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IN THIS ISSUE

Turfgrass Advances in the 21st Century

James B Beard

Prior to a crystal ball gaze into the next millennium it is important to have a proper perspective as to the major turfgrass advances that have occurred during the last century. Point in fact, most technical advances have occurred since 1945 as summarized in the following table.

Evolution of Turfgrass Advances Since 1945.

Time period	Key areas of research emphases and achievements
1945–55	• Selective broadleaf weed control: phenoxy-herbicides. • Insecticides developed for efficacy and persistence.
1950–60	• Equipment: powered coring, slicing, spiking, and vertical cutting machines. • Mowing practices—heights and frequencies specific to species. • Culture of turfgrass communities: mixtures and blends.
1955–65	• Post- and pre-emergence grassy weed control through selective herbicides. • Turf-type fertilizer ratios and formulations. • Warm-season cultivar development: bermudagrasses and zoysiagrasses.
1960–70	• Root zone modification, Perched-Hydration Method. • Turfgrass establishment techniques, improved mulching methods.
1965–75	• Cool-season cultivar development: Kentucky bluegrasses, perennial ryegrasses, and tall fescues. • Sod production cultural practices and specialty equipment.
1970–80	• New disease characterizations, plus systemic fungicides. • New nutritional practices, emphasizing potassium and iron plus autumn fertilization.
1975–85	• Turfgrasses stress tolerance enhancement: cold, heat, drought, wear, and shade. • Plant growth inhibitor advances.
1985–95	• Cultural practices and cultivars that conserve water, energy, and nutrient resources. • Prediction modeling for ET and pests.

As shown in the table, there have been dramatic advances in the science of turfgrass management during the 20th century. Equally dramatic changes will occur in the 21st century as well. The following sections on turfgrass advances for the 21st century involve a considerable amount of crystal ball gazing, which is a high risk endeavor. Some may prove correct and some innovations will not be mentioned. This is to be expected. The main focus is to stimulate the thought processes of our readership as to what changes may occur and how these changes may affect their own professional activities.

New Turfgrass Species and Cultivars

There will be a number of new species introduced for turfgrass use in North America. Most will be low maintenance turf-

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grass species. Examples include such warm-season turfgrasses from southeast Asia as sarangoongrass (*Digitaria didactyla*) and tropical carpetgrass (*Axonopus compressus*). Cool-season turfgrasses that may emerge include Idaho bentgrass (*Agrostis idahoensis*) and tufted hairgrass (*Deschampsia caespitose*). In addition, multiple cultivars of such species as kikuyugrass (*Pennisetum clandestinum*) and seashore paspalum (*Paspalum vaginatum*) may become available. There will be other turfgrass species that will receive attention and be introduced into various parts of the world as we become more and more a global community.

Concerning new turfgrass cultivars, the greatest need is improved resistance and/or tolerance to environmental stresses such as drought, heat, cold, wear, and shade. To date turfgrass breeders have emphasized turfgrass characteristics and resistances to certain pests. There is a great need to refocus attention on developing improved stress tolerant cultivars, which will in turn result in healthier, stronger plants that will be even less prone to a broad range of weed, disease, and insect pests, thereby reducing the pesticide need.

Transgenic turfgrass cultivars will play a very important role in the 21st century, similar to what is developing in medical applications, pharmaceuticals, and food crops. Currently, there is a significant activist movement focused on blocking this advance in food crops. At one time the horse enthusiasts put up great resistance to the introduction of the automobile. These advances are of the magnitude that will eventually come to the fore. The approach most probably will be through proper labeling to offer choices for the end user and through appropriate safety research and development of these new transgenic materials. These new cultivars will possess internal resistance to the major diseases and insects, which will significantly reduce the need for pesticide use. There also are genes already developed that provide enhanced rooting and drought resistance. Other genes allow seed germination at very low soil temperatures or impart foliage color modification, with many more types of genes yet to be identified.

Some day is it possible that professionals may be growing turfgrasses that are basically red or yellow in color? One might call this a "Star Turf" concept, which is a spin off of the popular term Star Wars.

Pest Management

The amount of pesticide usage can be expected to decline (1) as better turfgrass cultural practices are developed, (2) as more sophisticated techniques such as physiological modifiers and enhancers are introduced and their use becomes widespread, and (3) as turfgrass cultivars are developed with resistances to a wider array of pest disease and insect problems. The transgenic cultivar techniques will provide the most rapid advances in this regard.

By the same token, there will be a need for certain pesticides to properly manage turfgrasses to meet the functional, recreational, and aesthetic needs of people living in densely populated urban areas. There will be continued emphasis on integrated pest management (IPM) practices, including more sophisticated scouting techniques and the development of computer-based prediction models for individual disease and insects that are derived from the monitoring of key microenvironment parameters.

Future pesticides will be more target-pest specific. There will be an increase in spot treatment of key problem areas rather than broad-area treatment. Finally, there will be an increased requirement for documenting of scouting activities on which pesticide use decisions are based, as well as documenting the specific procedures followed and materials used on a given turfgrass area.

Weeds. Weeds have been the number one problem in turfgrasses. Actually, 90% of the potential weed problems are controlled through proper mowing and the use of adapted turfgrass species. The development of more stress tolerant and pest insect and disease resistant cultivars will result in dense, persistent turf stands that will provide increased competitiveness against the encroachment of weeds. Most probably there will be an increase in the corrective treatment of weed problems relative to preventive applications. A survey of key research scientists raises serious questions as to just how effective the new biological weed controls, such as certain bacteria, will be in the control of turfgrass weeds.

Finally a "Star Turf" perspective. This could involve the development of a herbicide applicator that moves across the turf area with forward monitoring devices that identify the particular weeds in the plant community. By onboard computer models the appropriate pesticide and rate will be selected, and subsequently the specific area onto which the herbicide treatment is to be made is automatically controlled. Impossible?

Diseases and Insects. It is likely that some significant new species of both pest diseases and insects will arise in the 21st century. In addition, target-specific pesticides will be developed that affect only the causal fungal pathogen or insect pest of concern. Emphasis will be placed on curative rather than preventive pest control solutions. Transgenic turfgrass cultivars with resistance to the major pest diseases and insects will be a key advance during the 21st century.

It is the consensus of knowledgeable turfgrass pathologists and entomologists that biological techniques for the control of either insects or diseases will not approach the success rate achieved with chemical materials. In the case of diseases, a limited degree of control will be achieved for certain foliar pathogens, but control of soil-borne causal pathogens of patch diseases is highly unlikely. By the same token, a limited degree of control can be anticipated for foliar-feeding insect species, such as cutworms and armyworms, via sustained applications at frequent intervals. However, there is little potential for the control of soil-inhabiting, root-chewing insects. Thus, the biological control approaches may be used if the customer or end user will accept partial control with noticeable turf damage and/or the pest problems in a specific area are limited to certain foliar active disease or insects of minimal severity.

Concerning a "Star Turf" development, what about a miniaturized monitoring unit located on key representative turfgrass

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FEATURE ARTICLE

Sod Webworms in Fairways and Putting Greens

Daniel A. Potter

Ordinarily when insect damage shows up in creeping bentgrass putting greens, we assume that cutworms are at fault. **This past summer, though, sod webworms reached outbreak levels on fairways and putting greens of many golf courses in the eastern half of the United States.**

Sod webworms are the larvae of small, buff-colored "lawn-moths" that often hover over turf while laying eggs at dusk. The larvae make silk-webbed tunnels in the thatch and soil, about the diameter of the stem of a golf tee. At night, they chew down the grass, leaving small sunken trails in the turf. In creeping bentgrass, the damage can look like some strange patch disease. The damage is compounded when flocks of foraging birds pull up tufts of grass to get at the larvae. Sod webworms don't form webs over the turf surface—those small patches of webbing made visible on the surface of greens and fairways by dew are the work of small, harmless spiders. A soap flush (2 tablespoons [30 mL]) of lemon-scented liquid dishwashing detergent in 2 gal (7.6 L) of water poured or sprinkled over 1.0 yd^2 (0.8 m^2) of turf will bring the small spotted caterpillars to the surface in 10 to 20 minutes. They don't come boiling out of the ground like cutworms and armyworms do.

I believe that the recent outbreaks of sod webworms in bentgrass fairways and putting greens were drought-related. Our problems in Kentucky seemed to be mainly from the bluegrass webworm (*Parapediasia teterella*) a ubiquitous species that normally is more abundant in roughs. Like most webworms, it has several generations per growing season. By mid- to late summer, the turf in nonirrigated roughs had become so dry that the moths were forced to lay their eggs in irrigated turf. As summer progressed, the population became increasingly concentrated on fairways and greens.

Sod webworms are fairly easy to control. **Pyrethroids are fast and effective, and offer the advantage of very low use rates and low toxicity to mammals, although pyrethroids are very toxic to fish.** In our tests, pyrethroids such as bifenthrin (Talstar), cyfluthrin (Tempo), deltamethrin (DeltaGard), and lambda-cyhalothrin (Scimitar) typically provide better than 95% control within one day. Organophosphates or carbamates such as acephate (Orthene), bendiocarb (Turcam), carbaryl (Sevin), chlorpyrifos (Dursban), and trichlorfon (Dylox) also work well. We've also had good success with the sprayable formulations of halofenozide (Mach 2) and spinosad (Conserve), two of the newer, reduced-risk insecticides.

Use liquid applications when treating for sod webworms, and postpone irrigation at least overnight. Treatments can be applied when damage begins to build up, or timed by watching the moth flights which precede each of the two to four successive generations or broods. Eggs hatch in about a week, so **timing applications for 2 weeks or so after peak moth activity will coincide with feeding of the young larvae.** Gempler's (tel. 1-800-382-8473) markets inexpensive kits containing sticky traps and lures with the sex pheromone of the bluegrass webworm. These traps attract only the harmless male moths from relatively short distances away. By placing one or more traps in low-lying trees or shrubs near infested areas, you can monitor the moth flight for spray timing, and also get a feel for where the highest levels of that species may occur.

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sites that contains computer-based prediction models with the findings derived from the sensing of key microenvironmental factors? The results are then transmitted to a central operations facility where the responsible individual can monitor the potential for various turfgrass disease and insect pests to occur in the upcoming few days or weeks, as well as suggested turfgrass cultural practices which should be considered within the particular environmental conditions relative to projected turfgrass shoot and root growth activity.

Energy and Water Conservation

Energy. Recent energy prices in the United States have minimized the concern about energy costs, that were an issue during the 1970s. However, high energy costs will reoccur during the 21st century, particularly as related to gasoline-powered internal-combustion engines. The conservation of energy should be a priority. Thus, it is important to give appropriate consideration and action to (a) energy efficient vehicles and machines,

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Seasonal Rooting and Mowing Height Effects on 'Penncross' Bentgrass in the Southern United States

Fred Yelverton

Bentgrass root growth is of particular concern to all golf course superintendents. In the warmer climates of the United States, such as in the transition zone, or other areas of the world with climates where bentgrass is marginally adapted, the loss of bentgrass roots during summer months is very important. Any cultural practice, pesticide, or other stress that increases or decreases root growth of bentgrass during periods of stress is extremely important.

Several questions arise regarding bentgrass root growth during the summer. For instance, how much root loss occurs in the summer; how much root loss can occur without loss of foliar density; what temperature will result in bentgrass root loss; and what is the soil temperature when air temperatures are in the 90s?

A study was initiated during 1997 near Pinehurst, North Carolina to answer some of these questions. Of course, some of the answers to the questions above are already known. For instance, when root zone temperatures exceed approximately 75°F (24°C), bentgrass root loss can occur. However, this study was initiated to develop a seasonal bentgrass rooting pattern for 'Penncross' bentgrass under three different mowing heights and also to examine the effects of plant growth regulators (Primo, TGR Turf Enhancer^{TM}, and Cutless^{TM}) on bentgrass root growth. The effects of plant growth regulators will be discussed in later issues of TurfFax.

This study was initiated from April 1997 to April 1999 on a native soil that was 94% sand and was conducted on a two-year-old stand of 'Penncross' creeping bentgrass (*Agrostis stolonifera*) at the Sandhills Research Station near Pinehurst. Samples for root biomass were collected every month for 2 consecutive years. Root biomass was measured by collecting 2 cores/plot, separating root growth from thatch, washing roots, drying roots, followed by weighing root mass, then ashing the root material to burn off the organic matter, and reweighing the root material. Root weight was determined by the difference in pre-ashing weight and post-ashing weight.

In this study, **maximum root biomass occurred in May** (Figure 1). Root loss started to occur in late May and **by the June measurement date, 35% of the root biomass had already been lost.** Root biomass continued to decline in the summer months, and reached a minimum in September. **From May to September, 'Penncross' creeping bentgrass lost 76% of its root biomass.** Soil probes placed 2 in. (50 mm) below the bentgrass indicated temperatures exceeded 75°F (24°C) in late May and never consistently dropped below 75°F (24°C) until late September.

Root growth was reinitiated in late September and by the October measurement date, root growth increased 39%. Root growth continued to increase through January, although root growth in the autumn never reached the maximum level that was obtained in the spring. Also of interest was the **root loss that occurred from January to March. During this period, a 15% root loss occurred.** It is unclear why this effect was seen. In this environment, temperatures do not drop low enough to result in cold injury to bentgrass. **However, light intensity can be very poor during this period and may be a more plausible explanation for bentgrass root loss in the winter.**

Also of interest was the effects of mowing heights on 'Penncross' root biomass. Three mowing heights were utilized in this study; 1/8 in., 5/32 in., and 3/16 in. (3.2 mm, 4.0 mm, and 4.8 mm). Figure 2 shows the effects of mowing height on bentgrass root biomass over a 2-year period. **There was no difference in root biomass between the 5/32 in. and 3/16 in. mowing height.** However, **the 1/8 in. mowing height had significantly less root biomass than did the higher mowing heights.** While this effect may or may not apply to other bentgrass cultivars, it is obvious that an 1/8 in. mowing height for 'Penncross' bentgrass in this environment is too low. Although the data are not shown, **bentgrass turf quality was lower for the 1/8 in. mowing height.** This was mainly due to a loss of foliar density from this low mowing height. The loss of foliar density also may have affected bentgrass root biomass.

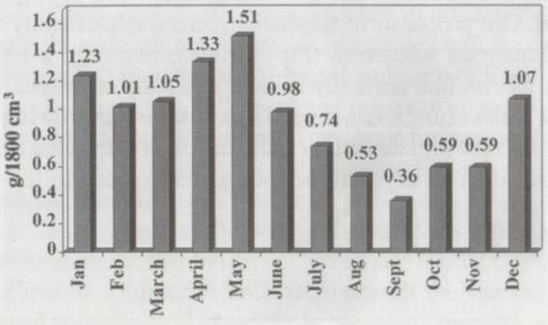

Figure 1. Seasonal Rooting Pattern for Penncross Creeping Bentgrass.

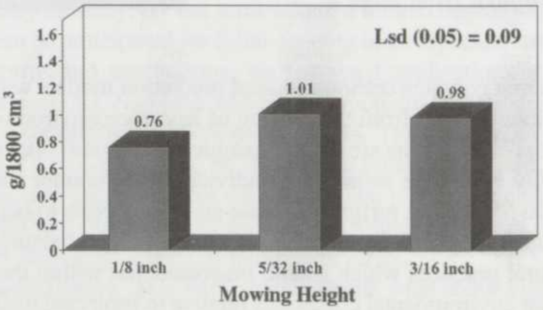

Figure 2. Effects of Mowing Heights on Penncross Creeping Bentgrass Root Biomass.

Fusarium Patch = *Microdochium* Patch = Pink Snow Mold

Peter H. Dernoeden

Winter is on the way and unfortunately there is no shortage of cold temperature-related diseases. Among the most common and destructive cold weather diseases of turf is *Fusarium* patch. The causal agent is the fungus *Microdochium nivale,* which was formally known as *Fusarium nivale.* This disease may be referred to by at least three different names. This is because of two reasons: (1) the disease may occur in the presence or absence of snow, and (2) the taxonomy or Latin binomial for the pathogen has been changed numerous times. Traditionally, the disease was known as *Fusarium* patch in the United Kingdom and as pink snow mold in the United States. Some pathologists argued that pink snow mold was an inappropriate name because the disease can occur in the absence of snow. Henceforth, the names *Fusarium* patch and pink snow mold were adopted to refer to the disease when it occurred either in the absence or presence of snow, respectively. To confuse matters, mycologists reclassified *F. nivale* as *Gerlachia nivalis* around 1980. In 1983, *G. nivalis* was declared a misnomer and the binomial *Microdochium nivale* was accepted. Hence, the names *Fusarium* patch, *Gerlachia* patch, and *Microdochium* patch appear in the literature, and all refer to the same disease. The latter genera represent the asexual stage of the pathogen. To further confound the issue, each of these asexual binomials also were assigned a sexual binomial. For example, the sexual binomial for *M. nivale* is *Monographella nivalis.* Since 1849, the pathogen has been given at least ten Latin binomials (Smith, Jackson, and Woolhouse, 1989). Therefore, *Fusarium* patch, *Microdochium* patch, and pink snow mold are all commonly used names for basically the same disease. For simplicity, many pathologists have decided to use the traditional name of *Fusarium* patch to refer to this disease, regardless of whether it is or is not associated with snow cover.

Fusarium patch attacks a wide range of turfgrass species under snow, at snow melt, or during extended periods of wet, overcast weather including: perennial ryegrass (*Lolium perenne*), bluegrasses (*Poa* spp.), bentgrasses (*Agrostis* spp.), and the fescues (*Festuca* spp.). **This disease generally is most destructive to annual bluegrass (*Poa annua*) and bentgrasses.** *Fusarium* patch is especially destructive to creeping bentgrass (*Agrostis stolonifera*) seedlings the first autumn to spring period following seeding. This is due to the overstimulation of growth and succulent tissues resulting from high levels of nitrogen fertilizer applied during establishment, as well as the immaturity of the plants. The disease can be especially severe when seedlings are covered with geo-thermal and other types of blankets. It is therefore important to check under blankets frequently.

Conditions favoring *Fusarium* patch include low (32–45°F; 0–7°C) to moderate (46–65°F; 8–21°C) temperatures; high relative humidity; abundant moisture; prolonged, deep snow; snow fallen on unfrozen ground; wet or poorly drained sites; wet shade; lush turf stimulated by late season applications of excessively high amounts of nitrogen fertilizer; and alkaline soil conditions. **Prolonged periods of cool to cold, overcast, and rainy weather are particularly conducive to disease development.** The disease may appear anytime between autumn and spring. In some maritime climates—such as the British Isles; Pacific Northwest, United States; and British Columbia, Canada—*Fusarium* patch can develop year round. In some U.S. regions, such as in the Mid-Atlantic states, the disease most often appears in April or May. May outbreaks of *Fusarium* patch often surprise or confuse superintendents because they think of this disease as a "snow mold."

Symptoms of *Fusarium* patch on close-cut putting greens initially appear as small, pink or reddish-brown spots or patches of 1 to 3 in. (2–8 cm) in diameter. Most fully developed patches are 3 to 8 in. (8–21 cm) in diameter, but some patches may range from 1 to 2 ft (30–60 cm) in diameter and coalesce. Reddish-brown rings or frog-eyes can occur, particularly in bentgrass seedlings. Large, circular patches are most likely to appear when the disease develops underneath a deep snow cover. The pink color of diseased turf at the edge of the patches is produced by the pinkish or salmon color of the mycelium. The mycelium mats leaves, and the plants eventually collapse and die. Matted leaves have a tan or white color, but on close inspection they may display a pale, pinkish cast.

On mature bentgrass or annual bluegrass putting greens, tees and fairways, *Fusarium* patch initially appears as circular spots or patches to 1 to 3 in. (2–8 cm) in diameter. These patches generally have a pink or reddish-brown color and may increase in size to 6 or more inches (≥16 cm) in diameter. During the early stages of the disease in the absence of snow, however, the small spots (1–2 in. diameter; 2.5–5.0 cm) may have whitish-tan center with a pink or reddish-brown fringe. Yellow patches or rings bordered by a reddish-brown periphery can easily be confused with yellow patch (i.e., *Rhizoctonia cerealis*). Hence, when in doubt, send a sample to a diagnostic lab. Gray-colored smoke rings at the edge of affected spots or patches also may be associated with *Fusarium* patch. Mycelium on the leaf blades produces fruiting bodies called sporodochia on which huge numbers of crescent-shaped spores are borne. These white or salmon-pink colored sporodochia are very tiny and appear as flecks on necrotic (dead) tissue. These flecks may be seen with a hand lens when the disease is active, but generally cannot be seen on dried tissue. The spores are easily spread by water, machinery and foot traffic. Therefore, blighting can appear in streaks or even straight lines when spores are carried on the wheels of

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...Pink Snow Mold

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mowers. This streaking-effect often is confused with a *Pythium* disease, especially during late spring outbreaks of *Fusarium* patch. When damage occurs under snow, the extent of injury usually is more severe than without snow cover. After snow recedes, the patches are bleached white and may or may not have a pink fringe. Normally, most plants in affected patches under snow are killed.

Management

***Fusarium* patch injury can be reduced by using a balanced N-P-K fertilizer in the autumn and by avoiding excessive, late-season applications of water-soluble nitrogen.** Ammonium sulfate may be suggested as a nitrogen source where soils are alkaline and *Fusarium* patch is common. Modest amounts ($\leq$1.0 lb N/1000 ft^2; 50 kg N/ha) of ammonium sulfate or other water-soluble nitrogen sources applied in late autumn, however, are not likely to enhance *Fusarium* patch in mature turf. Avoid the use of limestone where the soil pH is above 7.0 since soil alkalinity may encourage this disease. **Continue to mow late in to the autumn to ensure that snow will not mat a tall canopy.** On golf courses, snow fences and windbreaks should be used to prevent snow from drifting onto chronically damaged greens. **Divert skiers and snowmobiles around greens to avoid snow compaction.**

Pentachloronitrobenzene (PCNB, PenStar, Quintozene, Terraclor, Turfcide, others), chlorothalonil (Daconil), azoxystrobin (Heritage), fludioxonil (Medallion), iprodione (Chipco 26 GT), vinclozolin (Curalan, Touche, Vorlan), thiophanate (CL 3336, Fungo), myclobutanil (Eagle), propiconazole (Banner MAXX), triadimefon (Bayleton), and mancozeb (Fore) all have been reported to provide good control of *Fusarium* patch. **Except for possibly PCNB, most fungicides in any given year may provide only marginally acceptable Fusarium patch control when applied alone. Therefore, two or more of these fungicides normally are applied in a tank-mix combination.** Tank-mix combinations improve the level of control as well as provide a more broad spectrum scope of control of *Fusarium* patch, *Typhula* blight (also known as gray snow mold), and yellow patch. Some common tank mixes for the control of snow mold complexes include: PCNB + Chipco 26GT + Daconil; Chipco 26GT + Daconil; or PCNB + one of the following: CL 3336, Curalan, Fungo, Heritage, Medallion, Touche, Vorlan, or a sterol inhibitor (i.e., Banner MAXX, Bayleton, or Eagle). High rates of PCNB can yellow turf, particularly if applied during warm weather. ***Fusarium* patch control is best achieved with a preventive fungicide application made prior to the first major snow storm of the year. Subsequent applications to putting greens or other prone locations should be made during mid-winter thaws and at spring snow melt in areas where the disease is chronic.** As noted previously, turf covered with blankets should be monitored frequently for disease between autumn and spring. During extremely wet or snowy winters, *Fusarium* patch can cause extensive injury to lawns. It is best to spot apply fungicides to lawns where the disease has developed in localized pockets. Widespread blighting of lawns on some occasions may require a blanket fungicide treatment. In most regions of the United States, *Fusarium* patch prevention with fungicides is only warranted for golf course turf, and bentgrass/annual bluegrass bowling greens and tennis courts.

Reference

Smith, J.D., N. Jackson, and A.R. Woolhouse. 1989. *Fungal Diseases of Amenity Turf Grasses.* E. & F.N. Spon, New York.

RESEARCH SUMMARY

Winter Overseeding of High-Density Dwarf Hybrid Bermudagrasses on Putting Greens

Concern has been expressed regarding the ability to establish a winter overseeding of cool-season turfgrasses into the new, very-high density, dwarf bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) cultivars. Comparisons were made in three different warm-season environments including: hot-dry desert, hot-humid inland, and warm-humid coastal areas, using the cultivar Champion. The experimental sites were maintained at a 3.2 mm height of cut, with 3 replications for each of the 6 seed mixtures, 2 preplant methods, and 3 seeding rates. Monthly assessments made following winter overseeding included visual estimates of percent seedling coverage, and visual estimates of turfgrass quality. Shoot densities of the overseeded turfgrasses were counted, and the mat and root depths of the *Cynodon* were measured. Results indicated: (1) the best timing for overseeding should be determined by soil temperature rather than a calendar date; (2) the **optimum mixtures and seeding rates were:** (a) **8 lb/1000 ft^2 (4 kg 100 m^{-2}) of rough bluegrass (*Poa trivialis*) and 2 lb/1000 ft^2 (1 kg 100 m^{-2}) of creeping bentgrass (*Agrostis stolonifera*), followed in 30 days by 2 lb/1000 ft^2 (1 kg 100 m^{-2}) of rough bluegrass,** (b) **10 lb/1000 ft^2 (5 kg 100 m^{-2}) of rough bluegrass and 2 lb/1000 ft^2 (1 kg 100 m^{-2}) of creeping bentgrass, and** (c) **8 lb/1000 ft^2 (4 kg 100 m^{-2}) of rough bluegrass,** (3) **higher winter overseeding rates suppressed the spring root growth of bermudagrass substantially,** and (4) spring transition was successful using timely cultural methods involving lowering the cutting height, increasing the nitrogen rate, and weekly vertical cutting. By SI Sifers and JB Beard, *1999 Agronomy Abstracts,* p. 122.

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(b) efficient vehicle routings, (c) low-pressure irrigation systems and energy-efficient pumping stations, (d) turfgrass cultivars with slow vertical leaf extension rates to reduce the mowing frequency, and (e) use of recycling approaches where appropriate. These are just some of the many efforts that can be made to conserve energy.

Water. While energy will most probably be available, although at a higher cost, this may not be true for water in terms of turfgrass use. In some arid regions water use for turfgrasses may be severely restricted, and in certain semi-arid regions it may be available but at a very high cost, including the purchase of reclaimed water. Water conservation should be an ongoing priority in turfgrass maintenance including (a) the need to develop improved, efficient irrigation systems in terms of both operational hardware, and controllers, as well as the design itself, (b) increased use of evapotranspiration prediction models, typically involving the modified Penman equation, (c) increased role for reclaimed water, (d) the development of turfgrass cultivars with even lower evapotranspiration rates and enhanced root systems for dehydration avoidance, (e) development of improved drought resistant turfgrass species and cultivars, and (f) increased use of water harvesting techniques in the original design and construction of turf sites. These are only a few of the many approaches that will be employed increasingly in an effort to conserve our valuable water resource.

Cultural Practices

Like other aspects in growing turfgrasses the cultural practices also will have significant advances in the 21st century. These can be divided into the specialty areas of fertilization advances, physiological and growth regulation, computer-integrated agronomic applications, and matrix stabilization of high-sand, intensively-trafficked root zones. These four areas will be discussed in the following subsections.

Fertilization Advances. There will be continuing trends to lower nitrogen fertility levels, combined with higher rates of potassium and iron usage. The latter two will be especially important on intensively trafficked turfs.

There should be increased use of controlled-release fertilizer carriers, especially for nitrogen and potassium. In addition, there is further room for improvements in the types of controlled-release fertilizers available. While turfgrass science has led the entire fertilizer industry in the development of controlled-release fertilizers, we may still be only 50% advanced in achieving the ultimate product. Foliar fertilization will receive increased emphasis for environmentally sensitive areas.

Nutrient management plans will become important and may even be required by government legislation at some time in the future. This would be in addition to stringent requirements relative to recording and reporting fertilizer application practices.

Finally, regarding "Star Turf." A major advance in fertilizer applicators could be a forward-sensing device which determines the comparative need for nitrogen fertilizer. The radiation-based sensors would generate information that is fed into the onboard computer that determines and directs the amount of nitrogen fertilizer to be applied to any given micro-area, as the applicator device moves across the turf site. Yes this is possible, but when will it become economically and environmentally practical?

Physiological and Growth Regulation. Major advances in plant growth regulators have been achieved in the past two decades. However, there is much potential for further developments. Included are growth regulators that reduce the growth of individual plant morphological structures as well as differential effects at the interspecies level.

In addition, physiological regulators will be developed that are active in the enhancement of tillering, rooting, color, antisenescence, and stress tolerance such as heat, cold, and drought. These types of materials will probably be applied by a foliar method.

Computer-Integrated Agronomic Applications. Computers will play an increasingly definitive role in most phases of turfgrass culture. This will include automatically monitoring and processing both the atmospheric and soil microenvironmental perimeters that affect turfgrass growth as well as diseases, insects, and weeds. These types of site-specific information will be integrated by computers into prediction models to forecast (a) the timing and amount of irrigation needed, (b) the likelihood of specific disease, insect, or pest occurrences, and (c) the appropriate timing for specific cultural practices including fertilization, winter overseeding, and turf cultivation. From a mechanization standpoint, computers will play an increasing role, along with laser applications, in the operation of mowers, pesticide applicators, and fertilizer spreaders.

Root Zone Stabilization. Intensively trafficked turfs such as for sports fields, recreational areas, and park grounds will be subjected to greater soil compaction problems. Further advances will be made in the use of more permeable root zones, which will be stabilized by interlocking mesh matrices that provide not only stabilization of the permeable root zone, but also flexing self-cultivation activity and nutrient exchange sites.

Summary

The 21st century will offer many new challenges. Some individuals may view them as problems, while others see opportunities. There will be an increasing need for turfgrass managers with sound technical-based expertise who have both formal education in the agronomic-soil dimensions combined with real-world field experience. These turf managers will experience increased demands in terms of management skills, such as systems organization, personnel management, record keeping, cost control, and budgeting. It is not uncommon for many turf facilities to employ assistant turf managers. In the future, it may become more common to also have a business manager to support the overall operations of the turfgrass manager. The bottom line will be to maximize the cost efficiency of turf facilities while producing high quality functional turfs that are being subjected to ever increasing intensities of use.

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JB COMMENTS

I have been receiving a number of comments concerning the possible use of seashore paspalum (*Paspalum vaginatum*) on putting greens. There is one specific concern in this regard. Actually seashore paspalum is a serious weed in hybrid bermudagrass putting greens in areas of South America, such as Argentina. This is because **the local seashore paspalum genotypes have a very rapid vertical leaf growth rate. Thus, by noon following an early morning mowing the greens become very bumpy due to the scattered patches of seashore paspalum that are growing faster than the surrounding Tifdwarf bermudagrass.** For this reason, I do get numerous questions concerning potential herbicides for the removal of seashore paspalum from Tifdwarf bermudagrass. This comment is made as a caution. It is entirely possible that cultivars of seashore paspalum can be developed that have a sufficiently slow vertical leaf extension rate to provide putting quality similar to that of the new high-density dwarf hybrid bermudagrasses.

ASK DR. BEARD

Q *I have three-year-old Tifdwarf putting greens that are rapidly developing patches of off-type bermudagrass. What is the cause?*

A The development of an off-type grass in closely mowed hybrid bermudagrass putting greens is an all too common occurrence. Frequently the blame is placed on the development of mutations. It is true that the hybrid bermudagrasses (*Cynodon dactylon x Cynodon transvaalensis*) have a higher tendency to mutate than dactylon bermudagrass (*Cynodon dactylon*). However, it is still a relatively rare occurrence.

In most cases the cause for development of off-types is contamination. Evidence of this is supported by a large experimental putting green at Texas A&M University that I was involved with for 22 years. **It has been in place for 35 years, and is divided into halves consisting of Tifdwarf and Tifgreen. During that time a diverse array of various experiments and turf renovations have been conducted on the surface, yet no off-type problem has developed.**

Actually it takes only a few nodes on scattered stems to produce a significant contamination problem in a putting green. There are a number of potential sources by which contamination can occur.

1. Contamination can occur from the production field where the bermudagrass was originally grown prior to harvesting and transplanting onto the golf course putting green site.
2. Another possible contamination source involves the failure to fully eradicate the existing bermudagrasses from the putting green prior to planting. All to many people attempt to eliminate bermudagrass by the use of glyphosate (Roundup™) which is not a wise choice. Rather the preferred approach is by the use of methyl bromide.
3. Finally, contaminates can be introduced onto the putting greens via various types of turf maintenance equipment and via golf shoes.

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