Biosolid Residues as Soilless Media for Growing Wildflower Sod

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SUMMARY. Two biosolid-containing waste media [sewage sludge compost and incinerated biosolids (flume sand)] were tested individually, together, and in combination with a commercial growing medium for growing wildflower sod in greenhouse trials over a 3-year period. A medium composed of flume sand and Metromix (7:3 weight/weight) in 7.5 (XtimesX) 10.5 (XtimesX) 2-inch deep (19 (XtimesX) 27 (XtimesX) 5-cm) plastic trays seeded at 20 oz/1000ft² (6.1 g·m⁻²) with cosmos (*Cosmos bipinnatus*), cornflower (*Centaurea cyanus*), plains coreopsis (*Coreopsis tinctoria*), white yarrow (*Achillea millefolium*) and purple coneflower (*Echinacea purpurea*) produced a suitable wildflower sod in 10 to 12 weeks. A single application of slow release fertilizer (Osmocote 14-14-14, 14N-4.2P-11.6K) applied as a top dressing had no significant effect on sod development; however, a 4-mil [0.004-inch (0.10-mm)] polyethylene barrier placed in the base of each

container resulted in increased dry weight accumulation and a higher root to shoot ratio relative to sod grown without plastic.

The disposal or use of municipal organic solid residues (biosolids) is an important environmental issue. The United States Environmental Protection Agency (USEPA) has established minimum standards for the disposal and beneficial reuse of biosolids based on appropriate risk assessments to human populations and the environment (USEPA, 1998). These standards address the following categories: surface disposal in landfills; disposal by incineration; and application to land (soil) for conditioning and fertilization.

Landfills, once considered the easiest and least expensive method of dealing with solid waste disposal, are now closing because of inadequate space and more stringent pollution control requirements (He et al., 1992). New landfill sites are difficult to permit because of strict environmental regulations (USEPA, 1991). Thus, landfills are becoming a less available means of biosolid disposal. Incineration of biosolids as a means of disposal is a costly and infrequently used process, even though certain incineration ash by-products have the potential for beneficial use in horticultural production (Fitzpatrick, 1985). Limitations in acceptable disposal options have prompted renewed interest in finding alternative beneficial uses for biosolid residues, especially those that can be composted readily.

In this research, we investigated the use of a composted biosolid (Com-Til, Columbus Compost Facility, Columbus, Ohio) and the ash by-product of incinerated biosolids (flume sand) as possible growing media in the production of wildflower sod. Acknowledging that there are no promulgated federal standards for the ash by-product of biosolid incineration, we compared the heavy metal content of incinerated ash to pollutant concentrations established for sewage sludge. For our purposes, flume sand was incinerated ash with heavy metal concentrations lower than those specified by the USEPA and determined to be in compliance with their Toxicity Characteristic Leaching Procedure (USEPA, 1998). Ash by-products exceeding these standards were classified as incinerator ash and, conse-

quently, were not used in these investigations.

In the past 25 years, interest has expanded in the use of wildflowers in many landscape settings (Mitchell et al., 1994), and wildflower plantings have become increasingly popular alternatives to turf along highway rights-of-way (Harkness and Lyons, 1998). While not maintenance free, the costs of maintaining wildflower plantings are reported to be less than those for turf (Billings, 1990). Some of the benefits of wildflower plantings include: beautification, aesthetic variety, erosion stability, wildlife food and habitat (O'Brien and Barker, 1997) and, for highway plantings, an apparent psychologically calming effect on motor vehicle operators (Billings, 1990).

Based on the increased popularity and widespread use of wildflower plantings and the potential for growing wildflower sod on waste materials, this research was undertaken to identify and test two biosolid residues that could be successfully used, either singly or in combination with other horticultural media, for growing wildflower sod. The objective of this investigation was to develop and test technology for growing young, established wildflower sod strips on biosolid residues for transplanting into the field, thereby alleviating the problems and risks associated with direct seeding. To accomplish this objective, a series of greenhouse experiments was conducted over a period of about 3 years.

Materials and methods

Two biosolid-derived media, both products of the solid waste treatment facilities in Columbus, Ohio, were used in these studies: Com-Til (CT), a municipal sewage sludge composted with wood chips, and flume sand (FS), an ash by-product of incinerated municipal waste. Chemical analyses [mg·kg⁻¹ (ppm)] of these products are as follows: CT (total nitrogen = 3800; phosphorus = 13650; potassium = 6050; cadmium = 1.7; chromium = 52; copper = 145; lead = 34; nickel = 24; zinc = 1846); FS (total nitrogen = 1995; phosphorus = 67966; potassium = 16655; cadmium = 11.3; chromium = 230; copper = 738; lead = 211; nickel = 175; zinc = 4754). These media were tested either singly, together, or in combination with a commercially available growing medium [Metromix 360 (MM), Scotts-Sierra Horticultural Products Co., Marysville,

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We thank the City of Columbus, OH for financially supporting this work and for providing the Com-Til and flume sand. Use of trade names is for the reader's information only and does not imply endorsement over similar products with like properties. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Ohio] consisting of vermiculite, composted bark fines, peat moss, processed bark ash, and washed sand. To check whether or not the soluble salt content of CT and FS might be toxic to wildflowers, we measured the electrical conductivity (EC) and pH of leachate derived from 9.5 oz (269 g) samples of each medium or combinations of media. Samples were placed in 3.25 (XtimesX) 3.25 (XtimesX) 3-inch deep (8.3 (XtimesX) 8.3 (XtimesX) 7.6-cm) plastic pots and leached either zero, one or three times with 5.1 fl oz (150 mL) tap water before measuring EC and pH of the leachate.

Wildflower seed used were Midwest mix (Applewood Seed Co., Arvada, Colo.) and Baby Bloomers mix (Turf-Seed, Inc., Hubbard, Ore.) or, alternatively, selected species from the Midwest mix. Both mixes contained a combination of annual and perennial species, and both were planted at the recommended rate [5 oz/1000ft² (1.5 g·m⁻²) and 8 oz/1000ft² (2.4 g·m⁻²), respectively], unless otherwise noted. All experiments were conducted in a partially shaded greenhouse under the following range of conditions: 64 to 79 °F (18 to 26 °C); 65+/-15% relative humidity; 800 to 1200 μmol·m⁻²·s⁻¹ photosynthetically active radiation [natural daylight plus supplemental illumination from 40-W cool-white fluorescent lamps on a 12-h photoperiod (0600-1800 H)]. Depending on the experiment, seeds were planted in either 3.25 (XtimesX) 3.25 (XtimesX) 3-inch-deep plastic pots, 16 (XtimesX) 12 (XtimesX) 2-inch deep (41 (XtimesX) 30 (XtimesX) 5-cm) divided multipurpose carrying trays (Hummert International, Earth City, Miss.), or 3.5 (XtimesX) 7.5 (XtimesX) 2-inch deep (9 (XtimesX) 19 (XtimesX) 5-cm) and 7.5 (XtimesX) 10.5 (XtimesX) 2-inch-deep (19 (XtimesX) 27

(XtimesX) 5-cm) plastic trays (Mellinger's, North Lima, Ohio). Different container types were used to determine if one would be more suitable for growing strips of sod that could be readily transplanted into the field. As the plants in each study germinated and grew, they were observed daily, and each container was hand-watered from below to ensure adequate moisture.

In the first set of greenhouse experiments, germination and shoot growth of Midwest and Baby Bloomers seed mixes were evaluated when grown on FS, CT and combinations of these media. Both mixes were seeded at the recommended rate in divided multipurpose trays. Each tray section represented a single treatment. Germination was recorded after 10 d and 3 weeks; shoot growth and stand density were measured after 3 weeks. The experiment was repeated twice, once using 3.25 (XtimesX) 3.25 (XtimesX) 3-inch pots and the second time using 3.5 (XtimesX) 7.5 (XtimesX) 2-inch trays.

Based on observations made during the first experiments, additional greenhouse trials were initiated to measure the effect of fertilization [Osmocote 14-14-14 (Scotts-Sierra Horticultural Products Co., Marysville, Ohio)] and two different seeding rates on germination and growth of Midwest seed mix planted in FS and MM. Fertilizer [1.9 oz/ft² (580 g·m⁻²)] was applied as a top dressing to plants seeded at either 5 oz/1000ft² (1 (XtimesX) or 20 oz/1000ft² (4 (XtimesX) in 7.5 (XtimesX) 10.5 (XtimesX) 2-inch plastic trays. We also evaluated combinations of FS and MM (3:2 and 7:3) as growing media for little bluestem (*Schizachyrium scoparium*), a native warm-season grass frequently included

as an ecological and aesthetic supplement in wildflower plantings. Little bluestem was seeded at 2 oz/1000ft² (0.61 g·m⁻²) in 7.5 (XtimesX) 10.5 (XtimesX) 2-inch trays. Percent germination for the wildflowers and for little bluestem was recorded after 21 d.

In an effort to improve the performance of wildflower plantings grown on FS, a greenhouse experiment was conducted using selected wildflower species seeded in 7.5 (XtimesX) 10.5 (XtimesX) 2-inch trays containing a mixture of FS and MM (7:3). Based on earlier performance data, 10 seeds from each of the following seven species were planted together in the FS-MM mixture and grown for 3 weeks before measuring germination and growth (shoots and roots): cosmos, cornflower, plains coreopsis, white yarrow, purple coneflower, perennial gaillardia (*Gaillardia aristata*) and black-eyed susan (*Rudbeckia hirta*).

In a final set of greenhouse studies, we examined the effect of growing wildflower sod on 4-mil polyethylene sheets fitted in the bottom of 3.5 (XtimesX) 7.5 (XtimesX) 2-inch trays with or without 0.5-inch (1.3 cm) netting to facilitate knitting of the developing root systems. In these studies, seven seeds of each of five wildflower species (cosmos, cornflower, plains coreopsis, white yarrow and purple coneflower) were planted in trays containing FS and MM (7:3). Germination, shoot and root growth were measured after 3, 6, and 12 weeks.

As a general sampling protocol, seeded containers (trays or pots) from each experiment were transferred to the greenhouse; and after the prescribed period of time, the plants in each container were harvested, and measurements were recorded as indicated above.

Table 1. Electrical conductivity (EC) and pH of unleached media (0) and leachate of the same media after flushing either one (1(XtimesX)) or three times (3(XtimesX)) with 5.1 fl oz (150 mL) tap water.^z

Media ^y	EC (dS·m ⁻¹)			pH		
	0	1(XtimesX)	3(XtimesX)	0	1(XtimesX)	3(XtimesX)
Flume sand (FS)	1.71	1.12	0.58	6.81	7.35	7.46
Com-Til (CT)	2.98	2.03	1.56	5.30	7.41	7.64
3FS:1CT	1.67	2.46	0.75	6.04	7.19	7.24
1FS:1CT	2.42	2.63	0.97	5.63	7.28	7.25
1FS:3CT	3.16	2.90	1.26	5.41	7.45	7.41
Metromix 360 (MM)	0.50	0.94	0.85	5.80	7.06	6.82
1FS:1MM	0.94	2.59	1.61	6.42	6.61	6.78
3FS:2MM	1.12	2.50	1.01	6.44	5.71	5.99
7FS:3MM	0.74	1.38	1.18	5.60	5.85	5.89
2FS:1CT:2MM	1.40	3.41	2.35	6.01	6.20	6.31

^zEach value is the average of duplicate samples. EC and pH of tap water = 0.40 and 8.58, respectively.

^yCombinations of two or more media mixed by weight.

Table 2. Germination, stand density and shoot mass of two commercial wildflower seed mixes grown on biosolid-containing media for 3 weeks.^z

Media composition	Germination ^y (%)	Stand density ^x (plants/ft ²)	Shoot wt ^w (g)
		Midwest mix	
Flume sand (FS)	93 a	123 a	0.61 b
Com-Til (CT)	55 c	89 bc	0.59 b
3FS:1CT	80 ab	106 ab	0.54 b
1FS:1CT	61 bc	82 c	0.47 b
1FS:3CT	67 bc	89 bc	0.51 b
Metromix 360 (MM)	87 ab	112 ab	1.01 a
		Baby Bloomers mix	
FS	47 b	145 b	0.38 bc
CT	27 c	82 c	0.36 bc
3FS:1CT	36 bc	112 bc	0.43 b
1FS:1CT	23 c	74 c	0.32 bc
1FS:3CT	27 c	87 c	0.30 c
MM	87 a	249 a	0.79 a

^zSeeds were planted at recommended rates in divided plastic trays. Each tray section was 16 (XtimesX) 3 (XtimesX) 2-inches (41 (XtimesX) 7.6 (XtimesX) 5-cm) and represented a single treatment. Each value represents the mean of five replications. For each individual seed mix, means in a column followed by the same letter are not significantly different, $\text{LSD}_{0.05}$.

^yExpressed as percent of planted seeds that germinated.

^x1.0 plant/ft² = 10.8 plants/m².

^w28.4 g = 1 oz.

Shoot and root dry weight data were collected after oven-drying at 176 °F (80 °C) for 48 h. The experimental design used in each study was a randomized complete block with five or more replications.

Differences in treatment means were analyzed using the LSD method for pairwise comparisons (SAS Institute, Inc., 1988). To normalize the data, all germination percentages were converted to arcsin transformations before statistical analyses.

Results and discussion

In media containing only FS or CT, leaching with 150 mL of tap water lowered soluble salt content and raised pH (Table 1). In media containing FS and CT together, mixtures with greater quantities of FS had lower levels of soluble salts and, conversely, media with greater quantities of CT had higher levels of salts. This result was true before

or after leaching with tap water. Although mixtures composed of predominantly FS (3FS:1CT) exhibited initially higher pH values than those composed predominantly of CT (1FS:3CT) (6.04 versus 5.41), this trend was reversed after only one leaching with tap water. The rapid rise in pH of leachate from media containing higher levels of CT may be caused by the relatively high pH of tap water used in the leaching process or may possibly reflect the chemical qualities of substrates from which this compost was made (Fitzpatrick et al., 1998). In media containing FS and MM together, mixtures with greater quantities of FS (7FS:3MM) exhibited less soluble salts (lower EC values) and a lower pH than media containing proportionately smaller amounts of FS (1FS:1MM), regardless of the leaching treatment. Adding even small amounts of CT (20%) to a mixture of FS and MM

raised the soluble salt content above that of similar mixtures without CT present.

Soluble salt content and pH can be complicating factors in evaluating the effectiveness of biosolid-containing waste products as growing media for horticultural crops (Roberts et al., 1995). Although salt concentrations can be quite high in composted organic media (Chen and Hadar, 1987; Coosemans and van Assche, 1983; Logan et al., 1984), flushing the media with water before seeding largely overcomes this problem. In the present investigation, the soluble salt content of FS before leaching was 1.71 dS·m⁻¹. After leaching three times with 150 mL tap water EC was reduced about two-thirds (Table 1).

While the leaching procedure effectively purged FS of salts, the time required to reach this objective was

Table 3. The effect of fertilizer treatment and seeding rate on stand density and growth of Midwest wildflower mix 3 weeks after planting on flume sand amended with Metromix 360 (7:3 w/w).^z

Treatment ^y	Seeding rate ^x (oz/1000ft ²)	Stand density ^w (plants/ft ²)	Dry wt ^v (g)		Root to shoot ratio
			Shoot	Root	
Fertilizer	5	53 b	0.20 b	0.08 b	0.39 c
	20	233 a	0.46 b	0.27 b	0.58 bc
No fertilizer	5	69 b	0.24 b	0.22 b	0.91 ab
	20	203 a	0.79 a	1.01 a	1.27 a

^zEach value represents the mean of five replications. Means followed in a column by the same letter are not significantly different, $\text{LSD}_{0.05}$.

^yFertilizer (Osmocote 14-14-14) applied as a top dressing at 1.9 oz/ft² (580 g·m⁻²) 1 week after seeding.

^x1 oz/1000 ft² = 0.3 g·m⁻².

^w1.0 plant/ft² = 10.8 plants/m².

^v28.4 g = 1.0 oz.

substantial. Since the initial EC readings for unleached FS are not unreasonably high [Rosen et al. (1993) indicated that EC levels higher than 2 to 3 dS·m⁻¹ resulted in marginal necrosis in many plant species], the data from these experiments suggest that leaching FS with tap water may not be necessary, depending on the sensitivity of the individual plant species to be grown in this medium. Similar reasoning can be applied to the leaching requirement for CT, although the unleached salt content of this material is higher (2.98 dS·m⁻¹) than that for FS. Mitchell et al. (1994) reported that drenching compost with 2 inches (5 cm) of water before seeding had no significant effect on plant density readings taken 2 weeks later. Our experience suggests that EC and pH values should be tested and carefully evaluated by growers before deciding on the necessity of leaching these biosolid-containing media before planting, particularly since soluble salt content can vary considerably from batch to batch.

In our studies, either Midwest or Baby Bloomers seed mixes were grown successfully on FS or CT, although germination and stand density were always significantly greater for either mix when grown on FS alone versus CT alone (Table 2). For media containing FS and CT mixed together, germination and growth of both seed mixes were always better when the percentage of FS was high (e.g., 3FS:1CT) versus when it was low (e.g., 1FS:3CT). Although some significant differences in germination and stand density were observed for both wildflower mixes grown on media containing FS and CT, no such differences were observed for shoot dry

weight. These data suggest that although seed germination or the number of plants per unit area was influenced by media composition, ultimately shoot mass was not significantly different among the media tested in this study.

When comparing the performance of each individual seed mix on the various media used in these investigations, it became apparent that the Midwest mix performed better than the Baby Bloomers mix when grown in 100% FS, 100% CT, or combinations of these two media (Table 2) in that seed germination and shoot mass were consistently higher in the former wildflower mix. These results may reflect the difference in species composition between the two mixes. The overall performance of individual wildflower species included in the seed mixes used in our experiments seemed to compare favorably with that reported by other investigators using similar species grown in soil (Ahern et al., 1992; Harkness and Lyons, 1988; Johnson and Whitwell, 1997). For little bluestem, germination on either 3FS:2MM or 7FS:3MM was slightly less than half that for the Midwest wildflower mix 3 weeks after seeding (data not shown); however, plantings of this warm-season grass seemed to grow on either media once they became established.

Based on germination and stand density measurements collected in this first phase of our research, we decided to discontinue using CT as a component of our wildflower sod medium and to concentrate on FS as the primary ingredient in subsequent investigations. We also decided to amend the FS component with MM and, after considerable testing (Table 1), we selected a mixture

of 7FS:3MM as the primary medium for further investigation. We also decided, based on the growth data obtained with the two commercial seed mixes, to utilize the Midwest seed mix, or selected species from this mix, for subsequent studies on wildflower sod establishment.

Table 3 shows the results of fertilizer treatment and seeding rate on stand density and shoot and root dry mass accumulation for Midwest seed mix planted in 7FS:3MM. As expected, increasing seeding rate from 1_(XtimesX) to 4_(XtimesX) resulted in more plants per unit area and a corresponding increase in total mass regardless of the fertilizer treatment. Unexpected, however, was the observation that fertilization did not stimulate wildflower growth in this study. In fact, shoot and root mass were less in fertilized plants than they were in unfertilized ones, particularly at the higher seeding rate. Root to shoot ratio was always significantly lower in fertilized plants for both seeding rates used in these studies.

Although a literature search revealed no direct reference to fertilization effects for wildflower sod grown on ash by-products such as FS, it did reveal a study by Wootton et al. (1981) using a composted medium derived from anaerobically digested sewage sludge in which the shoot growth of container-grown marigolds was significantly reduced by Osmocote 14-14-14 applied as a top dressing at 8.3 oz/ft² (2500 g·m⁻²). Also, Hansen et al. (1998) reported in their research with hydroponically-grown chrysanthemums (*Dendranthema*_(XtimesX)*grandiflorum*) that horticultural systems containing high levels of phosphorus had no benefit in terms of shoot growth and may actually

Table 4. Germination, stand density, and biomass accumulation of selected wildflower species grown on flume sand and Metromix 360 (7:3 w/w) for 3 weeks in the greenhouse.^z

Species	Germination ^y (%)	Stand density ^x (plants/ft ²)	Dry wt ^w (g)		Root: shoot ratio
			Shoot	Root	
Cosmos	93 ab	136 a	0.51 a	0.13 b	0.24 c
Cornflower	85 bc	124 a	0.35 b	0.35 a	1.02 a
Plains coreopsis	97 a	140 a	0.15 c	0.12 b	0.76 b
Purple coneflower	83 bc	126 a	0.16 c	0.04 c	0.27 c
White yarrow	83 bc	121 ab	0.11 d	0.03 cd	0.29 c
Perennial gaillardia	47 d	68 c	0.07 e	0.02 c	0.22 c
Black-eyed susan	67 cd	97 b	0.06 e	0.02 d	0.26 c

^zTen seeds of each species were planted in 7.5_(XtimesX) 10.5_(XtimesX) 2-inch (19_(XtimesX) 27_(XtimesX) 5-cm) plastic trays. Each value represents the mean of six replications. Means in a column followed by the same letter are not significantly different, t-SD_{0.05}.

^yExpressed as percent of planted seeds that germinated.

^x1.0 plant/ft² = 10.8 plants/m².

^w28.4 g = 1 oz.

Table 5. Germination, stand density, and biomass accumulation of five wildflower species seeded in flume sand and Metromix 360 (7:3 w/w) and grown in plastic trays for 12 weeks in the greenhouse with or without 4-mil [0.004-inch (0.10-mm)] polyethylene liners.^z

Time (weeks)	Treatment	Germination ^y (%)	Stand density ^x (plants/ft ²)	Dry wt ^w (g)		Root to shoot ratio
				Shoot	Root	
3	Plastic liner	68 a	129 a	0.34 a	0.08 a	0.23 ab
	No liner	63 a	121 a	0.30 a	0.06 a	0.21 a
6	Plastic liner	66 a	126 a	1.32 b	0.41 b	0.31 c
	No liner	65 a	132 a	1.27 b	0.33 b	0.26 b
12	Plastic liner	68 a	129 a	2.77 d	0.95 d	0.34 c
	No liner	62 a	117 a	2.44 c	0.63 c	0.25 b

^zSeven seeds from each of the following five wildflower species (cosmos, cornflower, plains coreopsis, purple cone-flower and white yarrow) were planted together in 3.5 (XtimesX) 7.5 (XtimesX) 2-inch (9 (XtimesX) 19 (XtimesX) 5-cm) trays. Each value represents the mean of six replications. Means followed in a column by the same letter are not significantly different, $t_{59}P_{0.05}$.

^yExpressed as percent of planted seeds that germinated.

^x1.0 plant/ft² = 10.8 plants/m².

^w28.4 g = 1 oz.

have been detrimental to root growth. Studies by Ahern et al. (1992), as well as O'Brien and Barker (1997), revealed that applying fertilizer to soil-grown wildflowers was more advantageous to weeds than it was to wildflowers.

Therefore, based on our results and the reports of others, we do not recommend the use of the fertilizer rates tested here, at least during the initial stages of wildflower sod establishment on ash by-products such as FS. We do, however, suggest a higher seeding rate for Midwest mix of at least twice the recommended rate when using FS or a comparable soilless medium.

For the individual wildflower species tested in our greenhouse studies, germination exceeded 80% for all except gaillardia and black-eyed susan (Table 4). These data are reflected in stand density, which also was substantially less for these two species, especially gaillardia. Plains coreopsis exhibited the highest germination and, hence, the highest density, but cosmos, cornflower, purple cone-flower and white yarrow all germinated well, resulting in a substantial number of plants per unit area. Shoot mass of cosmos was significantly greater than the other species tested, but total biomass accumulation (shoots and roots) was greatest for cornflower.

In our experiments, black-eyed susan, a basic component of many commercial seed mixes, did not grow particularly well when seeded on the soilless medium containing 7FS:3MM (Table 4). However, others (O'Brien and Barker, 1997) report that this species produces good sod when seeded in a biosolid compost rich in total nitrogen. Since the nitrogen content of FS is only about one-half that of a composted

biosolid such as CT, this may help explain the rather mediocre performance of this species in our greenhouse trials.

The use of plastic film as a barrier in the production of wildflower sod was investigated by planting five wildflower species (cosmos, cornflower, plains coreopsis, white yarrow and purple cone-flower) in biosolid-containing media (7FS:3MM) in 3.5 (XtimesX) 7.5 (XtimesX) 2-inch plastic trays either with or without 4-mil polyethylene liners and with or without 0.5-inch netting. Although there were no significant differences in germination rate or stand density between plants grown in either plastic-lined or unlined trays, there were notable differences in dry weight accumulation and root to shoot ratio between the two treatments 12 weeks after seeding (Table 5). At the end of this time shoot and root mass, as well as root to shoot ratio, were all significantly greater for plants grown on plastic film. These data indicate that root growth was appreciably enhanced by growing the sod over a plastic barrier (e.g., root mass was 50% greater in plastic-lined than in unlined trays, while shoot mass was only 14% greater). The addition of 0.5-inch netting had no apparent effect on wildflower sod establishment (data not shown).

Growing turfgrass sod over plastic is a technology developed successfully by Decker (1975; 1989) and others; however, similar techniques for producing wildflower sod have been slower to develop. Mitchell et al. (1994) reported that plastic netting placed in the base of 12-inch (30.5-cm) trays enhanced the tensile strength of wildflower sod grown on a variety of municipal waste materials for 10 weeks. O'Brien and Barker (1997) successfully grew wildflower sod on com-

posts of mixed municipal solid waste, biosolids and woodchips, leaves and mixed agricultural wastes placed on plastic sheets in outdoor plots for a period of 8 weeks. Our experiments using a soilless medium (7FS:3MM) showed that wildflower sod could be produced within 6 to 12 weeks when grown over a plastic barrier. During this time the roots knitted together into a usable sod which could be easily removed from its container and readily transplanted into the field.

In conclusion, our results indicate that wildflower sod can be grown successfully in shallow plastic containers using a soilless medium composed of flume sand and a commercial growing medium (7FS:3MM). Sod development, especially root growth, was enhanced by placing a 4-mil plastic barrier in the base of each container before seeding.

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