Evaluation of spent mushroom substrate as a topdressing to established turf

A. S. McNitt, D.M. Petrunak, and W.X. Uddin

Introduction:

In the Northeastern United States, a number of sewage sludge composts are being shipped interstate for use on turfgrass sites. Numerous athletic field managers are using the composted sewage sludge as a topdressing prior to aeration. In Pennsylvania, spent mushroom substrate is a potentially inexpensive alternative organic matter source. Landschoot, McNitt, and Hoyland (1993) reported improved soil physical properties when spent mushroom substrate was tilled into a clay loam subsoil.

Objectives:

The objectives of this study were to evaluate the effect of mushroom substrate topdressing on the resistance to wear damage, surface hardness, and soil compaction of a sodded Kentucky bluegrass (*Poa pratensis*, L.) turf over time.

Procedures:

A silt loam soil was prepared at the Joseph Valentine Turfgrass Research Center in State College, PA. Kentucky Bluegrass big roll sod seeded to 40% Limosine, 30% Adelphi and 30% Midnight was installed on 16 May, 2001.

On 24 July, 2001 the first set of treatments was applied. Treatments were again applied on 19 December 2001 and 7 May 2002. The experimental design was a two by two by two factorial with eight replications. Treatments for the factorial included:

Level 1

- Mushroom Substrate Application (6.3 mm surface application)
- No Substrate Application

Level 2

- Heavy hollow-tine aeration (2 cm diameter tines on 5 cm by 5 cm spacing)
- No aeration

Level 3

- Nitrogen Fertilization (49 kg ha^{-1})
- No Fertilization

The individual plots were split with levels of simulated traffic (wear) beginning 8 Aug. 2001. There were two levels of wear: no wear and wear approximating a football game per day (Cockerham and Brinkman, 1989). The traffic was applied with a Brinkman traffic simulator (Cockerham and Brinkman, 1989). Wear ended on 2 Nov. 2001. During year two of the study wear began on 1 Jun 2002 and ended on 20 Oct 2002.

Each experimental unit was evaluated by measuring soil bulk density, soil water content, soil organic

matter content, surface hardness, and percent living ground cover. Soil chemical properties were also monitored but due to space limitations the data is not presented here.

Soil bulk density data and soil water content are derived from measurements of soil total density and volumetric water content taken with a Troxler 3400-B (Troxler Electronic Laboratories Inc., Research Triangle Park, NC) series surface moisture/density gauge. The Troxler gauge uses neutron scattering simultaneously with gamma ray attenuation to measure the volumetric water content and bulk density of the soil (Gardner, 1986).

Surface hardness was measured using a Clegg Impact Tester (CIT) (Lafayette Instrument Company, Lafayette, IN) equipped with a 2.25 kg missile (Rogers and Waddington, 1990). The average of six hardness measurements taken in different locations on each subplot was used to represent the hardness value of the subplot.

Percent living ground cover was rated visually and serves as an estimate of turfgrass cover.

Results:

Due to space restraints, only the data from subplots receiving wear will be presented. Data from the subplots not receiving wear can be obtained from the authors. The treatments in this study had significant effects on the turfgrass and soil physical properties measured.

The aeration and mushroom substrate applications affected percent turfgrass ground cover (Table 1). During 2001, only the mushroom substrate combined with nitrogen treatments measured higher than the control on 29 Oct 2002. These data were measured after only one topdressing application. Plots receiving aeration tended to have less ground cover than the control. During 2002, plots receiving aeration alone had a percent ground cover lower than the control on only two rating dates and were higher than the control on one date. In 2003, plots receiving aeration had higher percent ground cover than the control on 3 Jun 2003 and on every rating date from 23 Jun to the end of the 2003 growing season. As the study continued into the third growing season, treatment differences are becoming more pronounced.

Table 1. Percent ground cover[1] in 2001 and 2002 for Kentucky bluegrass plots receiving wear treatments[2].

2001										
Treatment[3]	**23-Aug**	**30-Aug**	**6-Sep**	**13-Sep**	**20-Sep**	**28-Sep**	**5-Oct**	**15-Oct**	**19-Oct**	**29-Oct**
Control	99.4	98.3	97.9	96.3	94.6	91.6	83.6	85.4	80.8	74.5
M	99.4	98.1	98.9	97.5	95.4	93.5	84.8	87.0	82.4	76.6
A	95.8	93.6	95.6	92.1	89.4	83.0	74.4	76.3	70.3	61.3
N	99.3	97.6	97.3	95.1	92.8	85.9	75.0	80.1	73.6	63.6
MA	96.4	94.6	96.4	94.1	91.1	87.8	78.4	81.3	74.3	65.9
MN	98.6	98.0	98.3	97.6	95.4	94.9	85.0	87.6	82.8	81.4
AN	97.3	95.5	98.0	94.5	89.3	85.6	77.0	82.4	74.9	65.1
MAN	97.8	97.1	98.3	96.6	94.3	92.4	82.4	85.6	81.5	76.4
LSD (p=0.05)	1.0	1.8	1.1	1.7	2.4	3.5	4.5	3.0	4.0	5.7

2002															
Treatment[3]	**7-Jun**	**14-Jun**	**21-Jun**	**28-Jun**	**8-Jul**	**12-Jul**	**18-Jul**	**29-Jul**	**9-Aug**	**16-Aug**	**26-Aug**	**6-Sep**	**13-Sep**	**7-Oct**	**14-Oct**	**21-Oct**
Control	91.5	85.1	83.8	84.9	77.9	71.8	68.0	65.0	61.4	63.0	67.9	61.4	63.1	59.8	56.0	41.9
M	96.8	95.3	94.1	94.0	91.6	90.9	89.0	87.9	86.4	87.4	88.6	80.3	82.6	79.8	75.8	68.8
A	86.8	82.3	77.8	82.3	76.1	71.6	75.4	69.5	72.9	72.9	73.9	67.9	72.1	70.9	66.4	53.1
N	91.4	88.6	87.3	88.1	80.5	77.6	76.8	74.3	70.1	72.3	76.3	64.8	68.9	66.5	61.6	45.1
MA	95.4	90.3	88.0	90.3	86.5	85.6	88.3	86.5	86.3	86.1	85.0	77.6	81.4	78.1	73.9	60.6
MN	99.4	99.0	98.5	98.3	97.9	95.3	96.3	95.4	92.5	93.5	93.0	88.3	87.5	85.8	84.9	79.9
AN	93.4	88.9	83.4	88.4	79.4	77.8	81.5	77.0	78.6	77.6	80.9	69.6	75.5	73.1	67.1	47.0
MAN	95.9	94.6	93.7	94.1	93.3	91.0	93.8	91.8	90.5	87.6	90.4	83.3	86.4	83.6	79.0	70.5
LSD (p=0.05)	3.7	4.3	4.9	4.9	5.2	6.0	6.5	6.5	6.2	6.0	5.9	6.2	5.5	5.9	7.1	9.2

[1] Percent ground cover was determined by estimating the percent of the plot area covered by living turf.

[2] Plots receiving wear treatments were exposed to wear as four passes three times per week with the Brinkman Traffic Simulator beginning on 8 Aug and ending on 2 Nov 2001and beginning on 4 Jun and ending on 21 Oct 2002.

[3] Treatments include untreated control, M = spent mushroom substrate application at 6.33 mm depth, A = aerification with 20 mm hollow tines, N= nitrogen fertilization at 49 kg ha^{-1} N with Nutralene 40-0-0 fertilizer, MA = mushroom substrate application followed by aerification, MN = mushroom substrate application followed by fertilizer application, AN = aerification followed by fertilizer application, MAN = mushroom substrate application followed by aerification followed by fertilizer application. Treatment applications were made on 24-26 Jul, 19 Dec 2001, and 8-10 May, 2002.

From the first rating date of 2002 through 12 Jul 2002, the plots receiving spent mushroom substrate consistently measured higher in percent ground cover compared to the other treatments. Beginning on the 18 Jul 2002 rating date all treatments measured higher in percent ground cover than the control but the plots receiving mushroom substrate tended to have more ground cover than those treatments not receiving mushroom substrate. For instance, the mushroom substrate alone tended to have greater turf cover than the nitrogen treatment alone and the mushroom substrate combined with aeration tended to have greater turf cover than the nitrogen combined with aeration treatment. These trends were more pronounced in 2003. The mushroom substrate treatment

resulted in a higher percent ground cover than the nitrogen treatment on every rating date in 2003. The 2002 data was collected after three treatments had been applied and the 2003 data was collected after five treatment applications. Nitrogen differences may have accounted for some of the percent ground cover results, although color differences between treatments receiving the mushroom substrate alone and those receiving the nitrogen treatment alone are small in 2001 (Table 2). Near the end of the 2002 growing season, the mushroom substrate may have been supplying more nitrogen than the nitrogen treatment as indicated by the higher color ratings (Table 2); however, this trend was not consistent in 2003 where few significant color differences between the nitrogen and mushroom substrate treatments were found.

Table 2. Turf color ratings[1] in 2001 and 2002 for Kentucky bluegrass plots receiving wear[2] treatments.

2001													
Treatment[3]	**2-Aug**	**10-Aug**	**16-Aug**	**23-Aug**	**30-Aug**	**6-Sep**	**13-Sep**	**20-Sep**	**28-Sep**	**5-Oct**	**15-Oct**	**19-Oct**	**29-Oct**
Control	3.8	3.9	4.3	3.7	3.9	4.1	3.7	3.7	3.0	2.6	2.2	1.6	1.4
M	4.3	4.3	4.5	3.9	4.2	4.3	3.8	3.9	3.3	2.9	2.3	1.7	1.5
A	3.2	3.9	4.2	3.8	4.0	4.1	3.9	3.9	3.3	2.9	2.3	1.7	1.5
N	3.8	4.3	4.4	3.8	4.0	4.1	3.9	3.9	2.9	2.7	2.3	1.6	1.4
MA	3.8	4.4	4.4	4.0	4.1	4.1	3.9	4.1	3.3	2.8	2.4	1.7	1.6
MN	4.2	4.8	4.6	4.4	4.4	4.3	4.1	4.2	3.5	3.1	2.5	1.9	1.7
AN	3.4	4.3	4.4	3.8	4.1	4.2	4.0	4.0	3.3	2.7	2.3	1.7	1.6
MAN	3.8	4.8	4.6	4.2	4.4	4.3	4.1	4.3	3.6	3.0	2.4	1.8	1.6
LSD (p=0.05)	0.2	0.2	0.2	0.3	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1

2002															
Treatment	**17-May**	**7-Jun**	**14-Jun**	**21-Jun**	**28-Jun**	**8-Jul**	**12-Jul**	**18-Jul**	**29-Jul**	**9-Aug**	**16-Aug**	**26-Aug**	**6-Sep**	**13-Sep**	**7-Oct**	**14-Oct**
Control	3.4	3.7	3.4	3.1	3.2	3.4	3.7	3.0	3.8	3.8	3.9	3.9	3.3	3.3	3.3	3.3
M	4.2	4.2	4.0	3.7	4.1	4.1	4.3	4.0	4.3	4.3	4.3	4.2	3.5	3.5	3.3	3.5
A	3.5	3.9	3.9	3.7	4.0	4.3	4.3	4.1	4.2	4.4	4.1	4.3	3.4	3.4	3.5	3.5
N	4.0	4.3	4.2	3.8	4.0	3.9	4.1	3.8	4.1	4.3	3.9	3.9	3.3	3.3	3.3	3.4
MA	3.7	4.3	4.4	4.3	4.6	4.7	4.7	4.5	4.6	4.6	4.5	4.3	3.6	3.6	3.5	3.5
MN	4.2	4.5	4.4	4.4	4.6	4.8	4.6	4.6	4.6	4.6	4.4	4.3	3.5	3.5	3.5	3.5
AN	3.7	4.5	4.4	4.2	4.4	4.5	4.5	4.2	4.3	4.4	4.0	4.1	3.5	3.5	3.4	3.4
MAN	3.8	4.7	4.8	4.8	5.0	4.9	4.9	4.8	4.8	4.7	4.7	4.3	3.8	3.8	3.4	3.5
LSD (p=0.05)	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1

[1] Color is rated on a 1-5 scale with half units with 1 = brown, 5 = dark green.

[2] Plots receiving wear treatments were exposed to wear as four passes three times per week with the Brinkman Traffic Simulator beginning on 8 Aug and ending on 2 Nov 2001and beginning on 4 Jun and ending on 21 Oct 2002.

[3] Treatments include untreated control, M = spent mushroom substrate application at 6.33 mm depth, A = aerification with 20 mm hollow tines, N= nitrogen fertilization at 49 kg ha-1 N with Nutralene 40-0-0 fertilizer, MA = mushroom substrate application followed by aerification, MN = mushroom substrate application followed by fertilizer application, AN = aerification followed by fertilizer application, MAN = mushroom substrate application followed by aerification followed by fertilizer application. Treatment applications were made on 24-26 Jul, 19 Dec 2001, and 8-10 May, 2002.

Differences in percent ground cover could also be due to the mushroom substrate treatments reducing soil bulk density and increasing soil water content. The mushroom substrate tended to lower soil bulk density, compared to the control, to a greater degree than other treatments (Table 3). As with many of the other parameters measured, this trend became more pronounced as more treatments were applied.

Table 3. Bulk density[1] (g cc[3]) of treatments receiving simulated traffic in 2001 and 2002[2].

Treatment[3]	2001		2002		
	16-Aug	2-Oct	13-Nov	23-May	23-Oct
Control	1.13	1.28	1.27	1.21	1.29
M	1.11	1.25	1.21	1.05	1.16
A	1.13	1.27	1.22	1.11	1.23
N	1.14	1.29	1.27	1.19	1.28
MA	1.11	1.26	1.21	1.03	1.17
MN	1.08	1.23	1.18	0.98	1.13
AN	1.15	1.29	1.24	1.14	1.24
MAN	1.07	1.22	1.17	0.95	1.14
LSD (p=0.05)	0.02	0.02	0.03	0.03	0.03

[1] Soil bulk density data were derived from measurements of soil total density and volumetric water content taken with a Troxler 3400-B Series Moisture-Density Gauge (Troxler Electronic Laboratories Inc., Triangle Park, NC).

[2] Plots receiving wear treatments were exposed to wear as four passes three times per week with the Brinkman Traffic Simulator beginning on 8 Aug and ending on 2 Nov 2001and beginning on 4 Jun and ending on 21 Oct 2002.

The application of spent mushroom substrate as a topdressing tended to increase the water retention of the soil (Table 4). The differences measured during 2001, while statistically different, may be of little practical significance. During 2002 and 2003, after three and five mushroom substrate applications, respectively, the water retention of the treatments containing mushroom substrate increased substantially. This may have been due to the increased organic content of the soil or due to the substrate acting as a mulch on the soil surface.

Table 4. Volumetric water content[1] of soil after exposure to simulated traffic in 2001 and 2002[2].

Treatment[3]	2001			2002				
	16-Aug	2-Oct	13-Nov	23-May	1-Aug	3-Sep	8-Oct	22-Oct
Control	28.7	19.4	23.5	21.5	27.9	19.6	20.1	27.8
M	31.7	20.2	25.5	24.8	36.9	23.8	25.9	36.3
A	29.3	18.6	23.7	22.4	27.6	20.1	21.5	29.8
N	28.3	18.3	22.5	20.9	27.5	18.5	19.2	28.3
MA	31.5	19.9	25.6	26.5	34.8	23.4	25.2	34.5
MN	32.0	20.3	25.8	26.6	35.3	24.6	26.2	37.0
AN	28.8	18.1	23.9	21.5	27.8	19.9	21.5	29.6
MAN	33.1	20.1	25.6	27.0	34.3	22.6	24.5	36.7
LSD (p=0.05)	0.9	0.7	0.8	1.1	1.6	1.3	1.1	1.3

[1] Volumetric water content data were derived from measurements of soil total density and volumetric water content taken with a Troxler 3400-B Series Moisture-Density Gauge (Troxler Electronic Laboratories Inc., Triangle Park, NC).

[2] Plots receiving wear treatments were exposed to wear as four passes three times per week with the Brinkman Traffic simulator beginning on 8 Aug and ending on 2 Nov 2001and beginning on 4 Jun and ending on 21 Oct 2002.

[3] Treatments include untreated control, M = spent mushroom substrate application at 6.33 mm depth, A = aerification with 20 mm hollow tines, N= nitrogen fertilization at 49 kg ha^{-1} N with Nutralene 40-0-0 fertilizer, MA = mushroom substrate application followed by aerification, MN = mushroom substrate application followed by fertilizer application, AN = aerification followed by fertilizer application, MAN = mushroom substrate application followed by aerification followed by fertilizer application. Treatment applications were made on 24-26 Jul, 19 Dec 2001, and 8-10 May, 2002.

The decrease of soil bulk density and the increase in water retention and percent ground cover could account for the measured reduction in surface hardness as measured by the Clegg impact tester. Treatments that received mushroom substrate applications tended to measure lower in surface hardness than treatments that did not (Table 5). This would indicate that an athletic field playing surface that received regular spent mushroom substrate topdressing applications would be safer when fallen upon by an athlete than the same field without the substrate applications.

Table 5. Surface hardness (Gmax)[1] of treatments exposed to simulated traffic in 2001 and 2002[2].

Treatment[3]	2001	2002					
	13-Nov	23-May	17-Jun	2-Jul	1-Aug	3-Sep	8-Oct
Control	93.4	77.2	57.5	99.2	71.4	104.8	102.7
M	91.5	65.2	55.6	85.5	62.1	86.8	87.0
A	96.1	67.1	62.9	94.0	63.3	98.5	98.8
N	107.0	77.6	56.2	105.1	76.1	105.1	102.2
MA	94.4	61.3	69.1	86.0	61.5	90.2	91.0
MN	92.6	61.1	64.8	80.7	63.2	81.1	85.7
AN	98.5	68.5	60.0	98.8	66.1	99.2	100.8
MAN	103.5	56.9	57.7	80.9	60.3	85.7	89.4
LSD (p=0.05)	5.6	3.3	4.3	6.3	2.2	5.3	6.5

[1] Surface hardness was measured using a Clegg Impact Tester (Lafayette Instrument Company, Lafayette, IN) equipped with a 2.25 kg missile and a drop height of 450 mm.

[2] Plots receiving wear treatments were exposed to wear as four passes three times per week with the Brinkman Traffic simulator beginning on 8 Aug and ending on 2 Nov 2001and beginning on 4 Jun and ending on 21 Oct 2002.

[3] Treatments include untreated control, M = spent mushroom substrate application at 6.33 mm depth, A = aerification with 20 mm hollow tines, N= nitrogen fertilization at 49 kg ha^{-1} N with Nutralene 40-0-0 fertilizer, MA = mushroom substrate application followed by aerification, MN = mushroom substrate application followed by fertilizer application, AN = aerification followed by fertilizer application, MAN = mushroom substrate application followed by aerification followed by fertilizer application. Treatment applications were made on 24-26 Jul, 19 Dec 2001, and 8-10 May, 2002.

The changes in soil fertility that resulted from five applications of spent mushroom substrate can be seen in Table 6. These changes, while significant, create no negative impact on turfgrass growth and development. The pH of plots receiving mushroom substrate increased from 6.7 to about 7.1. Individual turfgrass sites with a pH higher than 7.2 may need to consider an organic matter source other than spent mushroom substrate. High pH native soils are somewhat rare in the Northeastern United States. Phosphorus, potassium, magnesium, and calcium levels generally increased with increasing applications of spent mushroom substrate. The cation exchange capacity also increased as a result of mushroom substrate applications. Soluble salt levels, generally thought to prohibit the use of mushroom substrate on turfgrass were increased only slightly and do not begin to approach a level of concern.

Table 6. Nutrient[1] levels for treatment at the end of the 2003 growing season.

Treatment[3]	pH[4]	P (lb/A)[5]	Acidity[6]	Exchangeable cations[2]			CEC[7]	Soluable salts (mmhos/cm)[8]
				K	Mg	Ca		
Control	6.7	198.5	1.38	0.46	1.44	6.15	9.4	0.11
M	7.0	227.8	0.00	0.77	1.53	7.82	10.1	0.14
A	6.8	202.8	1.06	0.48	1.50	6.86	9.9	0.13
N	6.8	214.3	1.50	0.45	1.49	6.64	10.1	0.12
MA	7.1	346.5	0.25	0.72	1.66	9.44	12.1	0.16
MN	7.1	301.5	0.00	0.74	1.60	8.64	11.0	0.15
AN	6.7	184.5	1.31	0.44	1.42	6.31	9.5	0.11
MAN	7.2	355.3	0.00	0.75	1.72	9.96	12.4	0.16
LSD (p=0.05)	0.1	29.7	0.38	0.04	0.06	0.58	0.6	0.01

[1] Soil samples were collected on 15 November, 2003 from plots not receiving wear treatments.

[2] Determined by Mehlich 3 Extractant and expressed as meq/100g soil.

[3] Treatments include untreated control, M = spent mushroom substrate application at 6.33 mm depth, A = aerification with 20 mm hollow tines, N= nitrogen fertilization at 49 kg ha^{-1} N with Nutralene 40-0-0 fertilizer, MA = mushroom substrate application followed by aerification, MN = mushroom substrate application followed by fertilizer application, AN = aerification followed by fertilizer application, MAN = mushroom substrate application followed by aerification followed by fertilizer application. Treatment applications were made on 24-26 Jul, 19 Dec 2001, and 7 May, 2002, and 15 Apr 2003.

[4] 1:1 soil:water pH

[5] Determined by Mehlich 3 Extractant.

[6] SMP Buffer pH.

[7] Summation of cations.

[8] Determined by 1:2 (soil:water) method.

Conclusions:

It should be noted that data continued to be collected through the 2004 growing season. This is the fourth growing season in which data was collected. We have data from both the wear and no-wear splits of the treatments and only data from the wear side have been presented here. Soil nutrient data

has been collected in every year of the study and was presented this past November at the American Society of Agronomy meetings in Seattle, WA. Only nutrient data from 2003 is presented here. Although year four data is still being analyzed, it appears that there is a positive effect to adding spent mushroom substrate topdressing to the maintenance regime of high-wear Kentucky bluegrass turfgrass. The advantages of five 6.3 mm applications include an increase in percent ground cover after wear, decreased soil bulk density, increased soil water retention, and decreased surface hardness when compared to a control and the traditional practices of aeration and fertilization.

References:

1. Cockerham, S.T., and D.J. Brinkman. 1989. A simulator for cleated-shoe sports traffic on turfgrass research plots. California Turfgrass Culture 39(3&4):9-10.
2. Landschoot, P.J., A.S. McNitt, and B.F. Hoyland. 1993. Effects of composted waste products on turfgrass establishment, quality, and soil physical properties. Agronomy Abstracts, 1993 Annual Meeting p.160.
3. Rogers III, J.N., and D.V. Waddington. 1990. Effects of management practices on impact absorption and shear resistance in natural turf. p. 136-146. In R.C. Schmidt et al. (ed.) Natural and artificial playing fields: characteristics and safety features. American Society for Testing Materials. Standard Technical Publication 1073. Philadelphia, PA.