Physical and Chemical Soil Characteristics of Aging Golf Greens

A novel approach from University of Nebraska researchers yields information regarding how putting green rootzones change.

BY ROCH GAUSSOIN, R. SHEARMAN, L. WIT, T. McCLELLAN, AND J. LEWIS

Since 1997, research at the University of Nebraska has focused on a USGA-funded project centered on developing a better understanding of the agronomic characteristics of sand-based rootzones as they mature. We have been able to evaluate the long-term microbial, chemical, and physical characteristics of structured research greens ranging in age from one to eight years. This article will focus on a summary of the physical and chemical characteristics of aging golf greens.

EXPERIMENTAL SETUP AND DESIGN

Research was conducted at the University of Nebraska John Seaton Anderson Turfgrass Research Facility near Mead, Nebraska. Four experimental greens were constructed in sequential years from 1997 to 2000 following USGA recommendations. Treatments included two rootzones [80:20 (v:v) sand and sphagnum peat and an 80:15:5 (v:v:v) sand, sphagnum peat, and soil] and two establishment or grow-in programs (accelerated and controlled).

The accelerated establishment treatment included high nutrient inputs and was intended to speed turfgrass cover development and readiness for play (Table 1). The controlled establishment treatment was based on agronomically sound turfgrass nutrition requirements. Plots were seeded with Providence creeping bentgrass (*Agrostis stolonifera* Huds.) at 1.5 lbs. per 1,000 sq. ft. During the establishment year, the total amount of N, P, and K of the accelerated establishment treatment was two and four times the amount of the controlled establishment treatment for pre-plant and post-plant, respectively (Table 1).

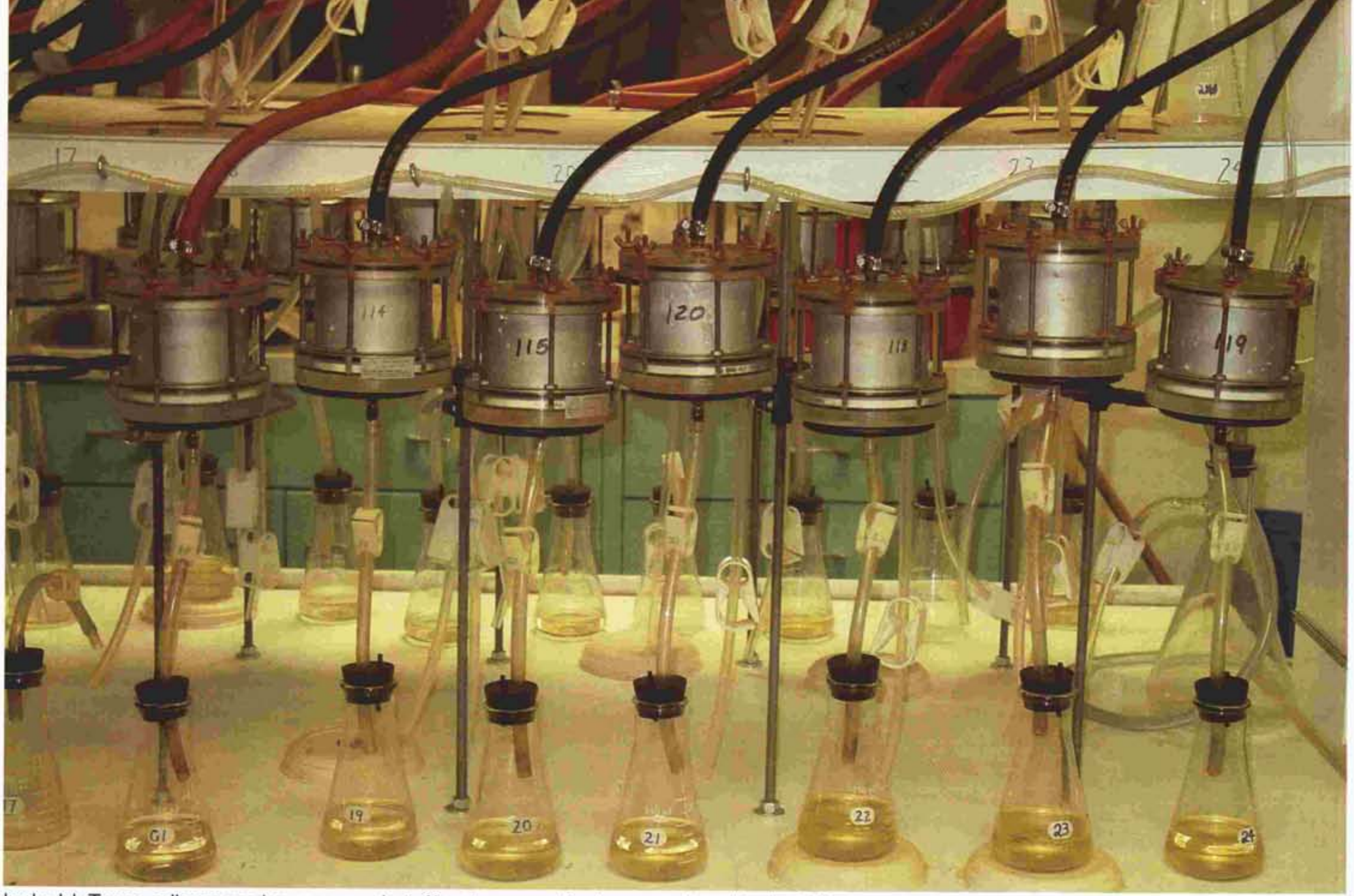
All construction materials met USGA recommendations for putting green construction. The first putting green was constructed in late summer of 1996. The rootzones were allowed to settle over the winter and they were seeded May 30, 1997. The same procedures were used for construction and seeding of subsequent greens in 1998, 1999, and 2000.

Following the establishment year, management practices applied to the putting greens did not differ and were maintained according to regional recommendations for golf course putting greens. Plots were mowed at 0.125 inch with annual fertility applications of N, P, and K at 3.5, 2, and 3.5 lbs. per 1,000 sq. ft., respectively. Management practices included sand topdressing as: (1) light, frequent during the growing season every 10 to 14 days at a rate relative to turfgrass growth, combined with vertical mowing, and (2) heavy sand topdressing twice annually (spring and fall) at a rate sufficient to fill coring holes (0.5-inch diameter spaced 2 × 2

Table 1
Establishment year treatments on United States Golf Association (USGA) greens at John Seaton Anderson Turfgrass Research Facility near Mead, Nebr., USA, from 1997 to 2000

	Establishment Treatment (ET)							
	Accelerated				Controlled			
Applications	N[1]	P	K	STEP[2]	N	P	K	STEP
	lbs. per 1,000 sq. ft.							
Pre-plant[3]	6	1.5	3.2	16	3	0.75	1.6	8
Post-plant[4]	5	1.5	3	2.3	1.2	4.2	0.75	2.3
Total[5]	11	3	6.2	18.3	4.2	7.5	1.2	10.3

[1]Amounts are actual N, P, and K.
[2]Micronutrient fertilizer with analysis 12Mg-9S-0.5Cu-8Fe-3Mn-1Zn.
[3]Pre-plant was incorporated into upper 8cm of the rootzone prior to seeding. Analyses for fertilizer sources applied were 0N-0P-0K (STEP), 16N-11P-10K, 15N-0P-24K, and 38N-0P-0K.
[4]Post-plant fertilizers applied during the growing season.
[5]Total application amounts during the establishment year.



In the lab, Tempe cells are used to measure the infiltration rates of soil cores collected in the field.

inches). Traffic stress was applied three times weekly using modified greens mower rollers with golf spikes attached to the rollers.

DATA COLLECTION

Rootzone infiltration was determined yearly in October with a thin-walled, single-ring infiltrometer at three locations per plot. Undisturbed soil cores obtained from each of the areas sampled were analyzed for infiltration using physical property testing procedures. Bulk density and capillary porosity data also were collected.

Soil samples were collected to a 3-inch depth in the fall of each year with a 1-inch diameter soil probe. Chemical analyses were performed for pH, electrical conductivity for total soluble salts, organic matter, nitrate-nitrogen (NO_3-N), phosphorus, potassium, calcium, magnesium, sodium, sulfur, zinc, iron, manganese, copper, and boron. The cation exchange capacity (CEC) of each sample was obtained by summing the exchangeable cations.

RESULTS: PHYSICAL CHARACTERIZATION

After the grow-in year, rootzone treatment influenced soil physical properties, while establishment treatments did not. Air-filled porosity (large pores), capillary porosity (small pores), total porosity (all pores), bulk density, and infiltration were significantly correlated with rootzone age for both rootzones. All soil physical properties demonstrated the same rate of change with age between the two rootzone treatments. Capillary porosity was correlated with rootzone age (increased as green aged) and increased 53% and 60% for the 80:20 and 80:15:5 rootzones, respectively. Air-filled porosity was negatively correlated (decreased as green aged) with rootzone age and decreased 28% for the 80:20 rootzone and 34% for the 80:15:5 rootzone.

Others have reported similar increases in capillary porosity and decreases in air-filled porosity in aging putting green rootzones. Habeck and Christians (3) reported an increase in capillary porosity and a decrease in air-filled porosity from clay contamination. Ok et al. (6) reported a 220% increase in capillary porosity and a 60% decrease in air-filled porosity three-and-a-half years after establishment due to changes in the pore size distribution and thatch accumulation. Murphy et al. (5) reported that air-filled porosity decreased as organic matter increased. McCoy (4) reported that decreases in air-filled porosity often resulted in decreased infiltration.

Infiltration was decreased as the greens matured. Infiltration declined 70% for the 80:20 rootzone, while the 80:15:5 rootzone declined 74%. The soil-amended rootzone, 80:15:5, initially had a lower infiltration than the 80:20 rootzone; however, both declined at similar rates. Our findings support Waddington et al. (9), who reported lower infiltration for rootzones amended with soil.

Reductions in rootzone infiltration have been attributed to contamination from silt and clay particles, fine particle

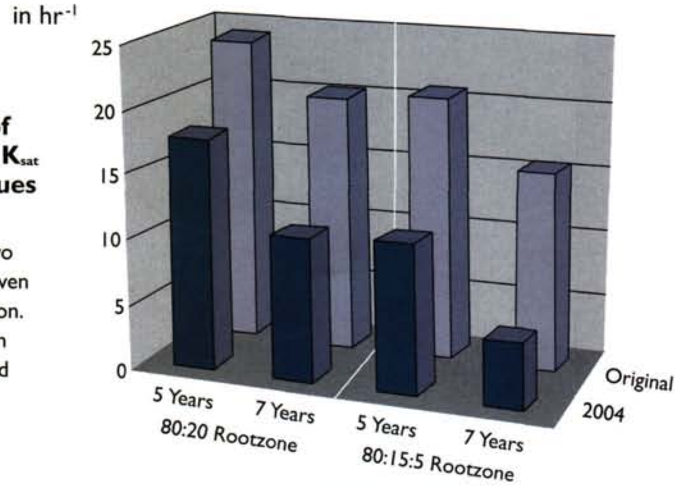


Figure 1
Comparison of preconstruction K_{sat} values to K_{sat} values taken 10/04

Infiltration rates of two rootzones, five and seven years after construction. Samples for infiltration analysis were collected below the mat layer in the original rootzone for all data.

migration, and organic matter layering. Our data indicate no increase in clay accumulation or clay migration. In addition, the soil-amended rootzone infiltration, while initially lower, did not decline at a faster rate than the rootzone without soil.

The light, frequent sand topdressing applications may explain the relatively slow decline in infiltration, as no layering was present in the rootzones. Surface organic matter accumulation has been reported to cause reduction in infiltration of putting green rootzones (5). In our study, a mat layer did develop, but data were not collected on the amount or rate of accumulation.

Rootzone samples taken in 2004 from below the visible mat layer had lower infiltration than the preconstruction infiltration values. The infiltration decline with age may have resulted from increased fine sand amounts and decreased coarse sand in the rootzone. The rootzone samples taken in 2004 had increased fine sand amounts in six of the eight rootzones, and decreased coarse sand amounts in five of the eight rootzones sampled, compared to the preconstruction rootzones.

These changes likely originated from the sand topdressing applications. The USGA recommends that topdressing sand meet rootzone particle size distribution specifications (7). The topdressing sand used in our study met USGA specifications; however, it had a higher amount of fine sand particles and less coarse sand than the sand used in the original rootzones.

Zontek (10) and Vavrek (8) reported that the long-term effects of sand topdressing on putting green soil physical properties are not well defined. Although the decline in rootzone infiltration may be attributed to the increased fine sand content of the rootzone, this does not completely explain the reduction of infiltration. Organic matter accumulation may account for the decrease, but it was not measured in this study.

Bulk density was correlated with rootzone age (increased as green matured), and increased 4% for the 80:15:5 and 6% for the 80:20 rootzone after the establishment year. Total porosity was negatively correlated with rootzone age and decreased 5% for the 80:20 rootzone and 7% for the 80:15:5 rootzone. An increase in bulk density is expected to be related to a decrease in total porosity. Compaction may account for the observed increased bulk density and decreased total porosity.

Few studies have reported changes in bulk density and total porosity with rootzone age. Ok et al. (6) reported minimal change in bulk density and total porosity over three years. Habeck and Christians (3) reported a decrease in bulk density with age, but concluded that these data were not as expected because their samples were contaminated with thatch. Murphy et al. (5) reported an increased total porosity with age, which may have been the result of sampling different locations.

CHEMICAL CHARACTERIZATION

USGA rootzone mixes comprised of 80:20 (sand:peat) generally were not significantly different from 80:15:5 (sand:peat:soil) during the establishment year or beyond for chemical properties investigated. For the purpose of clarity, establishment year and grow-in year will be used synonymously throughout this discussion.

During the grow-in year, all but four of the chemical properties investigated were significantly greater for the accelerated grow-in treatment when compared to the controlled grow-in treatment. Boron, organic matter, and sodium also were higher in the accelerated grow-in treatment, but these differences were not significant. Only pH was lower in the accelerated grow-in treatment during the grow-in year. This was likely caused by an acidification effect from increased fertilizer inputs containing ammonium-nitrogen and sulfur, both known to lower soil pH.

All USGA-recommendation putting greens receiving increased amounts of phosphorus during the first year of establishment retain significantly more phosphorus beyond establishment. This relationship was not evident for any other nutrients investigated. Phosphorus retention likely occurred because it is relatively non-mobile even in high-sand soils and thus does not readily leach. Furthermore, sands used in construction of these greens were calcareous sands with an alkaline pH. Alkaline conditions have been found to further contribute to limited mobility of phosphorus because alkalinity increases the tendency of phosphorus to form complexes with other elements in the soil, which makes it less soluble for plant uptake or leaching.

Putting green establishment year comparisons, when compared among the four experimental putting greens (i.e., green constructed in 1997 vs. 1998, etc.), were significant for all but three chemical properties investigated. While all four experimental putting greens were constructed in the same way from 1997 to 2000 and all met USGA rootzone recommendations, they were not constructed with exactly the same rootzone material each year and therefore were not identical (32). Results from this study suggest that USGA recommendation putting greens are also not the same in regard to nutritional status as evident by the variability among these four USGA experimental putting greens and the significant differences for nearly all chemical properties investigated.

All nutrients and chemical properties investigated, excluding pH and potassium, generally decreased following the grow-in year, but began to increase several years later. Increased chemical properties and nutrient retention may be explained, at least in part, by the development of a mat layer. Mat development was observed, although not measured, in the upper region of putting green rootzones in this study, particularly as putting greens increased in age.

Beard (1) and Carrow (2) define mat as an organic zone or layer that is buried below the soil surface and comprised of partially decomposed thatch. Organic matter in the mat is intermixed with soil from sand topdressing and enhances nutrient retention and cation exchange capacity in high-sand rootzones (5). As such, mat development and organic matter accumulation in our study likely contributed to increased chemical properties, such as CEC and nutrient retention in older putting greens.

Increased fertilizer inputs during the establishment year may not be feasible or environmentally responsible since they had negative effects on turfgrass establishment, and these rootzones did not retain these inputs over time compared to the controlled grow-in treatment. Additionally, since the rootzone containing soil was essentially equal to the rootzone without soil, incorporating an appropriate, locally available soil into the rootzone may be a more economical alternative than peat when used as an amendment in USGA greens.

LITERATURE CITED

1. Beard, J. B. 1973. Turfgrass: science and culture. Prentice-Hall, Englewood Cliffs, N.J.

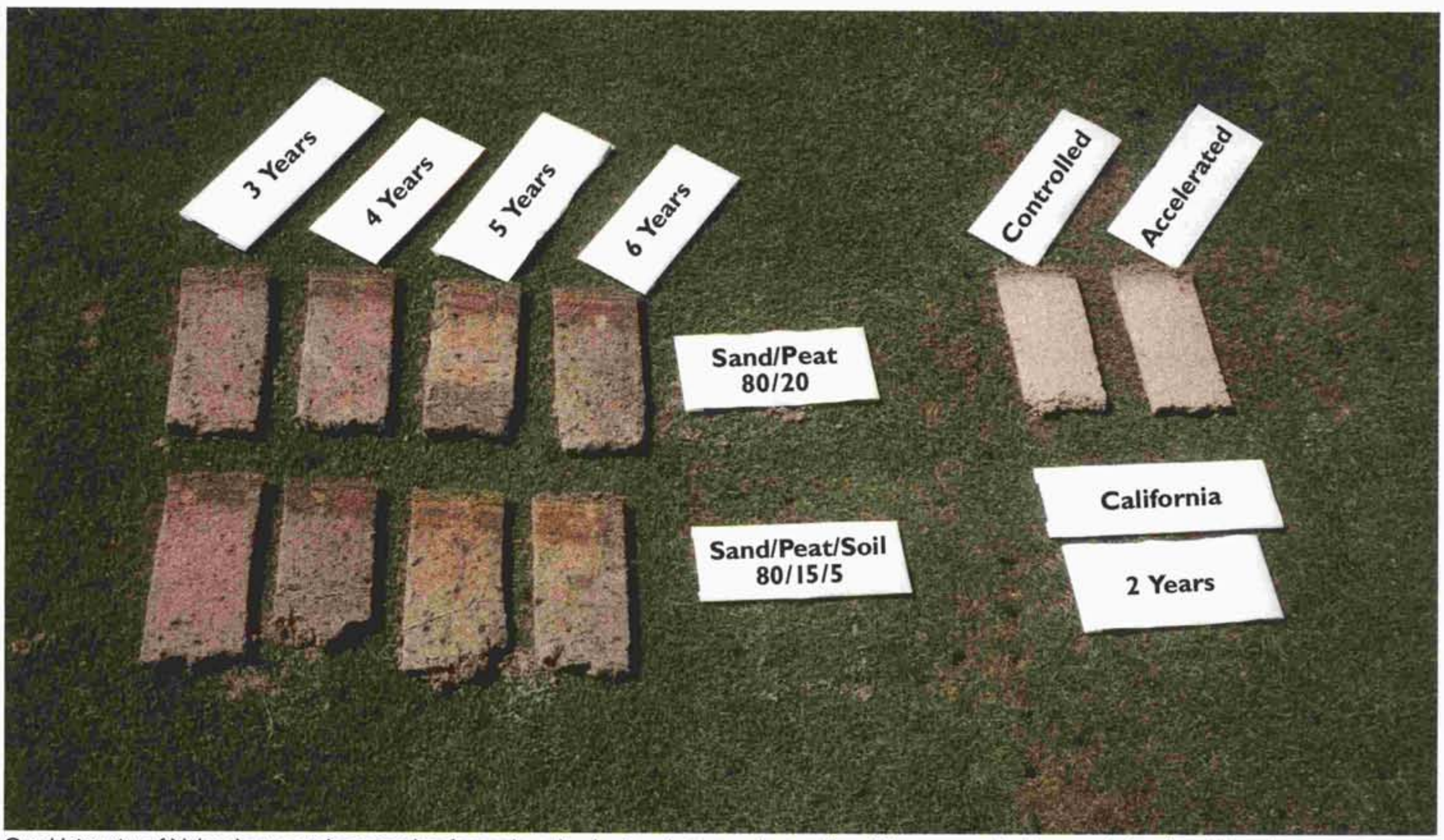
2. Carrow, R. N. 2004. Surface organic matter in bermudagrass greens: A primary stress? *Golf Course Management* 72(5):102-105.

3. Habeck, J., and N. Christians. 2000. Time alters greens' key characteristics. *Golf Course Management* 68(5):54-60.

4. McCoy, E. L. 1992. Quantitative physical assessment of organic materials used in sports turf rootzone mixes. *Agron J.* 84:375-381.

5. Murphy, J. W., T.R.O. Field, and M. J. Hickey. 1993. Age development in sand-based turf. *Intl. Turfgrass Soc. Res. J.* 7:464-468.

6. Ok, C., S. H. Anderson, and E. H. Ervin. 2003. Amendments and construction systems for improving performance of sand-based putting greens. *Agron. J.* 95:1583-1590.



One University of Nebraska research project has focused on developing a better understanding of the agronomic characteristics of sand-based rootzones as they mature over time. To date, the research has focused on the microbial, chemical, and physical characteristics of greens ranging in age from one to eight years.

CONNECTING THE DOTS

A Q&A with* DR. ROCH GAUSSOIN, *University of Nebraska, regarding physical and chemical soil characteristics of aging golf greens.

Q: Given the large input differences between the accelerated and controlled grow-in treatments, did it surprise you that only phosphorus continued to show greater amounts in the rootzone and not any of the other applied nutrients?

A: When you consider how easily some nutrients versus others move in a rootzone (e.g., nitrogen) and the relative immobility of phosphorus, the buildup was not surprising, given the large quantities that were applied. The more mobile nutrients were either effectively used by the actively growing turf or possibly leached below the area we sampled.

Q: You mentioned that incorporating soil into the sand-based rootzone may be an economical alternative to peat. This may seem controversial to many readers. What would you say to those who may feel that adding soil to sand-based rootzones is a surefire way to reduce infiltration to unacceptable levels?

A: People involved in golf course green construction must be cautious about practices that compromise or potentially contribute to decreased performance of the putting green. Our data clearly show that the addition of a locally available soil did not appreciably differ in infiltration from a conventional sand/organic amendment rootzone. This response was evident regardless of the age of the green. *The key to successful use of soil as part of the rootzone, however, hinges on the initial rootzone meeting USGA specifications.* If the addition of a locally available soil at a given percentage (by volume) does not meet USGA specifications, then the percentage might be decreased until the mix meets specifications. If the addition of the soil, even at low percentages, does not meet specifications, the use of the soil as an amendment is not recommended.

Q: Your research showed that as newly constructed putting greens age, several physical soil properties change. What is the take-home message to superintendents regarding how they should adjust their management of newly built putting greens as the years roll by?

A: The results of this research, combined with visits to numerous golf courses during grow-in, identified a clear take-home message. The light, frequent topdressing practices recommended routinely for golf green management are critical during the initial years of a green. This practice is especially true during the establishment year. If topdressing is done intermittently or infrequently, the development of a grow-in layer is almost guaranteed. The resultant grow-in layer will impair infiltration, promote black layer, and restrict the growth and quality of the putting surface.

Q: Although this study did not measure it, your article points out that organic matter buildup may be causing decreased infiltration as greens age. Do you have plans to continue this work with a specific focus on organic matter buildup?

A: We plan to continue monitoring the greens described in this study as well as do a nationwide survey of golf course putting greens and imposed management practices to determine the primary factors that contribute to organic matter accumulation. This work will also attempt to determine the relationship between organic matter content in the rootzone and green quality. This research is generously funded by the USGA, the Nebraska Golf Course Superintendents Association, and the Golf Course Superintendents Association of South Dakota.

JEFF NUS, PH.D., *manager, Green Section Research.*

7. USGA Green Section Staff. 1994. Topdressing sand. *USGA Green Section Record* 33(2).

8. Vavrek, R. C. 1995. A successful topdressing program requires consistency, commitment, and communication. *USGA Green Section Record* 33(5):8-10.

9. Waddington, D.V. 1992. Soils, soil mixtures, and soil amendments. p. 331-383. *In* D.V. Waddington, R. N. Carrow, and R. C. Shearman (ed.). Turfgrass. Agronomy Monograph No. 32. Am. Soc. Agron., Madison, Wis.

10. Zontek, S. J. 1979. Is sand topdressing right for you? *Golf Course Management* 47(6):15-21.

Editor's Note: A more complete version of this research can be found at USGA Turfgrass and Environmental Research Online at http://usgatero.msu.edu/v05/n14.pdf.

ROCH GAUSSOIN, PH.D., *Professor and Extension Turfgrass Specialist;* ROBERT SHEARMAN, PH.D., *Professor and Extension Turfgrass Specialist;* LEONARD WIT, *Research Station Manager;* TY MCCLELLAN, *Graduate Student; and* JASON LEWIS, *Graduate Student; Department of Agronomy and Horticulture, University of Nebraska, Lincoln, Nebr.*