How Alternative Materials Can Affect Soil pH and Turfgrass Performance

By David A. Munn

Low pH soils of golf courses in the North Central and Northeastern United States need periodic treatment (every three to six years) with liming materials to correct soil acidity, enhance nutrient availability and microbial activity, and to restore the supplies of exchangeable calcium and magnesium ions that are depleted with time by leaching and crop removal (McLean and Brown, 1984).

Turfgrass management texts routinely suggest a soil pH of 6 to 7 be maintained for optimum turfgrass nutrition and quality (Beard 2001, Emmons, 1984, Turgeon, 2001, and Turner and Hummel, 1992). The same introductory turfgrass management texts and widely used extension materials recommend fertilization at annual rates of 3 pounds to 6 pounds of nitrogen per 1,000 square feet. This robust nitrogen fertilization has the long-term consequence of increasing the soil's acidity thereby lowering the soil pH.

At the same time, Ohio and the North Central and Northeastern United States have acidic precipitation. Palazzo and Duel (1974) evaluated a number of grasses and legumes in their response to varied soil reaction. They reported optimal dry matter yield at a pH range of 5.5 to 6.5 for Kentucky bluegrass and 6 to 6.8 for perennial ryegrass.

Murray and Foy (1979) evaluated the differential ability of many turfgrass cultivars to tolerate aluminum (Al) stress and toxicity. They found the relationship noted in the literature for other crops was true in turfgrass. The problem of Al toxicity increases greatly in mineral soils as the pH is reduced below pH 5.5. Turner (1980) reported no beneficial or detrimental effects of limestone application on soils with an initial pH of 5.6 and 5.1 on established stands of perennial ryegrass and Kentucky bluegrass, respectively.

In their review paper, Turner and Hummel (1992) concluded that "the overall effect of soil reaction and liming becomes a complex issue with species, cultivars, soil texture, nitrogen (N) source applied and pest problems prevalent all influencing optimum soil pH levels."

FIGURE 1

Soil pH for various treatments 1998-2001

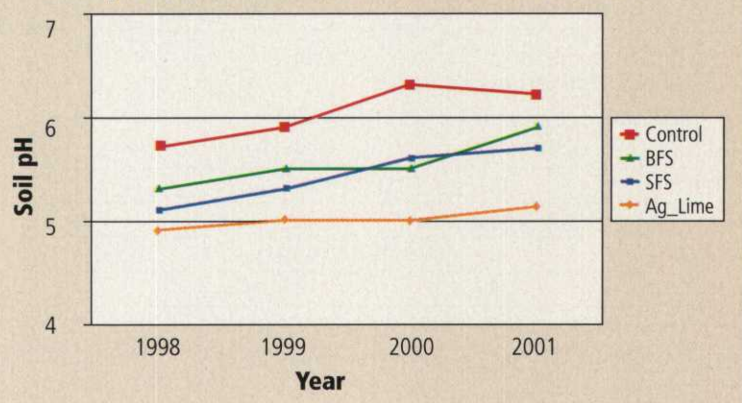
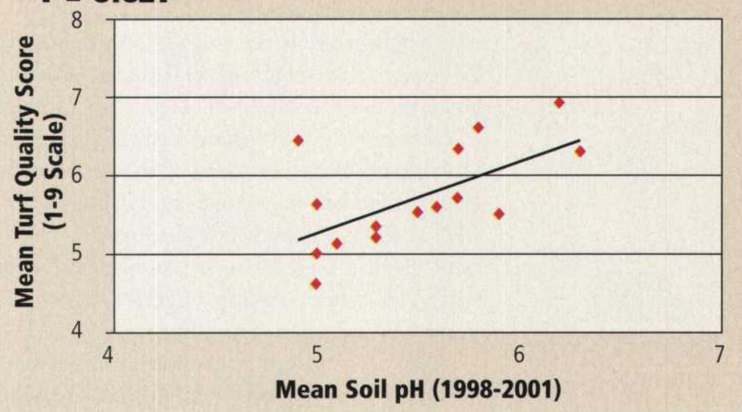


FIGURE 2

Turf Quality vs Soil pH
r = 0.621*



Steel and turf

Beyond the hills and ponds of its golf courses, Ohio and its neighboring states have significant steel-making capacity. Slags are nonmetallic byproducts of iron and steel making. Typically, a blast furnace with an ore feed with 60 percent to 66 percent

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TABLE 1

Chemical and physical characteristics of slags and agricultural lime used in these studies.

Identification	Steel Furnace Slag SFS	Blast Furnace Slag BFS	Agricultural lime
pH	12.5	10.3	8.2
CaCO3 Equiv (%)	79.8	81.1	97
ECCE[z]	22	27	77
Ca (%)	22.2	25.2	21.1
Mg (%)	5.53	5.07	12.6
Al (%)	1.64	3.79	.03
P (mg kg-1)	23	59	34
Fe (%)	15.9	.88	.16
Particle size distribution of slags[y] and lime[x]			
Mesh Size	----------------	(%) ----------------	----------------
>8	51 ± 1	36 ± 6.1	-
8-20	18 ± 2.1	35 ± 5	1
20-60	18 ± 2.8	23 ± 5.5	33
60-100	6.7 ± .3	5.9 ± 2.6	6
<100	6.5 ± 2	4 ± 1.6	60
Fineness effect.[w]	28	33	79

[z]ECCE (Effective CaCO3 equivalent = fineness efficiency @ CaCO3 equivalent, Troeh and Thompson, 1993)

[y]Mean and standard deviation of four replicate sieving analyses.

[x]Product guarantee for "Nutralime" on bag prior to pelletizing.

[w]Fineness efficiency (>8 mesh x 0.0, 8-60 mesh x .40, <60 mesh x 1.0, Troeh and Thompson, 1993)

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iron would generate slag outputs approximately 20 percent (by weight) of steel output (Kalyoncu and Kaiser, 1998). These slags are comprised of calcium (Ca) and magnesium (Mg) silicates, which can meet the criteria of liming materials (for example, are they able to supply Ca^{+2} and/or Mg^{+2} and to neutralize acidity). Ornamental horticulture can benefit from economical liming materials, while making effective use of an important industry's byproduct.

The U.S. steel industry reported annual sales averaging 12.6 million metric tons of blast furnace slag (BFS) and 19.3 million metric tons of steel furnace slags (SFS) in 1996-98, according to United States Geological Survey reports (Kalyoncu and Kaiser, 1998 and Kalyoncu, 1999). Their data indicates that more than half of U.S. iron and steel slag sales are generated in the North Central states of Illinois, Indiana, Michigan and Ohio.

The use of steel industry slags as a substitute for traditional limestone has a substantial history in Ohio (Williams, 1946, Volk et al., 1952 and Jones, 1968). Volk et al. (1952) evaluated granulated slag (water-quenched), air-cooled slag, and dolomitic limestone reconstituted by combinations of various sieve sizes into "agricultural screenings," "agricultural meal" and "agricultural ground" size grades as defined by Ohio's limestone law. They compared the three materials in both field and greenhouse studies with mixed alfalfa-timothy hay and corn (maize).

In field studies the average hay yields were higher for granulated slag than for air-cooled slag or limestone at each size gradation (screenings, meal and agricultural-ground).

Air-cooled slag and dolomitic limestone were equally effective when they had the same particle size distribution.

In the greenhouse studies, granulated slag and dolomitic limestone were more effective at correcting soil acidity than air-cooled slag. Since air-cooled slags produced crop yields quite comparable to limestone and yet did not raise pH as effectively, it indicated that crop-yield response to the slags involved more than simply soil acidity correction.

Jones (1963) reevaluated the effectiveness of granulated steel industry slag in field studies on acid Canfield silt loam (pH 5.5) that was cropped with a corn (maize), wheat and two years of alfalfa-hay rotation. He compared the performance of slag to comparable rates of calcitic and dolomitic limestone and concluded that granulated slag was as effective at the two rates used (1.5 tons per acre and 3 tons per acre) as either type of limestone.

The purpose of this four-year study was to compare the effectiveness of two steel industry byproduct slags with a dolomitic pelletized agricultural lime product when used on established turf as agricultural liming materials on acid (pH 4.9) Canfield silt loam soil. The slags are somewhat specific to the steels of which they are a byproduct. These contemporary slag materials may be valuable and economical aids to turf managers in managing soil pH on their landscapes. I also wanted to be sure there were no problems associated with their use.

Methods and materials

Two steel industry slags were supplied by either Stein Inc. in Broadview Heights, Ohio, from LTV Steel in Cleveland, or USS Kobe in Lorain, Ohio. Table 1 gives particle size and chemical proper-

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TABLE 2

Turfgrass clippings dry matter yield and visual quality evaluation summaries.

Treatment	Turf DM	Turf Visual Quality
2000		
Control	121	5
BFS	116	5.6
SFS	122	5.5
Agricultural Lime	118	6.3
LSD (.05)	Ns	ns
Two Way ANOVA Treatment Prob F	.979	.23

TABLE 3

Plant mineral analyses turf plant tops (2.5-10 cm height).

Treatment	P	Ca (%)	Mg	Mn	Fe (ppm)	Al
Turf 2000						
Control	.33	.37	.22	138	299	185
Ag Lime	.35	.41	.26	58	109	37
BFS	.35	.45	.24	85	133	53
SFS	.36	.44	.23	82	115	40
LSD (.05)	.02	.05	.02	31	ns	ns
Sufficient Range‡	.3-.55	.5-1.25	.2-.6	25-150	35-100	—

‡ Turner and Hummel (1992).

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ties of the slags and an agricultural lime product "Nutralime." This agricultural lime was a pelletized material (Mineral Processing, Carey, Ohio) with a manufacturer reported calcium carbonate ($CaCO_3$) equivalent of 97 percent with 21 percent Ca and 12 percent Mg derived from $CaCO_3$ and magnesium carbonate ($MgCO_3$).

The particle size data was obtained by sieving the slags and from the label guarantee for the Nutralime prior to its being pelletized. The chemical analyses were performed by The Ohio State University Research and Extension Analytical Laboratory (REAL) in Wooster, Ohio, and the Penn State Ag Analytical Laboratory, University Park, Pa., on samples digested in concentrated perchloric or nitric acid.

Soil tests were conducted in 1998 at REAL using 1 mole (M) of ammonium acetate for the exchangeable cations potassium (K), Ca and Mg (Brown and Warncke, 1988) and the Bray P1 test for extractable phosphorus (P) (Knudsen and Beegle, 1988). REAL closed to the public in December 1998 and the lab work was shifted to Penn State's Ag Analytical Lab using Mehlich III for soil P and extractable cations (Wolf and Beegle, 1995). Both labs used the (1:1) pH in water plus SMP Buffer test (Eckert and Sims, 1995) to assess the soil active and exchangeable acidity, respectively.

The experiment was arranged in a randomized complete block design with four treatments repeated in four blocks. Statistical analyses were performed using the General Linear Model of SAS to perform two-way ANOVA and mean separation procedures appropriate for the treatments. Plot size was 10 feet by 20 feet. Treatments were control, agricultural lime, blast furnace slag (BFS) and steel furnace slag (SFS), all at 2 tons per acre.

The appropriate experimental materials were applied to plots on the campus lawn by hand broadcasting after the last mowing operation of the fall on Nov. 13, 1997. This allowed frost action and winter rain and snow to carry the applied materials into the soil.

The first visual quality ratings and clippings for dry matter yield comparisons were performed on Oct. 14, 1998. On Nov. 12, 1998, after the growing and mowing season was over, the plots were treated with another two tons/acre of each material in the same manner as the previous year.

The turf was a perennial ryegrass-Kentucky bluegrass mix. The soil was Canfield silt loam with a 2 percent to 6 percent slope. The turf treatments received 2 pounds to 3 pounds N per 1,000 square feet annually in the form of broadcast urea. Turf was treated for broadleaf weeds with 2,4-D, dicamba and MCPP. The plots received 43 pounds per acre of phosphoric acid and potassium oxide during the spring of 2000.

The experimental area was a low-traffic area of the campus lawn. Turf yield and tissue samples were collected on Oct. 14, 1998, Oct. 7, 1999, Oct. 12, 2000, and Oct. 18, 2001, by harvesting a 21-inch width from the length of each plot with a hand powered reel mower and catch pan.

Soil samples were taken to a 4-inch depth on the turf plots in October 1998, October 1999, October 2000 and October 2001. At least 10 cores were collected from each plot and mixed to form a composite sample. My forage crops students assisted with this work and rated the visual quality of the plots.

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TABLE 4

Soil Test Results

Treatment	pH	Acidity meq 100g	Exch Ca (ppm)	Exch Mg (ppm)	Exch K (ppm)
2000					
Control	5	3.1	528	101	252
BFS	5.6	2.3	791	154	240
SFS	5.5	2.4	783	120	253
Ag Lime 6.3	2	879	260	298	
LSD (.05)	.3	ns	164	28	ns
Two Way ANOVA Treatment Prob F	.001	.148	.005	.001	.07

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Slag and lime characteristics

The slags and lime used in these studies varied in their physical and chemical characteristics. (Table 1). The order of particle size from coarse to fine was SFS was more than BFS, which was more than Ag lime.

Both slags had very low fineness factor and effective calcium carbonate equivalent (ECCE) as shown in Table 1. Steel furnace slag (SFS) was higher in pH than BFS or lime. The order of $CaCO_3$ equivalent was Lime > BFS > SFS. The steel furnace slag (SFS) was also higher in metals common to steel alloys such as chromium (Cr), venadium (V) and cobalt (Co). This slag had very high total Fe content (Table 1), but the Fe was apparently unavailable as there was no increase in turf tissue foliar iron levels (data not shown).

The BFS by contrast was higher in the metals barium (Ba), Strotium (Sr) and beryllium (Be).

Turfgrass quality

Rainfall from April through October totaled 25 inches in 1998, 21.4 inches 1999, 21.7 inches in 2000 and 20.9 inches in 2001. This can be compared to the 30-year average of 22.9 inches for the months of April to October that comprise the principal growing season for turf in northeast Ohio.

There were no significant differences in the dry matter yield (P is less than .05) for the turf plots treated with BFS, SFS, or agricultural lime in 1998 (Table 3). In 1999, with a dry late summer growing season, the dry matter yield differences were significant at the (P is less than .05) level.

The turfgrass visual quality ratings were significantly different (P less than .05 level) in 1998, but not in 1999, 2000, or 2001 (Table 2). There was an overall significant (P is less than .01) positive relationship between turfgrass visual quality and soil pH (Figure 2) over the pH range of 4.9 to 6.5 and the four years of this study. In each year the agricultural lime treatment had the highest visual quality rating and the highest soil pH (Figure 1).

The BFS, SFS and agricultural lime all increased the plant Ca content, and the lime and BFS increased the plant Mg content when compared to plant tissue sampled from the control plots (Table 3). The plant Mg content differences were significant all three years while in the first two years the Ca differences were not significant at the P.05 level.

The micronutrients iron (Fe), manganese (Mn) and the toxic factor Al were not significantly different between the treatments except in the third year (Table 3).

Treatments had no significant impact on plant tissue levels of N, K, boron (B), copper (Cu) and zinc (Zn). The N and K levels in the plant tissue were above sufficient levels for all treatments.

Annual soil tests

The lime and slags at 2 tons/acre in both 1997 and 1998 raised the soil pH in field experiments in 1998, 1999, 2000 and 2001 (Table 4 and Figure 1).

The campus lawn site was initially strongly acidic (pH 4.9) in the control plots. While differences between the slag products and lime were small, the lime always resulted in the highest pH and the lowest level of soil exchangeable acidity. However, the slags were apparently more effective than their ECCE would predict. Both slags and lime elevated soil test Ca and Mg levels (Table 3).

The soil extractable P levels were never significantly impacted by slag or agricultural lime treatments. Soil exchangeable K levels were not significantly impacted (P was less than .05 level) by the slag and lime treatments at the P was less than .05 level (Table 4).

Conclusions

Work conducted during 1998, 1999, 2000 and 2001 comparing the effectiveness of steel industry slags with a pelletized agricultural lime as liming material showed that these steel industry byproduct materials have potential as liming compounds. No adverse consequences were noted from the materials at the rates and conditions used.

Both of the slags did have a low fineness factor and effective calcium carbonate equivalent (ECCE) because of the coarse particle size of the material provided. That would need to be corrected by further grinding and sieving in order to spread uniformly and to react rapidly with soil acidity. However, the slags were apparently more effective than their ECCE would predict. The commercial agricultural lime resulted in the highest soil pH and produced the highest turf visual quality ratings.

There was a positive relationship between turfgrass visual quality and soil pH over the pH range 4.9 to 6.5 in this four-year study. Plant Ca and Mg were increased by the slag and agricultural lime products.

The slags give turfgrass managers an alternative and potentially less-costly product to choose if the particle size of available products is fine enough for rapid correction of soil acidity.

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REFERENCES

Beard, J. B. 2001. *Turf management for golf courses*, 2nd Edition. Ann Arbor Press, Inc.

Bureau, M.F., T.E. Graham, and R.J. Scherzinger. *1984 Soil Survey of Wayne County Ohio*, U.S. Dept. of Agriculture Soil Conservation Service, Washington, D.C.

Brown, J.R. and D. D. Warncke. 1988. "Recommended cation tests and measures of cation exchange capacity," p. 15-16. In W. C. Dahnke (ed.) *Recommended Chemical Soil Test Procedures for the North Central Region*. Bulletin No. 499 (Revised). North Dakota Agric. Exp. Sta., Fargo, North Dakota.

Eckert, D and J. T. Sims. 1995. "Recommended soil pH and lime requirement tests." In J. Thomas Sims and A. Wolf (eds) Recommended Soil Testing Procedures for the Northeastern United States. Northeast Regional Bulletin # 493k. Agricultural Experiment Station University of Delaware, Newark, DE.

Emmons, R. D. 1984. *Turfgrass science and management*. Delmar Publishers. Albany, N.Y. 106-118.

Jones, J. B. 1968. "Granulated slag for liming soils." *Ohio Report on Research and Development*. Ohio Agr. Res. and Dev. Center, Wooster, Ohio. July-August 62-63.

Kalyoncu, R.S. and R. Kaiser. 1998. *Mineral Industry Surveys Slag-Iron and Steel, 1997 Annual Review*. U.S. Geological Survey, 983 National Center, Reston, Va. 20192. August 1998.

Kalyoncu, R.S. 1999. *Mineral Industry Surveys Slag-Iron and Steel, 1998 Annual Review*. U.S. Geological Survey, Reston, Va. August 1999.

Knudsen, D. and D. Beegle. 1988. "Recommended phosphorus tests." In W. C. Dahnke (ed.) *Recommended Chemical Soil Test Procedures for the North Central Region*. Bulletin No. 499 (Revised). North Dakota Agric. Exp. Sta., Fargo, N.D.

McLean, E. O. and J. R. Brown. 1984. "Crop response to lime in the Midwestern United States p 267-303." In F. Adams (ed.) *Soil Acidity and Liming* 2nd Ed. Agronomy Monograph 12 ASA CSSA and SSSA, Madison, Wis.

Murray, J. J. and C. D. Foy. 1979. "Differential tolerance of turfgrass cultivars to an acid soil high in exchangeable aluminum." *Agron. J.* 70:769-774.

Palazzo, A. J. and R. W. Duell. 1974. "Response of grasses and legumes to soil pH." *Agron. J.* 65:678-682.

Troeh, F. R. and L. M. Thompson. 1993. *Soils and soil fertility* 5th Ed. p150-158. Oxford University Press, N.Y.

Turgeon, A. J. 2001. *Turfgrass management* 6th Edition. Prentice Hall Inc., Upper Saddle River N.J.

Turner, T. R. 1980. "Soil test calibration studies for turfgrass." Ph.D. Diss. The Pennsylvania

State University (Diss. Abstr. 80-24499)

Turner, T. R. and N.W. Hummel, Jr. 1992. "Nutritional requirements of turfgrass." In D.V. Woddington, R.N. Carrow and R.C. Sherman Co-Editors. *Turfgrass* 2nd Ed. Agronomy Monograph 32 ASA, CSSA, SSSA, Madison, Wis.

Volk, G. W., R. B. Harding and C. E. Evans. 1952. "A comparison of blast furnace slag and limestone as a soil amendment." Res. Bull 708 Ohio Agr. Exp. Sta. Wooster, Ohio.

Williams, H. T. 1946. "Blast furnace slag for agricultural use." NSA File 104-42A National Slag Association, Washington D.C.

Wolf, A.M. and D. B. Beegle. 1995. "Recommended tests for macronutrients: phosphorus, potassium, calcium and magnesium." In J. Thomas Sims and A. Wolf (eds) *Recommended Soil Testing Procedures for the Northeastern United States*. Northeast Regional Bulletin # 493k. Agricultural Experiment Station University of Delaware, Newark, Del.

TURFGRASS TRENDS

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