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Suitability of Composts as Potting Media for Production of Organic Vegetable Transplants

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Composts, used alone or in mixtures with other materials, can serve as horticultural potting media in organic production systems. In this study, we evaluated the suitability of two locally available composts as media for lettuce and tatsoi produced organically in an unheated greenhouse. One of the composts was produced from food residuals with landscape wastes as a bulking agent, while the other was generated from used horse bedding. Although the two materials had relatively similar total N contents, C:N ratios, and bulk densities, they performed very differently as potting media. Net N mineralization, measured in laboratory incubations, was high in the compost derived from food residuals, but the horse-bedding compost showed net N immobilization, perhaps due to high salinity. Crop production in the food residuals compost was statistically similar to a control treatment consisting of a commercial peat-based potting medium with synthetic fertilizer. Crop growth in the medium consisting of horse-bedding compost, used at 100% or in a 50%/50% mixture with a commercial substrate of bark, peat, and sand, was unacceptable for commercial production. Although the cost per flat of the food residuals compost was slightly higher than that of the commercial peat-based medium, for organic production this additional cost may be insignificant since there are limited potting media options, and price premiums are typically available.

Introduction

As more horticultural producers in the United States transition to organic production practices, they are challenged in finding consistent and economically viable sources of suitable potting media. Commercial, peat-based media approved for certified organic production are available and custom peat-based mixes that use certified organic fertilizers could also be used. Both of these options, however, are usually expensive and their sustainability is questionable given the dependence on peat, a resource generally considered to be nonrenewable, and processed organic fertilizers shipped long distances. One potential solution to this problem is the use of locally composted organic wastes that can serve as a partial or complete potting medium and nutrient source.

Considerable research has been performed over the past two decades evaluating composts, derived from various feedstocks, as potting media constituents in vegetable and ornamental plant production (Burger *et al.* 1997; Fitzpatrick 2001; Ozores-Hampton and Vavrina 1999; Raviv *et al.* 1998; Sánchez-Monedero *et al.* 2004; Sterrett 2001; Wilson *et al.* 2001a 2001b). This research generally has shown that composts can be used successfully as partial, and sometimes as complete, substitutes for peat. However, in many of these studies, the nutrient contributions are not addressed because the composts are considered only as substrate alternatives to peat. The plant-available nutrient contribution, a characteristic of high importance to organic producers, is often presumed to be inadequate.

In addition to nutrient content and availability, particularly for nitrogen, other important characteristics of composts used as potting media include maturity and/or stability, salinity, pH, particle size, and water-holding capacity. Compost maturity refers to the suitability of the material for a particular use while stability is the resistance of the material to further microbial decomposition (Sullivan and Miller 2001). A mature compost is one that does not undergo further active microbial decomposition (heat up) and is free of phytotoxic substances. In addition to these considerations, certified organic producers have limited choices of organic waste feedstocks for compost production. Composts made from biosolids (sewage sludge), for example, are not permitted in certified organic production systems (USDA 2005).

In 1999, the greenhouse operation of Berea College Farms, located in eastern Kentucky, began a transition from conventional to certified organic production. Local sources of organic waste and compost were considered for potting media and nutrients. The College initiated a food residuals composting program and began informally evaluating the finished compost as a potting medium (Clark and Law 2000). In addition, a commercial source of compost derived from used bedding of the thoroughbred horse industry was located (Clark 2002). The objective of this study was to evaluate the suitability of the two composts, used solely or diluted in a mixture, for organic vegetable transplant production.

Materials and Methods

The materials evaluated in this study included: 1) compost derived from preconsumer food residuals mixed with yard waste (primarily leaves) as a bulking agent (FR compost); 2) compost derived from used straw horse bedding (HB compost); and 3) a commercial peat-based potting medium with added synthetic fertilizer (Miracle-Gro, Marysville, Ohio) used as a control. In addition, both of the composts were mixed (50%/50% by volume) with a commercial substrate derived from finely shredded bark, peat, and fine sand (Southern Importers, Greensboro, North Carolina), referred to hereafter as "filler," to generate two additional treatments. The filler was also included as a treatment, for a total of six treatments.

The FR compost was produced by mixing preconsumer food residuals from Berea College's food service with fall-collected municipal yard waste using a standard tractor-driven manure spreader to form freestanding piles (Clark and Law 2000). The piles were aerated 2-3 times using the manure spreader or front-end loader over a three -month period and allowed to cure for about five months. The HB compost was produced at a large turned-windrow facility in Lexington, Kentucky (Clark 2002). The entire composting process at this facility required two months per batch. The commercial peat-based potting medium, used as a control to represent the conventional system previously used at the greenhouse operation, was comprised of 50-60% peat with composted bark fines, perlite, a wetting agent, and fertilizer (derived from ammonium nitrate, ammonium phosphate, calcium phosphate, and potassium sulfate).

The materials were evaluated and compared through chemical analyses and plant germination and growth experiments. The nutrient composition (N, P, and K) of the materials was analyzed by University of Maryland Cooperative Extension. The pH, electrical conductivity (EC), maturity, and bulk density were measured immediately prior to the plant germination and growth experiments at Berea College. The pH and EC of the materials were measured using the volume addition method (1:1 compost to water) (Sullivan and Miller 2001). The maturity of the composts and potting media mixtures was measured using the Solvita test (Woods End Research Laboratory, Mt. Vernon, Maine), which scores the material along an index based on CO_2 and NH_3 emissions (Changa *et al.* 2003). A material with an index value of 7 or 8 (minimum = 1, maximum = 8) is considered "finished" and suitable for potting mixes. The cost of the material per flat was calculated based on the cost of the material per unit weight or volume and the amount of material needed to fill a flat.

Plant germination and growth experiments were conducted in an unheated greenhouse at Berea College beginning in October, 2002. Two crops commonly produced at the facility were used as test crops: lettuce (*Lactuca sativa* var. *longifolia*) and tatsoi (*Brassica rapa* var. *rosularis*). For each crop, the experiment consisted of the six potting media treatments with four replications in a completely randomized design. All materials were sieved through a screen (≈1-cm mesh) before use. The experimental unit was a plastic horticultural flat (50 cm by 26 cm by 6 cm) filled with the designated potting medium and planted with 72 seeds of the designated crop in a uniform pattern. No inserts were used within the flats. Germination was measured 7 and 16 days after planting. Plant height was measured 16 and 44 days after planting. Fresh-weight marketable yield was measured 51 days after planting.

Samples of each potting medium treatment were taken for analysis of N and C mineralization at the USDA Sustainable Agricultural Systems Laboratory in Beltsville, Maryland. Initially the water holding capacity (WHC) of each potting mix was determined. Potting materials were allowed to absorb water and then left to drain (Paul *et al.* 2001). The amount of water remaining in the potting mixes was determined by drying the mixes to 65°C. The 100% WHC was determined as g water per g oven-dried potting mix. Total C and N of each potting mix was determined by dry combustion (Sollins *et al.* 1999).

Incubations were conducted in triplicate for each growth medium. Twenty-five g of each medium (moist weight) were placed in a plastic cup and brought to 72% WHC by adding water dropwise and then gently stirring the potting mix. Cups were then placed in canning jars (946 mL volume) and sealed with lids fitted with a septum. Jars were stored in a 25°C constant temperature room in the dark. The concentration of CO_2 in the headspace was measured periodically during 41 d of incubation to ensure that CO_2 levels never reached 6% (Paul *et al.* 2001). When headspace CO_2 levels neared 6%, jar lids were removed to aerate the jars, resealed and the headspace CO_2 concentration measured again after allowing sufficient time for re-equilibration of

CO_2 in the jars. Headspace samples were taken using a needle attached to a 1 mL syringe. Samples were immediately analyzed for CO_2 using an infrared gas analyzer (California Analytical Instruments, Model 3300, Orange, California). Cumulative CO_2 release curves were calculated for each replicate sample and C mineralization per day was calculated on a per flat basis.

N mineralization potentials were measured from the same samples used to measure C mineralization. On day 0, separate subsamples were extracted with 1 M KCl, filtered, and analyzed for ammonium (NH_4^+) and nitrate (NO_3^-) to establish initial inorganic N levels. At day 41, cups were removed from the jars and 1 M KCl was added to each cup (ratio of 1:10 (dry wt/volume)). Filtered KCl extracts were frozen and then thawed prior to analysis by autoanalyzer (Lachat Quikchem Series 8000, Zellweger Analytics, Inc., Milwaukee, Wisconsin). N mineralization per day was calculated as final inorganic N – initial inorganic N divided by 41 days on a per flat basis.

Statistical comparisons among the six treatments of all variables measured were made with ANOVA followed by the Student-Newman-Keuls (SNK) test for mean separation when significant differences were found ($P \leq 0.05$). Pearson correlation analysis was conducted for all N-related variables and plant marketable yield per flat. The relationship between C:N ratio and N mineralization potential was evaluated using the NLIN procedure in SAS (SAS Institute 2004).

Results

All of the materials evaluated in this study were considered adequately mature for use as potting media, ranking as a 7 or 8 on the maturity index (Table 1). The pH levels ranged from 5.6 for the commercial peat-based medium to 8.0 for the HB compost and the HB compost/filler mixture. The C:N ratios ranged from 13.7 for the HB compost to 65.3 for the filler. Likewise, total N was highest in the HB compost and lowest in the filler. The two composts, HB and FR, were very similar in C, N, C:N ratio, and P, but differed considerably in pH, EC, and K. The EC of the HB compost was very high, 8.5 dS m^{-1}, indicating a salinity level too high for general use as a potting medium (Sullivan and Miller 2001). The EC of the HB compost/filler mixture was 5.2 dS m^{-1}, which is still considered high for potting media.

The commercial peat-based medium had the lowest bulk density, as expected, and the bulk densities of the remaining materials ranged from 27-42 g cm^{-3} (Table 2). The HB compost had the lowest cost per flat, at $0.40, while the FR compost was the most expensive at $1.00 per flat. The cost per flat of the commercial peat-based material, at $0.70, fell in between these two extremes. Due to the cost of the filler, mixing it with the composts increased the cost of the HB compost/filler blend and decreased the cost of the FR compost/filler blend relative to using the pure composts as potting media.

TABLE 1.
Chemical characteristics of the materials evaluated as potting media for lettuce and tatsoi production, Berea, Kentucky, 2002.

Potting Medium	pH	EC (dS m^{-1})	Maturity	C %	N %	C:N	P %	K %
Filler	7.1	0.2	8	19.6	0.30	65.3	0.04	0.22
FR compost/ filler (50/50%)	7.3	0.6	7	22.7	0.92	24.7	0.15	0.32
HB compost/ filler (50/50%)	8.0	5.2	8	25.6	1.28	20.0	0.28	1.39
FR compost	6.6	2.9	7	28.8	1.97	14.6	0.25	0.41
HB compost	8.0	8.5	8	29.6	2.16	13.7	0.46	2.48
Commercial peat-based potting medium	5.6	0.7	8	42.6	0.89	47.9	0.07	0.21

TABLE 2.
Bulk density, weight per flat, and cost per flat of potting media.

Potting Medium	Bulk Density (g cm^{-3})	Weight Of Medium/Flat (kg $Flat^{-1}$)	Cost Per Flat ($)
Filler	0.42	3.27	0.50
FR compost/ filler (50/50%)	0.34	2.68	0.75
HB compost/ filler (50/50%)	0.38	2.95	0.45
FR compost	0.27	2.08	1.00
HB compost	0.34	2.63	0.40
Commercial peat-based potting medium	0.11	0.87	0.70

Germination of both crops was statistically similar among all treatments except for the two media containing HB compost, which had very low germination (Table 3). Plant growth, assessed by plant height and marketable yield, was highest in the FR compost and the commercial peat-based medium. Plant growth in the other four treatments was poor (Table 3).

Initial mineral N was very low in the filler and the two compost/filler blends and very high in both composts and the commercial potting medium (Table 4). Nitrogen mineralization was higher in the FR compost than in all other potting media (Table 5). Final inorganic N levels (initial inorganic N plus the

TABLE 3.
Germination, plant height, and marketable yield of lettuce and tatsoi grown in the six potting media.

Potting Medium	Lettuce: Germination At 16 Days (%)	Lettuce: Height At 44 Days (cm)	Lettuce: Marketable Yield At 51 Days (g flat^{-1})	Tatsoi: Germination At 16 Days (%)	Tatsoi: Height At 44 Days (cm)	Tatsoi: Marketable Yield At 51 Days (g flat^{-1})
Filler	85 a	0.9 b	0 b	85 a	1.6 b	0 b
FR compost/ filler (50/50%)	94 a	3.6 b	21 b	86 a	3.1 b	10 b
HB compost/ filler (50/50%)	50 b	0.9 b	0 b	24 b	4.0 b	0 b
FR compost	93 a	15.0 a	237 a	82 a	11.5 a	379 a
HB compost	7 c	0.8 b	0 b	1 c	0.0 b	0 b
Commercial peat-based potting medium	97 a	15.0 a	255 a	94 a	13.5 a	315 a

Different letters within a column indicate statistically significant differences among treatments according to ANOVA and SNK test ($P \leq 0.05$)

TABLE 4.
Initial and final mineral nitrogen levels (ammonium N + nitrate N) in the potting media during the 41-day incubation.

Potting Medium	Initial Mineral N levels (mg N Flat^{-1})	Final Mineral N levels (mg N Flat^{-1})
Filler	4 c	6 d
FR compost/ filler (50/50%)	20 c	27 d
HB compost/ filler (50/50%)	25 c	161 d
FR compost	3390 a	4769 a
HB compost	1290 b	876 c
Commercial peat-based potting medium	1314 b	1544 b

Different letters within a column indicate statistically significant differences among treatments according to ANOVA and SNK test ($P \leq 0.05$)

TABLE 5.
Carbon and nitrogen mineralization and the ratio of C to N mineralized in the media treatments during the 41-day incubation period.

Potting Medium	C Mineralized (mg C flat^{-1} d^{-1})	N Mineralized (mg N flat^{-1} d^{-1})	C Mineralized: N Mineralized (mg C flat^{-1} d^{-1}/ mg N flat^{-1} d^{-1})
Filler	625 b	0.1 b	16,668
FR compost/ filler (50/50%)	822 a	0.2 b	5,201
HB compost/ filler (50/50%)	808 a	3.3 b	316
FR compost	300 c	33.6 a	9
HB compost	328 c	-10.1 b	-66
Commercial peat-based potting medium	96 d	5.6 b	17

Different letters within a column indicate statistically significant differences among treatments according to ANOVA and SNK test ($P \leq 0.05$)

N released via mineralization), which indicates the amount of N available for plant uptake, was also greatest in the FR compost (Table 4). Mineral N levels actually declined in the HB compost during the incubation.

Carbon mineralization patterns were largely the opposite of N mineralization patterns, being highest in the blended materials, lowest in the composts and commercial potting medium, and intermediate in the filler (Table 5). The high C mineralization in the compost/filler blends may have resulted from increased microbial activity following the physical mixing. The C:N ratio and amount of N mineralized during the incubation were not significantly correlated. Since HB compost had high salinity, which can significantly reduce N mineralization (Tester and Parr 1983), and since the commercial potting medium has added to it a readily mineralizable form of N fertilizer, we evaluated the relationship between C:N ratio and N mineralization using only data from the other four media. For these four media, C:N ratio was strongly related to N mineralization potential (N mineraliztion potential = 1.78 x 10^{10} (C:N ratio)$^{-7.497}$, $P < 0.0001$; Figure 1). This model accounted for 99.6% (SS_{model}/SS_{total}) of the variability in the data.

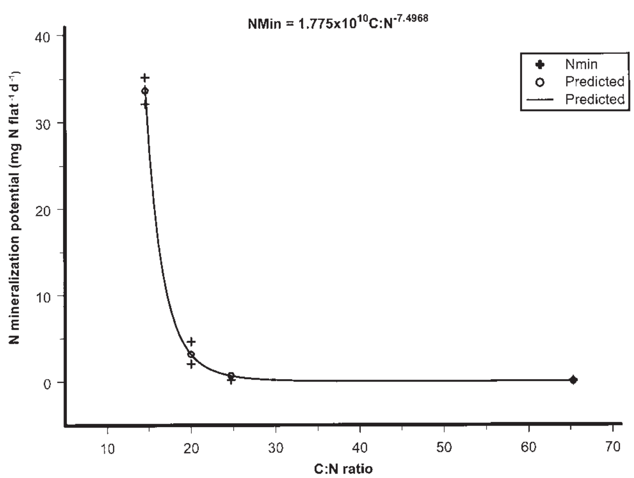

FIGURE 1. Relationship between C:N ratio and N mineralization potential (actual and predicted) for four compost materials used as potting media (filler, FR compost, 50%/50% FR compost and filler, and 50%/50% HB compost and filler). + = data (N=8); o = predicted values of N mineralization potential at the C:N ratios of the composts, based on the equation shown on the graph; and the line represents predicted values of the N mineralization potential at all C:N ratios between 15 and 65.

Plant growth, measured as marketable yield, was not correlated with the C:N ratio or total N of the media for either crop. However, initial mineral N level, N mineralized per day, and final mineral N level were significantly correlated with tatsoi growth (Table 6). The correlations between lettuce growth and initial mineral N level (P = 0.08) and final mineral N level (P = 0.07) were nearly significant (Table 6).

TABLE 6.
Correlations between mean lettuce and tatsoi growth, measured as marketable yield at 51 days, and N-related measurements derived from a 41-day incubation (N = 6).

N variable	Lettuce r	P	Tatsoi r	P
C:N ratio	-0.04	0.93	-0.11	0.83
Initial total N level (%)	0.16	0.76	0.24	0.64
Initial mineral N level (per flat)	0.75	0.08	0.83	0.04*
N mineralized (per flat)	0.71	0.11	0.81	0.05*
Final mineral N levels (per flat)	0.78	0.07	0.87	0.02*

* Indicates a statistically significant correlation ($P \leq 0.05$)

Discussion

Although the two composts evaluated in this study had relatively similar total N levels, C:N ratios, and bulk densities, they performed very differently as potting media for lettuce and tatsoi. Crop growth in the FR compost was similar to that in the commercial peat-based medium, while that in the HB compost (pure and blended with filler) was very poor. Although the HB compost was the least expensive material, the direct effects of the high salinity and/or the indirect effects via inhibition of N mineralization made this material completely unsuitable. By contrast, the FR compost performed very well as a potting medium, but was the most expensive material. Cutting the FR compost with filler reduced the cost, making it similar to that of the commercial medium, but resulted in unacceptable plant growth.

The differences in plant growth among treatments observed in this study were apparently due, at least in part, to mineral N availability. C:N ratio is often used as an indicator of N mineralization potential of composts and other organic materials. In this study, however, C:N ratio was not a good predictor of N mineralization among these growth media. It is likely that the high salinity level of HBC was responsible for the negative N mineralization of the HB compost (Tester and Parr 1983) in addition to causing poor germination. The commercial medium contained synthetic N fertilizer that would result in much higher N availability than that predicted by a relatively high C:N ratio. Among the four remaining growth media, however, the C:N ratio was strongly related to the N mineralization potential (Figure 1). The equation describing the relationship between C:N ratio and N mineralization potential is consistent with the general observation that N mineralization is significant for materials with C:N ratios < ~20 but negligible for materials with C:N ratios > ~30.

Low N mineralization and plant growth were expected in the filler material since it is not intended for use as a growth medium without added nutrients. The similarly low N mineralization and plant growth rates in the two blended media, however, were surprising since the C:N ratio was within a range normally expected to result in net N mineralization. Inorganic N levels in the blends were much lower than would be predicted by taking the average of the inorganic N levels of either the filler and FR compost or filler and HB compost. It is possible that significant N immobilization or denitrification occurred when a low C:N medium (composts) was mixed with a high C:N medium (filler). The high C mineralization rates of these two blends suggest that anaerobic zones may have been created during the incubations and in the greenhouse flats and that the high NO_3^- levels in the composts were lowered during ensuing denitrification.

In conclusion, the FR compost performed as well as the commercial peat-based medium for plant production, but was slightly more expensive. The higher cost per flat may be acceptable if the cost can be passed along to the consumer. Certified organic products are often more expensive to produce than their conventionally produced counterparts, and consequently more expensive for the consumer. Cutting the FR compost with filler to reduce costs was not a viable option due to low N mineralization and poor plant growth in the blend. The higher cost of the FR compost was partially the result of the scale and level of mechanization of the composting operation (Clark and Law 2002). No tipping fees were charged for collecting or accepting the raw materials (institutional food residuals and municipal leaves). Therefore, some basic changes in the operation could improve efficiency and reduce compost production costs. Nevertheless, this locally produced compost appears to be a suitable potting medium for organic vegetable transplant production.

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