Evaluating Composts to Produce Wildflower Sods on Plastic

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ABSTRACT. This research evaluated production of wildflower sods in soil and composts of mixed municipal solid waste, biosolids and woodchips, fall leaves, and mixed agricultural wastes. Soil or composts were laid on plastic sheeting in outdoor plots, and a mixture of wildflower seeds was sown in July and in September in separate experiments. Quality of sods was assessed in two growing seasons. Best sods with respect to seed germination, stand establishment, and intensity and diversity of bloom over two seasons occurred in mature biosolids compost and in agricultural waste compost. These composts were low in ammonium but rich in total N. Germination and growth of wildflowers were limited by high ammonium concentrations in immature biosolids composts. Nitrogen deficiency limited sod growth and quality in leaf composts. Poor N nutrition and weed competition restricted sod production in soil. Fertilization of soil promoted unacceptably large weed growth. Summer seeding or fall seeding resulted in good sods, but many annual flowers that appeared in the summer seeding were absent in the fall-seeded planting. Using plastic-lined plots was a convenient system for evaluating composts and other media in outdoor culture.

Composting municipal solid wastes (MSW) and agricultural wastes is potentially an important alternative in managing solid wastes. An end use of compost is needed to address economic concerns of waste disposal costs and environmental problems with landfills and incineration (Hyatt, 1995). One potential use of compost is to produce sods on plastic film (Cisar and Snyder, 1992; Mitchell et al., 1994). Plastic can serve as a barrier to limit weed growth and facilitate harvest of sods for marketing (Cisar and Snyder, 1992; Mitchell et al., 1994; O'Brien and Barker, 1995a). Wildflower sods were chosen because of their values in erosion stability, roadside beautification, and habitat and food for wildlife (Ahearn et al., 1992).

Unwanted materials in and lack of maturity of composts are causes for public concern; however, in compliance with state and federal regulations and in association with better means of sorting wastes, problems with composition are decreasing (Rosen et al., 1993). Means of measuring maturity are still a focus of current research (He et al., 1992; Inbar et al., 1993; Inbar et al., 1990; O'Brien and Barker, 1995b). High ammonium concentrations in compost indicate immaturity and may limit germination and plant growth (He et al., 1992; Inbar et al., 1990; O'Brien and Barker, 1995b).

The objectives of this study were to determine the effects of various composts on wildflower sod production using plastic film and to evaluate maturity of compost by evaluating ammonium concentrations in compost and the impact on wildflower germination and growth.

Materials and Methods

Fresh composts were delivered in June 1993 and were held in 10- to 30-m³ piles without turning. Composts were from cocomposted mixed MSW including biosolids (Delaware Solid Waste Authority, Dover), biosolids and woodchips (Springfield, Mass., Wastewater Treatment Plant; or Marlborough, Mass., sup-

plied by AllGro, Lebanon, N.H.), agricultural wastes including cranberry fruit pomace and chicken manure (MassNatural, Westminster, Mass.), and fall leaves (Springfield Wastewater Treatment Plant). Two studies were conducted: one with compost applied on 23 July 1993 and seeded on 26 July 1993 and the other with compost applied on 5 Sept. 1994 and seeded on 15 Sept. 1993. From our observations, we noted no other properties (e.g., structure, odor, density) that might affect plant growth (Barker, 1996).

Composts used in these studies differed considerably in total N and ammonium N contents (Table 1). Ammonium N in Springfield biosolids–woodchips on a dry mass basis was 2462 mg·kg⁻¹ in July and 1685 mg·kg⁻¹ in September. The ammonium content in the other composts was much lower than those in the Springfield biosolids–woodchips and did not differ appreciably between the

Table 1. Average initial ammonium N and total N concentrations in media for midseason and late season establishment of wildflowers.

Medium	N concn (dry mass)	
	Ammonium (mg·kg ⁻¹)	Total N (%)
Midseason (July) seeding		
Mixed MSW ^z	48 b ^y	1.18 c
Biosolids–woodchips (Springfield)	2462 a	3.82 a
Agricultural	81 b	1.55 b
Leaf	35 b	0.47 d
Unfertilized soil	15 b	0.18 e
Fertilized soil	228 b	0.22 e
Late (September) seeding		
Mixed MSW	57b	1.01c
Biosolids–woodchips (Springfield)	1685 a	2.13 a
Biosolids–woodchips (Marlborough)	63 b	2.17 a
Agricultural	70 b	1.59 b
Leaf	43 b	0.48 d
Sawdust	0	0

^zMSW = municipal solid waste.

^yWithin columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

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Table 2. List of wildflower species dominant in Northeast mix.^z

Common name	Scientific name
Annuals	
Plains coreopsis	<i>Coreopsis tinctoria</i> Nutt.
California poppy	<i>Eschscholzia californica</i> Cham.
Cosmos	<i>Cosmos bipinnatus</i> Cav.
Orange cosmos	<i>Cosmos sulphureus</i> Cav.
Farewell-to-spring	<i>Clarkia elegans</i> Dougl.
Baby's breath	<i>Gypsophila elegans</i> Bieb.
Bachelor's button	<i>Centaurea cyanus</i> L.
Catchfly	<i>Silene armeria</i> L.
Biennial	
Wallflower	<i>Cheiranthus allionii</i> Hort.
Dame's rocket	<i>Hesperis matronalis</i> L.
Black-eyed Susan	<i>Rudbeckia hirta</i> L.
Perennial	
Ox-eye daisy	<i>Chrysanthemum leucanthemum</i> L.

^zTwenty-five species in mixture, but 13 did not appear or were too infrequent to note in this experiment. See list of other species in Northeast Wildflower Mixture in O'Brien and Barker (1995a).

two setup dates. The Marlborough biosolids-woodchips compost was available after the July planting and was used only in the September planting. This compost had a total N concentration similar to that of the Springfield biosolids-woodchips compost but did not have a high concentration of ammonium, indicating a higher state of maturity in the Marlborough compost than in the Springfield compost.

At the time of receipt of the Springfield biosolids-woodchips compost, temperature of the pile was 65 °C. The pile temperatures of the other composts ranged from ambient temperatures 21 to 50 °C. The high ammonium and high temperatures in the Springfield biosolids-woodchips compost indicate that it was immature. The leaf compost was assessed as immature based on its low total N content and presence of unrotted fragments of fall leaves. Other media used in these studies included Winooski silt loam from the A horizon of the site where the plants were grown and also a mixture of pine and hardwood sawdust.

A wildflower mixture (Northeastern mix; Vermont Wildflower Farm, Charlotte, Vt.) (Table 2) was seeded at 4.8 g·m⁻² into wood-framed, plastic-lined plots holding 0.083 m³ of compost, soil, or sawdust in a 5-cm layer. The experimental design was a randomized complete block with four replicates and was sited at the Univ. of Massachusetts research farm at South Deerfield.

Growth responses of the wildflower sods were assessed by 1) germination and establishment; 2) quality (visual assessment); 3) purity of stand (weediness, wildflower species); 4) biomass; 5) species diversity; 6) flowering index; 7) N composition.

COMPARISON OF FRESH COMPOSTS AND SOIL FOR PRODUCTION OF WILDFLOWER SODS ON PLASTIC WITH A MIDSEASON SOWING DATE. Composts were arranged in four randomized complete

blocks in the wood-framed, plastic-lined plots described above. The media used in this experiment were mixed MSW compost, Springfield biosolids-woodchips compost, agricultural compost, leaf compost, and fertilized and unfertilized soil. Wildflower seeds were sown on 26 July 1993 and watered daily.

In the first season, ≈200-g samples of the media were taken from plots on the day of seeding and at about weekly intervals during 10 weeks for ammonium (Bremner, 1965) and total N analyses (Bradstreet, 1965) and conductivity analyses (2 water : 1 soil, vol/wt, extraction) (Richards, 1954). Germination and growth were measured at 2 and 5 weeks after seeding by indexing for uniformity and density of stand on a scale of 0 to 100 (0 = no stand, no coverage; and 100 = best stand, dense and full coverage of surface). After 9 weeks, species diversity and total plant numbers were assessed, and shoot biomass production was harvested from a randomly selected 0.25 m² of each plot. The wildflowers and weeds were separated and dry mass was recorded. Total N was determined in the wildflower tissues (Bradstreet, 1965). In the second season, wildflower stand, species diversity, biomass production, and flowering index were determined on 9 May 1994, and flowering indexing was repeated in July. Flowering indexing was a visual assessment of uniformity and density of specific flowering species (0 = no flowering, 5 = best flowering with showy profuse bloom over entire plot).

EVALUATION OF FRESH COMPOSTS AND SAWDUST TO PRODUCE WILDFLOWER SODS ON PLASTIC WITH A LATE SOWING DATE. Wood-framed, plastic-lined plots were used as above for application of composts of mixed MSW, biosolids-woodchips (two sources, the same one as above from Springfield and a newly obtained one from Marlborough, Mass.), agricultural wastes, and fall leaves. One additional treatment included a mixture of pine and hardwood sawdust with fertilization [20N-8.8P-16.6K (%) to supply N at 1 g/plot]. Sawdust was evaluated as a potential substitute for compost in sod production. Wildflower seeds were sown on 15 Sept. 1993 and watered daily.

Initial ammonium N and total N in the composts were determined at the time of seeding. On 16 June 1994, wildflower stand, biomass production, species diversity, and flowering index were

Fig. 1. Ammonium concentrations on a dry mass basis in soil and composts as a function of days after application and types of media ($\pm$ SD).

Table 3. Average electrical conductivities of composts as a function of time after midseason seeding (July 1993) of composts.

Medium	Conductivity ^a on days after application (dS·m ⁻¹)					Trend	Mean
	0	11	21	37	72		
Mixed MSW ^y	4.22	1.68	1.58	1.50	1.30	NS	2.06 d ^x
Biosolids–woodchips (Springfield)	3.86	1.16	1.35	0.70	1.09	NS	1.63 c
Agricultural	2.48	1.42	1.42	1.44	0.99	NS	1.56 c
Leaf	0.88	0.68	0.82	0.77	0.94	NS	0.81 b
Unfertilized soil	0.32	0.29	0.28	0.78	0.37	NS	0.41 a
Fertilized soil	0.61	0.53	0.95	0.51	0.37	NS	0.59a
Mean ^w	2.06	0.96	1.07	0.95	0.84		

^aUsing 1 medium : 2 water (w/v) extracts.^yMSW = municipal solid waste.^xWithin columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).^wMeans for media are significantly different ($P \leq 0.05$) by Duncan's multiple range test. LSD(0.05) for days = 0.19, for interaction of days × medium = 0.39.^{NS}Nonsignificant by polynomial regression.

assessed. On 19 July 1994, flowering index was repeated. Data were processed by analysis of variance (SAS Institute, Cary, N.C.).

Results

Midseason seeding

VARIATION IN COMPOST AMMONIUM N AND ELECTRICAL CONDUCTIVITY WITH TIME. Ammonium N and total N in composts were measured over a 70-d sampling period (Fig. 1). Ammonium N concentrations at 70 d were nil and are not reported. Ammonium N, starting at about 2500 mg·kg⁻¹ in Springfield biosolids–woodchips, decreased substantially in the first 11 d and was at virtually the same ammonium concentration as in the other composts after 21 d (Fig. 1). Total N in compost varied with source of compost, but did not change with time, remaining at the levels reported in Table 1.

Electrical conductivity as an assessment of salinity sharply declined in biosolids–woodchips, agricultural, mixed MSW, and leaf composts within the first 11 d; however, no consistent changes occurred afterward (Table 3). The mixed MSW, biosolids, or agricultural compost had higher salinities than the leaf compost or soils.

GROWTH PERFORMANCE OF WILDFLOWER SODS. At 2 weeks after seeding, wildflower germination was significantly better in mixed MSW than in other media (Table 4). After 5 weeks, wildflower stand (density of plants and visual assessment) was best in fertilized soil followed in order by stands in agricultural compost, mixed MSW compost, and unfertilized soil. Stand development was poor in Springfield biosolids–woodchips and leaf compost. After 9 weeks of growth, wildflower shoot mass was highest in the fertilized soil followed in order by those in the agricultural, Springfield biosolids–woodchips, and mixed MSW composts. Wildflower shoot masses in

Table 4. Germination, plant populations, stand quality, and dry mass of wildflowers in two growing seasons with an original midseason date of seeding.

Medium	Wildflowers				Weeds
	Germination ^z	Stand ^y	Total plants ^x	Dry mass (g·m ⁻²)	Dry mass (g·m ⁻²)
First season (1993)					
Mixed MSW ^w	29 a ^v	36 b	126 ab	21 bc	0 b
Biosolids–woodchips (Springfield)	1 b	2 c	15 d	32 bc	0 b
Agricultural	8 b	39 b	166 a	38 b	1 b
Leaf	6 b	8 c	107 bc	9 c	1 b
Unfertilized soil	8 b	17 bc	54 cd	8 c	5 b
Fertilized soil	8 b	68 a	40 d	68 a	34 a
Second season (1994)					
Mixed MSW	59 b	63 b	80 ab		
Biosolids–woodchips (Springfield)	4 d	11 c	52 abc		
Agricultural	85 a	97 a	89 a		
Leaf	34 c	97 a	52 abc		
Unfertilized soil	10 d	37 bc	39 bc		
Fertilized soil	2 d	12 c	33 c		

^zGermination measured 2 weeks after seeding on 23 July 1993. Visual indexing of uniformity and density of cover: 0 = no emergence, 100 = dense, full coverage of surface.^yStand assessment made 5 weeks after seeding. Visual indexing of uniformity and density of cover: 0 = poorest cover, 100 = best cover.^xTotal plants (density/m²) and dry mass was measured at 9 weeks after seeding in the first season and on 9 May 1994 in the second season. In the second season, weed growth was too small to estimate.^wMSW = municipal solid waste.^vWithin columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

Table 5. Total nitrogen in wildflowers grown in fresh compost and soil with midseason seeding.

Medium	N, dry mass ² (%)
Mixed MSW ³	2.82 ab ^x
Biosolids–woodchips (Springfield)	3.64 a
Agricultural	2.34 b
Leaf	3.36 a
Unfertilized soil	1.88 b
Fertilized soil	2.20 b

²Analyses are of plant materials collected 9 weeks after seeding in first season.

³MSW = municipal solid waste.

^xWithin columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

the leaf compost and unfertilized soil were small. Weed growth was about 33% of the total dry matter production in the plots of fertilized soil and about 36% of the dry matter production in the unfertilized soil, but weed biomasses differed greatly within these media, making weed growth in the fertilized soil much more noticeable than in the unfertilized soil. Weed growth was negligible in the mixed MSW, Springfield biosolids–woodchips, and agricultural composts. Weed growth, although small in the leaf compost, noticeably diminished the quality of the sod, because of the greatly suppressed wildflower growth.

In the second season, wildflower growth followed trends set in the first season (Table 4). In May of the second season, wildflowers in agricultural compost had significantly better stand, greater density, and more shoot biomass than in other media. Wildflowers quality in mixed MSW fell just below that in the agricultural compost. Mean dry mass in the agricultural and mixed MSW exceeded those in the other media. Growth of wildflowers in Springfield biosolids–woodchips, unfertilized soil, or fertilized soil was limited. Wildflowers grown in leaf compost showed signs of improvement relative to the first season as indicated by stand quality and density. Growth of weeds on 9 May of the second year was too small to be measured.

Wildflowers harvested after 9 weeks of growth (first season) were analyzed for total N (Table 5). Shoots of wildflowers grown in Springfield biosolids–woodchips or leaf composts had the highest total N concentrations. The lowest concentrations occurred in the plants grown in unfertilized soil, but differences were nonsignificant between fertilized soil and unfertilized soil.

FLOWERING PERFORMANCE OF WILDFLOWERS. Black-eyed Susan, coreopsis, ox-eye daisy, cosmos, poppy, clarkia, and baby's

breath were flowering 9 weeks after planting in the first season (Table 6). Wildflower species diversity and density were greater in agricultural or mixed MSW composts than in the other media (Tables 4 and 6). Coreopsis grew well in all media except in Springfield biosolids–woodchips in which all growth was limited.

In the second season, on 9 May 1994, dame's rocket and ox-eye daisy dominated the floral display, and a few bachelor's buttons were present (Table 7). Dame's rockets and daisies flowered best in mixed MSW or agricultural composts. Overall flowering quality indicated by the sum of the flowering indices was better in agricultural and mixed MSW composts than in the other media. Flowering of wildflowers was most limited in Springfield biosolid–woodchips and in fertilized or unfertilized soil. In July 1994, black-eyed Susan, coreopsis, bachelor's button, and catchfly were flowering, and the earlier-flowering species had ended blooming. Overall flowering quality was better in leaf compost, unfertilized soil, or agricultural compost than in other media. In general, black-eyed Susans dominated the display and grew well in all media. Coreopsis flowered better in unfertilized soil than in other media. Bachelor's buttons flowered better in leaf, agricultural, or mixed MSW composts than in other media. Catchfly was sparse and occurred only in the leaf and Springfield biosolids–woodchips composts and in unfertilized soil. In August, bloom was not different from that in July (data not shown).

Late seeding

GROWTH PERFORMANCE OF WILDFLOWER SODS. Since seeding took place late in 1993, cool weather limited germination, and germination in 1993 was not assessed. After overwintering, growth measured by stand, density, dry mass, and species diversity was assessed on 16 June 1994 when the bloom on some flowering plants was peaking (Tables 8 and 9). Weed growth was negligible in all media. No growth of any plants occurred in the sawdust. Stands and harvest mass of wildflowers were greater in Marlborough biosolids–woodchips compost and in mixed MSW compost than in other media (Table 8). Growth of wildflowers in Springfield biosolids–woodchips compost was the poorest among the group of composts. Species diversity in Marlborough biosolids–woodchips or in mixed MSW composts was greater than that in the other media (Table 9). Black-eyed Susan, bachelor's button, ox-eye daisy, coreopsis, and dame's rocket dominated the population. Diversity and density were low in the Springfield biosolids–woodchips compost. Black-eyed Susan dominated in the leaf compost. The agricultural compost supported enough density and diversity to give an attractive stand.

FLOWERING PERFORMANCE OF WILDFLOWER SODS. Flowering was indexed on 16 June and 19 July 1994 (Table 10). In June,

Table 6. Differences in species diversity in wildflower sods grown in fresh composts and soil (first season; after 9 weeks growth with midseason seeding).

Medium	Species density (no./m ²)							
	Black eyed Susan	Coreopsis	Daisy	Cosmos	Poppy	Clarkia	Baby's breath	Bachelor's button
Mixed MSW ²	37 a ^y	20 a	20 ab	3 b	15 a	5 b	24 b	8
Biosolids–woodchips (Springfield)	7b	3b	0c	2b	1b	0b	2c	2
Agricultural	44 a	33 a	26 a	6 a	6 b	14 a	42 a	13
Leaf	49 a	32 a	10 abc	1 b	2 b	4 b	6 c	3
Unfertilized soil	18 b	23 a	2 bc	1 b	0 b	0 b	5c	5
Fertilized soil	5 b	26 a	3b c	2 b	0 b	1 b	0 c	1

²MSW = municipal solid waste.

^yWithin columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

Table 7. Visual indexing in May and July of second season flowering of wildflower species in media seeded July 1993.

Medium	Flowering indices ^z				
	May-flowering species			Sum	
	Bachelor's button	Dame's rocket	Ox-eye daisy		
Mixed MSW ^y	0.00 a ^x	2.75 a	4.25 a	7.00 a	
Biosolids–woodchips (Springfield)	0.00 a	0.25 b	0.25 c	0.50 c	
Agricultural	0.50 a	2.50 a	5.00 a	8.00 a	
Leaf	0.75 a	0.50 b	2.50 b	3.75 b	
Unfertilized soil	0.25 a	0.75 b	1.00 c	2.00 bc	
Fertilized soil	0.00 a	0.25 b	0.00 c	0.25 c	
Medium	July-flowering species				
	Bachelor's button	Black-eyed Susan	Coreopsis	Catchfly	Sum
Mixed MSW	1.75 ab	1.75 ab	1.25 b	0.00 b	4.75 b
Biosolids–woodchips (Springfield)	0.00 c	4.25 a	0.25 b	0.25 b	4.50 b
Agricultural	1.50 ab	3.25 a	1.25 b	0.00 b	6.00 ab
Leaf	2.50 a	2.50 a	1.25 b	0.75 a	7.00 a
Unfertilized soil	1.00 bc	2.25 a	3.50 a	0.25 b	7.00 a
Fertilized soil	0.00 c	3.75 a	0.25 b	0.00 b	4.00 b

^zVisual index: 0 = no bloom, 5 = showy, profuse bloom covering entire plot.

^yMSW = municipal solid waste.

^xWithin columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

bachelor's button, dame's rocket, and ox-eye daisy were flowering. Overall flower quality, indicated by sum of the flowering indexes, was better in Marlborough biosolids-woodchips or mixed MSW compost than in the other media. Flowering quality in agricultural compost followed closely behind these composts. Flowering was significantly less in Springfield biosolids-woodchips compost than in the other composts. Dame's rockets and Bachelor's buttons flowered best in mixed MSW, Marlborough biosolids-woodchips, and agricultural composts, and Bachelor's buttons also flowered well in leaf compost. Ox-eye daisies flowered best in Marlborough biosolids-woodchips and mixed MSW composts. Poor quality of flowering of ox-eye daisy in the agricultural compost limited the overall quality of flowering in this medium relative to that in the mixed MSW or Marlborough compost.

In July, blooming of the dame's rocket and ox-eye daisy ended, and black-eyed Susan, coreopsis, bachelor's button, poppy, and catchfly were flowering. Black-eyed Susan and bachelor's button dominated the display. In July, overall flowering quality was the same in all composts, but flowering of individual species varied among composts. Black-eyed Susans flowered significantly better in Springfield biosolids-woodchips compost than in any other media, but were virtually the only flowering species in that compost. In August, no significant bloom change occurred from that in July.

Discussion

The system of growing sods in compost on plastic was successful with some composts producing a weed-free, marketable wildflower sod in 8 weeks. Except for leaf compost, weed seeds were not present directly in the composts, and weeds appearing in the composts were from seeds blown or carried in from the surrounding area. Production of wildflowers in fertilized soil was hampered by growth of soilborne weeds. With field application (O'Brien and Barker, 1995a) in which composts were applied directly on the soil surface or incorporated shallowly into the soil, soilborne weeds grew through the compost and greatly limited wildflower growth. Use of plastic serves as a barrier to weed growth and also provides

a tool for studying compost fertility. In this study, media were isolated in the frames allowing for a controlled system in which the media were the only source of fertility and in which few interferences for sod production were present.

Germination and growth of wildflowers on plastic varied with media. Nitrogen in the media was a factor affecting germination and growth. Germination of wildflowers was limited by the extremely high ammonium concentrations in Springfield biosolids-woodchips compost (Barker et al., 1967; Maynard and Barker, 1969). After concentrations of ammonium in Springfield biosolids-woodchips compost declined with time, some remaining viable seeds germinated, and surviving seedlings benefited from the abundance of residual total N although stand remained poor. Low concentrations of N in leaf compost limited establishment of stand and ensuing growth. Agricultural compost and mixed MSW com-

Table 8. Average stands, total plant numbers, and dry mass for late-seeded (September 1993) wildflowers in fresh compost or sawdust.

Medium	Measurement ^z		
	Stand ^y	Density (plants/m ²)	Dry mass (g·m ⁻²)
Mixed MSW ^x	75 a ^w	62 a	95 a
Biosolids-woodchips (Springfield)	36 c	34 b	14 c
Biosolids-woodchips (Marlborough)	73 a	53 ab	102 a
Agricultural	63 ab	67 a	70 b
Leaf	51 b	46 ab	59 b
Sawdust	0 d	0 c	0 c

^zWildflowers seeded in composts on 15 Sept. 1993; measurements conducted on 16 June 1994.

^yStand: visual index of uniformity and density of cover (0 to 100; 0 = poorest cover, 100 = best cover).

^xMSW = municipal solid waste.

^wWithin columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

Table 9. Species diversity of late-seeded wildflowers in fresh compost and sawdust.

Medium	Species, density (no./m ²) ^z				
	Black-eyed Susan	Bachelor's button	Ox-eye daisy	Coreopsis	Dame's rocket
Mixed MSW ^y	34 ab ^x	5 a	19 a	12 a	19 ab
Biosolids-woodchips (Springfield)	6 cd	2 bc	2 b	0 c	4 cd
Biosolids-woodchips (Marlborough)	43 a	8 a	18 a	9 ab	22 a
Agricultural	18 bc	7 a	6 b	4 bc	16 b
Leaf	26 ab	5 ab	4 b	4 bc	8 c
Sawdust	0	0	0	0	0

^zWildflowers seeded on 15 Sept. 1993; measurements conducted on 16 June 1994.

^yMSW = municipal solid waste.

^xWithin columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

post produced the best plant growth with respect to quality and density of stand and biomass. Each of these composts was relatively rich in N and low in ammonium at the time of seeding.

Early in the second year with all media, biennial and perennial wildflowers appeared to have an advantage over annual weeds so that the problem with weeds was much diminished in established plantings. However, later in the season, weeds began to interfere with the attractiveness of wildflowers in the fertilized and unfertilized soil but not with those in composts.

Based on the assessments of growth in the first year of the study, the best overall quality of sod was produced in the agricultural compost, which gave a uniform stand of relatively large, healthy plants. Second best overall quality of growth occurred in the mixed MSW compost. In the first year, quality of sod in the mixed MSW compost was limited by production of smaller plants relative to those in the agricultural compost. The population of plants in the Springfield biosolids-woodchips composts was limited by poor germination, but the surviving plants grew well and were second

only to those in the agricultural compost in total dry matter production. The sparse stand, however, diminished the quality of the sods relative to that in mixed MSW or agricultural compost, particularly in the second year. Wildflowers in the leaf compost were numerous but small and spindly, apparently in need of nutrition. Establishment of seedlings was limited in the soil relative to that in the composts. In the fertilized soil, this limitation was overcome by the response of the plants to the applied nutrients; however, weed growth in the fertilized soil gave an unacceptable quality of sod. Poor nutrition limited the growth of wildflowers in the unfertilized soil, and the high relative growth of spindly weeds also gave a poor quality of sod in the first year. The results with fertilized and unfertilized soil were similar to those of Ahearn et al. (1992), who found that applying fertilizer in the field was more advantageous to weeds than to the wildflowers.

Differences in plant growth among composts were less in the second year or with seeding late in the season. The similarities among composts in the second year appear to be due to increases

Table 10. Visual indexing of flowering of late-seeded wildflowers seeded in fresh compost and sawdust on plastic.

Medium	Visual indexing ^z				Sum	
	June-flowering					
	Bachelor's button	Dame's rocket	Ox-eye daisy			
Mixed MSW ^y	2.50 a ^x	5.00 a	3.50 a		11.0 ab	
Biosolids–woodchips (Springfield)	0.25 b	1.25 b	0.50 c		2.0 d	
Biosolids–woodchips (Marlborough)	4.00 a	5.00 a	4.00 a		13.0 a	
Agricultural	4.00 a	4.25 a	0.25 c		8.5 c	
Leaf	2.50 a	1.75 b	1.75 b		6.0 c	
Sawdust	0	0	0		0	
Medium	July-flowering					
	Bachelor's button	Black-eyed Susan	Coreopsis	Poppy	Catchfly	
	Sum					
Mixed MSW	2.50 a	1.25 b	0.25 a	0.75 a	0.25 a	5.0 a
Biosolids–woodchips (Springfield)	0.75 b	2.75 a	0	0	0	3.5 a
Biosolids–woodchips (Marlborough)	1.75 a	1.00 bc	0	1.00 a	0.25 a	4.0 a
Agricultural	2.75 a	1.50 b	1.25 a	0	0	5.5 a
Leaf	2.25 a	1.50 b	0.50 a	0.25 a	0.50 a	5.0 a
Sawdust	0	0	0	0	0	0

^zVisual index: 0 = no bloom, 5 = showy, profuse bloom covering entire plot. Seeding on 15 Sept. 1993. Ratings made on 16 June and 19 July 1994.

^yMSW = municipal solid waste.

^xWithin columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$). Zeros are not included in the range test.

in maturities and weathering of composts and removal of inhibiting factors, such as high ammonium concentrations and N deficiency. A problem with late seeding is that annual wildflower species do not become well established in either season. Species diversity creates a colorful and attractive floral display. First-year growth and diversity of wildflowers was better in the agricultural and mixed MSW composts than in other media except fertilized soil. Quality of wildflower stand was limited in the leaf compost by low diversity and low biomass. The agricultural and mixed MSW composts did not have high ammonium N concentrations. Many seedlings germinated in the leaf compost, but seedlings failed to grow well. Growth in unfertilized soil was similar to that in leaf compost but with even fewer wildflower plants. The lack of fertility, particularly available N, is deemed responsible for the limited growth in the leaf and soil media. Fertilization of leaf compost may be considered as a means of improving quality of sods, but fertilization of soil does not seem practical without a practice for weed control in the first season. Weeds similarly may be a problem in some leaf composts, which may bear seeds from yard wastes mixed in with the leaves.

Although N appears to be a limiting factor in production of wildflowers in some composts, plant tissue analysis did not give a good indication of the N status of the plants. Wildflowers grown in the leaf compost had a unexpectedly high total N concentration relative to that present in the medium and in the tissues of plants grown in the N-rich media. These results were similar to those in an earlier study (O'Brien and Barker, 1995b). These responses for plants grown in the leaf compost are likely due to the effects of concentrating a small amount of N in a small amount of tissue and to dilution of the N with dry matter production for plants grown in the N-rich media.

Growth of wildflowers in unfertilized or fertilized soil was limited in the second year relative to growth in composts. No fertilizer was added to any medium in the second season. Poor nutrition in the second year was more pronounced in the soil than in any compost. Relative to the first year, growth of wildflowers in leaf compost was improved in stand and biomass production. This improvement in growth is attributed to the additional year for maturation of the compost and to better availability of N.

The media affected the flowering of species in the second season as well as in the first season. In May 1994, dame's rocket and ox-eye daisy dominated the flowering display, and flowering was better in the agricultural and mixed MSW composts than in the other media. In July 1994, black-eyed Susans flowered well in all media. This species appears to be well adapted to growth in infertile media. Compared to other media, bachelor's buttons flowered better in leaf compost, whereas coreopsis flowered better in soil. Since little growth occurred in unfertilized soil and leaf media in the first year, space for reseeding was readily available. Reseeding is particularly important for appearance of annuals in the second and following years.

Overall Evaluations

Different kinds of composts have varying effects on wildflower sod growth. Agricultural compost consistently produced marketable wildflower stands with diverse species in about 8 weeks. Maturity of composts is important in stand establishment. High concentrations of ammonium in immature N-rich composts hindered stand establishment. High ammonium concentrations are associated with the N-containing compostable materials entering into the media, and immature N-rich composts often are high in ammonium. Maturation of composts in piles or application of

composts on a site with adequate time for ammonium dissipation (1 or 2 weeks) improves quality of high-ammonium composts as media for sod production. Fresh leaf compost limited growth because of its low state of decomposition as indicated by low N composition and visible leaf fragments. Wildflower growth in leaf compost improved in the second year.

Salinity did not appear to be a factor impeding growth in this experiment. However, electrical conductivity declined in the first 11 d in biosolids-woodchips, agricultural, and mixed MSW composts. Since the frames were self-contained, leaching of soluble salts was likely not a strong factor removing salt from the composts. Work of Mitchell et al. (1994) and Cisar and Snyder (1992) suggest that leaching is a significant factor removing salts from the media even though the plastic was an impermeable barrier. In the biosolids-woodchips compost, much of the change in electrical conductivity may be accounted for by the decline in ammonium by volatilization, particularly in the first 11 d.

The surface of the Marlborough biosolids-woodchips compost was attractive. In the second year, the woodchips appeared as if they were applied as a mulch to the plots, and the combined appearance of the compost and dense, diverse stand in this compost gave the best appearing sods of the group. Uniformity of size of individual woodchips in this compost was an aesthetic benefit.

Wildflower establishment in composts was superior to that in soil. Weed competition with wildflowers was less in composts than in the soil. Fertilization of soil was required to produce substantial plants, but weed growth was stimulated with fertilization of soil so that the sod was unacceptable. Fertilization of N-rich composts appears to be unnecessary for at least 2 years.

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