

TURFGRASS MANAGEMENT

Temporal Effects of Compost and Fertilizer Applications on Nitrogen Fertility of Golf Course Turfgrass

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ABSTRACT

Little information is available regarding the effects of compost topdressings on the fertility of low-cut fairway turfgrass. The objectives of this research were to assess: (i) the effects of compost and inorganic fertilizer applications on turfgrass color and growth, (ii) the duration and magnitude of compost topdressings on foliar N concentrations, and (iii) the interaction of compost and fertilizer applications on foliar N concentrations. Nitrogen was applied as inorganic fertilizer at rates of 96, 192, and 384 kg N ha⁻¹ in 1997 and at 48, 96, and 192 kg N ha⁻¹ in 1998 and 1999. Compost topdressings were applied every May and September from 1997 to 1999. Compost treatments consisted of: (i) 100% composted biosolids, (ii) a blend of composted biosolids and yard waste, and (iii) a nontopdressed control. Compost topdressings significantly increased turfgrass color, growth, and foliar N concentrations. Color enhancement lasted for up to 8 wk for plots receiving composted biosolids and for up to 5 wk for plots receiving the blend of composts. Composted biosolids increased foliar N concentrations for approximately 50 d following the May topdressings and for 26 d following the September topdressings. Foliar N concentrations following the May topdressings were increased by approximately 50% by the composted biosolids and by approximately 30% by the compost blend compared with the nontopdressed control. Differences in the duration of color enhancement brought about by the composts most likely can be explained by differences in N content of the composts used.

COMPOSTED MATERIALS AND HUMIC SUBSTANCES have long been used by the turfgrass industry as soil conditioners and organic fertilizers (Piper and Oakley, 1917, 1921; Connellan, 1921). Until the 1930s, composted organic amendments served as one of the principal sources of fertilizer used on golf courses (Piper and Oakley, 1921; Welton, 1930). However, the utilization of composts declined dramatically with the advent of synthetic, urea [(NH₂)₂CO]-based fertilizers and organic fertilizers such as Milorganite which offered more consistent and predictive nutrient release characteristics (Westover, 1927). The recent resurgence in the utilization of composted materials has been fueled by an increase in the diversion of solid wastes from surface waters and landfills and an intense desire by the public to develop more environmentally sound waste utilization methods (Schumann et al., 1993; He et al., 1992; Sims, 1990; Barkdoll and Norstedt, 1991). Composting frequently serves such a purpose and with this process

comes a renewed source of locally available organic fertilizer.

Much of the research on compost utilization by the turfgrass industry has focused on the suppression of diseases (Nelson and Craft, 1992; Liu et al., 1995; Craft and Nelson, 1996; Nelson, 1996; Landschoot and McNitt, 1997; Boulter et al., 1999; Garling et al., 1999; Garling, 2000), the potential for reducing fungicide use (Skorulski, 1990; Garling, 2000), the effects of composts on physical and chemical properties of soils (He et al., 1992; Giusquiani et al., 1995; Logan and Harrison, 1995; Sims, 1990; Pagliai and Antisari, 1993), and finally, the effects of composts on the fertility of high-cut turfgrasses (Markland et al., 1969; Landschoot and Waddington, 1987; Schumann et al., 1993; Norrie and Gosselin, 1996; Tester et al., 1982; Tester, 1989; Sikora et al., 1980). Little information is currently available on the effects of compost topdressings on the fertility of low cut, high-maintenance turfgrasses such as those typically grown on golf courses.

Schumann et al. (1993) observed enhanced color and growth of tall fescue (*Festuca arundinaceae* Schreb.) and a Kentucky bluegrass (*Poa pratensis* L.)-perennial ryegrass (*Lolium perenne* L.) mixture for up to 32 d following the application of composted biosolids. The authors suggested that the responses were most likely due to a release of plant available nutrients; however, the mineral composition of the turfgrass was not determined after the compost was applied. In both greenhouse and field studies, applications of composted biosolids at increasing rates resulted in a linear increase in tall fescue clipping yields and foliar N concentrations (Sikora et al., 1980; Tester et al., 1982; Tester, 1989). Clipping yields were increased further when inorganic fertilizer (N, P, or N + P) was applied in tandem with compost. Not surprisingly, the largest increases were associated with turf treated with both compost and supplemental N + P (Sikora et al., 1980).

Two separate studies evaluating one source of composted biosolids (Landschoot and Waddington, 1987) and two composted paper-mill sludges (Norrie and Gosselin, 1996) applied to established high-cut turfgrass found the products to be ineffective as fertilizers in the absence of supplemental fertilizer applications. An elevated C/N ratio and low nutrient levels in the composted paper-mill sludges contributed to foliar N con-

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Abbreviations: AUFNC, area under the foliar N curve; HR, high rate; LR, low rate; MR, moderate rate; OARDC, Ohio Agricultural Research and Development Center.

centrations below recommended levels unless the turf was treated with additional applications of fertilizer (Norrie and Gosselin, 1996). Although Landschoot and Waddington (1987) analyzed clippings for total N concentrations, the temporal dynamics of N uptake were not evaluated because they combined clippings from several sampling dates to form composite samples. Craft and Nelson (1996) suggested that enhanced turfgrass nutrition provided by a composted turkey litter-sand topdressing mix may have aided in the suppression of Pythium root rot (*Pythium graminicola* Subramanian) on a creeping bentgrass [*Agrostis stolonifera* var. *palustris* (Huds.) Farw.] putting green. Although Craft and Nelson (1996) determined the N characteristics (total N and H₂O-soluble N) of the compost used in their study, foliar N concentrations following compost applications were not measured, making it impossible to quantify the effects of the topdressing on the nutritional status of the turf beyond qualitative visual observations.

The objectives of this research were to assess: (i) the effects of topdressings prepared from composted biosolids or yard waste and inorganic fertilizer applications on the color and growth of an established creeping bentgrass ('Penncross')-annual bluegrass (*Poa annua* L.) sward; (ii) the duration and magnitude of any effects on foliar N concentrations resulting from compost topdressing applications; and (iii) the interactive nature of compost topdressings and N applied as inorganic fertilizer on the foliar N concentrations of low cut, high-maintenance turfgrass.

MATERIALS AND METHODS

Experimental Design

A replicated field trial was established in 1997 on an existing sward of creeping bentgrass and annual bluegrass (approx. 70:30%) at The Ohio State University Ohio Turfgrass Foundation Research and Education Facility, Columbus. The experimental design was a 3 × 2 × 3 complete factorial with inorganic fertilizer as the main plot factor, core cultivation as the subplot factor, and compost topdressings as the sub-subplot factor. Individual plots measured 2.13 by 2.13 m. A split-split block design was used ($n = 3$).

Treatments

Inorganic fertilizer was applied at either a low (LR), moderate (MR), or high (HR) rate with an 18-4-18 (N-P₂O₅-K₂O) complete fertilizer (1.56% NH₄-N; 5.22% H₂O-soluble N; 3.84% urea N; and 7.38% slow available H₂O-soluble N from methylene ureas). Total N applied to the plots during the 1997 growing season was 96, 192, and 384 kg N ha⁻¹, respectively, for the LR, MR, and HR. During 1997, damage caused by Pythium foliar blight [*Pythium aphanidermatum* (Edson) Fitzp.] and brown patch [*Rhizoctonia solani* Kühn] occurred in plots treated with 384 kg N ha⁻¹ and, to a lesser degree, in plots treated with 192 kg N ha⁻¹. To minimize the development of diseases that are favored by N-replete turf in subsequent years of the study, the N fertility rates in 1998 and 1999 were reduced by 50% to 48, 96, and 192 kg N ha⁻¹ for the LR, MR, and HR treatments, respectively. Inorganic fertilizer applications were initiated in May of each year of the study, and were applied in 1997 at 24 kg N ha⁻¹ at 40, 20, and 10 day intervals for the LR, MR, and HR treatments, respectively.

The intervals between fertilizer applications were doubled in 1998 to 80, 40, and 20 d for the LR, MR, and HR treatments, respectively, to account for the reduction in total fertilizer applied during the growing season. In 1999, inorganic fertilizer was applied at 48 kg N ha⁻¹ on 30 April for the MR treatment and on 30 April and 28 June for the HR treatment. The remaining fertilizer applications in 1999 were at a rate of 24 kg N ha⁻¹. The fertilizer rate in 1999 was increased to 48 kg N ha⁻¹ at specific times to establish greater differences in percent foliar N concentrations compared with those observed in 1998. One-half of each main plot was core-cultivated (10 by 0.95 cm hollow tines at a rate of 65-80 cores m⁻²) before topdressing.

The compost topdressing treatments used in this study were: (i) 100% composted biosolids, (ii) a blend of composted biosolids and composted yard waste [1:1 ratio (vol./vol.)], and (iii) a nontopdressed control. The source of composted biosolids in 1997 was Technagro [Akron, OH; municipal sewage sludge prepared by the in-vessel method (Kuter et al., 1985)]. In 1998 and 1999, the composted biosolids were ComTil [Columbus, OH; municipal sewage sludge prepared by the aerated static pile method (Finstein et al., 1983)]. Two locally available and equivalent sources of yard waste compost were used. Both sources were prepared via the passively aerated static pile method (Grebus et al., 1994). Both compost topdressings were applied at a rate of 31 852 L ha⁻¹ (14.5 L plot⁻¹) and brushed to achieve a uniform depth of approximately 0.31 cm. All topdressed plots were irrigated immediately following compost applications to reduce NH₃ volatilization and the potential for phytotoxicity. All plots were verticut and dragged to blend the soil cores with the topdressing materials. Excessive thatch and bulking agent were removed by mowing (1.27 cm). The plots were mowed three times per week (clippings removed) and irrigated daily.

The chemical characteristics of the compost topdressings used during 1997 and 1998 are presented in Table 1. All analyses were performed at the Ohio Agricultural Research and Development Center (OARDC) analytical laboratory (Wooster, OH). The percent total N was measured using a Heraeus Macro N Analyzer in accordance with the Dumas Method (Ebeling, 1968). Nitrate-N was determined by the saturated paste method (Gelderman and Beegle, 1998). All other compost nutrients were determined by inductive-coupled plasma analysis after acid digestion (Warneke, 1998). Heavy metal concentrations were determined by microwave-assisted acid digestion (USEPA, 1995). The percent total N and the concentration of NO₃-N were higher in the composted biosolids compared with the blend of composted biosolids and yard waste in 1997 and 1998 (Table 1). The concentrations of heavy metals added to each plot were below those allowed by USEPA Rule 503 (USEPA, 1997).

Measurements

Turfgrass color was assessed periodically throughout each growing season using a rating scale of 1 to 9 in which 1 represented straw-colored turfgrass and 9 represented the darkest green-colored turfgrass. Turfgrass growth was assessed in 1997 and 1998 every 14 to 20 d by collecting clippings and making dry weight measurements. Clippings were collected by mowing a 1-m² strip through the center of each plot with a walk-behind reel mower. Clippings were dried at 60°C until constant weights were obtained (48 h), after which dry weight measurements were recorded. Clippings were collected in 1999; however, measurements of clipping yields were not taken. Total percent N in clippings was determined from 1997 through 1999 at the OARDC analytical laboratory for analysis as described previously for the compost topdressings.

Table 1. Chemical characteristics of compost topdressings used in 1997-1998.

Characteristic	1997 Spring		1998 Spring	
	Biosolid†	Blend‡	Biosolid†	Blend‡
NO ₃ -N§, µg g ⁻¹	980	650	650	300
Total N¶, %	2.43	1.72	3.49	2.06
P#, %	1.01	0.76	2.00	0.80
K, %	0.21	0.29	0.90	0.70
Ca, %	2.42	4.71	2.60	2.40
Mg, %	0.32	0.71	0.60	0.70
Fe, %	1.43	1.55	0.80	1.90
Na, %	0.07	0.18	0.14	0.09
Mn#, µg g ⁻¹	0.32	0.76	0.6	0.07
B, µg g ⁻¹	20.8	44.6	32.1	39.1
Zn, µg g ⁻¹	801	579	1708	764
Cu, µg g ⁻¹	174	118	193	105
Cr††, µg g ⁻¹	36.1	52.3	45.3	40.8
Ni, µg g ⁻¹	27.1	23.6	28.6	27.3
Pb, µg g ⁻¹	68.4	75.2	36.0	82.5
Cd, µg g ⁻¹	<0.8	<0.8	1.6	<0.5
Mo, µg g ⁻¹	2.5	1.5	15.2	5.3
Ar, µg g ⁻¹	30.6	24.1	7.0	13.8
Se, µg g ⁻¹	0.91	0.69	1.42	0.59
Hg, µg g ⁻¹	<4.0	<4.0	<2.5	<2.5
Total C‡‡, %	32.77	30.04	37.22	23.56
C/N ratio	13:1	17:1	11:1	11:1

† Technagro was the composted biosolid used in 1997 (Akron, OH). ComTil was the composted biosolids used in 1998 (Columbus, OH).

‡ The composted blend used in 1997 was Technagro and composted yard waste (1:1; vol/vol.). The composted blend used in 1998 was ComTil and composted yard waste.

§ Determined by the saturated paste method (Gelderman and Beegle, 1998).

¶ Determined using a Heraeus Macro N analyzer according to the Dumas Method (Ebeling, 1968).

Determined by microwave digestion followed by inductively coupled plasma analysis (Warncke, 1998).

†† Determined by microwave-assisted acid digestion (USEPA, 1995).

‡‡ Determined by USEPA Method 9060A for total C determination of solid wastes.

Statistical Analysis

Turfgrass color ratings, clipping yields, and percent foliar N were analyzed by ANOVA or GLM procedures using Minitab statistical software (Minitab, State College, PA). Areas under the foliar N curves (AUFNCs) were calculated and analyzed by ANOVA, allowing for the comparison of the cumulative season-long effects of both the inorganic fertilizer and the compost topdressing applications (Campbell and Madden, 1990). All differences reported are significant at $P \leq 0.05$ unless otherwise indicated. Where appropriate, means were separated with Fisher's LSD (Steel et al., 1997).

RESULTS

Turf Color

Inorganic fertilizer applications significantly affected turfgrass color four times in 1997, twice in 1998, and once in 1999 (Table 2). For all cases in which applications of inorganic N fertilizer significantly affected turfgrass color, the most desirable turf color was always associated with the higher inorganic N fertility treatments. For example, on the 20 June 1997 rating date, the mean turf color ratings for the LR, MR, and HR treatments of inorganic N fertilizer were 6.7, 7.9, and 8.0, respectively. In general, core cultivation did not significantly affect turfgrass color.

The application of compost topdressings also affected turfgrass color after both the May and September topdressing events in all 3 yr of the study (Table 2). Turfgrass color generally was affected to a greater extent after the May topdressing applications compared with those in September. For example, compost topdressings enhanced turf color for 38 and 14 d after the May and

Table 2. ANOVA results from visual assessments of turfgrass color† (1997-1999).

Treatment	1997‡								
	23 May	6 June	20 June	11 July	5 Aug.	22 Aug.	2 Sept.	18 Sept.	
	<i>P</i> values								
Nitrogen (N)	0.06	0.00	0.04	0.44	0.43	0.03	0.06	0.01	
Core cultivation (C)	0.07	0.35	0.29	0.51	0.42	0.44	0.52	0.52	
Topdressing (T)	0.00	0.00	0.01	0.86	0.19	0.33	0.47	0.02	
N × T	0.00	0.03	0.04	0.96	0.65	0.35	0.53	0.06	
N × C	0.61	0.78	0.45	0.63	0.89	0.33	0.59	0.23	
C × T	0.02	0.14	0.68	0.41	0.37	0.08	0.47	0.15	
N × C × T	0.10	0.65	0.46	0.46	0.65	0.21	0.29	0.60	
	1998‡								
N	8 May	23 May	28 May	4 June	11 June	19 June	1 July	8 Sept.	8 Oct.
C	1.00	0.13	0.17	0.47	0.30	0.05	0.26	0.02	0.07
T	1.00	0.51	0.44	0.71	0.62	0.52	0.29	0.43	0.59
N × T	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00
N × C	1.00	0.24	0.35	0.38	0.45	0.01	0.33	0.69	0.24
N × T	1.00	0.63	0.83	0.82	0.66	0.70	0.62	0.18	0.83
C × T	1.00	0.80	0.51	0.67	0.83	0.60	1.00	0.80	0.78
N × C × T	1.00	0.91	0.46	0.46	0.67	0.10	0.15	0.36	0.60
	1999‡								
N	10 May	25 May	6 June	10 June	21 June	7 July			
C	0.08	0.43	0.08	0.11	0.05	0.25			
T	0.51	0.14	0.31	0.14	0.40	0.12			
N × T	0.65	0.00	0.00	0.00	0.00	0.03			
N × C	0.41	0.02	0.02	0.37	0.41	0.23			
C × T	0.21	1.00	0.74	0.80	0.45	0.34			
N × C × T	0.31	0.25	0.02	0.90	0.22	0.02			
N × C × T	0.63	0.91	0.69	0.37	0.80	0.06			

† Ratings of turfgrass color were assessed visually using a 1 to 9 scale in which 1 represented straw-colored turfgrass and 9 represented the darkest green color obtainable.

‡ Compost topdressings were applied on 13 May and 3 Sept. 1997, 14 May and 13 Sept. 1998, and 11 May 1999.

September 1997 topdressing events, respectively. Similar results were observed in 1998 and 1999 when turf color was affected for 52 and 58 d after May topdressings, respectively, and for 30 d following the September 1998 application. In general, the greatest effects both in magnitude and duration, were observed on turf treated with composted biosolids, followed by turf treated with the blend of composted biosolids and yard waste. For example, on the 28 May 1998 rating date, the mean turf color rating were 8.7, 7.2, and 6.0, respectively, for the composted biosolids, the blend of composted biosolids and yard waste, and the nontopdressed control. Significant inorganic fertilizer \times compost topdressing interactions were observed only on 25% of the rating dates over the 3 yr study, and all of these occurred within 50 d after the May topdressing applications.

Clipping Yields

Nitrogen applied as inorganic fertilizer significantly increased clipping yields in both 1997 and 1998 (Fig. 1). In 1997, clipping yields were significantly increased by incrementally increasing rates of inorganic fertilizer at

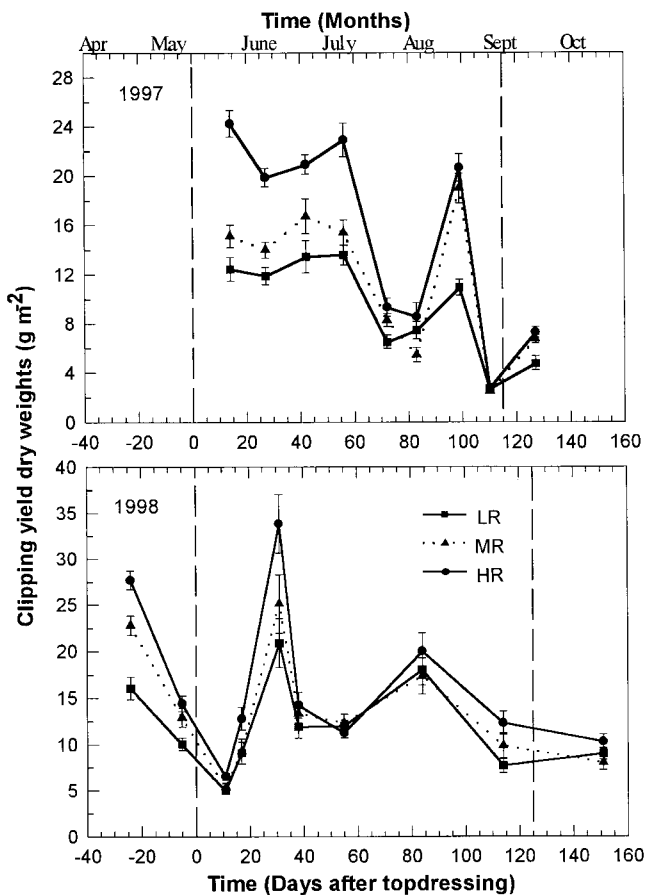


Fig. 1. Effects of inorganic fertilizer treatments on clipping yields. Error bars represent standard error ($n = 18$). Dashed vertical lines represent dates of compost topdressing applications. Means are averaged across compost topdressing treatments. N fertilizer applied in 1997 for the low (LR), moderate (MR), and high (HR) rate treatments were 96, 192, and 394 kg N ha⁻¹, respectively. N fertilizer applied in 1998 for the LR, MR, and HR treatments were 48, 96, and 192 kg N ha⁻¹, respectively.

each sample collected between 27 May and 7 July and later in season on 21 August. In 1998, clipping yields were significantly increased by inorganic fertilizer on 17 April and on 6 and 22 May. On 28 May, 12 June, and 3 September, a trend was observed suggesting higher clipping yields with increasing amounts of N applied as inorganic fertilizer ($P \leq 0.10$). Core cultivation did not affect clipping yield dry weights in either season (data not shown).

Compost topdressings significantly increased clipping yields harvested 14 d after the May topdressing application in 1997 (Fig. 2) and for up to 38 d after the May topdressing application in 1998. Compost topdressings did not significantly affect clipping yields following the September topdressings in either 1997 or 1998.

Percent Foliar Nitrogen

The concentration of foliar N was significantly increased by each incremental increase in N applied as inorganic fertilizer at all sampling periods in 1997 (Fig. 3). In 1998, the moderate and high rates of inorganic fertilizer significantly increased foliar N concentrations on 8 May, 3 September, and 10 October compared with the low rate of inorganic fertilizer. In addition, the high rate of fertilizer resulted in increased foliar N concentrations during the 1998 growing season on 12 and 19 June and 4 August (Fig. 3). Applications of inorganic N fertil-

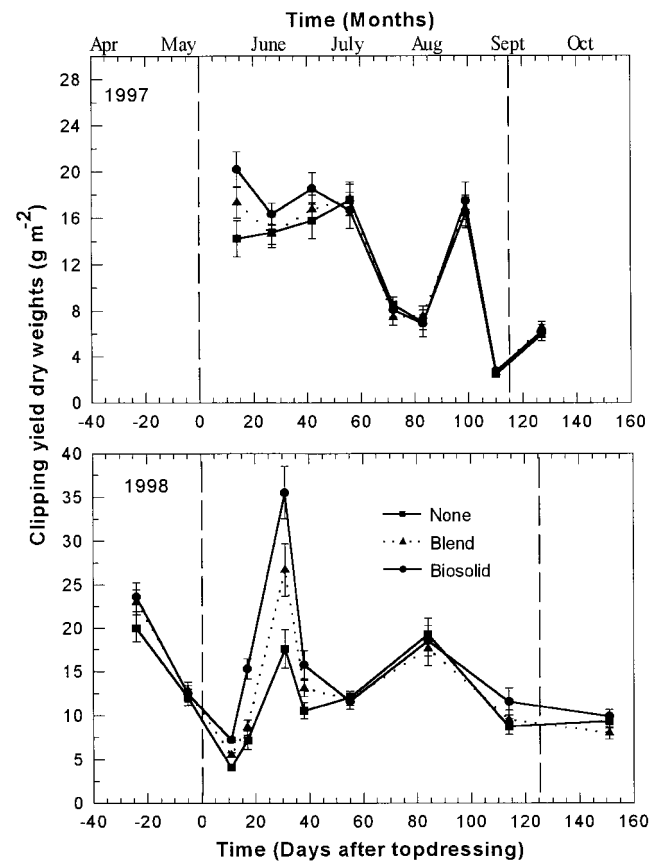


Fig. 2. Effects of compost topdressings on clipping yields. Error bars represent standard error ($n = 18$). Dashed vertical lines represent dates of compost topdressing applications. Means are averaged across treatments of inorganic fertilizer.

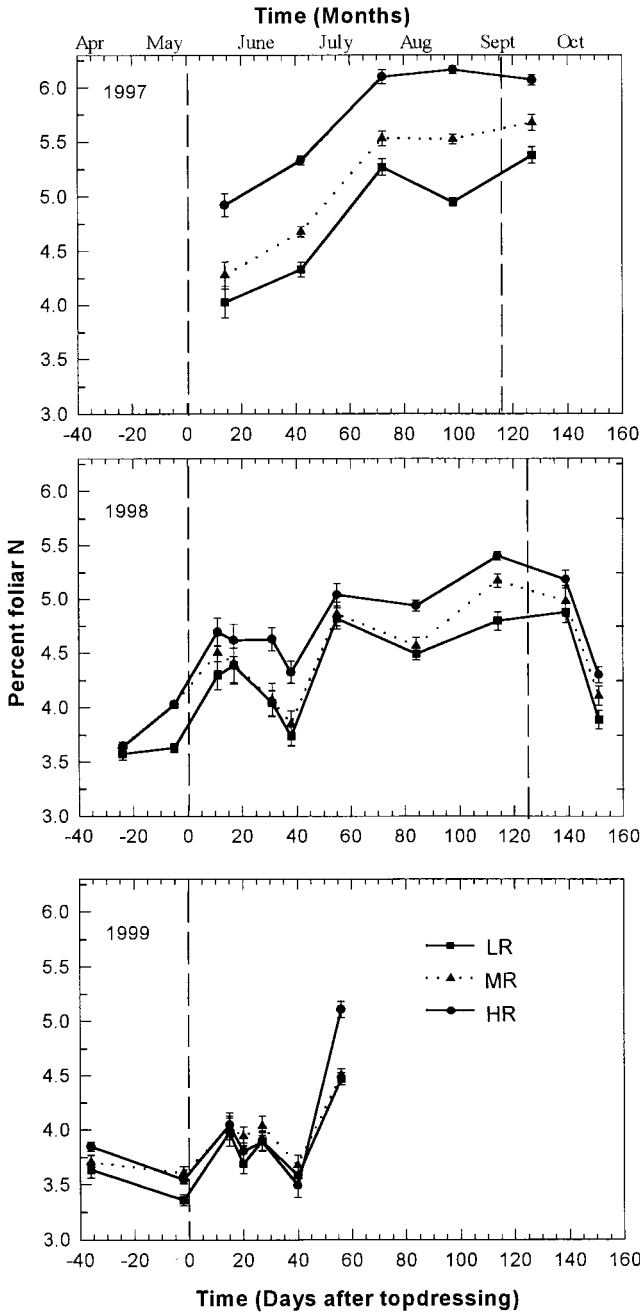


Fig. 3. Effects of inorganic fertilizer treatments on percent foliar N. Error bars represent standard error ($n = 18$). Dashed vertical lines represent dates of compost topdressing applications. Means are averaged across compost topdressing treatments. Nitrogen fertilizer applied in 1997 for the low (LR), moderate (MR), and high (HR) rate treatments were 96, 192, and 394 kg N ha⁻¹, respectively. N fertilizer applied in 1998 and 1999 for the LR, MR and HR treatments were 48, 96, and 192 kg N ha⁻¹, respectively. Significant inorganic fertilizer \times compost topdressing interactions were observed only on 25% of the rating dates over the 3-yr study, and all of these occurred within 50 d after the May topdressing applications.

izer did not significantly affect percent foliar N during the first half of the 1999 season. Core cultivation did not affect percent foliar N at any time during the 3 yr period.

The application of compost topdressings significantly increased percent foliar N in all 3 yr of the study (Fig.

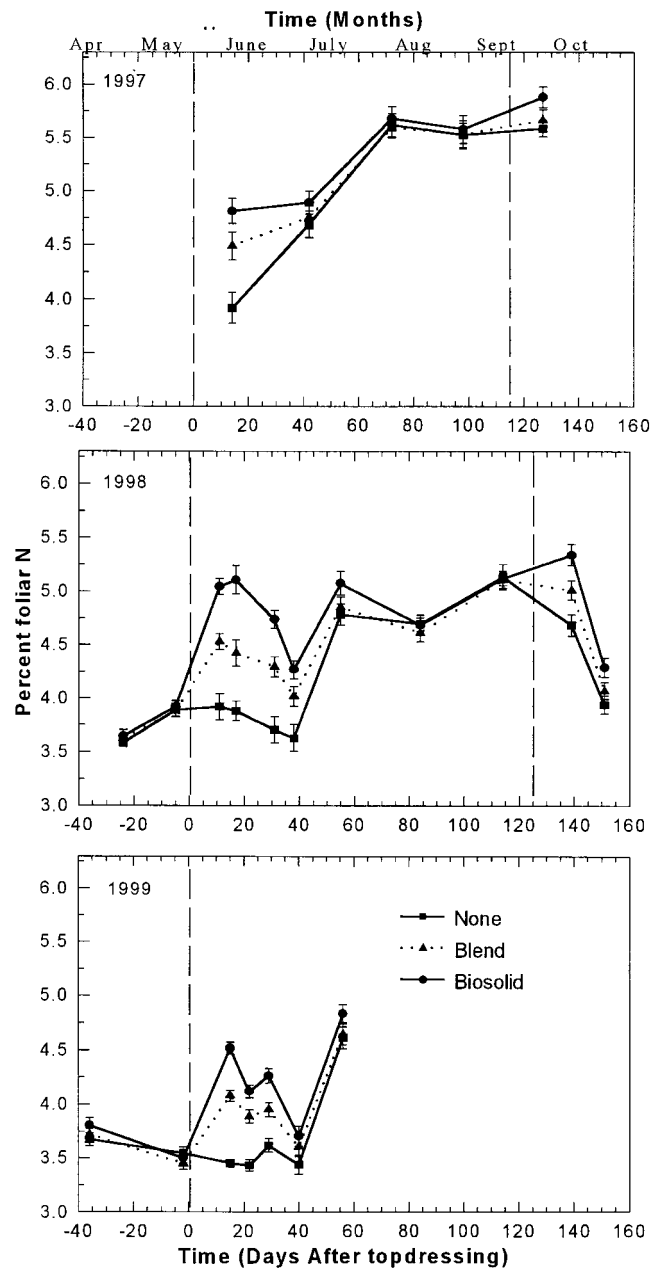


Fig. 4. Effects of compost topdressings on percent foliar N. Error bars represent standard error ($n = 18$). Dashed vertical lines represent dates of compost topdressing applications. Means are averaged across treatments of inorganic fertilizer. Significant inorganic fertilizer \times compost topdressing interactions were observed only on 25% of the rating dates over the 3-yr study, and all of these occurred within 50 d after the May topdressing applications.

4). In general, the compost topdressings had a greater effect on foliar N following the May applications compared with the September topdressing events. The application of compost topdressings in 1997 significantly increased foliar N concentrations for up to 42 and 13 d after the May and September topdressing events, respectively. Samples were not collected beyond 13 d following the September 1997 topdressing. Concentrations of foliar N were significantly increased in 1998 on plots treated with compost topdressings for 55 and 26 d after the May and September applications, respectively. Ap-

Table 3. The effects of inorganic fertilizer and compost topdressings on the area under the foliar N curve (AUFNC) from 1997 through 1999.

Treatment†	AUFNC‡		
	1997	1998	1999
	— % foliar N days —		
LR§	531a	725a	320a
LR + Blend¶	545ab	766ab	341b
LR + Biosolid#	554abc	803bcd	360cde
MR	573bcd	763ab	339b
MR + Blend	583bcd	784bc	351bcd
MR + Biosolid	597bd	833e	371e
HR	640e	813cd	344bc
HR + Blend	648e	835e	354bcd
HR + Biosolid	668e	858e	363de
LSD(0.05)	30	45	17

† LR, low rate; MR, moderate rate; HR, high rate.

‡ AUFNCs were calculated and analyzed by ANOVA for comparing N fertility and compost topdressing interactions within each growing season (Campbell and Madden, 1990).

§ Nitrogen fertilizer applied in 1997 for the LR, MR, and HR treatments were 96, 192, and 394 kg N ha⁻¹, respectively. Nitrogen fertilizer applied in 1998 and 1999 for the LR, MR, and HR treatments were 48, 96, and 192 kg N ha⁻¹, respectively.

¶ 1997 composted blend was Technagro and yard waste (1:1; vol/vol). 1998 and 1999 composted blend was ComTil and yard waste (1:1; vol/vol).

Technagro was the composted biosolid used in 1997 (Akron, OH). ComTil was the composted biosolid used in 1998 and 1999 (Columbus, OH).

plications of compost topdressings resulted in significantly higher concentrations of foliar N in 1999 for up to 58 d after the May topdressing application date with the exception of samples collected on 21 June (42 d post application).

The season-long cumulative effects of compost topdressing and inorganic fertilizer applications on the percent foliar N, as expressed by the AUFNCs, is presented in Table 3. In most cases, the increases observed in percent foliar N resulting from the application of the composted biosolids topdressings were approximately equal to or greater than those brought about by the incremental increases in applications of inorganic N fertilizer. For example, percent foliar N concentrations (expressed as AUFNC) in plots treated with 48 kg N ha⁻¹ and composted biosolid topdressings in 1998 and 1999 resulted in greater percent foliar N concentrations than plots receiving only the 96 kg N ha⁻¹ inorganic fertilizer application (Table 3). This trend, albeit not as pronounced, was also apparent in 1997 (Table 3).

DISCUSSION

Spring and fall topdressing applications of composted biosolids and a blend of composted biosolids and yard waste enhanced turfgrass color and increased growth and foliar N concentrations of a mixed sward of creeping bentgrass and annual bluegrass. Both the duration and magnitude of these growth characteristics were dictated by the source and chemical characteristics of the composts used in this work. Turf color following the May topdressing applications was enhanced for 6 to 8 wk by the composted biosolids and for 4 to 5 wk by the blend of composted biosolids and yard waste compared with the nontopdressed control. Differences in the duration of color enhancement brought about by the topdressing treatments most likely can be explained by differences

in N content of the composts used in this work. The composted biosolids contained higher concentrations of both total N and NO₃-N compared with the blend of composted biosolids and yard waste (Table 1). Not surprisingly, differences in clipping yields and foliar N concentrations in plots treated with the blend of composts were also less dramatic than on turf treated with 100% composted biosolids (Fig. 2 and 4, respectively).

The observation that turfgrass treated with composts containing a higher concentration of N yielded higher concentrations of foliar N in turf is further evidence to support the relationship described in the preceding paragraph (Fig. 4). Topdressing with composted biosolids caused an increase in foliar N that lasted approximately 8 wk while applications of the blend of composted biosolids and yard waste increased foliar N for only 6 wk. The magnitudes of the observed differences were also impacted by the N content in the topdressings (Fig. 4). In all 3 yr, the composted biosolids treatment increased the concentration of foliar N by approximately 50% above that measured in the nontopdressed control (Fig. 4). Blended product increased foliar N by only approximately 30% compared with the nontopdressed control (Fig. 4). This ability of compost topdressings to significantly enhance the color, growth, and concentration of foliar N in a mixed sward of creeping bentgrass and annual bluegrass is consistent with previous observations of compost topdressing applications on Kentucky bluegrass, perennial ryegrass, and tall fescue (Sikora et al., 1980; Tester, 1989; Schumann et al., 1993).

The positive cumulative effects of the applications of compost topdressing and inorganic N fertilizer, as expressed by AUFNCs, highlight some of the practical issues related to fertility management that end users must consider during the utilization of composts on high-maintenance turfgrasses. The AUFNCs (Table 3) clearly revealed that compost topdressings can substantially increase plant available N. For example, during the 1998 growing season, the low level of N applied as inorganic fertilizer combined with an application of composted biosolids resulted in a foliar N concentration, expressed as AUFNC, equivalent to the MR and HR of inorganic fertilizer alone. Similarly, the foliar N concentration, expressed as AUFNC, with the MR of N applied as inorganic fertilizer combined with an application of composted biosolids was equivalent to the HR of inorganic fertilizer alone and the HR superimposed on the blend of composts (Table 3). This fertility effect on turfgrass color resulting from the application of compost topdressings is significant and will need to be considered in the design of fertility programs that include both compost topdressing and applications of inorganic N fertilizer.

Although compost topdressings have been evaluated on creeping bentgrass for their ability to suppress diseases (Nelson and Craft, 1992; Liu et al., 1995; Craft and Nelson, 1996; Nelson, 1996; Landschoot and McNitt, 1997; Boulter et al., 1999; Garling et al., 1999; Garling, 2000), increase establishment rates in sand-based root zones (Markham, 1998), and now, improve turfgrass fertility, their widespread use by the golf course industry

has yet to occur. One reason for this lack of acceptance undoubtedly is the inherent variability in physical and chemical characteristics of most composts. Characteristics such as appearance, odor, moisture content, trace metal content, pathogen contamination potential, and fertility- and soil-conditioning values are a few of the indicators that have been used to determine the quality of a particular compost. Even so, definitive guidelines for these characteristics that are indicative of compost quality have yet to be established (Landschoot and McNitt, 1994; He et al., 1992; Dinelli, 1999). Secondly, inconsistencies in turfgrass responses within batches of the same compost source and among different sources of composts is another reason for the continued reliance on chemical fertilizers, pesticides, and cultural management strategies for management of turfgrass diseases (Landschoot and McNitt, 1997; Nelson, 1996; Jackson, 1999).

Despite these difficulties, the composts used in this work clearly enhanced turfgrass color and increased growth and foliar N concentrations of a mixed sward of creeping bentgrass and annual bluegrass maintained under golf course fairway conditions. Both the magnitude and duration of the turfgrass responses were directly related to the chemical characteristics (total N and $\text{NO}_3\text{-N}$) of the topdressing mixes. However, the possibility that plant nutrients other than N provided by the compost topdressings may also have contributed to the observed differences in color and growth cannot be ruled out. Likewise, the stimulation of indigenous plant growth promoting microorganisms and biocontrol agents or the addition of such microorganisms by the compost topdressings themselves (Hoitink and Boehm, 1999), also may have contributed to the observed differences in color, growth, or even foliar N. Further research is needed to separate the effects of N, macro- and micro-nutrients, and microbiologically mediated processes on turfgrasses induced by application of compost topdressings. This may be especially important for diseases such as dollar spot (*Sclerotinia homoeocarpa* Bennet), rust (*Puccinia* spp.), Pythium foliar blight and brown patch, which are affected by N fertility rate (Smiley et al., 1992). Nonetheless, the ability of these composts to provide nutritional benefits to golf course turf may prove to be an environmentally sound alternative use for ever-increasing sources of locally available urban solid wastes.

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