Effects of Curing Time on Physical and Chemical Properties of Composted Sewage Sludge and on the Growth of Selected Bedding Plants[1]

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Abstract

Raw sewage sludge treated with lime and ferric chloride was composted by the Beltsville Aerated Pile Method, screened and piled outdoors (cured) for 4, 6, 8, or 10 months. As curing time increased there was a decrease in CO_2 and temperature, and an increase in O_2 within the piles. The NH_4 concentrations and electrical conductivity (EC) of the compost decreased while pH, NO_3 + NO_2, and extractable P increased with time. Curing time did not influence extractable K while bulk density (BD) and particle size distribution (PSD) exhibited only moderate changes. Marketable seedlings of *Impatiens hybrida* 'Super Elfin Scarlet' and *Tagetes patula* L. 'Yellow Boy' were produced in peat:vermiculite (v/v) amended with 10 or 20% compost, regardless of compost curing time. Seedlings of *Coleus* x *hybridus* Voss. 'Saber Golden' were stunted and unmarketable in all compost amended media. Increasing compost curing time decreased EC, pH, and extractable N and K of the media at transplant time, and resulted in increased dry weight of *I. hybrida* and *T. patula.* Increasing compost concentrations in the media decreased plant top dry weight and visual ratings, and increased EC, pH, and NH_4, NO_3 + NO_2, and extractable N, P, and K.

Index words: *Coleus x hybridus, Impatiens hybrida, Tagetes patula,* marigold, peat, vermiculite

Introduction

Composting has become an acceptable, economically feasible and environmentally safe means of recycling sewage sludge. Various methods for determining compost maturity have been suggested. Hirai et al. (5) suggested that a C/N ratio of 5 to 6 be used as an indicator of compost maturity. Since microbial activity decreases as compost matures, Pressel and Bidlingmaier (8) suggested that O_2 levels in compost be used to indicate its maturity. Zucconi et al. (12) suggested that a seed germination index in water extracts of compost be used.

It has been assumed that sewage sludge compost is ready for use after composting for 21 days and curing for 1 month (2, 3, 10). Following this assumption, composte concentrations in excess of 50% (v/v) are considered detrimental to the growth of some potted plants (2, 4, 9). Compost can provide all P and trace elements required by some plants (2); there is also some indication that compost particle size can influence plant growth (7, 11).

The purpose of this study was to measure changes in physical and chemical properties of compost cured for extended periods, and to evaluate the growth response of 3 bedding plant species in media containing 10, 20 or 40% compost (by volume) cured for 0, 1, 4, or 8 months.

[1]Received for publication November 21, 1986; in revised form February 2, 1987. "Scientific Article No. A-4594, Contribution No. 7590 of the Maryland Agricultural Experiment Station."

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Materials and Methods

Experiment #1. Lime and ferric chloride dewatered raw sewage sludge, obtained from the Blue Plains Wastewater Treatment Plant in Washington, DC, was mixed at twice its volume with woodchips and composted for 21 days at the Montgomery County Composting Facility, MD, using the Beltsville Aerated Pile Method (10). After screening to remove wood chips > 1 cm (0.4 in), and curing with aeration for 1 month, conical piles of compost averaging 12 m^3 (15.7 yd^3) and 1.5 m (4.9 ft) high were formed outdoors at 2 month intervals from April to October, 1984. These piles were allowed to cure without mechanical aeration for an additional 3, 5, 7, and 9 months. The size and shape of the compost piles were selected to provide some aeration by convective air movement and by diffusion of the gases due to their partial pressure gradients. Each treatment was replicated 3 times in one continuous row.

A 0.6 m (2.0 ft) analog gauge probe (Premium Instruments, P.O. Box 69-A, Alsip, IL) was used to determine compost pile temperatures. Gas samples were suctioned from the center of each pile using a 1 m (3.3 ft), 1.25 cm (0.5 in) dia. probe and a hand operated rubber aspirator. Oxygen was measured with a portable O_2 analyzer (Teledyne Analytical Instruments, 16830 Chestnut Dr., City of Industry, CA) and CO_2 by gas chromatography (Hach Company, 57th St. and Lindbergh, Loveland, CO 80537). All measurements were made monthly in 3 different locations in each pile. Compost samples were taken at the end of each curing period from outer, middle, and inner sections from each pile, and mixed together before determining BD, PSD, pH, EC, and extractable N, P and K. Uncured compost and compost cured with aeration for 1 month were also analyzed. Bulk density was determined by filling a 500 ml graduated cylinder with weighed air dried compost shaken for

5 minutes with a sieve shaker (W.S. Tyler, Inc., Mentor, OH), and the weight divided by final volume.

The PSD was determined on 500 cm^3 (30.5 in^3) of air dried compost shaken for 5 minutes through stacked U.S. Standard Sieves numbers 2, 4, 8, and 16 using a sieve shaker. Percent composition of differences in particle size is based on the weight of particles retained by each sieve. Electrical conductivity and pH were determined on saturated paste extracts with de-ionized water and 0.01 M $CaCl_2$, respectively (1). Extractable N was measured by modified semi-micro Kjeldahl (6) after 50 g of moist compost (as taken from the piles) was mechanically shaken for 40 min with 250 ml of 2M KC1, and filtered through Whatman #1 filter paper before distillation (personal communication, Dr. Jack Meisinger, Soil Nitrogen Lab., USDA, Beltsville, MD). To calculate N concentration on a dry weight basis, a similar sample was dried at 45 °C (113 °F).

Double acids were used to extract P (HNO_3 + $HClO_4$) and K (1N HCl + 1N H_2SO_4) from air dried ground compost; concentrations were determined using a Technicon Autoanalyzer II and atomic absorption spectrophotometry, respectively.

Experiment #2. Uniform seedlings of *C.* x *hybridus* 'Saber Golden,' *I. Hybrida* 'Super Elfin Scarlet,' and *T. patula* 'Yellow Boy' were transplanted into 5.7 cm (2.3 in) deep, 6.1 cm (2.4 in) wide 4 units cell-packs filled with peat:vermiculite (v/v), amended with 10, 20, or 40% compost which had been cured for 0, 1, 4, or 8 months. Similar plants were grown in Pro-Mix BX (Premier Brands Inc., New Rochelle, NY) as a control. Each treatment was replicated 4 times and arranged in a split plot design with treatments completely randomized within species and each 4 unit cell pack as an experimental unit. Plants were grown on raised benches in a glass greenhouse with minimum temperatures of 15 °C (59 °F) and ventilation at 24 °C (75 °F). Control plants were fertilized immediately after transplanting and at each irrigation with 200 N, 87 P, and 166 K (mg/liter). Plants in compost amended media received tap water during the first 2 weeks and then irrigation with 200 N, 18 P, and 133 K (mg/liter). Eight weeks after transplanting, the number of open, unopened, senesced and total flowers were recorded on *T. patula* and all plants were evaluated (4 = excellent, 1 = poor) for appearance and saleability by a panel of students and professors. Tops were weighed after drying in a forced draft oven (45 °C-113 °F). Media EC, pH, and extractable N, P and K were determined before transplanting, using the procedures described earlier.

Results and Discussion

Experiment #1. As compost curing time increased from 1 to 6 months, there was an increase in O_2 and a decrease in CO_2 and temperature (Fig. 1). Mean O_2 and CO_2 concentrations in piles cured for 6 months were 20.7% and < 1%, respectively. High CO_2 and low O_2 levels combined with high temperature during the initial curing months indicated that composting was still in progress (Fig. 1). As microbial activity diminished, less O_2 was utilized resulting in lower CO_2 levels. Correlation coefficients between curing time and CO_2 ($r = -.94$, $p = .0001$); curing time and O_2 ($r = .91$, $p = .0001$); O_2 and CO_2 ($r = -.95$ $p = .001$); CO_2 and pile temperature ($r = .95$, $p = .0001$) and O_2 and pile temperature ($r = -.90$, $p = .0001$) indicate that aerobic decomposition continued for 4 to 6 months after the initial composting period.

Compost pH increased during the first month of curing, followed by a decrease (Table 1). In general, EC decreased as curing time increased while P concentrations increased. Since the piles were cured outdoors, the reduction in EC could be attributed to leaching. Loss of organic matter by decomposition may account for the increase in concentration of P, which is not readily leached.

Bulk density did not follow any trend and increased only during the 6th and 8th months. However, K concentrations remained constant since it can be held against leaching on cation exchange sites.

Uncured compost had the highest NH_4 concentration, with no detectable NO_3 + NO_2 (Table 2). As curing time increased from 0 to 8 months, NH_4 concentrations decreased and NO_3 + NO_2 concentrations increased. After 8 months of curing, NO_3 + NO_2 concentrations decreased, probably due to denitrification, leaching, immobilization, or N recycling through other organic compounds. Extractable N decreased as curing time increased. Correlation coefficients between NH_4 and curing time ($r = -.86$, $p = .0001$); NH_4 and NO_3 + NO_2 ($r = -.82$, $p = .0001$); and curing time and NO_3 + NO_2 ($r = .61$, $p = .0001$) indicates that nitrification rates increase until the 8 month.

Compost cured for 10 months had a significantly higher percentage of particles > 2.4 mm (0.1 in) than other curing times (Table 2). For each curing period the highest percentage was of particle size 1.2 mm (0.05 in) or smaller, except in 10 months old compost. Decomposition of organic materials during curing would be expected to decrease particle size, with little change in bulk density. The effect on particle size was evidently obscured by differences in the initial particle size distribution between piles.

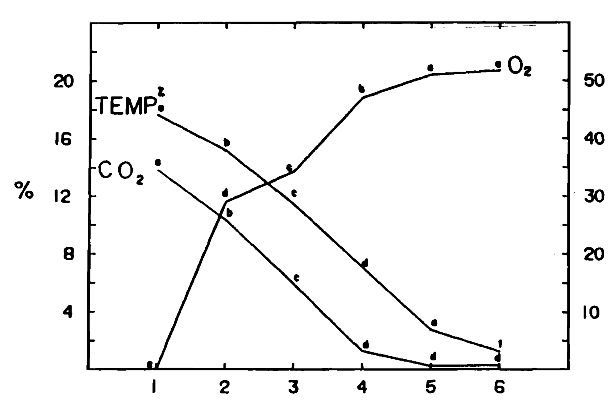

Fig. 1. Effects of curing time (months) on CO_2, O_2, and °C in piles of screened composted sewage sludge stored outdoors from July 17, 1984, to January 15, 1985, following 21 days of composting. ([z]Means on each line, followed by the same letter or letters, are not significantly different using Duncan's Multiple Range Test at the 5% level.)

Experiment #2. Compost concentration in the media had a significant effect on the dry weight of the bedding plants and on EC, pH, NH_4, NO_3 + NO_2, extractable N, P and K (Table 3). Increasing the curing time of compost significantly affected the dry wt of *I. hybrida* and *T. patula,* EC, pH, NH_4, NO_3 + NO_2, and extractable N concentrations in the media. Significant interaction occurred between compost curing time and concentration with pH, NH_4, NO_3 + NO_2, and extractable K.

Increasing curing time of compost from 0 to 8 months increased dry wt of *I. hybrida* and *T. patula,* and improved visual ratings of *C. hybridus* and *I. hybrida* (Table 4). Curing time had no effect on dry wt of *C.* x *hybridus,* or on the visual rating or number of open, unopen, senesced and total flowers of *T. patula* (Table 4). Increasing the compost concentration in the media from 10 to 40% decreased dry wt and visual rating of all species, and decreased the number of open and total flowers in *T. patula.* Only *I. hybrida* in media amended with compost cured from 1 to 8 months had higher dry wt and visual ratings than plants grown in Pro Mix BX.

Media EC and pH levels determined before transplanting, decreased as curing time increased from 0 to 8 months (Table 5). However, increasing compost concentrations in the media increased EC and pH, which were higher than those in Pro-Mix BX.

Increasing compost curing time from 0 to 8 months decreased NH_4, and extractable N and K concentrations, but increased NO_3 + NO_2 in the growing media (Table 5). Extractable P concentrations were not affected by curing time. Concentrations of NH_4, NO_3 + NO_2, and extractable N, P, and K increased as compost concentrations in the media increased. Pro-Mix BX and media amended with compost cured for 4 and 8 months, regardless of concentration, had similar NH_4 concentrations. Media amended with 10% compost cured for 4 and 8 months had similar NO_3 + NO_2 and extractable N concentrations as Pro-Mix BX, but higher P and lower K concentrations.

Correlation coefficients between compost concentrations in the media and dry wt of *C.* x *hybridus* ($r = -.89$, $p = .0001$), *I. hybrida* ($r = -.81$, $p = .0016$), and *T. patula*

Table 1. Mean pH, EC (mmhos/cm), bulk density (g/cm³), and extractable P and K concentrations of screened composted sewage sludge as influenced by curing time (month(s)) after 21 days of composting.

Curing time (months)	pH	mmhos/cm	g/cm³	ppm P	ppm K
0	7.1 c[z]	22.0 a	.55 c	1400 b	1400 a
1	7.4 a	15.1 b	.53 c	1420 b	1360 a
4	7.3 b	10.3 c	.54 c	1480 ab	1160 a
6	7.3 b	15.1 b	.58 ab	1500 ab	1380 a
8	7.3 b	13.9 b	.60 a	1180 c	1300 a
10	7.3 b	7.8 c	.56 bc	1620 a	1190 a

[z]Means within a column followed by the same letter are not significantly different, using Duncan's Multiple Range Test at 5%.

Table 2. Mean NH_4, NO_3 + NO_2, extractable N, and particle size distribution (PSD) of screened composted sewage sludge as influenced by curing time (month(s)) after 21 days of composting.

Curing time (months)	ppm			PSD in mm (%/total dry wt)				
	NH_4	NO_3 + NO_2	Extractable N	>8.0	4.8-8.0	2.4-4.8	1.2-2.4	< 1.2
0	1895.3 a[z]	0.0 d	1872.9 a	0.4 b	4.2 d	20.5 b	27.9 b	46.8 b
1	1140.9 b	457.1 c	1598.0 a	0.9 b	7.6 b	20.1 b	20.2 c	51.0 b
4	123.2 c	772.8 ab	896.0 b	1.4 b	6.3 bc	21.5 b	31.9 a	38.7 c
6	208.2 c	742.5 ab	950.7 b	0.5 b	5.6 c	16.1 c	15.9 d	61.5 a
8	40.0 c	801.4 a	841.5 b	1.2 b	3.4 d	15.4 c	28.0 b	50.8 b
10	20.1 c	522.7 bc	544.1 b	8.9 a	14.2 a	25.2 a	30.8 ab	20.7 d

[z]Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test at 5%.

Table 3. Significance of compost curing time (curtime), concentration (concn) and their interaction, on electrical conductivity (EC), pH, extractable N, P, and K in the growing medium of peat:vermiculite (v/v) and on top growth dry weight of 3 bedding plants.

Source of variation	EC	pH	NH_4	NO_3+NO_2	Extractable N	Extractable P	Extractable K	Dry weight C. hybridus	Dry weight I. hybrida	Dry weight T. patula
curtime	*[z]	**	**	**	**	ns	*	ns	**	*
concn	**	**	**	**	**	**	**	**	**	**
curtime*concn	ns	*	**	**	ns	ns	*	ns	ns	ns

[z]Significant at the 5% level (*), 1% level (**), or non-significant (ns).

(R = -.89, p = .0001); between compost concentration in the media and EC, pH, extractable N and K concentrations ($r > .75$, $p < .05$), and between plant dry wt., and EC, pH and extractable N and K concentrations in the media ($r > -.80$, $p < .05$), suggest that an increase in EC, pH, and extractable N and K in the media, or some interaction between these variables, may have a detrimental effect on plant growth. However, it is unlikely that increases in extractable N (unless in the NH_4 form) or in K concentrations, would have a detrimental effect.

Curing more than 1 month may not be necessary for some species since high quality *I. hybrida* and *T. patula* were grown in media amended with 10 or 20% compost cured for 0, 1, 4 or 8 months. Compost concentration in the media had a greater effect on plant growth than curing time.

Significance to the Nursery Industry

Sewage sludge compost can be a valuable resource to the landscape horticulture industry. Until now it has been assumed that compost was ready for use after composting for 21 days and curing for one month. However, the results of these studies indicate that compost is not completely cured for at least 4 to 5 months after composting when temperatures, CO_2, and O_2 approach ambient levels and much of the ammonia is converted to nitrate. Although the extended curing time from 0 to 8 months had an effect on the growth of Impatiens and Tagetes, it did not influence the growth of Coleus. Compost concentration in the media had greater influence on the growth of all species than did curing time. All of these studies were conducted using compost

Table 4. Top growth responses (g), and visual rating of *C. hybridus, I. hybrida,* and the flowering of *T. patula* as influenced by compost curing time (month(s)) and concentration in peat:vermiculite (v/v) media.

	Per cell pack									
	g			Visual rating[y]			T. patula flowering			
Compost curing time (months)	C. hybridus	I. hybrida	T. patula	C. hybridus	I. hybrida	T. patula	No. open buds	No. unopen buds	No. senesced flowers	Total flowers
0	0.8 a[z]	7.9 c	8.5 b	1.6 b	2.5 b	2.8 a	14.2 a	29.8 a	3.7 a	47.7 ab
1	0.9 a	10.2 b	8.5 b	1.8 ab	2.6 b	2.4 a	14.5 a	27.5 a	3.5 a	45.5 b
4	1.0 a	11.1 ab	9.9 a	1.9 ab	3.2 a	2.8 a	15.8 a	31.1 a	4.0 a	50.8 a
8	1.1 a	12.1 a	9.4 ab	2.0 a	3.3 a	2.8 a	13.6 a	29.5 a	3.6 a	46.8 ab
concentration										
10%	1.4 a	12.9 a	11.0 a	2.5 a	3.2 a	3.1 a	17.3 a	31.0 a	3.8 a	52.1 a
20%	0.9 b	10.7 b	8.9 b	1.7 b	3.1 a	2.6 b	14.3 b	28.4 a	3.7 a	46.4 a
40%	0.5 c	7.4 c	7.3 c	1.2 c	2.3 b	2.3 b	12.0 c	29.1 a	3.6 a	44.6 b
Pro Mix BX[x]	3.5	8.5	16.1	3.2	2.4	3.9	20.0	32.0	2.5	54.5

[z]Means within a column followed by the same letter or letters are not significantly different, using Duncan's Multiple Range Test at 5%.

[y]Low = 1, High = 4.

[x]Premier Brands, Inc.

Table 5. Electrical conductivity (mmhos/cm), pH, and extractable N, P and K (determined before transplanting) as influenced by media containing peat and vermiculite (v/v) amended with 3 concentrations of screened composted sewage sludge of different curing time (month(s)).

Compost				ppm				
						Extractable		
Curing time	--%	mmhos/cm	pH	NH_4+	$NO_3- + NO_2$	N	P	K
0 month(s)	10	1.5 de[z]	7.03 c	429.6 c	0.0 f	418.3 h	5000 c	1091.9 cd
,,	20	2.7 bc	7.20 ab	611.9 b	0.0 f	603.1 d-f	9300 ab	1234.7 bc
,,	40	5.6 a	7.30 a	888.2 a	0.5 f	850.3 b	9800 ab	1320.6 b
1 month(s)	10	1.5 ed	6.77 d	352.7 d	188.1 e	540.8 fg	4800 c	1085.0 cd
,,	20	2.6 b-d	7.00 c	483.4 c	279.1 d	762.6 bc	8600 b	1196.3 bc
,,	40	5.5 a	7.23 ab	601.2 b	426.0 c	1027.2 a	11110 ab	1395.8 b
4 month(s)	10	1.2 e	6.57 e	55.4 e	305.3 d	360.7 h	5700 c	1027.6 cd
,,	20	2.1 c-e	6.93 c	67.8 e	505.8 b	573.6 e-g	9100 ab	1072.7 cd
,,	40	3.7 b	7.17 b	54.2 e	634.5 a	688.6 c-e	11500 a	1100.9 cd
8 month(s)	10	1.5 ed	6.67 de	59.6 e	319.2 d	378.8 h	5700 c	899.4 d
,,	20	2.0 c-e	6.93 c	59.3 e	420.4 c	479.7 gh	10600 ab	1024.1 cd
,,	40	3.7 b	7.17 b	51.1 e	661.7 a	712.8 cd	11600 a	1356.3 b
Pro Mix BX[y]	--	1.0 e	5.80 f	54.9 e	310.0 d	365.0 h	1700 d	2622.1 a

[z]Means within a column followed by the same letter or letters are not significantly different, using Duncan's Multiple Range Test at 5%.

[y]Premier Brands, Inc.

made from lime-dewatered raw sewage sludge; plant's growth response can be expected to be different when compost is made from polymer dewatered sludge.

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Propagation of *Osmanthus* X *fortunei* by Softwood Cuttings[1]

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Abstract

Moderate rooting (64%) was achieved with nontreated, softwood cuttings of Fortune's osmanthus (*Osmanthus* X *fortunei* Carr.). Treatment of cuttings with 2500 ppm indolebutyric acid (IBA) significantly increased percent rooting (92%). Higher auxin concentrations resulted in rooting comparable to the nontreated cuttings. None of the treatments had any influence on root number or root length.

Index words: rooting, auxin, indolebutyric acid, Fortune's osmanthus

Introduction

Fortune's osmanthus (*Osmanthus* X *fortunei* Carr.), an interspecific hybrid between holly osmanthus [*O. heterophyllus* (G. Don) P.S. Green] and fragrant tea olive [*O. fragrans* (Thunb.) Lour.], is a large, dense, oval to rounded evergreen shrub which reaches a height of 4.6 to 6.1 m (15 to 20 ft) (1, 3). Leaves are dark green and leathery in appearance and small, extremely fragrant, white flowers are produced in the fall. At Raleigh, flowering generally occurs from mid-September through mid-October.

Although common in southern landscapes, specific propagation information is lacking, and nurserymen describe the hybrid as difficult to propagate by cuttings. Rooting trials conducted by the senior author over the last several years utilizing semi-hardwood and hardwood cuttings have resulted either in total failure or very low rooting percentages. However, a study conducted in mid-June 1984 suggested softwood cuttings might be the key to achieving greater success.

The 1984 research utilized cuttings in a transitional growth stage between a softwood and semi-hardwood condition with the best treatment resulting in 36% rooting. Although most propagators would regard such rooting as unacceptable, the results were encouraging as this was the greatest success achieved to date. The 1984 study suggested that softwood cuttings might provide greater rooting and with this objective in mind, the following investigation was undertaken to investigate the feasibility of propagating Fortune's osmanthus by softwood cuttings.

Materials and Methods

Terminal, softwood stem cuttings each 8 cm (3.1 in) long were taken May 13, 1986 from a single plant growing on the campus of North Carolina State University. Stems and leaves of the cuttings were light green. Leaves were fully expanded and the leaf tissue was soft yet sufficiently firm so that the leaves did not appear flaccid. Stem tissue was similar in that it was soft but firm. No

[1]Received for publication December 24, 1986; in revised form February 13, 1987. Paper No. 10841 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh, NC 27695-7601.

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