Growth of Perennials and Leaching of Heavy Metals in Media Amended with a Municipal Leaf, Sewage Sludge and Street Sand Compost[1]

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Abstract

Municipal leaves, sewage sludge, and street sand were composted by a modified Beltsville aerated pile technique. Rooted cuttings of *Aster novi-belgii* L. 'Peter Harrison,' *Gaura Lindheimeri* Engelm. & A. Gray and *Sedum purpurem* (L.) Link 'Autumn Joy' were grown for 4 months in 2 l (2 qt) containers filled with media containing 0, 10, 30, 60, 80 and 100 (percent by vol) compost. The medium with 0% compost contained loamy sand topsoil, peat, sand and Styrofoam pellets (1:5:2:2 by vol). The pH of all media was between 6.0 and 7.0. Half the containers in each treatment received liquid fertilization in mid-season and half did not. Leachate from the containers was collected at monthly intervals and analyzed for the heavy metals Cd, Cr, Cu, Mn, Ni, Pb and Zn to determine their potential for leaching.

Growth of perennials was equal or greater in all media containing compost, compared to the medium containing no compost. Liquid fertilizer further improved growth. Adding compost increased media aeration, available plant nutrients and heavy metals and decreased moisture retention and bulk density. Heavy metal concentrations in leachate were low, probably due to the near neutral media pH, and not likely to pose an environmental risk.

Index words: liquid fertilizer, municipal compost, peat

Species used in this study: *Aster novi-belgii* L.; *Gaura lindheimeri* Engelm. & A. Gray; *Sedum purpurem* (L.) Link

Significance to the Nursery Industry

Composts derived from municipal wastes such as leaves, sewage sludge, and street sand will likely become increasingly available for use in container media. This study suggests that these composts, can replace some or all of the more conventional media components such as topsoil, peat, sand, and Styrofoam with no reduction in plant growth. If the media pH is near neutral leaching of the heavy metals Cd, Cr, Cu, Mn, Mn, Ni, Pb, and Zn will be minimal.

Introduction

Many municipalities have begun composting organic wastes with the intention of producing a marketable soil amendment (7). A wide variety of these composts have been shown to improve media used in the culture of nursery and greenhouse plants (4, 8). Compost is an economical substitute for conventional media components such as peat (4) and plant nutrients in compost may reduce the need for fertilizer (8). This study examines compost derived from a mixture of leaves, sewage sludge, and street sand to determine its usefulness in media for container-grown perennials.

Uses for compost could be restricted if pollutants move from the compost to the surrounding environment (13). Leaching of heavy metals is a concern because some metals accumulate in the soil, thus becoming toxic to plants and humans. The present study examines the concentrations of Cd, Cr, Cu, Mn, Ni, Pb and Zn in leachate from media amended with compost.

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Materials and Methods

Leaves, digested sewage sludge, and sand collected from streets and catch basins were mixed (4:1:1 by vol) at the municipal compost facility in Greenwich, CT during November 1987. Materials were composted over the winter in typical Beltsville aerated piles (18) except that leaves, which had been ground in a tub grinder, were used in place of wood chips for all but the pile cover and base.

A potting medium used by some perennial flower growers containing loamy sand topsoil, Canadian peat, sand, and Styrofoam pellets (1:5:2:2 by vol) was amended with compost to form the experimental media shown in Table 1. Except for the medium containing 30% peat, compost was added to completely replace a component and therefore simplify the mix. Topsoil and peat were replaced before the remaining components because topsoil and peat are often the most costly. To obtain media with a pH of 6.0–7.0, 12 kg/m^3 (20 lb/yd^3) of calcitic limestone and 12 kg/m^3 (20 lb/yd^3) of dolomitic limestone was added to the acidic peat prior to mixing it with the other less acidic components. Media components were blended in a rotary cement mixer. During mixing, 1.5 kg/m^3 (1 lb/yd^3) superphosphate 0N-9P-0K (0-20-0), 3.0 kg/m^3 (2 lb/yd^3) Osmocote 18N-3P-10K (18-6-12), and 1.5 kg/m^3 (1 lb/yd^3) Electra 5N-4P-2K (5-10-3), was added to all media. The fertilizer additions correspond to a rate successfully used by a local grower.

Chemical properties of the media components were measured on three randomly selected samples. Organic carbon was determined by the loss-on-ignition (2) process and pH was measured with a glass electrode in a 1:1 (by vol) mixture of medium and distilled water. The plant nutrients NO_3-N, NH_4-N, P, K, Ca, and Mg were extracted using the Morgan Soil Testing System (12). No_3-N and NH_4-N were determined colorimetrically (9) and the remaining nutrients were

Table 1. Components and physical properties of media used to grow three species of perennials.

Media components[z] (% vol)	Aeration (% vol)	Easily available water (% vol)	Less easily available water (% vol)	Total water (% vol)	Total pore space (% vol)	Bulk density ($g \cdot cm^{-3}$)
0:10:50:20:20	10.5 a[y]	51.7 e	7.1 a	58.9 e	69.4 c	0.68 e
10:0:50:20:20	14.7 b	50.4 e	7.9 ab	58.3 e	73.1 d	0.55 c
30:0:30:20:20	15.1 b	43.6 d	8.2 ab	51.9 c	67.0 b	0.62 d
50:0:0:20:20	20.4 d	29.6 a	13.6 d	43.3 a	63.7 a	0.65 de
70:0:0:0:20	24.6 e	32.6 c	15.6 e	48.2 b	74.8 d	0.40 a
100:0:0:0:0	26.6 f	29.5 a	20.2 f	49.7 bc	74.3 d	0.48 b

[y]Means within a column followed by the same letter are not significantly different at the 5% level as measured by Duncan's multiple range test.
[z]Compost:soil:peat:sand:Styrofoam (by vol.).

determined by inductively coupled plasma spectrophotometry (ICP). Salinity was measured by the electrical conductivity (EC) of a saturated paste extract (3). The heavy metals Cd, Cr, Cu, Mn, Ni, Pb, and Zn were extracted by the DTPA method (11). Total metals in the compost were determined following digestion with HNO_3 and H_2O_2 (15). Cd was determined by graphite furnace atomic adsorption spectrophotometry (GFAA) and the remaining metals by ICP.

Physical properties of the media were measured on 5 replicates in 2 l (2 qt) containers identical to those used for the growth studies except that no plants were grown in these containers. Media were irrigated twice a week for one month to permit natural settling, weighed, allowed to drain for 48 hours, and weighed again. Aeration was considered the difference in weight expressed as a percentage of the medium volume. Media were then allowed to dry until tensiometers (Irrometer, Model M, Riverside, CA) placed in the containers indicated a volumetric water potential of 300 kPa (0.30 atm). Containers were again weighed and easily available water (5, 10) calculated. Less easily available water, total pore space, and bulk density were determined similarly from the weight of the oven-dried medium.

On May 27, 1988 rooted cuttings of Sedum, Aster and Gaura were placed in 2 l (2 qt) square plastic containers filled with each medium. To enhance establishment, plants were protected in an unheated greenhouse for three weeks prior to being placed in the field. Each medium was replicated 10 times and arranged in complete randomized blocks with two replicates of all media per block. The combined blocks were surrounded by a border row.

Rainfall was supplemented by overhead irrigation to provide 1.2 cm (0.5 in) of water per day through July 17 and 2.4 cm (1 in) per day throughout the remainder of the experiment. On July 14, one container of each medium per block received 300 ml (10 oz) of liquid fertilizer containing 400 mg/l (400 ppm) N, 88 mg/L (88 ppm) P, and 332 mg/l (332 ppm) K, and the remaining media received 300 mL (10 oz) of water with no added fertilizer. Plant growth response to each medium and fertilization regime was determined by harvesting the aerial plant parts on 3 October 1988 and separating the flowers from the stems and leaves. Plant parts were dried at 75°C (167°F) for one week and weighed. Plant growth is reported as the mean dry weight of the five plants which received liquid or no liquid fertilizer.

Leaching of the heavy metals Cd, Cr, Cu, Mn, Ni, Pb, and Zn was determined by suspending containers filled with each medium over 5 l (5 qt) plastic buckets. To prevent water from entering the collection buckets from outside the containers, plastic sheets were fastened from the inside of the container rim to the outside of the bucket rim. Six additional replicates of each medium were arranged in non-randomized blocks with one block adjacent to each species of perennial. Three replicates received liquid fertilization and three replicates received tap water. No plants were grown in the containers used for the leaching study. Leachate was collected periodically when 1 to 2 l (1 to 2 qt) of water collected in the buckets. Samples were collected for analysis on June 30, July 20, August 9, September 9, and October 3. On each date, samples from the three replicates of each medium, which received liquid or no liquid fertilizer were combined, refrigerated and analyzed for Cr, Cu, Mn, Ni, Pb, and Zn by ICP and for Cd by GFAA.

Results and Discussion

Increasing percentages of compost resulted in higher levels of aeration and less easily available water (Table 1), and

Table 2. Fertility of media components used to grow three species of perennials.

Component	pH	Salinity EC ($ds \cdot m^{-1}$)	C (%/wt)	Plant nutrients ($mg \cdot kg^{-1}$): N: NO_3	NH_4	P	K	Ca	Mg
Compost	6.6 d[z]	3.1 c	27.6 d	10 c	12 c	60 abc	871 c	3119 d	526d
Peat	3.7 a	0.1 ab	97.5 e	2 c	9 b	32 abc	219 b	328 bc	317 c
Sand	5.1 bc	0.0 a	0.0 a	1 a	0 a	1 a	15 a	36 a	2.73 a
Styrofoam	4.9 bc	0.0 ab	0.0 a	1 a	0 a	83 c	150 b	199 abc	150 ab
Soil	4.8 b	0.1 ab	2.6 c	2 b	0 a	2 ab	26 a	172 ab	16 ab

[z]Means within a column followed by the same letter are not significantly different at the 5% level as measured by Duncan's multiple range test.

Table 3. DTPA extractable metals in media components and total metals in compost used to grow three species of perennials.

Component	Bulk Density (g/cc)	Heavy metals (mg·kg⁻¹) Cd	Cr	Cu	Mn	Ni	Pb	Zn
Peat	0.08 a[z]	0.34 c	1.1 e	4.6 bc	147.8 d	2.1 d	28.2 c	64.4 b
Sand	1.55 d	0.00 a	0.0 a	0.6 a	1.8 a	0.1 a	1.0 a	0.3 a
Styrofoam	0.02 a	0.01 ab	0.3 c	2.8 bc	0.4 a	0.4 d	1.2 ab	99.9 c
Soil	1.07 c	0.02 ab	0.1 b	1.9 ab	25.0 b	0.3 b	5.0 ab	1.6 a
Compost	0.54 b	4.53 d	0.4 d	40.5 d	80.0 c	1.6 c	30.4 c	168.2 d
Compost[y]	0.54	6.72	144	202	353	355	115	296

[z]Means within a column followed by the same letter are not significantly different at the 5% level as measured by Duncan's multiple range test.
[y]Total.

reduced quantities of easily available and total water. These physical properties can be an advantage during wet weather when media will be less likely to remain excessively wet and a disadvantage during dry periods when the reduced moisture retention will require the media to be irrigated more frequently. Media containing 100% compost and 80% compost:20% Styrofoam had the lowest bulk densities which could reduce handling and shipping weight but may increase the toppling of containers in the field.

Compost was generally higher in plant nutrients than the other media components (Table 2) but was excessive in none (12). Low NH_4-N suggests composting time was sufficient and further curing was unnecessary (17). Because most perennials prefer neutral to slightly acidic soil (1), use of compost with pH 6.6 will reduce the need for amendments with limestone. Although the salinity of the compost was higher than the other components it was not considered excessive (6).

Analysis of the media components for extractable heavy metals (Table 3) showed the compost to be generally highest in Cd, Cu and Pb, while peat was highest in Cr, Mn and Ni. The DTPA extractable metals in the compost was generally only a fraction of the total concentration of metals. Table 3 includes the bulk density of air-dried samples of each component. Because the components were mixed on a volume basis, the amount of a metal in a container will be a function of the bulk densities of the components. Consequently, media high in compost would be expected to contain the highest levels of metals.

In general, growth of the three species of perennials was improved by additions of compost (Fig. 1). Liquid fertilization generally increased growth, although the effects were not as large in media containing compost.

Additions of compost caused little or no increase in leachable metals when compared with media containing no compost (Table 4). When concentrations were less than the detection limits, the means were calculated assuming these concentrations to be zero. If the calculated mean was less than the detection limit, the detection limit is reported. The concentrations of all metals in leachate tended to decrease with time (data not shown). Analysis of leachate collected on July 20 revealed the liquid fertilizer had lowered the average leachate pH from 7.42 to 6.08 and caused an increase in the concentrations of most metals, particularly Cd and Zn. These differences largely disappeared in the samples taken on August 9. Previous work has shown a positive

Table 4. Mean pH and heavy metals in leachate from media.

Compost (% vol)	pH NLF[z]	pH LF[y]	Cd NLF	Cd LF	Cr NLF	Cr LF	Cu NLF	Cu LF
0	7.22	6.84	<0.005	0.008	<0.065	<0.065	0.010	0.020
10	7.38	6.90	<0.005	0.009	<0.065	<0.065	0.010	0.020
30	7.18	6.82	<0.005	0.007	<0.065	<0.065	0.022	0.032
60	7.34	7.20	<0.005	0.005	<0.065	<0.065	0.049	0.051
80	7.42	7.24	<0.005	0.005	<0.065	<0.065	0.057	0.067
100	7.46	7.26	<0.005	0.007	<0.065	<0.065	0.069	0.071

Heavy metals (mg·l⁻¹)

Compost (% vol)	Mn NLF	Mn LF	Ni NLF	Ni LF	Pb NLF	Pb LF	Zn NLF	Zn LF
0	0.021	0.086	<0.020	0.021	<0.008	0.013	0.048	0.188
10	0.070	0.075	<0.020	<0.020	<0.008	<0.008	0.040	0.212
30	0.036	0.047	<0.020	<0.020	<0.008	<0.008	0.048	0.206
60	0.055	0.078	<0.020	<0.020	<0.008	0.008	0.062	0.243
80	0.056	0.065	<0.020	<0.020	<0.008	<0.008	0.060	0.234
100	0.071	0.102	<0.020	0.024	<0.008	<0.008	0.103	0.264

[z]No liquid fertilizer.
[y]Liquid fertilizer.

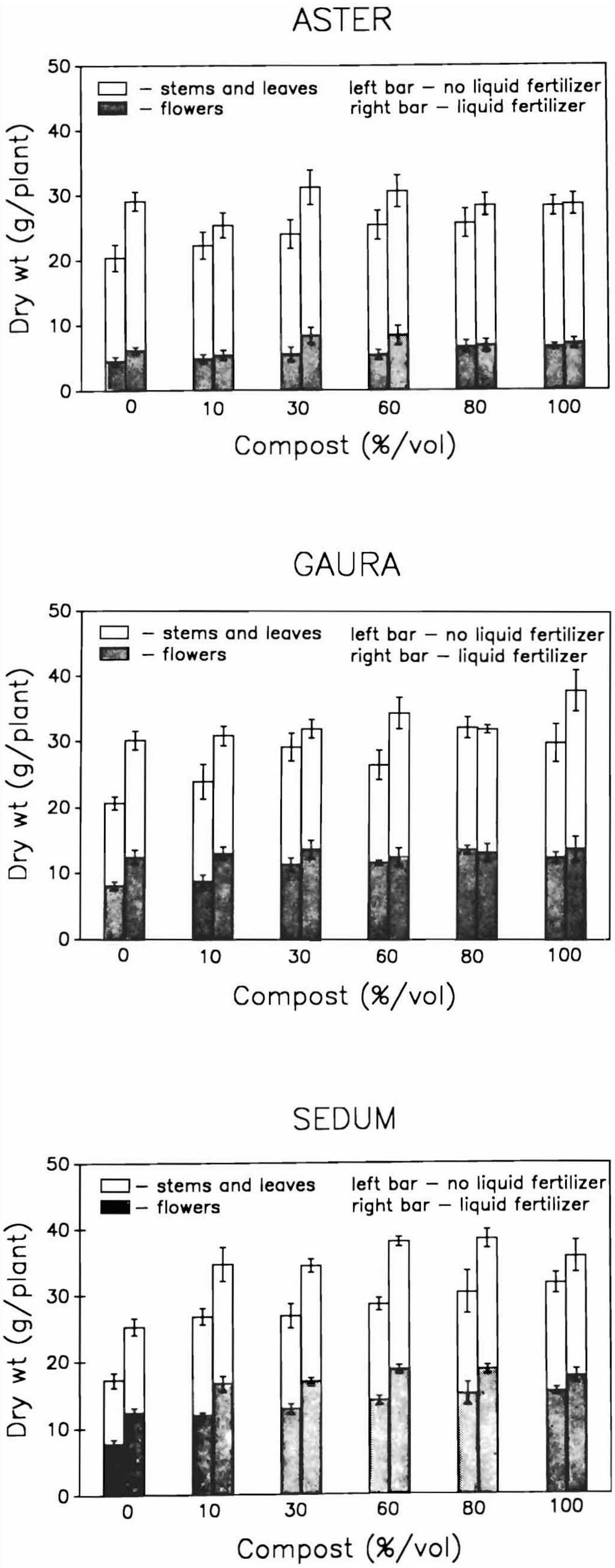

Fig. 1. Growth of perennials in media amended with a compost derived from municipal leaves, sewage sludge and street sand.

correlation between the lowering of the pH of compost and the increase in leaching of these metals (14). Analysis of the liquid fertilizer solution revealed <0.01 mg/l (<0.01 ppm) Cd and 0.55 mg/l (0.55 ppm) Zn; thus some of the Zn may have been introduced in the liquid fertilizer.

The environmental risk of heavy metals in leachage may be conservatively assessed by comparing the concentrations to the federal primary drinking water standards (16). All Pb and Cd concentrations were less than the standard of 0.05 mg/l (0.05 ppm) for Pb and 0.01 mg/l (0.01 ppm) for Cd. Concentrations of Cr were near or below the standard of 0.05 mg/l (0.05 ppm). No primary standards exist for Cu, Mn, Ni and Zn. This experiment suggests that leaching of these metals from media amended with similar composts, with a near neutral pH, will not pose a threat to the environment.

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