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Rootzone Amendments for Putting Green Construction

So many greens, so many soils, so many soil amendments. Making sense of it all.

By James A. Murphy

This photo shows one grow-in plot location in June 1998 at the Rutgers field station. Among the objectives of this study were to evaluate the effects of 1) sand size distribution, 2) plot locations (poor vs. excellent air circulation), 3) rootzone amendments, 4) rootzone depth, 5) options to reduce water and nutrient inputs for managing putting greens, and 6) rootzone physical and chemical changes over a nine-year period.

Sandy, infertile soils have long been recognized as highly suitable for golf courses since the earliest days of golf course development on the links land bordering the sea in Scotland (Alister Mackenzie, 1995). Such land provides good drainage and low to moderate turf growth, both conducive to playing the game of golf. As interest in the game expanded, golf courses were built in locations lacking sandy, infertile soil. Thus, the need arose for specifications to guide the construction of rootzones (soil), particularly for putting greens, that were suitable for the game. The USGA Green Section first published guidelines on rootzone construction in 1960, with the most recent update being completed in 2004. These guidelines primarily describe the physical parameters for constructing a rootzone that will create a well-drained playing surface. Research has demonstrated that the range of properties described in the guidelines is large enough to provide a notable range in the behavior of the rootzone (that is, requirements for water and nutrient management). Thus, particular combinations of sand and amendment(s) can be selected to produce a specific influence on the vigor of the turf, which, as previously mentioned, is often intended to be low to moderate for good playing conditions.

The selection of amendment(s) for a sand mix varies throughout the United States and other parts of the world, and it is often based on the biases of individuals involved in the design, construction, and future management of new or rebuilt putting greens. Regardless of personal biases, it is important to understand that sand and amendments should be selected based on climatic and other environmental and management conditions that can limit putting green performance. Peat continues to be the most widely used amendment for sand-based rootzone construction; however, a number of materials have been proposed and used over the years as a replacement for peat in sand-based rootzones. Many involved in the design and construction of putting greens do not realize that considerable insight has been gained from recent research on putting green rootzone materials. This article summarizes major findings from a nine-year field study of rootzone amendments conducted by the Rutgers Center for Turfgrass Science and draws from the findings of others as well.

100% SAND CONSTRUCTION (NO AMENDING)

Constructing putting greens with 100% sand (non-amended) is popular with some architects, builders, and superintendents. The cost savings in construction associated with not blending an amendment into the sand is typically the primary justification used by advocates for straight-sand construction. However, often overlooked are the increased long-term costs associated with maintenance of these putting greens, discussed later. Construction with 100% sand is also rationalized with the misconception that problems associated with the accumulation or organic matter (thatch) will be reduced by this type of rootzone. Advocates argue that accumulating organic matter "amends" the sand rootzone over time, therefore eliminating the need to amend the and at the time of construction (Hurdzan, 2004). Research has proven that this concept is flawed. Measurements of organic matter accumulation in field studies clearly indicate that the vast majority of organic matter addition is not in the rootzone (Table A and Image 1). Rather, the majority of organic matter accumulates above the rootzone in the form of thatch or mat, which is thatch plus topdressing. It is the thatch-mat layer above the rootzone that reduces water infiltration and increases water retention at the surface of putting greens, not the underlying rootzone. A rootzone of 100% sand does not become "amended" over time and will continue to have very low (too low) water and nutrient retention. The end result is putting green turf that requires frequent, intensive management inputs to avoid drought stress and maintain adequate plant nutrition.

Image 1. Profile samples of nine-year-old rootzone plots visually indicate that very little organic matter has accumulated within the original rootzone (note yellow sand color of 100% sand profile on left) compared to the large amount of organic matter above the rootzone (note brown colored thatch-mat layer of both profile samples). Profile on right is from an 80:20 (v/v) sand-peat rootzone mix, which has a similar accumulation pattern.

On the other hand, experience demonstrates that the dry, infertile condition of 100% sand construction does gradually alleviate over time as the developing thatch-mat layer becomes thick enough to improve water and nutrient availability. Nevertheless, our field trial experience indicates that there are meaningful differences between a rootzone of 100% sand and a sand-peat rootzone even after nine years (Figure 1). Turf performance on 100% sand plots frequently was poorer than turf grown on sand-peat rootzones. Also, hand-watering needs were sometimes greater (more frequent) on 100% sand rootzones than sand-peat rootzones (Figure 2). The author and numerous USGA agronomists have worked with many superintendents in every region of the country who struggle with water management on 100% sand putting greens during dry weather, even during late winter months when evapotranspiration is low. Thus, it is unreasonable to expect thatch-mat layer development on 100% sand rootzones to match the performance of putting greens constructed of a sand-peat mix without an increase in maintenance costs. Moreover, there will be opportunity costs incurred by the superintendent and staff; that is, the additional time managing 100% sand putting greens will take time away from other management needs on the golf course. Eventually, the unending need to assess and tweak the management program of 100% sand putting greens can shift from an intriguing mental challenge for the superintendent to a seemingly infinite frustration.

INORGANIC AMENDMENTS

Various mineral sources - including clay, diatomaceous earth, clinoptilolite (zeolite), and volcanic rock - are used to produce inorganic amendments (IAs), which are comprised of hard, porous (lightweight) sand-sized particles. The internal pores of IAs increase effective surface area within the rootzone and are small enough to retain water against the pull of gravity (capillary) as well as increasing cation exchange capacity (surface chemistry). The amount of CEC depends on the mineral source of the IA; generally, zeolites have the greatest CEC.

Table A

Concentration of organic matter and saturated hydraulic conductivity of surface layers of putting green rootzones after nine years of growth of L-93 creeping bentgrass maintained as putting green turf in North Brunswick, N.J.

	Organic Matter Concentration[1]		Saturated Water Conductivity[2]	
Profile Layer	100% Sand	90:10 Sand-Peat[3]	100% Sand	90:10 Sand-Peat
	% by Weight		Inches per Hour	
Thatch-Mat layer above the rootzone (1.3 inches thick for sand) (1.4 inches thick for 90:10 sand-peat)	4.52	5.38	7.8	8.3
0- to 3-inch depth of the rootzone	0.22	0.40	32.1	28.5

[1]Organic matter concentration determined by combustion (360° C) of 3-inch-diameter cores taken from the respective layer of the rootzone plots in 2006.

[2]Saturated water conductivity determined from undisturbed 3-inch-diameter cores taken from the respective layer of the rootzone plots in 2006.

[3]Type of peat is sphagnum.

The improved nutrient retention of a sand-IA mix can improve turf vigor and quality, especially during establishment of new turfs when ample amounts of water and fertilizers are being applied (Murphy et al., 2004). However, the longer-term effects of sand-IA mixes on turf vigor and quality are not as consistent as those observed during establishment (Figure 1). The differences in turf performance between establishment and maintenance programs on sand-IA rootzones are often attributed to water availability. Despite greater water retention for sand-IA mixes, we only observed sand mixes with Axis™ and Isolite™ to reduce the need for hand watering compared to 100% sand rootzones (Figure 2). Sand-IA mixes with Profile,™ Greenschoice,™ and ZeoPro™ typically required similar hand-watering as 100% sand rootzones. At various times during the trial, localized dry spot developed in some plots of 100% sand, 90:10 sand-IA mixes of Profile™ and Greenschoice,™ and 95:5 and 80:20 sand mixes with loam. Putting greens on golf courses constructed of sand-IA mixes have also been observed to suffer droughty conditions and localized dry spot. Reasons for these observations continue to be studied, but it is likely that changes in the structure of macro-pores (air-filled porosity) versus micropores (capillary porosity) within the rootzone profile contribute to performance issues related to water. Thus, our experience indicates that medium sand mixed with IAs will be very well drained and aerated, but some sand-IA mixes can suffer from droughty conditions.

The fact that IAs do not decompose is another purported benefit. Since organic matter can undergo decomposition, it is argued that organic amendments in a rootzone will degrade into finer particles and contribute to the challenges of managing organic matter in a rootzone. Focus on the rootzone profile is one important flaw in this rationalization. Our research and others clearly show that it is the accumulation of organic matter above the rootzone that is the site of declining physical conditions, not the rootzone mix itself (Table 1). The physical changes in the rootzone of a sand-peat or sand-compost mix are relatively small and of little consequence compared to the changes occurring above the rootzone mix. This observation, combined with the fact that turf performance on sand-IA mixes most typically does not exceed that of sand-peat or sand-compost mixes, indicates that the agronomic value of a non-decomposing amendment in the rootzone profile is very limited. Moreover, high-quality peat amendments are typically humified; that is, the organic matter has been microbially altered into relatively stable organic matter.

Table 1
Data pertaining to Figure 1 (Quality)

Treatment	1999	2000	2001	2002	2003	2004	2005
Sand 100%	6.8	6.5	7.0	5.6	4.1	5.3	5.2
Sphagnum 10%	7.4	6.5	6.8	5.9	6.0	6.8	6.0
Reed Sedge 10%	7.3	7.6	7.4	6.4	7.1	7.9	6.5
AllGro 10%	7.3	8.0	7.6	8.2	7.9	8.5	8.0
Profile 10%	5.6	6.6	6.4	5.7	4.6	5.8	6.7
ZeoPro 10%	6.2	7.1	7.2	6.2	4.7	6.8	6.9
LSD	0.3	0.7	0.4	0.6	0.8	0.7	0.5

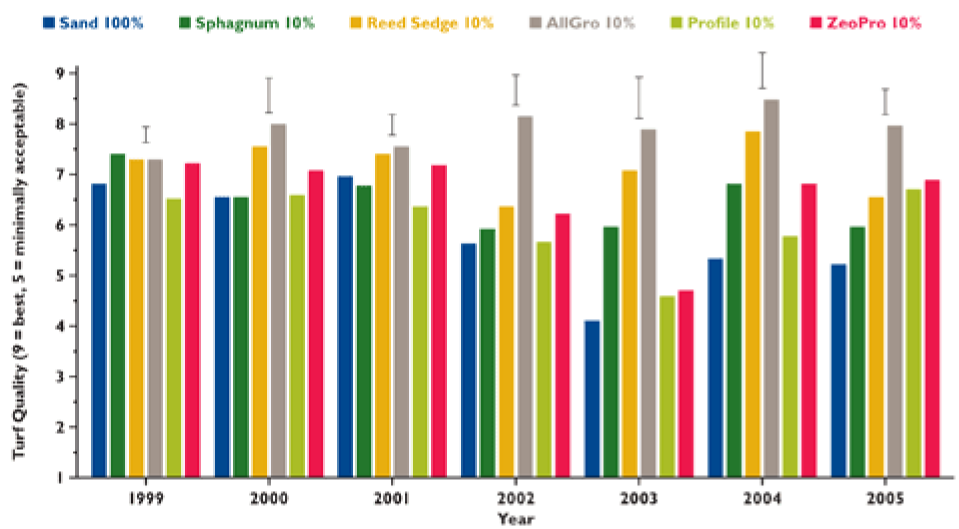

Figure 1. Average annual turf quality ratings for L-93 creeping bentgrass grown on rootzone plots in North Brunswick, N.J., from 1999 to 2005. All amendments were mixed at 10% by volume with medium sand that conformed to USGA guidelines. Error bars represent the least significant difference among means ($P < 0.05$); that is, mean differences greater than the error bar are statistically different.

Thus, other benefits may be needed to justify the greater cost of constructing putting green rootzones with IAs. There are some advantages to IAs that may be important. The better IA products are very uniform and therefore make quality control easier, unlike peat and compost, which can vary considerably in water content, other physical attributes, and chemical properties during the blending operation. Inorganic amendments are very dry and flowable, making blending much easier and more consistent. Inorganic amendments will displace a significant volume within a mix with sand, whereas peat does not. For example, blending 7,000 cubic yards of a 90:10 sand-IA rootzone mix will require approximately 10% less sand than a 90:10 sand-peat mix. This 10% reduction in sand (700 cubic yards) will significantly reduce shipping costs. If peat were to be used, you will still need to haul all 7,000 cubic yards. Nelson (2003) discussed this in a cost analysis of materials for constructing 140,000 sq. ft. (3.2 acres) of putting green rootzones using either peat or IAs. This analysis demonstrated that use of a sand-IA (90:10 by volume) mix would increase material cost by $86,000 on average compared to a sand-peat (90:10) mix. The analysis used modest values for shipping cost compared to today's costs, and thus would be a significant underestimate. A savings in shipping cost may be a substantial factor for some regions in the United States where high-quality sands and/or organic amendments are not readily available, particularly considering the recent increase in fuel costs.

COMPOST

Compost is a very popular organic amendment among those interested in "organic" or "natural organic" methods to manage turf and other plants. Unfortunately, the quality and consistency of composts can vary widely, presenting a significant challenge when selecting composts. The physical, chemical, and biological qualities of compost will vary depending on the source material (feedstock) as well as the composting process itself. Unlike fertilizer products, there are limited government regulations or certification standards in place that provide a guaranteed analysis for compost. Thus, the onus of documenting compost quality and consistency (quality control) often falls to the buyer.

High-quality composts for amending sand rootzones are produced by aerobic decomposition of organic matter and should be mature, stable, and weed free. Examples of organic matter sources for compost (feedstock) include agricultural, food or industrial residuals, class A biosolids, yard trimmings, or source-separated municipal solid waste. Composted biosolids should meet all applicable USEPA CFR, Title 40, Part 503 Standards for Class A biosolids. Compost should be free of objectionable odors. Nutrient content can vary, but compost used to amend sand should be slightly acidic (pH 6.2-6.8), relatively low in salts (EC<10dS/m, preferably <5dS/m), and low in chemical (arsenic, cadmium, lead, zinc, etc.) and biological (pathogens, weed seed) contaminants. Composts should not contain visible refuse or other physical contaminants, substances toxic to plants, or sufficient fine particles such that the specifications for particle size distribution and other physical properties of a sand-compost mix cannot be met. Blending operations will proceed more easily and be more uniform if the compost is moist but not excessively wet (not clumpy) and capable of passing through a screen. Certainly, there should be no visible water or dust produced when handling compost. More information on compost specifications can be viewed at the U.S. Composting Council Web page: http://compostingcouncil.org/pdf/fgcu_4-Characteristics-Parameters.pdf.

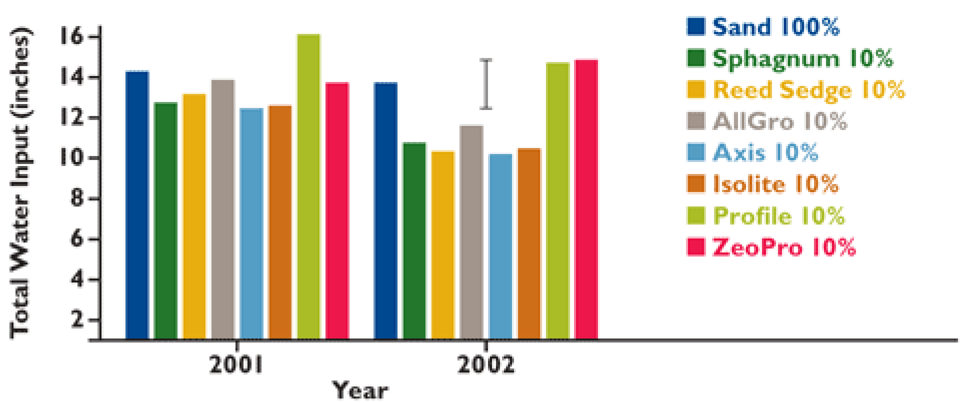

Figure 2. Total water applied to rootzone plots by sprinkler irrigation and hand-held hose based on visual wilt stress and low soil water content measurements from April to October of 2001 and 2002. Hand watering was

done to avoid overwatering plots that were able to retain a greater amount of plant-available water and reduce the frequency of watering. Sprinkler irrigation applied 8.7 inches of water in 2001 and 8.8 inches in 2002. Error bar for 2002 represents the least significant difference among means ($P < 0.05$); that is, mean differences greater than the error bar are statistically different. No differences were observed among root zones in 2001.

Table 2
Data pertaining to Figure 2 (Water input, inches)

	2001	2002
Sand 100%	14.34	13.78
Sphagnum 10%	12.87	10.69
Reed Sedge 10%	13.22	10.44
AllGro 10%	13.98	11.66
Axis 10%	12.52	10.34
Isolite 10%	12.64	10.51
Profile 10%	16.24	14.72
ZeoPro 10%	13.74	14.83
LSD	NS	2.4

The composts evaluated in our trials have generally improved soil fertility, particularly phosphorus and micronutrient content. Turf performance on a 90:10 sand-compost mix was as good as or better than sand-peat mixes (Figure 1), and hand-watering needs were similar to 90:10 sand-peat mixes (Figure 2).

These research findings, along with an ample supply of consistent and high-quality composts within the NY/NJ/PA region, have encouraged more blenders and suppliers of sand mixes to offer compost as a component of construction mix products. It cannot be overemphasized that the quality of compost is essential for success. There are unfortunate examples where use of an improperly composted material had disastrous results. Thus, buyers should confirm (test) the quality and consistency of composts or sand-compost mixes available in your region before using.

FINER-TEXTURED SOIL

Sand can also be amended with a finer-textured soil to subtly increase the organic matter and fine particle size content (silt and clay) of a mix, which is intended to improve nutrient and water retention. We observed that sand-loam mixes were effective at improving nutrient retention and turf quality in our trials; however, we could not demonstrate improvements in water availability by amending sand with loam. Moreover, we found that amending sand with excessive amounts of loam (too much silt and clay) resulted in a more compacted rootzone and turf that was very sensitive to drought stress.

Putting green construction using finer-textured soil native to the site was very common during the early years of golf course construction; this type of construction is often referred to as "push-up" greens. These native soils were often mixed with small amounts (relative to today's standards) of sand and/or an organic matter source such as manure, compost, or peat. Additionally, many "push-up" greens have been aerated and topdressed for numerous years, developing as much as 6 inches of an improved rootzone over the original soil profile. This improved rootzone in the uppermost profile is generally much closer to current USGA construction mix guidelines than the original underlying soil base.

Dr. Jim Murphy describes results of the comprehensive root zone mix project at the Rutgers Field Day in August 2005. The USGA, GCSAA, and other state and regional associations helped fund this landmark nine-year study.

Many older golf courses in cooler temperate climates have outstanding putting greens originally constructed and managed in this way. However, repositioning, expansion, or recontouring of putting greens is sometimes necessary to update older golf courses and accommodate modern playing standards. Use of sand-based construction in these cases can produce significant inconsistencies in playability and turf management that are undesirable. As a result, there is interest in mimicking push-up construction on older golf courses.

Our research corroborates field observations of excellent putting greens maintained on sand-topdressed push-up greens. However, mimicking push-up construction has two major challenges: developing a successful profile design and identifying a builder experienced in construction means and methods compatible with manipulating and layering of finer-textured soil. Detailed specifications for this type of construction are not available due to the wide variation in soil textures and layering used to construct and manage putting greens on older golf courses. Thus, it is essential to work with a qualified agronomist who can assist in rootzone design and the interpretation of physical property tests of potential construction materials (soils).

Inclusion of an improved sand-based layer in the uppermost part of the profile is an essential design element in this type of construction. Care must be taken to avoid working the native finer-textured soil when it is too wet or too dry. It is essential that the builder have an understanding of how to till and firm the soil so that excessive settling is avoided, yet prevent excessive compaction during the construction process. Lightweight equipment with low p.s.i. tracks or turf tires must be used to avoid excessive compaction of the soil. These can be difficult challenges for inexperienced builders, so diligence in selection is critical.

SUMMARY

Research clearly documents the benefits of properly amending sand for construction of putting green rootzones. Justifications for not amending sand are clearly based on short-term cost savings and not improvements in long-term management or costs. While IAs can improve some characteristics of a sand mix, a cost-benefit analysis should be considered since IAs are not typically cost effective in a sand mix where high-quality sand and organic amendments are readily available at moderate shipping costs. Compost can also be a highly effective amendment in a sand mix; however, it is critical that a high-quality and consistent supply of compost be identified before selecting. Push-up putting green construction may be appropriate in situations requiring expansion, recontouring, or movement of greens on older golf courses. Push-up construction requires a thorough understanding of finer-textured soil and layering (i.e. a skilled agronomist) as well as an experienced builder to be successful.

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