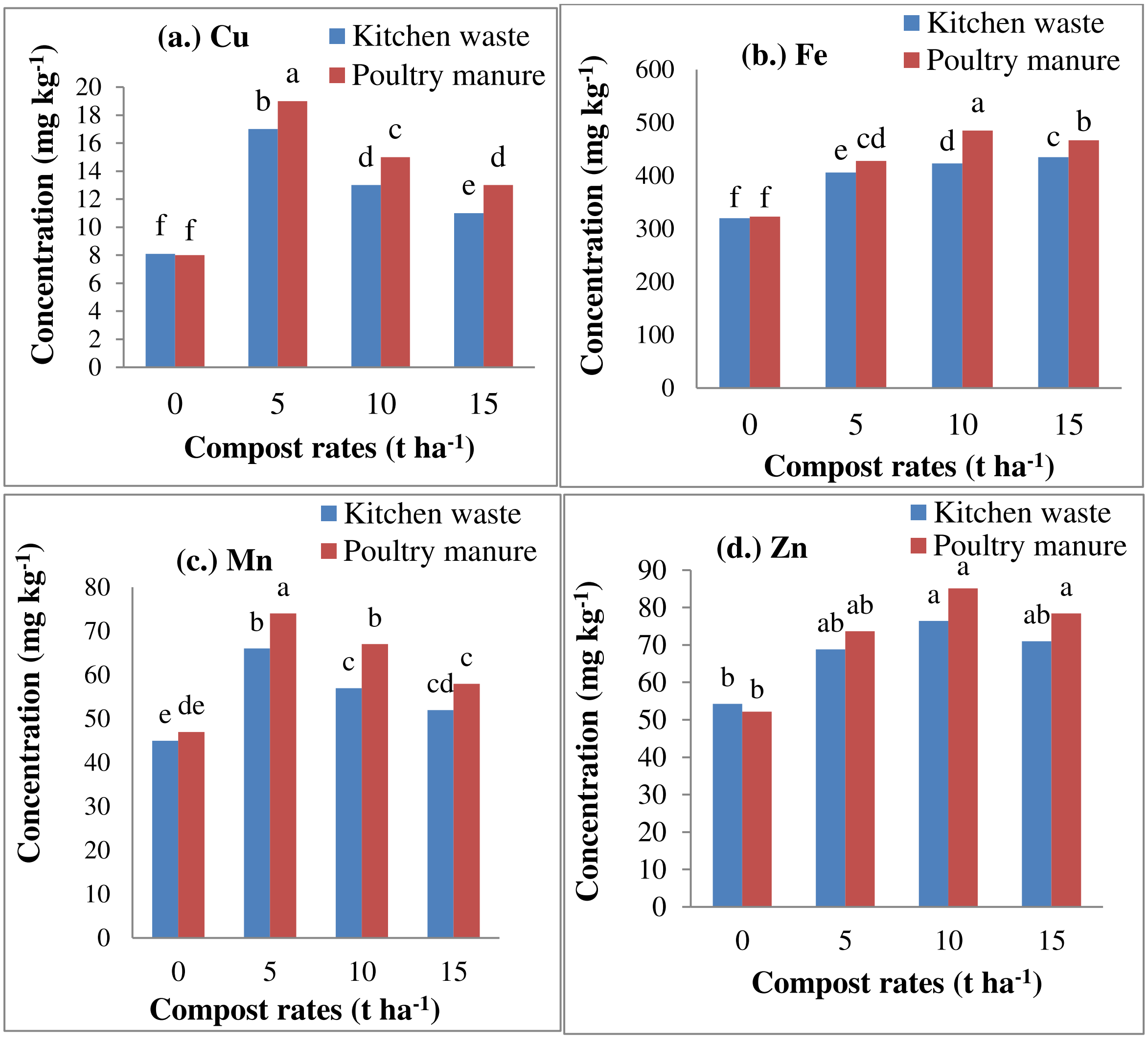

Figure 1: Effects of composted kitchen waste and poultry manure amendments rates on concentration of heavy metals in leaf tissues of Jute mallow 6 WAS. Bars with different letters indicate significant differences between treatments ($p \leq 0.05$)

Generally, concentration of metals in leaf tissue of Jute mallow increased significantly ($p \leq 0.05$) with increased rate of both KW and PM over no compost amendment (control) Fig. 1 (a-d). Copper concentration was highest at 5 t ha^{-1} for PM (19.0 mg kg^{-1}) and KW (17.0 mg kg^{-1}) Fig. 1 a. The concentration of Cu in leaf tissue decreased from 17.0 to 11.0 mg kg^{-1} with KW and from 19.0 to 13.0 mg kg^{-1} with PM as compost rate increased from 5 to 15 t ha^{-1}. The concentration of Cu in leaf tissue of Jute mallow when 10 t ha^{-1} of KW was applied was comparable with that of PM applied at 15 t ha^{-1}. A similar decrease in Cu uptake with increase rate of poultry manure and compost amendment was observed in biomass of oat (Hanč *et al*., 2008). Leaf tissue concentration of Fe increased significantly ($p \leq 0.05$) with both KW and PM as the rate of amendment increased (Fig. 1 b). Across compost rates, concentration of Fe in leaf tissue of Jute mallow was significantly higher with PM than KW amendment. The highest concentration of Fe found in leaf tissue of Jute mallow at 10 t ha^{-1} compost rate was 485 mg kg^{-1} with PM. But for KW, the highest concentration of Fe (435 mg kg^{-1}) was recorded at 15 t ha^{-1}. The highest concentration of Mn in leaf tissue of Jute mallow was 74.0 mg kg^{-1} at 5 t ha^{-1} of PM (Fig. 1 c). Manganese concentration in edible leaf of Jute mallow decreased from 66 to 52 mg kg^{-1} and from 74 to 58 mg kg^{-1} with KW and PM, respectively as the rate of amendment increased from 5 to 15 t ha^{-1}. Bioaccumulation of Zn increased with compost rate up to 10 t ha^{-1} and decreased afterwards at 15 t ha^{-1} although with no significant difference (Fig. 1 d). The highest Zn concentration of 85.12 mg kg^{-1} (PM) and 76.44 mg kg^{-1} (KW) were recorded at 10 t ha^{-1} compost rate. Higher concentration of the metals in Jute mallow leafs with compost amendment over the control as well as higher metal concentration with PM compared to KW was a reflection of the levels of these metals in the composted materials. However, reduction in concentration of the metals in leaf tissues of the plant at higher dosage of the compost amendment can be attributed to its immobilization roles (Clemente *et al*., 2005 b; Yassen *et al*., 2007). Apart from this, it can be attributed to the role of organic compounds (humified fraction) in the organic amendment among other soil factors which must have increased the chelation tendency of the metals thereby reducing their availability for plant uptake (Ross 1994; Walker *et al*., 2003; Cooper *et al*., 2011). Walker *et al*. (2004) also found reduction in tissue concentration of Cu, Zn, and Mn in *Chenopodium album* L grown in heavy metal contaminated soil amended with manure and compost.

Table 3: Residual effect of composted kitchen waste and poultry manure soil amendment rates on metals transfer factor in leaf tissue of *Corchorus olitorius* at 6 WAS

Compost rate (t ha^{-1})	Copper		Iron		Manganese		Zinc	
	Kitchen waste	Poultry manure	Kitchen waste	Poultry manure	Kitchen waste	Poultry manure	Kitchen waste	Poultry manure
0	0.83	0.80	0.038	0.038	0.36	0.37	2.62	2.62
5	1.37	1.25	0.039	0.036	0.40	0.39	2.38	2.20
10	0.94	0.91	0.035	0.032	0.33	0.33	1.84	1.76
15	0.77	0.79	0.027	0.026	0.29	0.24	1.46	1.50
LSD (0.05)	0.179		0.001		0.046		0.157	

Heavy metal transfer factor in Jute mallow

The TF from soil to leaf tissues of Jute mallow of all metals with the exception of Fe in PM and for Zn in both amendments initially increased with 5 t ha^{-1} of the amendments and decreased afterwards with increased amendment rate (Table 3). Generally, KW compost gave higher TF than PM. The highest TF of 1.37 and 1.25 were recorded for KW and PM, respectively at 5 t ha^{-1}. The lowest TF of 0.77 for KW and 0.79 for PM were recorded in leaf tissues of Jute mallow at 15 t ha^{-1} of the compost amendment. The highest TF of Fe and Mn were 0.039 and 0.40 with KW amendment at 5 t ha^{-1}. Transfer factor of Zinc decreased from 2.62 under no amendment to 1.46 with 15 t ha^{-1} of KW and from 2.62 to 1.50 with PM amendment. Higher TF of Zn in leaf tissue of Jute mallow in this study corroborates observation of Jolly *et al*. (2013) who reported that TF of Zn were generally high in all types of vegetables including Spinach (1.148), Amaranthus (0.567), Bean (0.699), Cauliflower (0.430) and Carrot (0.463) among other vegetables. Mireck *et al*. (2015) also found higher TF of Zn in many crops including cabbage and lettuce which ranged from 2-3 in unpolluted soil. The observation in this study was therefore similar, indicating that heavy metals TF can also be high in non-amended (control) soil particularly for Zn and Cu.

However, TF of Cu and Mn in our study was high and moderate, respectively which is contrary to moderate and low classification ascribed to these metals by Jolly *et al*. (2013). Hence, in respect of TF in the order Zn > Cu > Mn > Fe in edible leaf of jute mallow, this vegetable can be regarded as hyper, high, moderate and low accumulators of Zn, Cu, Mn and Fe, respectively. Plants with potential hyper and high accumulators of metals usually have TF ratio of greater than one while those with TF of less than one are low accumulators (Sajjad *et al*., 2009; Teofilo *et al*., 2010). Jolly *et al*. (2013) had also found Fe as one of the metals with low TF from soil to vegetables. Other studies had it that some plant especially leafy vegetables such as cabbage are hyper-accumulator while others are mono accumulators of specific metals (Xiong, 1998; Zhuang *et al*., 2009; Mireck *et al*., 2015). The higher TF with KW than PM was an indication of higher binding effect of PM on the metals than KW amendment. In the control soil without amendment, the higher TF of Cu and Zn in particular indicated that these metals have their ions been freely taken up by Jute mallow probably due to some soil factors. Soils low in pH and organic matter have been reported to be inherently low in its capacity of binding free metal ions (Beesley *et al*., 2014).

Table 4: Residual effect of composted kitchen waste and poultry manure amendment rates on heavy metal accumulation in soil cultivated with *Corchorus olitorius*

Compost rate (t ha^{-1})	Copper		Iron		Manganese		Zinc	
	mg kg^{-1}							
	Kitchen waste	Poultry manure	Kitchen waste	Poultry manure	Kitchen waste	Poultry manure	Kitchen waste	Poultry manure
0	10.07	9.99	11182.42	11098.25	126.26	127.29	164.58	165.42
5	12.43	15.22	12967.00	14389.17	163.35	188.66	209.75	246.83
10	13.52	16.08	13326.50	15218.08	175.99	200.87	245.50	286.25
15	14.26	16.85	16768.58	18126.42	180.66	247.16	279.50	315.92
LSD (0.05)	0.520		401.013		13.406		17.171	

It was apparent that increased compost rate resulted in higher concentration of heavy metals in the amended soil (Table 4). However, the decline in TF of metals (Cu, Fe, Mn and Zn) with increased compost rate in this study was in congruent with observation of Mirecki *et al*. (2015) that TF of metals including Zn and Cu decreased in crops grown in soil with higher contamination of metals.

Heavy metal concentration of amended soil

Post-harvest assessment of heavy metals (Cu, Fe, Mn and Zn) in the soil showed that both composted KW and PM amendments significantly ($p \leq 0.05$) increased metal levels (Table 4). Soil amended with PM accumulated higher concentration of the heavy metals than those amended with KW across rates. This supports the assertion that the origin of organic amendment could be a potential source of contaminant (Hanč *et al*., 2008). Metals contamination of the soil increased with rates of compost amendments. Compost rate of 5 t ha^{-1} gave the least soil metal concentration while 15 t ha^{-1} amendment rate gave the highest concentrations of Cu, Fe, Mn and Zn in the soil for both KW and PM. This implied that addition of the organic amendment contributed to accumulation of the metals in the soil. Kabata-Pendias (2001) had earlier reported accumulation of Cu, Cd, Pb and Zn in their stable forms in organic horizon of the soil following addition of organic materials.

CONCLUSION

Soil amendment with composted KW and PM although promotes growth and development of Jute mallow, it also increased the levels of Zn and Cu in leaf tissues. Composted organic amendment above 5 t ha^{-1} used in this study reduced concentrations of Cu and Mn in leaf tissues of Jute mallow. However, higher rate of amendment reduced transfer factor of metals in leaf tissues of jute mallow. Composted poultry manure of up to 10 t ha^{-1} is more suitable for remediation of heavy metals than kitchen waste.

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