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Selecting the Right Grass

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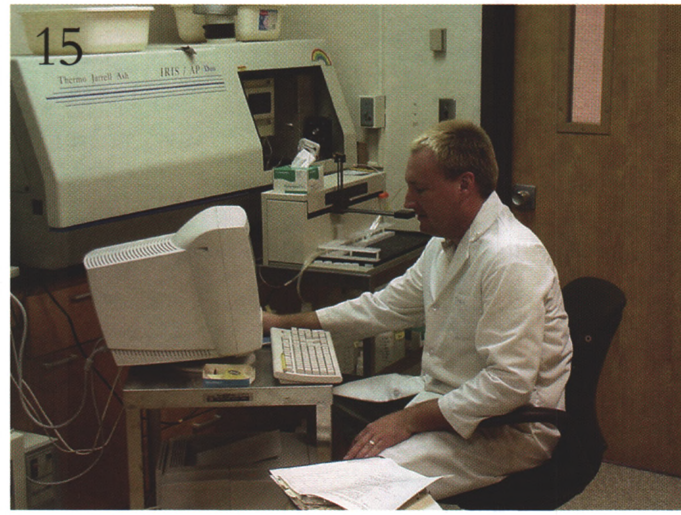
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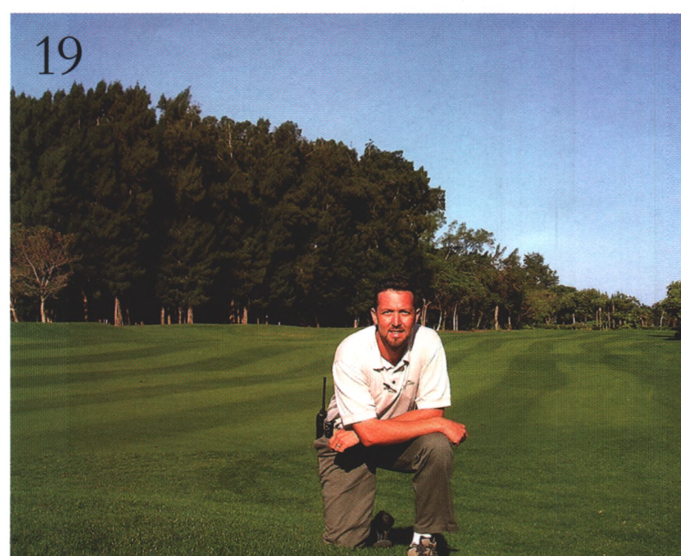
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Cover Photo
Selecting the proper turfgrass species and varieties for a new golf course project is a critically important first task.

Selecting The Right Grass

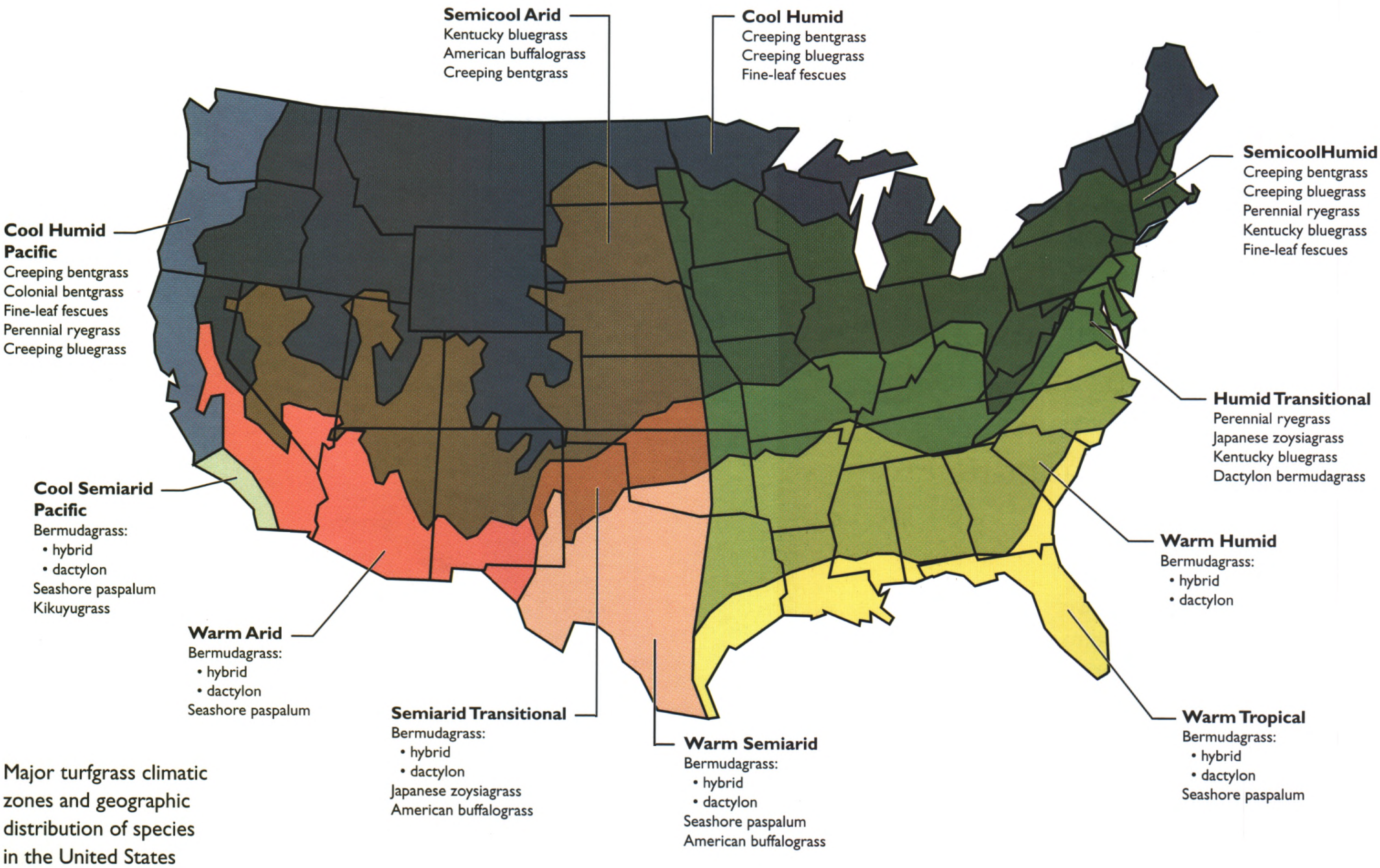
With many warm-season turfgrass options available, determining the most appropriate is a daunting task.

BY JOHN FOY

Ten years ago, if you were building or renovating a golf course in the southern portion of the United States where warm-season turfgrasses have traditionally been used, grass selection was a simple proposition. Bermudagrass, and primarily the hybrid cultivar Tifway (419), was the standard and was considered to have very good overall adaptation for tee, fairway, and rough areas. Similarly, Tifdwarf bermuda was the standard for putting greens. However, golfer demands and expectations for fast putting speeds have also resulted in efforts to push bentgrass further south. In less than a decade, the turfgrass selection equation has become much more complicated.

Introduction of the ultradwarf bermudagrasses — Champion, Floradwarf, TifEagle, and MiniVerde — started the revolution and raised the bar for quality and conditioning of warm-season putting greens. The increase in the number of entries in the National Turfgrass Evaluation Program (NTEP) from a total of 26 (16 seeded, 10 vegetative) in 1992 to 42 (29 seeded, 13 vegetative) in 2002 clearly illustrates that a lot of work has been put forth to develop additional bermudagrass options for fairways and roughs. Furthermore, while bermudagrass has long been the king of warm-season grasses, an increasing number of seashore paspalum and zoysiagrass cultivars or varieties are available today.

There has been a big slowdown in new course construction in the United States; however, there has also been a surge in course renovation projects. In Florida alone, there were more than 50 renovation projects slated for 2006, and it is estimated that a similar amount of work will be undertaken annually for the next several years.



Major turfgrass climatic zones and geographic distribution of species in the United States (adapted from Beard 2002).

Resurfacing of putting greens and conversion to an ultradwarf cultivar are the driving forces behind much of the project work being undertaken. Yet, there are also complete course renovation and replanting projects being performed, and there are more than 100 courses being built across the country annually. To assist in selecting the best suited and appropriate warm-season golf course turfgrass options, the following is a review of their general characteristics along with guidelines to use in the decision-making process.

RANGE OF ADAPTATION

Turgrasses have long been separated into two basic groups based on their climatic adaptation and specifically the temperature range required for optimum growth. The warm-season turfgrasses grow best in the temperature range of 80 to 95 degrees F, whereas the cool-season turfgrasses exhibit optimum growth when temperatures are in the 60 to 75 degrees F range. In general, warm-season turfgrasses have better drought, heat, and wear tolerance compared to cool-season species, but they enter into a dormant stage and go off-color (brown) when temperatures in the 50-degree F range or colder occur. Poor tolerance to cold winter temperatures and winter kill are limiting factors in the distribution and use of warm-season species through the upper transition zone and northern portion of the United States. Geographic distribution of the warm-season turfgrasses in relation to the major climatic zones of the U.S. is depicted in Figure 1.

There are approximately 14 warm-season species utilized for turfgrass purposes around the world.[2] However, for the remainder of this article, discussions will focus on bermudagrass (*Cynodon* species), seashore paspalum (*Paspalum vaginatum*), and zoysiagrass (*Zoysia* species) because they are currently the main species used on primary playing surfaces in North America. Buffalograss (*Buchloe dactyloides*) is a native species of the Great Plains of North America and is extremely well adapted to semi-arid regions. Although improved cultivars have been developed over the past few years, it is definitely under utilized.

SPECIES/CULTIVAR ADAPTATION

For selecting the best-suited warm-season species and cultivar, a number of factors need to be taken into consideration. Across the country, irrigation water availability and quality are major concerns for golf courses. This brings to the forefront water usage rates, salinity tolerance, and drought resistance as factors to consider. Also, it is essential that every effort be made to minimize potential negative environmental impacts and conserve resources. Thus, pest problems and management inputs such as fertilizer requirements need to be components in the selection equation.

WATER USAGE, SALINITY TOLERANCE, AND DROUGHT RESISTANCE

As a group, warm-season grasses have lower water use rates (based on mean summertime evapotranspiration rates) compared to cool-season species. Buffalograss is at the head of the pack and has a relative ranking of very low water usage. It is followed by bermudagrass and then zoysiagrass, with low to medium rankings. Based on previous research, seashore paspalum is also ranked as having a medium water usage rate relative to these other species.

New bermudagrass, zoysia, and paspalum cultivars have become available since these water use rate studies were conducted, and variability among cultivars does occur. This is especially true with seashore paspalum. There have been advertising and marketing claims that seashore paspalum needs only 50% of the irrigation of bermudagrass, but research conducted by Dr. Bob Carrow at the University of Georgia determined that water requirements of SeaIsle I, which was the most drought-tolerant paspalum, are similar to Tifway bermuda.[3] With proper nitrogen fertilization and irrigation management to maintain maximum root system development, an additional reduction in water usage of SeaIsle I is possible. In another study conducted at Clemson University, it was found that improvements in water use rates and drought tolerance have been achieved with some of the newer bermudagrasses that are now available.[1] Additional unbiased cultivar and species evaluation of this very important performance character is needed.

In the past, salinity and water quality problems were, for the most part, only an issue in arid to semi-arid regions. Degradation of ground and surface water supplies along with increased use of effluent and non-potable water sources, however, has resulted in salinity tolerance becoming a concern in humid regions as well. Bermudagrass, and in particular the hybrid cultivars, are ranked as having very good salinity tolerance along with zoysiagrass. Seashore paspalum is considered the most salt tolerant of all warm-season species, and several cultivars are available today that also have improved turfgrass quality characteristics. Once again, there is variability in salinity tolerance of the paspalums, and some selections can survive irrigation with brackish or even ocean water. However, additional management inputs are required when irrigation water contains moderate to high salt levels. In particular, larger quantities of irrigation water must be available for periodic leaching of salt accumulations out of the rootzone. Buffalograss is ranked as having fair salinity tolerance.

With irrigation restrictions becoming a fact of life in more areas of the country, the ability to survive drought conditions has become an even more important factor in turfgrass selection. Bermudagrass, buffalograss, seashore paspalum, and zoysia get relative rankings of superior, excellent, to good as far as their drought resistance. Avoidance, tolerance, and/or escape are the mechanisms by which turfgrasses achieve drought resistance. Bermudagrass enters into a dormant stage and thus uses an avoidance mechanism with the onset of drought stress. The brown, off-color character that results is not aesthetically attractive, but as long as excessive wear or damage does not occur, a turf cover will persist. Also, with reestablishment of adequate soil moisture by rainfall or irrigation, a rapid recovery and green-up response will occur. Furthermore, it has been observed in the field that the green-up and recovery response of some of the new fine-leaf zoysiagrasses is faster than bermuda.

Even when maintained at very low heights of cut, seashore paspalum can produce an extensive root system.

With the ability to produce an extensive and deep root system, seashore paspalum is able to utilize moisure from lower depths in the soil and is an example of drought tolerance. However, with the onset of drought stress, shoot die-back occurs and turf coverage and surface quality deteriorate to an unacceptable condition. Excellent root and rhizome survival does allow full recovery, but redevelopment of a good quality turf cover can take significantly longer when compared to bermuda and zoysiagrass.

Not forgetting about buffalograss, it can persist on as little as two inches of rainfall or irrigation annually. However, attempts to utilize it in the humid eastern part of the country have met with limited success because of too much rain.

PEST PROBLEMS

To produce and maintain top-quality playing surfaces in keeping with current golfer expectations, controlling insect, disease, and weed problems is necessary. Yet, pesticide usage on golf courses has and will continue to be a major concern because of perceived and potential impacts on the environment. Treatments can also add significantly to annual course operating costs. Clearly, selecting species and cultivars that have pest resistance or tolerance is advisable.

In humid and tropical regions, insect and disease pressure can be very high. Mole crickets have long been the number-one pest problem of bermudagrass-based golf courses in the lower Southeast and Florida. Without annual insecticide treatments, significant turf damage and loss will occur. At the long-running bermudagrass breeding program at the Coastal Plains Experiment Station in Tifton, Georgia, Dr. Wayne Hanna found that there was a consistent pattern of lower mole cricket numbers and reduced damage in TifSport plots compared to the other cultivars being evaluated. This is considered a "non preference" characteristic as opposed to resistance. However, on golf courses where TifSport has been used, insecticide treatments for mole cricket control have still been required.

Fall, early winter, and spring preventive fungicide treatments on fairways can be required for control of zoysia patch and large patch disease on zoysiagrass. Large patch disease has also been experienced on seashore paspalum, and while extensive turf loss has not occurred, preventive fungicide treatments are being made. Pest tolerance/resistance is one of several important selection criteria.

Foliage-feeding caterpillars (army worms and sod webworms), grubs, billbugs, and chinch bugs are some of the other common insect pests encountered on warm-season golf courses. With increased use of seashore paspalum on courses in Florida, it has been found that insect pests similar to those that plague bermudagrass are being experienced. This is especially true as far as sod webworms and army worms. More attention is being given to screening for and identification of insect resistance mechanisms with all of the warm-season turfgrasses, and with luck this will pay dividends in the near future.

Plant parasitic nematodes are replacing mole crickets as the number-one pest problem of Florida courses. With limitations on nematicide treatments today and into the future, dealing with this pest problem is naturally a major concern. Turf resistance to nematodes would be a highly desirable trait, but it is not an option at this time. Thus, an alternative strategy would be to select turfgrasses that are able to produce extensive, deep root systems and also have an aggressive growth habit that provides increased tolerance to nematodes. Seashore paspalum and some of the new bermudagrass cultivars have exhibited improved tolerance to nematodes because of these growth characteristics.

Compared to cool-season turfgrasses, the warm-season species have significantly fewer disease problems. The aggressive growth habit of bermudagrass provides tolerance to most diseases, even though fungal pathogens are always present. Very rarely do disease activity and turf damage reach the point that fungicide treatments can be justified on bermudagrass tees and fairways. Spring Dead Spot (SDS) disease is the exception and is considered a major problem on courses in the transition zone. Identification of tolerant or resistant cultivars is desperately needed.

In the fall, as the growth rate of both zoysia and seashore paspalum naturally begin to slow down, outbreaks of patch diseases have been experienced on numerous courses. Large patch (*Rhizoctonia solani*) and yellow patch (*R. cerealis*) are the main problems for zoysia fairways, while large patch has been identified on paspalum. Also, dollar spot (*Sclerotinia homeocarpa*) outbreaks have been experienced on paspalum. Preventative fungicide treatments in the fall are being recommended for control of patch disease problems through the winter and spring and until sustained growth resumes. With seashore paspalum, improper nitrogen fertilization and irrigation can contribute to increased patch disease incidence, but it should be pointed out that no cases of devastating turf damage and loss have been

A classic case of bermudagrass winterkill. Replanting with a more cold-tolerant cultivar could help minimize recurrence of this problem.

reported. Nevertheless, the disease problems that have been experienced to date and increased fungicide usage are concerns.

A very dense turf is a key component minimizing weed invasion, and this is a common characteristic of zoysiagrass, seashore paspalum, and bermudagrass. There are, however, several opportunistic and highly invasive annual and perennial weeds that can become established in all warm-season turfgrasses. Thus, herbicide treatments are needed to maintain acceptable levels of weed control, and with both zoysia and bermuda, an adequate arsenal of pre- and post-emergent materials is available. The list of options for seashore paspalum is also growing.

The superior salinity tolerance of seashore paspalum also makes topical applications of salt a weed control option. Directly applying rock salt or spraying ocean water on weeds can provide acceptable control of a number of problem species. However, this strategy has not worked satisfactorily for controlling bermudagrass infestations in paspalum. Nor are there any selective herbicides currently available that provide good control/suppression of bermudagrass without also causing unacceptable damage to the paspalum. Most golfers do not recognize this weed problem, and thus it can be debated as to whether or not it is a truly significant problem. However, at least in Florida, a lot of time and effort are being devoted to bermudagrass control.

FERTILITY REQUIREMENTS

Fertilization is a basic and necessary turfgrass and golf course management practice. However, as with pesticides, potential negative impacts on groundwater and/or surface water supplies are major concerns with fertilizer usage. Fertilizer can also be one of the bigger line items in the annual operating budget for a course. Thus, a low fertilizer requirement is a highly desirable characteristic. Bermudagrass has a relatively high fertilizer requirement, and in the past excessive nitrogen applications were unfortunately all too common in an effort to produce a darker green color. Bermuda cultivars are now available that perform satisfactorily with lower fertilizer inputs and also have a more aesthetically pleasing color character.

Seashore paspalum is extremely efficient as far as nitrogen utilization is concerned, even on infertile, sandy soils; fertilization requirements can be less than half of what is required for bermudagrass. Zoysiagrass also requires less fertilization compared to bermuda, but it has been found that the new, finer-leaf cultivars require more nitrogen than older cultivars.

COLD TOLERANCE

Throughout the transition zone of the United States, cold tolerance is a critically important selection factor with warm-season turfgrasses. Even in the mid to lower South, where the ground does not freeze for extended periods of time, periodic winter kill of bermudagrass can occur. This and its brown color when it is dormant have been limiting factors in its use. Excellent strides have been made in the development of more cold-tolerant bermudagrasses, increasing its range further north in the transition zone.

The cold tolerance of seashore paspalum is similar to that of bermudagrass, but further evaluation of this characteristic is also needed. In areas such as Central to South Florida, where bermudagrass does not go fully dormant and brown, paspalum maintains a greener color, very similar to a winter overseeding cover. Yet, cart traffic and wear damage problems similar to what is experienced with bermuda can occur when moderate to heavy play is hosted. It has also been found that seashore paspalum transitions out of overseeding smoothly and better than bermudagrass.

Zoysiagrass has better cold tolerance relative to bermudagrass. This and its ability to maintain a greener color character longer into the fall are factors in its increased use. Yet, once again, variability in cold tolerance occurs among the zoysias, and some of the new fine-leaf types have significantly reduced tolerance compared to Meyer and Emerald.[4] Furthermore, good drainage, minimal shade, and proper management play a role in minimizing the potential for winter kill with all warm-season turfgrasses.

SUNLIGHT REQUIREMENTS

All plants require sunlight for photosynthesis and growth, and as a group the warm-season turfgrasses have a high light requirement. Lack of shade tolerance has long been recognized as a major limiting factor with bermudagrass, and eight hours of direct sunlight is considered the minimum requirement for sustained healthy growth. Seashore paspalum was initially thought to be very similar to bermuda as far as its tolerance to tree shade. It has been found, however, that paspalum is persisting and performing satis-

Lack of a selective herbicide to control bermudagrass infestation in seashore paspalum is a problem, especially when converting from one species to another.

factorily in shaded locations where bermuda failed. Paspalum is also more tolerant to periods of reduced sunlight intensity due to heavy, persistent cloud cover.

Zoysiagrass has moderate shade tolerance, and in the past it has been used as an alternative to bermuda. Development of more bermudagrasses with shade tolerance has been a goal of some breeding programs, and there are commercially available cultivars now available that have performed as well as, if not better than, zoysia in shaded locations.

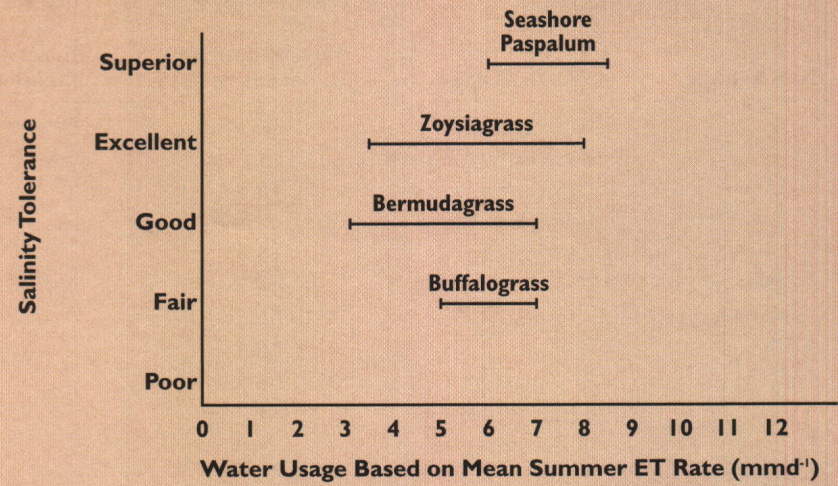
OTHER CONSIDERATIONS

Going beyond the basic factors that affect warm-season turfgrass growth, establishment rate, wear tolerance, and recuperative ability are characteristics that need to be considered in the selection process. Until recently, the best quality cultivars were vegetatively propagated, and thus sprigs or sod has been used for establishment. When environmental conditions are favorable to sustain active growth in the summertime, both bermudagrass and seashore paspalum have a very rapid establishment rate. A full turf cover and appropriate conditions can be developed in as little as 8-12 weeks after sprigging. If poor quality irrigation water must be used during the grow-in process, however, the rate of paspalum establishment will be significantly slower. A number of seeded bermudagrasses are now available that have comparable quality to the vegetative hybrids and, in general, their establishment rate is similar. Zoysia establishment from sprigs is slow, and thus strip or solid sodding has typically been employed despite the additional cost.

As a group, bermudagrass, seashore paspalum, and zoysiagrass have very good wear tolerance. The aggressive growth habit of bermuda also provides it with good recovery from damage. Paspalum has good recuperative ability as well, but its recovery from mechanical damage such as mower scalping and drought stress can be quite slow. The inherently slow growth rate of zoysiagrass is a problem as far as recovery from damage is concerned.

Aesthetics and play characteristics are two other factors that must be considered. From the purely agronomic standpoint, color is a minor consideration, but American golfers expect and demand lush green playing surfaces. Both seashore paspalum and zoysiagrass have a "greener" color compared to bermuda, and this color is very

Table 1
Summary and Comparison of Relative Salinity Tolerance to Water Usage Rates



appealing to most golfers. Furthermore, mower striping patterns are more pronounced with both paspalum and zoysia compared to bermuda. The combination of these characteristics results in an aesthetic "WOW factor" that is being heavily weighted in the selection process.

Hybrid bermudagrasses, seashore paspalum, and the fine-leaf zoysias all have a very dense and upright shoot growth character, providing an excellent tee and fairway surface condition. The "stiffer" leaf of paspalum and zoysia also provides greater ball support so that it sits right on top of the turf surface. Some, but not all, golfers like the very tight and firm fairways that can be produced. There are also distinct differences in the play character of the putting green surrounds and roughs of the warm-season grasses, but that's a topic for another time.

With regard to warm-season putting surfaces, the old standard of Tifdwarf is not a bad grass; with the tools available today, appropriate and good quality conditioning for daily play can be provided. However, the ultradwarf cultivars have raised the bar as far as the level of conditioning and quality that can be provided. As a result, there is no longer the push to try to maintain bentgrass putting greens in hot and humid regions where it is not adapted to survive on a year-round basis. The ultradwarfs are certainly not bullet proof, but along with being better adapted for meeting current golfer demands, they have exhibited a more stable performance character compared to Tifdwarf. There is a consensus opinion that the ultradwarfs have replaced Tifdwarf as the standard.

Table 2
Summary of Mean Rates of Turfgrass Evapotranspiration

Turfgrass Species[1]			
Cool Season	**Warm Season**	**Mean Summer ET Rate (mmd⁻¹)[2]**	**Relative Ranking**
	Buffalograss	5-7	Very low
	Bermudagrass hybrids	3.1-7	Low
	Centipedegrass	3.8-9	
	Bermudagrass	3-9	
	Zoysiagrass	3.5-8	
Hard fescue		7-8.5	Medium
Chewings fescue		7-8.5	
Red fescue		7-8.5	
	Bahiagrass	6-8.5	
	Seashore paspalum	6-8.5	
	St. Augustinegrass	3.3-6.9	
Perennial ryegrass		6.6-11.2	High
	Carpetgrass	8.8-10	
	Kikuyugrass	8.5-10	
Tall fescue		3.6-12.6	
Creeping bentgrass		5-10	
Annual bluegrass		>10	
Kentucky bluegrass		4->10	
Italian ryegrass		>10	

[1]Based on the most widely used cultivars of each species

[2]Mean rates of water use based on research by Aronson et al. 1987a; Aronson et al. 1987b; Beard 1985; Biran et al. 1981; Carrow 1991; Gibeault et al. 1985; Johns, Beard, and van Bavel 1983; Kim and Beard 1988; Kneebone and Pepper 1982; Kneebone and Pepper 1984; Kopec et al. 1988; Krans and Johnson 1974; Meyer, Gibeault, and Younger 1985; O'Neil and Carrow 1983; Pruitt 1964; Shearman and Beard 1973; Sifers et al. 1987; Tovey, Spencer and Muckell 1969; van Bavel 1966; and Younger et al. 1981.

Table 3
Relative Salt Resistance of Several Turfgrass Species Used in the United States

Turfgrass Species*		
Cool Season	**Warm Season**	**Ranking**
Alkaligrass	Seashore paspalum	Excellent
Creeping bentgrass Tall fescue	Zoysiagrass St. Augustinegrass Bermudagrass hybrids Bermudagrass Bahiagrass Centipedegrass Carpetgrass	Good
Perennial ryegrass Fine fescues	Buffalograss	Fair
Kentucky bluegrass		Poor

*Based on the most used cultivars of each species

Similar to Tifdwarf, appropriate and good quality conditioning can be produced with seashore paspalum putting greens. However, maintaining a consistent putting speed through the day and keeping speeds comparable to the ultradwarfs have become concerns at some facilities. Growth regulator treatment programs can help, but at this time, mowing and rolling inputs are much higher relative to what is conducted with bermuda greens.

Finally, with comparison of a number of the selection factors discussed in this article, seashore paspalum and zoysiagrass have advantages over bermudagrass. Absolutely, if a poor quality saline irrigation water source is a factor, paspalum is a logical choice. Also, the cold tolerance of zoysiagrass favors its use in the most northern portion of the transition zone. However, in regions where bermudagrass is well adapted and has performed satisfactorily for many years, it would be urged not to put too much emphasis on the aesthetic "WOW" factor. With both paspalum and zoysia, mowing and cultural management requirements, increased equipment maintenance costs, and having to conduct large-acreage preventive fungicide treatments can negate cost savings achieved in other areas.

For assistance in selecting the right grass, the logical starting points are the National Turfgrass Evaluation Program (NTEP) and state university trials in a similar climatic zone. The Green Section regional agronomists are also an excellent source of unbiased information on species and cultivar performance on area courses. While not always an option, on-site evaluation is strongly encouraged, and at least two to five years needs to be allowed to gain a good understanding of performance and management requirements.

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JOHN FOY *has spent more than 20 years helping golf courses select the right warm-season turfgrasses.*

Physical Soil Testing

Testing by accredited laboratories can have a positive impact on the profitability, playability, and longevity of a golf course.

BY SAM FERRO

Physical testing labs provide a variety of soil testing and agronomic consulting services that can offer valuable insight when evaluating the current condition of your turf. Labs are also commonly used during construction and renovation projects to provide assurance that proper materials are being used. This article describes some common testing procedures, when testing should be performed, and how testing can benefit the golf course.

PARTICLE SIZE ANALYSIS

Particle Size Analysis (PSA) is one of the most versatile and descriptive analyses performed on soil materials. The PSA should be the first test performed when evaluating the potential for a sand or soil to be used in fairways, greens, bunkers, rootzone mixes, and topdressing. It is also an excellent diagnostic tool. Particle size results can provide an indication of a soil's stability/potential for compaction, tendency to drain/retain moisture, and compatibility with existing site soils.

During a construction project, PSA testing is used as an indicator of whether a supplier's materials (greens, tees, and bunker sands, topdress, capping sand) are consistent. The PSA test is usually performed on every lot of sand/soil delivered to the golf course. If the PSA results are consistent from lot to lot, then the sand is considered consistent and acceptable. If the PSA results show excessive variance, then it may be grounds for rejection.

The PSA includes a determination of the sand, silt, and clay content, and the sand grain distribution. Parameters such as the D_{15} (particle diameter at which 15% of the particles present are finer) and D_{85} (particle diameter at which 85% of the particles present are finer) are determined. A textural classification based on the United States Department of Agriculture (USDA) can also be provided.

The PSA is composed of two distinct phases. One phase is the textural analysis of a soil where the sand, silt, and clay contents are determined. Another phase of the PSA is the sand grain distribution analysis. The sand grain distribution is determined via the use of a stack of sieves with decreasing sized openings from the top sieve to the bottom, and it is based on the USDA sand distribution definition. Sand grain distributions should be determined on the sand component that has had all of the silt and clay removed.

For most high-performance turf systems, it is desirable to have a minimal amount of silt and clay present. The sand particle sizes should be distributed over a range of 0.05mm to 2.00mm, with most of the particles being between 0.25 and 1.00mm. Significant quantities of particles greater than 2mm can cause problems later if the same sand is used for topdressing. Significant quantities of particles smaller than 0.15mm can negatively affect drainage. The uniformity coefficient (Cu), which is a calculation indicating the distribution of the particle sizes of the soil, is usually in the range of 2 to 4. Cu values higher than 4 suggest that the soil particles may pack too tightly and produce a hard surface and poor drainage. Cu values lower than 2 suggest that the materials may not pack well enough, producing a loose surface and a lack of moisture retention.

PHYSICAL PERFORMANCE EVALUATION

Building new greens? Then a physical performance evaluation (PE) should be performed along with the particle size test. The physical performance evaluation is used when designing and evaluating rootzone mixes. It is the key test for determining the need for rootzone amendments, and for determining how much amendment is needed to optimize performance.

Having problems with drainage or moisture retention with your current greens? Want to benchmark the performance of your greens? The PE test is an excellent source of information regarding the performance of existing rootzones. It is often used as part of a diagnostic profile core assessment. The results of the diagnostic core evaluation can be used to provide recommendations regarding green reconstruction, green modification (removal of surface layers), and modification and verification of maintenance practices such as topdressing and core aeration.

The physical performance evaluation provides information about the saturated hydraulic conductivity (which is often referred to as K-Sat or infiltration rate), bulk density, particle density, and porosity characteristics of a proposed rootzone material. The methods used for determining the parameters are based on standard agronomic test methods and the USGA protocol. Testing involves compaction of a sample at field capacity (or undisturbed cores for existing rootzones), followed by determination of the listed parameters.

The PE analysis is a useful tool for determining the suitability of submitted materials for use in turf systems such as the USGA putting green system. Important parameters that aid in this assessment are the K-Sat and capillary porosity values. The PE is performed on a compacted sample (samples are compacted using a 14.3 ft.-lbs./in^2 force) and represents a worst-case scenario in regard to the rootzone performance.

Infiltration Rates as determined in the lab are a measurement of how fast water penetrates and drains through the test sample. Infiltration rates are determined using a constant head saturated hydraulic conductivity (K-Sat) method. K-Sat results are useful when evaluating greens, tees, bunkers, and even fairway performance.

The desired K-Sat on any given project is dependent on a variety of factors, including usage, typical rainfall and evaporation conditions, and water quality. The USGA recommends that K-Sat values greater than 6 inches/hour are acceptable for golf greens. Other construction methods suggest that higher or lower rates are desirable. Regardless of the desired rate, care should be utilized when evaluating this result. Reproducibility of results within a single laboratory is typically around +/- 3 in./hr. Results among different labs can show a high amount of variability.

The **Porosity** data are broken up into three sub-categories: total porosity (the amount of space between the soil particles), capillary porosity (the pore space that is water-filled), and non-capillary porosity (the pore space that is air-filled). It is desirable for a rootzone to have approximately half of its volume solid and half pore space. The amounts of air-filled and water-filled pore spaces ought to be present in roughly equal amounts. This should provide advantageous conditions for root growth, proper oxygen levels, and good mineral and water holding.

Bulk Density is a measurement of the mass of the bulk rootzone material per unit volume. Bulk density results can be an indication of excess compaction or loose or unstable soil. Most turf systems will have a bulk density between 1.3 and 1.6 grams/cubic centimeter. Higher values may indicate the turf system is too hard, and lower values may indicate the turf system is too soft.

Particle Density is a measurement of the mass of the individual rootzone particles per unit volume. The primary use for particle density is in calculation of the porosity values. Caution should be used to avoid confusing particle density with bulk density. Bulk density is a measurement of the particles plus the air space between them, while the particle density excludes the air. Particle density for sand is around 2.65 g/cc.

Organic Matter (OM) is reported on a dry weight basis in order to provide the most accurate assessment of the rootzone. Soils and rootzone mixes used in sand-based golf and sports turf usually contain less than 2% organic matter by dry weight.

Organic matter testing is used as an indicator of whether the rootzone mix is consistent during construction projects. The OM test (along with particle size) is usually performed on every lot of rootzone mix that is to be delivered to the golf course. If the OM, PSA, and performance results are consistent from lot to lot, then the mix is considered consistent and acceptable. If there is excessive variance, then it is grounds for rejection.

BUNKER EVALUATION

Choosing a bunker sand can be like trying to hit a moving target. Bunker sand preference among golfers is highly personal and often inconsistent. What's thought of as a good bunker by one golfer may be despised by others. Laboratory testing can help to provide a consistent guide during the bunker sand selection process.

Bunker sand evaluation in the laboratory is a process that involves several tests. Sand is tested for particle size, penetrometer value, infiltration rate, crusting, setup, shape, and color. This evaluation process provides a good indication of how the sand will perform in the bunker and affect nearby greens.

The performance aspects of bunker sand involve ball impact/ball lie characteristics as well as maintenance factors. The performance of a particular bunker sand is largely the result of the sand size distribution and particle shape. Infiltration rate, crusting, and setup are negatively affected by very fine sand, silt, and clay. Thus, a minimal amount of these particles is usually desirable. Sand shape has an effect on ball lie. Angular sands usually provide a better lie than round sands.

GRAVEL DISTRIBUTION

Gravel testing is usually performed almost in conjunction with some type of construction. It is only occasionally used for diagnostic purposes. Gravel is typically used to aid the drainage and/or water-holding capabilities of a drainage system. The gravel is at the bottom of the turf system or sand bunker, with the sand or rootzone medium on top.

Drainage gravel is often selected after choosing the rootzone materials. This is because of concern about the "bridging and permeability" between the rootzone material and the gravel.

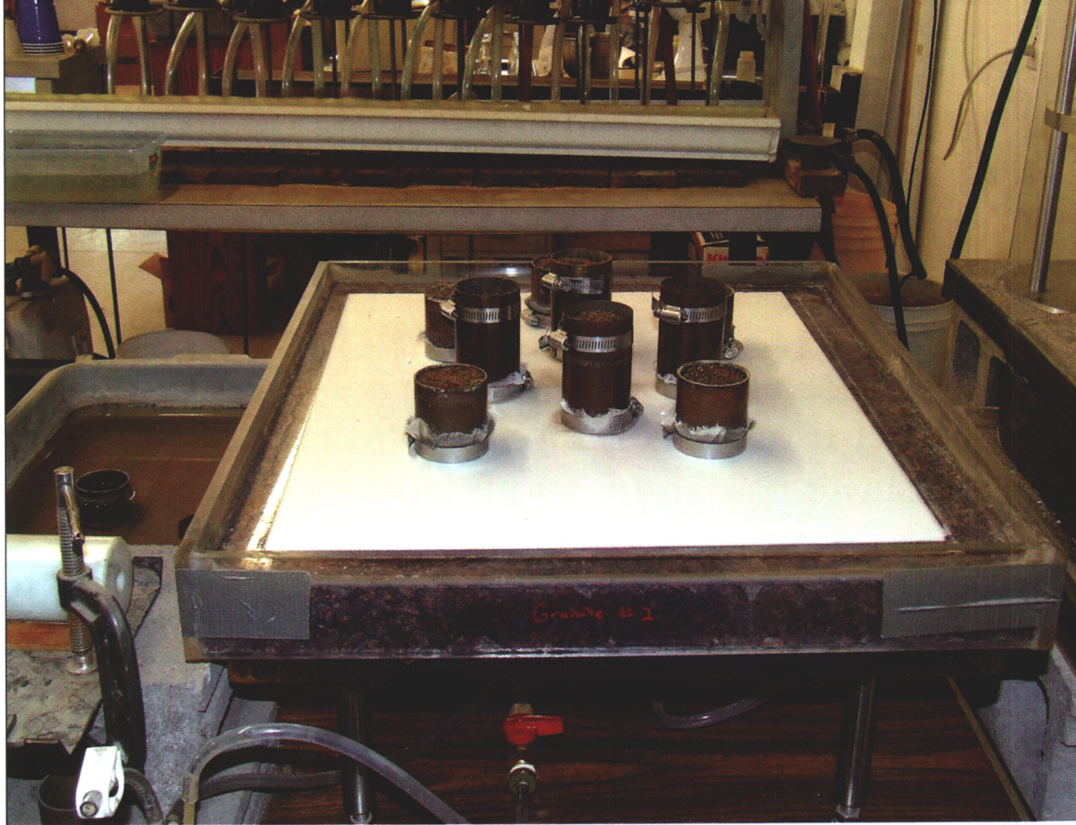
Bridging refers to using rootzone material and gravel of the proper sizes so that the rootzone mix will stay suspended over the gravel. If the rootzone particles are too small in comparison to the size of the gravel, there is a potential for these materials to migrate down into the gravel over time. Permeability also refers to using rootzone material and gravel of the proper sizes. However, the goal of proper permeability is to ensure that there is a distinct difference in sizes between the gravel and rootzone layers. Proper permeability indicates that there will be a capillary break between the finer rootzone mix and the coarser gravel. The calculations for checking the bridging and permeability are:

Bridging: $D_{15gravel} \leq 8 \times D_{85rootzone}$

Permeability: $D_{15gravel} \geq 5 \times D_{15rootzone}$

Proper bridging and permeability are required for adequate water movement. Using properly sized gravel increases rootzone moisture retention, aids in maintaining uniform moisture levels across the rootzone, and ensures that excess water will move rapidly to the drains.

The gravel distribution test is analogous to the sand grain distribution. It is a measurement of the size distribution of gravel particles. Gravel used in greens and bunkers typically ranges in size from 1mm to 12.5mm.



Physical testing labs provide critical information on which to base decisions during golf course construction and renovation. A wide variety of soil testing can be done to offer valuable insight when evaluating the current condition of your turf and also provide assurances that proper materials are being used during on-course projects.

WATER RELEASE CHARACTERIZATION

Water release characterization testing is used for moisture release and retention evaluation. This test is especially useful for determining the water holding and drainage capabilities for systems in which the USGA protocols aren't applicable, such as fairways, native materials construction, and straight sand systems. Water release data can be used to evaluate the suitability of a soil or amendment to a particular turf system. A common use for water release testing is to aid in determination of sand/soil capping depths for fairways. It can also be directly related to moisture readings taken in the field and provide useful information for irrigation timing and water management practices.

The water release testing can be performed over a range of soil tensions from 15 bars (permanent wilt point), to ⅓-bar pressure (field capacity for continuous soil profile), to 30cm (tension at which USGA performance evaluation is performed), to 0cm (saturation). Water release testing involves obtaining water moisture measurements at several tensions. A series of moisture release points is then plotted to determine at which pressures a soil or amendment product releases moisture. This testing determines the depth of the rootzone necessary to hold the proper amount of moisture for plant growth.

TEST WITH THE BEST

Physical testing should be an important element in the management of an agronomically sound golf course. However, not all lab testing and reporting is created equal. Make sure to use a lab that is accredited for physical soil analysis for the golf industry. An accredited lab will have the knowledge and capabilities to ensure that the proper test procedures are performed and performed correctly. Some of the benefits of using an accredited testing lab include:

- Provides valuable information in determining the need for modifying, renovating, or rebuilding of existing golf courses.
- Provides assurance to turf managers, owners, and builders that quality materials are being used in construction projects.
- Provides a tool for assessment of the current condition of a turf system, and can aid in diagnosis of turf problems.
- Provides the information needed to help select good bunker sands based upon performance rather than appearance.
- Accredited labs provide data, reporting, and consulting that are an excellent resource for the turf manager.

In this magazine (and on the USGA Web site), there is a list of laboratories that are accredited by the American Association for Laboratory Accreditation (A2LA). These labs specialize in physical soil analysis for the golf industry and have demonstrated ongoing competency in testing materials specified in the USGA's Recommendations for Putting Green Construction. The USGA recommends that only A2LA-accredited laboratories be used for testing and analyzing materials for building greens according to USGA guidelines.

SAM FERRO *is the President of Turf Diagnostics & Design, an A2LA-accredited soil testing laboratory in Linwood, Kans.*

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Research *You Can Use*

Water and Turfgrass in the Arid Southwest

Water use rates of Tifway 419 bermudagrass, SeaIsle1, seashore paspalum, and inland saltgrass.

BY D. M. KOPEC, STEPHEN NOLAN, P. W. BROWN, AND M. PESSARAKLI

The arid Southwest is the fastest-growing area of the United States. With low annual rainfall and a dependency on well and river-fed water, golf courses and turfs in general are under close public scrutiny regarding water use. Advancements in irrigation systems and the use of weather stations to closely determine irrigation amounts based on grass type and local weather have been big improvements in reducing the amount of water applied to turfs. Other advancements that can help save water or provide acceptable turfs at less than optimal amounts of applied water include the development of heat-, drought-, and salt-tolerant turfgrasses. The advantage of the commercial acceptance of salt-tolerant turfgrasses is that they can use existing saline water supplies, which saves potable water from being used on turf.

Usually, but not always, salt-tolerant grasses also are drought tolerant. Seashore paspalum and inland saltgrass are two warm-season grasses that have very good to excellent salt tolerance. But what is the water use rate of these two grasses compared to the standard bermudagrass Tifway 419 in a semi-arid environment?

This is the logical place to start when answering questions about the water use rate of "new" grasses. This information will help in applied irrigation trials later on — which tell a golf course manager how much water the grass needs when the turf is expected to look good without struggling to absorb water from the soil as the rootzone moisture becomes depleted through evapotranspiration.

A field study is being conducted by the University of Arizona to determine the relative water use rates (ET) of two turf-type saltgrass single-plant selections (A-48, A-119), SeaIsle1 seashore paspalum, and Tifway bermudagrass. This information will show if either seashore paspalum or inland saltgrass uses less water than Tifway 419 bermudagrass under non-drought soil moisture conditions. Each of the four grasses are single-clone genotypes derived from one original plant each. The test is being conducted for two years. Results from the first summer (2005) are reported below. The second-year testing is in progress.

TESTING METHODS

A field test area surrounded by Tifway bermudagrass was planted to eight plots each of Tifway 419 bermudagrass, SeaIsle1 seashore paspalum, A-48 saltgrass, and A-119 saltgrass in late June of 2004. The paspalum and bermudagrass were plugged while the two saltgrass clones were sprigged with washed rhizomes in rows 10"-12" on center. Each grass appears in eight different plots in the test (32 plots total). At the center of each plot, a lysimeter is installed for measuring turfgrass water use. The lysimeter is made from 6" round PVC and has 12" of rootzone depth.

The terms *ET* and *consumptive water use* are interchangeable and represent the amount of water lost from grass leaves (transpiration) and that from the soil surface (evaporation). Thus the term ET. When ET is summed over a defined time period (days, weeks, or months), it is called *consumptive use*. ET is often expressed in millimeters per day. There are about 25mm in 1".

Grass water use was determined by weighing the 32 lysimeters at pre-dawn conditions each day for three consecutive days. The change in weight in a lysimeter is the result of water loss through ET.

After the lysimeters were weighed on the morning of the third day, they were removed and taken into the greenhouse, where they were mowed by hand while the field plots were mowed at the same height of 1.25". Then the field plots were fertilized as needed and irrigated overnight. At the same time, the lysimeter pots in the greenhouse were hand mowed and fertilized as necessary and then filled with water and drained. The next morning, at dawn, the lysimeters were weighed and placed in the field. This is the starting point for determining the ET. Each lysimeter was weighed again the following two mornings, and then the whole process was repeated.

The testing period for 2005 started on June 1 and ended on September 15, 2005. During this period, 56 individual ET measurement days (28 ET cycles) were measured. There were eight days on which rain negated functional measurements of ET, and ET is not measured on the day of field plot irrigation and mowing.

RESULTS AND DISCUSSION: ET ON A DAILY BASIS

Of the 56 measurement days, the main effect of the grass treatment was statistically significant on 50 ET measurement days. This means that there were true differences in water use among these three grass species. There were only three days in July, two days in August, and one day in September when this was not the case.

Seashore paspalum had the highest ET rate (used the most water) in mm/day, ranging from a high value of 11.8mm/day in June to 5.7mm/day in September, and during cloudy days in late July and August (humid monsoon). Seashore paspalum ranked first for ET on all 36 measurement days in June and July, and on 12 of 20 days in August and mid-September.

During June, A-48 saltgrass used the least amount of water in mm/day, followed by saltgrass A-119. Saltgrass A-119 was often similar in water use to Tifway bermudagrass, which was almost always lower in daily water use than seashore paspalum.

Observing daily ET values in July showed that paspalum used the most water, while either one of the two saltgrass accessions used significantly less than the paspalum. Tifway 419 bermudagrass had statistically similar water use rates to paspalum on 9 of 19 measurement days in August 2005.

For daily ET values in August and September, seashore paspalum ranked highest in ET on 12 of 20 ET measurement days, with no statistical differences for ET occurring between Tifway bermudagrass and paspalum on 4 of 20 ET determination days.

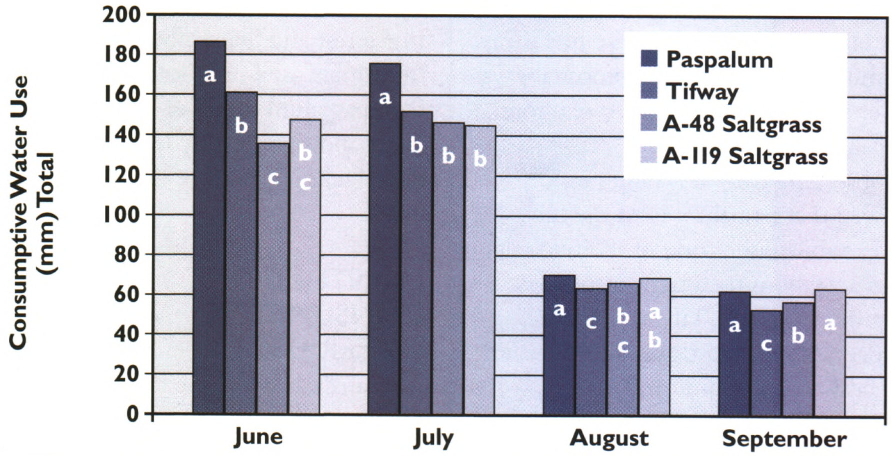
The relative ET rates of saltgrass increased as the summer season progressed into the monsoon. Saltgrass A-119 had rates similar to paspalum on 19 of 20 ET evaluation events, and A-119 saltgrass had the highest ET rate on 6 of these 20 measurement days. In August and September, Tifway bermudagrass used significantly less water than paspalum on 15 of 20 evaluation dates, and significantly less water than A-119 saltgrass on 8 of 20 evaluation dates.

MONTHLY CONSUMPTIVE WATER USE

This analysis was done to see what the water use was for each calendar month. Remember that it takes three days of measurements to get two days of ET, and that rain events negated water use calculations. This analysis was based on the consumptive water use for June, July, August, and midway into September. Results showed that paspalum had statistically higher ET values than all other grasses in June and July, and was

With low annual rainfall, water use is an important characteristic to consider when selecting grasses in the arid Southwest. After several weeks of drought, saltgrass (background) was able to maintain its green color longer when compared to the buffalograss (foreground) plots.

Figure 1
Total Consumptive Water Use by Month, 2005, University of Arizona
Grasses with the same letter in common are similar in water use



equal to saltgrass A-119 in August and September (Figure 1). Note that August is a humid month in the desert, and there were eight rainout events when ET measurements were not possible. Tifway bermudagrass always had statistically lower water use values than paspalum in each month. Saltgrass A-48 had statistically lower water use totals than A-119 saltgrass for the two-week measurement period in September. Otherwise, monthly ET (consumptive water use) values showed no statistical difference between the two saltgrass clones.

CONSUMPTIVE WATER USE FOR THE SEASON

Total consumptive water use (mm water) summed over the 56 measurement days ranged from 495.4mm for paspalum to 405.8mm for A-48 saltgrass (Figure 2). Both saltgrass clones and Tifway bermudagrass used less water over the measurement days than did seashore paspalum. Compared to SeaIsle1 seashore paspalum, Tifway bermudagrass, A-48 and A-119 saltgrass used 87%, 81%, and 86% of the water that seashore paspalum used over all 56 measurement dates when soil moisture was not limited.

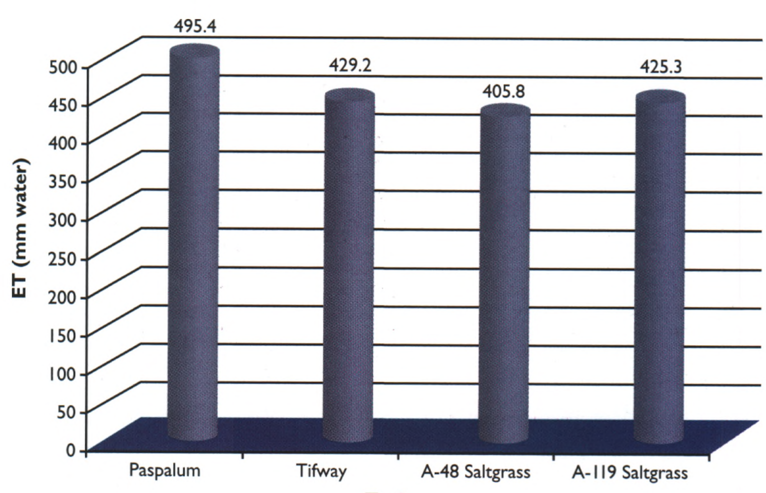
A summation analysis showed that for season water use totals: (1) SeaIsle1 paspalum used more water than Tifway bermudagrass, (2) SeaIsle1 seashore paspalum used more water than the other three grasses collectively, and (3) both saltgrass clones collectively used less water than paspalum and bermudagrass together. This test demonstrates that at a 1.25" mowing height, the consumptive water use rates differ between saltgrass, bermudagrass, and seashore paspalum in a semi-arid environment, when soil moisture is not limiting.

RESEARCH CONCLUSIONS

- Bermudagrass always had a statistically lower ET rate (and consumptive water use values) than seashore paspalum.
- Summation analysis showed that the combined water use of A-48 and A-119 saltgrass was statistically significantly less than that of the combined water use of SeaIsle1 seashore paspalum and Tifway bermudagrass for the sum of 56 daily ET measurements in 2005.
- Based on the measurement period of June 1 to September 15 (56 days), seashore paspalum used 495mm of water, while Tifway bermudagrass used 429mm, A-48 saltgrass used 405mm, and A-119 saltgrass used 425mm of water.
- For the total water use of 56 ET measurements, Tifway bermudagrass, A-48 and A-119 saltgrass used 87%, 81%, and 86% of the water that seashore paspalum used, respectively, when soil moisture was not limiting.

D. M. KOPEC, PH.D., *is a professor in the Plant Science Dept. at the University of Arizona. His colleagues* STEPHEN NOLAN, P. W. BROWN, *and* M. PESSARAKLI *also are associated with the University of Arizona.*

Figure 2
Total Consumptive Water Use (mm) of Four Grasses for 56 Days, Summer 2005, University of Arizona



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Research *You Can Use*

Soil Testing Methods for Sand-Based Putting Greens

Iowa State University research explores nutrient-holding capacity of putting green rootzones.

BY RODNEY ST. JOHN AND NICK CHRISTIANS

The procedure for measuring exchangeable basic cations involves using an extracting solution that is passed through a soil sample, removing all the exchangeable cations from the cation exchange sites. The collected solution is then taken to a machine and the exchangeable cation concentrations are measured. Then it is common to "add up" all of the exchangeable cations and their relative charges to provide an estimation of cation exchange capacity. This summation of exchangeable cations is referred to as the ECEC, or estimated cation exchange capacity.

To more accurately measure a soil's cation exchange capacity, CEC, a double extraction technique should be used that utilizes two processes: a saturating step and an extracting step. The soil sample is saturated several times with a saturating solution that is fairly concentrated with a known index cation (e.g., NH_4^+) that replaces all of the exchangeable cations in the soil with the index cation. The second solution, the extracting solution, is a concentrated solution of another cation (e.g., Mg^{+2}). The sample is washed several times with the extracting solution. The solution is collected from the sample and the NH_4^+ is measured. Essentially, one NH_4^+ ion will occupy one negatively charged site, and one can relate the number of NH_4^+ ions extracted from the sample to the number of negative charge sites in the soil, the CEC.

Rootzones of many putting greens, particularly in the Midwest, are constructed from calcareous sand, i.e. sands that contain more than 1% free calcium carbonate. However, current soil analysis methods can overestimate calcium and cation exchange capacity (CEC) of calcareous sands. Research conducted at Iowa State University investigated various methods to attain more accurate estimations of CEC of calcareous sand.

However, most soil test reports do not designate this distinction between ECEC and CEC because the difference between the ECEC and measured CEC is usually negligible. But many soil testing procedures dissolve calcium carbonate ($CaCO_3$), which will cause an increase in the measured extractable calcium concentration. Since the exchangeable cations are added together to create an ECEC, this dissolution will also increase the calculated estimation of the cation exchange capacity.

On the high-sand, low-organic matter, calcareous rootzones used for construction of some putting greens, the dissolution of calcium carbonate can greatly influence the results. Therefore, the objectives of this research were to determine the effects of $CaCO_3$ on different soil testing procedures and to make recommendations for soil testing methodology for sand-based putting greens.

EFFECT OF CALCIUM CARBONATE ON SEVERAL PROCEDURES

A set of manufactured sand samples was created for quantifying the effect of $CaCO_3$ on different analysis techniques for measuring exchangeable cations and

CEC. Twenty-four sand samples were created in the lab using a silica sand base and adding increasing percentages by volume of either a laboratory-grade $CaCO_3$ or local calcareous sand. The calcareous sand had 11% $CaCO_3$. There were 24 one-pound bags of silica sand mixed with either reagent-grade $CaCO_3$ or calcareous sand from which sub-samples were taken for each analysis. The extraction techniques for exchangeable cations, CEC and ECEC, performed in this study are listed in Tables 2 and 3.

WHICH EXCHANGEABLE CATION TESTS ARE BEST?

The different extractants affected the solubility of $CaCO_3$ in different magnitudes. The extractable Ca concentrations from sands amended with reagent-grade $CaCO_3$ were nearly double compared to Ca concentrations from sands amended with calcareous sand. This is to be expected, and it is attributed to particle size and purity. The laboratory-grade $CaCO_3$ was a finely ground pure powder, whereas the sand had a much larger particle size, and the individual particles of sand-based $CaCO_3$ probably contained impurities, both of which are going to cause a reduced dissolution rate.

Mehlich 3 dissolved a much larger proportion of lab-grade calcium carbonate than any other procedure, as much as 400% more. While Mehlich 3 did not appear to dissolve as much $CaCO_3$ from silica sands amended with natural calcareous sand as from lab-grade samples, Mehlich 3 should not be used to measure exchangeable cations or ECEC of calcareous sand samples, since there is such great potential for $CaCO_3$ dissolution.

The NH_4Cl (ammonium chloride) method (5), which utilizes calculations and corrections to estimate the amount of calcium carbonate that was dissolved, reduced extractable Ca concentrations compared to ammonium acetate at pH 7.0 (NH_4OAc pH 7.0) and Mehlich 3. But, due to the labor involved with the several post-extraction procedures needed and its limited effectiveness, it is doubtful that many routine soil testing laboratories will adopt this procedure.

Raising the pH of the industry standard ammonium acetate (NH_4OAc) solution from pH 7.0 to pH 8.1 reduced the Ca concentration of the soil extracts an average of 33%. Raising the pH of the industry standard NH_4OAc pH 7.0 procedure to a pH of 8.1 to limit $CaCO_3$ dissolution is recommended for calcareous soils (5) and appears to reduce $CaCO_3$ dissolution. Based on the results in this paper, measuring exchangeable basic cations of calcareous sand-based samples should be done by NH_4OAc at pH 8.1 because of its reduced $CaCO_3$ dissolution and its ease of use.

The average nutrient concentration recorded using the water extract procedure was considerably lower than the extractable cation concentrations. Moreover, the nutrient concentrations from the water extract procedure did not directly correlate with the extracted nutrient concentrations. Since the water extraction method only analyzes the soluble and solution phase elements, nutrient concentrations from water extraction techniques are going to be very small compared to exchangeable nutrient concentrations derived from chemical extractions.

The solution and soluble portions of nutrients in the soil are going to change easily and rapidly throughout the season due to fertilizer, irrigation, and rainfall

Table 1

List of "manufactured sand" samples created in the laboratory to measure the effects of $CaCO_3$ on different soil testing procedures for measuring exchangeable cations, CEC and ECEC. The amendments were either reagent grade $CaCO_3$ (Lab Grade) or a local calcareous sand (Calcareous) and were added by a percent volume basis. The 24 bags of air-dried sand mixed with amendment were sub-sampled for soil analysis.

Sample Number	% Silica Sand	% Amendment	Type of Amendment	% $CaCO_3$
1	100	0	Lab Grade[1]	0
2	99.5	0.5	Lab Grade	0.5
3	99	1	Lab Grade	1
4	98	2	Lab Grade	2
5	97	3	Lab Grade	3
6	96	4	Lab Grade	4
7	95	5	Lab Grade	5
8	90	10	Lab Grade	10
9	85	15	Lab Grade	15
10	80	20	Lab Grade	20
11	75	25	Lab Grade	25
12	70	30	Lab Grade	30
13	99.5	0.5	Calcareous Sand[2]	0.055
14	99	1	Calcareous Sand	0.11
15	98	2	Calcareous Sand	0.22
16	97	3	Calcareous Sand	0.33
17	96	4	Calcareous Sand	0.44
18	95	5	Calcareous Sand	0.55
19	90	10	Calcareous Sand	1.1
20	85	15	Calcareous Sand	1.65
21	80	20	Calcareous Sand	2.2
22	75	25	Calcareous Sand	2.75
23	70	30	Calcareous Sand	3.3
24	0	100	Calcareous Sand	11

[1]Reagent-grade calcium carbonate $CaCO_3$ (Fisher Scientific C64-500 CAS 471-34-1)
[2]Local calcareous sand with a $CaCO_3$ percentage of 11% determined gravimetrically (2)

Table 2
List of methods used to determine exchangeable cations of 24 samples of sand mixed with amendment

	Method	Reference
1	0.5*M* Ammonium Acetate pH 7.0 (NH_4OAc pH 7.0)	5
2	0.5*M* Ammonium Acetate pH 8.1 (NH_4OAc pH 8.1)	5
3	0.5*M* Ammonium Chloride pH 7.0 (NH_4Cl)	5
4	Mehlich 3	1
5	Water Extract	4

Table 3
List of methods used to determine cation exchange capacity (CEC) and estimated cation capacity (ECEC) of the 24 samples of sand mixed with amendment. ECEC was determined by summation of exchangeable basic cations.

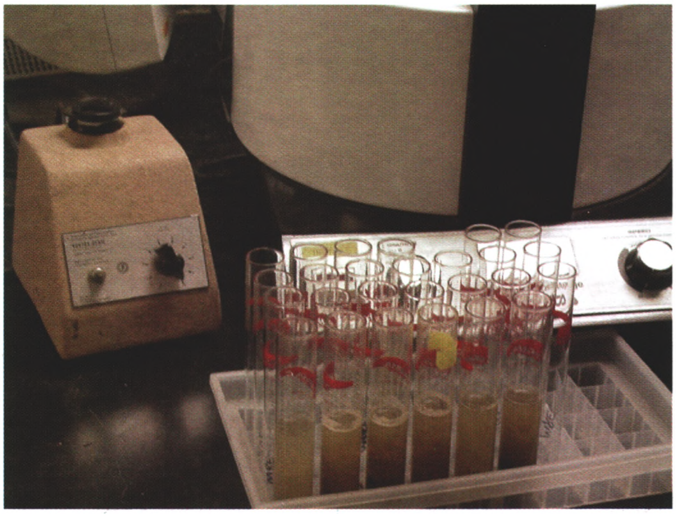
	Method	Reference
1	0.2*M* $CaCl_2$ / 0.5*M* $Mg(NO_3)_2$	6
2	0.5*M* NaOAc – 0.1*M* NaCl / 0.5*M* $Mg(NO_3)_2$	3
3	ECEC from NH_4OAc pH 7.0	5
4	ECEC from NH_4OAc pH 8.1	5
5	ECEC from NH_4Cl	5
6	ECEC from Mehlich 3	1

inputs. Using water-extractable nutrients to gauge the nutritional status of sand-based samples can be difficult and misleading. Measuring exchangeable nutrients will offer insight to long-term nutritional status.

WHICH CEC/ECEC TESTS ARE BEST?

The effect of $CaCO_3$ dissolution was nearly negligible when using a double-extraction CEC technique like $CaCl_2$/$MgNO_3$ or NaOAc-NaCl/$Mg(NO_3)_2$ compared to creating an ECEC technique that sums together the extractable cations. Therefore, to achieve accurate CEC measurements of calcareous sand-based samples, only double extracting techniques should be used, and ECEC estimates should be avoided.

With that being said, measuring small differences in CEC by using different techniques may not provide that much more valuable information to the turfgrass manager. It is more important for the turfgrass manager to know that the sand-based green has a low CEC and that care should be taken when developing a fertilization program. But using more complicated double-extraction techniques for accurately measuring CEC may be important when conducting research or trying to compare rootzone media from different locations. Lastly, accurate CEC measurements that utilize double-extraction techniques should also be used when evaluating the statements of products that claim to have the ability to modify the CEC of a soil.



Various extractants were used to best quantify cation exchange capacity (CEC) of calcareous sand because current methods tend to overestimate CEC by dissolving some of the free calcium carbonate contained in calcareous sand.

WHAT ABOUT SILICA SAND GREENS?

Since silica sand is relatively unaffected by any of the procedures used in the study, pure silica sand samples can potentially be analyzed with any procedure studied in this research. But if the rootzone mix contains any carbonates, the samples should be treated as calcareous and analyzed as such.

ACKNOWLEDGEMENTS

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CONNECTING THE DOTS

A Q&A with* DR. RODNEY ST. JOHN *regarding testing methods for sand-based putting greens.

Q: Your research suggests that estimates of cation exchange capacity (CEC), or the ability of rooting media to hold nutrients, can be quite different on calcareous sands depending on the choice of extractant. How much different can these estimates be?

A: Depending on the type of extractant and the sand sample, the difference can be as much as 10 times. We've seen reported CEC change from 10-12 meq/100g when using ammonium acetate and summing the cations to 1-2 meq/100g when using a double-extraction type procedure.

Q: To your knowledge, what proportion of sand-based putting greens are constructed from calcareous sand? Is this a regional issue?

A: Many greens across the United States are constructed with calcareous sands, most predominately in the Midwest. However, calcareous sands are found in several parts of the country. Most calcareous sands are based on calcium carbonates and are derived from limestone, and some calcareous sands near the coasts are derived from shells. There are simple procedures available at soil testing laboratories that can determine the amount of carbonates present in your sand.

Q: Can an overestimation of cation exchange capacity lead to serious errors in nutrient management of putting greens built with calcareous sand?

A: Yes, if the CEC is used in making fertility recommendations or management decisions, like those derived from the basic cation saturation ratio theory that involve adding calcium, magnesium, or potassium to correct a cation ratio. The safest approach to managing sand-based greens is to utilize light and frequent fertilizer applications to prevent leaching.

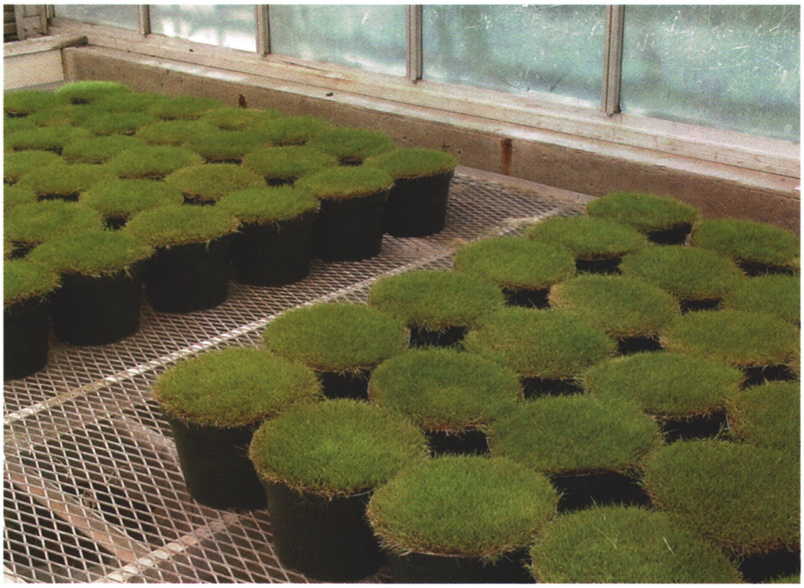
Q: To your knowledge, are most labs using a double-extraction technique to measure CEC or sandy media?

A: To our knowledge, most labs are not using a double-extraction technique to measure CEC. It is generally a procedure used in research where very accurate results are required. Hopefully, with more research, a procedure can be developed or adopted that is both simple and accurate.

Q: Do you think that the results of your work will affect how labs measure CEC of sand rootzone mixes?

A: Maybe. At this point, we just want to draw people's attention to the facts that the results from some CEC tests can be misleading if you have a calcareous sand rootzone, and that there are other procedures available that can more accurately measure CEC.

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



Research at Iowa State University tested five soil testing techniques to measure exchangeable basic cations from sand-based rooting media.

Editor's Note: A more complete summary of this research may be found on USGA Turfgrass and Environmental Research Online at http://usgatero.msu.edu/v05/n13.pdf.

RODNEY ST. JOHN, PH.D., *Assistant Professor/Turfgrass Extension Specialist, Horticulture and Forestry Dept., Kansas State University, Olathe, Kans.;* NICK CHRISTIANS, PH.D., *Professor of Turfgrass Management, Dept. of Horticulture, Iowa State University, Ames, Iowa.*

Converting Bermudagrass to Seashore Paspalum

A successful case study on why and how turfgrass conversion should occur.

BY TODD LOWE AND KYLE SWEET, CGCS

Regrassing is a major project for any golf course and is one that should not be taken lightly. There are many factors that determine when a golf course should regrass and which turfgrass species is the correct choice. For The Sanctuary Golf Club on Sanibel Island, Fla., these factors included high salts, high sodium, heavy soil, low elevation, and contaminated bermudagrass playing surfaces. Any of these factors alone is tolerable to some extent, but together they made for patchy, off-color playing conditions that did not meet the members' expectations. Sanibel is near Naples, Fla., a city with many well-conditioned golf courses. Certified Golf Course Superintendent Kyle Sweet was forced into overseeding each winter to provide acceptable playing conditions for the peak golfing season. Few courses overseed in Southwest Florida because of the added expense, disruption to play, and spring transition problems. For Mr. Sweet, the decision to regrass was simple . . . seashore paspalum as soon as possible.

Seashore paspalum has long been known for its salt tolerance. Although it has out-performed bermudagrass in Hawaii at golf courses with salt problems for the past decade, it had not proven itself in Florida until 2001, when clubs like The Old Collier Golf Club, Crown Colony Country Club, and Hammock Bay Golf & Country Club were successful with wall-to-wall seashore paspalum. Each golf course had relatively high salt levels and chose seashore paspalum because of its tolerance to salt. It soon became a grass

The golf course was treated with herbicides, stripped, tilled, and fumigated in spring 2005 prior to sprigging.

The golf course was sprigged and sodded in early summer 2005. It nearly grew-in five weeks after establishment.

favored by golfers due to its improved ball lie on tees and fairways, improved mower striping, vibrant green color, increased cool-weather color retention, and increased shade tolerance. Often referred to as the "WOW" factor, these improvements have caused quite a stir in South Florida, with an increasing number of courses switching over from bermudagrass. While there is no perfect grass (please read the preceding article entitled "Selecting the Right Grass"), each course in this region has been very pleased with the results.

The Sanctuary was blessed to have had several years to evaluate seashore paspalum at several golf courses in the region before regrassing. In addition, several on-site test plots were established at The Sanctuary on a heavily used par-3 tee and on a practice putting green nearly one year prior to making the final decision. There are several seashore paspalum varieties available, and most are quite similar in turf quality. The Sanctuary chose SeaIsle varieties for their improved breeding and darker green color. SeaIsle1 was chosen for tees, fairways, and roughs, while SeaIsle Supreme was planted on putting greens.

The first step in The Sanctuary's renovation was regrassing only the practice facility in summer 2004. Bermudagrass eradication is nearly impossible, and Mr. Sweet embarked on an aggressive chemical program, similar to what had been done at other regrassing projects,[1] as Roundup and Fusilade II (fluazifop) treatments were applied several times to the bermudagrass turf. The practice facility was then tilled, fumigated, and sprigged with seashore paspalum. Renovating the practice facility on time and on budget was valuable for the continued support of the entire project, but even more impressive was the improved quality that seashore paspalum provided.

Bermudagrass is a perennial plant and recovers from underground stems (rhizomes) following herbicide injury. Therefore, the most effective means of killing bermudagrass is a series of herbicide treatments over several months.[2] It is vitally important to kill the existing bermudagrass to reduce its emergence following the renovation, as there are no herbicides to selectively remove bermudagrass from seashore paspalum. Therefore, Roundup and Fusilade II treatments were applied three times, with the first application in fall 2004. All playing surfaces except bunker faces and putting greens were killed and overseeded with perennial ryegrass for the winter play season. This is an aggressive measure and requires an understanding membership and an appropriate establishment rate (700 to 1,000 lb. per 1,000 sq. ft.) and period (4 to 8 weeks). Eventually, the ryegrass established and provided great playing conditions for the peak season.

The golf course was closed May 1, 2005, and sprayed twice with Roundup and Fusilade II at 21-day intervals. The dead grass was stripped and buried, and each hole was tilled and fumigated with methyl bromide. Seashore paspalum was sodded on all green/tee slopes, bunker faces, and lake banks, and sprigged on the remaining playing surfaces. Sprigs were established at a rate of 1,200 bushels per acre. The increased sprig rate was beneficial for grow-in and allowed the course to open three months after sprigging. Ronstar (oxadiazon)-treated starter fertilizer was applied shortly after sprigging to reduce weeds.

All playing surfaces were mowed for the first time two weeks after sprigging. Roughs were mowed at 1 inch, tees and fairways at 0.04 inch, and greens at 0.187 inch. This encouraged lateral spread, and nearly complete coverage occurred within six weeks! On greens, mowing height was reduced as density improved so that the target height of 0.110 inch was achieved by the opening date. All playing surfaces were rolled shortly after mowing to provide uniform, smooth conditions. Tees, fairways, and roughs were rolled with a two-ton unit, and greens were rolled with a tennis court roller and a vibratory triplex unit. All playing surfaces were fertilized, rolled, spiked, and topdressed with sand as needed to improve surface uniformity. The golf course was fertilized occasionally throughout the grow-in to improve turf health and encourage coverage.

Managing seashore paspalum has not been difficult for Mr. Sweet. In fact, while there are some differences in management practices, there are many similarities to bermudagrass. Less water and nutrients are necessary for all playing surfaces, and this is most likely due to the significantly increased root depth and mass. Even putting greens mowed at 0.110 inch have a thick root system that stretches 6 to 8 inches into the soil! As far as cultural practices are concerned, putting greens require a little extra work to provide premium playing conditions as compared to the previous bermudagrass greens. Seashore paspalum has relatively thicker leaves and stems than bermudagrass, and putting greens must be rolled and double-cut more often than bermudagrass to obtain consistently favorable speeds. Also, the plant growth regulator Primo (trinexapac-ethyl) is applied at nearly twice the rate as was applied to the previous bermudagrass putting greens. But, Mr. Sweet remarks, "Our expectation level rose following the renovation, and the golfers are quite pleased with the results. Putting speeds are maintained between 8.5 to 9.5 feet during summer months and 9.5 to 10.5 feet during our peak winter months." A significant financial savings occurred as the golf course is no longer overseeded due to the improved cool-weather color retention that now occurs with seashore paspalum.

The Sanctuary Golf Club reopened in November 2005 to rave golfer reviews. The vibrant green playing conditions that seashore paspalum provides are a far cry from the drab, patchy bermudagrass that once existed. Also, mower striping occurs with each mowing, and the increased shoot density significantly improves ball lie. The likelihood of complaints is always a possibility with any major renovation, but only positive remarks have been voiced since the reopening of The Sanctuary. Every course is different in regard to expectation level, and no turfgrass is perfect for every region, but regrassing The Sanctuary in Sanibel, Fla., with seashore paspalum was a big success with the golfers and the golf course superintendent!

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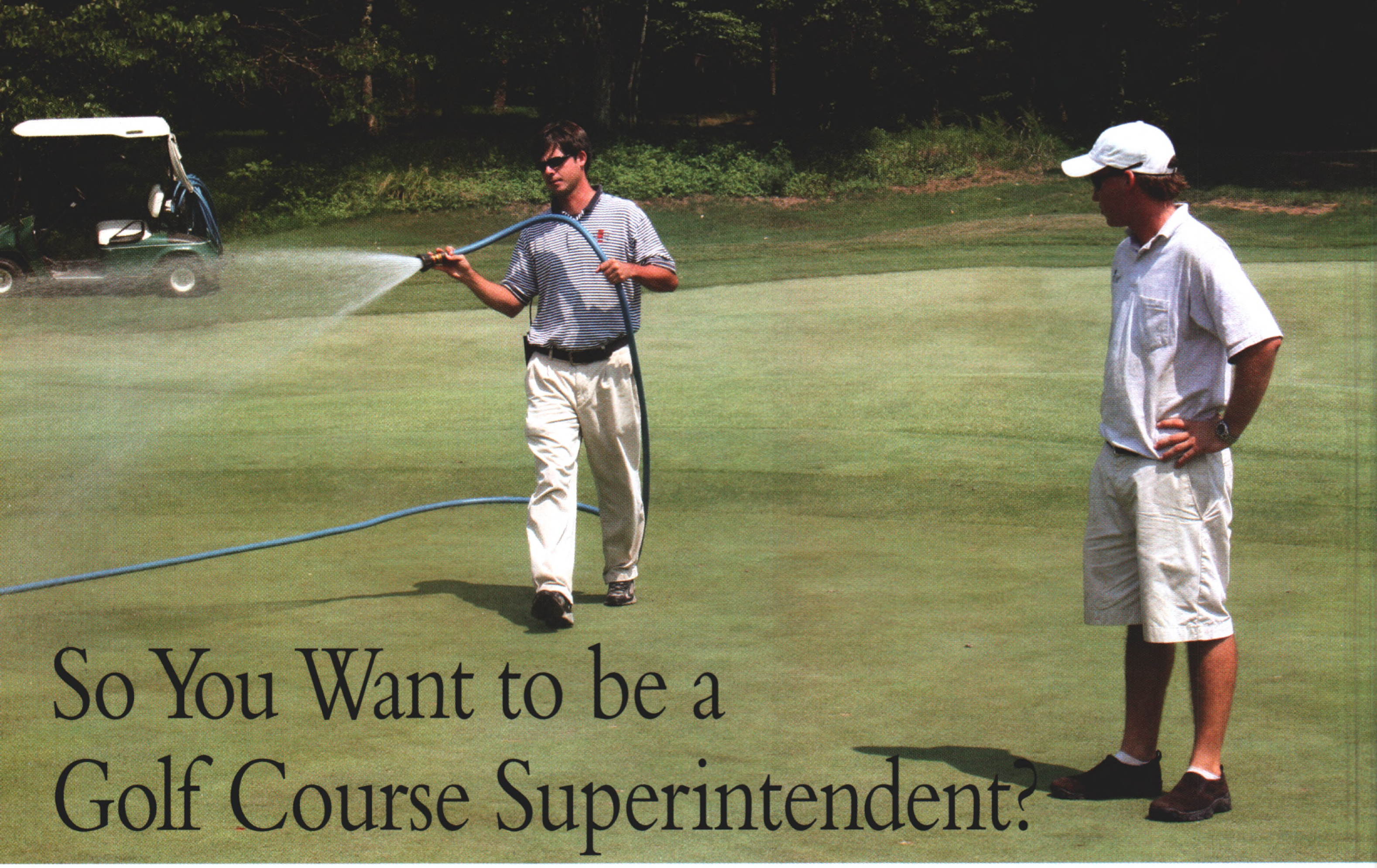
TODD LOWE *is an agronomist in the Green Section's Florida Region;* KYLE SWEET, *CGCS, is the superintendent at The Sanctuary Golf Club on Sanibel Island, Fla.*

Playing surfaces were rolled multiple times to provide smooth, uniform playing conditions.



So You Want to be a Golf Course Superintendent?

A turf student's perspective on the golf course manager career path.

BY TRAVIS JAMES MOORE

Assistant superintendent Nelson Coron demonstrates for intern Travis Moore the proper way to hand water greens. Internships provide students the opportunity to experience new places, management styles, and grasses. The golf course staff have the responsibility to not only show the interns how to properly accomplish maintenance tasks, but also to instruct them on the reasons why tasks are done a certain way.

Once you have made the decision to pursue the vocation of golf course superintendent, you had better be prepared to answer a few pointed questions from your unenlightened friends.

"What does a superintendent do? I thought the golf pro took care of the course."

"Can you make any money doing that?"

"What do you do all winter?"

"You mean they have schools for that?"

From those who know more about the golf business, the questions will be quite a bit different.

"Are you sure you want to work that many hours?"

"You do know that job security is not all that great — right?"

"The competition for good jobs is fierce. Are you ready to study hard and get a good education?"

Ask superintendents what it takes, and they will quickly inform you that the profession requires years of hard work, dedication, long hours, and not always the highest wages. They go on to explain that you must be willing to work holidays and weekends, and strive to meet golfers' expectations, no matter how demanding. And it is a given that some with a single-digit handicap will think they know a lot more about taking care of a golf course than you ever will.

Still interested?

In spite of these drawbacks, a career in golf course management is appealing to many of us because it combines a unique combination of skills. Few jobs require blending scientific knowledge, communication skills, a committed work ethic, leadership ability, and more on a daily basis. Since careers in golf course management can be found almost anywhere in the world, there is a chance to apply these skills in the most beautiful of environments. Finally, for many of us, the most appealing aspect of this industry is that it allows us to be intimately close to the game of golf.

There are many possible paths to becoming a golf course superintendent, ranging from working your way up from the maintenance crew to pursuing an advanced degree in agronomy or horticulture with a specialization in turfgrass management. So where do you start? The following steps are the most commonly followed.

STEP 1

While in high school, get a summer job on a golf course.

The first step is to gain experience as early as possible. Work experience is crucial for finding internships, relating classroom information to the real world, and most importantly, deciding if this is a career you want to pursue. When you apply, be sure to tell the superintendent you want to learn more about the profession. As with most jobs, you will start out at the bottom and have to earn your way to bigger and better things. Your first three friends on the golf course will most likely be the shovel, the rake, and the line trimmer. The longer you stay, the more you will learn about what it is like to work in golf course maintenance.

This experience will likely be your first exposure to the fact that grasses are seemingly under constant attack from weeds, insects, and disease organisms. You will also learn that attention to detail is extremely important in golf course management. Hopefully you will have the chance to work for a superintendent who loves the job and will inspire you to take the next step.

STEP 2

Formal education — two-year or four-year program?

Not too many years ago there were very few choices for studying turf management, and almost none specifically focused on golf course management. In most cases, you studied agronomy or horticulture and took just a couple of classes that related directly to the profession. Today there are many options, ranging from two-year programs all the way up to advanced degrees from top universities throughout the world. In fact, there are so many good choices you might have a hard time deciding where and what to study.

For those who are certain their long-term future will be to manage individual golf courses, there are many good two-year programs that take more of a vocational approach to your education. Many successful superintendents obtained their associate degrees from these programs. Fortunately, almost every state now has institutions offering this course of study. Also, the cost of your education will be much less and you will be able to start earning a paycheck more quickly.

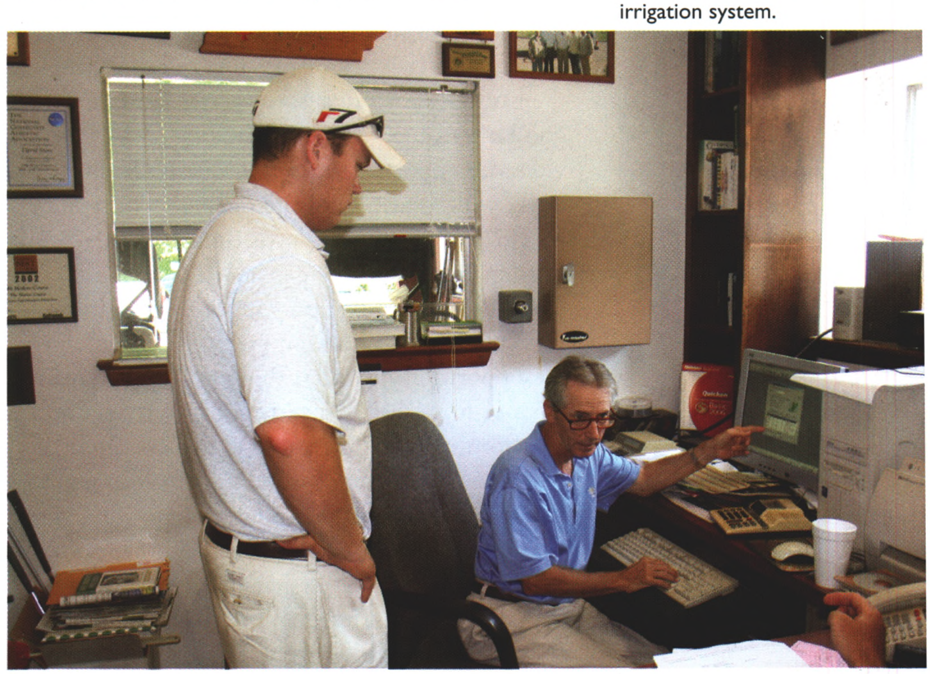
On the other hand, four-year universities offer much broader and more in-depth curricula. Here you will study, in much greater detail, science-based subjects such as plant physiology, plant pathology, chemistry, taxonomy, entomology, and so on. In addition, you will have the opportunity to take valuable courses in business, engineering, English, and many other subjects that will serve you well regardless of your career path. Such an education is obviously more expensive and takes more time and effort on your part. However, you are prepared for a wider range of professions and will have more options once you graduate. Plus, you might decide to go on to graduate school.

There are also those who have combined all of these options. Some have joined the maintenance crew right out of high school and attended either a junior college or a vocational school part-time. Once they were certain of their goals, they eventually decided to pursue their four-year degree.

STEP 3

The internship.

Perhaps the most valuable aspect of your educational experience will be the internship. The importance and benefit of internships cannot be overstated. Interns experience new places, management styles, and different grasses; become more familiar with irrigation and chemical applications; and are involved with special projects, tournament preparation, and more. As an intern you have the opportunity to learn on some of the country's top courses and from first-rate superintendents and assistants. Many courses have



Superintendent David Stone demonstrates to intern Brooks Riddle how to operate the irrigation system.

multiple interns and provide housing, competitive wages, and possibly even golfing privileges. The hours are very long and you will likely work harder than you thought possible. You probably will be too tired to play a lot of golf. But when you return to school, you will have a much expanded view of the industry and profession and will be able to better tailor the remainder of your education to meet your future needs.

WHEN AND WHERE DO I START?

The key to finding a great internship is to start looking early. Keep in mind that the top jobs are competitive and will go quickly. I have talked to several interns who had their summer internships finalized in early to mid-fall. Many students are able to complete as many as three or four internships while attending a four-year institution. Students who plan on completing more than one internship should try to work in different parts of the country and in significantly different climates. Such broad experience will prove invaluable when competing for jobs after graduation.

Student advisors will often maintain good connections to industry and former students and will be able to help you with your search. Many state turfgrass associations will post such opportunities on their Web sites. Be sure to contact the Golf Course Superintendents Association of America (www.gcsaa.org) and ask for their help. While you're at it, it is a good idea to join GCSAA and your state chapter since this will provide many additional avenues to make contacts in the industry.

You also should contact the USGA agronomist in your area (www.usga.org/turf) since during their travels they often come across courses with good internship programs. The USGA also provides the opportunity for multiple students to travel with members of the Green Section staff on Turf Advisory Service visits for one week during the summer. The goal of the internship program is to provide students with a broader view of the golf course industry and to provide the opportunity to learn about golf course maintenance from the perspective of Green Section agronomists. State and national turf conferences offer the opportunity to find information and to meet new people in the industry.

When speaking with a particular golf course superintendent, don't hesitate to ask questions regarding your duties as an intern, and be sure to stress your desire to learn as much about the profession as possible. As mentioned earlier, hard work and long hours are part of the package, but there also should be opportunities to learn more about the management side of the industry as well.

TIPS FOR SUCCESS WHEN LOOKING FOR INTERNSHIPS

- **Communicate professionally.** As with any job search, you need to communicate in a professional manner to be successful. If you use e-mail, make sure to use correct English and leave out the text message abbreviations you might be used to using. When contacting the course superintendent, don't rely just on e-mail and phone calls. Put together a good resume and have someone at school take a look at it to be sure it is professional looking and well written. Write a personal letter to the superintendent and stress your desire to learn and become a part of the profession. Don't underestimate the power of written communication. It is good to have something that can sit on top of your potential employer's desk.
- **Keep an open mind.** There are many opportunities across the country and even internationally. Do not be afraid to travel away from home and experience new places.
- **Begin your search early.** This point cannot be stressed enough.
- **Know the course.** Before you interview for an internship, take the time to do a little research about the course. For example, knowledge of the history of the course and which grasses are used will demonstrate your willingness to learn and your desire to be a contributing member of the maintenance team.
- **Know the game.** Knowledge of the game of golf will make you a much more valuable asset to your employer. You also should be able to play the game with a reasonable amount of skill. Having a love for the game positively influences the quality of your work.
- **Behave professionally.** The contacts you make while interning will almost certainly be crucial later on as you search for your first post-school position. Be certain they will be able to give you nothing but the best of references.
- **Take pictures.** The importance of documenting your experiences with pictures cannot be overstated. Photograph projects you work on and maintenance procedures such as topdressing, aeration, etc.

Internships should provide a chance to learn new things. At The Honors Course, interns evaluate the effectiveness of new fertilizer products on the fairways.

STEP 4

Assistant Superintendent.

In most cases, the first job you will search for after graduation will be as a second or first assistant. As an assistant, you will gain much more experience with many of the tasks that you were introduced to as an intern, such as: supervisory skills, budgeting, chemical and pesticide applications, special projects, tournament preparation, and more. The length of time that one spends as an assistant varies depending on many factors. Be prepared to move a few times, since this is often the best way to build your experience and prepare yourself for your first job as the "head" superintendent.

CONCLUSION

The road to becoming a golf course superintendent is longer and more difficult than many realize. Those willing to put this much time and effort into their education and work experience could likely find more lucrative vocations in other industries. But for those of us who want to work with nature and be close to the game, the road is well worth traveling. If you decide to pursue a career in this industry, keep in mind these words of advice from Superintendent David Stone of The Honors Course in Tennessee. Stone states that in order for one to be truly competitive and successful as a golf course superintendent, one must not only possess a committed work ethic and the desire to continually learn, but one must also have an undying love for the game — both as a player and as a golf course manager.

Good luck!

ACKNOWLEDGEMENTS

The author would like to thank the staff at The Honors Course, including assistant superintendents Nelson Coron and Chris Dill, and head superintendent David Stone for their input and advice. Brooks Riddle, a senior at North Carolina State University, and Will Misenhimer, a recent graduate of Mississippi State University, contributed to this article by sharing their experiences. They have completed numerous internships and will soon be seeking employment as assistant golf course superintendents.

TRAVIS MOORE *graduates from Texas A&M University in December 2006 with a degree in agronomy, specializing in turfgrass management. He wrote this article while completing an internship at The Honors Course (Tennessee) working for David Stone.*

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).

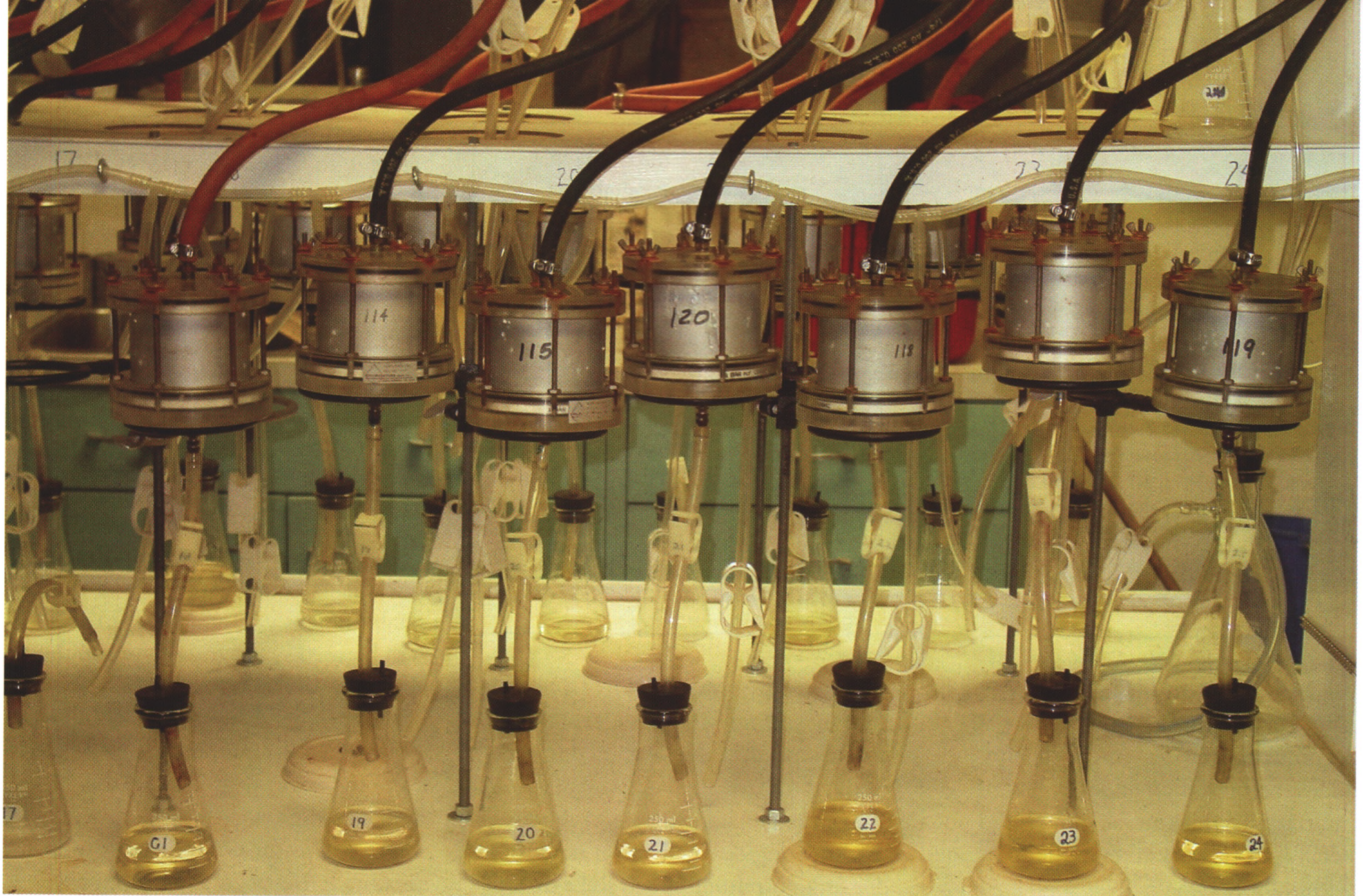
All construction materials met USGA recommendations for putting green construction. The first putting green was constructed in late summer of 1996. The rootzones were allowed to settle over the winter and they were seeded May 30, 1997. The same procedures were used for construction and seeding of subsequent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

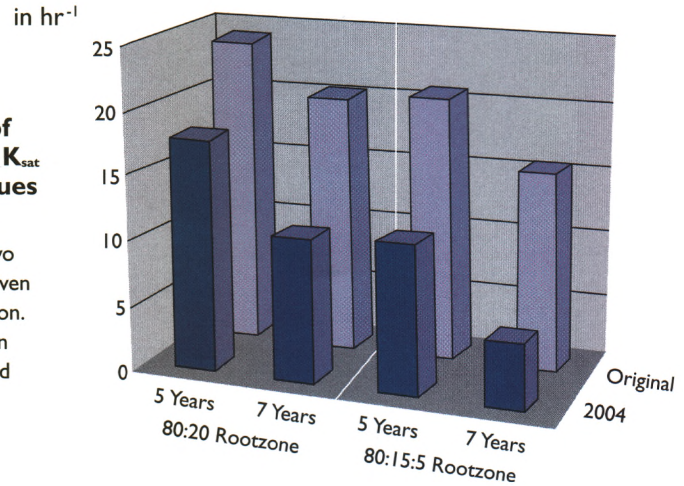
Others have reported similar increases in capillary porosity and decreases in air-filled porosity in aging putting green rootzones. Habeck and Christians (3) reported an increase in capillary porosity and a decrease in air-filled porosity from clay contamination. Ok et al. (6) reported a 220% increase 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.

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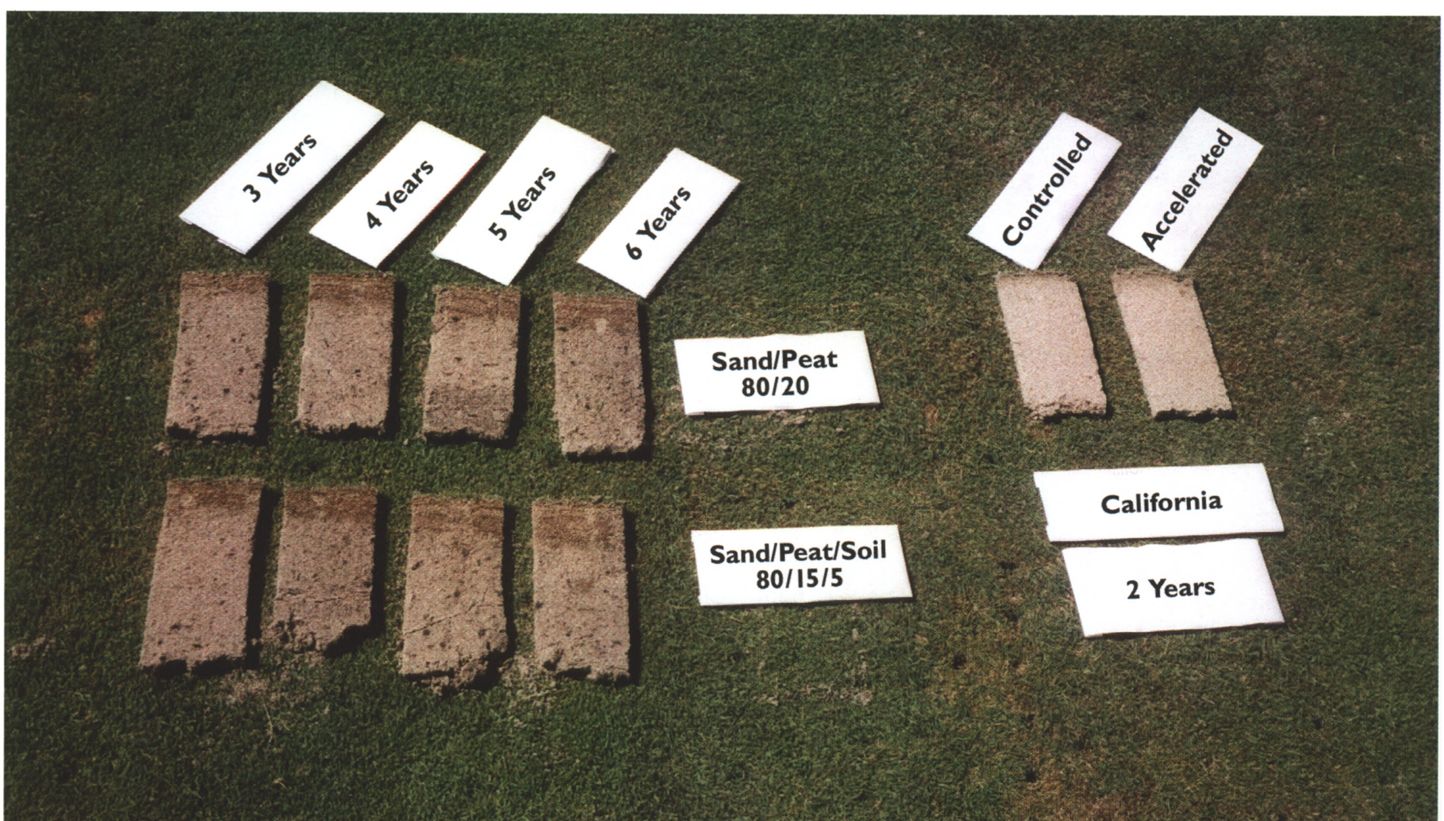

One University of Nebraska research project has focused on developing a better understanding of the agronomic characteristics of sand-based rootzones as they mature over time. To date, the research has focused on the microbial, chemical, and physical characteristics of greens ranging in age from one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

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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.*

Improving Environmental Performance

It improves more than just the environment.

BY KEVIN A. FLETCHER

An Environmental Management System is a voluntary approach to improving environmental performance that often saves both money and resources (Shadow Wood Country Club, Florida).

The environment is a key issue facing businesses of all types, including golf courses, in the 21st century. Reducing risks and liabilities and preventing pollution are part of the solution, but responsible environmental management no longer means simply *doing no harm*. Leading golf courses are also increasing efficiency, reducing waste, and finding business value in improved environmental performance.

GETTING THE JOB DONE

An Environmental Management System — or EMS — is a voluntary approach to improving environmental performance that has begun to take center stage in the U.S. Widely used by companies in Europe, Japan, and a handful of other countries, an EMS provides structure for setting policies and goals, taking action, and measuring results.

An effective EMS follows a common sense formula: PLAN-DO-CHECK-ACT. Using a systematic approach that starts with management buy-in, companies set standards and adopt policies and procedures to meet them. Equally important, they monitor and report the effectiveness of environmental efforts.

Golf courses enrolled in the Audubon Cooperative Sanctuary Program (ACSP) or Audubon Signature Program will recognize this approach. Audubon International's education and certification programs are built upon these same basic tenets. For instance, ACSP members begin by taking stock of their environmental resources, identifying any potential problems or liabilities, and developing a plan of action to improve environmental performance (PLAN). They then implement the plan (DO), evaluate and document their efforts (CHECK), and make adjustments and improvements as needed (ACT).

Certification in the ACSP or Signature Program serves as an incentive for action and a tool for continuous improvement. In a sense, the process of becoming certified formalizes the Plan-Do-Check-Act formula and provides

an independent external review and guidance for participants.

GOOD FOR THE ENVIRONMENT, GOOD FOR BUSINESS

An EMS is a continual cycle of planning, implementing, reviewing, and improving the ways that an organization meets its environmental goals. The results tend to be not only good for the environment, but also good for business. Benefits typically include cost savings from more efficient operations, reduced risks, and improved community relations and regulatory compliance.

After years of taking a regulatory approach to environmental policy, the U.S. Environmental Protection Agency (EPA) has recently come out in support of EMSs. The reason is simple: EMSs are proving to be an effective tool for managing the environment. In contrast to regulation, which is imposed externally, EMSs tend to have greater employee and company buy-in and result in greater innovation and long-term change because they are adopted internally. Likewise, they allow for acting on environmental issues in a more comprehensive and effective way.

RETURN ON INVESTMENT

According to results documented by members of the ACSP, improving environmental performance can yield a strong return on investment. Here are a few examples of how golf courses have saved money and conserved resources by implementing best management practices recommended by the ACSP.

- Under the direction of its new superintendent, Anthony Williams, Stone Mountain Golf Club in Stone Mountain, Georgia, reduced fertilizer costs by $2,100, pesticide costs by $4,500, and fuel use by 467 gallons in 2005, compared with 2004.
- At Donald K. Gardner Memorial Golf Course in Marion, Iowa, Superintendent David Roe and his crew naturalized 20 acres of turfgrass and added two additional acres of wildflowers. The project cost $500 and will save $1,000 per year in maintenance labor.
- State College Elks Country Club in Boalsburg, Pennsylvania, now saves approximately 100,000 gallons of water per complete irrigation cycle. David Williams, CGCS, achieved the savings by altering watering and turf management practices.
- Similarly, Superintendent Jeff Therrien at The Ranch Country Club in Westminster, Colorado, reported that changes in watering and turf management save 3-4 million gallons of water per year.
- Shadow Wood Country Club in Bonita Springs, Florida, has reduced pesticide applications by 32 percent since 2002. By increasing pest monitoring and defining hot spots, Director of Golf Course Operations Kyle Kenyon also reduced herbicide use from a pre-emergent treatment on 290 acres to the treatment of 13 to 75 acres once or twice a year as needed. Reducing wall-to-wall fertilizer applications further saved approximately $30,000 and 80 tons of fertilizer.
- Superintendent Chuck Manning calculated savings achieved by removing eight acres of turf at Quail Run Golf Course in Sun City, Arizona. The course saved 16 million gallons of water and 800 gallons of fuel needed to maintain the area previously.
- Under the direction of Golf Course Superintendent Pat Blum, Colonial Acres Golf Course in Glenmont, N.Y., became the first golf course in the nation to be recognized through the EPA's National Environmental Performance Track Program. Colonial Acres was certified as an Audubon Cooperative Sanctuary in 1998, and the PLAN-DO-CHECK-ACT process required to earn certification played a large role in gaining recognition by the EPA.

In the U.S. and around the world, EMSs will soon be the norm, not the exception. Golf course participation in EMSs will serve the industry and the environment equally well.

RESOURCES

"Environmental Management Systems (EMS)," United States Environmental Protection Agency, www.epa.gov/ems/.

"The External Value Environmental Management System Voluntary Guidance: Gaining Value by Addressing Stakeholder Needs," March 2004, Multi State Working Group, www.mswg.org/documents/guidance04.pdf.

ISO 14000 Information Center, www.iso14000.com/.

NDEMS, National Database on Environmental Management Systems, http://ndems.cas.unc.edu/.

U.S. Environmental Protection Agency's National Environmental Performance Track, http://www.epa.gov/performancetrack/.

KEVIN FLETCHER, PH.D., *is Director of Programs and Administration at Audubon International. He has worked as a university researcher and educator and served as vice president of a management consulting firm working in environmental business strategy and environmental management system development and implementation.*

Look Before You Leap

Other insects besides the turfgrass ant can cause temporary disruption to a putting surface.

BY BOB VAVREK

One night's worth of ant tunneling can deposit a considerable amount of sand on a green. Other digging insects, however, can produce similar putting surface disruption.

Competition for golfers is intense across the country, especially at popular resorts where many courses have been built. The smoothness and consistency of the putting surfaces considerably influence how golfers judge the quality of a particular course. Consequently, superintendents have no qualms about making as many applications of insecticides to greens as needed to manage insect pests that they believe are causing disruption to the playing surface.

Unfortunately, insect pest damage to greens is often misdiagnosed. For example, unrepaired ball marks or dollar spot disease activity can mask the injury caused by surface feeders, such as cutworms or sod webworms, on greens. On the other hand, anthills are an unmistakable symptom of insect pest activity. The turfgrass ant, *Lasius neoniger*, prefers well-drained sites to build a nest, and a sand-based green or a green with a significant accumulation of sand topdressing in the upper rootzone is ideal.

Soil or sand deposits on the playing surface generally are attributed to either earthworms or ants. However, the large nightcrawler *Lumbricus terrestris* L. is rarely a problem on greens, likely due to the high sand content of the upper profile and the fact that fungicides are routinely applied to the turf. Mole crickets, green June beetles (*Cotinis nitida* L.), and cicada killer wasps (*Specius speciosus* [Drury]) are other digging-type insect pests that are, on occasion, known to disrupt putting surfaces.

Small mounds of sand above aerifier holes that were filled with topdressing have been a concern on a small but increasing number of courses over the past few years. Enough sand is deposited on the surface to affect mowing operations. The problem sometimes is severe enough to warrant matting or poling before mowing. These operations level the mounds, but they may surprisingly reappear within several hours. Superintendents normally blamed the turfgrass ant, but a close inspection of problem areas reveals different causes. On a few courses the excavations were caused by larger harvester ants, *Pogonomyrex spp.* A single ant was found beneath each mound of sand. The cause of the mysterious mounding at several courses in Minnesota and Michigan was a predatory ground beetle, specifically *Stenolophus comma* (F.), the striped seed corn beetle.

Why make such a fuss over an accurate diagnosis of these problems when a number of insecticides labeled for turf are capable of controlling these insects? On one hand, there is ample justification for applying an insecticide to control a damaging population of cutworms or sod webworms. These insects are true turf pests that are capable of causing a great deal of damage to a green. On the other hand, ants and in particular the ground beetle may do more good than harm, in spite of their annoying habit of depositing sand on a putting surface.

The ants most commonly found on greens are foragers that cause no direct injury to the turf. In fact, research at several universities indicates that the turfgrass ant plays a significant role in controlling more serious pests like black cutworms. The ants consume a significant percentage of cutworm eggs that are deposited on grass blades by the adult moths at night.

The striped seed corn beetle, sampled from greens at a number of courses across the North Central Region, is considered a biocontrol agent that helps reduce the insect pest population of several agricultural crops. Their role in controlling turfgrass pests has not been studied, but it is likely similar to the beneficial role that ants play in the turfgrass ecosystem.

The take-home message is — *always make an extra effort to clearly identify possible insect pest concerns on greens or anywhere else on the course before making a decision to apply an insecticide.* Get down on your hands and knees, dig around a bit to obtain a specimen of the pest and avoid making a decision based solely on symptoms. When in doubt, consult with the Green Section staff or university professionals. Reducing beneficial insect populations may result in increased pressure from more serious insect pests later in the season. The critical prerequisite for developing a successful integrated pest management program for turf or any other commodity is an accurate diagnosis of the pests. Look before you leap.

This carabid beetle, sampled from greens at a number of North Central Region courses, is considered to be a biocontrol agent that consumes eggs and larvae of insect pests of several agricultural crops.

BOB VAVREK *is a senior agronomist for the North Central Region who "bugs" superintendents to make an accurate diagnosis of insect pest problems.*

BEVARD RECOGNIZED WITH 'SENIOR AGRONOMIST' DESIGNATION

Darin Bevard, an agronomist in the USGA Green Section's Mid-Atlantic Region, has been promoted to senior agronomist. This designation is awarded to Green Section agronomists who have demonstrated an outstanding commitment and dedication to their work over a minimum period of ten years on staff.

Darin has worked in the Mid-Atlantic Region since joining the Green Section in 1996, conducting Turf Advisory Service visits on golf courses in Pennsylvania, Delaware, Maryland, Virginia, and West Virginia. Darin joins fellow senior agronomists Keith Happ (Mid-Atlantic), Chris Hartwiger (Southeast), Matt Nelson (Northwest), Jim Skorulski (Northeast), Bob Vavrek (North-Central), and Bud White (Mid-Continent).

WHAT WERE THEY THINKING?

Sometimes it's hard to let go ....

PHYSICAL SOIL TESTING LABORATORIES

The following laboratories are accredited by the American Association for Laboratory Accreditation (A2LA), having demonstrated ongoing competency in testing materials specified in the USGA's Recommendations for Putting Green Construction. The USGA recommends that only A2LA-accredited laboratories be used for testing and analyzing materials for building greens according to our guidelines.

Brookside Laboratories, Inc.
308 Main Street, New Knoxville, OH 45871
Attn: Mark Flock
Voice phone: (419) 753-2448
FAX: (419) 753-2949
E-Mail: mflock@BLINC.COM

Dakota Analytical, Inc.
1503 11th Ave. NE, E. Grand Forks, MN 56721
Attn: Diane Rindt, Laboratory Manager
Voice phone: (701) 746-4300 or (800) 424-3443
FAX: (218) 773-3151
E-Mail: lab@dakotapeat.com

European Turfgrass Laboratories Ltd.
Unit 58, Stirling Enterprise Park
Stirling FK7 7RP Scotland
Attn: Ann Murray
Voice phone: (44) 1786-449195
FAX: (44) 1786-449688

Hummel & Co.
35 King Street, P.O. Box 606
Trumansburg, NY 14886
Attn: Norm Hummel
Voice phone: (607) 387-5694
FAX: (607) 387-9499
E-Mail: soildr1@zoom-dsl.com

ISTRC New Mix Lab LLC
1530 Kansas City Road, Suite 110
Olathe, KS 66061
Voice phone: (800) 362-8873
FAX: (913) 829-8873
E-Mail: istrcnewmixlab@worldnet.att.net

Sports Turf Research Institute
hyperlink to www.stri.co.uk
St. Ives Estate, Bingley
West Yorkshire BD16 1AU
England
Attn: Michael Baines
Voice phone: +44 (0) 1274-565131
FAX: +44 (0) 1274-561891
E-Mail: stephen.baker@stri.org.uk

Thomas Turf Services, Inc.
2151 Harvey Mitchell Parkway South, Suite 302
College Station, TX 77840-5247
Attn: Bob Yzaguirre, Lab Manager
Voice phone: (979) 764-2050
FAX: (979) 764-2152
E-Mail: soiltest@thomasturf.com

Tifton Physical Soil Testing Laboratory, Inc.
1412 Murray Avenue, Tifton, GA 31794
Attn: Powell Gaines
Voice phone: (229) 382-7292
FAX: (229) 382-7992
E-Mail: pgaines@friendlycity.net

Turf Diagnostics & Design, Inc.
613 E. First Street, Linwood, KS 66052
Attn: Sam Ferro
Voice phone: (913) 723-3700
FAX: (913) 723-3701
E-Mail: sferro@turfdiag.com

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I certify that the statements made by me above are correct and complete. — JAMES T. SNOW, Editor

All Things *Considered*

It Takes A Team

Working together toward a common goal.

BY PAUL VERMEULEN

Given the new-found interest in America's classic venues, course officials in all regions of the country are becoming more familiar with extensive renovation, or, if you prefer, restoration plans. Nowhere is this trend taken more seriously than in the upper half of the Mid-Continent Region, where more than 40 projects have been completed in the past five years, and another ten are scheduled for completion in the next 12 to 18 months. Having been involved with much of this work, I have come to appreciate that producing exceptional results requires much more than the efforts of a single individual.

For a major renovation/restoration project to be successful, several key players must be involved with its development and implementation. These players would include the architect, superintendent, golf professional, course manager, ranking course officials, and technical advisors. As all of these individuals must work collaboratively for a successful project, it is important that each recognize his or her own role and avoid overreaching into someone else's realm of expertise.

Starting with the architect, his/her primary role is to develop working drawings and project specifications that clearly define the scope of work. To this end, an architect must rely on others for valuable input. For instance, architects must have a complete briefing on overriding agronomic issues, how the course is played and by whom, financing limits, and any special interests in a particular architectural theme before they can produce plans that will ultimately garner high praise. As a person in need of specific and detailed information, it stands to reason that an architect can only be as good as those with whom he/she is surrounded.

Next on the team roster is the superintendent. With experience and education in all things agronomic, the clear role of the superintendent is to provide technical expertise and to implement quality control procedures as the project unfolds. Additionally, the superintendent should seek out and work with various technical advisors, where appropriate, to ensure that the results will endure when the project is completed rather than fade through the years.

The golf professional's role in the success of a renovation/restoration project is one of unique importance and, unfortunately, is too often ignored. While lacking certain technical detail, providing insight as to how the course can best be enjoyed by golfers of all skill levels can be of equal value when compared with the selection of a particular turf species for the fairways. Also important is the fact that golf professionals are in close contact with the golfers and, as such, are ideally positioned to accept the responsibility of building support and enthusiasm in the preliminary stages of a project.

Rounding out the team roster are the club manager and ranking course officials, whose responsibilities include determining the financing of a project, providing leadership when faced with project opposition, and keeping golfers informed as to the project's progress. As one can readily appreciate, all of these individuals must believe in the renovation/restoration objectives in order to communicate a unified, positive message.

Absent committed members of a team, the task of developing, selling, and completing a major improvement project is virtually impossible. Furthermore, if completed without a unified team, the results will probably become the subject of harsh criticism, as the renovation project would not reflect a collective effort, but rather the lone ideas of one or two individuals.

With the outcome of a renovation/restoration project hanging in the balance, the best place to start is by recognizing the roles that must be filled by key individuals. Then, as the project unfolds, individuals must focus on their own duties in a manner that supports the activities of the others. In the end, it is only the results that are truly important and not who receives credit.

PAUL VERMEULEN *joined the USGA Green Section in 1987 as an agronomist in the Western Region and has been the director of the Mid-Continent Region since 1996.*

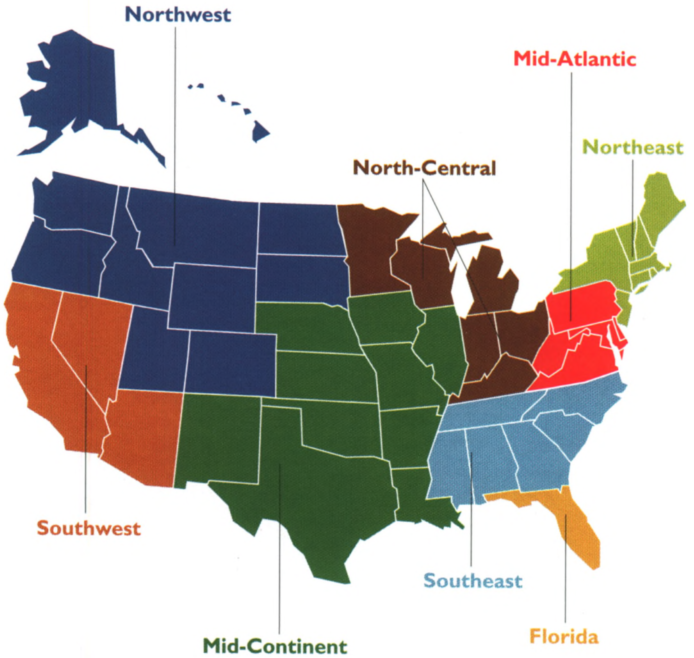
GREEN SECTION NATIONAL OFFICES

United States Golf Association, Golf House
P.O. Box 708
Far Hills, NJ 07931
(908) 234-2300 Fax (908) 781-1736
James T. Snow, *National Director*
jsnow@usga.org
Kimberly S. Erusha, Ph.D., *Director of Education*
kerusha@usga.org

Green Section Research
P.O. Box 2227
Stillwater, OK 74076
(405) 743-3900 Fax (405) 743-3910
Michael P. Kenna, Ph.D., *Director*
mkenna@usga.org

1032 Rogers Place
Lawrence, KS 66049
785-832-2300
Jeff Nus, Ph.D., *Manager*
jnus@usga.org

Construction Education Program
770 Sam Bass Road
McGregor, TX 76657
(254) 848-2202 Fax (254) 848-2606
James F. Moore, *Director*
jmoore@usga.org



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●Northeast Region
David A. Oatis, *Director*
doatis@usga.org
James H. Baird, Ph.D., *Agronomist*
jbaird@usga.org
P.O. Box 4717
Easton, PA 18043
(610) 515-1660 Fax (610) 515-1663

James E. Skorulski, *Senior Agronomist*
jskorulski@usga.org
1500 North Main Street
Palmer, MA 01069
(413) 283-2237 Fax (413) 283-7741

●Mid-Atlantic Region
Stanley J. Zontek, *Director*
szontek@usga.org
Darin S. Bevard, *Senior Agronomist*
dbevard@usga.org
485 Baltimore Pike, Suite 203
Glen Mills, PA 19342
(610) 558-9066 Fax (610) 558-1135

Keith A. Happ, *Senior Agronomist*
khapp@usga.org
Manor Oak One, Suite 410,
1910 Cochran Road
Pittsburgh, PA 15220
(412) 341-5922 Fax (412) 341-5954

●Southeast Region
Patrick M. O'Brien, *Director*
patobrien@usga.org
P.O. Box 95
Griffin, GA 30224-0095
(770) 229-8125 Fax (770) 229-5974

Christopher E. Hartwiger, *Senior Agronomist*
chartwiger@usga.org
1097 Highlands Drive
Birmingham, AL 35244
(205) 444-5079 Fax (205) 444-9561

●Florida Region
John H. Foy, *Director*
jfoy@usga.org
P.O. Box 1087
Hobe Sound, FL 33475-1087
(772) 546-2620 Fax (772) 546-4653

Todd Lowe, *Agronomist*
tlowe@usga.org
127 Naomi Place
Rotonda West, FL 33947
(941) 828-2625 Fax (941) 828-2629

●Mid-Continent Region
Paul H. Vermeulen, *Director*
pvermeulen@usga.org
9 River Valley Ranch
White Heath, IL 61884
(217) 687-4424 Fax (217) 687-4333

Charles "Bud" White, *Senior Agronomist*
budwhite@usga.org
2601 Green Oak Drive
Carrollton, TX 75010
(972) 662-1138 Fax (972) 662-1168

●North-Central Region
Robert A. Brame, *Director*
bobbrame@usga.org
P.O. Box 15249
Covington, KY 41015-0249
(859) 356-3272 Fax (859) 356-1847

Robert C. Vavrek, Jr., *Senior Agronomist*
rvavrek@usga.org
P.O. Box 5069
Elm Grove, WI 53122
(262) 797-8743 Fax (262) 797-8838

●Northwest Region
Larry W. Gilhuly, *Director*
lgilhuly@usga.org
5610 Old Stump Drive N.W.,
Gig Harbor, WA 98332
(253) 858-2266 Fax (253) 857-6698

Matthew C. Nelson, *Senior Agronomist*
mnelson@usga.org
P.O. Box 5844
Twin Falls, ID 83303
(208) 732-0280 Fax (208) 732-0282

●Southwest Region
Patrick J. Gross, *Director*
pgross@usga.org
505 North Tustin Avenue, Suite 121
Santa Ana, CA 92705
(714) 542-5766 Fax (714) 542-5777

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Turf *Twisters*

Q: After years of 7:30 a.m. tee times seven days a week, the golf course superintendent and Green Committee are requesting a policy change. In addition to making 8:00 a.m. the first tee time, the course will be closed one half day each week for maintenance. Accommodating member play during the winter season is already difficult because of the reduced day length during this time. Is limiting play further during the prime season really necessary, and will we see any real benefit as far as better course conditioning? (Florida)

A: Yes and yes. The accepted standards for putting greens and overall course quality have risen dramatically over the past 10 to 15 years. To provide putting green conditioning in keeping with current expectations, ongoing adherence to good basic management programs is necessary. Having an extra 30 minutes each morning and being able to stay ahead of play provide improved efficiency and effectiveness with routine mowing and other practices. Proper timing of practices and treatments also is critical for producing the desired outcomes. If consistent and good quality conditions are desired, golfers must understand and accept that allowing time for maintenance is a necessity, not a luxury.

Q: We have a small practice range tee that gets wiped out with divots in a very short period of time. Do you have any tips to help the grass grow back faster? We're already fertilizing every week and hand watering daily. (Nevada)

A: Extra water and fertilizer will help, but it is not the complete answer. Given the fact that you have a small tee area, it would help to focus on ways to use the surface area more efficiently, which would allow more time for turf recovery. Here are a few suggestions:

- Begin referring to your practice range as the "warm-up area," which implies that golfers should only be there for a short time before their round and not hang around for an extended practice session.
- Avoid the practice of providing unlimited practice balls. Golfers tend to hit as many balls as they can until the pile is gone, leaving hundreds of divots in their wake. Instead, offer golf balls in small canvas bags, which hold about 25-30 balls.
- Encourage golfers to concentrate the divot pattern so that the tee stations can be moved laterally the next day. The maintenance department or pro shop staff should follow a very specific plan for rotating tee stations so you can maximize the use of the total area.
- Consider installing a row of artificial turf mats at the rear of the tee area that can be used one or two days per week.
- If the tee surface gets completely inundated with divots every year, there may be no alternative but to replace the sod as part of your annual maintenance schedule.

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