Research Reports

Growth of Bedding Plants in Substrates Amended with Compost and Fertilized with Three Different Release Rates of a Controlled-release Fertilizer Product

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SUMMARY. Growth of 'Aladdin Peach Morn' petunia (*Petunia ×hybrida*) and 'Accent White' impatiens (*Impatiens wallerana*) was compared in substrates containing 0%, 30%, 60%, or 100% compost made from biosolids and yard trimmings and fertilized with Nutricote Total 13-13-13 (13N-5.7P-10.8K) Types 70, 100, and 140 incorporated at rates of 0.5x, 1x, 2x, or 3x (x = standard application rate for a medium-feeding crop). Petunia shoot dry weight of plants fertilized with Type 70 incorporated at 0.5x increased as the percentage

of compost in the substrate increased from 0% to 60% and then decreased, while shoot dry weight of plants fertilized with Type 70 incorporated at 1x, 2x, or 3x increased as the percentage of compost increased from 0% to 30% and then decreased. Impatiens shoot dry weight of plants fertilized with Type 70 incorporated at 0.5x and 1x also increased as the percentage of compost increased from 0% to 30% and then decreased, while shoot dry weight of plants fertilized at 2x and 3x decreased as the percentage of compost increased from 0% to 100%. Both petunia and impatiens shoot dry weight of plants fertilized with Type 100 and Type 140 incorporated at 0.5x, 1x, 2x, or 3x increased as the percentage of compost increased from 0% to 60% and then decreased.

Substrates containing compost products made from urban waste can contain significant levels of certain plant nutrients, but they rarely contain them in sufficient concentrations to provide a nursery crop's entire requirement (Chaney et al., 1980; Faliahi-Ardakani et al., 1987; Fitzpatrick et al., 1998; Wootton et al., 1981). One of the advantages of using composted biosolids (sewage sludge) is that compost products made from biosolids tend to be more nutrient rich than compost products made from feedstocks that contain lower concentrations of nitrogen (N) (Rynk et al., 1992). For example, Chaney et al. (1980) reported that using 33% compost made from sewage sludge and wood chips in their growing substrate provided all the required trace elements, limestone, phosphorus (P), and part of the required N for 'Double Eagle' marigold (*Tagetes erecta*) growth. Klock-Moore (2001) also reported that a top-dress application of 4.0 g (0.14

oz) Nutricote Total 13-13-13 Type 100 (Florikan, Sarasota, Fla.) per pot augmented the nutrients provided by substrates containing biosolid compost and increased impatiens and salvia (*Salvia farinacea*) growth beyond that achieved by control plants.

Most bedding plant growers incorporate controlled-release fertilizer products into their growing substrate prior to transplanting and use different release rates of controlled-release fertilizer products, depending on the crop they are growing, as well as the time of year and geographic location. Little research has been published on the use of controlled-release fertilizer products with varying release rates incorporated into growing substrates containing composted urban waste. The objective of this experiment was to compare petunia and impatiens growth in substrates containing 0%, 30%, 60% or 100% compost made from biosolids and yard trimmings, and fertilized with three different release rates of the same controlled-release fertilizer.

Materials and methods

Plugs of petunia 'Aladdin Pink Morn' and impatiens 'Accent White' from a #392 square plug tray were transplanted into 10.16-cm-diameter (4.0 inches) round pots [400 mL (13.5 fl oz) volume] filled by volume with: 1) 100% compost; 2) 60% compost: 25% vermiculite: 15% perlite; 3) 30% compost: 30% Canadian sphagnum peat moss: 25% vermiculite: 15% perlite; or 4) 0% compost, 60% Canadian sphagnum peat moss: 25% vermiculite: 15% perlite.

The compost product was a 1:1 by weight mixture of biosolids and yard trimmings obtained from the Solid Waste Authority (SWA) of Palm Beach County, Fla. Biosolids used by SWA were a combination of polymer-dewatered wastewater residuals (~14% dry solids) generated by two local wastewater treatment facilities. The yard trimmings were mainly woody waste ground and screened to a 1.27 to 3.30 cm (0.5 to 1.3 inch) mulch that was collected by SWA through residential collection programs. The compost was made using a rectangular agitated bed system. Materials were mixed and composted for about 21 d, cured for 3 months, and screened to pass a 1.27-cm screen. The compost was stockpiled for 6 months prior to use in these experiments. The compost product did not

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contain any significant amounts of inert materials (e.g., glass fragments) that would require protective measures when being handled by bedding plant growers or consumers.

Prior to transplanting, Nutricote Total 13-13-13 Types 70, 100, and 140 [the fertilizer will release 80% of its N evenly over a 70, 100, or 140-d period, respectively, at a constant temperature of 25 °C (77.0 °F)] was incorporated into the four test substrates at rates of 0.5x, 1x, 2x, or 3x, where x is the standard rate for a medium-feeding crop. Nutricote Type 70 was incorporated at rates of 1.48, 2.97, 5.93, or 8.90 kg·m⁻³ (2.5, 5.0, 10.0, or 15.0 lb/yd³) while Type 100 was incorporated at rates of 2.22, 4.45, 8.90, or 13.35 kg·m⁻³ (3.75, 7.5, 15.0, or 22.5 lb/yd³). Nutricote Type 140 was incorporated at rates of 2.67, 5.34, 10.68, or 16.02 kg·m⁻³ (4.5, 9.0, 18.0, or 27.0 lb/yd³). Pots were arranged in a completely randomized design with five single pot replications per treatment (percent compost by fertilizer type by application rate).

Plants were watered daily at 0800 HR for 10 min to deliver approximately 1.01 to 2.03 cm (0.4 to 0.8 inch) or 100 to 200 mL (3.4 to 6.8 fl oz) per pot of water to establish a 20% leaching fraction. The irrigation water used throughout the experiment had 0.36 dS·m⁻¹ (230.4 ppm) electrical conductivity (EC), 94 mg·L⁻¹ (ppm) calcium carbonate (CaCO₃) total alkalinity (1.88 meq·L⁻¹), 0.6 mg·L⁻¹ nitrate-nitrogen (NO₃-N), 28 mg·L⁻¹ calcium (Ca), 6 mg·L⁻¹ magnesium (Mg), and 22 mg·L⁻¹ sodium (Na).

When control plants (0% compost) reached a marketable size (approximately 35 to 40 d after transplanting), shoots of all plants were cut at the surface of the substrate, dried at 60 °C (140.0 °F) for 48 h, and weighed. At harvest, the surface 2.03 to 3.05 cm (0.8 to 1.2 inch) of the 9.40-cm (3.7 inches) substrate column was removed from every pot to ensure that substrate samples were taken from the active root-zone in the remaining substrate column.

Compost product quality was assessed by determining the initial air-filled porosity (AP), water-holding capacity (WHC), and moisture content (MC) as well as the initial cation exchange capacity (CEC) and pH, EC, N, P, potassium (K), Ca, and Mg. Final substrate EC also was recorded.

Percent AP, WHC, and MC were determined on five replicate samples of each substrate in 9.40-cm-tall × 10.16-cm-diameter (3.7 × 4.0 inches) round pots (400 mL volume) by volume displacement methods (Niedziela and Nelson, 1992). Initial CEC, pH, N, P, K, Ca, and Mg and initial/final EC were determined on five replicate samples by A&L Southern Agricultural Laboratories, Pompano Beach, Fla., which used a Morgan extract (Soil and Plant Analysis Council, Athens, Ga.).

The experiment was conducted in Fall 2001 and repeated in Spring 2002 at the University of Florida Fort Lauderdale Research and Education Center in an open-sided greenhouse. Plants were exposed to ambient air temperatures averaging 30/21 ± 2 °C (86.0/69.8 ± 3.6 °F) day/night. All data collected were analyzed by analysis of variance and regression procedures (SAS Institute, Cary, N.C.).

Results and discussion

There was no significant difference in petunia or impatiens shoot dry weight between the two runs of this experiment and therefore the data were combined (Table 1). Both petunia and impatiens shoot dry weight, averaged for fertilizer type (release rate) and application rate, increased as the percentage of compost in the growing substrate increased from 0% to 30% and then decreased at 60% and 100% (Table 1). Substrates containing compost had higher initial CEC, pH, EC, N, P, K, Ca, and Mg concentrations than control substrates but had lower water-holding capacity and moisture contents than control substrates (Tables 2 and 3). Bugbee and Fink (1989) reported that compost made from leaves, biosolids, and street sand was higher in plant nutrients than peat, sand, Styrofoam, or soil. Shiralipour et

Table 1. Shoot dry weight of 'Aladdin Peach Morn' petunia and 'Accent White' impatiens plants grown in substrates containing 0%, 30%, 60%, or 100% compost made from biosolids and yard trimmings and fertilized with Nutricote Total 13-13-13 (13N-5.7P-10.8K) Types 70, 100, or 140 incorporated at rates of 0.5x, 1x, 2x, or 3x (x = standard application rate for medium feeding crops).

Substrate compost content (%)	Fertilizer type	Petunia	Impatiens
----- Shoot dry wt (g) -----			
0	70	2.10	1.30
30	70	2.61	1.85
60	70	2.02	0.95
100	70	1.89	0.94
Avg		2.16	1.26
0	100	1.98	0.95
30	100	2.16	1.37
60	100	1.97	1.26
100	100	1.39	1.05
Avg		1.88	1.16
0	140	1.69	0.68
30	140	2.03	1.15
60	140	1.86	1.00
100	140	1.20	0.95
Avg		1.69	0.95
<u>Significance^y</u>			
Experiment		0.1260	0.3933
Replicate		0.1003	0.2214
Compost content (C)		0.0001	0.0001
Fertilizer type (F)		0.0001	0.0001
C × F		0.0514	0.0001
Application rate (R)		0.0001	0.0001
C × R		0.0114	0.0001
F × R		0.1101	0.0329
C × F × R		0.0109	0.0001

^z28.35 g = 1.0 oz.

^ySignificance is reported as *P* > *F*.

Table 2. Initial chemical characteristics of substrates containing 0%, 30%, 60%, or 100% compost made from biosolids and yard trimmings. Mean separation within rows by Duncan's multiple range test ($P = 0.05$). (N = 5)

Substrate compost content (%)	Cation exchange capacity (meq/100g)	pH	Electrical conductivity ($\text{dS}\cdot\text{m}^{-1}$) ^z	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
<i>Initial substrate^v</i>								
						$\mu\text{g}\cdot\text{g}^{-1}$ (ppm)		
0	3.20 c	5.2 b	0.14 d	43 b	6 b	17 b	230 b	123 b
30	9.46 b	6.5 a	1.06 c	167 a	80 a	409 a	1470 a	214 a
60	8.63 b	6.5 a	1.45 b	155 a	80 a	425 a	2070 a	280 a
100	15.01 a	6.8 a	1.62 a	163 a	80 a	471 a	2200 a	257 a
Suggested standards ^v		5.5–6.5	0.2–1.0	25–150	12–60	50–250	500–5000	50–500

^z1 $\text{dS}\cdot\text{m}^{-1} = 640$ ppm.

^vSuggested standards are based on recommendations from A&L Southern Agricultural Laboratories, Pompano Beach, Fla., which used a Morgan extract.

al. (1992) have reported that as the percentage of compost in the medium increases above 50%, plant growth can decrease as a result of high soluble salt concentrations, poor aeration, heavy metal toxicity, or phytotoxicity. Klock (1997) also observed that petunia and dianthus (*Dianthus chinensis*) shoot dry weight increased as the percentage of composted biosolids and yard trimmings in the growing substrate increased from 0% to 60% and then decreased.

Both petunia and impatiens shoot dry weight, averaged for compost percentage and fertilizer application rate, was greater in substrates fertilized with Nutricote Total 13–13–13 Type 70 than in substrates fertilized with Types 100 or 140 (Table 1). Nutricote is designed to release 80% of its N evenly over a 70, 100, or 140-d period for Types 70, 100, and 140, respectively, at a constant temperature of 25 °C but will release more quickly under warmer temperatures (Nutricote label, Florikan, Sarasota, Fla.). Florikan states that nutrient release from Nutricote is not significantly affected by soil moisture, soil type, soil pH, or microbial activity in the soil. Therefore, it could be expected that larger percentages/fractions of nutrients would be released from Type 70 than from Types 100 and 140 during the short 35 to 40-d growing period. Final substrate EC was higher in substrates fertilized with Types 100 and

Table 3. Initial physical characteristics of substrates containing 0, 30, 60, or 100% compost made from biosolids and yard trimmings. Mean separation within rows by Duncan's multiple range test ($P = 0.05$). (N = 5)

Substrate compost content (%)	Air-filled porosity (%)	Water-holding capacity (%)	Moisture content (%)
0	28 a	59 a	74 a
30	29 a	37 b	61 b
60	20 a	36 b	59 b
100	25 a	22 c	47 c
Suggested standards ^z	5–30	20–60	50–80

^zSuggested standards based on recommendations from Fonteno (1996).

140 than in substrates fertilized with Type 70, and there was no difference in final substrate EC among the compost products or among the fertilizer application rates (Table 4). All final substrate EC values were within recommended guidelines [0.2 to 1.0 $\text{dS}\cdot\text{m}^{-1}$ (128 to 640 ppm)] (A&L Southern Agricultural Laboratories). This suggests there were still some nutrients left in the substrates fertilized with Types 100 and 140 but that the nutrients in the Type 70 were either taken up by the petunia and impatiens plants or leached from the growing medium. It also suggested that the ions responsible for initial EC concentrations in the compost substrates were either readily leached or taken up by the petunia and impatiens plants under normal bedding plant growing conditions.

As expected, petunia and impatiens shoot dry weight, averaged across compost percentage and fertilizer type, increased as fertilizer application rate increased from 0.5x to 3x (Fig. 1).

Table 4. Final substrate electrical conductivity (EC) for 'Aladdin Peach Morn' petunia and 'Accent White' impatiens plants grown in substrates containing 0%, 30%, 60%, or 100% compost made from biosolids and yard trimmings and fertilized with Nutricote Total 13–13–13 (13N–5.7P–10.8K) Types 70, 100, or 140 incorporated at rates of 0.5x, 1x, 2x, or 3x (x = standard application rate for medium-feeding crops) (N = 20).

Substrate compost content (%)	Fertilizer type	Final EC ($\text{dS}\cdot\text{m}^{-1}$) ^z
0	70	0.22
30	70	0.30
60	70	0.33
100	70	0.39
0	100	0.67
30	100	0.72
60	100	0.45
100	100	0.81
0	140	0.52
30	140	0.51
60	140	0.73
100	140	0.67
Suggested standard ^v		0.2–1.0
<i>Significance^x</i>		
Compost content (C)		0.5954
Fertilizer type (F)		0.0011
C × F		0.2366
Fertilizer rate (R)		0.4589
C × R		0.6987
F × R		0.5486
C × F × R		0.2158

^z1 $\text{dS}\cdot\text{m}^{-1} = 640$ ppm.

^vSuggested standard is based on recommendations from A&L Southern Agricultural Laboratories, Pompano Beach, Fla., which used a Morgan extract.

^xSignificance reported as $P > F$. Because there was no difference in final substrate EC between the two bedding plant species, these values were combined.

Fig. 1. Shoot dry weight of 'Aladdin Peach Morn' petunia plants grown in substrates containing 0%, 30%, 60%, or 100% compost made from biosolids and yard trimmings and fertilized with Nutricote Total 13-13-13 (13N-5.7P-10.8K) Types 70 (A), 100 (B), or 140 (C) incorporated at rates of 0.5x (■), 1x (●), 2x (▲), or 3x (◆) (x = standard application rate for medium feeding crops). (28.35 g = 1.0 oz.)

Klock-Moore (2001) also reported that impatiens and salvia (*Salvia farinacea*) shoot dry weight linearly increased for plants grown in 0%, 30%, 60%, and 100% compost as top-dress applications of Nutricote Total 13-13-13 Type 100 increased from 0.5 to 4.0 g (0.018 to 0.14 oz) per pot.

Petunia and impatiens shoot dry weight varied among the four compost percentages with respect to fertilizer type and application rate (Table 1, Figs. 1 and 2). Petunia shoot dry weight of plants fertilized with Type 70 at 0.5x increased as the percentage of compost in the substrate increased from 0% to

Fig. 2. Shoot dry weight of 'Accent White' impatiens plants grown in substrates containing 0%, 30%, 60%, or 100% compost made from biosolids and yard trimmings and fertilized with Nutricote Total 13-13-13 (13N-5.7P-10.8K) Types 70 (A), 100 (B), or 140 (C) incorporated at rates of 0.5x (■), 1x (●), 2x (▲), or 3x (◆) (x = standard application rate from medium-feeding crops). (28.35 g = 1.0 oz.)

60% and then decreased, while shoot dry of plants fertilized with Type 70 at 1x, 2x, or 3x increased as the percentage of compost increased from 0% to 30% and then decreased (Table 5, Fig. 1). Impatiens shoot dry weight of plants fertilized with Type 70 at 0.5x and 1x also increased as the percent-

Table 5. Regression equations for final shoot dry weight of 'Aladdin Peach Morn' petunia and 'Accent White' impatiens plants grown in substrates containing 0%, 30%, 60%, or 100% compost made from biosolids and yard trimmings and fertilized with Nutricote Total 13-13-13 (13N-5.7P-10.8K) Types 70, 100, or 140 incorporated at rates of 0.5x, 1x, 2x, or 3x (x = standard application rate for medium-feeding crop).

Fertilizer type	rate	Regression equation
<i>Petunia</i>		
70	0.5x	$Y = -1.37 \times 10^{-4}x^2 + 1.47 \times 10^{-2}x + 0.995, r^2 = 0.99$
	1x	$Y = 1.64 \times 10^{-5}x^3 + -2.60 \times 10^{-3}x^2 + 0.103x + 1.80, r^2 = 0.99$
	2x	$Y = 8.81 \times 10^{-6}x^3 + -1.46 \times 10^{-3}x^2 + 0.055x + 2.40, r^2 = 0.99$
	3x	$Y = 7.34 \times 10^{-6}x^3 + -1.22 \times 10^{-3}x^2 + 0.043x + 2.90, r^2 = 0.99$
100	0.5x	$Y = -1.64 \times 10^{-4}x^2 + 1.75 \times 10^{-2}x + 0.658, r^2 = 0.73$
	1x	$Y = -4.01 \times 10^{-4}x^2 + 4.34 \times 10^{-2}x + 0.741, r^2 = 0.97$
	2x	$Y = -4.92 \times 10^{-6}x^3 + 5.54 \times 10^{-4}x^2 + -0.012x + 2.50, r^2 = 0.99$
	3x	$Y = -3.33 \times 10^{-4}x^2 + 2.83 \times 10^{-2}x + 2.34, r^2 = 0.92$
140	0.5x	$Y = -2.85 \times 10^{-4}x^2 + 2.73 \times 10^{-2}x + 0.609, r^2 = 0.99$
	1x	$Y = -1.89 \times 10^{-4}x^2 + 1.99 \times 10^{-2}x + 1.14, r^2 = 0.77$
	2x	$Y = -4.51 \times 10^{-4}x^2 + 3.65 \times 10^{-2}x + 1.68, r^2 = 0.99$
	3x	$Y = -2.34 \times 10^{-4}x^2 + 2.67 \times 10^{-2}x + 1.98, r^2 = 0.97$
<i>Impatiens</i>		
70	0.5x	$Y = 2.11 \times 10^{-5}x^3 + -3.40 \times 10^{-3}x^2 + 0.12x + 1.10, r^2 = 0.99$
	1x	$Y = 1.62 \times 10^{-5}x^3 + -2.41 \times 10^{-3}x^2 + 0.06x + 2.40, r^2 = 0.99$
	2x	$Y = -8.97 \times 10^{-6}x^3 + 1.75 \times 10^{-3}x^2 + -0.10x + 2.90, r^2 = 0.99$
	3x	$Y = -7.34 \times 10^{-6}x^3 + 1.38 \times 10^{-3}x^2 + 0.08x + 2.90, r^2 = 0.99$
100	0.5x	$Y = -2.06 \times 10^{-4}x^2 + 2.44 \times 10^{-2}x + 0.414, r^2 = 0.99$
	1x	$Y = -1.14 \times 10^{-4}x^2 + 1.40 \times 10^{-2}x + 0.821, r^2 = 0.93$
	2x	$Y = -1.68 \times 10^{-4}x^2 + 1.87 \times 10^{-2}x + 1.05, r^2 = 0.77$
	3x	$Y = -1.76 \times 10^{-4}x^2 + 1.50 \times 10^{-2}x + 1.28, r^2 = 0.96$
140	0.5x	$Y = -1.50 \times 10^{-4}x^2 + 1.97 \times 10^{-2}x + 0.36, r^2 = 0.90$
	1x	$Y = -1.87 \times 10^{-4}x^2 + 2.28 \times 10^{-2}x + 0.496, r^2 = 0.99$
	2x	$Y = -1.96 \times 10^{-4}x^2 + 2.16 \times 10^{-2}x + 0.472, r^2 = 0.97$
	3x	$Y = -3.49 \times 10^{-4}x^2 + 3.78 \times 10^{-2}x + 0.843, r^2 = 0.93$

age of compost increased from 0% to 30% and then decreased while shoot dry weight of plants fertilized at 2x and 3x decreased as the percentage of compost increased from 0% to 100% (Table 5, Fig 2). Both petunia and impatiens shoot dry weight of plants fertilized with Type 100 and Type 140 at 0.5x, 1x, 2x, and 3x increased as the percentage of compost increased from 0 to 60% and then decreased (Table 5, Figs. 1 and 2).

In general, Type 70 Nutricote should release a greater percentage of its nutrients in the same time frame as Types 100 and 140. This in combination with the higher initial EC in the

substrates containing compost may have limited petunia and impatiens plant growth. However, Nutricote Types 100 and 140 should release nutrients a smaller percentage of nutrients and probably did not contribute to the initial high EC in the compost substrates. When petunia and impatiens are grown with Nutricote Total 13-13-13 Type 70, the growing substrate should not contain more than 30% biosolids compost. However, if Nutricote Total 13-13-13 Type 100 or Type 140 are used the growing substrates should not contain more than 60% biosolids compost.

Literature cited

- Bugbee, G.J. and C.R. Frink. 1989. Composted waste as a peat substitute in peat-lite media. *HortScience* 24(4):625-627.
- Chaney, R.L., J.B. Munns, and H.M. Cathey. 1980. Effectiveness of digested sewage sludge compost in supplying nutrients for soilless potting media. *J. Amer. Soc. Hort. Sci.* 105:485-492.
- Faliahi-Ardakani, A., J.C. Bouwkamp, F.R. Gouin, and R.L. Chaney. 1987. Growth response and mineral uptake of vegetable transplants grown in a composted sewage sludge amended medium. I. Nutrient supplying power of the medium. *J. Environ. Hort.* 5(3):107-111.
- Fitzpatrick, G.E., E.R. Duke, and K.A. Klock-Moore. 1998. Use of compost products for ornamental crop production: Research and grower experiences. *HortScience* 33(6):941-944.
- Fonteno, W.C. 1996. Growing media: types and physical/chemical properties. p. 93-122. In: D.Wm. Reed (ed.). *A growers guide to water, media, and nutrition of greenhouse crops*. Ball Publ., Batavia, Ill.
- Klock, K.A. 1997. Growth of dianthus and petunia in media amended with composted urban waste. *J. Environ. Hort.* 15(3):135-137.
- Klock-Moore, K.A. 2001. Effect of controlled-release fertilizer application rates on bedding plant growth in substrates containing compost. *Compost Sci. and Utilization* 9(3):215-220.
- Niedziela, C.E., Jr. and P.V. Nelson. 1992. A rapid method for determining physical properties of undisturbed substrate. *HortScience* 27:1279-1280.
- Rynk, R., M. van de Kamp, G.G. Willson, M.E. Singley, T.L. Richard, J.J. Kolega, F.R. Gouin, L. Laliberty, Jr., D. Kay, D.W. Murphy, H.A.J. Hoitink, and W.F. Brinton. 1992. *On-farm composting handbook*. Northeast Reg. Agr. Eng. Serv., Ithaca, N.Y.
- Shiralipour, A., D.B. McConnell, and W.H. Smith. 1992. Uses and benefits of MSW compost: A review and an assessment. *Biomass and Bioenergy* 3:267-279.
- Wootton, R.D., F.R. Gouin, and F.C. Stark. 1981. Composted, digested sludge as a medium for growing flowering annuals. *J. Amer. Soc. Hort. Sci.* 106:46-49.