GCM 2007

# Soil physical and chemical characteristics of aging golf greens

Researchers studied the changes in creeping bentgrass greens over an eight-year period.

Since 1997, the USGA has funded research at the University of Nebraska focused on developing a better understanding of the agronomic characteristics of sand-based root zones 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. The research on the microbial ecology of greens has been reported in numerous publications. 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, Neb. Four experimental greens were constructed following USGA recommendations in sequential years from 1997 to 2000 (Figure 1). Treatments included two root zones, 80:20 (v:v) sand and sphagnum peat and 80:15:5 (v:v:v) sand, sphagnum peat and soil (silty clay loam), and two establishment or grow-in programs, accelerated and controlled.

Establishment treatments were based on recommendations gathered by surveying superintendents and a USGA agronomist with experience in establishing putting greens. A consensus of their recommendations for establishment treatments can be found in Table 1. The accelerated establishment treatment included high-nutrient inputs and was intended to speed turfgrass cover development and readiness for play. The controlled establishment treatment was based on agronomically sound turfgrass nutrition requirements. Pre-plant fertilizer was incorporated into the top 3 inches (8 centimeters) of the root zone before seeding. Analyses for pre-plant fertilizers applied were 16N-11P-10K, 15N-0P-24K, 38N-0P-0K, and 0N-0P-0K (STEP). STEP is a micronutrient fertilizer with an analysis of 12Mg-9Su-0.5Cu-8Fe-3Mn-1Zn. Plots were seeded with Providence creeping bentgrass (*Agrostis stolonifera* Huds.) at 1.5 pounds/1,000 square feet (7.3 grams/square meter). Post-plant fertilizers were applied during the growing season with an analysis of 0N-0P-0K (STEP) and 16N-11P-10K. During the establishment year, the total amount of nitrogen, phosphorus and potassium of the accelerated establishment treatment was twice the amount of the controlled establishment treatment for pre-plant and four times the amount for post-plant (Table 1).

All construction materials were tested and met USGA recommendations for putting green construction (17). The first putting green was constructed in late summer 1996. The root zones were allowed to settle over the winter and were seeded May 30, 1997. The same procedures were used for construction and seeding of three other greens in 1998, 1999 and 2000.

Following the establishment year, all the greens were maintained according to regional recommendations for golf course greens. Plots were mowed at 0.125 inch (3.2 millimeters) with

**Figure 1.** The John Seaton Anderson Turfgrass Research Facility near Mead, Neb. **Photo by J. Kuddes**

USGA

Environmental Institute for Golf

The USGA funded this research with assistance from The Environmental Institute for Golf.

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**Figure 2.** Profiles were collected from USGA 80:20 (sand:peat) greens on June 15, 2004. The profiles are from four greens aged five, six, seven and eight years.
**Photo by R. Gaussoin**

annual fertility applications of 3.5 pounds/1,000 square feet (17.1 grams/square meter) each of nitrogen and potassium and 2 pounds (9.8 grams/square meter) phosphorus. Management practices included light, frequent sand topdressing during the growing season every 10 to 14 days at a rate relative to turfgrass growth, combined with vertical mowing; and heavy sand topdressing twice annually (spring and fall) at a rate sufficient to fill coring holes (0.5-inch [1.3-centimeter] diameter spaced 2 × 2 inches [5.1 × 5.1 centimeters]). Traffic stress was applied three times weekly using greensmower rollers with golf spikes attached.

## Soil physical characterization data collection

Root-zone infiltration was determined *in situ* yearly in October with a thin-walled single-ring infiltrometer at three locations per plot. Infiltration measurements were obtained in the field, and undisturbed soil cores were taken and analyzed for infiltration, bulk density and porosity data using physical property testing procedures.

## Chemical characterization data collection

In the fall of each year from 1997 to 2003, putting green soil samples were collected to a 3-inch (8-centimeter) depth with a 1-inch (2.5-centimeter) diameter soil probe. After the thatch was removed, the soil samples were air-dried and analyzed for electrical conductivity for total soluble salts, pH, organic matter, nitrate-nitrogen ($NO_3$-N), phosphorus, potassium, calcium, magnesium, sodium, sulfur, zinc, iron, manganese, copper and boron. The cation exchange capacity of each sample was obtained by summing the exchangeable cations.

## Results

*Soil physical characterization*

After the grow-in year, root-zone treatment influenced soil physical properties but establishment treatments did not. Capillary porosity (small pores), total porosity (all pores), bulk density and infiltration all correlated significantly with root-zone age. As the root zones of the greens aged, capillary porosity increased 53% for the 80:20 root zone and 60% for the 80:15:5 root zone, but air-filled porosity decreased 28% for the 80:20 root zone and 34% for the 80:15:5 root zone.

Infiltration decreased as the greens matured, declining 70% for the 80:20 root zone and 74% for the 80:15:5 root zone. Reductions in root-zone infiltration have been attributed to contamination from silt (0.002-0.05 millimeter) and clay (<0.002 millimeter) particles, fine particle migration, and organic matter layering. Our data indicate no increase in clay accumulation or clay migration. In addition, although infiltration in the soil-amended (80:15:5) root zone was initially lower, it did not decline at a faster rate than infiltration of the root zone without soil (80:20).

A mat layer did develop in our study, but data were not collected on the amount or rate of accumulation (Figure 2).

Root-zone samples taken in 2004 from below the visible mat layer had lower infiltration than the preconstruction infiltration values (Figure 3). In comparison to the preconstruction root zones, the root-zone samples taken in 2004 had increased fine sand amounts in six of the eight root zones and decreased coarse sand amounts in five of the eight root zones sampled. These changes, which may be the cause of the decreased infiltration, likely originated from the sand topdressing applications. The USGA recommends that topdressing sand meet root-zone particle-size distribution (18). The topdressing sand used in our study met USGA specifications, but it had had more fine sand particles (0.25-0.15 millimeter) and fewer coarse sand par-

### Establishment treatment

| Applications | Accelerated | | | | Controlled | | | |
|---|---|---|---|---|---|---|---|---|
| | N | P | K | STEP† | N | P | K | STEP |
| | pounds/1,000 square feet | | | | | | | |
| Pre-plant‡ | 6 | 1.5 | 3.2 | 16 | 3 | 0.75 | 1.6 | 8 |
| Post-plant§ | 5 | 1.5 | 3 | 2.33 | 1.2 | 4.2 | 0.75 | 2.3 |
| Total// | 11 | 3 | 6.2 | 18.3 | 4.2 | 7.5 | 1.2 | 10.3 |

Note. Amounts shown are actual nitrogen, phosphorus and potassium. Analyses for fertilizer sources applied were 0N-0P-0K (STEP), 16N-11P-10K, 15N-0P-24K and 38N-0P-0K.
†Micronutrient fertilizer with analysis 12Mg-9S-0.5Cu-8Fe-3Mn-1Zn.
‡The pre-plant application was incorporated into upper 3 inches (8 centimeters) of the root zone before seeding.
§Post-plant fertilizers applied during the growing season.
//Total application amounts during the establishment year.

**Table 1.** Establishment-year treatments on USGA putting greens at John Seaton Anderson Turfgrass Research Facility near Mead, Neb., from 1997 to 2000.

ticles (0.5-1.0 millimeter) than the sand used in the original root zones (Figure 4). The fine sand particles may have been placed into the root zone during core cultivation and topdressing, especially during the first two years.

The long-term effects of sand topdressing on putting green soil physical properties are not well defined. Even though the increased fine-sand content of the root zone may have reduced root-zone infiltration, it does not completely explain the reduced infiltration. Organic matter accumulation may account for the decrease, but it was not measured in this study.

From the establishment year until 2003, bulk density increased 4% for the 80:15:5 root zone and 6% for the 80:20 root zone. For the same period, total porosity was negatively correlated with root-zone age, decreasing 5% for the 80:20 root zone and 7% for the 80:15:5 root zone. 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.

*Soil chemical characterization*

USGA root-zone mixes composed of 80:20 (sand:peat) generally were not significantly different from 80:15:5 (sand:peat:soil) root zones 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.

All USGA putting greens that were built following USGA recommendations and received increased amounts of phosphorus during the first year of establishment retained significantly more phosphorus beyond establishment. This relationship was not evident for any other nutrients investigated. Phosphorus was probably retained 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. Alkalinity increases the tendency of phosphorus to form complexes with other elements in the soil and therefore makes phosphorus less soluble for plant uptake or leaching.

Calcium carbonate in calcareous soils may also limit the mobility of phosphorus because, in the presence of calcium carbonate, calcium bonds with phosphorus and forms insoluble calcium phosphates. In a two-year study on a sand-based putting green with a soil pH of 8.0, phosphorus was found to increase rapidly in the soil after only one to two years of annual fertilizer applications. Therefore, slightly alkaline soil conditions and calcareous sands may have contributed to phosphorus retention in the root zone.

High soil pH can also limit the solubility of nutrients in addition to phosphorus, including iron, manganese, copper, boron and zinc. Iron, copper and zinc all exhibit varying degrees of solubility and mobility in soils and were also observed to be consistently higher beyond the establishment year for greens receiving the accelerated grow-in treatment. However, these differences were not always significant for iron, copper or zinc.

Nitrate-nitrogen ($NO_3$-N) is highly soluble and very mobile in soils. Numerous studies have documented nitrate-nitrogen detection in leachates from sand-based turfgrass root zones. As expected, nitrate-nitrogen in our study was not retained beyond the grow-in year for root zones receiving the accelerated grow-in treatment when compared to root zones receiving the controlled grow-in treatment.

When the chemical compositions of the four experimental greens in their establishment years were compared (that is, the green constructed in 1997 vs. 1998, etc.), significant differences were found for all but three of the chemical properties investigated. Although all four greens were constructed in the same way from 1997 to 2000 and all met USGA root-zone recommendations, they were not constructed with exactly the same root-zone material and therefore were not identical. Results from this study suggest that greens built to USGA recommendations are also not the same in regard to nutritional status, as evidenced by the

## Root-zone infiltration

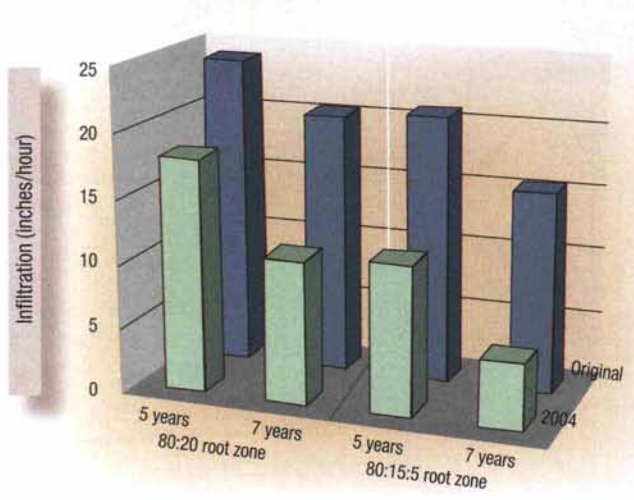


**Figure 3.** Infiltration of the 80:20 root zone and the 80:15:5 root zone five and seven years after construction. Samples for infiltration analysis were obtained below the mat layer in the original root zone for all data.

variability among these four experimental greens and the significant differences for nearly all the 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 the root zones in this study, particularly as the greens aged. Mat development and organic matter accumulation in our study likely contributed to increased chemical properties, such as cation exchange capacity and nutrient retention in older greens.

In summary, the 80:20 (sand:peat) root-zone mix was generally not chemically different from the 80:15:5 (sand:peat:soil) during or beyond the establishment year. In addition, the root zone generally had no effect on turfgrass establishment or quality ratings for the greens in this study. Because root-zone mix generally had no effect, soil may be a more economical alternative to peat as an amendment in USGA greens.

### Sand specs

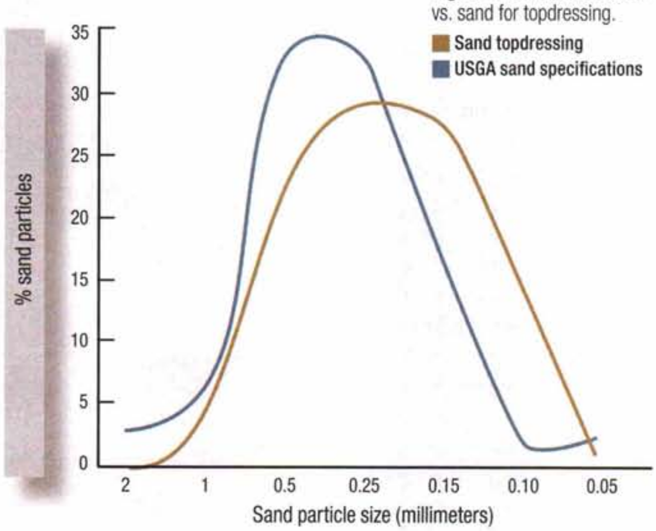


**Figure 4.** Sand for root zone vs. sand for topdressing.

### Phosphorus vs. years

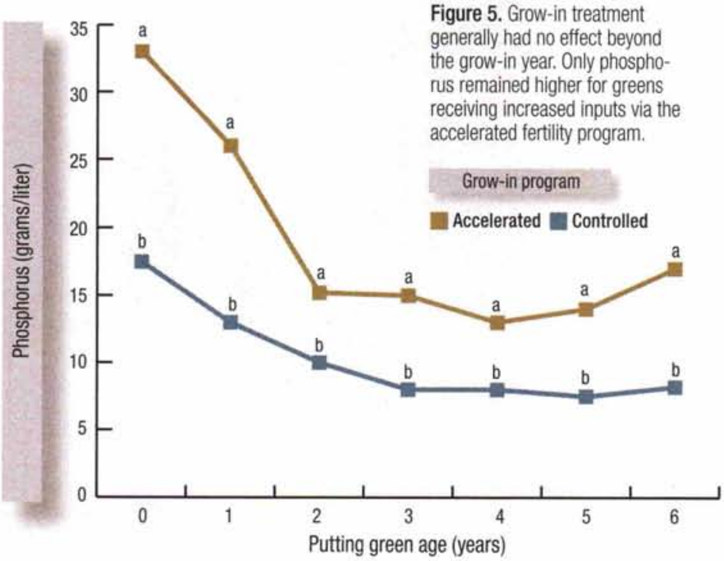


**Figure 5.** Grow-in treatment generally had no effect beyond the grow-in year. Only phosphorus remained higher for greens receiving increased inputs via the accelerated fertility program.

## Conclusions

*Soil physical characterization*

After eight years, root-zone infiltration remained acceptable. There was no apparent negative response from the addition of soil to the root zone. The change in soil physical properties was, in part, the result of fine sand accumulation from topdressing sand, which increased capillary porosity and decreased air-filled porosity and infiltration. Future studies of organic matter dynamics are needed as their influence on soil physical properties are not well defined or, in some cases, contradictory in the turfgrass literature. Although this research investigated physical dynamics of sand root zones as they age, minimal organic matter data were obtained.

*Soil chemical characterization*

During the grow-in year, all but four of the chemical properties investigated were significantly higher for the accelerated grow-in treatment compared to the controlled grow-in treatment. Only soil pH was lower in the accelerated grow-in treatment compared to the controlled grow-in treatment. Excluding phosphorus, establishment treatment generally had no effect beyond the grow-in year. Only phosphorus remained higher for greens receiving increased inputs from the accelerated fertility program (Figure 5). Furthermore, the accelerated establishment treatment did not speed turfgrass establishment for greens investigated in this study. In fact, root zones receiving the accelerated establishment treatment had lower creeping bentgrass quality ratings because of increased injury from pythium foliar blight (*Pythium* species).

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

### Funding

The authors gratefully acknowledge the support of the USGA, the Nebraska Turfgrass Association and The Environmental Institute for Golf.

### Acknowledgments

Special note of thanks is expressed to Jim Murphy, Ph.D., at Rutgers University for technical support; the Nebraska GCSA; and Paul Vermeulen, former director, USGA Green Section Mid-Continent Region, for help with initial grow-in recommendations.

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## The research says

→ **Water infiltration decreases** as a sand-based root zone matures. The decrease is associated with a decrease in air-filled porosity and an increase in capillary porosity over time. Total porosity, however, remains relatively constant.

→ **The decrease in** infiltration may be attributable to fine sand particles from topdressing sand. (Accumulated organic matter, which was not measured in this study, may also contribute to decreased infiltration.)

→ **Adding soil to** the root zone does not decrease infiltration with maturity, and soil may be an economical alternative to peat in root-zone construction.

→ **Beyond the grow-in year,** phosphorus was the only element that accumulated in the root zone from initial applications during establishment.

→ **Nitrogen and phosphorus** begin to accumulate in the later years of a green's maturity, indicating the potential for decreasing inputs as greens mature.