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Leaching of Nitrogen and Phosphorus from Potting Media Containing Biosolids Compost as Affected by Organic and Clay Amendments

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Disposal of the biosolids from municipal sewage treatment is a problem. Traditional methods such as landfilling, ocean dumping and incineration are now discouraged or illegal. Composting is a popular means for turning biosolids into a soil amendment (Goldstein and Steuteville 1996). Biosolids compost can be used in potting media to grow plants in greenhouses and nurseries (Bugbee 1996, Bugbee and Frink 1989). The compost contains substantial amounts of nitrogen (N) and phosphorus (P) that may improve plant growth and reduce the need for fertilizer. Movement of N and P from potting media to surface or groundwater may cause contamination. Nitrate (NO_3-N) is the most common chemical contaminant in drinking water wells (USEPA 1990) and non-point sources of N may contribute to hypoxia in marine estuaries (Frink 1991). Elevated levels of P in ponds and lakes promotes the growth of nuisance algae and accelerates eutrophicaton (Frink and Norvell 1984).

The effects of biosolids compost on the environment is intensely scrutinized by regulatory agencies and the public. Most research has concentrated on the environmental loading of heavy metals and results suggest levels will fall within acceptable limits (Sawhney et. al. 1995, Bugbee et. al. 1991). Leaching of N from biosolids compost may be a problem, although, potting media made with no biosolids compost can leach considerable amounts of N as well. Rhododendron grown in media containing biosolids compost leached about 177 kg/ha N in a growing season (Bugbee 1996). This compares to 24 to 705 kg/ha N from fields of container grown juniper and spruce planted in media containing no biosolids compost (Rathier and Frink 1991). Soluble nitrogen in biosolids compost is often in the ammonium (NH_4-N) form and NH_4-N can be the primary form of N in leachate (Bugbee 1996; Bugbee et. al. 1991). Through the process of nitrification, NH_4-N can be readily converted to NO_3-N by soil bacteria (Bunt 1976). Much of the nitrogen leached from container media amended with biosolids compost can occur within a few weeks of planting (Bugbee 1996) when water soluble N is greatest and plant utilization is least. Rapid leaching of P occurs in potting

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Table 1. Identification and composition of potting media treatments.

Treatment (ID)	Compost	Peat	Sand	Bark	Coir	Saw-dust	Calcined Clay	Vermic-ulite	Zeolite
	(%/vol)								
Control mix	50	30	20	0	0	0	0	0	0
Bark mix	50	0	20	30	0	0	0	0	0
Coir mix	50	0	20	0	30	0	0	0	0
Sawdust mix	50	0	20	0	0	30	0	0	0
Cal. Clay mix	50	30	0	0	0	0	20	0	0
Vermiculite mix	50	30	0	0	0	0	0	20	0
Zeolite mix	50	30	0	0	0	0	0	0	20

media amended with inorganic fertilizers (Marconi and Nelson 1984, Yeager and Barrett 1984). Little information is available on leaching of P from media containing biosolids compost. Potting media amendments that could rapidly reduce leaching of N and P would conserve these nutrients for later uptake by plants and minimize their impacts on the environment. Organic or clay amendments that increase microbial immobilization (Allison et. al. 1963), chemical binding or ionic adsorption (Bunt 1976) could retain N and P in media. This study determines if amending a media containing biosolids compost with the organic materials; bark, sawdust, or coconut processing waste (coir), or the clays; calcined clay, vermiculite or zeolite, will reduce the quantities of N and P in the leachate without adversely affecting plant growth.

MATERIALS AND METHODS

Biosolids compost from the Hartford, CT USA municipal in-vessel composting facility was obtained on May 9, 1996. The compost was made from biosolids and hardwood chips (1: 1.5 by volume) that had been composted for 21 days and cured outdoors in a windrow for six months. A potting medium, that might typically be used by a grower, was made by mixing the biosolid compost in a rotary mixer with peat from Canadian sphagnum deposits and coarse masonry sand. This formed the control mix shown in table 1. Instead of the peat in the control mix, shredded softwood bark, coir, or coarse hardwood sawmill sawdust was added to make the bark mix, coir mix, and sawdust mix treatments in Table 1. Calcined clay (Turface, Quick Dry, Applied Industrial Materials Corp., Deerfield, IL), horticultural vermiculite (#2, medium grade) and Zeolite (clinoptilolite, -40 mesh, REA Gold Corp., Reno, NV) was added instead of the sand to form the cal. clay,

Table 2. Chemical properties of individual potting media components.

Component	Organic Carbon (%/wt)	Total N (%/wt)	C:N Ratio (wt/wt)	pH	Soluble Salts (ds/m)	Bulk Density[y] (g/cc)
Compost	33 b[z]	2.1 d	16 a	6.5 f	5.4 d	0.28 c
Peat	45 d	0.8 c	36 b	3.3 a	0.2 a	0.20 b
Sand	0 a	0.0 a	-	5.8 e	0.2 a	1.63 f
Bark	44 c	0.3 b	146 d	4.9 b	0.5 a	0.20 b
Coir	44 c	0.7 c	62 c	5.1 bc	0.2 a	0.10 a
Sawdust	46 e	0.1 ab	460 e	5.2 cd	0.2 a	0.19 b
Calcined Clay	0 a	0.0 a	-	7.2 g	1.8 b	0.70 d
Vermiculite	0 a	0.0 a	-	5.6 de	0.1 a	0.16 ab
Zeolite	1 a	0.0 a	-	8.4 h	3.2 e	0.90 e

[z]Means within a column, for each type of compost, followed by the same letter are not significantly different (p=0.05) as measured by the Tukey multiple comparison test.

[y]Oven dry

Table 3. Plant available nutrients in individual media components.

Component	NO_3-N	NH_4-N	P	K	Ca	Mg
	(mg/L)[y]					
Compost	26 e[z]	742 b	153 d	168 b	1089 b	175 de
Peat	8 cd	14 a	7 bc	33 a	328 ab	251 f
Sand	11 d	0 a	2 abc	33 a	122 ab	13 a
Bark	3 ab	1 a	8 c	161 b	304 ab	42 ab
Coir	1 a	1 a	3 abc	318 c	91 ab	109 c
Sawdust	3 abc	4 a	2 abc	126 ab	789 b	25 a
Calcined Clay	7 bc	0 a	5 abc	448 d	4432 d	190 e
Vermiculite	1 a	6 a	1 a	72 ab	239 ab	292 g
Zeolite	22 e	0 a	2 abc	1389 e	2175 c	77 bc

[y]Expressed on a volume basis to give the best estimate of the amount of nutrient in each treatment. mg/kg = mg/L divided by the components bulk density in Table 2.

[z]Means within a column, for each type of compost, followed by the same letter are not significantly different (p=0.05) as measured by the Tukey multiple comparison test.

vermiculite and zeolite mixes. No fertilizers or pH adjustments were added to any treatments.

Chemical properties and plant available nutrients of individual media components (Table 2 and 3) were measured on three randomly obtained samples. Organic carbon was determined by loss on ignition, total nitrogen by the Kjeldahl method, pH by glass electrode and soluble salts by the electrical conductivity of a saturated extract. Plant available NO_3-N, NH_4-N, P, K, Ca and Mg were extracted with Morgan's solution (Lunt et.al. 1950). NO_3-N and NH_4-N were determined using the Brucine and Nessler's methods (Grewling and Peech 1965) and a Milton Roy Spectronic 20D spectrophotometer. Concentrations of P, K, Ca and Mg in the extracts were determined using a Thermo Jarrell Ash AtomScan 16 inductively coupled plasma spectrometer.

On May 29, 1996, 2L (12 cm x 12 cm x 15 cm) plastic pots were filled with each of the treatments shown in Table 1. Eight week old *Rudbeckia hirta* L. 'Toto' (Black-Eyed Susan) seedlings were transplanted into the pots the same day. Each treatment was replicated 14 times and pots were placed outdoors at Lockwood Farm, Hamden CT USA. Pots were arranged in a complete randomized block design. Overhead irrigation supplied 1.8 cm of water per day when rainfall was insufficient. On July 10, 1996, 6 g of 19 N-2.6 P-9.6 K (Osmocote 19-6-12) controlled release fertilizer was applied to each pot. Rudbeckia were grown until August 29, 1996 when aerial plant parts were harvested. Flowers were separated from the stems and leaves and plant parts were dried at 75° C for one week. Relative plant growth was determine from the mean dry weights of each treatment.

Leaching of NO_3-N, NH_4-N and P was monitored on six replicates of each treatment. Pot size and culture of plants in the leachate collection treatments were identical to the plant growth experiment, although, the plants were not used for growth measurements. Leachate collection devices were made by cutting 12 cm square openings in lids for 5L plastic buckets. Pots were glued in the lid opening and the pot plus lid was placed on the bucket. This allowed only the leachate passing through the media to be collected. Collection buckets and lids were painted silver to help moderate leachate temperatures and prevent light from causing algal growth. Leachate samples were obtained from the collection buckets at one week intervals for the first eight weeks and once every two weeks thereafter. After sampling, the collection buckets were emptied. Activated carbon was added to the leachate samples to remove color and samples were then centrifuged to separate the carbon. NO_3-N and NH_4-N was determined using the Brucine and Nessler's methods (Grewling and Peach 1965) on a Milton Roy Spectronic 20D spectrophotometer, P was determined using the molybdate-ascorbate method (Murphy and Riley 1962) and a Milton Roy Spectronic 1001 spectrophotometer.

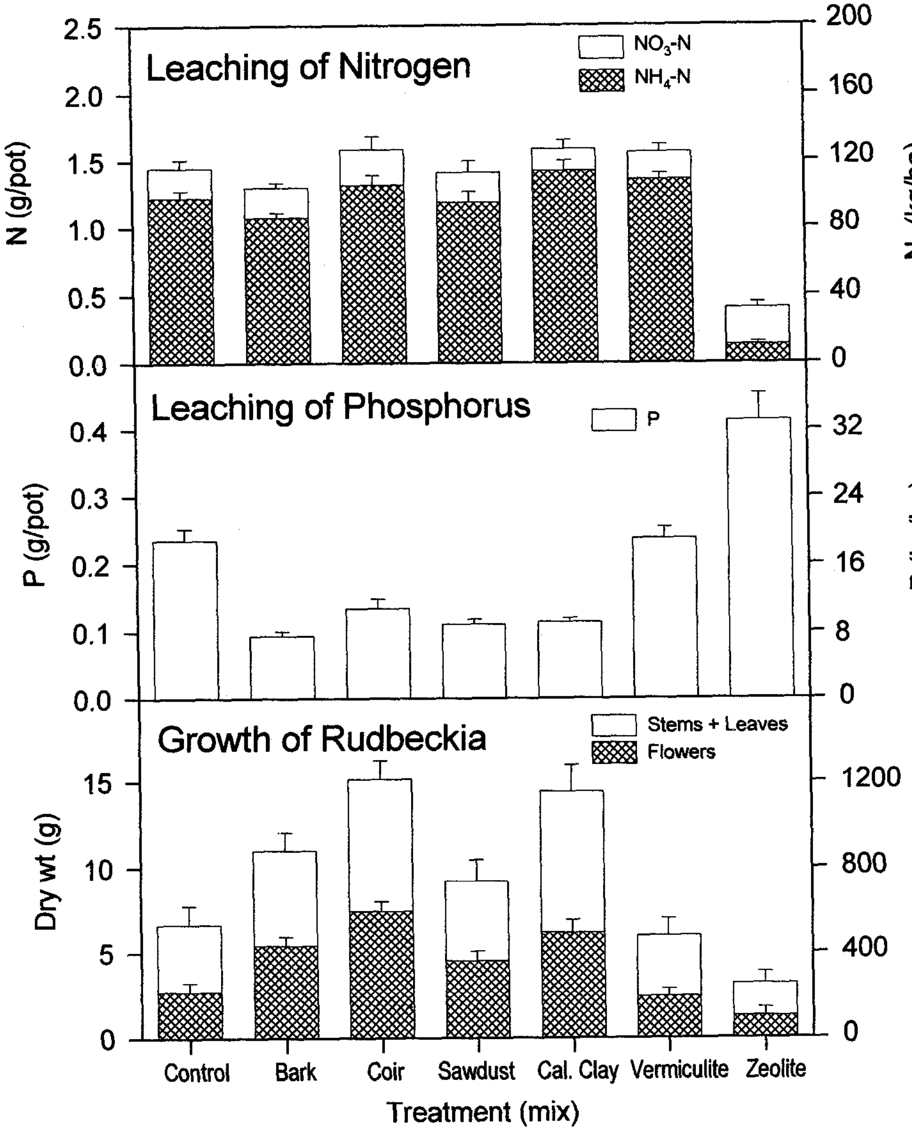

Figure 1. Leaching of N and P and growth of Rudbeckia in media containing composted biosolids and organic and clay amendments. Error bars equal one standard error of the mean for total N, NH_4-N, P, flowers and total growth.

RESULTS AND DISCUSSION

Chemical analyses of the individual media components are shown in Table 2. Bark, coir, and sawdust contained similar amounts of carbon and less N than the peat they replaced. If the carbon in these amendments was more readily available to microbes than the carbon in the peat, greater immobilization of N should occur and reductions in N leaching should result. Calcined clay, vermiculite and zeolite contained negligible amounts of carbon and N and were similar to sand they replaced. Any reduction in N or P leaching by these amendments should be related to chemical binding or adsorption. Compost had a lower C:N ratio and more N than any other media component. The pH of the components varied considerably. Peat had was the most acidic with a pH of 3.3 and the zeolite was the most alkaline with a pH of 8.4. These pH differences did not result in any major differences in the pH of the final media because pH measurements taken six weeks into the experiment found all media had a pH between 5.0 and 6.0.

Plant available nutrients in the individual potting media components are shown in Table 3. The biosolids compost contained high levels N and P compared to all other components. Most of the N in the compost was in the NH_4-N form. NH_4-N would be expected to be the primary form of nitrogen in leachate until nittrification in the media converts it to NO_3-N. Prior to the application of fertilizer on July 10, the biosolids compost represented the primary source of N and P to leachate and plants. Levels of K, Ca, and Mg varied among amendments. These differences could effect the amount of N and P in leachate and plant growth.

Total leaching of NH_4-N , NO_3-N and total N (NO_3-N+NH_4-N) is shown in Figure 1. The right vertical axis on Figure 1 converts mg/pot data to kg/ha using a typical pot density of 80,000 pots/ha. Most of the total N leached as NH_4-N in the first four weeks of the experiment. Zeolite was effective at reducing the total N probably because of its high exchange capacity for monovalent cations such as NH_4^+ (Barbarick and Pirela 1984). The control mix leached 1.4 g/pot total N, compared to 0.4 g/pot for the zeolite mix, 1.4 g/pot for the sawdust mix, 1.3 g/pot for the bark mix, 1.6 g/pot for the coir, cal. clay, and vermiculite mixes. Leaching of nitrate commenced six weeks into the experiment. This is consistent with the lag period for nitrification of NH_4-N to NO_3-N found in other potting media by Elliott (1986). Further evidence that the process of nitrification was proceeding rapidly was that the application of fertilizer high in NH_4-N on July 10 1997 failed to increase NH_4-N in the leachate. The negligible effect of the coir, bark and sawdust mixes on reducing N in the leachate was probably because the carbon in these amendments was not available quickly enough for microbial populations to rapidly increase and utilize NH_4-N. Sawdust that is less coarse or derived from softwoods may have yielded different results.

Figure 1 shows the effect of each component on the leaching of P. The control mix leached 0.24 g/pot P. The bark, coir, sawdust, and cal. clay mixes decreased phosphorus leaching to 0.09, 0.13, 0.11, and 0.11 g/pot, respectively. The vermiculite mix leached the same amount of P as the control mix , while the zeolite mix increased P leaching to 0.41 g/pot. Unlike N, where most leached early in the experiment, P leaching was more consistent throughout the experiment.

The effects of each amendment on the growth of Rudbeckia is shown in Figure 1. Coir and sawdust mixes produced plants with greatest growth while the least growth occurred in the zeolite mix. Plant growth in the control, bark, calcined clay and vermiculite mixes was intermediate. Plants in the zeolite mix were small, poorly rooted. This may indicate that less zeolite should be added to potting media. Reasons for the growth differences between other treatments were not readily apparent but may be related to levels of K, Ca, or Mg or changes in moisture retention in the media. The increase in P leaching from the zeolite mix might be explained by the poor growth of plants in this treatment and less plant uptake of P.

This study finds that reducing the nitrogen in leachate from potting media containing composted biosolids without adversely effecting plant growth may be difficult. With the exception of zeolite, the organic and clay amendments tested here had little effect on leaching of N. Zeolite holds some promise because of its ability to bind NH_4-N, however, a rate must be found that is not be detrimental to plant growth. Reducing P in leachate with media amendments appears easier than N. When bark, sawdust, or replaces peat or calcined clay is used instead of sand, leaching of P is reduced.

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