Utilization of Mixed Municipal Solid Waste Compost as a Soilless Potting Component in Greenhouse Production of Four Floricultural Crops[1]

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Abstract

Mixed municipal solid waste compost (MSWC) was evaluated as a soilless potting mix component for greenhouse production using four floricultural crops: dusty miller (*Senecio cineraria*), hybrid petunia (*Petunia× hybrida*), Japanese holly fern (*Cyrtomium falcatum*), and begonia (*Begonia × semperflorens-cultorum*). Dusty miller and petunia plugs were transplanted into 36-cell trays filled with MSWC based substrates and grown for two months. Petunia only grew well in the blend with the lowest MSWC ratio (33%), while dusty miller grew well in all MSWC blends. Japanese holly fern and begonia liners were transplanted into 15 cm (6 in) azalea pots and grown for 12 weeks in five substrates: 100% pine bark (PB), 3:1 PB:MSWC, 1:1 PB:MSWC, 1:3 PB:MSWC, and commercially available Fafard 3B Mix. In addition to substrate, a controlled-release fertilizer was applied at two rates to form a two-way factorial completely randomized design. Replacement of PB with MSWC resulted at least equal plant quality and growth of begonia in the aspects of growth index, leaf greenness (SPAD value), flower number, visual rating, and shoot fresh and dry weight. For Japanese holly fern, replacement of PB with MSWC resulted in a lower visual rating, but without other negative responses in plant. For the four greenhouse crops tested, plant growth and quality were seldom negatively affected at low ratios of MSWC (25 to 33%). However, our studies indicate the impact of blending traditional pine bark with higher than 50% MSWC is species specific.

Index words: container substrate, pine bark, bedding plants.

Species used in this study: dusty miller (*Senecio cineraria*), hybrid petunia (*Petunia× hybrida*), Japanese holly fern (*Cyrtomium falcatum*), begonia (*Begonia × semperflorens-cultorum*).

Significance to the Nursery Industry

Various organic waste composts have long been regarded as alternative substrate components. As an organic waste, municipal solid waste (MSW) or household garbage, is always locally available and composting is encouraged as an effective pathway to reduce volumes of MSW. However, growers in the nursery industry have often been skeptical about the quality of municipal solid waste compost (MSWC) and are also reluctant to shift to substrates other than pine bark (PB) unless absolutely necessary. The results of two experiments using four popular floriculture crops grown in 0 to 100% MSWC based substrates reported here provides useful information for both sides of a emerging market for compost utilization. Replacement of PB with MSWC at a low ratio (30% or less) often increased plant growth. At a higher ratio (up to 75% MSWC in the substrate), plants often grew equally well as in 100% PB. Results suggest that MSWC can be a viable alternative to pine bark for container grown floricultural crops.

Introduction

Selection of substrates for horticultural use is often based on cost, availability, ease of handling, function and reproducibility. Peat and pine, or other types of bark, are the most common substrate components for nursery and greenhouse growers in the United States. However, horticultural crop growers have been under increasing pressure to find consistent and affordable supplies of peat and pine bark. Increased transportation costs, limited natural resources of peat, and related environmental regulations for peat mining have posed limitations for peat supply. Likewise, in recent years, nursery growers have had increased difficulty maintaining reliable pine bark supplies (6, 10). The availability of inexpensive bark is a rising concern due to alternative demands (e.g., industrial fuel), reduced timber production, and closing or relocation of primary timber processing mills to other regions or abroad (10). The needs for alternative substrate components are evermore urgent. Factors such as transportation costs, consistency of product, disease and insect infestation, and availability of the various alternative materials have been the primary concerns for growers.

An attractive substrate alternative is MSWC. Major advantages of MSWC include: 1) local availability; 2) practically unlimited resources, as every community generates trash continuously year around; 3) approximately two-thirds of MSW in the United States is organic matter, which makes it easy to compost (13); and 4) like other composts, high quality MSWC can suppress certain diseases and pathogens (5).

Compost of MSW or co-compost of MSW with other materials has been tested as a potting mixture component for ornamental plant production in both greenhouse and nursery crops with mixed results (2, 4, 7). In general, results have shown that while a low MSW or MSWC ratio in the blend often promotes better plant growth than in non-amended blends, at higher ratios (50% or more) such benefits often disappear or even cause reduced growth compared with conventional container mixtures. Among the many factors contributing to the various plant growth responses, variations from the compost itself, different cultural conditions, and plant species are most obvious. While composting of source-separated MSW generally produces a more uniform product with less undesirable materials, such as metals, glass,

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or rubber, composting of mixed MSW requires no efforts from individual households and therefore is more economical and easier to implement.

This paper reports greenhouse production of four popular floricultural crops using MSWC produced from a mixed MSW stream. The overall objective was to evaluate the general performance of mixed MSWC as a soilless potting component in greenhouse ornamental crop production. Specifically objectives were to determine: 1) how crops respond to MSWC blends ranging from 0 to 100%; 2) causes of different plant growth responses in MSWC blends; 3) how crops respond to different fertilizer rates incorporated with MSWC; 4) effect on plant quality and marketability from different MSWC blends and fertilizer rates; and 5) directions for future research of alternative organic waste composts.

Material and Methods

The MSWC in all experiments reported in this paper was derived from mixed household wastes without any presorting (WastAway Services, LLC, McMinnville, TN). Arriving waste feedstock had about 60 to 70% organic matter (by vol), such as yard wastes, food scraps, and paper products, etc. Aluminum and ferrous metals were removed with remaining MSW processed by a system of grinders, shredders and pressurized heat, after which the material was further composted with an indoor, turned windrow method. Before mixing, the compost was sifted through a 25.4 mm (1 inch) screen to remove any large particles. Besides organic components, the compost had inert components ground to small particles (majority <12.7 mm or 0.5 in), such as glass, plastics, rubbers, etc. The compost had above neutral pH (7–8), high soluble salt concentration (electrical conductivity: 4–8 dS/m with saturated media extract method), and C:N ratio of 20 to 30. Besides high pH and EC reading, other physical and chemical properties were within recommended range for nursery crops (11, 16).

Experiment 1. Three substrates were blended (by vol): 100% MSWC, 2:1 MSWC:Perlite (PRL), and 1:1:1 pine bark (PB):MSWC:PRL. Our previous studies on nine ornamental crops and commercial grower's field trial on multiple greenhouse and nursery crops found that replacement of PB with 1/3 or less MSWC had very few adverse effects on plant growth (11) and thus the 1:1:1 PB:MSWC:PRL was treated as our baseline substrate. Each substrate blend was amended with 6.6 kg/m^3 (11 lbs/yd^3) Osmocote 18–6–12 (18N–2.6P–10K; The Scotts Company, Marysville, OH), 0.9 kg/m^3 (1.5 lbs/yd^3) Micromax (The Scotts Company, Marysville, OH), and 3.0 kg/m^3 (5 lbs/yd^3) dolomitic limestone. On March 17, 2004, plugs of dusty miller (*Senecio cineraria*) and petunias (*Petunia × hybrida*), were transplanted into 36-cell trays with 3 trays for each species and substrate combination.

All trays of bedding plants were placed under overhead irrigation in a double layer polyethylene-covered greenhouse at the Paterson Greenhouse Complex, Auburn University, AL (32° 36'N × 85° 29'W, USDA Hardiness Zone 8a) for 2 months. A completely randomized design was utilized, with each tray regarded as an experiment unit and each plant in each tray regarded as subsamples.

Initial leachates, leachates at one week after transplant (WAT), two WAT, and final leachates at the end of the study were taken for determination of pH and electrical conductivity (EC). Leachates were collected using the nondestructive Virginia Tech Extraction Method (VTEM) (14) and analyzed using a Model 63 pH and conductivity meter (YSI Incorporated, Yellow Springs, OH). Survival and growth of dusty miller and petunia were visually evaluated. At the end of the study, shoots of dusty miller were harvested for determination of fresh weights and then dry weights were determined after oven-drying at 70C (158F) for 72 hr.

Experiment 2. Five substrates were blended (by vol): 100% PB, 3:1 PB:MSWC, 1:1 PB:MSWC, 1:3 PB:MSWC, and commercially available Fafard 3B Mix (Conrad Fafard, Inc., Agawam, MA, a blend of peat, perlite, vermiculite, and pine bark) served as the control blend. All blends were amended with 0.9 kg/m^3 (1.5 lbs/yd^3) Micromax (The Scotts Company, Marysville, OH), and 3.0 kg/m^3 (5 lbs/yd^3) dolomitic limestone. All substrate blends were then further amended (pre-plant incorporated) with one of two rates of a controlled-release fertilizer (CRF): Polyon NPK 19–6–12 6-month (19N–2.6P–10K; Pursell Technologies Inc., Sylacauga, AL) at 4.7 kg/m^3 (7.9 lbs/yd^3, low rate) or 9.4 kg/m^3 (15.8 lbs/yd^3, high rate).

Liners of begonia (*Begonia× semperflorens-cultorum*) and Japanese holly fern (*Cyrtomium falcatum*) were transplanted into 15-cm (6-in) azalea pots on September 13, 2006, and grown in a double-layer, polyethylene-covered greenhouse at the same Greenhouse Complex of Expt. 1 for 12 weeks. Each treatment combination (a species, fertilizer and substrate combination, total of 20) had 10 pots as repetitions and all plants were placed with a completely randomized design. Plants were hand-watered as needed.

Initial leachates were collected from three representative samples for each of five substrate blends using the VTEM. Leachates were then analyzed for pH and EC as in Expt. 1. After the initial leachate analysis, leachates were collected two WAT, and final leachate (at 12 WAT) for pH and EC determination.

Leaf chlorophyll values (greenness) were nondestructively measured on three of the youngest, fully developed leaves for all plants with a portable chlorophyll meter (SPAD-502) (Minolta Camera Co., Japan) (15) at 12 WAT. Readings are expressed in SPAD values, which are technically unit-less and crop specific.

At 12 WAT, plant growth was measured using a growth index (GI), calculated as the average of plant height plus widest plant width plus plant width perpendicular to widest width / 3. Also at 12 WAT, numbers of fully blooming flowers for each begonia plant were counted. The quality of begonia and Japanese holly fern was visually estimated by grouping plants with similar quality together: 5 = best quality, with no obvious visual defect in aspects of color, morphology, overall health, and/or blooming; 4 = very good, but with minor defect; 3 = good, with 2–3 defects; 2 = fair, obvious visual defect; 1 – poor, overall quality undesirable, marketability very low. Quality similarity was based on agreement by estimation of two research assistants. At the termination of the experiment at 12 WAT, aboveground parts of plants (shoot) were harvested. Shoot fresh and dry weights were determined as in Expt. 1.

Analysis of variance (ANOVA) was performed on data of both experiments where appropriate. Any statistical test with p-value < 0.05 was considered as significant and reported as such. For Experiment 2, the main effects of fertilizer and substrate blend and their interaction were analyzed using

Table 1. Leachate analysis and effect of substrate blends on growth of dusty miller (Expt. 1).

Blends[z]	pH				Electric conductivity (EC, dS/m)				Fresh weight (g)	Dry weight (g)
	Initial	1 WAT[y]	2 WAT	Final	Initial	1 WAT	2 WAT	Final		
100% MSWC	7.06	6.89	7.05	6.85	14.08	5.32	2.76	0.31	12.29	1.81b[x]
1:1:1 PB:MSWC:PRL	7.02	7.16	7.10	6.88	9.32	2.43	1.37	0.30	15.49	2.49ab
2:1 MSWC:PRL	6.34	6.72	6.81	6.86	8.42	4.12	2.18	0.37	15.24	2.68a

[z]MSWC = municipal solid waste compost; PB = pine bark; PRL = perlite.

[y]WAT: week(s) after transplant.

[x]Means within columns followed by a different letter are different according to Tukey's studentized range (HSD) test (p-value < 0.05).

two-way factorial ANOVA. All statistical analyses were conducted using SAS for Windows v.9.1 (SAS Institute Inc., Cary, NC).

Results and Discussion

Experiment 1. Survival of petunias in the 100% MSWC was low (less than 20%), about 50% of the petunias survived and grew well (without obvious visual defect, such as discoloring, margin burning, small or stunt leaves) in the 2:1 MSWC:PRL blend, and almost all petunias grown in 1:1:1 PB:MSWC:PRL survived and grew well. Dusty miller grew well in all three blends (100% survival). There were no significant differences in the fresh weights of dusty miller from different blends, but shoot dry weight for plants grown in 2:1 MSWC:PB were higher than that found in 100% MSWC (Table 1). Initial leachate EC readings of the blends, especially the 100% MSWC, were very high and may have contributed to the low survival of petunias; however, EC readings were within or close to intermediate salt levels (1.0–2.5 dS/m) (2) by 2 WAT. Similar studies concluded that salts leach quickly, especially in shallow flats or plugs and a few days' leaching under mist will lower soluble salts of waste-derived substrates to acceptable levels (1, 2, 3, 9). Even where EC values were higher than recommended (16) two weeks after transplanting (Table 1), effects of high EC levels on dusty miller's growth were mostly minimal. The highly organic nature of waste-based substrates was believed to provide a high salt-buffering capacity and protection for root systems (4).

Table 2. Leachate analysis at two weeks after transplant for begonia and Japanese holly fern (Expt. 2).

Species	Treatment[z]	pH[y]	Electric conductivity (EC, dS/m)
Begonia	Blend		
	100% PB	6.01ab	0.57
	3:1 PB:MSWC	6.13ab	0.45
	1:1 PB:MSWC	6.64a	0.80
	1:3 PB:MSWC	6.59a	0.70
	Fafard 3B Mix	5.61b	0.83
	Fertilizer		
	Low rate	6.20	0.67
	High rate	6.19	0.66
Japanese holly fern	Blend		
	100% PB	5.75b	0.58
	3:1 PB:MSWC	6.16ab	0.63
	1:1 PB:MSWC	6.80a	0.67
	1:3 PB:MSWC	6.44a	0.66
	Fafard 3B Mix	5.76b	0.75
	Fertilizer		
	Low rate	6.25	0.63
	High rate	6.11	0.68

[z]PB = pine bark; MSWC = municipal solid waste compost.

[y]Means within rows followed by different letters are significantly different according to Tukey's studentized range (HSD) test (p-value < 0.05).

Experiment 2. Similar to Expt. 1, initial EC readings were high (data not shown) but by two WAT, EC readings were well within recommended ranges (Table 2). Compared with results of Expt. 1 (Table 1), leachate soluble salts decreased faster with minimal, if any visible damage from initially high EC levels. This observation agreed with results from similar studies (1). The much lower EC values in Expt. 2 (0.45–0.80 dS/m) than in Expt. 1 (1.37–2.18 dS/m) at two WAT in substrate with similar MSWC proportion was due to a much higher irrigation amount received from the hand-watering in September than from mist irrigating in March. The commercial Fafard 3B mix and 100% PB mix had lower pH levels than blends with 50 and 75% MSWC, a difference of about 0.7 to 1 pH unit.

Both substrate blend and fertilizer rate affected some aspects of plant growth (Tables 3–5). Begonias grown in Fafard 3B had statistically higher fresh shoot weight than plants in 100% PB and 25 to 75% MSWC replaced blends (Table 3). There was no statistical difference among substrate blends for leaf greenness (SPAD values), growth index, quality rating, or flower number. However, the plant marketability or quality based on visual evaluation was rather obvious from plants in 100% PB (average rating 3.33) to plants in the Fafard 3B (average rating 4.33). Overall, replacement of 25 to 75% PB with MSWC did not have any negative effect on begonia growth and quality. Interestingly, CRF rate had a similar effect on begonia growth:shoot fresh and dry weights were increased by more CRF in containers, while all other indicators were not statistically affected by CRF rate. However, there were marginal interactions between substrate blends and CRF rates on begonia SPAD values and visual quality rating (Table 3). Separation of CRF effect from blends indicates that high fertilizer rates increased SPAD values (p-value = 0.009) from 49.5 in low CRF to 56.0 in high CRF and also marginally increased SPAD values of plants grown in 100% PB (p-value = 0.096; Table 5). Visual rating of begonias was also marginally increased when grown in 100% PB or 1:1 PB:MSWC (both with p-value = 0.054). The actual increase in rating was rather impressive: from 2.67 to 4.0 in 100% PB, an improvement from mostly fair to very good and from

Table 3. **Effects of substrate blends and fertilizer levels on SPAD reading (greenness), growth index (GI), quality rating, flower number, shoot fresh weight, and dry weight of begonia (Expt. 2).**

Treatment[z]	SPAD value[y]	GI	Quality rating	Flower number	Fresh weight (g)	Dry weight (g)
Blend						
100% PB	51.71	25.39	3.33	15.17	110.37b	4.55c
3:1 PB:MSWC	51.03	27.61	4.17	16.33	136.51b	5.61bc
1:1 PB:MSWC	52.91	27.06	4.00	15.50	131.13b	5.68bc
1:3 PB:MSWC	52.30	26.50	4.00	14.50	147.07b	6.72ab
Fafard 3B Mix	52.76	29.11	4.33	19.83	193.63a	8.12a
Fertilizer						
Low rate	51.42	26.91	3.87	15.40	131.05b	5.37b
High rate	52.87	27.36	4.07	17.13	156.43a	6.91a
P value						
Main effect						
Blend	0.7831	0.2270	0.2802	0.2308	<0.0001	<0.0001
Fertilizer	0.1767	0.6585	0.4992	0.2668	0.0135	0.0004
Interaction	0.0621	0.5015	0.0688	0.6997	0.1662	0.2327

[z]PB = pine bark; MSWC = municipal solid waste compost.

[y]Means within rows followed by different letters are significantly different according to Tukey's studentized range (HSD) test (p-value < 0.05).

3.33 to 4.67 in 1:1 PB:MSWC, an improvement from mostly good to mostly best quality.

The effect of MSWC replacement on Japanese holly fern growth was different from other species (Table 4) in many aspects. Plant height, growth index as overall canopy volume indicator, and shoot fresh weight and dry weight were all similar among five substrates. Japanese holly fern had higher SPAD values in 1:1 PB:MSWC mix than in 100% PB mix. The handheld SPAD meter measures the greenness of leaves as reflected by the chlorophyll content and N status. The relationship between leaf greenness and N sufficiency is well documented (12, 15). However, higher greenness was no guarantee of plant quality, as the quality rating between plants in 100% PB was higher than in 1:1 PB:MSWC blend, a completely reverse relationship. Based on visual rating, the marketability and quality of Japanese holly fern was adversely affected by the increased MSWC fraction (1:3 PB:MSWC), although such decrease in quality was not observed in other aspects. Other than increased SPAD values of ferns grown in the high CRF rate, fertilizer had negligible effects on other plant growth and quality indicators. Marginally significant interaction between blend and CRF on fern dry weight was evident and further analysis indicated that plants with high CRF rate in the 25% PB replaced blend (3:1 PB:MSWC) had higher shoot dry weight, but there was no effect on plants in other blends (Table 5). Other than sufficient supply of N and other nutrients, other properties of substrates, such as pH, drainage (air space), moisture (water holding capacity) can be more important and may have contributed to our results.

Overall, replacement of 25 to 75% PB with MSWC mostly improved begonia's growth, while growth of Japanese holly fern was negatively affected in visual quality. Expt. 2 indicates different responses between two greenhouse crops. Such varied effects on different species are mostly expected based on previous work that has shown that no universal percentage of any compost can be applied to all situations (8).

For the four greenhouse crops we tested, we found plant growth and quality were seldom negatively affected at low

Table 4. **Effects of substrate blends and fertilizer levels on SPAD reading (greenness), growth index (GI), quality rating, shoot fresh weight, and dry weight of Japanese holly fern (Expt. 2).**

Treatment[z]	SPAD value[y]	Height (cm)	GI	Quality rating	Fresh weight (g)	Dry weight (g)
Blend						
100% PB	38.45b	21.33	29.17	4.50a	23.11	4.60
3:1 PB:MSWC	41.02ab	20.00	28.22	3.67abc	21.15	4.34
1:1 PB:MSWC	45.77a	19.83	27.06	3.17c	18.58	3.74
1:3 PB:MSWC	42.83ab	19.17	26.22	3.33bc	20.36	4.03
Fafard 3B Mix	40.68ab	24.17	30.72	4.67a	22.86	4.60
Fertilizer						
Low rate	39.44b	20.27	27.91	3.73	20.51	4.13
High rate	44.06a	21.53	28.64	4.00	21.91	4.37
P value						
Main effect						
Blend	0.0719	0.2334	0.1130	0.0035	0.1569	0.1626
Fertilizer	0.0062	0.3897	0.5047	0.3140	0.2738	0.3324
Interaction	0.4186	0.7211	0.1844	0.4825	0.3073	0.0966

[z]PB = pine bark; MSWC = municipal solid waste compost.

[y]Means within rows followed by different letters are significantly different according to Tukey's studentized range (HSD) test (p-value < 0.05).

Table 5. **Effects of fertilizer on SPAD value and visual rating of begonia, on dry weight of Japanese holly fern for different substrate blends (Expt. 2)[z].**

Blend	SPAD value, begonia			Quality rating, begonia			Dry weight, fern		
	Low[y]	High	P	Low	High	P	Low	High	P
100% PB[x]	49.70	53.72	.096	2.67	4.00	.054	4.52	4.69	.759
3:1 PB:MSWC	51.36	50.70	.791	4.00	4.33	.614	3.61	5.07	.012
1:1 PB:MSWC	54.18	51.64	.288	3.33	4.67	.054	3.83	3.65	.743
1:3 PB:MSWC	52.32	52.28	.987	3.67	4.33	.317	3.80	4.25	.421
Fafard 3B Mix	49.52	56.00	.009	4.00	4.67	.317	4.88	4.20	.220

[z]Effects reported in this table are where there are marginally significant interactions between substrate blend and fertilizer rate based on Table 3 and Table 4.

[y]Low: low fertilizer rate; high: high fertilizer rate.

[x]PB = pine bark; MSWC = municipal solid waste compost.

ratios of MSWC (25 to 33%). At higher level, however, replacement of the traditional pine bark with MSWC can either benefit or limit plant growth, which is often species specific. In our study, rapid leaching in Expt. 2 is believed to have reduced potential damage from high soluble salt concentrations in the MSWC we used. Similar to experiences with pine bark, some species can grow well even in 100% compost based substrates, while some other species may be negatively affected with less than 50% compost in the mix. However, unlike pine bark, MWSC, and probably most other composts, has chemical and physical properties that are often beyond the commonly recommended range (16) and thus always need careful attention on a crop by crop basis under varying horticultural crop production methods. Also vital to both researchers and industry, is the vast variation among different types of compost made from different raw material, regions of the country, composting methods, and maturity level, etc.

Our studies indicate that actual compost materials must be carefully evaluated before large scale use, but with careful attention should be considered viable blending components for nursery and greenhouse crops.

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