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Effect of Compost Amendment on Heavy Metals, Nitrogen and Phosphorus in a Peat-Based Container Medium

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ABSTRACT

A laboratory study was conducted to evaluate the effect of compost amendment on mobility and leaching potential of heavy metals, nitrogen (N) and phosphorus (P) from a peat-based commercial container medium containing 700 g kg^{-1} peat, 200 g kg^{-1} perlite and 100 g kg^{-1} vermiculite at varying amendment rates of compost (0, 0.25, 0.50, 0.75 and 1.00 L L^{-1}). Increasing compost amendment significantly and linearly increased the pH ($P < 0.01$), the total concentrations of organic carbon ($P < 0.05$), copper (Cu) ($P < 0.01$), cadmium (Cd) ($P < 0.01$), and lead (Pb) ($P < 0.01$), and increased the bulk density ($P < 0.01$) of the medium. The electrical conductivity (EC), and total N and P of the medium increased significantly ($P < 0.01$) and quadratically with increasing compost amendment. The relationship of the C/N ratio of the medium with the compost amendment rate was decreasing, significant ($P < 0.01$) and cubic, while that of the total Zn was increasing, significant ($P < 0.01$) and cubic. Extractable P, NO_3-N, and NH_4-N increased initially with an increasing compost amendment of up to 0.50 L L^{-1} and then decreased with further increasing compost rate. Increasing compost rates resulted in a highly significant ($P < 0.01$) and linear increase in total Cd, Cu, and Pb, and a highly significant ($P < 0.01$) and cubic increase in total Zn in the medium. Increasing compost rates also significantly ($P < 0.01$) increased extractable Cu (linearly) and Zn (quadratically), but significantly ($P < 0.01$) decreased extractable Pb (linearly). There was no significant effect of compost amendment on the extractable Cd concentration in the medium. However, with increasing compost rates from 0.25 to 1.00 L L^{-1}, extractability of P, Cd, Cu, Pb and Zn (extractable concentration as a percent of total) was decreased, indicating that compost amendment could lower the leachability of these elements from the medium.

Key Words: compost amendment, heavy metals, nitrate, peat-based medium, phosphate

INTRODUCTION

Composts in the floriculture and nursery industries have been reported to be beneficial as a complete or partial additive to commercial peat-based media (Burger *et al.*, 1997; Raymond *et al.*, 1998; Wilson *et al.*, 2001, 2004). Many soils in Florida are extremely sandy and possess very low adsorption capacities for nutrients and heavy metals, so compost utilization may result in pollution of the environment (He *et al.*, 2000; Qiao *et al.*, 2000; Zhang and Ke, 2004). To address environmental concerns it is necessary to evaluate the leachability of nutrients and heavy metals from compost to surface waters and groundwater.

Several studies have evaluated municipal solid waste compost and biosolids for agricultural use and land reclamation (Emmerich *et al.*, 1982; Tisdell and Breslin, 1995; Gove *et al.*, 2001). Municipal solid waste (MSW) compost could contain high concentrations of Cd, Cr, Pb, and Zn (He *et al.*, 1992; Woodbury, 1992; Qiao and Luo, 2001; Fan *et al.*, 2004). Leaching of metals occurred initially at relatively high concentrations in compost. It was suggested that contamination of groundwater with heavy metals including Cd, Cr, Cu, Ni, Pb, and Zn from source-separated MSW compost applied as a soil amendment should be negligible, as the low concentrations of metals in the leachates leaving the surface soil would be further attenuated by the clayey subsoil (Sawhney *et al.*, 1994; Chen, 2000; Wang *et al.*, 2001; Zhang *et al.*, 2004). However, the concentrations of NO_3-N, NH_4-N, and PO_4-P were reported to be high in leachate from sandy soil columns amended with various composts (Li *et al.*, 1997;

Lin and Lin, 2003; Zhou and Li, 2003).

The solubility or extractability of N, P, and heavy metals in composts and biosolids influences the leachability of these elements. This property is important for evaluating leaching potential, but few studies have been conducted that have addressed solubility in relation to the leaching of heavy metals from biosolids or yard waste as a whole or as partial substitution for a peat-based medium. The objectives of this study were to determine total and available Pb, Cd, Cu, Zn, N, and P in a peat-based medium amended with a biosolid based compost and to assess the leaching potential of these elements.

MATERIALS AND METHODS

The compost used in this study was a mixture of biosolids and yard waste (1:1, w/w) (Solid Waste Authority, Palm Beach County, Florida). The peat-based medium consisted of 700 g kg^{-1} peat, 200 g kg^{-1} perlite, and 100 g kg^{-1} vermiculite (Metro-Mix 200, The Scotts Co., Marysville, Ohio). The peat-based medium was amended with compost at rates of 0, 0.25, 0.50, 0.75 and 1.00 L L^{-1} with three replicates.

Moisture content of the mixture was adjusted to 90% of field capacity, and the mixture was then left to equilibrate for three days at 25 °C. Subsamples were taken, air-dried, and ground to < 2 mm for measurement of pH and electrical conductivity (EC) using a pH/ion meter (Accumet Model 50, Fisher Scientific, Atlanta, GA). For determination of total elemental concentrations subsamples of the compost-amended medium were ground to pass a 0.25-mm sieve and digested using a three-acid method (HNO_3:$HClO_4$:H_2SO_4 = 8:1:1, 10 mL). Total C and N were measured using a CN analyzer (Vario MAX CN, Elementar Analysen Systeme GmbH, Germany). Extractable NH_4-N and NO_3-N were analyzed using a cadmium reduction auto-analyzer (Alpkem Corporation, Clackamas, Oregon) after shaking a 4.0-g sample (oven-dry basis) in 40 mL 1 mol L^{-1} KCl for 1 h with the suspensions then being filtered through Whatman filter paper. Subsamples of the mixture were also extracted following the Mehlich 3 procedure (Mehlich, 1984). The concentrations of P, Cd, Cu, Pb, and Zn in the Mehlich 3 extracts and those from the above three-acid digests were determined using inductively coupled plasma atomic emission spectrometry (ICP-AES) (J-Y Horiba Group, Edison, NJ). The detection limits of the ICP-AES were 0.22, 2.50, 1.96, 0.60, and 1.55 μg L^{-1} for Cd, Cu, Pb, Zn, and P, respectively. Standard stock solutions of 1 000 mg L^{-1} Cd, Cu, Pb, Zn, and P were obtained from Spex Industries (Edison, NJ). Instrument calibration standards were also obtained from Spex Industries. Quality assurance samples (a blank and a spike) were analyzed every 15 samples, and all the target elements had matrix spike recoveries within ±5%.

Data were subjected to analysis of variance by the SAS Statistical Analysis System (SAS Institute, 2000) and main effects of treatments were partitioned into orthogonal contrasts.

RESULTS AND DISCUSSION

With increasing compost amendment in the medium, total N and P concentrations increased significantly ($P < 0.01$) and quadratically (Table I); whereas the C/N ratio decreased significantly ($P < 0.01$) and cubically, which was an indicator of increased bioavailable N in the medium. Davidson *et al.* (1994) suggested that medium C/N ratios below 20 were considered optimum for plant growth. Meanwhile, EC increased significantly ($P < 0.01$) and quadratically while pH values increased significantly ($P < 0.01$) and linearly with increasing compost amendment in the medium (Table I). Increases in pH and EC of this magnitude did not appear to affect the marketability of container grown Mexican heather (*Cuphea hyssopifolia*) (Wilson *et al.*, 2001). As the compost rate increased, the moisture content in the medium decreased significantly ($P < 0.01$) and cubically, but the bulk density increased significantly ($P < 0.05$) and linearly (Table I), suggesting that addition of large volumes of compost could decrease moisture retention and water filtration (Wilson *et al.*, 2004) of the mixtures.

Mehlich 3 extractable P increased significantly ($P < 0.05$) and cubically with increasing compost amendment, but KCl extractable NH_4-N significantly ($P < 0.01$) and quadratically and NO_3-N signi-

TABLE I

Some basic properties of a peat-based medium (700 g kg^{-1} peat, 200 g kg^{-1} perlite, and 100 g kg^{-1} vermiculite) amended with varying amounts of compost and their significance levels from orthogonal tests

Compost rate	pH	Electrical conductivity	Moisture	Bulk density	Total N	Total C	Total P	C/N ratio
L L^{-1}		dS m^{-1}	g kg^{-1}	g cm^{-3}		g kg^{-1}		
0	5.90	0.97	558	0.082	13.4	313	0.97	23
0.25	6.47	1.34	491	0.123	18.2	311	5.47	17
0.50	6.55	1.67	374	0.185	23.6	318	10.2	13
0.75	6.64	1.84	325	0.232	27.2	315	13.6	12
1.00	6.68	1.97	321	0.262	31.2	319	17.0	10
Significance level[a)]	L**	Q**	C**	L**	Q**	L*	Q**	C**

[a)]Linear (L), quadratic (Q), or cubic (C) significance at $P < 0.05$ (*) or 0.01 (**).

ficantly ($P < 0.01$) and linearly increased at compost rates from 0 to 0.50 L L^{-1}, and then decreased with further increases in compost in the medium, although a slight increase for NH_4-N occurred at compost rate from 0.75 to 1.00 L L^{-1} (Table II). Because of higher concentrations of Cd, Cu, Pb and Zn in the compost than in the peat-based medium, increasing compost resulted in a highly significant ($P < 0.01$) and linear increase in total Cd, Cu, and Pb, and a highly significant ($P < 0.01$) and cubic increase in total Zn in the medium (Table II). Extractable Cu and Zn tended to show a similar trend to total Cu and Zn. However, extractable Pb in the medium significantly ($P < 0.01$) and linearly decreased with increasing rate of compost, indicating that the bioavailability of Pb was lower in the compost than in the peat-based medium although the former had a higher total Pb than the latter, probably due to the difference in the chemical status of Pb between these two materials. Compost amendment did not significantly affect extractable Cd in the peat-based medium (Table II).

TABLE II

Extractable nutrients and heavy metals, and total concentrations of heavy metals in container medium amended with compost and their significance levels from orthogonal tests

Compost rate	Mehlich-3 extractable P	KCl extractable NH_4-N	KCl extractable NO_3-N	Total				Mehlich-3 extractable			
				Cd	Cu	Pb	Zn	Cd	Cu	Pb	Zn
L L^{-1}	g kg^{-1}					mg kg^{-1}					
0	0.29	3.3	121	0.55	24	6.9	55	0.13	2.5	4.02	9.9
0.25	1.99	9.8	129	1.04	85	14.0	141	0.23	13.6	3.58	68.6
0.50	2.09	34.1	130	1.31	143	16.8	239	0.23	14.1	3.00	78.1
0.75	1.97	13.3	91	1.78	201	24.0	348	0.21	13.0	2.50	74.8
1.00	2.03	15.7	71	2.12	275	29.0	388	0.20	15.0	2.66	83.1
Significance level[a)]	C*	Q**	L**	L**	L**	L**	C**	NS	L**	L**	Q**

[a)]Linear (L), quadratic (Q), or cubic (C) significance at $P < 0.05$ (*) or 0.01 (**) and non-significance (NS).

The Mehlich 3 extractability of P and heavy metals (defined as percent of the total in extractable forms) was regarded as a potential availability indicator of these elements for plant uptake or leaching. Given the same total concentration, higher extractability indicated greater availability. The extractability of P, Cu, and Zn in the medium increased from 0 to the low compost rate (0.25 L L^{-1}), but decreased with increasing compost rates from 0.25 to 1.00 L L^{-1} (Table III). However, with increasing compost rates the extractability of Cd and Pb consistently decreased. The mechanisms responsible for reduced extractability of P and the heavy metals were not understood, but the reduction indicated that compost amendment could lower the leachability of P and these heavy metals in the peat-based medium.

CONCLUSIONS

Amendment of compost to a peat-based container medium reduced moisture retention capacity and

TABLE III

Effect of compost amendment on the extractability of P and heavy metals as a percent of total by the Mehlich 3 method

Compost rate	Mehlich 3 extractable concentration as a percent of total				
	P	Cd	Cu	Pb	Zn
$L\ L^{-1}$			%		
0	29.9	23.6	10.4	58.3	18.0
0.25	36.4	22.1	16.0	25.6	48.7
0.50	20.5	17.6	9.9	17.9	32.7
0.75	14.4	11.8	6.5	10.4	21.5
1.00	11.9	10.8	5.5	9.2	21.4

increased bulk density, pH and EC. Depending on the relative concentrations of their elements in the medium with compost, the compost amendment could increase the total concentrations of organic C and N, and heavy metals in the medium. However, compost amendment from 0.25 to 1.00 L L^{-1} decreased the Mehlich 3 extractability of P, Zn, Cd, Cu, and Pb (extractable concentration as a percent of total), indicating that compost amendment could lower the leachability of these elements from the medium.

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