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Composted, Digested Sludge as a Medium for Growing Flowering Annuals[1]

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Additional index words. Tagetes erecta, Zinnia elegans, Petunia hybrida

***Abstract. Tagetes erecta* L. cv. Golden Jubilee, *Zinnia elegans* Jacq. cv. Fire Cracker, and *Petunia hybrida* Hort. cv. Sugar Plum were grown in various sludge compost-based media based on fraction size. Growth determined by shoot dry weight was greatest in media containing greater portions of small compost particles. No nutrient deficiency symptoms or toxicity symptoms were observed. Shoot weight was increased by addition of a N-P-K fertilizer.**

As municipalities upgrade wastewater treatment processes to comply with federal requirements there is an increase in the availability of sludge, the solids removed during wastewater treatment. Sludge can be stabilized and converted to a usable material by composting it at a cost comparable to land disposal. Sludge compost contains essential nutrients in slowly available forms, and has an appearance and odor similar to garden compost (7).

A knowledge of particle size distribution within a soilless medium can aid in standardizing and characterizing materials used in preparation of a growing medium (1). If particle size is controlled, bark or wood chips mixed with sand or soil provide a medium with acceptable physical and chemical properties (4). Wood, because it decomposes, may indirectly cause N deficiency as microflora use available N, but composting the wood product with sludge eliminates this problem (3).

In this study a series of experiments was conducted to evaluate sewage sludge composted with wood chips as a medium for growing annual bedding plants.

Materials and Methods

Compost, supplied by Maryland Environmental Services, was made from anaerobically digested sludge from the District of Columbia Wastewater Treatment Plant at Blue Plains, according to procedures outlined by Willson and Walker (8). Air-dry compost was screened into uniform size fractions through U.S. Standard Sieves, 8, 4, and 2 (2.38 mm, 4.76 mm, and 9.52 mm openings), and 3 fractions were isolated: fine (< 2.38), medium (2.38–4.76), and coarse (4.76–9.52 mm). Compost that would not pass through the No.2 sieve was discarded. The 3 size fractions were combined by volume to formulate growing media; each medium is identified by percentage of the fractions (fine, medium, coarse).

Three flowering annuals, 'Golden Jubilee' Marigold, 'Fire Cracker' Zinnia, and 'Sugar Plum' Petunia, were greenhouse grown in 10-cm plastic pots with 2 plants in each. Seeds were germinated in a sphagnum peat-vermiculite medium; uniform seedlings were transplanted to the various growning media as the second pair of true leaves became visible. Plants were watered at the first sign of wilting, and fertilizer treatments were initiated 3 days

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Table 1. Growth of 3 flowering annuals as influenced by 2 levels of Osmocote, particle size distribution and 5 ratios of No. 2 grade vermiculite.

Cultivar	Osmocote top-dressed (g/pot)	Medium	Shoot dry wt (g) Vermiculite[z] 100%	75%	50%	25%	0%
Petunia 'Sugar Plum'	0	Fine[y]		1.70 i-p[u]	2.70 b-g	2.15 f-l	2.45 d-j
		Medium[x]		1.60 j-p	1.90 g-n	2.00 f-m	1.85 h-o
		Coarse[w]		0.65 p-q	0.70 p-q	0.95 n-q	1.00 n-q
		60-20-20[v]		2.50 c-i	1.95 f-n	2.50 c-i	2.40 d-j
		Unsieved		0.85 o-q	1.35 l-q	2.05 f-m	2.30 d-k
		Sand:Peat (3:2 by vol.)					0.70 p-q
		No. 2 grade vermiculite	0.40 l-q				
	5	Fine		3.50 a	2.70 b-g	3.35 a-b	2.70 b-g
		Medium		2.25 e-k	3.00 a-e	2.60 c-h	2.20 e-l
		Coarse		1.20 m-q	1.15 m-q	1.10 m-q	1.00 n-q
		60-20-20		3.25 a-c	2.50 c-i	2.75 b-f	3.05 a-d
		Unsieved		1.85 h-o	1.95 f-n	2.15 f-l	1.70 i-p
		Sand:Peat					1.45 k-p
		No. 2 grade vermiculite	1.00 n-p				
Zinnia 'Fire Cracker'	0	Fine		2.80 h-p	3.10 f-n	4.00 c-i	2.35 j-p
		Medium		1.85 m-p	2.55 i-p	3.00 h-o	2.95 g-o
		Coarse		1.15 p-q	1.30 o-p	1.35 o-p	1.65 n-r
		60-20-20		4.25 a-h	2.80 h-p	2.00 m-r	3.90 d-j
		Unsieved		2.05 l-q	2.35 j-p	2.30 j-p	1.95 m-r
		Sand:Peat					.40 r
		No. 2 grade vermiculite	.45 q-r				
	5	Fine		4.60 a-f	5.45 a-b	2.25 k-p	5.50 a
		Medium		4.15 b-h	4.45 a-g	3.75 d-k	3.75 d-k
		Coarse		3.60 e-l	4.10 b-i	3.20 f-n	2.35 j-p
		60-20-20		5.35 a-c	5.10 a-d	5.05 a-e	5.05 a-e
		Unsieved		5.15 a-d	4.95 a-e	4.90 a-e	3.90 d-j
		Sand:Peat					3.30 f-m
		No. 2 grade vermiculite	3.00 g-o				
Marigold 'Golden Jubilee'	0	Fine		4.85 j-m	7.25 g-i	8.15 b-h	5.85 i-k
		Medium		4.00 k-o	5.40 i-l	5.35 i-l	4.75 j-n
		Coarse		1.15 q-s	2.25 o-s	2.70 n-r	1.35 p-s
		60-20-20		4.55 k-n	5.45 i-l	4.35 k-o	5.00 j-m
		Unsieved		2.65 n-r	3.15 m-q	4.90 j-m	3.40 i-p
		Sand:Peat					.5 r-s
		No. 2 grade vermiculite	.25 s				
	5	Fine		9.65 a-e	11.20 a	9.70 a-e	10.20 a-b
		Medium		8.25 b-h	10.70 a	8.05 c-h	8.00 d-h
		Coarse		8.10 b-h	7.80 e-h	7.65 f-h	5.60 i-k
		60-20-20		9.80 a-b	9.95 a-c	10.15 a-b	10.55 a-b
		Unsieved		9.65 a-e	10.95 a	9.60 a-f	8.80 b-g
		Sand:Peat					4.00 k-o
		No. 2 grade vermiculite	6.65 h-j				

[z]No. 2 grade vermiculite.
[y]Sieve No. 8 (compost particles between 0-2.4 mm).
[x]Sieve No. 4 (compost particles between 2.4 and 4.8 mm).
[w]Sieve No. 2 (compost particles between 4.8 and 9.5 mm).
[v]60% (No. 8), 20% (No. 2) screened and blended.
[u]Mean separation for comparable means by Duncan's multiple range test, 5% level.

after transplanting. Osmocote 14–14–14 (14N–6.1P–11.6K) was top-dressed on each pot at varying rates. The experiments continued until the first plant of a given species developed a flower bud showing color. Growth response was measured as shoot dry weight with shoots dried in a forced-air oven at 60°C for 96 hr before weigning.

Experiment 1.—Sieved compost amended with No.2 grade vermiculite. The influence of compost particle size on the growth of the 3 flowering annuals was determined by blending the 3 sieved fractions in 4 different ratios with No. 2 grade vermiculite, in a 60-20-20 sludge particle size blend (60% < 2.4 mm; 20% 2.4–4.8 mm; 20% 4.8–9.5 mm by volume) and in a medium of sand and Canadian sphagnum peat (3:2 by volume) amended with 111 g of fritted trace elements (FTE 503) per m^3 and sufficient dolomite to adjust the pH to 6.5 which was selected as a standard soilless medium. Half the pots in each treatment were topdressed with 5 g Osmocote; the other half received no supplementary fertilizer. Treatments were analyzed as a split-plot design with 2 replications.

Experiments 2 and 3.—Sieved-sludge compost media. Mari-

Table 2. Influence of sludge compost particle size on shoot dry weight, pore space and available water

Compost particle size (% by volume) Fine[y]	Medium[x]	Coarse[w]	Marigold shoot dry wt (g)	Air-filled pore space (%)	Available water (%)
100	0	0	14.63 ab[z]	7.65 d	18.63 a-c
80	20	0	12.50 b-e	7.40 d	23.50 a
80	10	10	16.40 a	7.88 d	16.13 b-d
80	0	20	13.00 b-d	8.43 cd	18.16 a-c
60	30	10	10.60 c-e	9.42 cd	21.91 a-c
60	20	20	9.53 e	8.63 cd	16.71 a-c
60	10	30	15.13 ab	9.80 cd	15.27 c-e
50	25	25	10.27 c-e	10.60 bc	23.27 ab
40	40	20	13.60 a-c	12.35 ab	15.20 c-e
40	30	30	9.20 c	12.27 ab	15.37 c-e
40	20	40	12.13 b-e	12.65 ab	7.41 e
Unsieved sludge compost			13.87 a-c	14.17 a	9.89 de

[z]Mean separation for comparable means by Duncan's multiple range test, 5% level.
[y]0 – 2.4 mm
[x]2.4 – 4.8 mm
[w]4.8 – 9.5 mm

golds were grown in 11 prepared mixes of the 3 sieved-sludge compost fractions and in unsieved compost (as received from the composting site).

Percentage of air-filled pore space of media was determined (2). A 15-bar ceramic plate extractor was utilized for percent available moisture determinations at –0.33 and –15 bars matrix potential. Additionally, the 3 species of annual flowers were grown in unsieved compost and in a sludge compost blend with a particle distribution of 80% < 2.4 mm, 10% 2.4–4.8 mm, and 10% 4.8–9.5 mm by volume as well as sand and Canadian sphagnum peat medium (3:2 by volume). The entire experiment was topdressed with 12 g Osmocote. Treatments were analyzed as a split-plot design with 3 replications.

Experiment 4. Fertilizer response. To establish guidelines for fertilizer levels, marigolds were grown in unsieved compost and in a sludge compost blend with a particle distribution of 80% < 2.4 mm, 10% 2.4–4.8 mm, and 10% 4.8–9.5 mm by volume. Fertilizer treatments were 0, 5, 10, 15, 20 and 25 g per pot Osmocote applied as a topdressing. Data were analyzed as a split-plot design with 5 replications.

Results and Discussion

Experiment 1. As compost particle size increased, growth of plants in both fertilized and unfertilized treatments decreased (Table 1). Plants grown in the fine (< 2.4 mm) and the medium (2.4-4.8 mm) sludge fractions, as well as the 60-20-20 sludge particle size blend, produced more shoot growth in both fertilized and unfertilized treatments. Generally, plants grew better in the topdressed plot. Since sludge and sludge-vermiculite media resulted in plant growth greater than the sand-peat medium used as a standard, additional particle size blends of screened compost were selected to be evaluated.

Experiments 2 and 3. Significant differences were noted in the dry weight of marigolds grown in the 12 sludge compost media (Table 2). Plants grew best when media contained higher percentages of fine particles (< 2.4 mm). Correlation coefficients show that percent air-filled pore space was significantly correlated with dry weight of shoots (r_{xy} =–.38, P =0.02), and percent available water (r_{xy} =–36, P = 0.03). As expected, the decrease in percent available water was directly related to increased percola-

Table 3. Growth of flowering annuals in 3 media topdressed with Osmocote.

Media	Dry wt (g) Petunia	Zinnia	Marigold
80-10-10[z]	12.5 a[y]	2.7 a	8.4 a
Unsieved sludge compost	8.3 b	1.7 b	6.1 b
Sand: peat (3:2 by volume)	13.1 a	2.8 a	7.1 ab

[z]Sludge compost blend: 80% No. 8 sieve, 10% No. 4 sieve, 10% No. 2 sieve.
[y]Mean separation for comparable means by Duncan's multiple range test, 5% level.

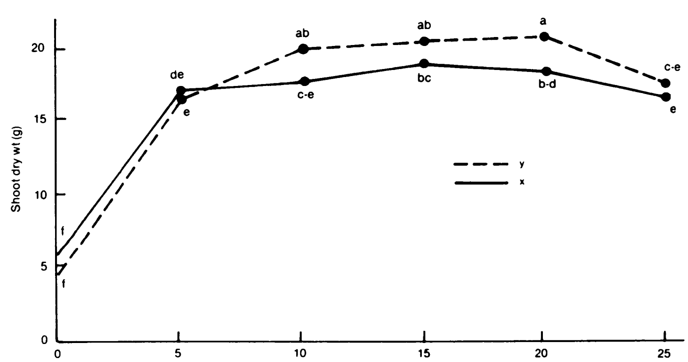

Fig. 1. Growth of marigolds in 2 sludge composts top-dressed with 6 levels of Osmocote. y = sludge compost blend (80% No. 8 sieve, 19% No. 4 sieve, 10% No. 2 sieve). x = unsieved sludge compost. Mean separation at each point by Duncan's multiple range test, 5% level.

tion. Decrease in growth with increasing pore space may be attributed to water stress.

Growth of the annuals did not differ when plants were grown in 80-10-10 or the sand-peat medium (Table 3). The unsieved compost, used as received from the composting site, was not uniform in particle distribution, and as a result the annuals grew significantly better in both the sand-peat and the 80-10-10 medium.

*Experiment 4.*Osmocote at 25 g significantly reduced top growth of marigolds (Fig. 1). Plants grown in 80-10-10 sludge particle size blend were larger than those grown in unsieved compost. If large particles were screened from the compost at the composting site, much of the variability experienced with the unsieved compost may have been eliminated and resulted in a product that could have been used as a growing medium without additional screening.

Results of these studies indicate that the municipal sludge used in this series of experiments is comparable to sand-peat as a growing medium for flowering annuals. Melsted (5) reported that municipal sludge contains all the nutrient elements necessary for plant growth; however, our studies indicate that nutrients are not necessarily at levels needed for optimum growth or in proper balance. No toxicity symptoms from soluble salt or heavy metals were observed. Growth was increased with addition of an N-P-K fertilizer.

Sludge compost meets the requirement of good structure, and air-drying the compost before screening resulted in aggregates that were stable for the 2–3 month production period for annuals. Myers (6) reported stability upon dehydration. Several of the compost media tested provided good plant support, adequate aeration, good moisture retention, and suitable nutrient retention. Regulation of pore space by controlling particle size distribution influenced plant growth as well as physical, and perhaps chemical, properties of media. We conclude that screened, composted sludge has significant value to nurserymen and florists as a medium for growing ornamental and floricultural crops in containers.

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Sweet Corn Growth, Yield, and Nutrient Uptake Responses to Tillage Systems[1,2]

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Additional index words. Zea mays, soil strength

Abstract. **Response of sweet corn (*Zea mays* L.) to tillage methods on a Tifton loamy sand was investigated during 1976 and 1977. The greatest volume of soil having a strength of less than 100 N/cm^2 core index resulted from moldboard plowing to a depth of 28–30 cm. The smallest volume of low-strength soil resulted from disk harrowing to a depth of 10–13 cm. Soil strength patterns produced by these tillage methods were relatively uniform across the seedbed. A subsoil-bed system produced a channel of low-strength soil under the row to a depth of 40 cm; however, soil strengths 15 cm to the side of the row were similar to the disk harrow method. Soil strength patterns resulting from subsoil-plant systems were similar to subsoil-bed. Soil strength increased during the growing seasons with tillage differences evident near harvest. Root growth, plant growth, yield, and nutrient uptake efficiency responses of sweet corn were proportional to the volumes of low-strength soil at planting.**

Soil conditions which impede root growth have been measured as soil density (2, 3, 4, 5, 6, 8, 10, 17, 19) and as soil strength (7, 9, 11, 12, 13, 14, 15, 16). Greater soil strength or density reflects a compacted condition or a reduced soil porosity, although the relationship of strength to density varies with soil type (7, 9). Soils generally become more dense or compact from settling by water during growth of the crop (9). However, settling of soils by water did not have the detrimental effect on root growth impedence as that produced by mechanical compaction (17). Mechanical compaction produced primarily by equipment traffic (6) has formed high-strength pans in many coarse-textured soils (5). These pans can be broken by subsoiling or deeper plowing, although soil strength is often restored to its original level by pressure of the tractor wheel (9, 10, 13) and subsequent tillage practices.

The ability of roots to penetrate soil strengths of less than 25 bars (250 N/cm^2 core index) varies widely among plant species (5, 14, 15, 19). The ability of plant roots to penetrate high-

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