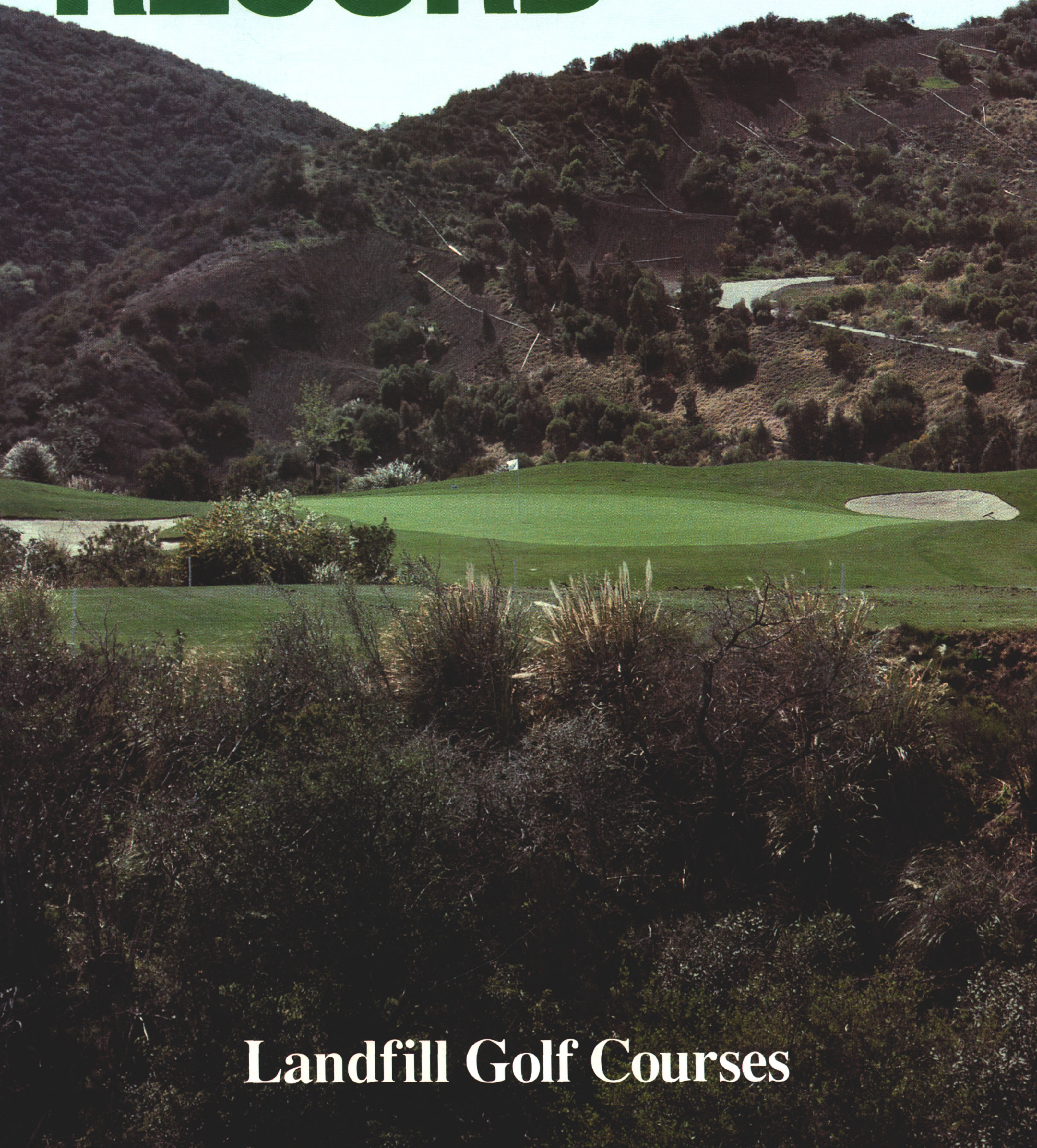
USGA® Green Section RECORD

July/August 1994

A Publication on Turfgrass Management by the United States Golf Association®



Landfill Golf Courses

USGA® Green Section
RECORD

Vol. 32, No. 4
JULY/AUGUST 1994

Cover Photo:

Beautiful golf courses, such as Mountaingate Country Club in Los Angeles, have been successfully built on landfill sites.

GREEN SECTION RECORD (ISSN 0041-5502) is published six times a year in January, March, May, July, September, and November by the UNITED STATES GOLF ASSOCIATION®, Golf House, Far Hills, NJ 07931. Postmaster: Send address changes to the USGA Green Section Record, P.O. Box 708, Golf House, Far Hills, NJ 07931-0708. Subscriptions, articles, photographs, and correspondence relevant to published material should be addressed to: United States Golf Association Green Section, Golf House, Far Hills, NJ 07931. Second-class postage paid at Far Hills, NJ, and other locations. Office of Publication, Golf House, Far Hills, NJ 07931. **Subscriptions $12 a year. Foreign subscriptions $15 a year (surface mail) or $24 a year (air mail).**

At the Industry Hills Golf Courses, a chlorinated polyethylene liner was installed beneath a methane-affected green to prevent gas migration into the root zone.

What Can You Do If Your Golf Course Has Gas?

by PATRICK J. GROSS
Agronomist, Western Region, USGA Green Section

IT IS NOT UNCOMMON for superintendents to get indigestion from the everyday rigors of the job. But for the purpose of this article, we are going to discuss a different type of gas — the gas produced by sanitary landfills. Most turf managers are highly trained to deal with above-ground turf stress caused by weather, pests, and traffic, but a small but growing number of superintendents are having to face new and different challenges: how to maintain golf courses built on landfill sites and deal with the effects of landfill gas and other problems.

Landfill Sites as Golf Courses

As the popularity of golf continues to grow throughout the world, there is an ever-increasing need to build more golf courses, especially public golf courses. As land resources are becoming more scarce, it is difficult to find prime land for course construction. Many cities, counties, and developers are looking at the feasibility of building golf courses on previous landfill sites. It is estimated that more than 60 golf courses in the United States have been built on landfill sites. Japan has been a leader in this area due to the popularity of golf and the limited availability of land resources in that country.

From an environmental and economic standpoint, landfills and golf courses are a good match. Golf courses are one of the few legal land uses for landfill sites. Golf courses can recycle a previously unusable site and provide a greenbelt and recreational opportunities for the surrounding community. Furthermore, golf courses provide valuable habitat for birds and wild animals in urban settings. A landfill golf course can have a positive economic impact, too, by creating jobs and tax revenue for the community.

Landfill sites also produce large quantities of methane gas as a byproduct of solid waste decomposition. Considered a nuisance byproduct in the past, methane gas can be captured and used as a valuable energy source for heating, air conditioning, and other purposes. For example, Mountaingate Country Club in Los Angeles, California, processes 5 million cubic feet of methane gas per day. This gas is transported to nearby UCLA through a 5.5-mile pipeline and is used in the university's central steam boiler. It is estimated that energy costs at the UCLA campus have been lowered by $250,000 annually through the use of landfill gas. Another example in Southern California is the Industry Hills Conference Center and Sheraton Resort. Although only a portion of the 600-acre site is on a landfill, enough methane gas is produced to supplement the energy needs of the hotel and conference center as well as heat the two olympic-size swimming pools on the premises.

One of the benefits of a landfill site to the golf course owner or developer is the lower initial investment to purchase the land, although this saving often is offset by the higher cost of construction and the agronomic challenges associated with long-term maintenance. Developers wishing to purchase landfill sites also should be aware of future liabilities for containment of leachate (liquid waste produced by the landfill) or any remedial work necessary on the site.

(Above) Methane, a large component of landfill gas, can be captured and used as a valuable energy source. This processing plant at Mountaingate Country Club in Los Angeles processes methane for use at the nearby UCLA campus.

(Right) Soil settling occurs as the solid waste is decomposed within the landfill cavity. This is disruptive to golfers and causes severe problems with routine maintenance activities.

Agronomic Challenges

Building and maintaining a golf course on a landfill site is no easy task. If the golf course is to provide quality playing conditions on a long-term basis, several construction and maintenance considerations must be addressed.

Landfill Gas — Various gases are produced when solid waste is decomposed by anaerobic bacteria. Landfill gas is comprised of approximately 50% methane (CH_4), 50% carbon dioxide (CO_2), and trace amounts of hydrogen (H_2) and nitrogen (N_2). Gas production can fluctuate throughout the year depending on the composition of the solid waste and the amount of moisture in the landfill cavity. Soil temperature has little to do with gas production, but soil temperature does affect methane oxidation at the soil surface. These gases must be collected or vented to prevent the buildup of pressure below ground. If the gases are not adequately diverted, problems with plant growth can occur. The methane and carbon dioxide migrate to the surface and displace oxygen in the root zone. This leads to anaerobic soil conditions. Symptoms on turfgrass, trees, and shrubs include slow growth, stunting, limited root development, discoloration, defoliation, and, in severe cases, necrosis.

Ground Shifting and Settling — Landfills are capped with several feet of soil to cover and encapsulate the solid waste. As the solid waste decomposes, the soil cap tends to settle, causing cracks, shear lines, and contour changes. The uneven surface can damage equipment, disrupt mowing operations, and detract from the playability of the

Growing healthy trees and shrubs can be a challenge on a landfill site due to the effects of landfill gas and poor-quality soil often used to cover the waste.

golf course. This can be a problem in any area of the golf course, but it is most disruptive on putting greens. Engineers have developed methods to predict settling based on the composition of the solid waste, air space, and the fill method. Generally, the fill area can be expected to settle approximately 10% over time. Unfortunately, the degree and rate of settling cannot be accurately predicted in a specific area such as a green site.

Drainage — As surface contours change, drainage pathways are disrupted. Broken or crushed drain lines restrict the rapid removal of excess water, creating wet conditions or areas of standing water. This is particularly troublesome on putting greens. Due to state and local regulations, many courses are required to capture all drainage water and reuse it on their site. It is unacceptable to simply dig a dry well to collect drainage water, since this could possibly filter into the solid waste and produce harmful leachate.

Irrigation — Frequent breaks in irrigation mainlines, laterals, and wiring are other challenges associated with soil settling. This can have a devastating impact on turf quality, causing drought stress and turf loss in the affected areas.

Soil Quality — Unfortunately, the soil used to cap the landfill is not always well suited for plant growth. Generally, soil is removed from nearby areas or hillsides to cover the solid waste. Engineers prefer a heavy clay soil as a cap material. Needless to say, this type of soil poses several agronomic challenges for golf course superintendents due to poor drainage characteristics and potential compaction problems.

Fire — Methane gas can be explosive under certain conditions. This presents a potential safety risk for golfers and the golf course maintenance staff. Methane wells and recovery systems, if properly placed and installed, do a good job of capturing methane before it reaches the soil surface. Fires and explosions have been reported at some golf courses during the early stages of site development and construction.

Considerations for Construction and Renovation

The best way to minimize future problems is to employ proper construction techniques from the beginning. Sound agronomic decisions and construction methods are not always the most economical in the short term, but they can minimize disruption and costly repairs in the future.

The first item to consider is the installation of a methane recovery system. Such systems often are mandated and usually are in place before golf course construction begins. An important consideration is to make sure all areas of the golf course that will be located directly over solid waste will be serviced by the recovery system. Even if methane gas is not actively produced at the time of construction, some courses have installed vertical recovery wells in the area that can be connected to the system at a later date.

The depth of the soil cap covering the solid waste is another factor to consider. Although the architect and superintendent have little to do with recommending the actual landfill method, the depth of the soil cap can play a role in selecting suitable green sites. Personal observations and reports from golf course superintendents indicate that fewer problems are associated with sites that have a shallow, well-compacted layer of solid waste covered by a deep soil cap (approximately 35 to 40 feet). If the soil cap is inadequate in depth, problems can be anticipated when digging trenches for the irrigation system or doing other excavation work on the golf course.

To improve the chances for good plant growth, it would be ideal to cover the existing cap with 8 to 12 inches of good quality fill dirt or topsoil. Unfortunately, the cost is often prohibitive. Architect Robert Muir Graves faced this problem during the design and construction of the Santa Clara Golf and Tennis Club in Santa Clara, California. Given the different types and depths of soil cover, he believed the only way to avoid future problems was to cover the entire site with 5 to 7 feet of soil. This would add millions of dollars to the construction cost. As an alternative, it was decided to strip and stockpile the existing soil, grade the refuse to the desired contours, and then cap the golf course with the stockpiled soil. Graves was then informed that recycled wastewater would be used to irrigate the golf course. In an effort to improve the internal drainage characteristics of the soil, a good quality sand was located from a nearby dredging operation in San Francisco Bay. Due to the high price of topsoil in the area, it was more economical to plate the entire golf course with a 12-inch layer of sand. Covering the entire course with good quality sand or soil may not always be feasible, but it does improve the quality of the turfgrass and trees.

To reduce the frequency of irrigation breaks, some landfill golf courses use high-density polyethylene pipe (HDPE), especially in high-settlement areas. There are several advantages to using this product, including better flexibility, high temperature tolerance, resistance to water hammer, and flow characteristics similar to that of standard PVC pipe. There also are fewer leaks with this type of pipe since all joints are heat fused. David Bermudez, superintendent at Mountaingate Country Club, installed HDPE mainlines on two golf holes and estimated that it has reduced repair costs by 80%. Due to the high cost of the pipe, HDPE normally is used only for mainlines.

The location and construction of putting greens is a primary concern. If at all possible, it is desirable to locate greens on solid ground. Since this is not always feasible, other construction techniques can be employed to prevent gas migration into the putting green soil profile. At the Industry Hills golf courses, one methane-affected green was rebuilt in 1989 using a 30 mil chlorinated polyethylene (CPE) liner placed beneath the green. The liner was protected above and below with geotextile fabric, and then a 6-inch soil cap was placed on top of the liner. The soil cap was shaped to the desired contours, and construction proceeded according to USGA Putting Green Construction Recommendations. An additional methane well also was installed to capture gas in the area. Kent Davidson, CGCS, Director of Golf Course Maintenance at Industry Hills, reports that the project was a complete success and no problems have been experienced since the liner was installed.

Growing healthy trees and shrubs can be difficult on a landfill site. Successful tree establishment depends mainly on the depth of the soil cap and proper tree selection. Trees planted in an area with a deep soil cap tend to have a better chance for survival. In areas with a shallow soil cap, tree mounds can be created by adding soil to the intended planting site to enhance the rooting area. Tree selection should be based on hardiness and tolerance to oxygen-poor conditions. It is reported that pines (*Pinus sp.*) and alders (*Alnus sp.*) tolerate such conditions, as do eucalyptus (*Eucalyptus sp.*), sycamore (*Platanus sp.*), and pepper trees (*Schinus sp.*). Most turfgrass species will survive on landfill sites due to the relatively shallow rooting characteristics of turfgrass plants. Currently, no turf species are considered tolerant of landfill gas.

A final consideration is compliance with laws and regulations. Legislation concerning the control and disposal of landfill gas already has been imposed by the federal government and many states. Environmental concerns about landfill gas contributing to the *greenhouse effect* have prompted much of this legislation. In California, several state and local agencies are involved in monitoring landfill sites, including the Department of Health, local Air Quality Management Districts, the California Integrated Waste Management Board, and others. In most states, the Solid Waste Division or state EPA has jurisdiction over landfill sites. Testing and routine monitoring are often required to comply with regulations and should be considered a regular part of the maintenance budget.

Maintenance Considerations

After a golf course has been built on landfill, one might say "the fun is just beginning." Problems caused by soil shifting and settling will require frequent repairs that must be planned for in the annual maintenance budget.

The budget should be expanded to account for added irrigation repairs and maintenance. Installation of HDPE pipe can help to reduce repairs on mainlines; however, lateral line repair and sprinkler head leveling will be necessary on a recurring basis. As an example, David Bermudez at Mountaingate Country Club budgets $3,000 per month for irrigation repairs at the 27-hole facility. Mountaingate also employs three full-time irrigation technicians to handle the work load.

Soil settling can be expected for several years. This can severely affect cart paths, bridges, roads, and drainage systems. Some repairs will be minor; however, recurring expenses for renovation of settlement areas and associated golf course features should be forecast in the budget.

Putting green management on landfill golf courses can be a challenge. For greens affected by methane gas, there is little that can be done except to rebuild. Mike Huck, former superintendent at Industry Hills, tried several methods to cope with the negative effects of methane gas on the 15th green of the Eisenhower Course. During the mid-1980s, Mike implemented programs that included mole plowing, deep drilling, frequent core aeration, and supplemental fertilizer applications. These programs only provided temporary relief from the anaerobic conditions until the green was rebuilt in 1989.

Soil settling and unexpected contour changes also affect greens. Sometimes, the contour changes are hardly noticeable and do not affect daily maintenance operations. Some innovative techniques have been tried to prevent settling of putting greens. For example, one course tried building greens on top of a concrete saucer in the hope that, if settling did occur, the entire green would settle evenly. Unfortunately, many of the concrete saucers broke or the greens tilted in a direction unsuitable to the direction of play. The most practical advice available is to scout nearby areas where minimal settling occurs and try to relocate the green in that area. According to Tom Shuput, Director of Project Development for SCS Field Services, areas with a deep soil cover also would be good locations for putting greens.

Due to the poor quality soil often found on the fairways, be prepared to schedule additional slicing or core aeration to relieve compaction and improve air and water penetration. Installation of a continuous cart path system and restricting carts to the paths also helps minimize compaction and maintain quality turf. Fairway topdressing can be another tool to improve conditions on fairways afflicted with impermeable, poor quality soils.

Conclusion

Many golf courses have been constructed on landfill sites. It is likely this trend will continue as available land for golf course construction diminishes. The key to success is understanding the effects of landfill gas and carefully coordinating the design and construction of the golf course with the installation and operation of a gas collection system. After a golf course has been constructed on a landfill site, there is little that can be done to prevent the damage and disruption caused by settling. In these situations, extra expenditures for repair and maintenance of the golf course should be anticipated for several years. Additional research is necessary to determine the cultural practices that can minimize the effect of landfill gas on plant materials.

Overall, golf courses built on landfill sites make a positive contribution to the environment, the economy, and the community. Despite the challenges, good quality playing conditions can be achieved — even if your golf course has gas.

Acknowledgements

The author wishes to thank the following people for their valuable contributions to this article: Kent Davidson, CGCS; Mike Huck, David Bermudez, and Tom Shuput.

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WET GREENS: LET'S TRY THIS FIRST

Before drainage was installed, the green remained wet and soft for several days after a rainfall.

by LES CARPENTER
Superintendent, Roxiticus Golf Club, Mendham, N.J.,

and

DAVID A. OATIS
Director, Northeastern Region, USGA Green Section

Plywood sheets were laid down along the trench line to protect the turf and make cleanup easy.

IT IS COMMON KNOWLEDGE that poor internal drainage characteristics in putting green soils can make it difficult or impossible to grow consistently healthy and reliable putting green turf. To combat this problem, many management programs and techniques have been developed over the years. In many cases, soil modification through frequent aerification in combination with topdressing (with straight sand or high-sand mixes) has been successful in converting difficult or marginal soils into more manageable ones. However, more drastic measures may have to be used with particularly difficult soils.

In dealing with poorly drained greens, complete reconstruction is one option that must be considered. Due to the disruption and cost involved, however, it sometimes is worthwhile exploring other alternatives. This is especially true if the problems are confined to a few greens on an older course. Consistency among greens is highly desirable, and it is very difficult to achieve consistency where there exist different grasses and radically different construction materials and maintenance practices. New, high-sand greens have completely different management requirements, and they exhibit very different playing characteristics from older soil-based greens. Having both types of greens on the same course complicates the maintenance program, and it can make achieving consistency difficult or impossible. This is precisely the dilemma that faced officials at Roxiticus Golf Club in Mendham, New Jersey.

All of the original greens at Roxiticus were constructed from heavy clay soils that

A thin layer of gravel was put in the trench, followed by 3-inch perforated drainage tile and more gravel. Topmix was added and tamped in layers to minimize possible settling problems.

Essential tools included a narrow shovel and a tamping device made especially for the project.

exhibited extremely poor internal drainage characteristics. No drain lines of any type were installed when the greens were built, and more than a few are located in poor grass-growing environments. Several of the greens were very prone to developing anaerobic soil conditions and had to be kept closed after periods of wet weather. General thinning, along with moss, algae, disease, and scalping problems, also was frequently experienced. Soil modification techniques, including conventional aerification and topdressing programs, did not provide adequate relief. Deep-tine aerification was tried, but this practice actually caused the greens to hold even more water. After a wetter than normal summer in 1992, it was decided that something had to be done, and we began to collect information on the various options available.

Eventually it was decided that we should try to install a drainage system in one of the existing greens. We had heard of this type of drainage work being done regularly in New Zealand (*Green Section Record*, March/April 1992, "Drainage Improvement — Remedy Without Reconstruction"). Upon further investigation, we also learned that Mr. Al Rathjens, golf course superintendent at Raritan Valley Country Club, Somerville, New Jersey, had installed drainage systems in two existing greens with good results. After a lengthy visit to Raritan Valley, where we discussed the program with Mr. Rathjens and viewed the results firsthand, Ron Renee, chairman of the Green Committee at Roxiticus Country Club, and I became convinced that a putting green drainage installation project was worth a try as an alternative to complete reconstruction. In late October of 1992, we cut a temporary green for the third hole and got to work.

The first step was to design the layout of the drainage system and identify an existing drain line to serve as an outlet. We decided to space the trenches 4' apart and to extend them all the way through and off the green. The rationale behind this was to provide as much drainage as possible to compensate for the poor internal water movement characteristics of the existing soils, and to avoid having to make drainage connections in the green itself. Thus, the drain lines were extended into the first cut of rough on either side of the green. Turf paint was then used to draw the outline of the system on the green.

The next step was to bring in a sod cutter. The sod was cut and moved out of the way by hand. Half-inch plywood was then laid out on each side of the proposed trench. On one side, the 4' × 8' sheets of plywood were laid end to end, but on the side where the trencher would throw the soil, the plywood was laid side by side. This was done to provide additional area for the soil and to allow a small maintenance vehicle to be driven on the plywood alongside the trench to help with soil removal.

Grades were checked frequently, and after the trench was thoroughly cleaned and leveled, a thin layer of ⅜" gravel was spread evenly and tamped to prevent future settling. Three-inch perforated flexible drainpipe was then laid in the trench, and several layers of gravel were added and tamped until the top of the gravel was approximately 12" below the surface of the green. A manifold type of arrangement was used to connect the drain lines from the green to existing drains located nearby.

NOTE: The high ends of the drain lines were extended well out into the first cut of rough and were brought to the surface and enclosed in a valve box. This provides a clean-out mechanism in the event of future problems, and a method to check how well the drain lines are functioning.

After some experimentation, we decided to make our own root zone mix with which to backfill the drainage trenches. The mix consisted of an 80% sand and 20% soil combination. We hoped that it would have adequate water- and nutrient-holding capacity so that the turf over the trenches would not require extra moisture or fertilizer. The mix was then added to the trench. Again, we worked in layers, with each 3" increment being gently tamped by hand. We were very concerned about future settling problems and worked diligently to prevent this by tamping carefully and thoroughly, something that Mr. Rathjens had stressed as being a key to the success of his project at Raritan Valley. We followed this advice closely, and we have not seen any significant amount of settling in the 18 months since the system was installed.

The final step was to reinstall the sod, taking care to replace it just as it was removed. After a final tamping, the green was covered with a geotextile fabric for the winter.

The following spring the cover was removed and the trenches were topdressed as needed. Fortunately, settling was not a big problem, and we attribute that to the amount of tamping performed during the backfilling operation. The summer of 1993 was quite dry, so the system was not thoroughly tested. Nonetheless, the initial results were good enough to convince us to perform the same procedure on another green in the fall of 1993. We are hopeful that this drainage installation project will increase our water management capabilities to such an extent that complete reconstruction will not be necessary on either green. Despite an extremely wet spring in 1994, both greens have performed well to date.

As far as cost was concerned, the greatest expense by far was that for labor. Materials such as sand, gravel, drainage pipe and valve boxes amounted to less than $1,500 per green. However, the project required approximately 544 man-hours to complete. Even though we did not hire additional labor for the project, its completion resulted in other work being neglected.

This type of renovation project is likely to improve conditions in many situations, but there is always a possibility that it will not improve conditions to a sufficient degree. We decided to try this method of drainage improvement knowing full well that we could always employ the more expensive and disruptive option of complete reconstruction at a later date if the results were not acceptable. Fortunately for Roxiticus, the results thus far have been very satisfactory.

Great care was taken to replace the sod as it had been removed.

The high ends of the drain lines were brought to the surface, off the green, and eventually were attached to valve boxes for easy access.

Following is a list of the do's and don'ts that helped make our project a success:

• Communicate the problem as well as the solution to the appropriate committees and enlist their support for undertaking this type of project. Be sure not to sell it as a cure-all.

• Take the time to design the system carefully and procure all necessary materials before the project begins.

• Cover the putting surface on either side of the trench with plywood so that no

mechanical injury is inflicted upon the existing turf.

• Check grades often to insure a constant and adequate fall.

• Extend the drain lines beyond the edges of the green by several feet in both directions. Extending the high end of the drain outside of the green and enclosing it in a valve box provides a valuable flush point. Extending the low end beyond the edge of the green is important so that connections are not made in the putting green. If additional drain lines are deemed necessary in the future, they can be installed and connected with less putting surface disturbance.

• Utilize a qualified soil testing lab to perform physical soil testing work before selecting a material with which to backfill the trenches. The material selected should have adequate drainage properties as well as adequate moisture and nutrient rentention so that the trenches do not require supplemental irrigation or fertilization.

• Tamp the gravel and topmix by hand at regular intervals. Settling can cause major problems and for the most part is avoidable.

• Reinstall the sod just as it was removed to minimize visible disturbance.

• If the work is done in the fall, be sure to cover the trenches with a geotextile fabric to prevent desiccation of the sod during the winter.

(Above left) The following spring, trench lines were topdressed several times to account for some slight settling.

(Above right) The sod was cut back and topdressing was added where settling was more severe.

(Right) A final tamping helped smooth the sod over the trenches.

TISSUE TESTING: QUESTIONS AND ANSWERS

by KEITH HAPP
Agronomist, Mid-Atlantic Region, USGA Green Section

HAVING the opportunity to monitor the cutting edge of technology in the golf course maintenance industry is an exciting part of the work of USGA agronomists. We are continually asked questions about new products and procedures, and we are among the first to see them in action. Unfortunately, not all questions have easy or direct answers. The question about the value and use of tissue testing falls into this category. Tissue testing is being performed more and more, and questions about this practice have grown more numerous and pointed. Following are some of the most often asked questions about tissue testing, along with some answers that provide a perspective on the potential value of this technology in the turfgrass industry.

In preparing these questions and responses, references were obtained through the Turfgrass Information File (TGIF), and university researchers throughout the country were interviewed for their views on this timely topic.

Question: What is tissue testing?

Answer: *Tissue testing* involves analysis of foliar tissue (grass clippings) for nutrient content, and should not be confused with *plant analysis*, which determines the elemental content of all the plant tissue (leaves and roots).

The goal of tissue testing is to better meet the nutritional needs of golf course turf. In theory, knowing the nutritional content of turfgrass tissue would allow the design of a more efficient fertility program to produce healthier and better quality turf. However, nutrient interactions occurring within the turfgrass plant (combined with varying environmental conditions) are not completely understood, and modifying a fertility plan based on tissue test results is difficult and is not recommended by most turfgrass scientists at this time.

Question: Are all tissue testing techniques the same?

Answer: No, they are not the same. Basically, there are two approaches that can be used: Wet Chemistry techniques and Near-Infrared Spectral analysis (NIRS).

Tissue Testing Methods
(Jones & Kalra, 1992)

Wet Chemistry
Atomic Absorption Spectrometer
ICP Plasma Spectrometer
DC Plasma Spectrometer

Other
Near-Infrared Spectral

Wet chemistry techniques utilize sophisticated laboratory equipment and dilution materials to determine nutrient concentrations. The Atomic Absorption spectrometer (a wet chemistry technique) can provide very accurate data, but the turnaround time for receiving results after submitting a sample may be as long as two weeks.

Recently, an effort has been made to adapt NIRS technology for analyzing the nutrient content of turfgrass tissue samples. Near-infrared spectral analysis can be done much more quickly and cost effectively than wet chemistry, and was first used to analyze forage grasses for protein content (Wilkinson & York, 1986). NIRS utilizes a spectrum of light in the near-infrared region. The instrument measures reflectance at specific bands or wavelengths of this light spectrum. A computer then uses this information to statistically predict the content of specific nutrient elements.

Unfortunately, many turf managers confuse the two methods. Wet chemistry analysis is a primary method of determining nutrient concentrations, while NIRS is a secondary method. In other words, a single wet chemistry lab (providing repeatable results) must be used to generate the database which then is used by NIRS technology. These data are stored in the computer and serve as a base from which tissue nutrient concentrations can be estimated. This process is ongoing.

The bottom line is that *wet chemistry* and *NIRS* techniques are different, and the terms should not be used interchangeably.

Question: Which method provides the most accurate results?

Answer: Wet chemistry techniques provide an accurate analysis of the nutrient concentrations within turfgrass leaf tissue (Jones & Kalra, 1992). On the other hand, available information and research literature do not support the accuracy of the newer NIRS procedure at this time. With the exception of nitrogen, correlation studies between NIRS and wet chemistry have produced weak to moderate relationships for many nutrient concentrations. NIRS provides results very rapidly, but unfortunately, interpreting the data is difficult and the accuracy of this technique currently is questionable.

Question: Can tissue analysis provide information about fertilizer needs that cannot be obtained from soil analysis?

Answer: Yes, but the information gained is difficult to interpret. Soil testing is the place to begin when designing a fertility program.

Many turf managers have the impression that plant uptake of nutrients is directly related to the amount of nutrients available in the soil. Research has shown that this is not always true. The relationship between nutrient supply in the soil and nutrient concentrations in the plant is strongest when nutrient supplies become so low that they limit the growth of the turf. Plants have internal mechanisms that allow them to control nutrient uptake to meet their needs when nutrient concentrations in the root zone are plentiful. Nutrient deficiency develops when demands are in excess of supply (Kussow, 1993). Therefore, adequate nutrition levels may exist in the soil, but plants, for a number of reasons, might not be taking up those nutrients. Tissue tests could be used to indicate nutrient deficiencies in the plant that do not actually exist in the soil. In some cases, adjusting the soil pH may be all that is needed to correct a nutrient availability problem.

Question: Do baseline tissue nutrient concentration levels exist for turfgrass?

Answer: Unfortunately, no. Baseline nutrient levels for turfgrasses do not exist. Baseline levels refer to nutrient concentrations within turfgrass plants that correspond to optimum development, growth, and appearance. The nutrient concentration levels established for forage grasses were first used as the standard for turf, but one could question the use of forage standards in making decisions about turfgrass fertilization!

The fact remains that nutrient levels in turfgrass vary considerably depending on species, cultivar, time of sampling, and management practices (Overman & Wilkinson, 1993). J. R. Jones (1980) summarized the literature and suggested sufficiency ranges for elemental tissue contents. These ranges, however, are not applicable in all situations (Turner, 1992; Turner & Hummel, 1992). For example, interpreting tissue test results for a polystand of turf (such as *Poa annua* and bentgrass) is even more difficult. Nutrient concentrations that are acceptable for bentgrass might not be acceptable for *Poa annua* or vice versa. Very few golf course putting greens consist of a single turf species. Even mixed stands of perennial-type and annual-type *Poa annua* could present a problem, as could blends of bentgrass cultivars. Much more research is needed.

Question: If I choose tissue testing as a tool to monitor my fertility plan, how frequently should tissue testing be performed?

Answer: Weekly testing would provide data that could be analyzed for possible trends. Maintaining weather records would also help. For instance, nitrogen will accumulate during cooler weather, while nitrogen depletion will take place during warmer weather. Nitrogen concentrations are dynamic. On one day it may be adequate and two days later it can be deficient. Also, other nutrient concentrations may be affected by nitrogen fluctuations, which may or may not affect turf quality. The more data generated, however, the greater the chance that strong correlations (with soil tests, time of year, weather, visual quality, playability, etc.) will exist. Two or three years of data collection may be necessary before this information is of value.

Question: What are some of the pitfalls commonly associated with tissue testing?

Answer: Difficulty in interpreting results is a significant pitfall. Cost is also a consideration. Testing can become expensive if many samples are analyzed. In addition, if test results indicate deficiencies of micronutrients and corrective treatments are made, these applications can be expensive. Also, micronutrients are required in small amounts and overapplication is a risk.

Representative tissue samples can be easily obtained thanks to clipping removal programs.

Question: Since micronutrients are required in very small amounts, how can I tell if the materials being applied are doing any good?

Answer: A common pitfall in turfgrass maintenance is the lack of test plots. Test plots not only provide areas to calibrate spray equipment, but also provide an excellent opportunity to visually examine turf quality differences following different treatments. Tissue testing will not accurately determine nutrient concentrations unless all of the material applied has been absorbed. Any residuals that remain on the leaf will cause inaccuracy. In fact, some fungicides can solubilize nutrients and allow for uptake into the plant. The practical approach is to utilize a test area before deciding to make blanket applications of micronutrients.

Question: Is there a governing body or an association that monitors the testing procedures being used by testing laboratories?

Answer: Yes, the *Council on Soil Testing and Plant Analysis* was formed in 1969 (Jones & Kalra, 1992). Its major objectives are:

1. To promote uniform soil testing and plant analysis methods, use, interpretation, and terminology.

2. To stimulate research on the calibration and use of soil testing and plant analysis.

3. To provide a forum and information clearinghouse for those interested in soil testing and plant analysis.

4. To bring individuals and groups from industry, public institutions, and independent laboratories together and share information.

A survey was sent to testing laboratories in the United States and Canada. The results indicated that a majority of the laboratories responding to the survey provide a wide range of services and utilize the latest available technology. Interestingly, not one of the nearly 200 laboratories responding to the survey (601 surveys were mailed) were using the NIRS technology to determine tissue nutrient levels. All were using wet chemistry techniques. The accuracy of NIRS has not been substantiated by research and thus is not recognized by the Council as a reliable testing method. However, NIRS is being used by a number of vendors nationwide, and this is where many of the concerns and questions from turf managers arise.

Question: Of what practical value is "tissue testing" in day-to-day golf course maintenance?

Answer: For tissue testing to be helpful in day-to-day turfgrass management, the results from tissue testing must be obtainable in a timely fashion. Regrettably, wet chemistry tissue testing takes time to complete, often days or weeks. Thus, if an immediate problem needs to be addressed, tissue testing would not be practical.

For tissue testing to be helpful as a diagnostic tool, it must provide results that are interpretable and also correspond well with soil tests. Much of the research examining soil nutrient levels to determine low, medium, and optimum ranges was performed more than 20 years ago. The fertility trends of that era, particularly for nitrogen, were higher than those rates commonly applied today, so soil test interpretations that are based on 1970s protocols may be erroneous.

It is fair to conclude that correlating soil test data with tissue nutrient concentrations is very difficult (Hall, 1974; Goss & Brauen, 1985; Spear & Christians, 1991) and misleading.

Question: Is fast and accurate tissue testing unobtainable by the turf manager?

Answer: There is new technology available that can provide rapid, accurate, and inexpensive results. Inductively Coupled Plasma-emission spectrometry (ICAP) is an advanced wet chemistry technique that can analyze a sample for a wide range of elements. An increasing number of testing laboratories are using ICAP, although the atomic absorption wet chemistry method is still the most frequently employed procedure (Jones & Kalra, 1992).

Also, NIRS technology is improving. New hardware, software, and a new and expanded data base are being developed. In time, this technology may have greater application in the turfgrass management industry.

Summary

Tissue testing may prove to be useful for monitoring nutritional fluctuations within turfgass. However, information on which to base a complete fertility program has not been developed (Christians, 1993). The usefulness of tissue testing is very site-specific due to variables such as soil pH, CEC, soil type, plant species, soil moisture, height and frequency of mowing, time of sampling, soil temperature, herbicide, fungicide or growth regulator applications, fertility regimes, topdressing schedules, and other cultural programs.

Tissue testing may be used to supplement soil test results but should not be considered as a replacement for soil testing. It is the consensus of all the scientists contacted while preparing this article that more research is needed to make tissue testing a standard tool on which to base fertility recommendations.

Tissue analysis has long been used in production-based agriculture to help achieve maximum yields (Smith et al., 1985). But turf management is not focused on maximum tissue yields. Quality is more important than quantity.

As with any new technique or management strategy, university research and field testing must be combined to document the usefulness and practical value of tissue testing. Establishing a strong foundation (cultural practices, sound water management, balanced fertility) is important before the full benefits of fine-tuning techniques such as tissue testing can be realized.

Many turf managers are integrating tissue testing into their management programs. It is one of many new tools being developed, all focused on helping the turf manager become more effective and efficient. New technology stimulates questions that are investigated, and this leads to better understanding and ultimately better management techniques.

Tissue testing results are no better than the sample taken. Samples should be free of weeds and other contaminants such as moss.

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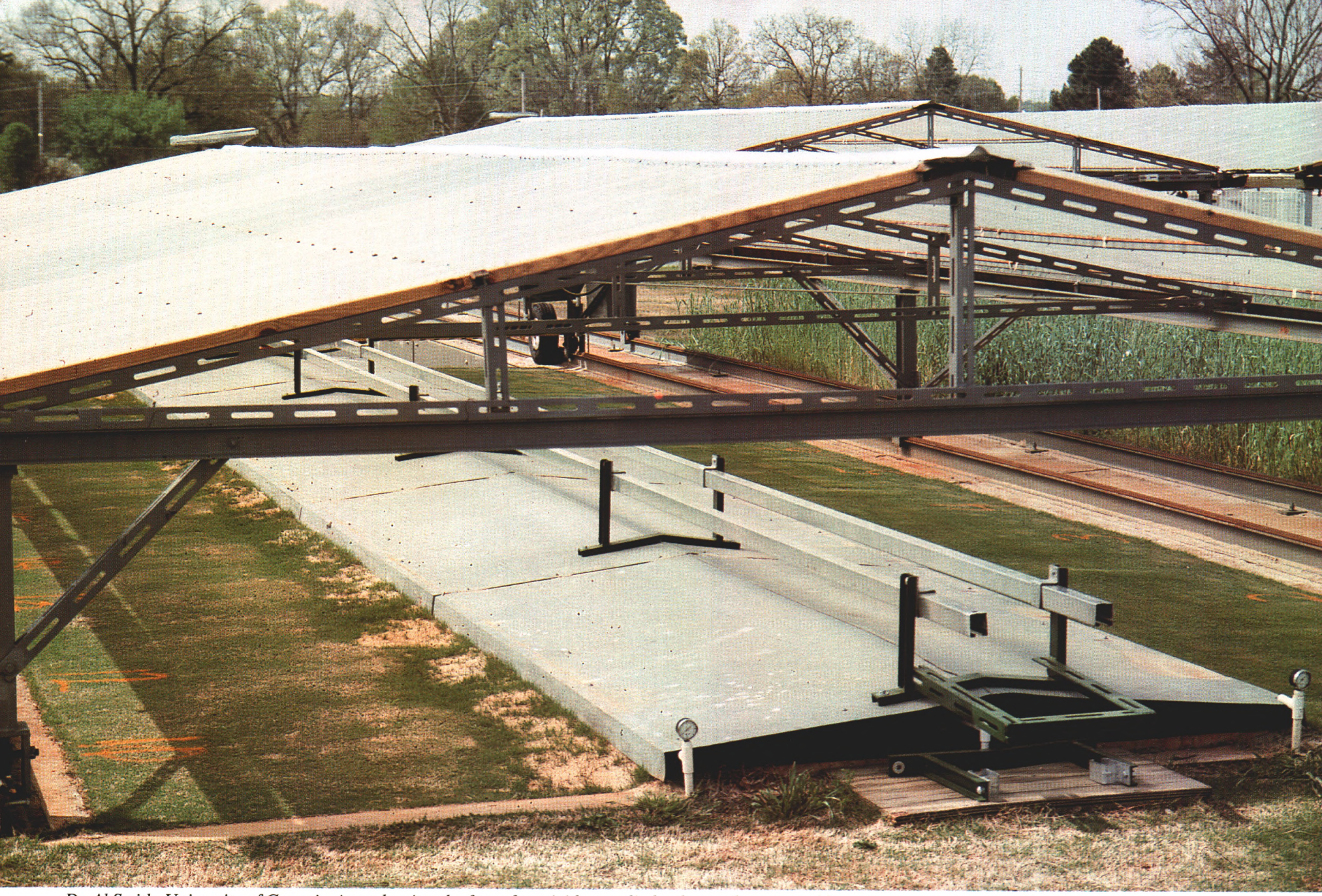


Dr. Al Smith, University of Georgia, is evaluating the fate of pesticides applied to bermudagrass and bentgrass putting greens. The lysimeter facility contains a series of buckets (not shown) buried underneath the surface of the green that collect water moving through the soil. Water samples analyzed in the laboratory indicate that the amount of properly applied pesticides passing through putting greens is negligible.

Beyond Appearance and Playability: GOLF AND THE ENVIRONMENT

by DR. MICHAEL P. KENNA
Director, USGA Green Section Research

IT WAS just a short time ago at the 1990 U.S. Open at Medinah Country Club that then USGA President Grant Spaeth announced the funding of a three-year research program that would focus on the impact of golf course activities on the environment.

In the spring of 1991, 21 research projects were selected to focus on the following objectives: 1) the fate of pesticides and fertilizers applied to golf courses, 2) development of alternative methods of pest control, and 3) the benefits of turfgrass and golf courses to humans, wildlife, and the environment.

The research effort has already yielded several important publications. *Golf Course Management and Construction: Environmental Issues* by Drs. James Balogh and William Walker provides a comprehensive summary of the effects of construction and management of turfgrass systems. The *Landscape Restoration Handbook* by Donald Harker offers information to property owners and managers about naturalizing the managed landscape. Dr. James Beard has published a scientific article on turfgrass benefits entitled "The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans" in the May/June 1994 *Journal of Environmental Quality.*

The alternative pest management projects funded as part of the program have made progress sorting out what may or may not work on the golf course for non-pesticide control of turfgrass diseases and insects. At Rutgers University, a new nematode was developed and released, holding promise as a control for white grubs equal to some insecticides. Researchers at the University of Kentucky have documented several beneficial predators of white grubs and cutworms that can help reduce pest egg populations if properly managed. However, it will require more time to evaluate these and some of the other alternative pest management strategies before their ultimate effectiveness in reducing pesticide use on golf courses can be determined.

This past April, the research project leaders involved with pesticide and fertilizer studies discussed their results with the USGA's Turfgrass Research Committee at Golf House. The November 1994 issue of the *Green Section Record* will feature summaries of the pesticide and nutrient fate projects prepared by the researchers. Overall, the preliminary reports indicate that there is a lot of good news, but there also are some areas where we can do an even better job protecting the environment.

Among the positive results is that when a fertilizer is properly applied, the amount of nitrogen that reaches groundwater is negligible. Researchers at Iowa State University (ISU) and Michigan State University (MSU) reported preliminary results that indicate that less than one percent of the nitrogen applied to a Kentucky bluegrass turf traveled to a depth of two and four feet, respectively. The MSU study also demonstrated that there were no differences between late fall and early spring nitrogen fertilizer applications (*Figure 1*). The ISU study indicated that four quarter-inch water applications were better than a single one-inch irrigation after nitrogen fertilization.

Often overlooked by scientists who study the fate of pesticides and fertilizers is the positive effect of thatch in retaining and breaking down organic chemicals. The preliminary results from most all of the projects indicate that pesticides break down faster in the turfgrass environment than what is typical when these materials are applied to agricultural crops.

The turfgrass leaves, shoots, and thatch intercept most of the pesticide during application (*Figure 2*). Over time, the amount of pesticide recovered in the leaves decreases due to irrigation, rainfall, and clipping removal. The thatch layer, which retains pesticide residues and is somewhat unique to turfgrass systems, generally contained the greatest amount of pesticide residue.

Research projects at the University of Massachusetts and the University of California at Riverside indicate that pesticides applied to turf volatilize in various amounts. Volatilization is the process by which a solid or liquid changes to a gas.

The amount of applied pesticide lost as volatile residues was generally less than 13 percent for the products tested. After two weeks, volatile residues were either non-detectable or less than 0.03 percent of the total applied to turf. The vapor pressure and surface temperature of the turfgrass site were directly related to the volatilization process. Irrigation after pesticide application delayed

The two diagrams show the fate of a fall and spring application of fertilizer two full years after the initial treatment. Less than 1 percent of the nitrogen fertilizer reached a depth of four feet during the two-year study. The 18.4 and 35.9 percent of nitrate nitrogen not recovered for the fall and spring applications, respectively, is thought to have volatilized or undergone denitrification. Critics of turfgrass fertilization programs have incorrectly assumed that nitrate nitrogen not found in the verdure, thatch, soil, and clippings leaches into groundwater.

FIGURE 1
Percent of Total Nitrogen Applied Recovered Two Years After Application

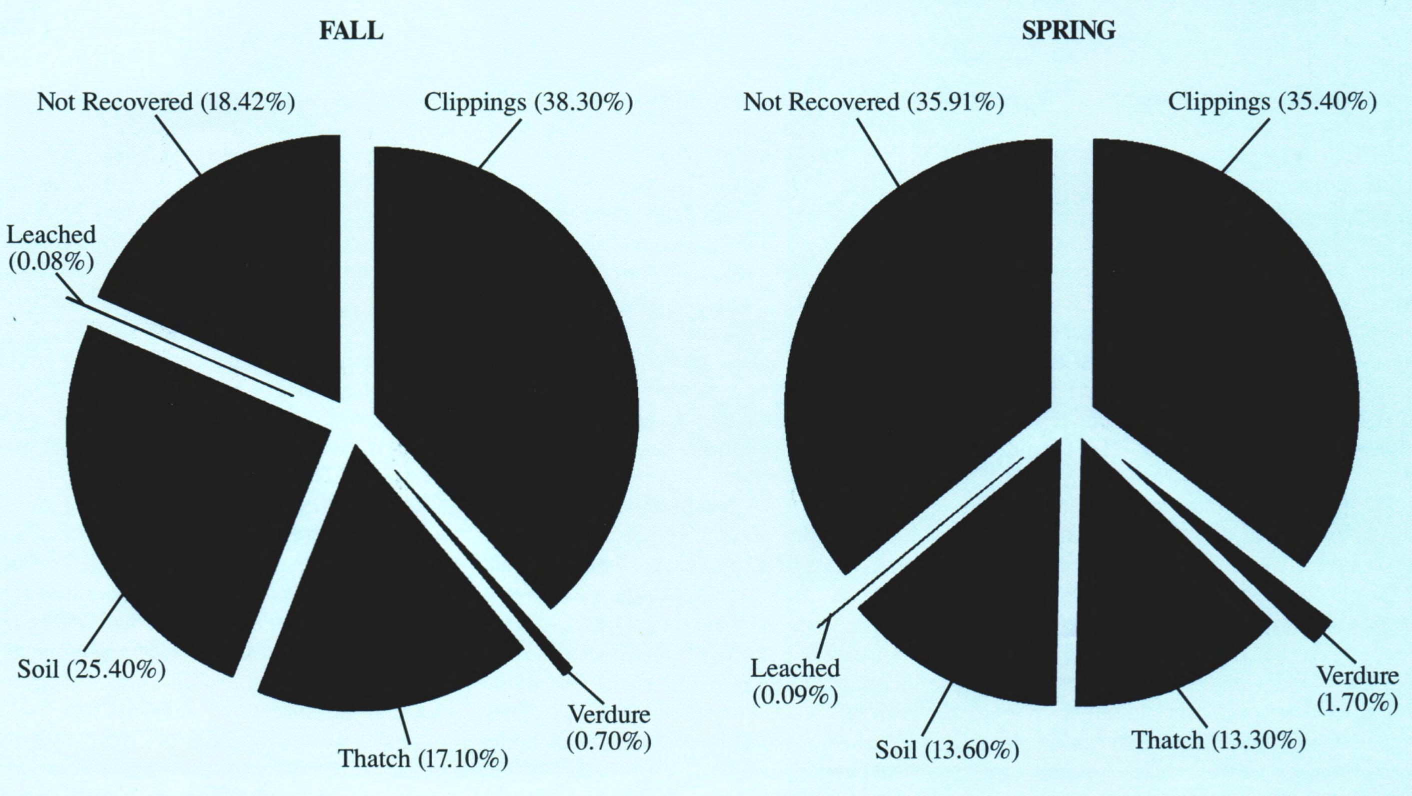
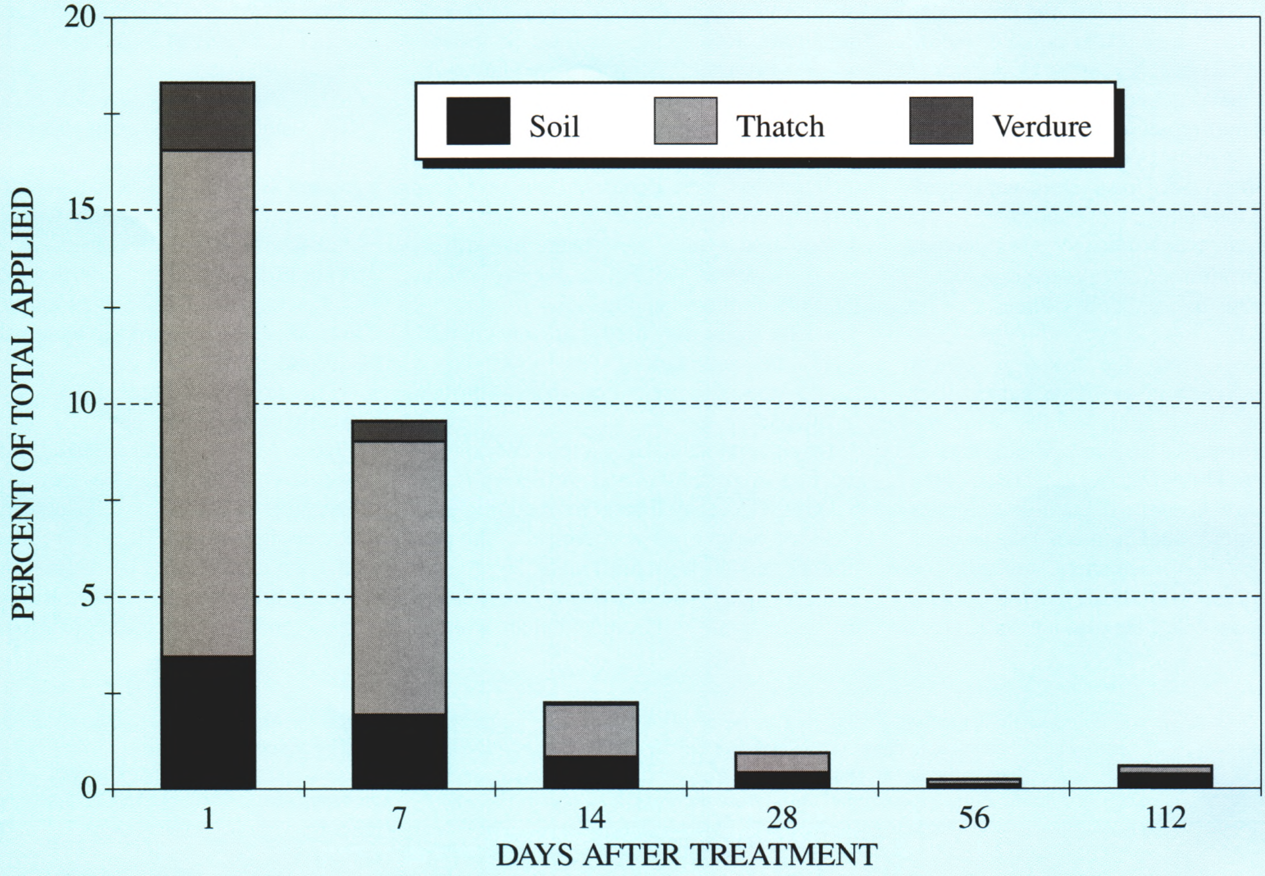


FIGURE 2
Pesticide Residues on Turf/Soil (Triumph applied at 2 lbs. ai per acre)



Preliminary results indicate that pesticides break down faster than what is typical when these materials are applied to agricultural crops. The turfgrass verdure (leaves, shoots, stolons, etc.) and thatch intercept most of the pesticide after application.

volatilization, but did not prevent the production of volatile residues.

Dislodgeable pesticide residues were only significant immediately after a pesticide was applied to turf. Research at the University of Florida and the University of Massachusetts indicated that once the leaf surface dried, dislodgeable residues were greatly reduced. Irrigation reduced dislodgeable residues on the first day after application, but apparently due to an upward wicking type of movement, dislodgeable residues were present two and three days after the pesticide was applied.

Preliminary estimates of the health effects for the amount of dislodgeable and volatile residues indicate that the levels found are safe, according to EPA standards. However, caution should be taken immediately after a pesticide has been applied to the golf course. Golfers, owners, and municipalities need to recognize that golfers should not be following spray equipment around the golf course.

Preliminary results from studies concerned with the loss of pesticides and nutrients in runoff have been variable. Pennsylvania State University runoff plots irrigated with six inches of water per hour have yielded nitrogen and phosphorus amounts less than or equal to what was found in the irrigation water itself. Pesticide concentrations reported thus far are less than or equal to one part per millon. An interesting finding of this study was that bentgrass fairway plots had significantly lower amounts of water runoff than mature ryegrass plots. Compared to ryegrass, bentgrass has higher shoot density, stoloniferous growth habit, and more thatch, which ultimately reduced the amount of runoff.

The first year's results from runoff plots at the University of Georgia indicate that heavy-textured, kaolinite clay loam soils will not be as forgiving as the sandy loam soil found at the Penn State runoff plots. At least 40 percent of the water from a one-inch rainfall simulation moved off the sloped plots. Also, this water contained up to 10 percent of the herbicides that were applied 24 hours before the rain simulation. These data would indicate that precautions should be exercised when applying some pesticides to golf course fairways with heavy-textured soils and slopes greater than 5 percent.

The mathematical models used by environmental regulators and scientists to predict the fate of pesticides and fertilizers will need some major overhaul before they accurately represent what happens on golf course turf. The study at the University of Georgia demonstrated that the GLEAMS (Groundwater Loading Effects of Agriculture Management Systems) model significantly overestimated the amount of 2, 4-D that moved through a putting green root system (*Figure 3*).

The GLEAMS mathematical model is commonly used to help identify chemical and soil properties, as well as plant and meteorological factors, influencing the transport of pesticides through soils in agricultural lands. Only minute quantities of 2, 4-D were actually detected in the water that leached from the putting green root system lysimeters.

Even though the GLEAMS model greatly overestimated the amount of herbicide moving through the putting green, the maximum predicted was still below the maximum contamination level established by the U.S. EPA. The difference between the measured and predicted amounts of herbicide found in water moving through the lysimeter may be due to a lack of understanding of the role played by a dense surface of turfgrass leaves and thatch in pesticide fate. Also, surface evapotranspiration (ET) and water movement through the turfgrass/soil system are not adequately accounted for in current prediction models.

During the last three years, USGA-sponsored environmental research has demonstrated that nitrogen leaching is minimal, that the turf/soil ecosystem enhances pesticide degradation, and that the current agricultural models are inadequate at predicting the fate of pesticides and fertilizers applied to turfgrass maintained under golf course conditions. There are still some questions with regard to runoff, volatilization, and dislodgeable residues that need to be addressed.

The USGA is committed to continuing environmental research at land grant universities. The program will expand our focus to investigate best management practices, bioremediation, and human and wildlife exposure issues. Pesticide and nutrient fate projects will continue to evaluate products not examined during the first three years and will start the process of overhauling existing mathematical prediction models.

Best management practices projects will apply appropriate agronomic principles to demonstrate that golf course turf can be maintained while protecting the environment. The emphasis of these projects will be to identify cultural practices that minimize volatilization and surface runoff.

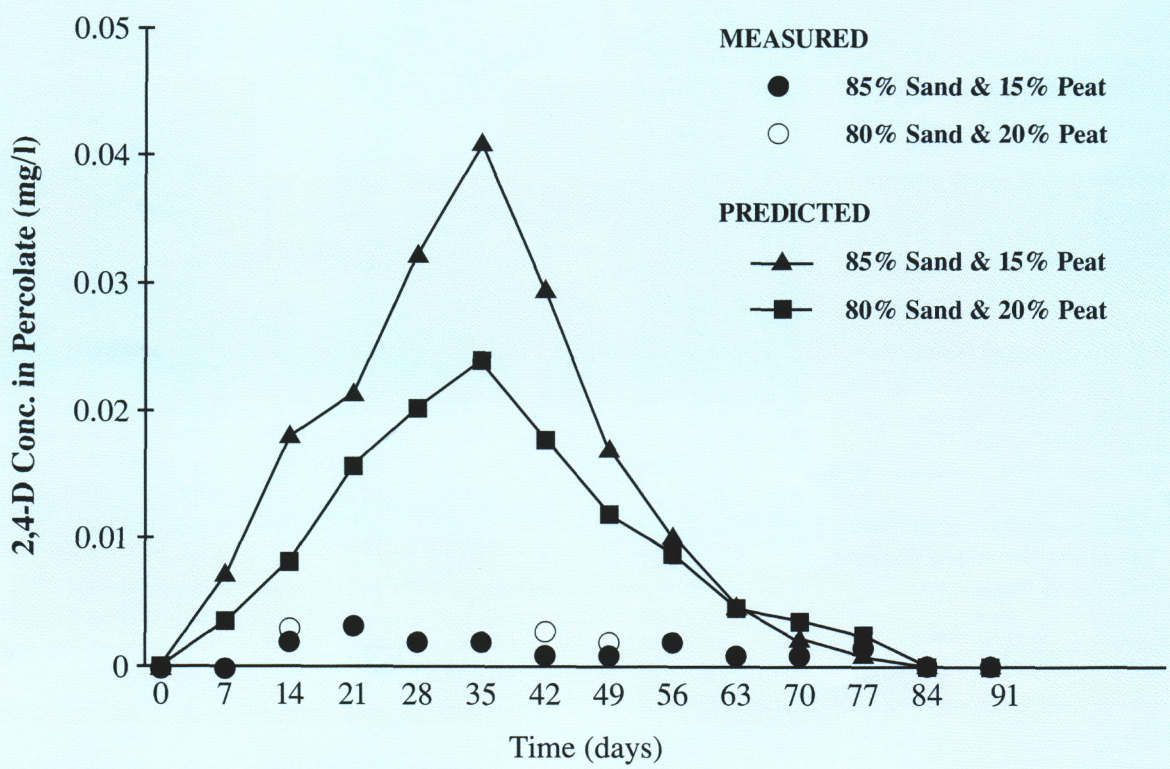
Bioremediation studies will demonstrate the potential of turfgrass to serve as a biological filter. The benefits that plants and microorganisms found on golf courses provide when dealing with storm water runoff from parking lots and rooftops needs to be addressed. The positive role golf courses can play in further cleansing effluent wastewater also needs to be documented.

Pesticide and nutrient fate research will continue because there remains a need to classify the chemical, physical, and microbial characteristics of the turf/soil ecosystem and their effects on nitrogen cycling, uptake and movement of phosphorus, and pesticide degradation and transport. With a better understanding of the positive role turf plays in breaking down, adsorbing, and absorbing pesticides and fertilizers, existing computer models used to predict their fate will be overhauled to accurately estimate the impact golf courses have on the environment.

At the USGA 1994 annual meeting held in Scottsdale, Arizona, outgoing President Stuart Bloch said, "The player, club, and ball have always been essential elements to the integrity of the golf equation. Our challenge today is to tackle the fourth element of that equation: the environment. Properly mastering the environmental element may be the USGA's most important contribution to preserving the future of golf."

The mathematical models used by environmental regulators and scientists to predict the fate of pesticides and fertilizers will need a major overhaul before they accurately represent what happens on golf course turf. Values predicted by the GLEAMS model and measured 2,4-D transport in water percolated from greenhouse lysimeters containing soil mixtures of 85:15 and 80:20 (sand:peat) did not agree.

FIGURE 3
Measured and Predicted Levels of Pesticide Transport in Water Percolated from Greenhouse Lysimeters



Helping the Osprey on the Road to Recovery

by NANCY P. SADLON

IF YOU GOLF ON ONE of the many courses located near large bodies of water, you may have an opportunity to catch a glimpse of a large bird — gleaming white below, dark brown above, and showing a distinct crook in its wings. You may also see the bird's massive nest — a huge pile of sticks built within the crotch of a tree or on a man-made platform. This majestic bird is the osprey.

Osprey populations have declined drastically in the past. Osprey, like the bald eagle and brown pelican, were impacted by the hydrocarbon chemical DDT used widely on agricultural fields. Discovered in the 1960s as a problem causing reproductive difficulties for a number of birds, the compound was banned in 1972 in the United States. However, the chemical is still widely used worldwide. This presents a problem for some osprey that migrate out of the country and continue to ingest fish exposed to DDT. The osprey encounters a number of other problems in its struggle for recovery both in the U.S. and in other countries. These include:

- Loss of desirable waterfront nest sites due to development.
- Pollution, causing mortality or inability to reproduce.
- Reduction of available food supply because of over-fishing.
- Increased competition for limited food supply by other bird species, including the black-backed gulls, herring gulls, and cormorants.
- Predation by gulls, great horned owls, raccoons, and opossums.

Matt Jankowski holds a young osprey to be tagged by osprey expert Gilbert Fernandez. This osprey has already developed good size and fierce talons necessary for catching fish and survival.

When golf courses are located in close proximity to water, they can help by providing nest platforms for the osprey. Providing suitable nest sites for the osprey has been very successful in some areas. Massachusetts and Rhode Island have witnessed population increases that have justified removal of the osprey from official protection lists. In other states, osprey populations are still low and remain listed as protected species. New Jersey lists the osprey as threatened. Florida and Pennsylvania consider the osprey a species of special concern. Experts are encouraged by the ospreys' population growth, but feel the species is still in need of continued assistance for complete recovery.

For superintendent Matt Jankowski of the Acoaxet Country Club, Westport, Massachusetts, this is the time of year for osprey tagging. With the assistance of local osprey expert Gilbert Fernandez of the Lloyd Center for Environmental Studies, the Acoaxet Club is doing its part to aid the osprey species by providing a nest platform on the perimeter of the golf course that borders on tidal Cockest Pond. Annual tagging of the young helps monitor the birds' recovery. One of Mr. Fernandez's fledged ospreys from Westport was sighted in Iquazu Falls, Paraguay — the world record for migration distance. Two other Massachusetts courses, Hyannisport Country Club and New Seabury Golf Course, also have been successful with osprey nest platforms. Assistance in platform design and location for these two golf courses was provided by Mr. Fernandez and Bill Davis of the Massachusetts Division of Fisheries and Wildlife.

The osprey range is not exclusive to Massachusetts. This species can be found in various areas of the country — along waterways and ocean coastlines, wherever tall tree snags or poles can be found for nesting and fish can be found for eating. There are five large regional osprey populations: Atlantic Coast, Florida, Gulf Coast, Pacific Northwest, and Great Lakes region.

Is Your Golf Course Suited for an Osprey Platform?

Not all sites are suited for the osprey. Essential elements for a successful osprey program include:

- Large bodies of water near the course.
- Good fishing grounds such as bays, wetlands, lakes, ponds, and rivers that provide a good supply of uncontaminated fish.
- Open areas for the osprey platform location. Platforms located too close to tall trees will not be used due to fear of predation by great horned owls.
- Isolated areas for the nest platform or a means of restricting human interaction. Golfers passing by are generally not a concern, especially when the nest is mounted at a 30- to 40-foot height.
- Osprey populations need to be existing in the area. Osprey do not readily colonize new areas, and therefore it is not recommended that platforms be put up in hopes of getting one to nest.
- Nest platforms with predator guards.

Nest Platforms

There are numerous osprey programs throughout the nation administered by the state fish and game divisions. These programs offer information about the bird and provide construction guidelines for osprey platforms. Specific dimensions and mounting height will vary and are not considered critical. For example, a nest platform in an open marsh that is remote from human activities can be mounted at 15-foot height and be successful. The nest platform on a golf course where golfers may pass by regularly needs to be mounted much higher, approximately 30 to 40 feet high to provide privacy. The most important aspect of any osprey program is to meet the bird's needs by providing a platform in an appropriate location.

For help and more information on osprey, contact your state fish and wildlife division. Inquire about the status of the osprey populations in your area and whether your golf course site is suitable for an osprey nest platform. The Audubon Society of New York State, administrators of the Audubon Cooperative Sanctuary System, also provides information on the osprey and can help you identify osprey experts in your region.

ALL THINGS CONSIDERED

The Religion of Golf

by LARRY GILHULY
Director, Western Region, USGA Green Section

IS IT MY IMAGINATION, or is there a movement underway out there among a small but widely distributed and vocal group of golfers who actually believe the GAME of golf is more than just a game? These fanatics insist that under all circumstances the putting surfaces should be maintained at or above 10 feet on the Stimpmeter; the fairways should be totally green, yet firm and with no wet areas; the bunkers should be in perfect condition with no bad lies; and tees must be perfectly flat and mowed to a height that only a military barber could appreciate! At the same time, they also want roughs at 2 inches or higher, and the course must be set up for championship conditions at all times. They completely forget that most golf courses are played by golfers with handicaps of 16 and above.

Guess who's caught in the middle of this? You've got it — the golf course superintendent. Regardless of the type of irrigation system, drainage, trees, topography, weather patterns, grass species, amount of play, size of greens, soil type, and countless other variables the superintendent must deal with, they are expected by this vocal minority to perform miracles in growing turf.

I would remind this minority of vocal players of one thing: Golf is a game that is supposed to be fun! Sure it can be exasperating and difficult. However, it is not a matter of life and death. If your ball lands in a wet spot, play it. If it's buried in a bunker, hit the ball and continue on your way. If the ball comes up a bit short on your first putt, remember to adjust your putting stroke for the rest of the round.

For those who are starting to recognize themselves, allow your superintendent to do the following:

- Maintain greens at a moderate speed that puts healthy turf first and speed second. Most golfers prefer smoothness over speed, and an 8- to 9-foot Stimpmeter reading is entirely acceptable when the greens are smooth.

- Maintain firm conditions, but don't force the superintendent into losing control of large areas of turf by insisting that irrigation practices be changed to suit your game. Remember, one of the superintendent's main functions is to keep players from messing up their own golf course!

- Realize that the golf course superintendent has a staff and a family that rely on his decision-making skills. It should be a game to you, but it is a livelihood for the superintendent. Remember this the next time you explode after missing a 4-footer and immediately blame everyone but yourself!

I hope everyone recalls these thoughts the next time they tee it up. It truly does put the GAME of golf in its proper perspective. Say Hallelujah!

TURF TWISTERS

THERE'S NO DEBATE

Question: We have had a running debate on the placement of tee markers. How far apart and how close to the back of the tee should they be placed? Also, is there such a thing as an "illegal tee marker location"? (New Jersey)

Answer: The Rules of golf describe the teeing ground as being "a rectangular area two club-lengths in depth, the front and sides of which are defined by two tee markers." As detailed in the USGA publication *How to Conduct a Championship*, it is recommended that tee markers be placed 5 to 6 paces apart. But because tee size and wear problems may make these recommendations impractical or impossible, consider them as guidelines and do your best to adhere to them whenever possible. There is no such thing as an *illegal* tee marker location.

USGA publications are available through the USGA Order Department (800-336-4446).

TURFGRASS NURSERIES

Question: I am planning to construct a putting green nursery later this year. Do you have any guidelines regarding how big it should be and what kind of materials I should use for the construction of the root zone? (Utah)

Answer: As a general rule, most putting green nurseries are about the size of the two largest greens on the golf course, or roughly 10,000 to 15,000 square feet. To prevent soil layering, the material you select for the root zone should match as closely as possible the material found on your greens. The sand currently used for topdressing the greens on your course should work well for this purpose.

MAKE PERFECT SENSE

Question: It is easy to confuse yards and tons when ordering sand for projects. Is there an easy way to keep these straight? (Texas)

Answer: It just so happens that a cubic foot of dry sand weighs about 100 pounds. Since there are 27 cubic feet in a cubic yard, one cubic yard of sand weighs about 2700 pounds — well over a ton. If you divide 2700 pounds by 2000 pounds, you get the figure 1.35. Therefore, to convert yards to tons, multiply the number of yards by 1.35.