Composted Biosolids Incorporation Improves Turfgrass Establishment on Disturbed Urban Soil and Reduces Leaf Rust Severity

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Abstract. The effects of incorporation of compost to a disturbed urban soil on turfgrass establishment, growth, and rust severity were assessed in a replicated field study. A blend of two locally available composted biosolids (sewage sludge) was incorporated into a nutrient-deficient subsoil at a rate of 130 m³·ha⁻¹, adding NO₃-N, P, and K at 126, 546, and 182 kg·ha⁻¹, respectively, to each compost-amended plot. Kentucky bluegrass (*Poa pratensis* L.), perennial ryegrass (*Lolium perenne* L.), and a mixture of these two species were seeded into both compost-amended and nonamended plots and observed for 1 year. Turfgrass establishment estimated from visual assessments of percentage cover and growth measured by clipping yields were significantly ($P < 0.05$) enhanced by the incorporation of the composted biosolids. These effects were first observed and most pronounced on plots seeded with perennial ryegrass and were apparent for the duration of the study. The severity of leaf rust caused by *Puccinia* sp. was significantly ($P < 0.05$) less on perennial ryegrass seeded on the compost-amended plots. This study demonstrates the feasibility and potential benefits of amending disturbed urban soils with composted biosolids to enhance turfgrass establishment and is the first report of the suppression of a foliar turfgrass disease through the incorporation of compost into soil.

Establishing lawns following construction of new homes is frequently difficult. During construction the topsoil often is removed or covered with basement fill, construction debris is buried, and heavy equipment compacts the remaining subsoil. New homeowners face the challenge of growing a lawn on these disturbed soils. Early in the 20th century, homeowners were advised to grow cover crops for one or more seasons to improve soil tilth and fertility before seeding turfgrass (Barron, 1923). Current recommendations based on agronomic research include amending the soil prior to seeding with organic materials (Pound and Street, 1991). Manures and other organic agricultural wastes sometimes are used for this purpose in field soils (Larney and Janzen, 1996), but transportation costs and availability of these materials limit their use in urban

settings. Urban sources of organic matter such as sewage sludge and yardwastes, which until recently posed waste disposal problems, are increasingly composted today and used as soil conditioners.

Incorporation of composted urban wastes into soil reduces the bulk density and increases the moisture holding capacity of amended soils (Darmody et al., 1983; Hornick and Parr, 1987), improves aggregate stability and cation exchange capacity (Aggelides and Londra, 1999), and may also increase the depth of the Ap horizon (Darmody et al., 1983). The effects of various composted materials on soil fertility and plant nutrition have been documented extensively (Darmody et al., 1983; O'Keefe et al., 1986; Pascual et al., 1997; Sikora and Yakovchenko, 1996). Composts also have been shown to reduce the incidence and severity of diseases caused by soilborne plant pathogens, such as Pythium root rot and damping off of ornamental and nursery crops (Hoitink and Boehm, 1999), Fusarium wilt of flax (Serra-Wittling et al., 1996), and Phytophthora crown rot of citrus and avocado (Lumsden et al., 1983).

Research on turfgrass also has demonstrated beneficial effects of compost amendments and topdressings. Most of this research, however, was conducted on golf course turf or was based on greenhouse or laboratory studies using sand or topsoil. For example, establishment rates and color of creeping bentgrass (*Agrostis palustris* Huds.) were enhanced by the incorporation of composted biosolids to a

sand-based putting green rootzone mix (Markham, 1998). Composts have also been used to replenish or even substitute for soil in sod production (Logsdon, 1991; Murray, 1982). Topdressings consisting of composted biosolids have been used to supplement or replace urea-based fertilizers on putting greens and fairways (Eguiza et al., 1991; Garling and Boehm, 2001).

Composts also have been shown to reduce the severity of both root and foliar diseases of turf. Thurn (1993) in a field study and Craft and Nelson (1996) in a laboratory bioassay documented the suppression of Pythium root rot of creeping bentgrass seeded into composted biosolids-amended, sand-based rootzone mixes. There are numerous reports of compost topdressings reducing the severity of dollar spot caused by *Sclerotinia homoeocarpa* Bennett (Boulter et al., 1999; Garling, 2000; Nelson and Craft, 1992a), brown patch caused by *Rhizoctonia solani* Kühn (Nelson and Craft, 1991a), Typhula blight caused by *Typhula* sp. (Nelson and Craft, 1992b), and red thread caused by *Laetisaria fusiformis* McAlpine (Nelson and Craft, 1991b).

There is little information, however, in either the scientific or the popular literature on the use of composts for the establishment of lawns on disturbed urban soils and no previous reports on the suppression of a foliar turf disease, such as leaf rust, through the incorporation of compost to the soil. The objectives of this research were to evaluate the effects of the incorporation of composted biosolids (sewage sludge) into a nutrient-deficient, structureless subsoil typical of new housing developments on the establishment of Kentucky bluegrass and perennial ryegrass and on the development of leaf rust caused by *Puccinia* species.

Materials and Methods

Field plot. A 390-m² field plot was established at The Ohio State Univ. Ohio Turfgrass Foundation Research and Education Facility in Columbus in July 1998. To simulate typical construction disturbance, existing topsoil was removed to a depth of 20 cm and replaced with a nutrient-deficient subsoil. Three blocks, each consisting of nine 3 × 3-m plots separated by 0.6-m alleys, were delineated. A 1.3-cm layer of compost (130 m³·ha⁻¹) was incorporated to a depth of 10–15 cm on one randomly assigned half of each plot. A mixture (1:1; v/v) of two different composted biosolids was used. One source (ComTil™) was obtained from the city of Columbus, Ohio, where it was prepared from sewage sludge mixed with wood chips by the static aerated pile method (Finstein et al., 1983). The other compost (TechnaGro™), received from the city of Akron, Ohio, was prepared from sewage sludge mixed with tree trimmings in an in-vessel system (Kuter et al., 1985).

The compost mixture added NO₃-N, P, and K at 126, 546, and 182 kg·ha⁻¹, respectively, to each compost-amended plot. Tables 1 and 2 list the nutrient properties and heavy metal content of the subsoil and the composted biosolids used in this study. Total N was

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Table 1. Properties of the subsoil and the composted biosolids used in this study and the loading rate for each nutrient supplied by the incorporation of 130 m³·ha⁻¹ composted biosolids into the subsoil.

Property	Subsoil	Composted biosolids	Nutrient loading rate
pH	8	5.4	
	—mg·kg ⁻¹ —		—kg·ha ⁻¹ —
Total N ^z	800	27,300	1,014
NO ₃ ⁻ -N	4 ^y	3,400 ^s	126
P	2 ^w	14,700 ^v	546
K	51 ^u	4,900 ^v	182
Ca	3,490 ^u	33,700 ^v	1,252
Mg	199 ^v	6,700 ^v	249
Fe	Not tested	16,100 ^v	598
Mn	Not tested	1,000 ^v	37
B	Not tested	41 ^v	2
Zn ^u	82	1,400	4
Cu ^u	25	214	8
Mo ^u	8	17	<1

^zDetermined by the Dumas (combustion) method.

^yDetermined by the electrode method.

^sDetermined by the saturated paste method.

^wDetermined by the Bray and Kurtz P-1 method.

^vDetermined by the neutral ammonium acetate after extraction procedure.

^uDetermined by the inductively coupled plasma (ICP) method after acid digestion.

Table 2. Concentrations of heavy metals in the composted biosolids and the subsoil used in this research relative to average background concentrations in Ohio soils and maximum EPA allowable levels.

Element ^z	Subsoil	Composted biosolids	Avg background in Ohio soils	Maximum EPA allowable level ^y
			—mg·kg ⁻¹ —	
Se	<1	1	<1	100
Zn	82	1400	93	7500
Cu	25	214	24	4300
Cd	<1	2	<1	85
Ni	26	152	27	420
As	19	25	30	75
Hg	<1	<3	<1	57
Mo	8	17	153	75
Pb	12	69	24	840
Cr	15	167	28	---

^zDetermined by microwave-assisted acid digestion.

^yU.S. Environmental Protection Agency, 1997.

determined by the Dumas (combustion) method (Cunniff, 1995). Soil and compost NO₃-N was determined by the electrode and saturated paste methods, respectively (Gelderman and Beegle, 1998). Soil available P was determined by the Bray and Kurtz P-1 method (Frank et al., 1998). Soil K, Ca, and Mg were determined by the neutral ammonium acetate after extraction procedure (Warncke and Brown, 1998). All other soil and compost nutrients were determined by the inductively coupled plasma (ICP) method after acid digestion (Warncke, 1998). The concentration of heavy metals in both the soil and compost were determined by microwave-assisted acid digestion (US EPA, 1995). The heavy metal concentrations added to each amended plot (Table 2) were well below those allowed by the US Environmental Protection Agency Rule 503 (US EPA, 1997).

Plots were seeded 11 d after compost incorporation with either: 1) Kentucky bluegrass ('Cheri', 'Baron', and 'Washington', 85% germination) at a rate of 98 kg·ha⁻¹; 2) perennial ryegrass ('Accent', 88% germination) at a rate of 195 kg·ha⁻¹; or 3) a mixture of Kentucky bluegrass and perennial ryegrass

(85:15; w/w) at a rate of 146 kg·ha⁻¹. The turfgrass treatments were assigned randomly with three replicates per block. All plots received a single starter fertilizer application (49, 37, and 24 kg·ha⁻¹ N, P, and K, respectively) immediately after seeding, and were also fertilized with NPK at a rate of 49 kg·ha⁻¹ in May 1999 and again in June 1999. The turf was maintained at a mowing height of 6.5 cm with a rotary mower (clippings removed) and irrigated as needed.

Assessment of turfgrass establishment, growth, and rust severity. Establishment was estimated as the percentage turfgrass cover and was assessed visually (on a 0 to 10 scale, where 0 = no turf cover and 10 = 100% turf cover) in each plot about every 2 weeks between Aug. and Nov. 1998, and between May and Aug. 1999. Turfgrass cover was not assessed from Dec. 1998 to Apr. 1999 due to winter dormancy. Assessments were performed by one rater who evaluated the center portion of each plot from two directions and determined percentage cover based on the amount of exposed soil vs. turf. Turfgrass growth was measured from clippings collected in a 0.85-m² area from the center of each plot

with a rotary mower equipped with a side adapter designed to draw the clippings into an attached paper bag. Clippings were dried for 2 d at 50 °C, and yield data are presented on a dry weight basis. Clipping yields were not assessed during winter dormancy and were discontinued in early July 1999 due to heat-induced stress. The severity of rust caused by naturally occurring *Puccinia* inoculum was assessed visually by one rater as the percentage of symptomatic turf in each plot at 6 and 9 weeks after seeding. Classification of the causal agent to the genus *Puccinia* was determined by microscopic examination of uredospores and by host specificity (Smiley et al., 1992). Disease severity was not rated at other times due to insufficient disease severity.

Experimental design and statistical analysis. A split-plot design with three replicates per treatment per block (three blocks) was used. Grass species served as the main plot factor and compost incorporation served as the subplot factor. Although not directly relevant to this study, the three treatment replicates per block were included in this study design to allow for the future addition of three inorganic fertilizer application treatments following turfgrass establishment as part of a long-term study. Analyses of variance were conducted with Minitab statistical software (Minitab Inc., State College, Pa.). The experiment was performed twice, designated Expts. 1 and 2, respectively, in adjacent fields using the same seed lots and compost batches.

Results and Discussion

The incorporation of composted biosolids into the nutrient-deficient subsoil used in this study significantly ($P < 0.05$) enhanced turfgrass establishment and growth. These effects were first observed and most pronounced on plots seeded with perennial ryegrass due to its shorter germination time and faster growth rate. By the 5th week after seeding in Expt. 1, all treatments showed significantly ($P < 0.05$) greater turfgrass establishment in the compost-amended compared to the nonamended plots (Table 3). Turfgrass growth as measured by clipping dry weight also was significantly ($P < 0.05$) greater for the compost-amended plots (Table 4). Similar trends in turfgrass establishment (Table 5) and growth (Table 4) were observed in Expt. 2. These compost-induced effects were apparent for the duration of the study.

The enhanced turfgrass establishment and growth observed on the compost-amended plots are most likely a result of the plant-available nitrogen and phosphorus introduced into the seedbed with the compost (Table 1). This conclusion is supported by previous reports by Sikora et al. (1980), who attributed a similar increase in the growth of greenhouse-grown fescue (*Festuca arundinacea* Schreb.) to the N supplied to the soil by composted biosolids amendment. Chen (1997) found a positive linear relationship ($r^2 = 0.992$) between the amount of N supplied by a composted biosolids amendment and the yield of greenhouse-grown perennial ryegrass. Most re-

Table 3. Establishment of turfgrass on compost-amended and nonamended subsoil in Expt. 1.

Treatment	Turfgrass cover (%) ²														
	Weeks after seeding														
	2	4	5	7	8	38	39	41	43	45	46	48	50	52	54
<i>Kentucky bluegrass</i>															
Compost ³	3	18	33*	57*	69*	76***	81***	81*	85*	82	90***	92	97***	96**	97*
No compost	3	14	18	26	42	45	57	69	72	77	77	86	84	86	89
SE	0.7	2.9	6.2	7.4	9.6	4.8	2.2	3.6	3.8	5.2	1.5	2.9	2.1	1.8	2.2
<i>K. bluegrass/P. ryegrass mix</i>															
Compost	10*	20*	41*	72**	75**	73**	87*	86*	82	84	87**	89	92***	92**	96*
No compost	6	13	27	43	48	54	68	72	74	77	77	80	80	83	87
SE	1.5	2.5	4.9	5.8	5.1	4.6	5.5	4.5	3.5	3.2	2.2	5.3	1.8	2.4	2.7
<i>Perennial ryegrass</i>															
Compost	40	75***	83***	92***	93***	77*	81*	83	84*	83*	86	88*	89*	89*	91*
No compost	23	36	50	60	69	59	72	72	73	77	82	83	78	81	86
SE	7.3	6.7	6.0	4.9	2.1	5.4	2.6	4.9	4.0	1.9	1.9	1.8	3.1	2.7	1.9

²Establishment was measured visually.³Composted biosolids (130 m³·ha⁻¹) incorporated to a depth of 10–15 cm. The compost amendment of NO₃-N, P, and K supplied at 126, 546, and 182 kg·ha⁻¹, respectively, to each compost-amended subplot.

*, **, ***Significant at ≤ 0.05, 0.01, and 0.001, respectively, by ANOVA.

Table 4. Growth of turfgrass seeded on compost-amended and nonamended subsoil.

Treatment	Dry wt of clippings (g·m ⁻²)									
	Weeks after seeding ²									
	Expt. 1					Expt. 2				
	6	14	39	42	45	6	14	39	42	45
<i>Kentucky bluegrass</i>										
Compost ³	1.4	4.4	15.3**	14.8**	4.4*	0.6	6.4**	31.6***	25.0**	7.6*
No compost	1.0	0.7	3.1	4.3	1.7	0.6	0.3	4.4	6.0	2.1
SE	0.3	2.1	2.3	2.1	1.0	0.1	1.4	2.9	3.6	1.9
<i>K. bluegrass/P. ryegrass mix</i>										
Compost	2.1	10.1*	17.6*	16.1**	3.3**	1.6*	6.0*	18.4*	17.1	3.4
No compost	1.1	0.7	6.7	8.4	2.6	0.3	1.4	12.4	13.3	3.0
SE	0.8	2.8	4.4	1.5	0.1	0.5	1.2	2.5	2.8	0.3
<i>Perennial ryegrass</i>										
Compost	16.9*	8.8**	9.2	11.5	2.0	11.4*	8.2*	15.8**	17.3***	3.8*
No compost	2.1	0.7	6.3	8.8	1.9	2.3	0.9	8.9	8.6	1.8
SE	4.1	1.9	2.4	3.1	0.5	3.6	1.6	1.7	1.5	0.7

²Growth was measured by collecting clippings from each plot with a rotary mower followed by drying at 50 °C for 2 d.³Composted biosolids (130 m³·ha⁻¹) incorporated to a depth of 10–15 cm. The compost amendment of NO₃-N, P, and K supplied at 126, 546, and 182 kg·ha⁻¹, respectively, to each compost-amended subplot.

*, **, ***Significant at ≤ 0.05, 0.01, and 0.001, respectively, by ANOVA.

Table 5. Establishment of turfgrass on compost-amended and nonamended subsoil in Expt. 2.

Treatment	Turfgrass cover (%) ²														
	Weeks after seeding														
	2	4	5	7	8	38	39	41	43	45	46	48	50	52	54
<i>Kentucky bluegrass</i>															
Compost ³	3	14	22	44	65*	74**	83*	84	87*	89*	91*	94	96	99	99*
No compost	3	10	15	29	43	49	68	67	72	77	82	87	92	92	96
SE	1.3	4.2	5.3	6.3	7.4	5.1	5.7	7.0	6.0	4.4	3.7	3.3	3.3	3.0	1.4
<i>K. bluegrass/P. ryegrass mix</i>															
Compost	9	23	33	53	72*	80*	81	83*	84	87	88*	92*	96*	96	97
No compost	7	21	27	38	46	62	76	73	76	77	80	83	88	89	95
SE	1.9	3.7	5.7	7.2	7.8	6.3	3.6	3.5	3.4	4.1	3.1	3.6	3.1	2.8	1.5
<i>Perennial ryegrass</i>															
Compost	29	59*	69**	80*	91***	89**	84***	88***	86***	84**	87	92*	93	96*	97**
No compost	25	43	49	64	72	71	75	79	78	76	79	86	88	87	91
SE	8.1	4.9	5.0	5.5	3.2	4.3	1.7	1.2	1.2	1.7	3.0	1.8	3.1	2.5	1.2

²Establishment was measured visually.³Composted biosolids (130 m³·ha⁻¹) incorporated to a depth of 10–15 cm. The compost amendment of NO₃-N, P, and K supplied at 126, 546, and 182 kg·ha⁻¹, respectively, to each compost-amended subplot.

*, **, ***Significant at ≤ 0.05, 0.01, and 0.001, respectively, by ANOVA.

cently, Markham (1998) attributed enhanced establishment of creeping bentgrass on a composted biosolids-amended putting green rootzone mix to the N and P introduced by the incorporation of the composted biosolids to the rootzone mix.

The year-long enhancement of turf establishment and growth observed in this study is also consistent with previous reports in other cropping systems of prolonged effects of nutrients introduced into soil through the incorporation of composted biosolids. For example, O'Keefe et al. (1986) reported an extended availability of N to maize (*Zeamays* L.) planted in soil with incorporated composted biosolids, with a rapid rate of N mineralization for the first 28 weeks and a slow but sustained rate for the next 45 weeks. Darmody et al. (1983) reported high residual levels of Ca, P, and K 3 years after incorporation of composted biosolids into soil. They also reported a decrease in bulk density and an increase in the moisture-holding capacity 4 years after composted biosolids were incorporated into a silt loam. It is highly likely that similar changes, although not measured, took place in the heavy clay subsoil used in this study.

The severity of leaf rust was significantly ($P < 0.05$) lower on perennial ryegrass seeded on the compost-amended plots at 6 weeks after seeding in Expt. 1 and for up to 9 weeks after seeding in Expt. 2 (Table 6). Although it has been reported that applications of compost topdressing can suppress foliar turf diseases and that the incorporation of compost into soil can suppress soil-borne diseases, this is the first report of a foliar turf disease being suppressed by the incorporation of compost into soil. Since it is well-documented that the development of rust in turfgrass is greatly reduced by increased N fertility (Smiley et al., 1992), the lower rust severity observed in the compost-amended ryegrass plots was most likely due to an increase in plant-available N supplied by the compost (Table 1). Garling (2000) attributed suppression of dollar spot on creeping bentgrass to the plant-available N provided by composted biosolids and yardwastes topdressings. Although increased growth rates and removal of symptomatic turf via mowing are usually cited as the mechanisms of how increased N fertility results in decreased disease, the exact mechanism(s) have yet to be documented experimentally. Given the spatial separation between the location of the compost and the site of pathogen activity, however, it is possible that the suppression of rust observed in this study was due to the induction of systemic resistance by microorganisms present in the compost. Zhang et al. (1996) demonstrated compost-induced systemic acquired resistance in cucumber to *Pythium* root rot and anthracnose. Most recently, Enebak and Carey (2000) showed that such a mechanism was responsible for resistance to fusiform rust (*Cronartium quercuum* f. sp. *fusiforme* Burds. et Snow) of loblolly pine (*Pinus taeda* L.) seedlings treated with plant growth promoting rhizobacteria (PGPR).

These results clearly demonstrate that composted biosolids can be used to enhance

the establishment and growth of turfgrass on disturbed urban soils. This is of particular benefit for the installation of new lawns on nutrient-deficient, structureless urban soils where erosion is likely when turf is slow to establish. These results also present the first evidence of a foliar turf disease being suppressed by the incorporation of composted biosolids into the soil profile. Future research focusing on the mechanisms of compost-induced improvements of turf will help in the development of practical guidelines for the use of composted urban wastes to improve the quality of urban soils and the establishment, growth, and overall vigor of turf.

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Table 6. Severity of rust (*Puccinia* sp.) on turfgrass seeded on compost-amended and nonamended subsoil.

Treatment	Rust severity (%) ^a			
	Weeks after seeding			
	Expt. 1		Expt. 2	
	6	9	6	9
<i>Kentucky bluegrass</i>				
Compost ^b	7	8	6	6
No compost	10	5	8	8
SE	2.2	2.5	1.2	2.3
<i>K. bluegrass/P. ryegrass mix</i>				
Compost	9	14	10	19
No compost	12	15	12	23
SE	2.1	4.0	2.1	5.5
<i>Perennial ryegrass</i>				
Compost	27**	38	37**	49*
No compost	52	46	60	71
SE	6.1	6.0	5.1	8.1

^aRust severity was assessed visually prior to mowing.

^bComposted biosolids (130 m³·ha⁻¹) incorporated to a depth of 10–15 cm. The compost amendment of NO₃-N, P, and K supplied at 126, 546, and 182 kg·ha⁻¹, respectively, to each compost-amended subplot.

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