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Spent Mushroom Compost in Soilless Media and its Effects on the Yield and Quality of Transplants

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Abstract. **Lettuce (*Lactuca sativa* L.), tomato (*Lycopersicon esculentum* Mill.), cucumber (*Cucumis sativus* L.), and marigold (*Tagetes patula* L.) transplants were grown from seed in leached and unleached media containing 0%, 25%, or 50% (by volume) peat and/or fresh or aged spent mushroom compost with 50% vermiculite. Reduced growth and symptoms of ammonium toxicity were seen in transplants grown in fresh spent mushroom compost. Transplants grown in 0% or 25% compost were larger than those grown in 50%, probably due to high salinity in 50% compost. Leaching reduced media soluble salts and generally improved plant yields. K and Ca were higher and P and Mg were lower in the tissue of transplants grown in spent mushroom compost than of those in the peat-lite control mix. High quality transplants were produced in 25%, aged spent mushroom compost, while acceptable plants of slightly reduced quality were produced in 50%, aged compost.**

Rising costs of peat moss, a major ingredient in many soilless potting mixes, have led to the search for inexpensive and locally available alternative substrates for container grown crops (4, 20, 23). Concern about the future availability of peat and of bark, a common peat substitute, also has fostered research in this area (1, 18). Spent mushroom compost (SMC), a by-product of the mushroom industry, has been considered as a peat substitute, but it contains high levels of NH_4-N and soluble salts which could restrict its use in potting mixes (11). Controlled aging of SMC before use in potting media has been recommended (5, 17), and leaching has been shown to lower soluble salt levels in SMC (5, 11). Results from the yields of foliage plants grown in SMC suggested that leaching may be unnecessary (5).

This study was designed to examine the use of soilless media containing SMC which was either fresh or aged, leached or unleached, and at 25% or 50% by volume. Transplants grown in these mixes were examined and compared to those grown in a commercially available, peat-vermiculite medium.

Materials and Methods

SMC was used fresh ("fresh") and after 6 weeks of aerobic aging ("aged") (11). Four potting mixes containing SMC were prepared with the following ingredients (v/v): 1) 25% fresh SMC, 25% peat, 50% vermiculite, 2) 50% fresh SMC, 50% vermiculite, 3) 25% aged SMC, 25% peat, 50% vermiculite, and 4) 50% aged SMC, 50% vermiculite. These basic mixes were used directly and after leaching with 4 volumes of water for a total of 8 SMC treatments. The control mix contained 50% peat and 50% vermiculite with added nutrients. The experimental design was a randomized complete block with these 9 treatments (2 × 2 × 2 factorial plus detached control group) and 6 blocks.

'Sweet Slice' cucumber (*Cucumis sativus* L.), 'Orange Boy' marigold (*Tagetes patula* L.), 'Black Seeded Simpson' lettuce (*Lactuca sativa* L.), and 'Better Boy' tomato (*Lycopersicon esculentum* Mill.) seedlings were greenhouse grown in the media in cell packs with six 4 × 6 × 6 cm cells. The 6 plants in each cell pack represented the experimental unit.

Plants were fertilized weekly with 35N–15P–30K mM which was applied at a rate of about 150 ml per cell pack. The number of days from transplanting until color was visible in the flower bud of at least one marigold per cell pack was determined. After 5 weeks, most plants of all species had reached marketable transplant size, and all were harvested. A quality rating for consumer acceptability, based on a scale from 1 to 5, was determined. Plants receiving a rating of one were unsalable. A rating of 2 was used for plants which consumers would buy only at reduced prices. Average cell packs received ratings of 3. Cell packs with ratings of 4 and 5 contained uniform plants of good and exceptional quality, respectively. Fresh weight, height, and dry weight also were determined.

Elemental concentration was determined for plants from 3 random blocks. Plant tissue was rinsed 3 times in deionized water, oven-dried (60°C), and ground in a cyclone mill to pass a 1-mm screen. Plant samples were wet-ashed, after which K, Ca, and Mg were measured by atomic absorption spectrophotometry (7). P was measured by a vanadomolybdophosphoric yellow colorimetry (8). Total N was measured colorimetrically

Table 1. Effects of age, level, and leaching of spent mushroom compost on transplants grown in soilless media.[z]

Linear contrast	Lettuce	Tomato	Cucumber	Marigold[y]
Fresh vs. aged	**	**	**	**
25% vs. 50%	**	**	**	**
Leached vs. unleached	**	NS	**	**
Level of SMC × leaching	*	*	**	**
Age of SMC × level	**	**	NS	*
Age of SMC × leaching	*	**	NS	NS
Age × level × leaching	NS	NS	NS	NS

[z]Significance level based on multivariate analysis, considering simultaneously dry weight, percentage of dry weight, and height.
[y]Days to bloom also considered for marigolds.
NS,*,**Nonsignificant (NS) or significant at 5% (*), 1% (**) levels.

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Table 2. Dry weight, percentage of dry weight, height, and quality rating of crops grown in soilless media with and without spent mushroom compost.[z]

SMC Treatment	Dry wt (g)	Dry wt (%)	Ht (cm)	Quality rating[y]	Days to bloom	P[x]
			Cucumber			
25% fresh: unleached	2.02	6.65	33.0	3.0	---	**
leached	1.93	7.05	33.2	3.0	---	**
50% fresh: unleached	1.50	6.60	29.2	2.3	---	**
leached	1.82	6.85	32.4	2.8	---	**
25% aged: unleached	2.99	6.72	37.4	3.3	---	NS
leached	2.87	7.49	36.2	3.5	---	NS
50% aged: unleached	1.86	6.43	31.4	3.0	---	**
leached	2.70	7.25	37.1	3.3	---	†
0% control	3.04	7.46	37.4	3.5	---	
			Lettuce			
25% fresh: unleached	0.81	3.18	16.1	2.7	---	**
leached	1.04	3.34	18.0	2.8	---	**
50% fresh: unleached	0.19	2.83	9.2	1.5	---	**
leached	0.72	3.10	15.3	2.2	---	**
25% aged: unleached	2.22	3.91	20.9	4.7	---	NS
leached	2.26	3.89	21.1	4.3	---	NS
50% aged: unleached	1.47	3.91	18.3	3.5	---	**
leached	2.00	3.81	20.9	4.0	---	†
0% control	2.43	4.09	21.6	4.7	---	
			Tomato			
25% fresh: unleached	1.16	7.66	22.3	3.2	---	**
leached	0.76	6.57	20.7	2.3	---	**
50% fresh: unleached	0.59	7.21	16.5	2.2	---	**
leached	0.53	6.37	18.0	2.2	---	**
25% aged: unleached	2.29	9.09	25.5	4.3	---	NS
leached	2.05	9.47	24.8	4.7	---	†
50% aged: unleached	1.67	8.46	25.1	3.7	---	**
leached	1.98	9.16	24.9	4.7	---	*
0% control	2.32	9.73	25.1	4.8	---	
			Marigold			
25% fresh: unleached	1.39	8.08	13.5	2.8	35	**
leached	1.65	8.55	14.5	3.3	39	**
50% fresh: unleached	0.84	7.97	12.1	2.2	38	**
leached	1.35	8.31	14.3	3.2	39	**
25% aged: unleached	2.53	9.70	13.4	4.3	34	**
leached	2.75	9.84	13.5	4.7	34	NS
50% aged: unleached	1.48	9.38	11.3	3.2	35	**
leached	1.97	9.43	13.2	4.0	35	**
0% control	3.01	9.68	13.9	4.9	33	

[z]Mean of 6 blocks.
[y]Based on a scale from 1 to 5: 1 = unsalable, 5 = excellent.
[x]Probability based on multivariate comparison of treatment to control group, using dry weight, height, quality rating, and days to bloom.
[NS,†,*,**]Nonsignificant (NS) or significant at 20% (†), 5% (*), 1% (**) levels.

by the indophenol method, after digestion with sulfuric acid and hydrogen peroxide (21). The electrical conductivity (EC) and pH of saturated paste extracts from the growth media before leaching and after plant growth in 3 blocks were measured.

Multivariate analyses of variance were conducted with orthogonal linear contrasts to test the main effects and interactions within the 2 × 2 × 2 factorial among the levels of SMC (25% vs. 50%), age of SMC (fresh vs. aged), and leaching (with vs. without), and with nonorthogonal linear contrasts to compare SMC treatments to the control (10, 15). Multivariate analysis was chosen for this problem because it allowed related yield factors such as weight, height, and rating to be considered simultaneously. EC, pH, and elemental concentrations were compared with Tukey's honestly significant difference (HSD).

Results and Discussion

Effects of age, level, and leaching of SMC on transplant growth. Considering dry weight, percentage of dry weight, and height together (with days to bloom for marigolds), there were significant differences due to the age of SMC in all crops studied (Table 1). Plants grown in fresh SMC generally were smaller than those grown in aged SMC (Table 2), and marigolds grown in fresh SMC took longer to bloom than those in aged SMC. The reduction in growth in fresh SMC may have been caused by ammonium toxicity, since many crops, including tomato and cucumber, are sensitive to high levels of ammonium, and reduction in growth is a common symptom of toxicity (6, 14, 16). Levels of NH_4-N in fresh SMC can rise to more than 20 mmoles kg^{-1}, whereas NH_4-N levels in aged SMC are about

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1 mmole kg^{-1} (11). Media containing fresh SMC had consistently higher pH values than media prepared with aged SMC (Table 3). This may have contributed somewhat to the reduced growth and delayed flowering in fresh SMC, since organic soils with pH levels between 7.0 and 8.0 contain P, Mn, and B in forms which are relatively unavailable for plant uptake (13).

Plants grown in 50% SMC had significantly lower yields than those grown in 25% SMC, and flowering in marigolds was delayed in 50% SMC (Tables 1, 2). The reduction in growth and the reduced percentage of dry weight were probably due to the increased levels of soluble salts in the media with 50% SMC (Table 3). A reduction in the percentage of dry weight implied an increase in succulence, often related to increasing salinity (12).

The effect of leaching was significant for all crops except tomato (Table 1). Dry weight, the percentage of dry weight, and the height of cucumber, lettuce, and marigold all increased with leaching (Table 2). The initial soluble salt levels in all media containing SMC were high, and leaching was effective in reducing these levels (Table 3).

Three-way interactions among age of SMC, level of SMC, and leaching were not significant for any of the crops studied, whereas many of the 2-way interactions were significant (Table 1). The interaction between level of SMC and leaching was significant for all crops. Leaching at both 25% and 50% SMC resulted in increased growth in marigolds and lettuce, but the increase from leaching was much greater for those plants grown in 50% SMC compared to those grown in 25% SMC (Table 2). Leaching resulted in increased growth for cucumbers in 50% SMC but not for those in 25% SMC. Salinity tolerances among plant species may account for these differences.

The interaction between age and level of SMC was significant for all crops except cucumber (Table 1). As the level of SMC increased from 25% to 50%, dry weight, percentage of dry weight, and height were reduced for all crops (Table 2). The reduction in growth at 50% SMC was greater for marigold, lettuce, and tomato plants grown in fresh SMC than for those grown in aged SMC. This difference may have been due to salinity and pH effects. As the level of SMC changed from 25% to 50%, the soluble salts and pH in the media rose, but the rise in pH was slight in fresh SMC compared to aged SMC (Table 3).

The interaction between age of SMC and leaching (Table 1) was significant for lettuce and tomato. Leaching increased the average growth of cucumber, marigold, and lettuce (Table 2). This increase was much greater for lettuce grown in fresh SMC than for that grown in aged SMC. Leaching generally did not improve the growth of tomato, and leaching of fresh SMC actually resulted in the reduced growth of tomato.

Transplants grown in SMC compared to transplants in control media. The successful use of SMC should result in the production of transplants not significantly different from those grown in the control medium. To be conservative, an alpha level of 0.20 was chosen in order to mark any possible differences between the groups.

Most of the crops grown in 25%, aged SMC were not significantly different from the control plants (Table 2). Dry weight, height, and quality rating of cucumber and lettuce plants grown in leached and unleached 25% SMC were similar to those of the controls. Means for marigolds in leached, 25%, aged SMC and tomatoes in unleached, 25%, aged SMC also were similar to those for the controls.

The plants from treatments containing fresh SMC and the treatments containing 50%, aged SMC were different from the control for all crops tested (Table 2). The dry weight, height, and quality rating of plants grown in these treatment media generally were lower than those of the control plants. Marigolds grown in these mixes were not always shorter, but the mean number of days to bloom was greater for these plants than for the controls. While plants produced in leached, 50%, aged SMC received lower quality ratings than the control plants, they were still marketable. For example, lettuce and marigolds in leached, 50%, aged SMC received a mean rating of 4.0, indicating uniform plants of good quality.

The pH and EC in media containing SMC were higher than in the peat-lite control (Table 3). Generally, high salinity was not a serious problem. For example, the mean dry weight of tomatoes grown in unleached, 25%, aged SMC (6 dS/m) was reduced only 1% compared to tomatoes grown in the control mix (3 dS/m) (Tables 2, 3). Based on tables presented by Bressler, McNeal, and Carter (2), a 30% reduction in yield would be expected as salinity increases from 3 dS/m to 6 dS/m. The differing conditions in the field compared to those in a small cell pack, where higher moisture contents must be maintained, might account for this discrepancy.

Table 3. Electrical conductivity (EC) and pH of saturated paste extracts from soilless media with and without spent mushroom compost, before and after growing crops.

SMC Treatment		EC (dS/m) Day 1	EC (dS/m) Day 35	pH Day 1	pH Day 35
25% fresh:	unleached	7.1	5.7	5.8	7.2
	leached	---	3.7	---	7.2
50% fresh:	unleached	10.7	7.8	6.3	7.4
	leached	---	4.7	---	7.4
25% aged:	unleached	8.5	6.0	6.3	6.6
	leached	---	4.4	---	6.7
50% aged:	unleached	13.9	8.9	7.0	7.1
	leached	---	5.6	---	7.2
0% control		4.5	2.7	5.6	5.8
HSD (5%)			1.0		0.1

Elemental analysis. The concentrations of N in the tissue of plants grown in SMC were not significantly different from those in control plants (Table 4). Concentrations of P in plants grown in SMC were generally, but not always significantly, lower than those in control plants. Reduced P concentrations may have contributed to the delay in flowering in marigolds. Plants grown in fresh SMC seemed slightly stunted, and a reddish coloring was observed on the stems and leaves of tomatoes and marigolds. This coloration is a symptom associated with P deficiency (3) and with high salinity (2). Yet because the plants were relatively compact and dark-green in color, they received a high quality rating.

Concentrations of K and Ca were higher and concentrations of Mg were lower in the tissue of transplants grown in media containing SMC than in control plants (Table 4). High concentrations of Ca and K in SMC (11) probably reduced the uptake of Mg through antagonism (19, 22).

Summary and Conclusions

Plants grown in fresh SMC generally were smaller than those grown in SMC which was aged for 6 weeks, and plants in fresh SMC received much lower quality ratings than those in the peat-lite control mix. Reduction in growth was probably due to high concentrations of NH_4-N in fresh SMC. Fresh SMC should not

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Table 4. Elemental concentration in leaf tissue of crops grown in soilless media with and without spent mushroom compost.[z]

SMC Treatment	N	P	K	Ca	Mg
	Millimoles per kilogram of dry tissue				
			Cucumber		
25% fresh: unleached	2960	228	1870	630	309
leached	2880	293	1740	604	267
50% fresh: unleached	3150	151	2020	545	319
leached	2810	252	1830	611	253
25% aged: unleached	3370	303	1790	666	351
leached	2690	333	1540	621	290
50% aged: unleached	3690	220	1790	730	403
leached	2880	265	1740	718	313
0% control	3000	345	1420	433	520
HSD (5%)	1000	70	280	80	74
			Lettuce		
25% fresh: unleached	4190	308	2300	344	185
leached	4220	324	2240	327	153
50% fresh: unleached	4660	236	2190	272	167
leached	4160	263	2190	318	153
25% aged: unleached	4190	320	2390	292	197
leached	3430	340	2360	270	172
50% aged: unleached	4070	275	2440	311	229
leached	3980	271	2490	316	199
0% control	3550	366	2080	225	259
HSD (5%)	1300	87	360	55	48
			Tomato		
25% fresh: unleached	2880	153	1840	586	316
leached	3570	191	1940	638	282
50% fresh: unleached	3870	113	1870	536	360
leached	3730	166	1800	685	295
25% aged: unleached	3590	215	1640	531	373
leached	2420	254	1610	567	269
50% aged: unleached	3710	195	1870	604	448
leached	3340	159	1580	633	336
0% control	3010	235	1260	346	394
HSD (5%)	1000	62	290	121	81
			Marigold		
25% fresh: unleached	3270	223	1410	442	238
leached	3250	176	1300	455	217
50% fresh: unleached	3700	159	1690	438	255
leached	3430	175	1460	460	204
25% aged: unleached	3390	282	1250	483	294
50% aged: unleached	3190	238	1270	457	303
leached	3400	210	1350	537	281
0% control	3190	312	1120	309	346
HSD (5%)	650	122	250	100	70

[z]Mean of 3 blocks.

be recommended for use in soilless potting media, at least for the crops and levels examined in this experiment.

Plants grown in 50% SMC were smaller than those grown in 25% SMC, probably due to the increased salinity level at the high level of SMC. Leaching reduced soluble salts in the treatment media and improved the growth of cucumbers, lettuce and marigolds, but not that of tomatoes.

Transplants grown in media with SMC generally contained higher concentrations of K and Ca and lower concentrations of P and Mg than control plants; however, large differences in elemental concentrations at this stage of growth often have little effect on the final yield of crops (9).

High-quality plants were produced in growth media containing leached or unleached, 25%, aged spent mushroom compost with 25% peat and 50% vermiculite. Plants grown in leached, 50%, aged SMC were of marketable quality. The use of unleached mixes may be preferable because leaching is cumbersome, time consuming, and a potential source of pollution.

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